T869 Climate Change: from science to lived experience

Module 1: Introduction to climate change in the context of sustainable development

TEXTBOOK

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Lived Experience of Climate Change e-learning

Education and Culture DG
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Before you start: aims, learning outcomes and how to study this module

The overall purpose of Module 1[1] is to introduce the concept of climate change within a context of sustainable development.

The module asks the fundamental question: How can we evaluate what others tell us should be done about climate change in order to make our own reasoned judgements?

It therefore has primarily an analytical rather than a normative focus. In other words, the module does not offer prescriptions of what should be done. Rather, it equips you to make sense of, and critically analyse, the prescriptions of others from a variety of perspectives. 'Others' may be literally anybody, from:

Politicians to concerned citizens;

Policy makers to practitioners who are charged with enacting policy;

International bodies such as the United Nations and European Union to governments at all levels;

Non-governmental organizations to private sector firms.

Learning outcomes

Learning outcomes concern what you should know, understand and be able to do on completion of a module. They are important indicators of your learning development. We recommend that you use them as a checklist of your progress as you work through Module 1.

After studying *Introduction to climate change in the context of sustainable development* you should be able to:

a) *Demonstrate knowledge and understanding of:*

(i) The perspectives on climate change causes, impacts and mitigation/adaptation possibilities from a range of sciences: natural science, economics, political science and sociology

(ii) The basic association of climate change with human energy requirements

(iii) The impacts of climate change on natural resources, especially water, and consequent effects on human welfare

(iv) The integration of different scientific perspectives on climate change through the concept of sustainable development.

b) *Be able to:*

(v) Examine critically a range of media and perspectives on climate change and sustainable development

(vi) Apply the concept of sustainable development to integrate a range of climate change perspectives

c) *Apply the following key skills:*

[1] There are two other modules in this series. Module 2 is *The lived experience of climate change*. Module 3 is *Interdisciplinary methodologies for investigation into the 'lived experience' of climate change*. A *Water case* study is also provided as an extended text. These other modules and the Water case study might be referred to from time to time in this e-textbook and corresponding e-workbook.

(vii) Interpret scientific, statistical and other data

(viii) Search for and make judgements on evidence from a range of sources

(ix) Marshall evidence, and develop and communicate in your own words an argument.

(x) Construct knowledge on climate change through communicative exchange with others and develop transboundary competence.

How to study this module

As with other teaching modules in this series, *Introduction to climate change in the context of sustainable development* consists of a 'textbook' comprising a central narrative about the subject, a 'workbook' containing a series of activities for you to perform, and a detailed case study on water and climate change. The 'textbook' follows on in this document. It is like a conventional book, although being in a virtual learning environment it may refer to a range of media and not just the printed word. Once you have read through the textbook carefully you should be able to meet the 'knowledge and understanding' learning outcomes above.

The 'workbook' is contained in a separate document, and again it may refer to a range of media. The 'workbook' helps you reach a more extensive and deeper, critical understanding of the subject matter. It does this in two complementary ways, by providing: you with:

- Further reading and audiovisual links, and asking you to search yourself for additional sources.
- Opportunities to develop through practice the 'be able to' skills (which we call cognitive or thinking skills in relation to the subject) and the 'key skills' (skills which are transferable across a range of subjects) above.

Thus, although, with one possible exception[2], the choice is ultimately yours, we recommend that you do not neglect the workbook and its activities. Your sense of overall satisfaction with the module is likely to be greater if you engage with them. Also, although the textbook may refer directly to the water case study, the purpose of this case study is for you to apply critically the principles and concepts of the module to a real-world challenge associated with climate change. One or more of the workbook activities will help you do this and therefore the workbook is the main point of reference for the water case study.

How in practice might you combine the three main resources at your disposal in this module – the textbook, workbook and water case study? You should choose the method which best suits your own learning style. One way is to go to workbook activities at the points that they are indicated in the textbook. Another way is to read the whole of the narrative in the rest of this textbook (and the water case study), without worrying too much about remembering the detail. Then, having completed your reading, work through the activities in the workbook systematically, analysing sections of the narrative and water case study again more closely as appropriate.

[2] The exception concerns any workbook activities which might be deemed compulsory by your accrediting institution. The obvious example concerns workbook activities which are designed for group work. If the key skill of transboundary competence or similar formulation is part of the learning outcomes of the accrediting institution, satisfactory participation in activities that deliver that learning outcome is likely to be a requirement.

1. Introduction to Module 1

By Gordon Wilson, Víctor Fairén and Carolien Kroeze

The subject of this module, Climate Change within Sustainable Development, is situated in an area in which natural science, and more recently other disciplinary subjects in the social sciences, must address a problem that modern society and technology have created in part.

There is some confusion between weather and climate and it is best to address this at the outset. Although they both apply to how the atmosphere behaves, they are not synonymous. Weather is the condition of the atmosphere that prevails at a given moment and at a given place which is perhaps a few kilometres across, and may change within days or even hours. It is then correct to state weather is sunny and warm **today** and will be rainy and cold **tomorrow**. The chaotic nature of weather makes it unpredictable beyond a few days and it is the reason why weather forecast does not extend beyond a week or so.

In spite of the irregular behaviour on a daily basis, observations show that there is some long-time regularity in the behaviour of the atmosphere. We define, for example, a Mediterranean climate, with mild winters and hot, dry summers because along the years those have been the general atmospheric conditions ruling the Mediterranean basin. This is what is termed as 'climate', the atmospheric character of some geographic area, shown by records over many years. Climate is then defined as the average weather, generally over a period of thirty years. Atmospheric variability on timescales of months or longer is known as *climate variability*, and statistics relating to conditions in a typical (as opposed to a particular) season or year are referred to as *climatological-mean* statistics. Projections in climate (long-term average weather) are more manageable than their counterparts in particular weather predictions.

When speaking about climate and its variability (whether "natural" or not), we mean a highly dynamic system in whose description the equations of physics play a fundamental role. Therefore, it is of interest to natural scientists. But it is also an issue that has always transcended the boundaries of science and involves perspectives that derive from the fields of economics, politics, sociology or cultural and religious beliefs. As long as it is so, issues regarding climate are the subject of debate and disagreement, in part because science does not meet the expectations that society demands from it, but also because we weigh against one another different ways of understanding science and scientific knowledge and, above all, because it is interpreted in the light of the diversity of beliefs, values, attitudes, aspirations and behaviour. This problem is not unique to climate change. Biomedicine, ecology, resource management, just to name a few, are all topics where it is the same: their objects of study are complex, scientific understanding is limited and they have a profound impact outside the field of science.

Societies have always sought security in both climate and the supply of basic resources: water, food and energy. And this is because this security is a prerequisite both for meeting fundamental human needs and for economic growth and development. Climate and those basic resources are all intimately tied together. Food and water are dependent on both climate and energy. Before the industrial revolution, energy derived primarily from animal and manpower (which relied on an adequate supply of food and water) and wood as fuel. The intensive use of fossil fuels (carbon, oil and gas) has altered the equation for a number of reasons. We can basically underline four:

1) For almost two hundred years, we have been returning to the atmosphere billions of tonnes of carbon as carbon dioxide, which were fixed long ago by plants and plankton and later deeply buried, thus reversing a process that has led to the conditions which have witnessed the development of Nature and human societies as we know them today.

2) There is strong scientific evidence in favour of a possible climate alteration due to the release of such amount of carbon dioxide and other greenhouse gases. How large this shift in climate will be is uncertain and maybe scientific knowledge will never be able to provide a definite answer. In spite of that, what it is feared from our knowledge of past climate events is the possibility of a large shift due to the highly nonlinear nature of climate processes – yet unknown feedbacks might give rise to large unexpected consequences.

3) This eventual climate modification raises the suspicion of a non-negligible impact on our food and water supplies, among other consequences.

4) There is no foreseeable end to our dependence on burning fossil fuels. Other sources of energy are not yet technologically and economically competitive. If we are to meet the growing demand of populations that will presumably reach ten thousand million in a few years from now, there is no apparent alternative in sight that is able to supply such cheap and abundant sources of energy as the otherwise dwindling fossil fuels do.

Set up jointly in 1988 by the United Nations Environment Programme and the World Meteorological Organisation, the Intergovernmental Panel on Climate Change (IPCC) concluded in its fourth Scientific Assessment that most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations *[IPCC, 2007b]*. The question now concerns what will happen in the future? This question is not easily answered.

The future of our climate is uncertain. This uncertainty is related to uncertainties about future trends. There are many individual causes of climate change, including fossil fuel combustion as noted above, deforestation and land use change leading to a range of greenhouse gas emissions of which carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the most important. Exploring the future, therefore, requires projections of all these activities and processes. In addition, as you will see, the climate system is very complex with many feedbacks. We know the system to some extent, but many uncertainties remain making it difficult to quantify the local impacts of future climate change. Moreover, appropriate climate policies are not easily identified, and range from adapting to climate change impacts to mitigation measures aimed at reducing greenhouse gas emissions. Finally, there are many stakeholders involved and the stakes are high.

Module 1 illustrates this complexity. It discusses the science of climate change, as well as economic, political and societal aspects. The different chapters in Module 1 are written from different disciplinary perspectives.

Despite this complexity, the question how to approach climate change is being addressed by scientists. This is done in so-called integrated assessments. Such assessments apply the judgment of experts to existing knowledge to provide scientifically credible answers to policy-relevant questions *[Leemans, 2008]*.

The IPCC Scientific Assessments are among the most widely used and most credible in this regard. The fourth IPCC Scientific Assessment was published in 2007, and includes a synthesis report *[IPCC, 2007a]*, and summaries for policy makers *[IPCC, 2007c]*. We suggest that you read these two documents for an overview of the current state of knowledge on climate change. The IPCC scenarios indicate an increase in the global temperature by 1–6 degrees Celsius by 2100, which may considerably alter precipitation patterns and sea levels.

Thus, it is in this context of what is both known and what is uncertain for the future, that anthropogenic (human-induced) climate change has emerged as a global challenge in recent decades because of its potential to disrupt dominant models of human development, lives and livelihoods in affluent and poor countries alike across the world. Proximate explanations of climate change are to be found in the natural sciences. Human contextual explanations are to be found in a) the dominant model of economic development and its fundamental dependence on energy; b) the challenges facing political leaders and policy makers to agree and enact courses of action for mitigation and adaptation. While human beings impact on climate change, mainly through their energy requirements, climate change in turn impacts on them, their lives and livelihoods. Such impacts, however, are felt unevenly across human societies, being mediated by social relations of wealth, power and inequality.

The combination of these human factors is often integrated into the concept of sustainable development, which seeks a model of economic development that does not irreparably harm the natural environment on which it depends, and which is equitable and just for both future and current generations. This leads to the well-documented three pillars of sustainable development – environment, economy and society. The relation of climate change to sustainable development and the integration of economic and social dimensions with those of the natural environment are illustrated by recent holistic practices of natural resource management.

The following chapters in this module develop the above skeletal argument:

Chapter 2 covers the science of climate change;

Chapter 3 covers the economics, including economic and technological approaches to mitigating climate change and their importance when making policy;

Chapter 4 overlaps with Chapter 3 as the economics always spawns a politics. It addresses the geopolitics of climate change: the international institutional setting and the factors that influence the effectiveness of global governance.

Chapter 5 examines the social impacts of climate change, and how these impacts are mediated by social relations of power and inequality.

Chapter 6 is the module Conclusion. It brings together Chapters 2, 3, 4 and 5 within the broad idea of sustainable development, while providing a critical examination of the concept. This final chapter also draws together issues of ‘scale’ and inter-scalar connections. The inquiry in Chapter 2 on the science is necessarily focused on the planet Earth, while that in Chapters 3 and 4, on the economics and politics of climate change respectively, is conducted both at national and international scales. In contrast, Chapter 5 is at the local scale as it examines the impacts on people and communities. Thinking of these scalar dimensions raises two basic questions for Chapter 6. How does the national and international affect the local? How does the local affect the national and international? The module ends by briefly examining these questions.

You might like to end this introductory chapter by reflecting upon its key message and on the usefulness of locating climate change within a context of sustainable development. If you undertake this reflection now, it will provide a useful overview within which you can locate the rest of Module 1. Activity 1.1 in the module workbook provides specific guidance and a discussion.

2. What science tell us about climate change

By Víctor Fairén, Javier García-Sanz, Ignacio Zúñiga ('Before you start' is by Gordon Wilson, Module 1 coordinator, with Figures 2.1 and 2.2 supplied by Victor Fairén)

Before you start: the aim and learning outcomes of this chapter

Chapter 2 aims to introduce you to the science of climate change.

After studying Chapter 2 you should be able to understand:

1) The Earth's climate as being driven by an energy input-output system, which originates with the energy received from the sun.
2) The concept of feedback in its many dimensions and its importance in analysing, and attempts to model, climate.
3) The mechanisms by which climate changes over both long and shorter time periods.
4) Especially the role in climate change of forcing agents, both natural and those deriving from human activity.
5) In basic terms, the main models that have been developed to simulate climate, how it changes historically, and how it is predicted to change.

I am introducing this 'Before you start' to chapter 2 on behalf of Victor Fairén, Javier García-Sanz and Ignacio Zúñiga from the Universidad Nacional de Educación a Distancia (UNED) in Spain. I write as someone who was trained originally in natural science (chemistry) and moved later to social sciences. I have, therefore, some experience of the challenges that non-scientists face when they try to understand natural science, and vice versa.

Natural science can be difficult for non-scientists, in a way that doesn't operate with respect to social science. Most people have an everyday knowledge of social science concerns. Some they confront or experience directly (for example, when the national economy is doing well or badly and it impacts on them and their livelihoods), and/or others through what they read through the media or internet. Such commonsense knowledge has its challenges when students have to face the rigour of formal social science study. However, at least it provides a tacit 'hook' that enables one to engage.

Natural science for non-(natural) scientists, however, seems much more distant and abstract. It works through formulae and equations which can appear to bear little relation to the world around us.

A key challenge concerns scale. The social sciences are by definition at a human scale. This might be at a big human scale when social scientists investigate, say, the global economy or a global issue such as the socio-economic impacts of climate change. Equally, however, social science investigation is at a small scale, as when anthropologists do detailed studies among relatively small groups of people to unearth their livelihoods, social structures and relations between them. This (big or small) human scale facilitates common-sense understandings, even among lay people who also have an awareness of the connections between scales – how globalisation and the economic rise of China, for example, affect our own livelihoods and lifestyles.

Natural science, in contrast, can be, and is often, carried out at scales beyond our human imagination – both big and small. Take measurement. Size can be extremely small and measured by nanometres where a nanometre equals one billionth of a metre, and very big, for example gigatonnes, where a gigatonne equals one billion tonnes. Another example, which is crucial for our understanding of climate, is the scale of time. Social historians might go back several hundred years, but this is nothing compared to the geological timescales on which climatologists operate, which go back in time a billion years.

Despite these and other challenges, it is important for scientists and non-scientists alike who are interested in climate change to have a basic understanding of the natural science that lies behind it. One good reason for this is that this science remains uncertain in many respects. This does not only concern the debate between those who believe that anthropogenic (human) activity is largely responsible for global warming and those who are sceptical, but also within the former group there remains much debate about the rate and extent of warming and its impact on climate. Yet, in spite of, and perhaps even because of, this uncertainty policy makers draw on different aspects of the scientific evidence to make a case for whatever it is they are advocating. It is important then for anybody who is interested in climate change – both natural and social scientists -- to understand the evidence that is presented and be able to judge it.

Although I have presented understanding science as a challenge for non-scientists, do not despair if you fall into this group. Victor and his colleagues have produced this chapter of the module in a manner that should allow a good basic engagement with the subject, and don't be put off if you don't understand everything. It's more important that you grasp the overall picture of the ways by which scientists themselves seek to understand our climate. The activities in the chapter 2 section of the Module 1 workbook are designed to test your grasp of the overall picture. If you can make a reasonable attempt at these activities, you have nothing to worry about.

Repeatedly this chapter refers to the different geological periods which, as noted above, stretch back in time up to a billion years. Within the big periods there are smaller periods of interest and within the smaller periods there are 'events' which themselves can last many years. Figure 2.1 summarises this timescale, and you may wish to refer to it as necessary as you go through the module.

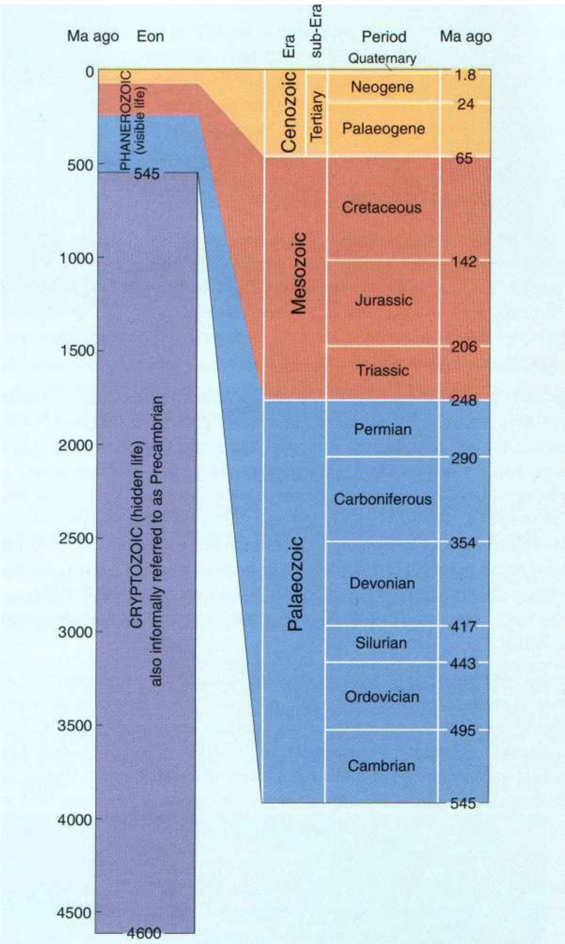

Figure 2.1 Geological timescales and their periods

Another useful chart which you might wish to view repeatedly concerns the first two layers of the atmosphere. These are continually referred to throughout chapter 2. This is Figure 2.2.

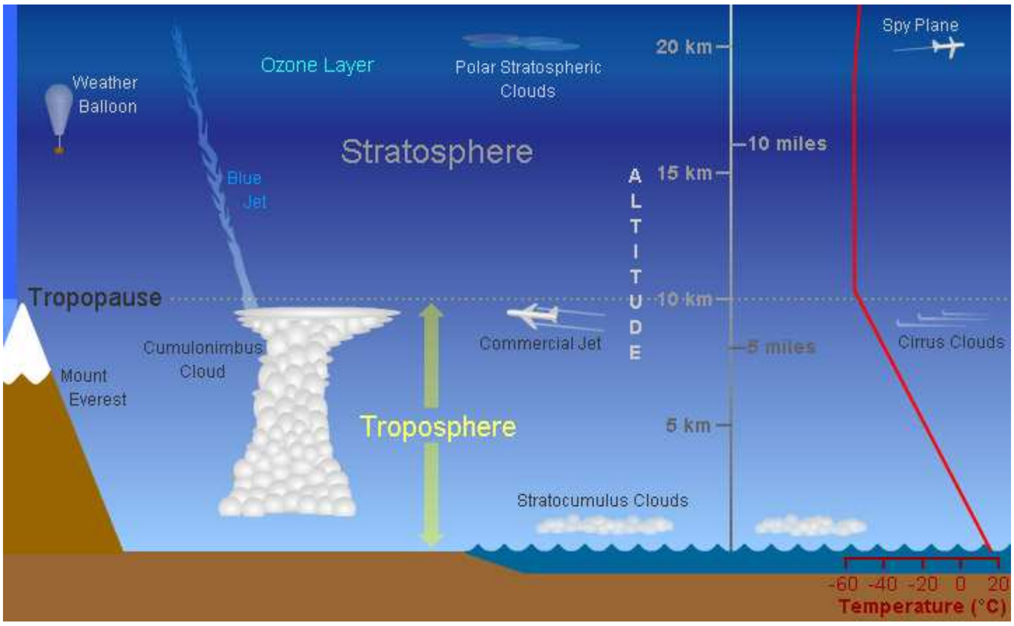

Figure 2.2 The first layers of the atmosphere

2.1 Introduction to the science of climate change

Some 20-30 years ago, people started hearing about global climate and its troubles. For scientists, however, the problem has a long history. In the early 19th century already, Joseph Fourier seems to be the first in assessing the role of the atmosphere in acting as a greenhouse factor. Thanks to it the Earth temperature is higher than it would be in its absence. Some ten years later, another French scientist, Claude Pouillet, pointed at water vapour and carbon dioxide as the main greenhouse gases. We must wait until the end of that century in order to see a Swedish chemist, Svänte Arrhenius, a Nobel Prize winner for his work in electrochemistry, formulate quantitatively these ideas. Not only was Arrhenius aware of the possible negative effect of the gases emitted by the burning of coal by the industry of his time, but he went a step further and calculated this effect on temperatures. He concluded that the mean global temperature might rise several degrees.

By the 1930s, global warming was already a reality although most scientists invoked some natural cycle to explain it. There was, however, a discordant voice. Guy Stewart Callendar, a British engineer, insisted on a link between human-induced carbon dioxide and global warming. He thought, however, as all his contemporaries did, that global warming would even be beneficial.

In the late 1950s, the introduction of new tools – computers and global monitoring systems – allowed scientists to address the climate issue by launching specific international programmes. In the last fifty years, their results are at the root of society's awareness. One major step was the issuing of a formal declaration at the United Nations Earth Summit, in 1992, according to which all signatories agreed on the Climate Change Convention, expressing the determination of stabilizing greenhouse gases concentrations at a level precluding any dangerous anthropogenic (i.e. human) perturbation of the climate system. Specific measures to implement this declaration were initially adopted in 1997 in Kyoto and entered into force on February 16, 2005.

At the end of 2012 the Kyoto Protocol runs out. On December 2009, a U.N. Convention on Climate Change took place in Copenhagen. Despite some good will, it came to naught. The accord, which falls short of a binding treaty sought by many nations, sets a goal of limiting global warming to below 2 degrees Celsius (3.6 Fahrenheit) above pre-industrial times. But it leaves each nation to set its own targets for 2020. It is even less mandatory than the Kyoto Protocol.

It is clear that the implementation of effective measures aimed at counteracting the present global warming cannot be made without the support of the World's citizens, fully aware of the impending threat to the planet. This is presently lacking. In the current mood of "business as usual" the fulfilment of this goal has become a long-term contest of unpredictable outcome.

The scientific community is one of the participants. It has the privileged position of being one of the contributors to the generation of the needed knowledge for completing a picture of what awaits us. However, it must not only be right in its conclusions, but it must also learn how to argue its case and, above all, be convincing. It is not an easy task when we realise that we are confronted by a very difficult case. Climate is indeed a very complex system, but in spite of its persistent uncertainties, climate science and in particular climate change science is solidly grounded. In spite of that, a complete and comprehensive assessment of climate is surely an unreachable target: climate has too many intrinsic uncertainties to deal with. However, life is fundamentally uncertain and people are conscious that decisions must always be made in a context of less than a hundred percent assurance. The role of science is then that of unloading all reasons to make its case and convince despite all uncertainties. It is hoped that the present text will encourage the reader to participate in the achievement of this objective.

2.2 Global Warming

2.2.1 Escalating temperatures

Upon examining Figure 2.3 we realise that global temperatures have indeed increased over the last 120 years, in spite of year to year, or even decadal decreases, as happened in the period 1940–1960.

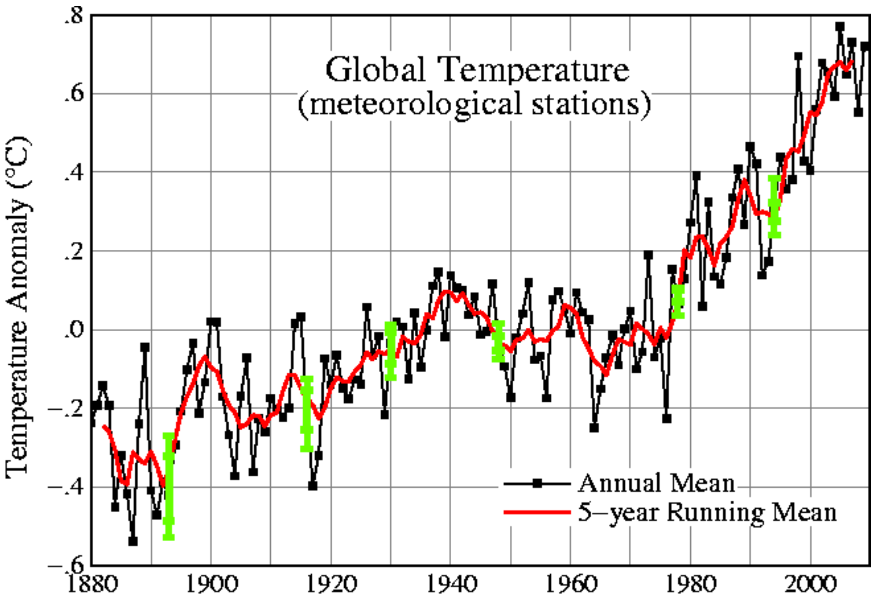

Figure 2.3 Graph of global annual surface temperatures relative to 1951–1980 mean temperature (Air and ocean data from weather stations, ships and satellites). Source: http://data.giss.nasa.gov/gistemp/graphs/ (accessed 6 March, 2012)

Instrumental measurements starting around the middle of the 19th century plus the extrapolations made on values of temperatures in previous centuries lead to the conclusion that never in the last millennium have temperatures shown such a high rate of increase. But temperatures and mean precipitations do not only go up but also show more variability over the planet in the last one hundred years. Important differences between land and sea, between different regions, between seasons, or even between day and night, constitute a natural phenomenon. What characterises the last hundred years is that those differences are accentuating and becoming largely superior to the statistical variability. Winters are warming faster than summers. This is particularly striking in Eastern and Southern Europe, where the number of cold days has notably reduced while days with suffocating temperatures are more frequent (See Figure 2.4).

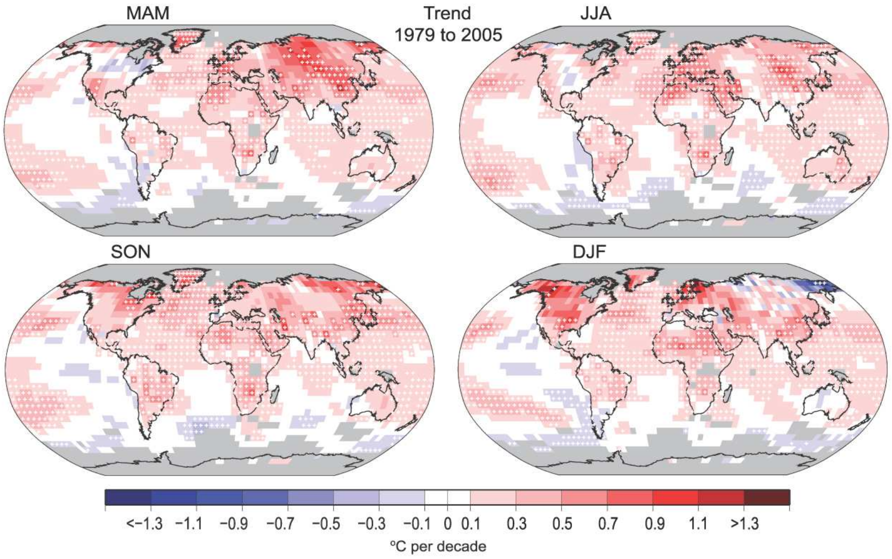

Figure 2.4 Linear trend of seasonal March-April-May (MAM), June-July-August (JJA), September-October-November (SON) and December-January-February (DJF) temperature for 1979 to 2005 (°C per decade). Grey areas indicate insufficient data. Source: IPCC Fourth Assessment Report, chapter 3: Observations: Surface and Atmospheric Climate Change. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch3s3–2–2–7.html (accessed 6 March 2012)

This global warming is not only detected in thermometer readings all over the world. There is much evidence coming from other sources as the following sub-sections illustrate.

2.2.2 Precipitations

Evaporation goes hand in hand with the scaling up of temperatures. It accounts for the 2 percent rise in precipitations that has been observed over the last one hundred years.[3] But this is not at all good news because the apparently beneficial effect is mitigated by the large regional differences (See Figure 2.5). The IPCC states in its 4th report (2007, Chapter 3: 262):

> "Observations show that changes are occurring in the amount, intensity, frequency and type of precipitation. These aspects of precipitation generally exhibit large natural variability, and El Niño and changes in atmospheric circulation patterns such as the North Atlantic Oscillation have a substantial influence. Pronounced long term trends from 1900 to 2005 have been observed in precipitation amount in some places: significantly wetter in eastern North and South America, northern Europe and northern and central Asia, but drier in the Sahel, southern Africa, the Mediterranean and southern Asia. More precipitation falls now in the form of rain instead of snow in northern regions. Widespread increases in heavy precipitation events have been observed, even in places where total amounts have decreased. These

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3 IPCC Fourth Assessment Report 2007, 0. See also Chapter 3, p. 254. http://www.grida.no/graphicslib/detail/precipitation-changes-trend-over-land-from-1900-to-1994_3f8d *(accessed 6 March 2012)*

changes are associated with increased water vapour in the atmosphere arising from the warming of the world's oceans, especially at lower latitudes. There are also increases in some regions in the occurrences of both droughts and floods".

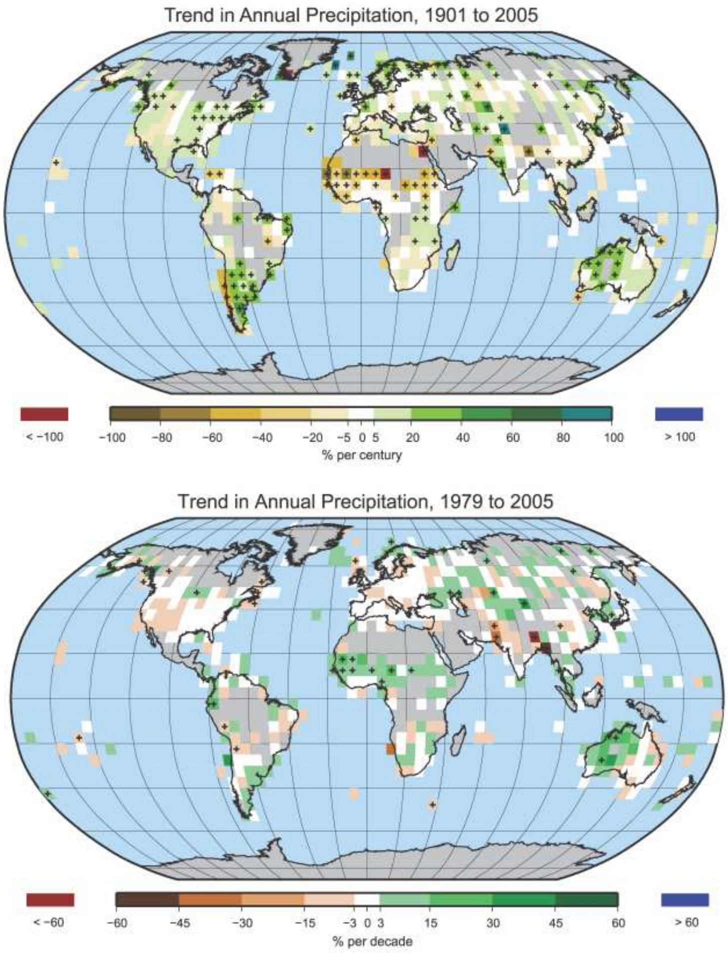

Figure 2.5 (Top) Trend of annual land precipitation amounts for the period 1901 – 2005; (bottom) for the period 1979 – 2005. Source: IPCC Fourth Assessment Report, chapter 3 Observations: Surface and Atmospheric Climate Change http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch3s3–3–2–2.html (accessed 6 March 2012)

2.2.3 Oceans are also slowly warming up

Oceans levels and temperatures have been also rising since the end of the 19th century and the trend has been accelerating, starting in the early 1990s. In some locations, part of this change may be due to natural causes. Nevertheless, the alterations observed at the planetary scale cannot but be connected to global warming. Instrumental readings lead to an estimate of 0.6ºC for the global increase since 1860 [Folland *et al.*, 2001]. However, that warming is unevenly distributed. Ocean dynamics and local conditions induce differences in warming among the different seas. Figure 2.6 displays those differences in seas contiguous to continental Europe. The North Atlantic has been warming less than the North and Baltic Seas, due to influences from the Arctic and the Ocean Conveyor Belt (See further ahead).

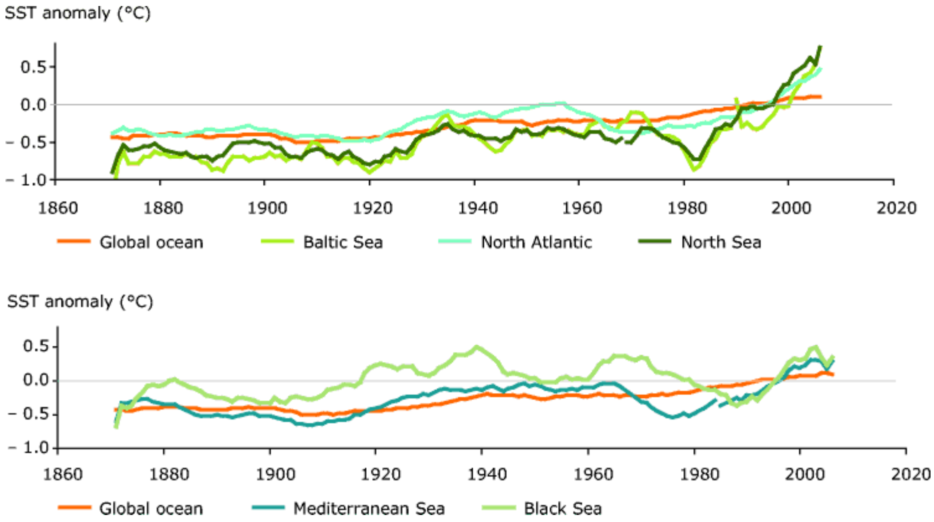

Figure 2.6 Sea surface annual average temperature anomaly for period 1870–2006 with respect to 1982–2006 mean in different European seas. Source: European Environment Agency, http://www.eea.europa.eu (accessed 6 March 2012). Figure link: http://www.eea.europa.eu/data-and-maps/figures/sea-surface-temperature-anomaly-for-period-1870–2006 (accessed 6 March 2012)

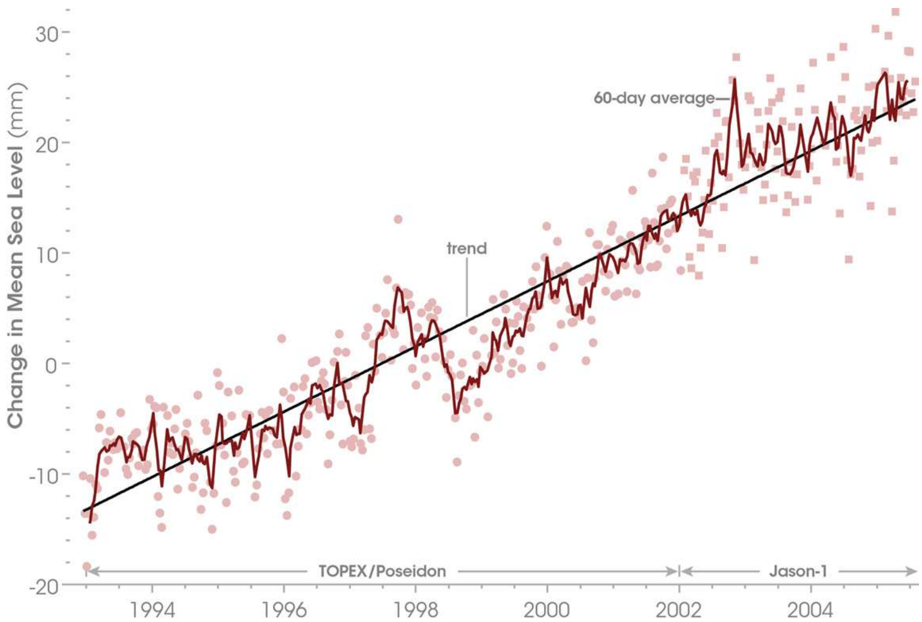

Figure 2.7 Satellite altimetry measurements of average sea level rise for the period 1994 – 2004. Red solid line: 60-day average. Black solid line: trend. Source: Nasa Earth Observatory, http://earthobservatory.nasa.gov/IOTD/view.php?id=6638 *(accessed 6 March 2012)*

Sea levels have increased up to 25 cm in some places (Figure 2.7). The extent of the phenomenon varies locally, as happens with tides, and depends on many factors, such as sea floor topography, irregularity of the coast line, land subsidence (as in Bangladesh) or isostatic land rises (see, for example, the isostatic rebound[4] of the Northern Baltic from the last Glaciation). Narvik, in Northern Norway, registers a 3 mm rise per year, while

[4] Isostatic rebound is a physical process by means of which a floating body rises when freed from a load. When a thick ice cap covered Scandinavia, the glaciers' tremendous weight "sank" the lithosphere (earh's crust) into the viscous upper mantle. Upon deglaciation, the buoyant force exerted by the upper mantle tends to re-establish equilibrium by raising the lithosphere. This process is extremely slow and still continues in the Scandinavian Peninsula, as well as in other parts of the World.

Marseille, on the French Mediterranean Coast, 1 mm/year. Surface water expands as a result of climbing temperatures. Expanding sea water then readjusts itself vertically as it is constrained by the continental limits of oceanic basins. Moreover, melting continental ice packs contribute further to ascending sea level, but by a much smaller amount.[5]

As shown in Table 2.1 other sources different from thermal expansion contribute to rising sea-level. We can observe that the trend has gained momentum since the early 1990s. New satellite measurements give it a global dimension that cannot but amplify in the future. Due to its thermal inertia sea water has been warming much less than the atmosphere. That means that even if temperatures are someday stabilised, the oceans will continue to show noticeable effects, and, in particular, they will continue their expansion.

Table 2.1 Observed sea-level rise, and estimated contributions from different sources (in mm yr^{-1}). Source IPCC 2007

Source of sea-level rise	1961–2003	1993–2003
Thermal expansion	0.42 ± 0.12	1.6 ± 0.5
Glaciers and ice caps	0.50 ± 0.18	0.77 ± 0.22
Greenland ice sheet	0.05 ± 0.12	0.21 ± 0.07
Antarctic ice sheet	0.14 ± 0.41	0.21 ± 0.35
Sum of individual contributions	1.1 ± 0.5	2.8 ± 0.7
Observed sea-level rise	1.8 ± 0.5	3.1 ± 0.7
Difference	0.7 ± 0.7	± 1.0

2.2.4 Shrinking ice packs

Most glaciers in the World are melting. In fact, the process has been particularly marked since the beginning of the 20th century (Figure 2.8). In the course of the last hundred years Mounts Kenya and Kilimanjaro, for example, have lost 92 percent and 82 percent of their glaciers, respectively [Kaser et al.,2004]. If the shrinking of African glaciers may be linked to local variations in the water cycle, no consensus exists on the reasons for similar observations of retreating glaciers in other parts of the planet. The melt is too fast in order to invoke global warming as the ultimate cause. As a matter of fact, the melt was already apparent well before global warming started to be significant (Figure 2.9).

5 A complete treatment of the issue may be found in: *Sea Level Rise: History and Consequences*, Edited By B.C. Douglas, M.S. Kearney and S.P. Leatherman, International Geophysics Series, Vol. 75, Academic Press, San Diego, 2001.

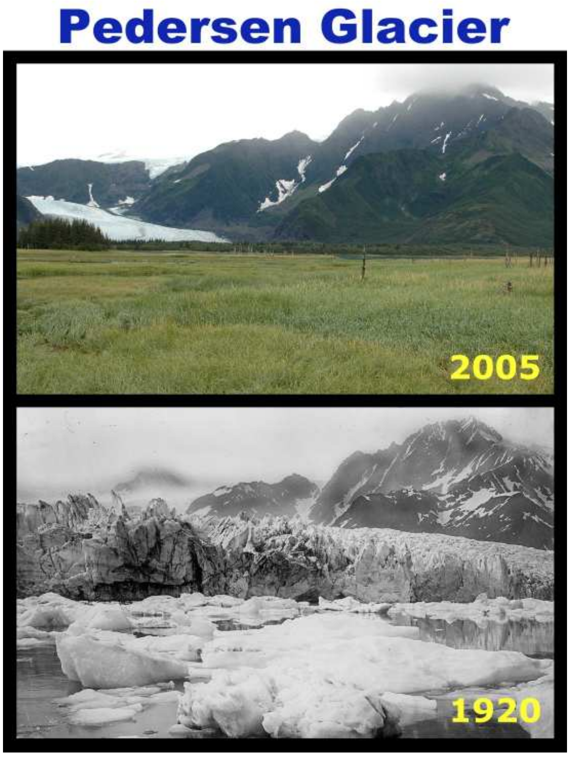

Figure 2.8 Pictures of a melting glacier (Pedersen Glacier Kenai Fjords National Park, Alaska) in 1920 and 2005. Photo composition: Robert A. Rohde. Source: Global Warming Art, http://www.globalwarmingart.com/wiki/File:Pedersen_Glacier_jpg *(accessed 6 March 2012)***).**

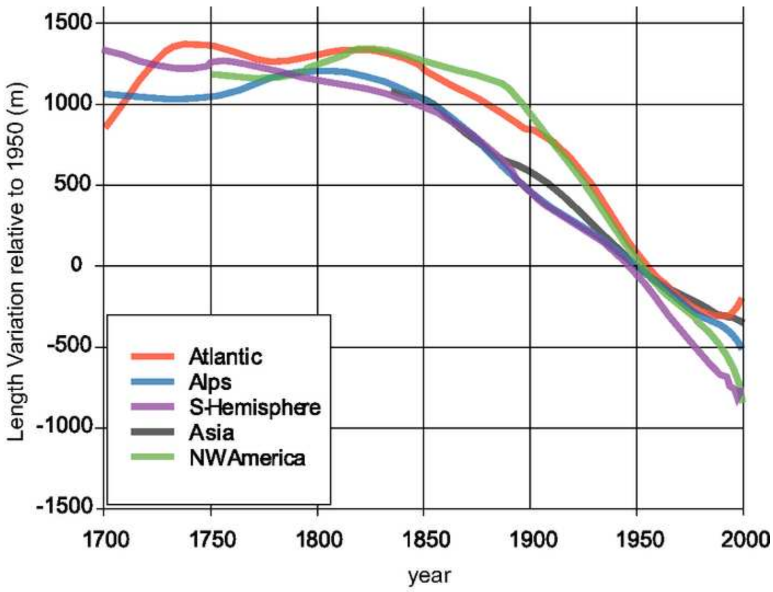

Figure 2.9 Large-scale regional mean length variations of glacier tongues. The raw data are all constrained to pass through zero in 1950. The curves shown are smoothed. Glaciers are grouped into the following regional classes: SH (tropics, New Zealand, Patagonia), northwest North America (mainly Canadian Rockies), Atlantic (South Greenland, Iceland, Jan Mayen, Svalbard, Scandinavia, European Alps and Asia (Caucasus and central Asia). Source: IPCC Fourth Assessment Report*, chapter 4: Observations: Changes in Snow, Ice and Frozen Ground (p.357)*. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter4.pdf *(accessed 6 March 2012)***.**

In any case, less snow is now falling. During winters (Northern and Southern Hemispheres), nearly one third of the planet is covered with snow. The surface covered by snow in the Northern Hemisphere has diminished by 10% since the 1960s[6] and the snow-covered period is diminishing between 7 and 10 days per decade. Spring comes earlier and the arrival of autumn snow is delayed.

It has been observed that a substantial part of Arctic ice is being lost, despite considerable year-to-year variability (see Figure 2.10). Its surface is estimated to suffer the loss of some 30,000 km^2/year (approximately 2.9% per decade), essentially during summer.[7]

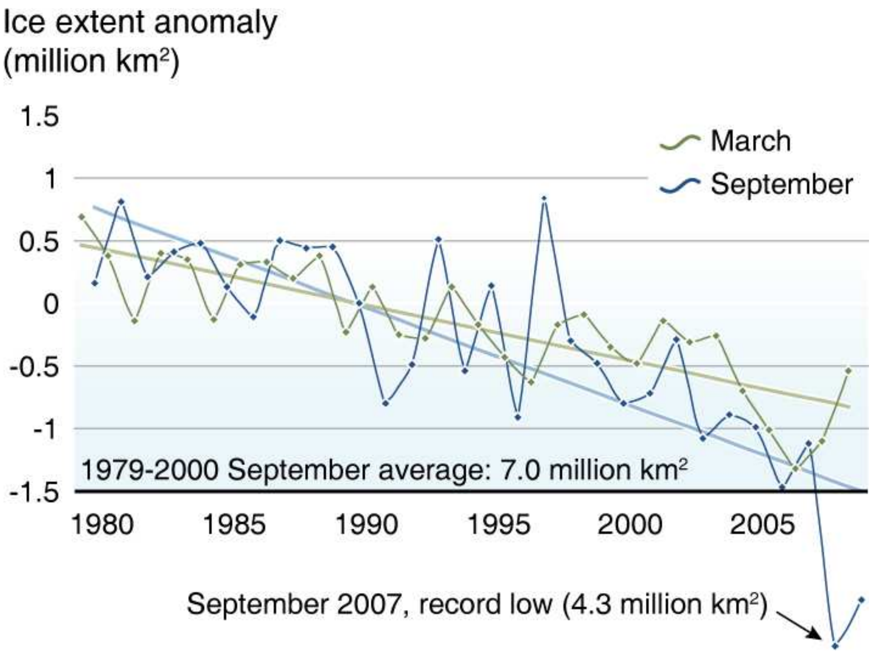

Figure 2.10 Trends in Arctic sea ice extent in March (maximum) and September (minimum) in the time period of 1979–2008. Cartographer: Hugo Ahlenius. Source: http://maps.grida.no/go/graphic/trends-in-arctic-sea-ice-extent-in-march-maximum-and-september-minimum-in-the-time-period-of-1979–20 *(accessed 6 March 2012)***.**

2.2.5 The energy budget

Why are temperatures climbing? Why is this so worrying if variability is intrinsic to climate? Variability is a notorious fact today as well as in the history of climate (see Section 2.3 for a deeper treatment). Past climatic events have left their mark on the Earth's surface. Research on these footprints has led us to realise that climate has undergone many changes during the Earth's history. With sophisticated and complex techniques, scientists have been able to proceed to a reconstruction of the history of the climate of our planet. The reconstruction of the recent past is certainly more accurate and reliable than that of the distant past, being related to the availability of pieces of evidence where transformations of the Earth's crust remove with time this evidence. Paleoclimatology has nevertheless allowed us to have a pretty good image of the last 800,000 years, essentially thanks to air bubbles trapped in the Greenland and Antarctic ice packs, while little is known of how climate was and evolved 500 million years ago. What we know is nonetheless more than enough to convince us of the existence of both colder and hotter periods than the present – both types thriving with life – and also of transitions between those extreme types.

What is singular to the present rise of temperatures is that there is a consensus of the scientific community linking it specifically to human activities, particularly, to the

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6 http://www.ncdc.noaa.gov/indicators/

7 http://www.guardian.co.uk/environment/video/2009/oct/14/arctic-sea-ice-coverage

burning of fossil fuels. On the other hand, it poses a threat not to life itself but to *"life as we know it now, including our present civilisation."*

So the initial question is changed to the following one: why are human activities behind the temperature switch? The answer lies in the modifications brought about by the flow of energy throughout the climate system by gases emitted from burning fuels: the so-called greenhouse gases. But before turning to those disrupting agents we must understand how the planet conveys and transforms the energy it receives from the Sun.

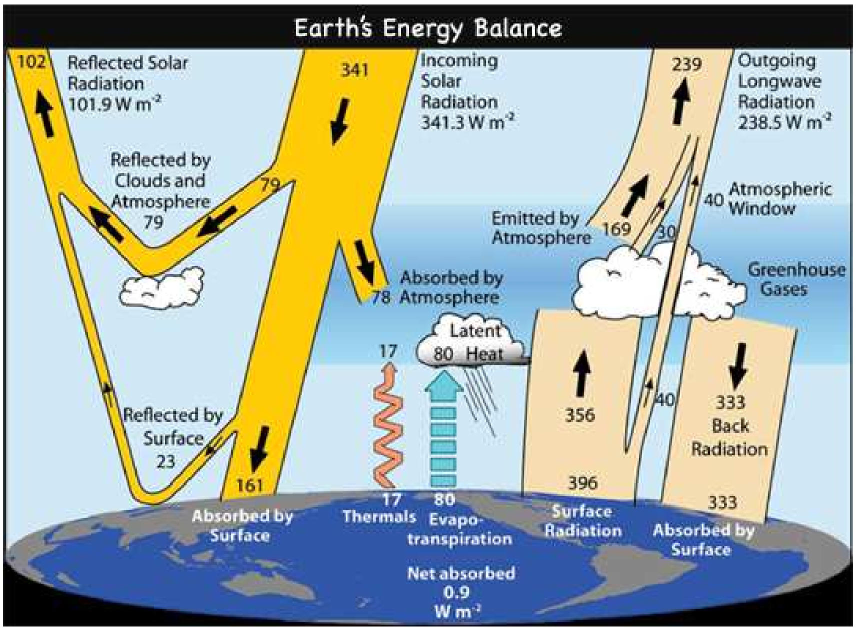


Figure 2.11 Estimate of the Earth's annual and global mean energy balance. Source: IPCC Fourth Assessment Report, chapter 1, Historical Overview of Climate Change Science. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1–1.html *(accessed 6 March 2012)*.

The flows of energy to which we refer to are sketched on Figure 2.11. According to the latest estimations, the Earth receives at the top of the atmosphere (TOA), in the form of shortwave radiation,[8] a mean incoming solar radiation of 341.3 W/m^2 (watts per square metre. The watt is the basic unit of energy -- the joule -- per second). Part of it (totalling 101.9 W/m^2) is directly returned by both the atmosphere and the planet's surface. Consequently, 341.3 W/m^2– 101.9 W/m^2 = 239.4 W/m^2 constitutes the absorbed solar radiation (ASR) by the planet, which sets the atmosphere and oceans into motion and thus defines climate. As a matter of fact, this absorbed energy follows a course of transformations and of complex exchanges between the climate agents. Figure 2.11 outlines the major features of this energy flow.[9]

This energy cannot remain on Earth. Otherwise, the planet would be heating up to untenable levels. In fact, it is returned to the outer space in form of long wave radiation – outgoing (infrared) long wave radiation (OLR). As shown in Figure 2.11, it is estimated that at the TOA the outgoing radiation is 238.5 W/m^2. Let us compare to the figure of 239.4 W/m^2 for the ASR: ASR – OLR = 239.4 W/m^2– 238.5 W/m^2 = 0.9 W/m^2. This means that 0.9 W/m^2 are not returned to the outer space: they have been captured by the Earth's atmosphere. The result is clear: The Earth is heating up and thus temperatures are rising.

8 Roughly speaking, shortwave radiation extends in the visible and near-visible range (0.4–4.0 μm in wavelength)

9 It must be understood that all indicated rates convey yearly averages and not instantaneous values.

2.2.6 Radiant energy and temperatures

We can now address the fundamental difficulty, which is that of trying to understand what is behind the energy imbalance and the ensuing temperature rise. We have been talking of incoming and outgoing short wave and long wave radiation. What do we mean by that? Energy is known, and traded, in a number of different forms. We have probably all heard about the epithets thermal, mechanical, chemical, electrical, elastic, nuclear, and so on, when referring to energy. The Earth, taken as a whole, which means including its atmosphere, exchanges energy with the outer space almost exclusively through a single form: radiant or light energy, that is, in the form of electromagnetic waves. This radiant energy is intrinsic to all bodies whose temperature is above the absolute zero on what is called the Kelvin (K) scale (0ºK which = –273ºC). For the simple fact of having a temperature above the absolute zero, a body emits light in a way which has been known to physics since the 19th century: the black body radiation. Moreover, it turns out that black body radiation provides us with a set of very precise working equations that relate the temperature of an object to the light it emits.

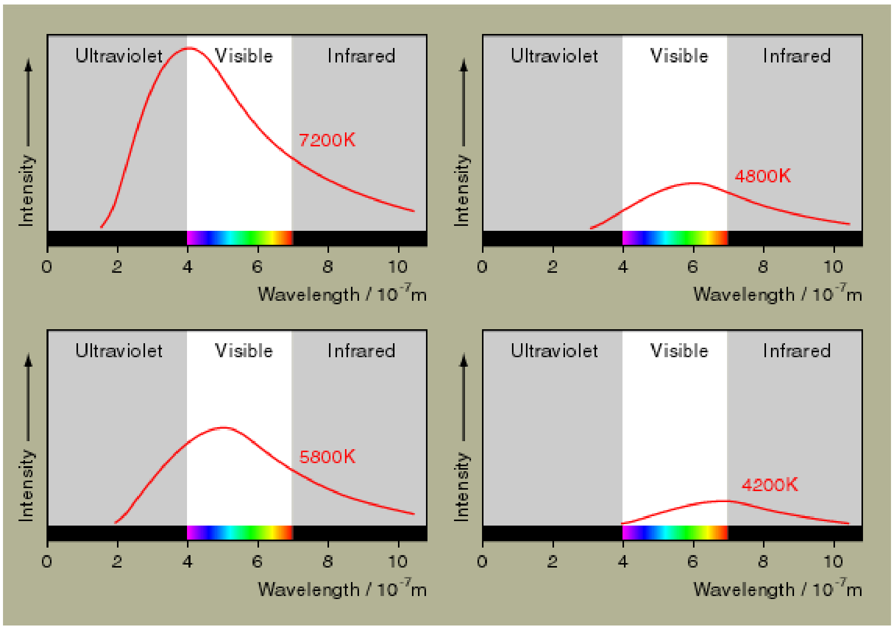


Figure 2.12: Displacement of the blackbody radiation spectrum with decreasing temperature (in ºK). Hotter objects emit preferably in the short wavelength window and, as a body becomes cooler its emission shifts to longer wavelengths (lower frequency and less energetic light). Source: Education Resources of the Hong Kong Space Museum, http://www.lcsd.gov.hk/CE/Museum/Space/EducationResource/Universe/framed_e/lecture/ch05/ch05.html *(accessed 6 March 2012)***)**

A blackbody does radiate energy at every wavelength although the intensity at which a given wavelength is emitted depends on the temperature of the body. If we draw the intensity at which a wavelength is emitted in terms of wavelengths we obtain a bell-shaped, universal curve: the theoretical black body curve at a given temperature, also known as the black body spectrum.[10] The graphs on Figure 2.12 depict four examples at different temperatures (in degrees Kelvin). We observe that the peak decreases in magnitude and shifts its position to the longer wavelengths region as the temperature lowers. It means that the light emitted by very hot bodies (> 7,000 K) is essentially ultraviolet light (short wave radiation). As the body becomes colder (in the range 4,000 K – 7,000 K) most radiant energy is in the form of visible light, or infrared light (long wave radiation) for temperatures below 4,000 K.

[10] The electromagnetic spectrum is the range of all possible frequencies of electromagnetic radiation.

The temperature of the outer, visible part of the Sun (the photosphere) is approximately 5,700 K. The peak is consequently in the visible range. This is why we see the Sun shine. On the other hand, the mean temperature of the Earth is 288 K (15 ºC). The Earth radiates in the infrared range. This is why our planet does not "shine", though that does not mean that it does not radiate light: its light is simply not visible; it is instead sensed as plain heat.[11]

We can now recall Figure 2.11. The outgoing long wave radiation (OLR), which was estimated to be 238.5 W/m2, is essentially infrared radiation. We are talking about infrared radiation and it is at this stage that the greenhouse gases come into action. We shall deal with who they are and what they do in the next few sections.

2.2.7 Atmosphere effects

Not all of the solar radiation received at the outer limits of the atmosphere reaches the surfaces of the Earth. The atmosphere selects various components of solar radiation. As we have already mentioned, part of the incoming solar radiation is reflected back. What is not reflected is, in part, either absorbed or scattered by atmospheric gases, vapours and dust particles.

Atmospheric gases absorb solar energy. They selectively do so at certain wavelength intervals called absorption bands. Those wavelength regions that are not absorbed are known as transmission bands or atmospheric windows. Most of the lethal, very short range of wavelengths (Gamma rays, X-rays and UV rays) is absorbed by oxygen, nitrogen and ozone. Carbon dioxide and water vapour, in contrast, absorb the red and infrared range. Due to the reflection, scattering, and absorption of radiation, the quantity of solar energy that ultimately reaches the ground is much reduced in intensity. The amount of reduction varies with the radiation wavelength, and depends on the length of the path through which the solar radiation traverses the atmosphere. It also varies with such factors as latitude, season, cloud coverage, and atmospheric pollutants.

On the other hand, the ground reflects, absorbs and emits light. Reflection from the ground is primarily visible light. The relatively small amount of energy radiated from the Earth at an average ambient temperature of 17°C at its surface consists of infrared radiation with a peak concentration at 970 nm (nanometres, 1nm= one billionth of a metre). This invisible radiation is dominant at night.

The graphs on Figure 2.13 show how the atmosphere filters both the incoming solar radiation and the surface emitted radiation. The top panel displays the transmitted wavelength ranges while the middle panel displays the complementary image. We can observe that the atmosphere absorbs chiefly in the UV and infrared-thermal domains. In the third panel we find the atmosphere chemical constituents liable for that effect. Surprisingly for many, water vapour is the major absorbent of thermal radiation and the chief responsible player for the warming of the atmosphere. Far behind, come, in this order, carbon dioxide, methane and nitrous oxide.

[11] Infrared radiation is nothing but heat.

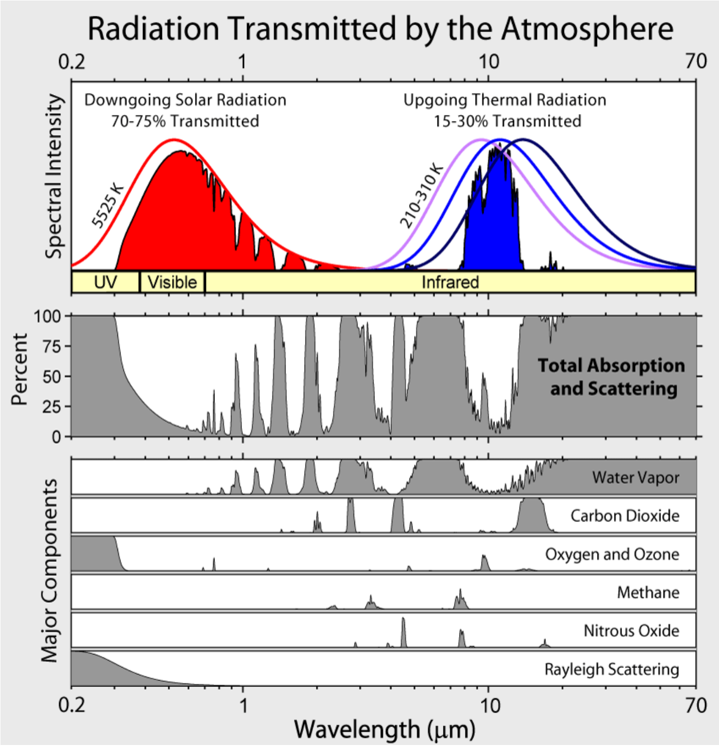


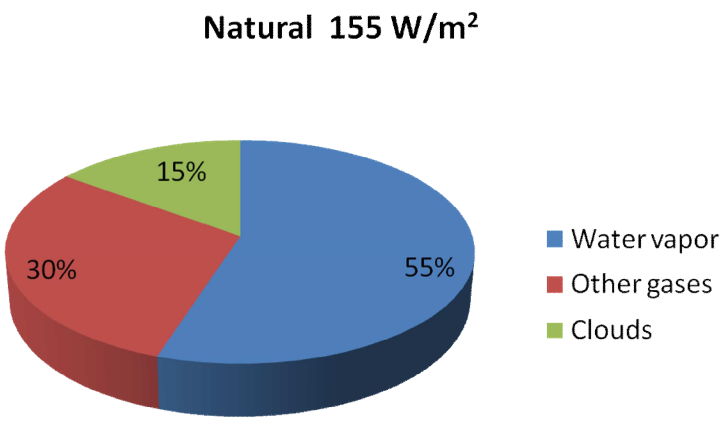
Figure 2.13 Absorption bands in the Earth's atmosphere created by greenhouse gases and the resulting effects on both solar radiation and upgoing thermal radiation. (Top) Solar (red) and soil (blue) radiations transmitted by the atmosphere. (Centre) Percentage of radiation captured by the atmosphere. (Bottom) Contribution of greenhouse gases to absorption and scattering of radiation. Credit: Robert Rohde. Source: Global Warming Art, http://www.globalwarmingart.com/wiki/File:Atmospheric_Transmission_png *(accessed 6 March 2012)***).**

If water vapour accounts for most of the atmospheric warming, why is there so much noise about the anthropogenic emissions of carbon dioxide? The atmosphere warming is a natural effect. It naturally warms, but also cools by radiating back to outer space. When both regulatory mechanisms are in balance, the atmosphere reaches a more or less constant temperature. This has permitted the existence of life on earth because, without an atmosphere, temperatures would mimic conditions on the Moon: a maximum surface temperature of 123 ºC and a minimum of –233 ºC. The problem comes when there is an imbalance between warming and cooling processes in the atmosphere. This is just what is presently occurring. Carbon dioxide which, although certainly less active than water vapour as a warming agent, is increasing its concentration at a very high rate. It is enough to disrupt the warming-cooling balance (water vapour concentration remaining constant) and thus be accountable for the temperature rise.

2.2.8 Greenhouse gases. [12]

All gases which absorb infrared radiation are greenhouse gases: water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3) and man-made molecules such as fluorinated gases or halocarbon compounds. The efficacy with which a gas contributes to the greenhouse effect depends on both its concentration in the atmosphere and its capacity to absorb infrared light.

12 Popular, expressions such as 'greenhouse effect' or 'atmosphere acts as a blanket' are actually misnomers. Usage of words like 'greenhouse' or 'blanket' is partly incorrect. The air inside a greenhouse certainly heats up but the great difference with the atmosphere is that air in the former is trapped and convection prevented. A blanket is an insulator, the purpose of which is to block energy transfer across it, which is of course not what happens in the case of the atmosphere. We shall nevertheless invoke here the conventional usage of the terms, while bearing in mind these differences.



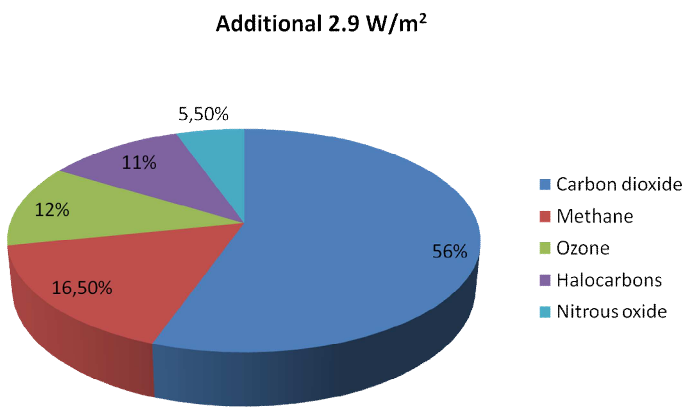
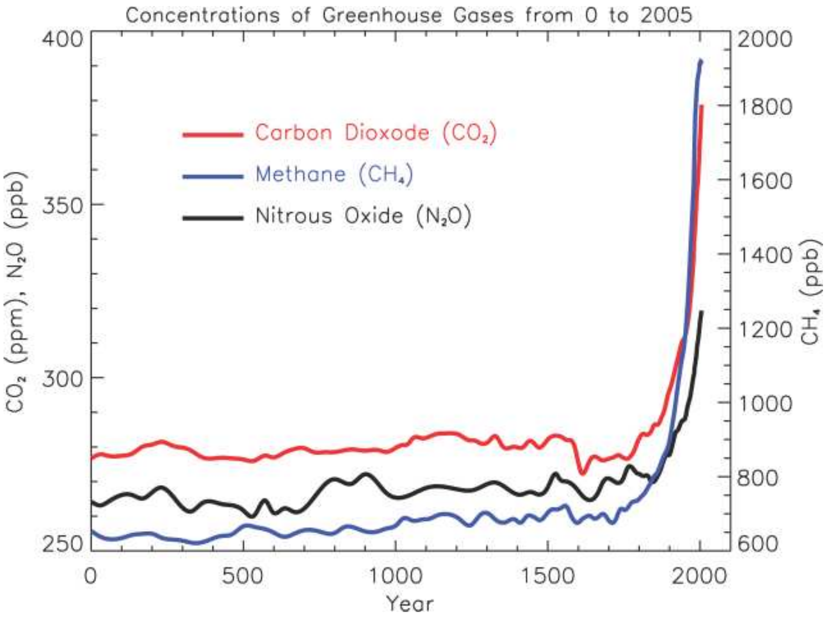


Figure 2.14 (Top) Relative contributions of some of the natural components of the atmosphere to radiative forcing (i.e. the contribution to the greenhouse effect). (Bottom) Man-made contribution to radiative forcing for main greenhouse gases; percentages denote the contribution for each type of gas – not to be confused to the actual concentration for that gas in the atmosphere. (Figure by Victor Fairén)

Figure 2.14 displays the figures for the contribution of each of these agents. The top chart refers to the natural contribution. Here, water vapour accounts for more than half of the total, while other gases (including naturally present carbon dioxide) account only for 30%. The bottom chart displays the added contributions, which result from human activities. Carbon dioxide collects the major part. Currently, methane amounts to 16.5% of the effect, which is a share in clear disproportion to its actual concentration. Its impact, molecule by molecule, is several times more powerful than that of carbon dioxide and it represents a potentially very dangerous source given the huge quantities of trapped methane that can be released if temperatures continue to rise.

Let us now analyse each of these agents.

Carbon dioxide (CO_2)



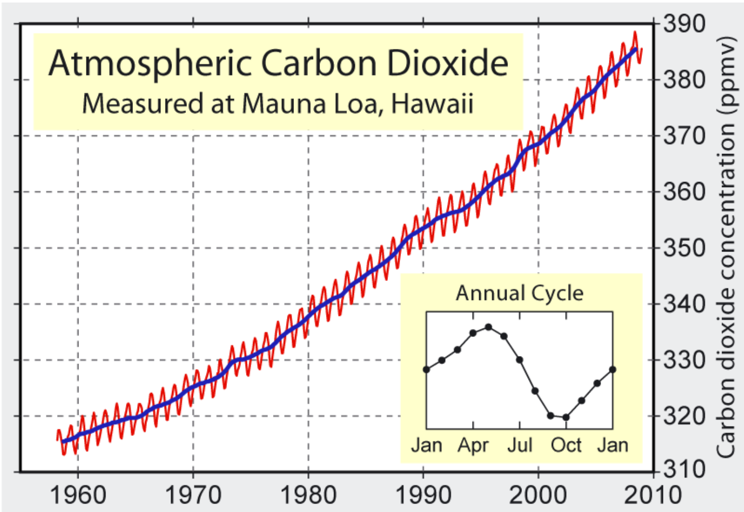
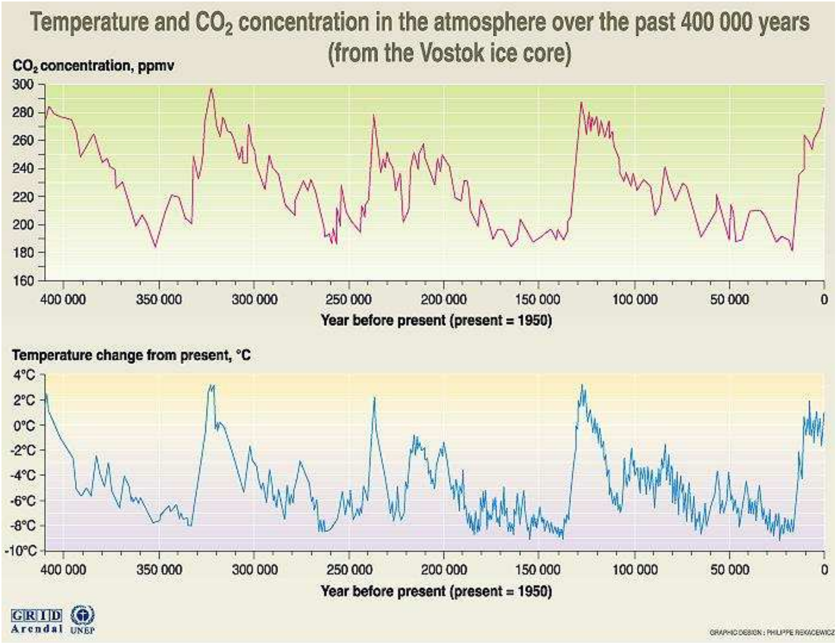


Figure 2.15 (Top) Atmospheric concentrations of important long-lived greenhouse gases over the last 2,000 years. Source: IPCC Fourth Assessment Report, chapter 2: Changes in Atmospheric Constituents and in Radiative Forcing:
http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-2–1.html *(accessed 6 March 2012)***).**

(Bottom) Atmospheric carbon dioxide concentrations as directly measured at Mauna Loa, Hawaii. This curve is known as the Keeling curve, after Charles Keeling, who started systematic instrumental measurements at Mauna Loa Observatory. Red line reflects seasonal variations (see insert) while blue line stands for trend. Credit: Robert Rohde. Source: Global Warming Art,
http://www.globalwarmingart.com/wiki/File:Mauna_Loa_Carbon_Dioxide_png *(accessed 6 March 2012)***).**

CO_2 belongs to the natural carbon cycle, whereby most plants absorb carbon dioxide and animals release it, and has always been a constituent of the atmosphere. Its atmospheric concentration has been increasing for more than a century due to the anthropogenic alteration of the natural carbon cycle, being today at a level never attained during the last 650,000 years[13]. The graphs of the evolution of CO_2 in two separate periods, 0–2005 (top) and 1960–2010 (bottom), are represented in Figure 2.15. We notice the rather dramatic upsurge since the 19th century. Pre-industrial CO_2 levels averaged 280 parts per million; as of 2010, the level is at 390 ppm and steadily climbing, representing an increment of 39% in less than 200 years. The figure is even more striking when seen in the perspective of the last 400 000 years. The top panel of Figure 2.16 shows the time-series of CO_2 concentrations for the last 400 thousand years, reconstructed from samples taken from trapped air bubbles in the Vostok ice core in Antarctica.[14] The top value for the concentration of carbon dioxide for the whole period analysed varies between 180 ppm at the coldest episodes and 280–300 ppm at the warmest, which is well under the present figure. Upon comparing top and bottom panels in Figure 2.16 we notice the correlation between carbon dioxide concentrations and temperatures.[15]



Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

Figure 2.16 Historical trends in carbon dioxide concentrations and temperature, on a geological and recent time scale. Cartographer: Philippe Rekacewicz, UNEP/GRID-Arendal. Source: http://maps.grida.no/go/graphic/temperature-and-co2-concentration-in-the-atmosphere-over-the-past-400–000-years *(accessed 6 March 2012)***).**

Seasonal variations observed on the annual cycle in the bottom chart of Figure 2.15 are due to the growth of vegetation during the warm season, which retrieves through photosynthesis CO_2 from the atmosphere, while the decomposition of that same vegetation during the cold season releases CO_2. Notice that these oscillations for the CO_2 concentration follow the seasonal fluctuations of the Northern Hemisphere because of the higher concentration of continental landmasses in that hemisphere.

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13 In a recent paper (Hönisch *et al.*, *Science* Vol. 324. no. 5934, pp. 1551 – 1554) the authors show that peak CO_2 levels over the last 2.1 million years averaged only 280 parts per million.

14 The Russian Vostok station in East Antarctica yielded the deepest ice core ever recovered, reaching a depth of 3,623 m in 1998.

15 Global climate and CO_2 are correlated, as inferred from Figure 2.16, but the causes of this correlation in the case of the Pleistocene ice ages are unknown. Temperature modifications are believed to have their cause in switches in insulation due to orbital cyclic variations – see Section 2.3.2.2. An ensuing mechanism of CO_2 release or sequestration by warmer or colder oceans, respectively, seemed to be at work here. There is much yet to learn about this quoted ocean uptake.

For the greatest part, this unrelenting accumulation of carbon dioxide is the result of two hundred years of the massive combustion of fossil fuels[16] – essentially, coal, oil and gas – which were produced eons ago as the result of the burial by sediments of plants and animals in anaerobic conditions. This CO_2 accumulation is happening at an ever increasing pace: in the decade 1998–2008 carbon emissions rose by an average of 2.5 percent – nearly four times as fast as in the 1990s *[Le Quéré et al., 2009]*.

It has been estimated that approximately fifty percent of all anthropogenic carbon dioxide ever emitted has been permanently removed from the atmosphere. In spite of that, its atmospheric concentration continues to rise. In the short term, the efficiency of oceans as CO_2 sinks may be impaired by global warming, as the gas solubility in water decreases with temperature.

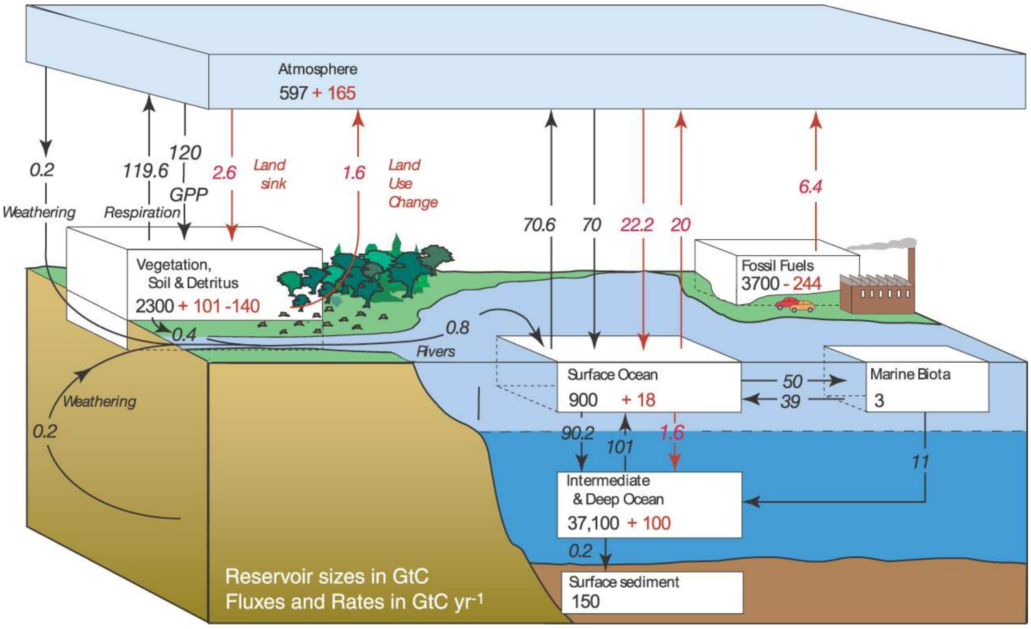

Figure 2.17 IPCC. The global carbon cycle for the 1990s, showing the main annual fluxes in GtC/y (Gigatonnes of carbon per year): pre-industrial 'natural' fluxes in black and 'anthropogenic' fluxes in red. At the end of 1994 the net cumulative atmospheric carbon content of anthropogenic origin amounted to 165 GtC, to be added to the estimated 597 GtC present in 1750, before the Industrial Era. Source: IPCC Fourth Assessment Report, chapter 7, Couplings Between Changes in the Climate System and Biogeochemistry. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch7s7–3.html#7–3–1 *(accessed 6 March 2012)***.**

Figure 2.17 displays the global carbon cycle in the early 1990s as estimated by the IPCC in its Fourth Assessment Report [2007].[17] The graph reveals (arrows in red) the effect of

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16 The two major sources are CO2 emissions from fossil-fuel combustion and industrial processes, and the CO2 flux from land-use change, mainly deforestation (see van der Werf *et al.*, Nature Geoscience, Vol. 2, pp. 737-8).

17 Actually, carbon budget estimates depend on authors. For example, Houghton [2009, p. 40] provides the range (0.5 to 2.7 GtC yr-1) for land-use change (LUC) emissions -from factors such as deforestation, land use data, fire observations, assumptions on carbon density of vegetation (Le Quéré et al., 2009) - with a mean estimate of 1.6 GtC yr-1, and a range (0.9 to 4.3 GtC; mean 2.6 GtC yr-1) for land sink (LS). Le Quéré et al. [2009] give the value 1.5 ± 0.7 GtC yr-1 for net LUC CO2 emissions for the period 1990-2005 and a mean land uptake (LS) of 2.2 ± 0.4 GtC yr-1 for the period 1990-2000. Sarmiento et al. [2010], upon comparing different source authors, evaluate the net land carbon sink (LS-LUC) at a mean value of 1.15 GtC yr-1 between 1989 and 2007. Despite this variability in the sources, these authors find agreement between different models in showing a clear tendency towards an increase of net land carbon sink values during the period 1960-2005, which, they conclude, may be attributed to a shift to a higher overall land uptake rate during that period. The reasons for the jump in LS values remain unclear .

human interference on natural values for fluxes[18](arrows in black) and reservoir contents (see boxes in graph). As a result of combustion of fossil fuels, 6.4 Gigatonnes[19] of carbon equivalent (GtC) per year, on average, were dispersed into the atmosphere during those years. Land use change (mainly deforestation) contributed to an additional input of 1.6 GtC/y. This total flux of carbon to the atmosphere was partly counterbalanced by the absorption of atmospheric CO_2 by both land and oceans. An estimated 2.2 GtC/y were absorbed by vegetation (growth) and soil (detritus). Oceans were estimated to take 1.6 GtC/y. All processes summed up, there was a net atmospheric gain of 3.8 GtC/y (8-4.2).

The figures in boxes (Fig. 2.17) give an idea of the relative impact of human activities since 1750. During the period 1750-1994, and according to IPCC estimates, 244 GtC of fossil carbon and 140 GtC from land-use changes, were transferred to the atmosphere, totalling 384 GtC. Part of this huge amount of carbon was reabsorbed by land and soil (101 GtC) or was dissolved in surface and deep oceans (18 and 100 GtC, respectively). Consequently, the atmosphere still retained at the end of that period 165 GtC (384-101-18-100), product of human activities. This amount is to be compared to the natural atmospheric carbon content in 1750, which was estimated by the IPCC to total 597 GtC. It means a net 28% increase in two hundred and fifty years.

An understanding of CO_2 exchanges between land and atmosphere is crucial in order to perfect the description of the carbon cycle and therefore make better predictions on the future levels of this greenhouse gas [Reich, 2010]. In the context of mitigation, much has been debated on the issue of CO_2 fertilisation, an intensification of vegetation growth due to higher carbon dioxide atmospheric levels. It may be one of the causes behind the gains in net land carbon sink values, although field studies are far from conclusive and the debate is still open. Apparently, vegetation should thrive in enriched carbon dioxide conditions as CO_2 is one of its primary resources. It is nevertheless not as simple as one might think. Net Primary production (NPP), which quantifies the amount of carbon dioxide fixed by terrestrial vegetation, showed the expected intensification in the 1980s and 90s [Nemani et al, 2003], although it is not clear if that happened in response to higher atmospheric carbon contents . However, in the first decade of the 21st century, the warmest on record, the trend has been inverted [Zhao and Running, 2010]. Large areas of South America, South Africa and Australia are the most affected. The phenomenon seems to be related to the unfavourable rainfall conditions which have dominated the decade in the Southern Hemisphere, and possibly fires and the substitution of large areas of tropical forest (in Brazil and South East Asia) by cash crops. Although the phenomenon needs to be confirmed by additional monitoring and studies, this reversal should be a clear warning to those who count on carbon sequestration by vegetation for counteracting fossil fuels burning.

In summary, roughly speaking, of the estimated 244 GtC emitted into the atmosphere since the beginning of the industrial era, some 165 GtC have settled there (a 27% increase with respect to pre-industrial levels). Meanwhile, current reserves of fossil fuels are estimated to be of the order of ten times the amount already gone into fumes. Although most of them are either unreachable or too expensive to exploit in present conditions, we cannot envisage a good prospect for the future if the world persists in its unabated dependence on fossil fuels.

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18 The word ‘flux’ (plural ‘fluxes’) appears many times in this chapter. Here and in Figure 2.17 it refers to the amount of carbon dioxide incident on an area (land surface, ocean, atmosphere, etc.) in a given time. It can also refer in a similar way to the amount of radiation/energy falling on an area in a given time.

19 A Gigatonne is equal to one billion (1,000,000,000) tons.

Methane and nitrous oxide

Methane (CH_4) is second to carbon dioxide in accounting for the present global warming, with nitrous oxide (N_2O) in third position. Accurate measurements yield increasing atmospheric concentrations for these two gases (see top plate in Figure 2.15), with little geographic variation. The rise with respect to pre-industrial levels is spectacular. This is particularly disturbing in the case of methane because no satisfactory explanation has yet been found.

Methane has a concentration two hundred times smaller than that of carbon dioxide[20] but it accounts for nearly 17 percent of the additional (anthropogenic) warming effect. Its effect, molecule for molecule, is thus more intense than that of carbon dioxide. This apparently paradoxical effect can be explained by the capacity of this gas to absorb infrared radiation due to its chemistry. In return, its lifetime in the atmosphere is much shorter than that of carbon dioxide – a few years compared to scales of the order of centuries to millennia [Archer et al., 2009].

Methane concentration has risen 150% with respect to pre-industrial times. Half of this amount is estimated to come from human activities. The main sources of methane are to be found in anaerobic fermentation (i.e. in the absence of air), cattle, termites, fossil fuels burning and natural gas leakages. Most anaerobic fermentation takes place in flooded areas. Swamps, ponds, rice fields and peat-bogs are thought to release annually some 300 million tonnes of methane. Ruminants are also an important source of methane – 100 million tons per year. In the southern hemisphere, termites play an active role in producing methane (15–30 million tonnes annually). Finally, some 300–450 million tonnes annually are freed as the result of natural gas leakages, fossil fuels burning, deforestation and fermentation in dumping sites.

Nitrous oxide (N_2O)[21] is the third most important contributor to radiative forcing. It is a natural component of the Earth's atmosphere. In pre-industrial times, the concentrations were about 270 ppbv (parts per billion by volume). Bacteria in soils and sediments are the most important source of atmospheric N_2O. They produce N_2O as a by-product of nitrification and denitrification, which are important processes in the natural nitrogen cycle. N_2O escapes from the soils and sediments to the atmosphere, and is eventually broken down in the stratosphere, more than 10 km above the Earth's surface, by ultraviolet radiation. The atmospheric lifetime of N_2O is relatively long (more than a century) making it a powerful greenhouse gas. It has a much larger warming potential than CO_2 and CH_4. One kg of N_2O emitted absorbs 296 times as much infrared radiation as one kg of CO_2 emitted (Global Warming Potential over 100 years [*IPCC*, 2007]).

The atmospheric concentrations of N_2O have been increasing for about a century to 319 ppbv in 2005. This increase is largely associated with increased emissions from soils associated with food production for a growing world population [*Kroeze et al*., 1999; *Mosier et al*., 1998]. Increased use of fertilisers in agriculture leads to increased levels of reactive nitrogen in soils and sediments. This stimulates bacteria to produce more N_2O in soils and sediments than under natural conditions. Not only is agricultural land a source of anthropogenic N_2O, but also natural soils and aquatic systems, where levels of reactive nitrogen have increased as a result of fertiliser losses and atmospheric N deposition *[Syakila and Kroeze*, 2011]. Industrial sources of N_2O add to this, but are of minor importance.

20 It is given in parts per billion (ppb) on Figure2.15 instead of parts per million (ppm)

21 We thank Dr. C. Kroeze for authoring the contribution on N_2O

Water vapour

Water vapour is by far the most important greenhouse gas. It produces more atmospheric warming than any other gas, even if a water molecule is less efficient in absorbing infrared radiation than a CO_2 molecule. The equilibrium vapour pressure of liquid water, and correspondingly the maximum amount of water in the atmosphere, augments exponentially with temperature. If this is a well-known physical fact, the consequences are not so clear. As a result, the infrared thermal radiation redirected by water vapour will consequently be boosted by the global warming produced by other gases (and itself), and temperatures will rise even more. But, on the other hand, cloud formation will be stimulated in a vapour rich atmosphere, and clouds are known to have a mixed effect on infrared thermal radiation. Water in the form of liquid droplets absorbs infrared thermal radiation as well. Depending on their type, clouds behave differently with respect to incoming solar radiation. Putting it in very simple terms, it can be said that low altitude clouds do usually reflect solar radiation, and allegedly cool the atmosphere, while high altitude clouds, on the contrary, show the opposite behaviour and warm it. However, our understanding of clouds and their effect on global warming and climate is still very incomplete. It is not then evident if a higher atmospheric vapour content will have a positive or a negative influence on global warming.

2.2.9 Climate variability and forcing agents

Physical climate models are a kind of compendium of the present body of knowledge on climate and its dynamics. Consequently, we shall ultimately have to resort to those models in order to fit together the different pieces of the climate puzzle. We will deal more profoundly with the nature of climate models later, in Section 2.4. In the meantime, we need for our present purpose to consider the factors we know to exert an influence on the long-term global behaviour of the atmosphere, and thus on climate.

In addition to the atmospheric chemical composition, other driving forces have an effect on climate: The amount of solar energy striking the Earth's surface and its geographical distribution, the distribution of continental landmasses and their drift over time, mountain formation, ocean levels or volcanic eruptions, are all physical realities to be taken into account in a comprehensive picture of climate behaviour and change.

The climate system is defined by the IPCC Fourth Report as: "… an interactive system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere [areas of ice], the land surface and the biosphere [areas of vegetation], forced or influenced by various external forcing mechanisms, the most important of which is the Sun (see Figure 2.18). Also the direct effect of human activities on the climate system is considered an external forcing…"

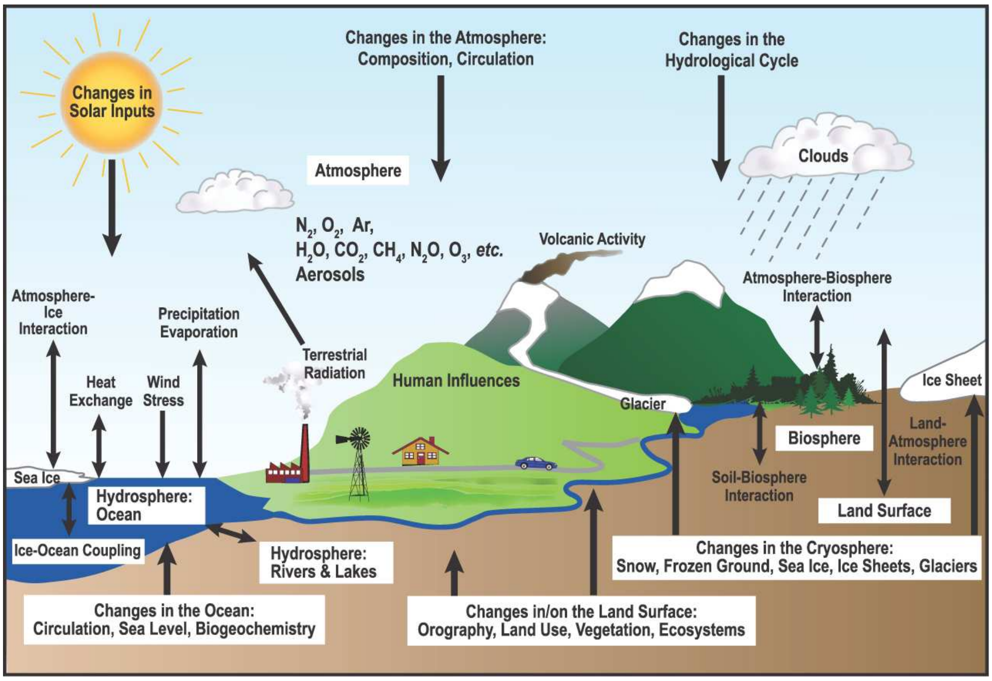

Figure 2.18 Schematic view of the components of the climate system, their processes and interaction. Source: IPCC Fourth Assessment Report, chapter 1, Historical Overview of Climate Change Science: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1–2.html *(accessed 6 March 2012).*

The very sketchy picture offered in Figure 2.18 does reveal that climate is indeed a very complex system, so are our models of it. We are not going to enter the particular issues concerning how the climate machinery is translated into mathematical equations and then processed by computers. We will deal with that in Section 2.4. Let us instead fix our attention on Figure 2.19. The diagram summarises how climate is modelled. At the centre, the climate system proper is outlined, as defined above, with its five components interacting by means of many processes, some of which are indicated on Figure 2.18. On the left of the diagram of Figure 2.19 we find some active sources with capacity to induce physical change on the climate system, also known as forcing agents or drivers. Any change in the climate must involve some energy redistribution among the components. Forcing agents govern ultimately the amount of energy given to the climate system and the way it is redistributed within it, and are thus responsible for its dynamics. Hence, changes in the Sun irradiance and in the planet orbit modify the total energy reaching the planet and thus will affect climate. The distribution of continental landforms influences the way the energy is redistributed among the climate system components. Volcanic activity, by varying the particle concentration in the atmosphere (particles which reflect back into space the incoming Sun radiation), and human actions, by changing the atmosphere composition, all alter the energy budget of the atmosphere.

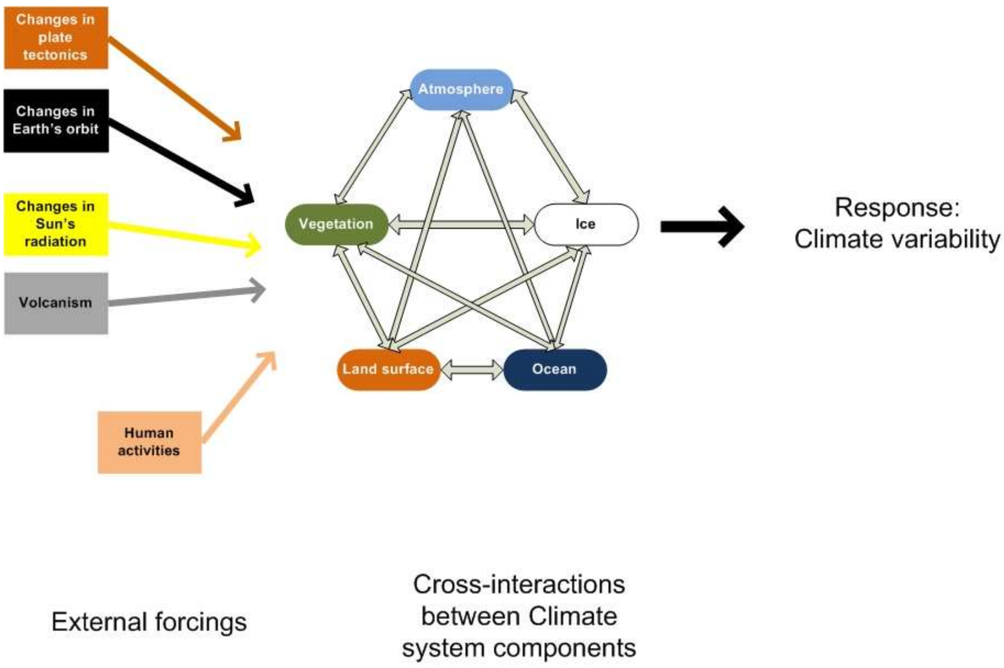

Figure 2.19 Schematic diagram showing the forcings, the processing of those forcings by interacting components of the climate system and the resulting climate variability (see text for details). Figure: Victor Fairén

Those forcing agents that are not affecting directly the net balance between the incoming solar energy and the outgoing terrestrial radiation are known as non-radiative forcings. For example, the form and distribution of continents define the geometry of the Earth and control the way energy is exchanged among components of the system, but not the net balance in and out of the Earth. In contrast, a radiative forcing alters the total energy of the Earth: An agent such as a greenhouse gas is considered a radiative forcing.

One relevant issue to consider when discussing a forcing agent is its associated time scale. By time scale we refer to the lapse of time in which something varies significantly. For example, in the context of atmospheric events, a typical summer storm has an associated time scale of the order of a few hours, while that of the Indian monsoon is of the order of months (typically, from June to September). In another context, variations in the orbit of the Earth occur in time scales of several thousand years, continental drift is measured on a scale of millions of years, as is also, for example, the evolution of species. When a phenomenon is periodic its time scale is given by its period: the orbital time scale of our planet is a year.

We have earlier made an exercise of extreme simplification by reducing climate driving mechanisms to a few forcing factors. As a matter of fact, there is a whole range of them and an enormous range of associated time scales. Let us consider human activities, for example. Significant human-induced changes in landscapes – the vegetation component – may take place in just a few years or alternatively have to wait for centuries to elapse. The generalised use of chlorofluorocarbons (CFCs) – contained in aerosol sprays for example – lasted just a few years, but that was more than enough to have a severe effect on the ozone layer. Massive emissions of carbon dioxide require decades or centuries to produce major impacts.

Table 2.2 contains a brief summary of some typical time scale ranges in the climate system (in years[22]).

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[22] For those of you who are not familiar with scientific notation, 10^{-1}=1/10, 10^2=100, 10^3=1000, 10^4=10,000, 10^5=100,000, 10^6=1 million, 10^9=1 billion.

TABLE 2.2 Approximate time scales in the climate system (in years)	
FORCING AGENT	
Solar variability	from 10^{-1} to 10^9
Continental drift, mountain building, sea level changes	from 10^6 to 10^9
Earth orbit variations	from 10^3 to 10^5
Volcanic emissions	from 1 to 10^6
Human activities	from 10^{-1} to 10^2
INTERNAL PROCESSES	
Atmosphere – ocean – cryosphere interaction	from 10^2 to 10^5
Atmosphere – ocean interaction	from 1 to 10^4
Atmosphere auto-variation	from 10^{-1} to 10

The comparison of time scales provides a simple way for simplifying the analysis of a problem. A simple rule of thumb is: events happening on very different time scales are not connected. For example, the eleven-year period of sunspots will not be relevant at a geological time scale of a million years. Conversely, the axial precession of the Earth (responsible for the precession of the equinox), a movement which takes 26,000 years to complete, will be irrelevant for the climate dynamics of the next twenty years, although is applicable upon the reconstruction of the last glacial episodes, which cover the past 400,000 years.

2.2.10 Natural and human-influenced climate variability

Much evidence, past and present, substantiates the idea of natural variability of climate. We shall review the past later (Section 2.3). Here, we address the problem of the recent warming and check whether it is the reaction to natural forcing or the response to the human-induced change in composition of the atmosphere.

Let us first analyse the available knowledge we possess on natural forcings, in order to uncover any suspect behaviour which might justify the present temperature rise. Before going any further we must recall the discussion about time scales. The present warming has taken place in the last century and a half, so we must discard events taking place on much longer time scales. Such phenomena as the drift of continents and that of the Sun in the Galaxy, mountain formation, or changes in the Earth's orbit, are thus clearly irrelevant (see Table 2.2). None of them has shown relevant changes in the last two centuries and cannot be blamed for the present warming, at least within the current knowledge of the climate system. Alternatively, we understand from data in Table 2.2 that solar variability and volcanism have associated time scales which span years to centuries, and are therefore clearly within our target range.

Total solar irradiance varies continuously. We are not concerned here by possible variations over a multi-millennial scale. On shorter time scales, the 11 year cycle (sunspot cycle), which is the longest recorded aspect of solar variability, involves changes of 0.1% in solar activity.[23] Figure 2.20 presents the reconstruction of the solar irradiance for the last three centuries (purple line). The sunspot cycle can be clearly discerned over the background with a seemingly long-term trend of a very slight increase – See Duffy et al. [2009] for a more extensive treatment of solar variability in the last decades.

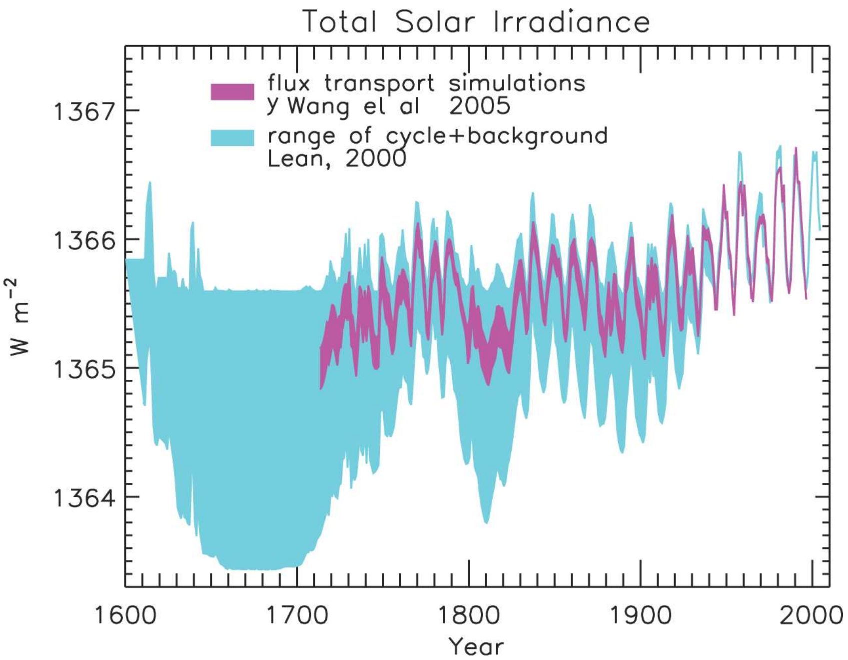

Figure 2.20 Reconstructions of the total solar irradiance time series starting 1600. The upper envelope of the shaded regions shows irradiance variations arising from the 11-year activity cycle. The lower envelope is a reconstructed total irradiance Source: IPCC Fourth Assessment Report, chapter 2, Changes in Atmospheric Constituents and in Radiative Forcing. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2–7–1–2.html *(accessed 6 March 2012)*

Volcanic activity has been comparatively highly episodic and can be attributed a limited influence, circumscribed to brief periods during and after major eruptions. During large eruptive phases volcanoes do certainly emit large quantities of carbon dioxide. On the other hand, large vented clouds (ash and sulphur dioxide) have accompanied the great eruptive processes of the 19th and 20th century: for example, during its 1991 eruption (the world's second largest of the 20th century) Mount Pinatubo on the island of Luzon in the Philippines is believed to have thrown into the atmosphere between 20 and 30 million tonnes of sulphur dioxide. This gas leads to the formation of sulphate aerosols, which cool the atmosphere by directly scattering sunlight back into space. In turn, the cooling effect is relatively short-lived because these sulphate aerosols do not remain for long in the atmosphere. Mount Pinatubo's eruption has been claimed to be responsible for the 0.5ºC – 0.6ºC global temperature drop which took place in the months thereafter.

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23 Sunspots are relatively dark areas on the surface of the Sun, characterised by intense magnetic activity.

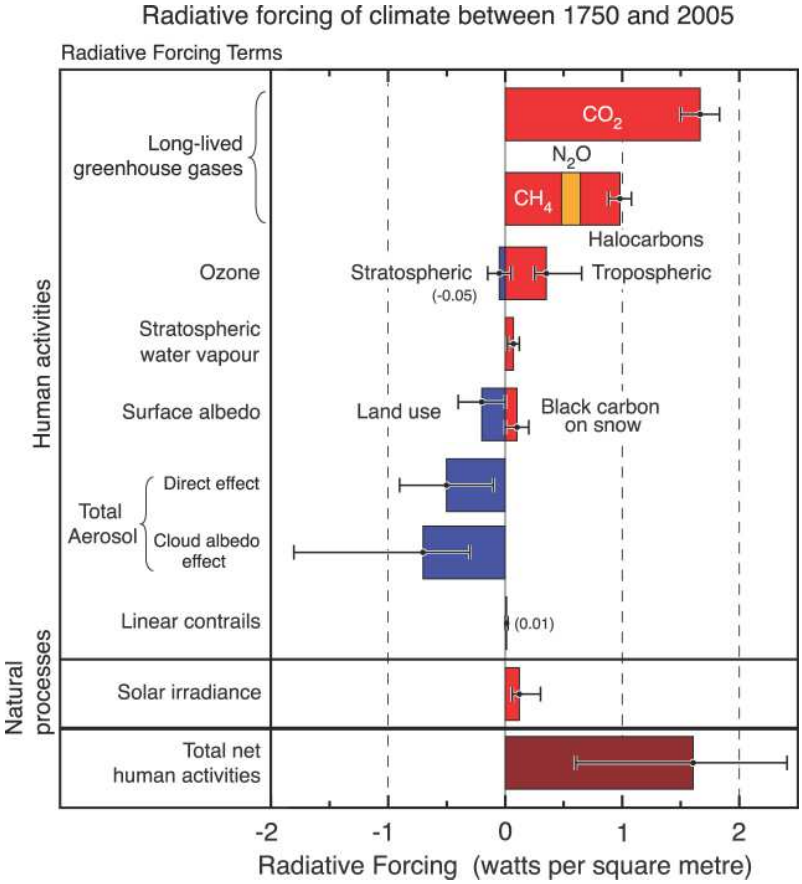

Figure 2.21 (Top) Global mean radiative forcings (RFs) from the agents and mechanisms discussed in this section, grouped by agent type. Positive RFs, favouring global warming, are in red; negative RFs, with a mitigating effect on global warming, are in blue. Source: IPCC Fourth Assessment Report, chapter 2, Changes in Atmospheric Constituents and in Radiative Forcing. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-2–1.html *(accessed 6 March 2012).*

The different types of "sustained" radiative forcing and their sign appear on Figure 2.21 (episodic volcanic events are considered in models but are not recorded in the panel). Positive and negative effects are represented in red and blue, respectively: on top, the greenhouse gases, with a positive radiative forcing (contributing positively to warming); on the middle of the panel, the negative effect of aerosols.[24]

Now comes the most interesting, though controversial part. Observed temperature series must be "linked" to known radiative forcings. All along, we have implicitly made use of a "verbal" description of the cause-effect relationship between forcings and global temperature response. This is good for story-telling but we cannot be satisfied with that: we need to provide a quantitative linkage, which must be constructed according to our present knowledge on how the different constitutive components of climate behave. We are talking about climate models (see Section 2.4). For the time being, however, we only need to know that models make use of the knowledge of the local interactions of air

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24 The word aerosol refers to suspended particles (liquid or solid) with a size ranging from 0.01 microns (1 mm =1,000 micron) to several tens of microns. "Primary aerosols" are formed directly at the source, examples of which include mineral dust, sea salt, and combustion products such as soot and black carbon. "Secondary aerosols" are those formed in the atmosphere from reacted gases, and are often complex mixtures of oxygen, hydrogen, sulfur, nitrogen, and carbon (Smith, 2008, in Encyclopedia of Global Warming and Climate Change, S.G. Philander Ed., Sage Pub., Los Angeles). Aerosols in the atmosphere have direct and indirect effects on the Earth's climate. Depending on their physical and chemical characteristics, aerosols scatter and/or absorb radiation (direct effect), thus modifying the planet's radiation budget. Aerosols also modify the properties of clouds (indirect effect) by acting as nuclei of droplets, thus favouring the formation of clouds. More on aerosols and their impact on climate may be found in Mahowald *et al.*, 2011, *Annual Review of Environment and Resources*, Vol. 36, pp. 45-74.

masses, water, energy, and momentum to explain, with the help of large computers, climate's variability as a response to forcings.

Figure 2.22 displays a summary of the model. On the top plate, the average of thousands of supercomputer simulations of global climate models, including the combined effect of anthropogenic and natural forcings (red line), is judged against the observed evolution of temperatures (black line) for the period 1900–2005. The bottom panel sums up the result when only natural forcings (the blue line) are considered. Upon comparing both figures, it is straightforward to infer that the simulations that include forcing of anthropogenic origin shadow observations much better than do the simulations without it. AOGCM in the Figure legend stands for 'atmospheric and general circulation model' – see section 2.4 later.

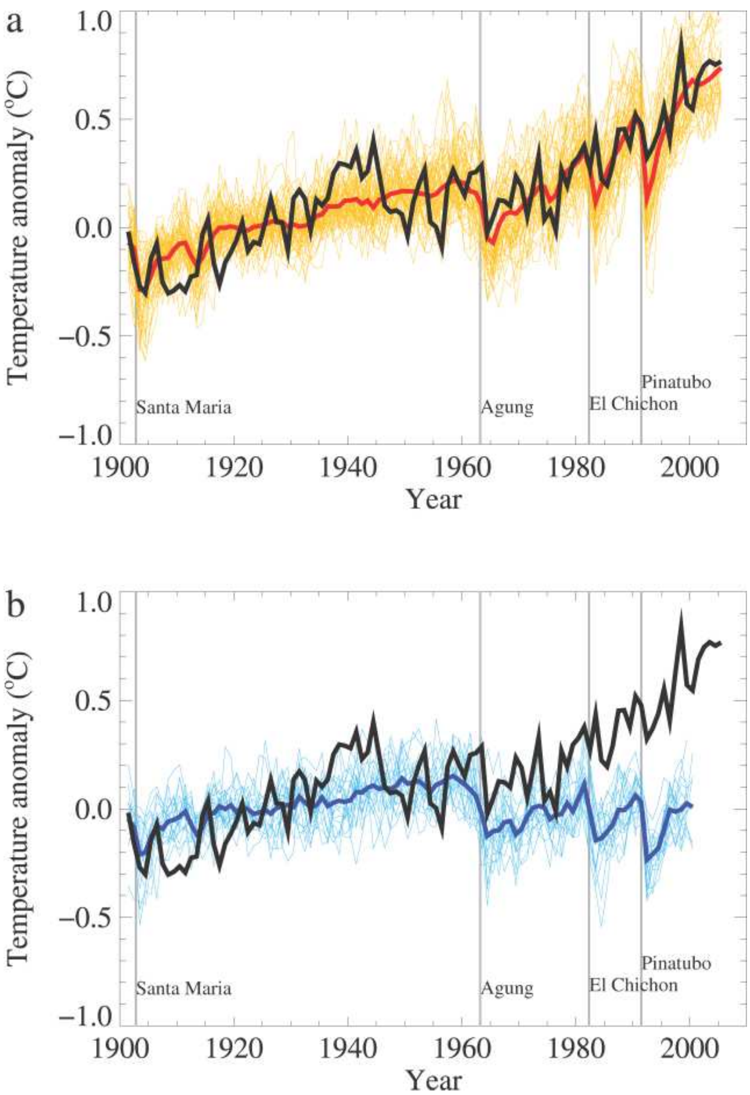

Figure 2.22 Comparison between global mean surface temperature anomalies (°C) from observations (black) and AOGCM simulations forced with (Top) both anthropogenic and natural forcings and (Bottom) natural forcings only. All data are shown as global mean temperature anomalies relative to the period 1901 to 1950. Source: IPCC Fourth Assessment Report, chapter 9, Understanding and Attributing Climate Change.
http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch9s9–4–1–2.html *(accessed 6 March 2012)*

For the periods 1901–2005 (left) and 1979–2005 (right), Figure 2.23 compares observations (top), model simulations of all forcings (centre) and model simulations of natural forcings only (bottom) for global geographical variability of warming trends per decade. The comparison permits us to check the extent to which climate models fit observations, and again the fit is better for simulations that include all forcings than those that include natural forcings only. We do observe, however, some differences between simulated values of all-forcings and observed values. Temperatures over the oceans may be up to 0.5 ° C colder in the aggregate of simulations than what is observed, with more pronounced differences in the North Atlantic. Over continental areas the differences may be somewhat greater, especially in the areas of mountains and high plateaus.[25]

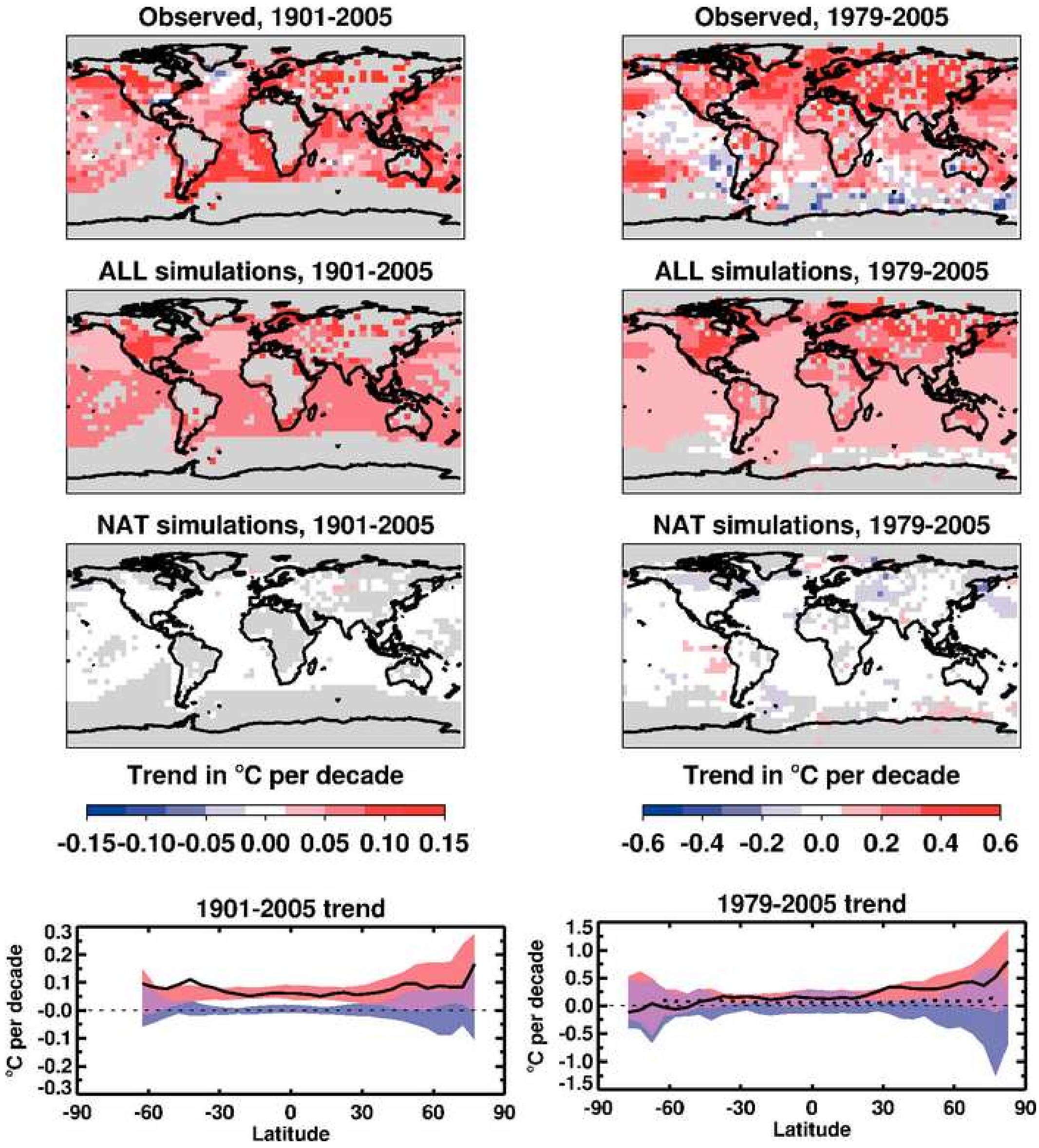

Figure 2.23: Trends in observed and simulated temperature changes (°C) over the 1901 to 2005 (left column) and 1979 to 2005 (right column) periods. First row: trends in observed temperature changes (Hadley Centre/Climatic Research Unit gridded surface temperature data set (HadCRUT3)). Second row: average trends in 58 historical simulations from 14 climate models including both anthropogenic and natural forcings. Third row: average trends in 19 historical simulations from five climate models including natural forcings only. Grey shading in top three rows indicates regions where there are insufficient observed data to calculate a trend. Source: IPCC Fourth Assessment Report, chapter 9, Understanding and Attributing Climate Change.
http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch9s9–4–1–2.html *(accessed 6 March 2012)*

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[25] It should be noted that this is because models do not address directly the surface temperature up to 2 m high. It is derived from interpolation between the ground and the bottom layer with different thickness in each model. Also, horizontal resolutions (size of cells) are not equal across models, so a horizontal interpolation to a common grid size of approximately 300 km is necessary.

In summary, the results indicate that the current global climate models are able to reproduce acceptably the Earth's climate and its spatial variability. However, it must be remembered that there are still uncertainties, largely associated with deficiencies in the settings of certain physical processes critical to climate (IPCC, 2007). In addition, their low spatial resolution cannot reproduce the level of detail which is determinant in the regional climate in many parts of the world.[26] This limitation makes global climate models inappropriate for simulating the various impacts associated with global climate change, because many of those impacts are confined to the regional scale.[27] To better simulate regional or sub-regional climates physical parameterisations (see Section 2.4.1 below) have to use more detailed spatial resolution than that of present global models, thus implying computation many times above what is reasonable with today's computers. It is therefore necessary to invoke other techniques to model adequately the climate on a regional scale. The technique that is considered most promising at present [IPCC, 2007] are the Regional Climate Models [Houghton, 2009].

How is all this to be interpreted? Is it the unambiguous proof that greenhouse gases are the source of global warming? Actually, the second question is difficult to answer without invoking the epistemological nature of climate models and the issue of model validation, which will be addressed more specifically in its technical facets in section 2.4.4.

Models are a mathematical representation of the modeller's reality, which is encapsulated within a formal system. By means of rules of inference (algorithms) new propositions are established which can be compared to observations. The physicist James C. Maxwell put this programme into words by asserting: "… the success of any modelling venture depends upon a judicious selection of observables and means of encapsulating these observables within the framework of convenient formal mathematical systems …" Certainly, scientists validate a model if its predictions match experimental data. But, there is a little more to model making: the ultimate goal of model *validation* is to make the model useful in the sense that the model addresses the *right problem*, provides *accurate information about the system being modelled*, and makes the model *actually used*. Compliance to all these requirements does not imply that a model is a true representation of reality. It is nothing but a *consistent* portrait of a part of this reality as long as it fulfils the stated requisites. It is then its degree of correspondence with what we know about what it is modelled that determines the validity of a model.

Controlled experiments cannot be performed on climate. We have at most single historical data sets to compare with the predictions of climate models: some come from instrumental records; some are proxies from past climates. Models are systematically put to the test and required to reproduce data within reasonable bounds. If we start a model run with specific initial conditions, we obtain a climate with features of a chaotic system. The good thing is that if we do that with a variety of runs with different initial conditions, predictions for global average temperature remain within a fairly narrow range. Climate models are robust. Any computer model, run with plausible initial conditions and including greenhouse gases, yields a global warming, and the match seems less and less accidental.

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[26] The grid mesh, on which they compute the physical quantities relevant for the climate, is too coarse (typically 200km) to capture the local aspects.

[27] Most people are not directly affected by global climate statistics. They care about the local climate and wish to know how global warming will affect the local climate.

2.3 Climate variability in the past

2.3.1 The history of climate

In this section we first review some of the climatic records and climatic changes that have taken place in the past. This section will describe the causes of such climatic changes and also briefly the most significant techniques used to determine past climate.

Paleoclimate

The word Paleoclimate refers to the climate of the Earth in the period preceding the onset of human civilisation and it extends back to the past billion years if not to the beginning of the Earth's history.

Looking at a broad span of the Earth's history, the global climate was much warmer than now – see Figure 2.24. For most of its existence the Earth has been free of permanent ice. These warm conditions were interrupted by perhaps seven comparatively brief periods of glaciation. There is geological evidence that the first glaciation dates about 2.3 billion years ago, followed by five between 900 and 300 million years ago. The latest is the Quaternary glaciation that began about 2 million years ago and which encompasses both the Holocene (the past 10,000–12,000 years) and Pleistocene (10,000 to 500,000 years ago) epochs [Gibbard and van Kolfschoten, 2004].

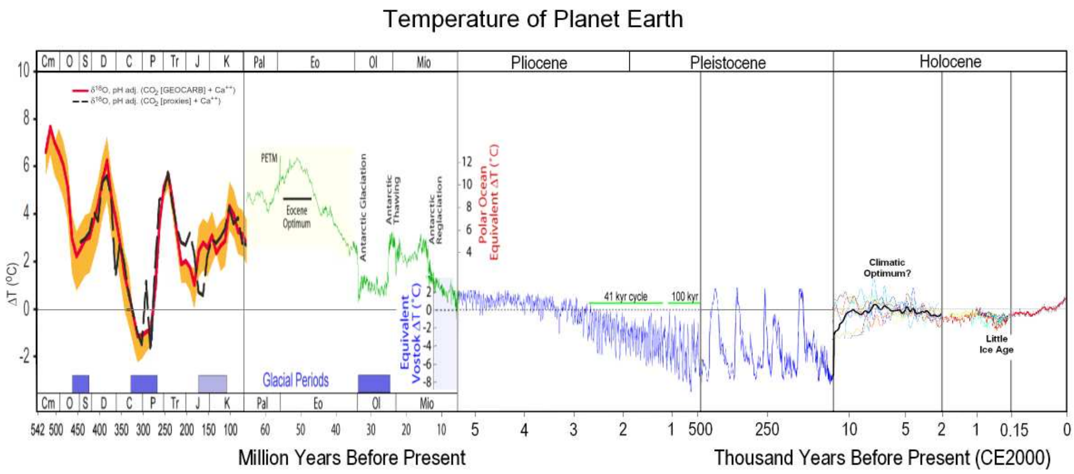

Figure 2.24 Overall perspective of Earth's temperature. The combination is not quite precise as different temperature definitions (global and polar) are used. Time in logarithmic scale increasing to the right. Source:
http://en.wikipedia.org/wiki/Geologic_temperature_record *(accessed 6 March 2012)*

The Quaternary glaciation, often referred to as *The Ice Age*, has been a period of continuous global temperature oscillations. As a result of the oscillations, the advance and retreat of glaciers have alternated over large portions of Europe and North America. These oscillations in temperature and ice cover are called glacial/interglacial periods and typically lasted for about 100,000 years.

The last glacial maximum took place about 20,000 years ago, when the ice caps in Eurasia and North America reached their maximum thickness and extension. During a glaciation an enormous quantity of water is transferred from ocean to land. An estimation of the amount of ice deposited in the ice caps suggests that the sea level has been 120 metres below the present level during glacial maxima.

The glaciers began to retreat about 14,700 years ago, leading to the Holocene, an interglacial period which began approximately 12,000 years ago and continues to the present. By the definition of ice age as a geological period in which extensive ice caps exist in both hemispheres we are still in the last glaciation, but in a warm interglacial. In fact, these warm conditions have allowed human civilisation as it falls entirely within the Holocene.

Data from the Greenland ice cores [Alley (2000)] show that the warming trend from the last glacial period to the Holocene was interrupted about 12,900 years ago when the global temperature suddenly dropped and glacial conditions returned to Eurasia and North America. The cold spell lasted about 1,300 years and is known as Younger-Dryas. It is named for the reappearance in Europe of the polar wild flower Dryas Octopetala. The end of Younger-Dryas came with an abrupt increase in temperature. Post Younger-Dryas changes have not duplicated the size, extent and rapidity of these paleo-climatic changes. The end of the glacial period was accompanied by an abrupt increase in temperature. As we see below, a theory for these rapid variations being caused by an interruption of the North Atlantic thermohaline circulation (a seawater circulation pattern) has been suggested.

During the Holocene (the past 12,000 years) the average temperature has been quite stable compared to the previous glacial period, see Figure 2.25. In the early Holocene from about 9,000 to 5,500 years BC, a relatively humid period in Northern Africa took place. During this phase, known as the *African Humid Period*, grasslands covered the Sahara/Sahel region, and many lakes and wetlands existed here. The termination of the African Humid Period was the most dramatic climate shift in Africa since the end of the Pleistocene. Much of northern and equatorial Africa went from a wet landscape to desert. An important temperature excursion accompanied the end of this period: a slightly warmer period, which lasted two millennia and which is called the *mid-Holocene maximum*. Because this period favoured development of vegetation it is also known as the Holocene Climatic Optimum. It can be seen in Figure 2.25 that about 4,000 years ago a cooling trend began, during which alpine glaciers returned.

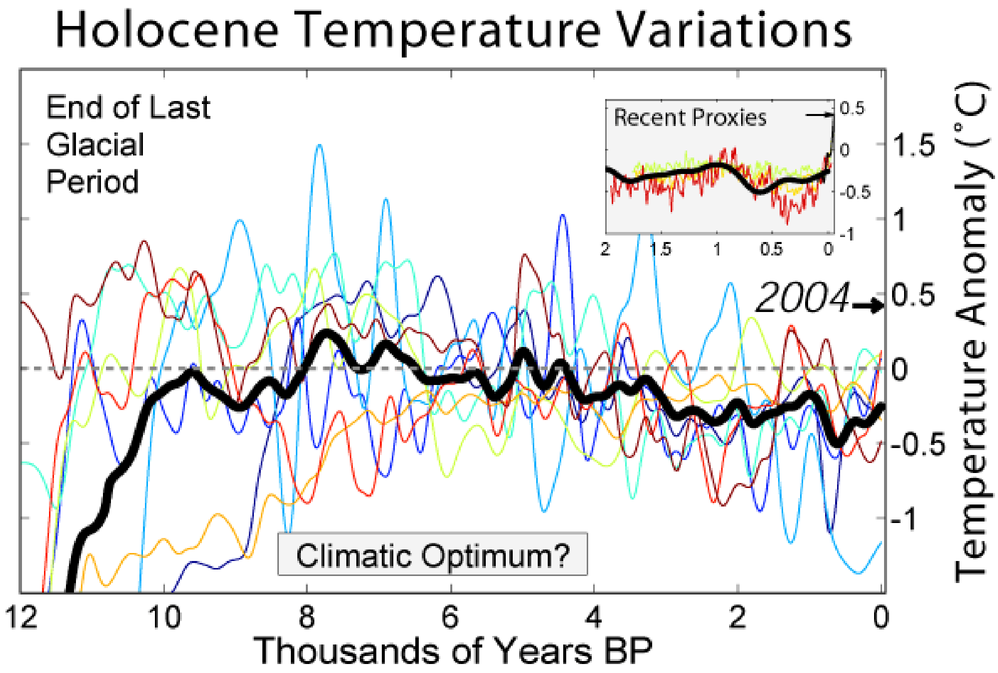

Figure 2.25 Local temperature variability through the Holocene. Reconstructions from eight data sources (ocean sediments, ice core and pollen distributions). The thick dark line shows the average of these data sources. The temperature variations are calculated with respect to the mid-20th century average temperature.. In the inset plot the most recent two millennia of the average temperature is compared with other recent proxies. Source: Wikimedia Commons
http://commons.wikimedia.org/wiki/File:Holocene_Temperature_Variations.png *(accessed 6 March 2012)*

The last millennium

Figure 2.26 illustrates average temperatures over the Northern Hemisphere for the last 1,300 years. It is possible to identify a relatively warm period during the 11th to the 14th centuries. Following this so-called *Medieval Warm Period*, Europe and North America entered a relatively cool period, the *Little Ice Age*, which spanned the 15^{th} to 18^{th} century. This chill was significant enough to allow alpine glaciers to increase in size. There is some evidence that this cold period extended worldwide, but over Europe and Northern America winters were certainly long and severe. During these colder times 1816 was such a cold year that it was described as the "year without a summer".

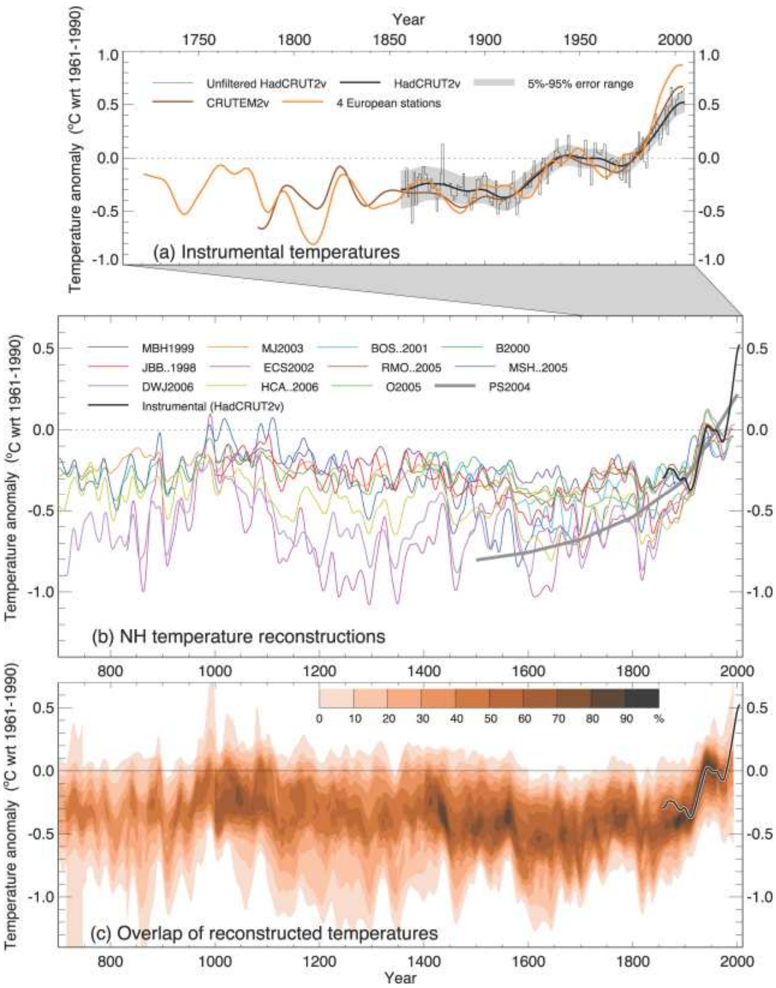

Figure 2.26 The average temperature variations over the Northern Hemisphere for the last 1300 years relative to the 1961 to 1990 average. (a) Annual mean instrumental temperature as recorded from circa 1700 to 2000. (b) Reconstructions from proxy records, tree rings, corals, ice records and historical records. (c) Overlap from ten reconstructions of proxy records. Source: IPCC Fourth Assessment Report, chapter 6, Paleoclimate. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch6s6–6.html *(accessed 6 March 2012)***.**

As we see in next section, several causes have been proposed for the millennium temperature variations, such as volcanic activity and solar activity. These variations have also been interpreted solely as a consequence of the climate system's inherent natural variability.

The climate of the last 150 years

Displayed in Figure 2.27 is the instrumental record for mean annual, global temperature since 1850. We know that the temperature varies from day to day and from season to season, but here we are considering yearly variations in the mean global temperature. The variability of temperature from year to year and also from decade to decade is noticeable from the figure. A warmer period from circa 1900 to 1945, with an increase of the average temperature of 0.5ºC, is followed by a cooling trend of 25 years or so. From the mid-1970s up to 2006 the figure shows a clear warming trend with a temperature increase of about 0.7ºC. Figure 2.27 also shows that linear trends fit the last 150, 100, 50 and 25 years (coloured straight lines), each of them indicating warming trends. More importantly, these trend lines indicate an accelerated warming: their gradients increase as we move from the red line representing the trend of the past 150 years to the yellow line representing that of the past 25 years.

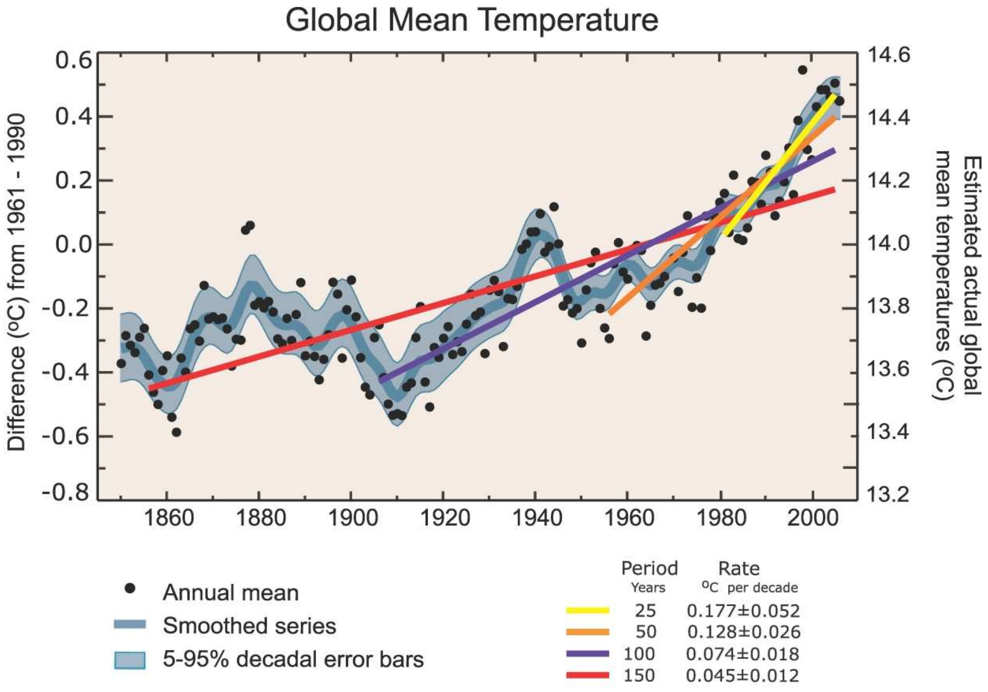

Figure 2.27 Annual global mean surface temperatures for 1950 to 2006. In the right hand axis the actual temperature values and in the left hand axis the anomalies relative to the 1061 to 1990 average. Linear trend fits to the last 25, 50, 100 and 150 years showing accelerated warming. Source: IPCC Fourth Assessment Report, chapter 3, Observations: Surface and Atmospheric Climate Ch*ange. p. 253:*
http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-3–1.html *(accessed 6 March 2012).*

2.3.2 Causes of climate variability

Many theories attempt to explain both short-term and long-term climate variability. The problem facing any comprehensive theory is the complex set of interactions of the elements forming the climate system. As we have seen, global climate is the result of a balance between incoming solar energy and outgoing energy from the Earth. There are a number of natural mechanisms that can upset this balance and therefore “force” the climate to change. When the climate system is perturbed by a *climate forcing*, the climate system responds by either amplifying (positive feedback) or diminishing (negative feedback) the effects of the perturbation. One example of positive feedback is the snow-albedo on a cooling planet. Lower temperature increases the snow cover and therefore increases the albedo, so more incident sunlight is reflected; thus less sunlight is absorbed at the surface which causes a further drop of temperature. Note that the snow-albedo is also a positive feedback in a warming planet as higher temperature leads to smaller snow cover and less reflected energy and thus further warming.

All feedback mechanisms operate simultaneously so that any one of the agents of change might interact with another in such a way that their effects do not merely sum up (see Section 2.1)

However, even in the case of no external forcing the Earth’s climate seems to show a natural variability as a result of spontaneous fluctuations due to internal causes. These variations may result from changes in the ocean motions, the atmosphere or interactions between the two. Examples of these fluctuations are the irregular cycling between warm (El Niño) and cold (La Niña) phases of the El Niño Southern Oscillation (ENSO). ENSO is a quasiperiodic pattern of the ocean surface temperature in the Pacific off the South American Coast. It takes place at irregular intervals of about five years and it causes extreme weather such as floods and droughts.

The point is how to determine if internal variability is enough to explain a climate change of the importance of the current global warming or if it is necessary to include external forcings. In this sense, the temperature record of the last millennium is particularly important because it gives indications of the range of natural variability in a period where there are enough data to determine the magnitude of possible forcings.

As we will see in the next section, one way for evaluating internal variability is to use global climate models, which show how the climatic system should evolve when each external forcing can be switched to zero. Alternatively, one can study events in the climate history trying to assess whether a climatic change can be explained as a consequence of an external forcing.

In this section we adopt the second approach reviewing how changes of external forcings may explain observed climatic variations, with the aim, whenever possible, of evaluating if any of these changes is playing a significant role in the present global warming.

Variations in solar activity

Direct measurements of solar output have been made from satellites since 1978. Those measurements show variations in the solar output in cycles of 11 years, with variations of about 0.1% between the maximum and minimum of the solar activity cycle.

It is known that the Sun’s energy output appears to be correlated with the number of sunspots. Sunspots also occur in 11 year cycles. The number of sunspots has been recorded since Galileo discovered them in 1610. This astronomical record shows a period (1645–1715) known as the Maunder Minimum with few, if any, sunspots. As this minimum occurred during the cold spell known as Little Ice Age, some scientist have suggested that the reduction in solar output energy is the cause of the Little Ice Age. Estimates of the reduction of solar energy incident on our planet during the Maunder Minimum are in the range 0.1–0.4%.

As we see below, another indicator of solar activity is the amount of carbon-14 found in trees. This record provides evidences that the solar activity has been relatively constant throughout the last 2000 years.

Therefore it seems unlikely that such a small change of 0.1% (1/1000) in the Sun’s irradiance may have been the direct cause of the Little Ice Age. In fact, the effect on temperature of the last 11-year cycle seems to be masked by the effect of greenhouse gases.

Volcanic eruptions

The presence of liquid and solid particles (aerosols) modifies the turbidity of the atmosphere, which has complex effects on climate. Some aerosols are released to the atmosphere through natural processes, such as land fires, dust storms, volcanic eruptions or asteroids impacts. Human activity also is a direct source of aerosols – mostly in the troposphere. The lifespans of aerosols vary from days or weeks in the troposphere to years in the stratosphere and thus do not exert long-term effects on climate.

During volcanic eruptions, ash and dust particles as well as gases can be ejected up to the stratosphere. Acidic gases combine with water vapour in the presence of solar radiation, forming droplets which ultimately develop into aerosols. Stratospheric aerosols due to volcanic activity absorb and reflect part of the incoming solar radiation. The effect of volcanic eruptions on climate can last several years as long as stratospheric aerosols remain in suspension.

Clear correlations of downturns in temperature and volcanic eruptions have been found in the past century. The cooling effect of an eruption lasts a few years depending on the amount of material injected into the atmosphere.

The most spectacular instance was the massive eruption of Mount Tambora in 1815 and the following extremely cold year (1816) that was described as having been like the year without a summer. Average global temperatures decreased by about 0.4–0.7 ºC, enough to cause significant agricultural problems around the globe.

Figure 2.28 shows monthly mean global temperature anomalies for atmosphere and surface. Times of major volcanic eruptions are indicated by dotted vertical lines. The short duration effect of a single eruption, or an increase of the average volcanic activity, may explain small global temperature changes.

The combination of an increase in volcanic activity and a decrease of solar radiation may have contributed to the Little Ice Age cold spell, if not as a direct cause, as the spark that started a climate instability (climate sensitivity to small perturbations). In any case, the effect of any current weakening or strengthening of solar radiation would be offset by the forcing effect of greenhouse gases.

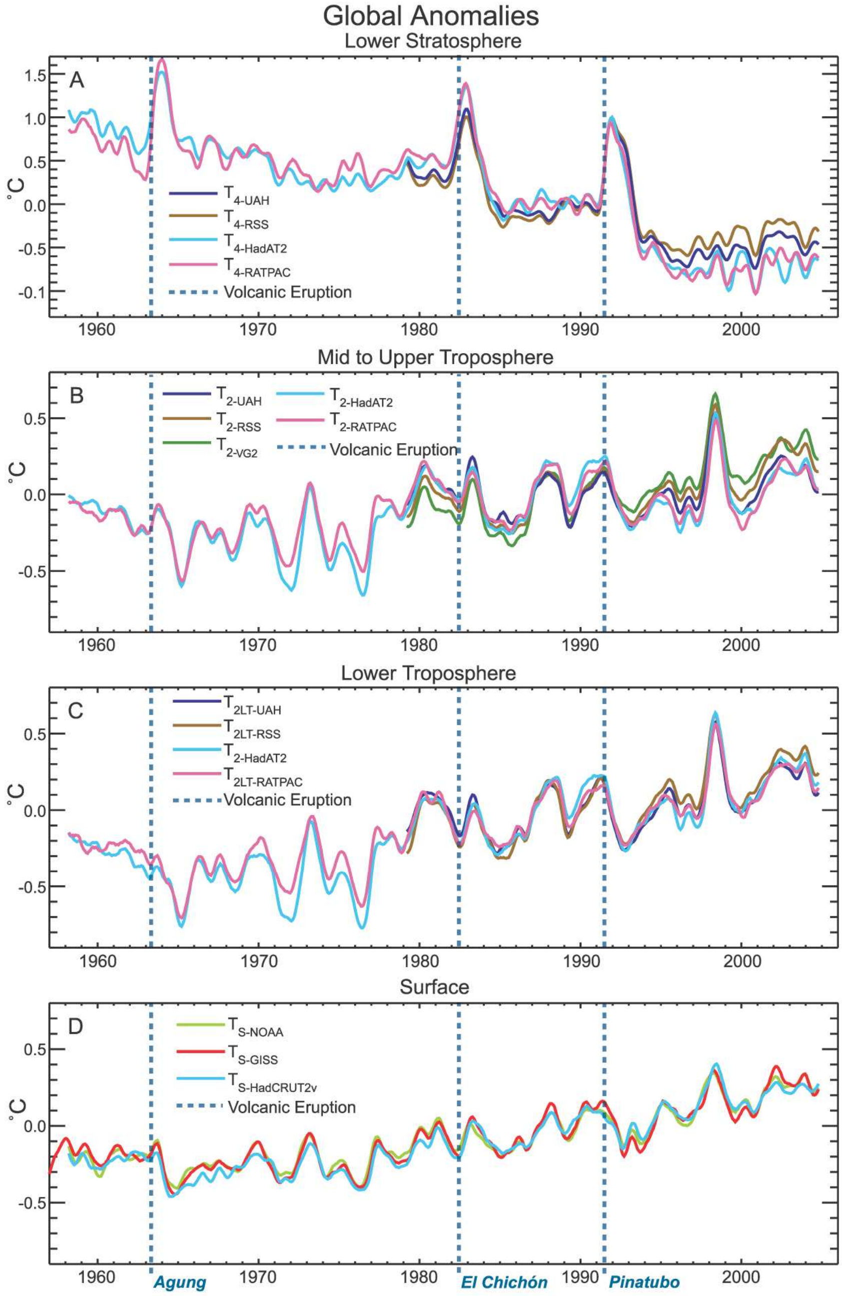

Figure 2.28 Temperature differences at several atmospheric altitudes. Dot vertical lines indicate main volcanic eruptions in last century. Source: IPCC Fourth Assessment Report, chapter 3, Observations: Surface and Atmospheric Climate Change. p. 268: **http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch3s3–4–1–2.html** *(accessed 6 March 2012)*

Variations of the Earth's orbit

The theory relating climatic changes to variations in the Earth's orbit is known as Milankovitch Theory, in honour of the early 20th century Serb climatologist Milutin Milankovitch, who developed this idea in the 1930s. There are three astronomical cycles that affect the amount and distribution of the sun's radiation that falls on Earth. This is known as solar forcing (a type of radiation forcing) See figure 2.29.

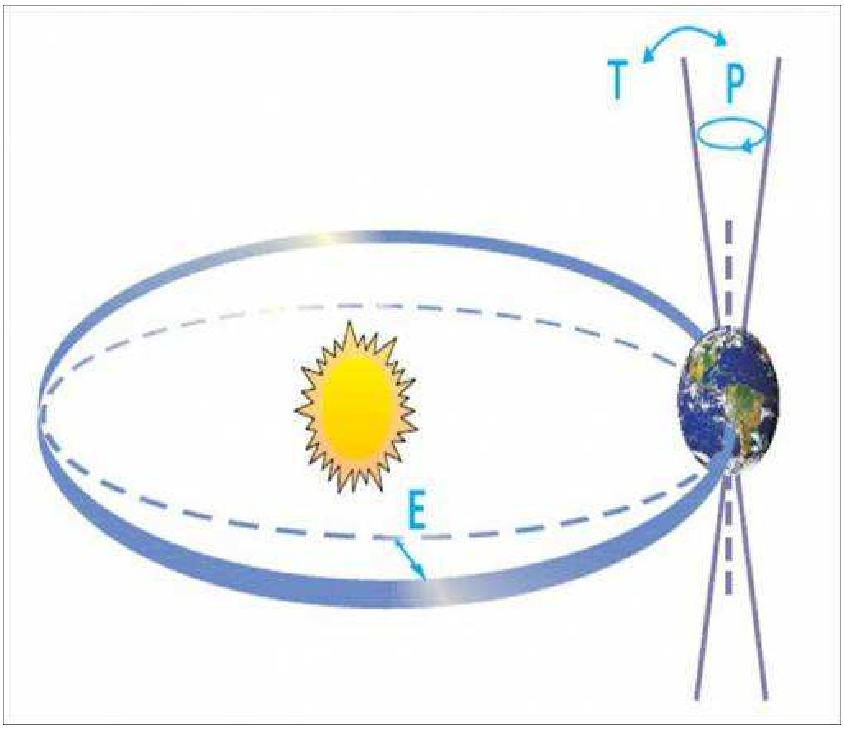

Figure 2.29 Schematic of the Earth's orbital changes in Milankovitch cycles. 'T' denotes tilt angle variations of the Earth's axis, 'E' denotes eccentricity changes of the orbit (due to variations in the minor axis of the ellipse), and 'P' denotes changes in the direction of the axis tilt at a given point of the orbit. Source: IPCC Fourth Assessment Report, chapter 6, Paleoclimate. p 449, [Rahmstorf and Schellnhuber, 2006]: **http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-6–1.html** *(accessed 6 March 2012).*

The first cycle is the change of the eccentricity of the orbit (i.e. its deviation from being a perfect circle). The Earth's orbit is elliptical, rather than circular, so that the distance to the Sun varies over the year. The second cycle is the time of year when the Earth's perihelion (the point at which it is closest to the sun) takes place. The Earth's axis wobbles – called precession – on a 27,000 years cycle. The third cycle is related to the tilt of the Earth's axis, the obliquity, which varies between 22.1º and 24.5º with a dominant period of 40,000 years. With a tilt angle of 23.5º we are now midway from maximum to minimum. The smaller the tilt angle implies less seasonal variation between summer and winter in middle- and high-latitude regions.

All three cycles combine to produce variations in the amount of solar radiation received on the Earth's surface, but more importantly variations in the distribution of the energy flux over the surface.

From paleoclimatic records the amount of ice deposited in Polar regions can be estimated over the last million years. On the other hand, since orbital variations are predictable, it is possible to model the insolation (average solar irradiance) both in the past and in the future. Such simulations show a strong correlation between the volume of ice caps in Antarctica and Greenland and computed summer insolation.

In spite of the clear success of Milankovich theory, there are several difficulties in reconciling theory with observations. The range of climate variability seems to be much larger than what might be expected from the Earth's orbital variations alone. Some positive and negative feedbacks are necessary for amplifying the ice build-up and retreat. In Figure 2.30 are shown atmospheric concentrations of different greenhouse gases for the last 600,000 years, obtained from trapped air bubbles in Antarctica ice cores. The strong correlation of atmospheric carbon dioxide and methane concentrations with average temperature suggests that the greenhouse effect is the enhancing mechanism for ice volume variations. But again concentration variations in these greenhouse gases are rather small to be the cause of such a large cooling and warming.

It has been argued that these rapid changes are due to the fact that the Earth did not warm and cool globally. Rather, there was a massive thermal redistribution between both hemispheres, the Bi-polar Seesaw [Stocker and Johnsen, 2003; Toggweiler and Lea 2010]. For instance, we see a rapid cooling by the end of an interglacial period (shadowed band in Figure 2.30). Due to global continental distribution the northern Hemisphere is more prone to be covered in ice by orbital forcing, while the southern hemisphere where the oceans are more extensive acts as both a carbon dioxide and a heat reservoir. In the process of the north being rapidly iced the Southern Hemisphere warmed with a subsequence release of carbon dioxide to the atmosphere. This increase in greenhouse gases produced a later warming of the Northern Hemisphere. The warming would then have been further enhanced by an albedo reduction as ice caps in the North retreated.

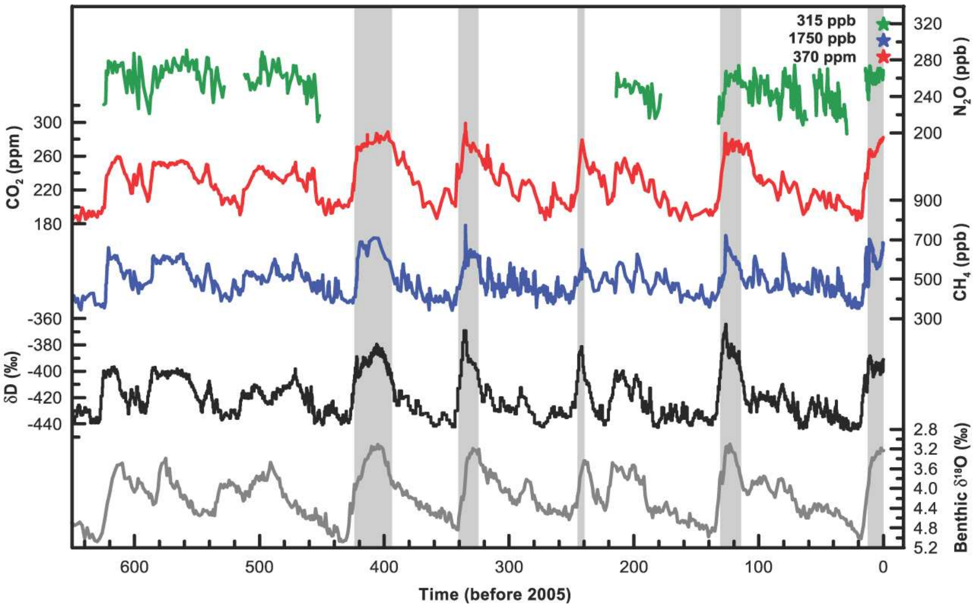

Figure 2.30 Note that the time scale is in kilo-years. Variations over the last 650 000 years of deuterium (δD, black – a proxy for local temperature), atmospheric concentrations of carbon dioxide CO_2 (red), methane CH_4 (blue) and nitrous oxide (green) from Antarctica ice cores. δ18O (dark grey) is a proxy for global ice volume, from marine records. Shading indicates interglacial warm periods. The stars and labels (top right-hand) indicate atmospheric concentrations at year 2000. Source: IPCC Fourth Assessment Report, chapter 6, Paleoclimate. p 444. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch6s6–4.html *(accessed 6 March 2012)*

According to Milankovitch's theory we are now in period of relatively small radiation variations and therefore in an unusually long interglacial. The scenario is for us to return to a period of glacial advance. The estimations for the next glaciation period range from 6000 years [Imbrie and Imbrie 1980], to 50,000 years [Berger and Loutre 2002]. The IPCC 2007 Report states "that it is very unlikely that the Earth would naturally enter another ice age for at least 30,000 years".

Changes in Ocean Circulation Patterns

Figure 2.31 illustrates a global-scale ocean circulation called the *Thermohaline Circulation*. This vast circulation connecting the oceans together is also known as the *Conveyor Belt*. As warm water from the Gulf of Mexico flows northwards it loses temperature and by evaporation increases salinity (concentration of salt). Both effects make the surface ocean water progressively denser. When water at the surface is denser than the water beneath it, it sinks. This displacement makes the conveyor flow southwards through the deep Atlantic Ocean, around Africa into the Pacific and Indian Oceans where eventually it rises again to the surface.

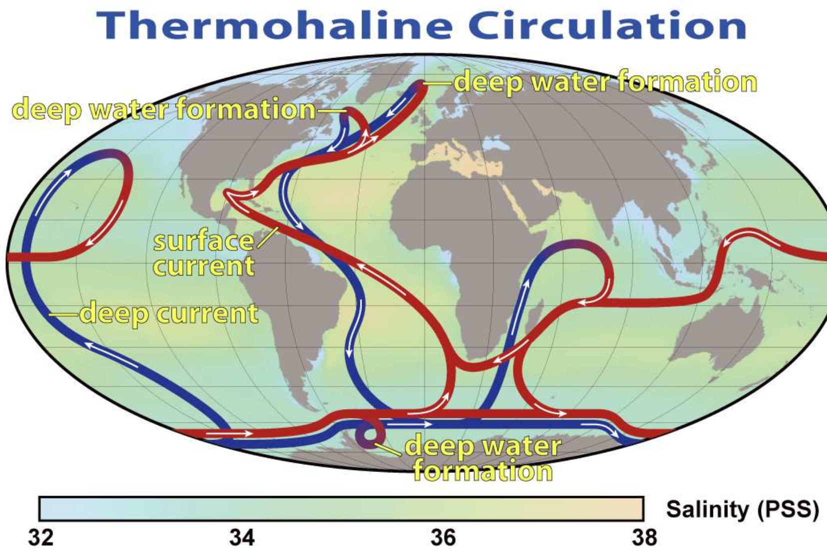

Figure 2.31 Thermohaline circulation or the Great Ocean Conveyor is a ocean global system. In red are warm superficial currents. In blue are cold deep-water currents. Water sinks mainly in North Atlantic and upwells in the Southern Ocean Source: Global Warming Art http://www.globalwarmingart.com/wiki/File:Thermohaline_circulation_png *(accessed 6 March 2012).*

The warm part of the conveyor delivers an important amount of the inter-tropical heat to the Northern Atlantic. Therefore, the intensity of the Thermohaline Circulation has important consequences for the temperature distribution across the globe. Strong circulation brings mild and relatively wet winters to northern Europe. On the contrary when the conveyor belt weakens, winters in Europe would be much colder and may produce an enhancement of heat to southern hemisphere.

The mechanism for Thermohaline Circulation is unstable density gradients, a situation where dense water is situated above lighter waters. Places where dense waters from the surface sink are located in relatively small regions of the North Atlantic and around the Antarctic. This sinking is enhanced when surface waters are cooler and have higher salinity. On the contrary, lighter waters at the surface, due to lower salinity and higher temperature, tend to establish a stable density stratification that can slow down or even inhibit Thermohaline Circulation.

An interruption of the Thermohaline Circulation has been proposed as the cause of the Younger Dryas period [Broecker and Wallace, 2006]. As mentioned above, this was a rapid cold spell during the warming period after the end of the last ice age. Massive floods of fresh water, and thus having low salinity, from melting North American glaciers poured through the St. Laurence River into the North Atlantic.

Another possibility is one of the so called Heindrich Events, the release of a huge number of icebergs produced by major break-ups of the ice sheets over Greenland and Eastern Canada. The melting of icebergs results in influxes of fresh water of low salinity large enough to alter ocean currents.

The Younger Dryas is just one of many episodes of abrupt climatic changes. Thus, in Figure 2.30, in the range of the last 500 000 years, as well as five glaciations, a series of rapid changes in the intermediate glacial periods can be observed. These rapid warming and cooling oscillations in the last glaciation are called Dansgard-Oeschger (D-O) events. Records from the ice core in Greenland show about 25 D-O oscillations in this glacial period. As D-O oscillations cannot be directly related to an amplification of radiation forcings, other reasons have been proposed. One is the above-mentioned of ice caps accumulating so much mass that they become unstable, producing Heindrich events. The other possibility is the Bi-polar Seesaw coupling of both hemispheres, as suggested by the asynchronous core records from Antarctica and Greenland [Stocker and Johnsen, 2003].

In any case, the thermohaline circulation seems to play a crucial role in these abrupt climatic changes as it is such an important heat transport mechanism.

2.3.3 How do we know the climate of the past?

Although there are huge gaps in our knowledge, it is quite remarkable that scientists can describe the past climates as well as they actually do. As is to be expected, the further back we go in time, the less detailed is the information left in indicators such as the geological records.

We now very briefly describe some methods for studying past climates moving from the present backwards in time.

Precise instrumental data are relatively recent. Systematic, instrumental temperature recordings started around 1850. The longest record of direct measurements of carbon dioxide concentration in the atmosphere was started by Keeling in 1958 at Mauna Loa Observatory, Hawaii.

One way to show climate changes is through the global average temperature of the air near the Earth's surface. But to estimate the average temperature of the air near the surface over land and seas all over the Earth is not an easy task for a number of reasons.

Since 1979, meteorological satellites have measured the atmospheric global temperature at different altitudes. Satellites have the advantage of providing data with global coverage but obviously this was not always the case. In earlier times temperature records of weather land stations had to be averaged with sea surface temperature from ships' observations. Another problem is that observations are not uniformly distributed over the globe because in some areas observation stations are scarce.

Another source of uncertainties is the evolution of instruments and procedures to measure temperature during the last two centuries. However, all these effects can be taken into account in the treatment of data and good agreements between analyses carried out by different research groups in a number of countries have been reached.

The consistency found between land and ocean surface temperature changes as well as between northern and southern hemispheres is another reason for confidence in the accuracy of this analysis.

Historical documents such as diaries, farmers' logs and other written records concerning droughts, floods, and crops yields provide valuable climate information. Annual growth of tree rings is another source of climate data. From the ring thickness can be deduced the temperature and precipitation in regions that experience annual cycles. Through observing overlapping sequences of rings, and thicknesses of living trees, beams and other wooden objects, it has been possible to obtain precipitation and temperature patterns for thousands of years in various regions of the world.

Radio carbon dating is a technique that uses the naturally occurring radioisotope of carbon called ^{14}C (isotopes are different forms of the same element, in this case carbon, which vary in their atomic mass; for this isotope it is 14) to determine the age of organic remains from archaeological sites. The technique provides a good estimation of the age of organic matter formed in the last 50,000 years. Carbon has three isotopes: ^{12}C (the most common) and ^{13}C which are both stable, and ^{14}C which is an unstable isotope. When plants fix atmospheric carbon dioxide during photosynthesis they incorporate carbon atoms in the same isotopic concentration as that which occurs in the atmosphere. After plants die the radioactive ^{14}C decays at a constant rate. So that comparing the remaining ^{14}C fraction of a sample to that expected from atmospheric ^{14}C, allows the age of the sample to be estimated.

^{14}C is created in the atmosphere by cosmic rays impacting on nitrogen atoms (along with oxygen, nitrogen is a major component of the air we breathe). Charged particles produced by the sun's radiation deflect cosmic rays, so that the amount of cosmic rays reaching the atmosphere and therefore the production rate of ^{14}C can be related to solar activity. Through knowing the age of a tree log by some other method, the rings then provide information of the solar activity through the concentration of the isotope ^{14}C that has been estimated.

Trees produce pollen that is trapped in layered deposits in lakes. Pollen decomposes slowly and each species of pollen can be identified by its distinctive shape. The percentage of pollen of a given species provides evidence to determine climate conditions for the past 11,000 years.

Other evidence of past climate comes from ocean floor sediments. Scientists have been drilling the ocean floor since the 1970s. They extract deep cores of material that has been deposited over very long periods of time. The sediments contain the residues of calcium carbonate shells of organisms such as plankton and benthic foraminifers that once lived in the sea.

Most oxygen in the air is in the isotopic form ^{16}O (atomic mass 16), but a small fraction (about 1/1000) has an atomic mass of 18, designated ^{18}O. Both isotopes form water molecules. Because ^{16}O is lighter than ^{18}O, when ocean water evaporates, molecules containing ^{18}O tend to be left behind. Glaciers expand by snow precipitation which is richer in ^{16}O than in ^{18}O. Thus, when melting glaciers are expanding, the oceans, which contain less water, have a higher concentration of ^{18}O. Since living organisms are constructed from the oxygen atoms existing in the ocean, the ratio ^{18}O / ^{16}O within their shells contains information about the global ice volume.

Ocean sediments also contain the so called ice-raft debris removed from land surface by glaciers. This material, deposited on the ocean floor when the icebergs melt, has been a clue for the discovery and dating of Heinrich events.

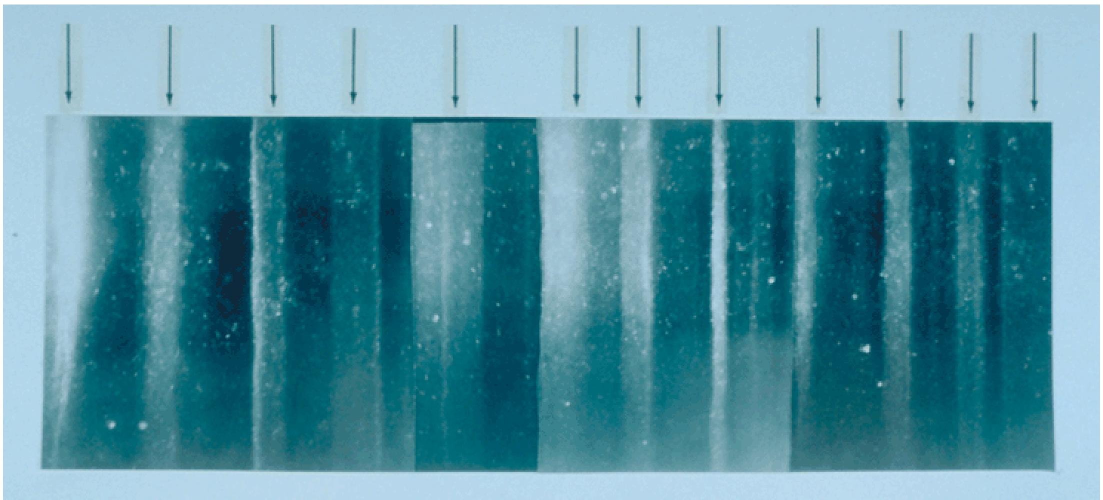

Figure 2.32 Ice core showing 11 annual layers (arrowed) sandwiched between darker winter layers. From GISP 2 site. Source: Wikimedia Commons.

Vertical ice cores extracted from ice sheets provide valuable information of past climates. Ice cores have been drilled mainly in Greenland and Antarctica, but also in several non-polar sites. The ice is formed by successive layers of snow fallen over many years, slowly re-crystallised under pressure into ice (see Figure 2.32). The ^{18}O / ^{16}O ratio gives information of the temperature at the time of freezing: Relatively warm snow is richer in the heavier isotope.

In addition to temperature patterns, an ice core provides information about the atmospheric composition and volcanic activity. Bubbles of the ambient air are trapped in the ice and therefore they constitute a long term record of the concentration of carbon dioxide and other trace gases in the atmosphere. Volcanic acids in snow layers as well as dust deposits provide indications of volcanic activity and stormy weather.

The most famous core is the Vostok ice core, which provides a record going back 420 000 years. The name comes from a 2.5 km deep drilling in the Antarctic ice pack by the Russians in the 1980s and 1990s. Another ice core reaches a depth of 3.5 km and contains a record of temperatures and carbon dioxide concentrations going back in time more than half million years.

One of the most interesting results from this record is the strong correlation between past temperature and atmospheric concentration of carbon dioxide and methane. With a lag of about 1000 years the greenhouse gas concentrations follow the temperature trends. This lag suggests a positive feedback process in which greenhouse gases enhance climate change. As the oceans became warmer carbon dioxide was released to the atmosphere and, conversely, when the oceans became cooler they absorbed carbon dioxide. This is because any water-soluble gas becomes more soluble as temperature decreases.

However, it is clear that the highest carbon dioxide concentrations in the Earth's atmosphere in the last half million years were about 300 parts per million by volume (see Figure 2.16), while in the last 50 years they have increased from 315.83 ppm in 1959 to about 380 ppm in 2005 (See Figure 2.15 bottom panel).

2.4 Climate Models

The aim of climate models is to understand the physical processes that produce climate and predict the effects of their changes and interactions. These interactions, however, operate at very different space-scales and have very different response times. So, some simplifications are needed in modelling climate. For example, atmospheric processes have time-scales of hours or a few days, whereas deep ocean processes have time-scales of hundreds of years, and these times increase up to thousands of years for the processes related to ice sheets. Hence, there is a variety of climate models depending on the number of different processes included and the range of time intervals considered. Because of limitations of computational resources, a trade-off between these features is usually necessary. It would be an error, however, to judge models including fewer processes to be worse than more complex ones. Models are developed for particular purposes and should be judged on that criterion. Often, a simple model is sufficient to elucidate the underlying mechanisms of a well-defined process that might otherwise be hidden by the complexity of a larger model.

2.4.1 Energy balance models

Early, and simplest, climate models are the *energy balance models* (EBMs). These models essentially attempt to determine the evolution of surface air temperature, T, due to changes in global radiative balance. The simplest EBM is the 0-D (zero dimensional) model, which takes the Earth as a uniform sphere. The rate of surface temperature variation is proportional to the difference between the energy received and the energy emitted by the Earth. An equilibrium temperature is attained when both received and emitted energies are equal. The emitted energy (by area unit) is given by the formula for the black body radiation, corrected by a coefficient which accounts for the absorption in the atmosphere. The received energy is the fraction of solar radiation which is not subject to that reflected by the surface (the albedo). However, the albedo is itself dependent on temperature, since low temperature should imply a larger snow and ice cover, thereby a larger albedo. So, in order to close the model it is needed to assume a particular form for this dependence. It is the simplest example of parameterisation in a climate model. A parameterisation is a simplified description of a case or phenomenon whose space-scale is smaller than the minimum space-scale which the model is able to resolve. In this particular example, a global albedo is used as an average value of albedos of different regions of the Earth, because the model is not able to resolve to the level of regional albedos. Parameterisation is a main ingredient of climate models as we will see later, but the simplified descriptions on which the process depends also mean that parameterisation is dependent on the assumptions made by the modeller who creates them. Parameterisation, therefore, can also be a source of model uncertainty.

The 0-D model is useful to estimate the global mean temperature responses to changes in radiative forcings. A step further beyond the 0-D model is the so-called (one-dimensional) 1-D *zone-averaged model*. Here, the Earth is not now taken as a uniform sphere, but its surface is divided by latitudinal zones. Now, the albedo can be made dependent on latitude as well as on temperature. Moreover, besides the energy emitted to space, a transfer of energy from one latitudinal zone to its colder neighbour is also considered. The energy emitted to space is parameterized as a linear function of temperature, the formula also taking into account the absorption of long-wave emitted radiation by clouds and aerosols in the atmosphere. The energy transfer to a neighbour zone is taken as being proportional to the difference between the zone temperature and a mean global temperature.

Originally this model was designed to study essentially the sensitivity of the Earth's equilibrium mean temperature to changes in the terrestrial orbit around the Sun.

2.4.2 Radiative-convective models

Other types of 1-D models are the radiative-convective models. In these models the referred dimension is the altitude over ground level. Now the atmosphere is resolved in a number of layers, not necessarily of the same thickness. Each layer radiates as a black body upwards and downwards. The ground radiates upwards. Moreover, each layer is characterized by an absorptivity (simply speaking, the fraction of radiation absorbed at a given wavelength). The radiative balance of these flows results in a temperature profile along the vertical direction. However, the temperature profile obtained in this way tends to exhibit vertical gradients exceeding the *lapse adiabatic rate*, that is, the temperature gradient above which the atmosphere fails to be mechanically stable against buoyancy forces. In this situation, movements of atmospheric gases between layers transfer energy by convection to restore the stability. So, this energy carried by convection must be added to radiative energy in the energy balance equations. These processes are numerically simulated until a stable equilibrium state is attained.

These radiative-convective models are amenable to many improvements. Contents of layers can include different types of gases and aerosols, together with their characteristic absorptivities of radiation of different wavelengths. In particular, these models have been used for the development of schemes for cloud formation and evolution. Clouds have different and opposed effects on the climate. On one hand, clouds increase the albedo and, consequently, tend to produce a decrease of received radiation, leading to a lower mean temperature. On the other hand, clouds retain the radiation upwards from the ground, producing a greenhouse effect. These effects depend on the type of clouds, and height and size of droplets. Therefore, while the global effect of clouds is far from obvious, these radiative-convective models are the best tool to develop cloud schemes to be included in more complex climate models.

A further step leads to two-dimensional (2D) models. Again, these models can be classified into two types according to the dimensions explicitly considered. For example, these two dimensions can be latitude and longitude, neglecting altitude over the ground. These models are very useful in the simulations of large scale atmospheric movements.

In other 2D models, the dimensions considered are the latitude and the altitude. For instance, over each latitudinal belt in a Budyko-Sellers model (a particular set of climate models into which we need not enter), we can consider an atmospheric column divided in vertical layers. Now, there are horizontal radiation fluxes between adjacent columns as well as vertical fluxes between layers within the same column (Figure 2.33). Likewise, the convective fluxes needed to restore the lapse adiabatic rate can act horizontal as well as vertically.

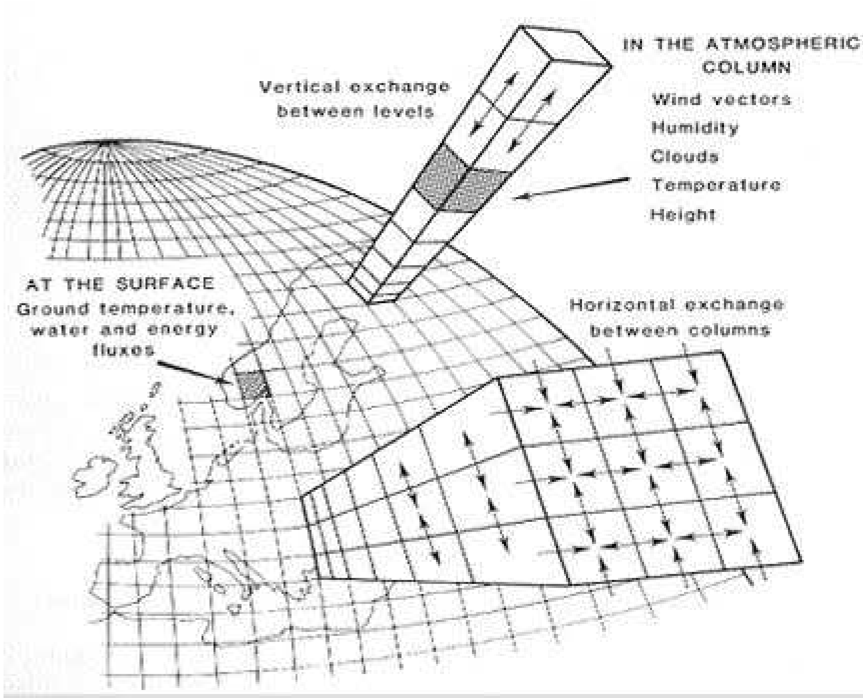

Figure 2.33 Adapted from McGuffie and Henderson-Sellers (2005)

2.4.3 Simple ocean models

Early ocean models were designed to simulate oceanic currents. Such an ocean model must encompass three phenomena: i) surface currents driven by winds, ii) deep currents driven by gradients of temperature and salinity, and iii) tides driven by gravitational effects. A very simple model was the Ocean Basin Model. Here, the ocean basin is rectangular. The circulation is driven by surface winds, ocean bottom friction, pressure gradients and Coriolis force (the force that arises from the Earth moving in a rotating system). The aim of the model was to study the influence of these factors on the velocity of the surface currents.

A different kind of model is the two-box model of Stommel [Stommel, 1961]. The ocean is modelled by two boxes: one corresponding to equatorial latitudes and the other one corresponding to polar latitudes (Figure 2.34). Each of these boxes contains well mixed water at a given temperature T_1 (Box 1), T_2 (Box 2) and a given salinity S_1 (Box 1), S_2 (Box 2). Both boxes exchange heat and moisture fluxes, H_S, with the atmosphere. Moreover, the boxes are connected by pipes through which water is transferred. The strength of the fluxes between the boxes, *q*, is assumed to be proportional to differences of temperature as well as differences in salinity. In order to separate surface currents from deep currents, each box can be further divided in two vertical layers. Models of this type have been used to study thermohaline circulation (THC) or simulate the onset of glaciations. For example, some studies have shown the possibility of several equilibrium states for THC and, consequently, bifurcations in the long term climate triggered by small forcings, according to chaos theory [Marotzke and Willebrand, 1991].

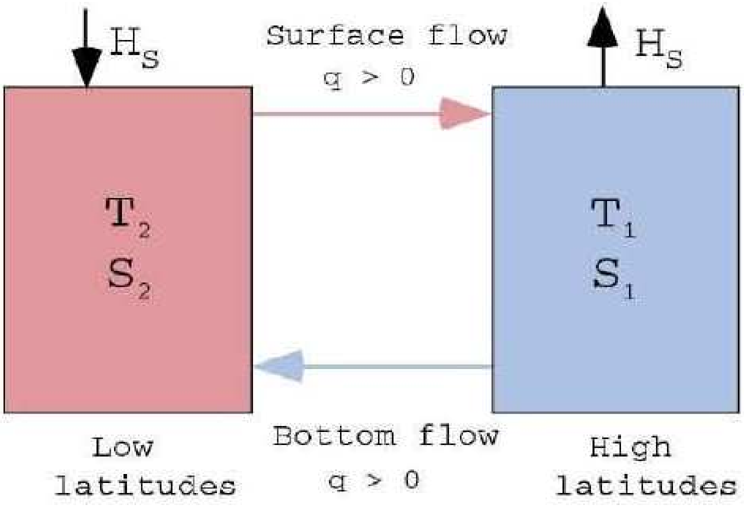

Figure 2.34 The two-box ocean model. Adapted from Marotzke (1991)

Simple 1-D models, similar to atmospheric radiative-convective models, have also been proposed for oceans. So, Figure 2.35 shows an upwelling-diffusion climate model which also takes into account radiation transfers with the atmosphere. As well as convective fluxes through movement of atmospheric gases, the model contemplates sinking of polar cold waters.

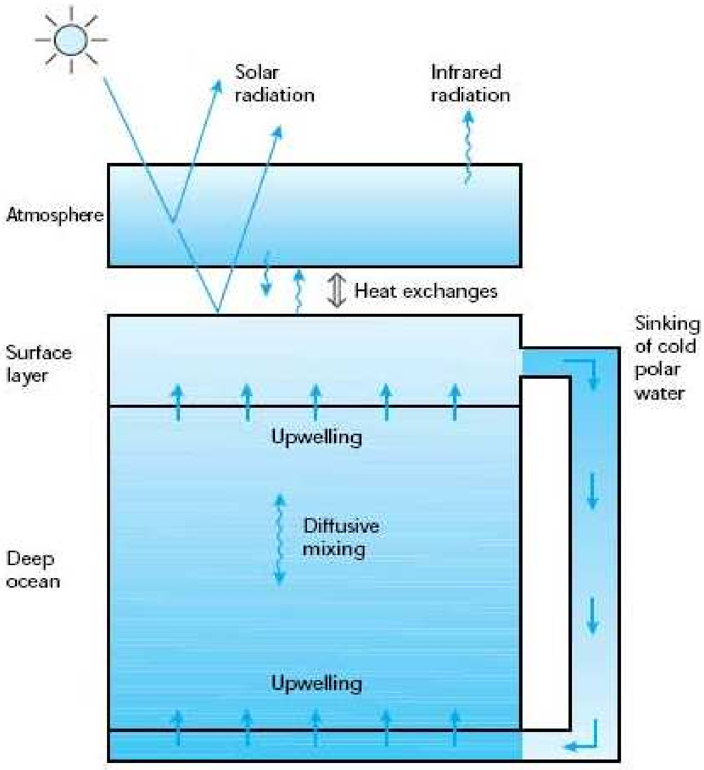

Figure 2.35 Illustration of the upwelling-diffusion climate model, consisting of a single atmospheric box, a surface layer representing both land and the ocean mixed-layer, and a deep ocean layer. Solar and infrared radiative transfers, air-sea heat exchange, and deep ocean mixing by diffusion and thermohaline effects are all represented in this model and are indicated in the figure (based on Harvey and Schneider, (1985)). Source: Harvey, D. et al. (1997). Source: An Introduction to Simple Climate Models Used in the IPCC Second ***Assessment Report. IPCC Technical Paper 2, P16.*** **http://www.ipcc.ch/pdf/technical-papers/paper-II-en.pdf** *(accessed 7 March 2012).*

This model combined with a box-model that is differentiated by latitude (for example Figure 2.34) evolves into a 2D model (see Figure 2.36).

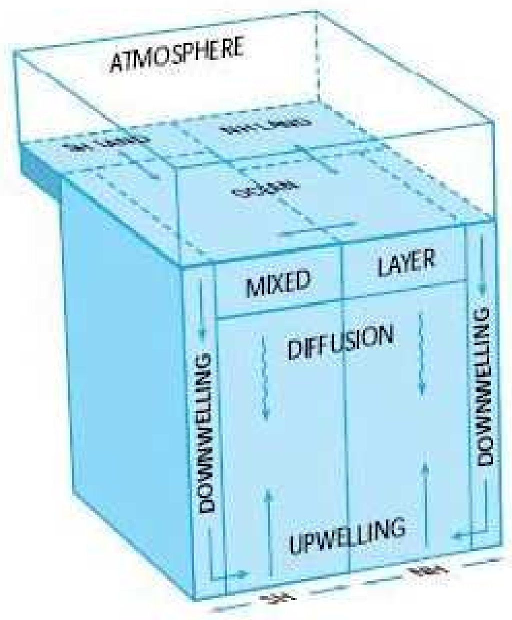

Figure 2.36 Sketch of a 2D model. Source: An Introduction to Simple Climate Models Used in the IPCC Second Assessment Report. IPCC Technical Paper 2, P28. **http://www.ipcc.ch/pdf/technical-papers/paper-II-en.pdf** *(accessed 7 March 2012).*

We will see later how these comparatively simple models can be very useful to elucidate important aspects of climate or simulate processes over very long time periods which would be inaccessible for more complex models requiring greater computational resources.

2.4.4 Global Climate Models (GCMs)

The most complex climate models are the GCMs. The acronym also stands for General Circulation Models. They aim at mimicking the general circulation of both atmosphere and oceans.[28] This type of model works in all three dimensions and contemplates both dynamic (physical movement of air and waters) and thermodynamic (heat movement) features.

Atmospheric GCMs

Dynamical core[29]

These models (usually referred to as AGCMs) are constructed from early models of weather forecast. They are built around a dynamical core represented by a set of mathematical equations describing the behaviour of a compressible fluid (air) on a rotating body. The variables which appear on these equations, and characterize the fluid, are the so-called *prognosis variables*: wind velocities, temperature, pressure and mass components. In particular, the amount of water vapour (the most important greenhouse gas) is included in the dynamical core.

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28 The general circulation is to be understood as the sum of all the movements of the atmosphere by which heat is transported away from the equator and into higher latitudes, winds are generated, and clouds and precipitation are produced (a good description is provided in M. Allaby, *Encyclopedia of Weather and Climate* (revised edition), Vol. 1, Facts on File, Infobase Publishing, New York, 2007, p. 202.)

29 It is not clear why climatologists use the word 'dynamical' and not 'dynamic', the former being a derivative of the latter. However, they do, so we keep with the convention throughout this section on climate models.

It is beyond our scope to describe how these equations are solved numerically, but they enable the values of prognosis variables to be calculated on different points of a grid which covers the whole Earth and extends vertically to the top of atmosphere (See Figure 2.33). Moreover, values in a given time can be calculated from values at previous times. However, numerical constraints impose strong restrictions on the step-time as against spatial cell sizes; otherwise, numerical error grows wildly. Altogether, numerical and storage limitations on computational power restrict the size of the grid cells, and hence the resolution. Most of the grids typically use cells defined by a certain amount of degrees of geographical longitude and latitude. Thus, the physical area corresponding to such cells depends on latitude (because, the higher the latitude, the smaller is the distance corresponding one degree of longitude). Near the equator, a cell as small as (1.4º x 1.4º), the smallest grid cell currently used, corresponds approximately to an area of 25,000 square kilometres.

So, GCMs cannot resolve physical processes at a smaller scale, such as cloud formation and coverage, local advection, land features, etc., in spite of their great importance for climate. The effects of these sub-grid-scaled processes must be statistically incorporated into the model by relating them to the prognosis variables through schemes based on physical laws – i.e. the process of *parameterisation* again. The following are some of the parameterisation schemes that are used.

Parameterisation

Radiation

One of the most important parameterisation schemes for AGCMs concerns radiation. It usually incorporates daily and annual solar cycles. When a GCM is used for simulations of paleoclimates or for very long term climate forecasts, variations of the solar constant due to changes in the Earth's orbit are also included. The solar radiation is eventually absorbed or scattered by clouds, gases and aerosols. Recent models include amongst natural aerosols, mineral dust and sea salt. The anthropogenic aerosols include carbon organic and sulphate aerosols. So, the scheme considers the amount of aerosols and their absorptive properties, measured for a wide range of spectral regions, both in the longwave and shortwave regions.

Finally, some models include explicitly chemical reactions in which atmospheric gases and aerosols are involved. For instance, very well known are the effects of chorofluorocarbon (CFC) aerosol gases on the ozone stratospheric depletion.

Clouds and precipitation

Cloud parameterisation is one of the most debated schemes and is therefore particularly dependent on assumptions made by the modeller. Clouds have multiple feedback effects on the climate: they determine the flux of radiation, produce precipitation, redistribute the atmospheric mass, redistribute energy through latent heat, etc. Early schemes described statistically the cloud field and used pre-specified, empirically determined values for albedos. More recent schemes diagnose the formation and distribution of clouds from the prognosis variables of the dynamical core. These schemes deal with clouds of different forms and heights of formation (basically cumulus and stratiform clouds), and give the corresponding albedo and absorption as a function of distribution and size of the water droplets that they contain.

Precipitation parameterisation is based on the modelling of the microphysical behaviour of clouds. In this scheme aerosols enter through their role as nucleation centres (particles on which water condensation occurs).

Boundary layer

Other atmospheric processes which have to be parameterised are the boundary layer processes. The boundary layer is the layer in direct contact with the ground, where the surface friction has a great effect on the momentum and heat fluxes .Moreover, effects of solar variations during the day are very sensitive with respect to temperature and moisture. So, these processes cannot be treated specifically even if a finer vertical resolution is used. Finally, boundary layer models need to conserve enstrophy (a quantity related to vorticity[30]); otherwise, the numerical schemes tend to yield a wrong energy transfer to smaller and smaller space-scales.

As the computational resources allow the use of finer grids, more local processes can be included in the models. Therefore, recent AGCM models show also a good performance in weather forecasts.

Ocean GCMs

Early ocean models represented the oceans as a set of boxes interchanging fluxes. However, advances in computation power have led to the development of Ocean GCMs (OGCMs) comparable to the AGCMs. The dynamical core is similar to the core of the AGCMs, with water playing the role of air, and salinity that of humidity. Moreover, whereas ocean processes are generally slower than atmospheric processes, the spatial scale of the former is smaller than that of the latter – because ocean eddies have a smaller size. So, the dimension of grid-cells can be as small as 1º x 1º (corresponding to about 12.000 square kilometres for a cell near to the equator). In some models the grid is progressively refined for latitudes smaller than 30º in order to obtain a better resolution of processes nearer to the equator.

Obviously, the grid does not span the entire surface of the Earth, but only the ocean basins. Therefore, the profile of continents must be simulated.

Typical values for the number of vertical layers go from 16 to 40. Due to the rapidly varying depth of the ocean floor near the continents, depth coordinates present difficulties. Alternatively, equal density coordinates are often used. These coordinates track much better the ocean currents which generally flow along surfaces of constant density.

Modelling the cryosphere

The cryosphere includes the snow cover, sea ice, glaciers and frozen ground. The amount of snow depends on temperature and humidity of atmospheric layers. The effects of the snow on the albedo differ depending on the type of land where the snow is falling. A further feature relevant to climate concerns the melting of continental ice sheets which releases great amounts of fresh water into the oceans which in turn can affect the Thermohaline Circulation.

Overall, the most important component of the cryosphere for the climate model is sea ice which prevents direct exchanges between atmosphere and ocean, whereas the sea ice itself interacts with both. Models of sea ice include a layer of snow and two or more layers of ice of different thickness. Each layer has a different albedo depending on depth and on dissolved gases and aerosols, and these albedos must be carefully parameterised, as well as their heat conductivity. Especially important are the pocket brines. This phenomenon concerns the release of brine (concentrated salt-water) when sea ice is formed, which increases the salinity and, thereby, the density of, surface water. The denser water then sinks, which feeds the Thermohaline Circulation.

Generally, models consider only the increase or decrease in extent of otherwise fixed sea ices, but some models take into account the motion of sea ice packs carried by ocean currents (‘free drift’ models).

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[30] Vorticity measures the rotational circulation of a fluid.

Modelling the land

Land schemes include several types of soils with different uses and vegetation cover. Up to ten different types of land are considered in some models, ranging from broadleaf evergreen to glacial ice. Each soil has a parameterised albedo, inversely proportional to vegetation cover. The vegetation is also important for the balance of carbon dioxide and water vapour through photosynthesis and evapotranspiration. Recent models also include a complete carbon cycle in soils. The inclusion of the terrestrial carbon cycle introduces a new feedback into the climate system with important effects on large time scales

The subsoil is characterised by its capacity for water storage. Water in the superficial layer can be either evaporated to the atmosphere, with subsequent release of latent heat and possible cloud formation as it condenses, or filtered to deeper layers. However, when the precipitation rate exceeds the storage capacity, the excess becomes runoff which is finally released as fresh water in river estuaries.

Coupler module

Obviously the different components of a GCM do not operate separately: They must be integrated into what is called a coupled global climate model (CGCM) through what is called the ‘coupler module’. This coupling allows the exchange of fluxes between components of the model, particularly between atmosphere and ocean. However, atmosphere and ocean components have different grids. In order to cope numerically with these exchanges of fluxes, these grids must be matched. Therefore the coupler module has to define a new grid by interpolation starting from the boundary cells of the grids of the components involved.

Likewise, since the time scales of different components of the climate system are different, the coupling is not necessarily called upon every step-time. This is termed asynchronous coupling. A usual procedure, which permits a considerable saving of computation time, is to couple atmosphere and ocean for a short period of time, during which mean values for the atmospheric variables are obtained; then both components are uncoupled, and the oceanic component evolves separately for a longer period keeping fixed the atmospheric values previously calculated. Next, both components are coupled again, and this process is repeated over again. Most recent models, however, do couple every time-step.

Initialisation and flux adjustments

Once the GCM has been developed, it is necessary to initialise it, that is, to introduce starting values for the variables. The oceanic and atmospheric components are initialised using values obtained either from observational data or from numerical integrations of model components separately.

Then the coupling between components produces flux exchanges and the global system evolves to attain an equilibrium state. This process takes place on two time scales. On the first scale the system attains a near equilibrium state within a period of a few tenths of years. Thereafter, the evolution is slower and is determined by the thermal inertia of the ocean.

However, the numerical uncertainties on the computation of fluxes cause an imbalance on the fluxes exchanged between atmosphere and ocean. This imbalance produces a climate drift, the origin of which is not physical but purely numerical. In order to neutralize this drift, models used to resort to artificial flux adjustments. While it is not very clear if these adjustments change substantially the predictions of models, recent GCMs avoid the flux adjustments through a better resolution of the grids (and, consequently, a lesser parameterisation) and the use of more appropriate methods for numerical solution of equations of the dynamical cores.

Once this equilibrium state is attained the radiative forcing is set back to pre-industrial conditions, dated around 1860, that represents the date from which reliable data are available, at least for some climate variables. Then the model is integrated for a few centuries, allowing the coupled system to partially adjust to this forcing. From this state the model is run with the known forcings, both natural and anthropogenic, between 1860 and 2000, and the results are checked against present climate observations. Moreover, the effects of internal variability can be quantified by running models many times from different initial conditions, provided that the simulated variability is consistent with observations.

A good ability of models to uncover features of the present climate as well as observed changes during the recent past is an obvious requirement and ensures that all the important processes have been adequately represented.

2.4.5 Model validation

But, is the ability to simulate present or recent past climates a guarantee for the accuracy of a model's projections of climate change? As said above, the dynamical cores of climate models are based on fundamental physical principles which we believe to be invariant in time. However, the parameterisations, while also based on physical laws, introduce approximations which hold in most situations but may break down in others that are quite different from current conditions. Therefore, in order to validate a model it is necessary to carry out a series of numerical experiments to ascertain the model's response to a variation of forcings. Different models often use different schemes or parameterisations; so a convergence of results of different models gives confidence about them.

Validation can be made at both an overall system level and for a particular component or scheme level. Obviously, in the latter case, schemes with parameters tuned to measured values cannot validate themselves. However, due to feedbacks in the model, it can be the case that a scheme tuned to certain climate processes results in a good validation for the complete system or even for a different scheme concerned with other processes.

These modes of validation of climate models have changed substantially in recent years, along with the multiplication of models. The number of GCMs has increased steadily from the last decade of past century. From two models used in the First IPCC Assessment in 1990, the number mounted to 23 in the Fourth IPCC Assessment in 2007. This allows for models also to be validated by comparing one another. For this purpose a *Programme for Climate Model Diagnosis and Intercomparison* (PCMDI) has been established.[31]

An important measure of the internal feedbacks on a model is the climate sensitivity. This is defined as the equilibrium global mean surface temperature change following a doubling of atmospheric CO_2 concentration. The climate sensitivity provides a simple way to quantify and compare the climate response simulated by different models to a specified perturbation. In spite of the difficulty of an exact measurement for the real climate, the climate sensitivity remains a useful concept because many aspects of a climate model scale well with global average temperature.

The current generation of GCMs covers a range of equilibrium climate sensitivity from 2.1°C to 4.4°C (with a mean value of 3.2°C).

The multiplication of models allows for simulations derived from model ensembles. A "perturbed physics ensembles" simulation gathers results of similar models with different values of parameters. Alternatively, a "multi-model ensembles" simulation gathers results of a variety of models with different parameterisation schemes. The multi-model

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31 The PCMDI (http://www-pcmdi.llnl.gov/) mission is to develop improved methods and tools for the diagnosis and intercomparison of general circulation models (GCMs) that simulate the global climate.

mean is an average across different models. Because the individual model biases tend to cancel each other, the multi-model mean shows a better agreement with observations.

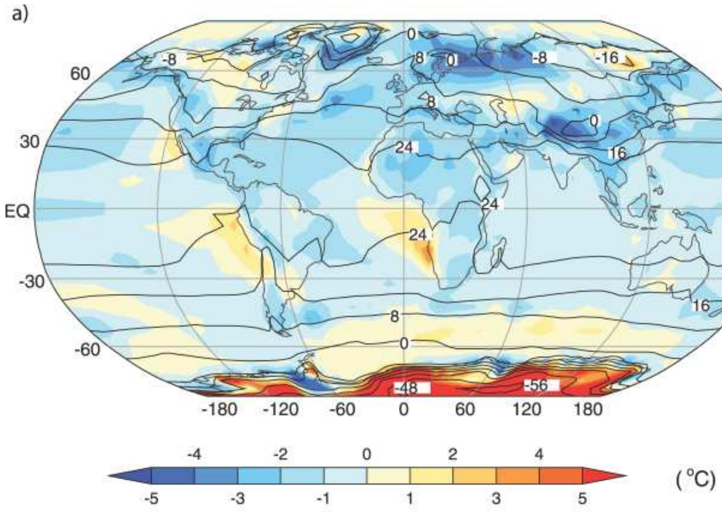

Figure 2.37 Contour lines for the observed time mean surface temperature as a composite of surface air temperature over regions of land and sea surface temperature (SST) elsewhere. Colours represent the difference between simulated and observed temperatures. Source: IPCC Fourth Assessment Report, Chapter 8, Climate Models and Their Evaluation: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch8s8–3–1.html *(accessed 7 March 2012).*

Figure 2.37 shows that the absolute errors of simulated temperatures in comparison with observed temperatures are nearly everywhere less than 2°C. (Larger errors correspond basically to polar and other regions with poor data records) Errors in individual models tend to be somewhat larger, although still less than 3°C, except at high latitudes. Therefore, it appears that models include appropriately the main processes governing surface temperature.

Likewise, the vertical profile of atmospheric temperature is well simulated, except at high latitudes in the tropopause (the boundary between the troposphere and atmosphere).

Figure 2.22, presented earlier, shows the difference between the global mean surface temperature observed and simulated over the 20th century.

The observed annual cycle of surface temperature is also well reproduced by models. Errors are larger when it comes to the diurnal variation range (the difference between daily maximum and minimum surface air temperature), in which case the models tend to give values that are too small. These exceptions to the overall good agreement illustrate a general characteristic of current climate models: the larger-scale features of climate are simulated more accurately than smaller-scale features.

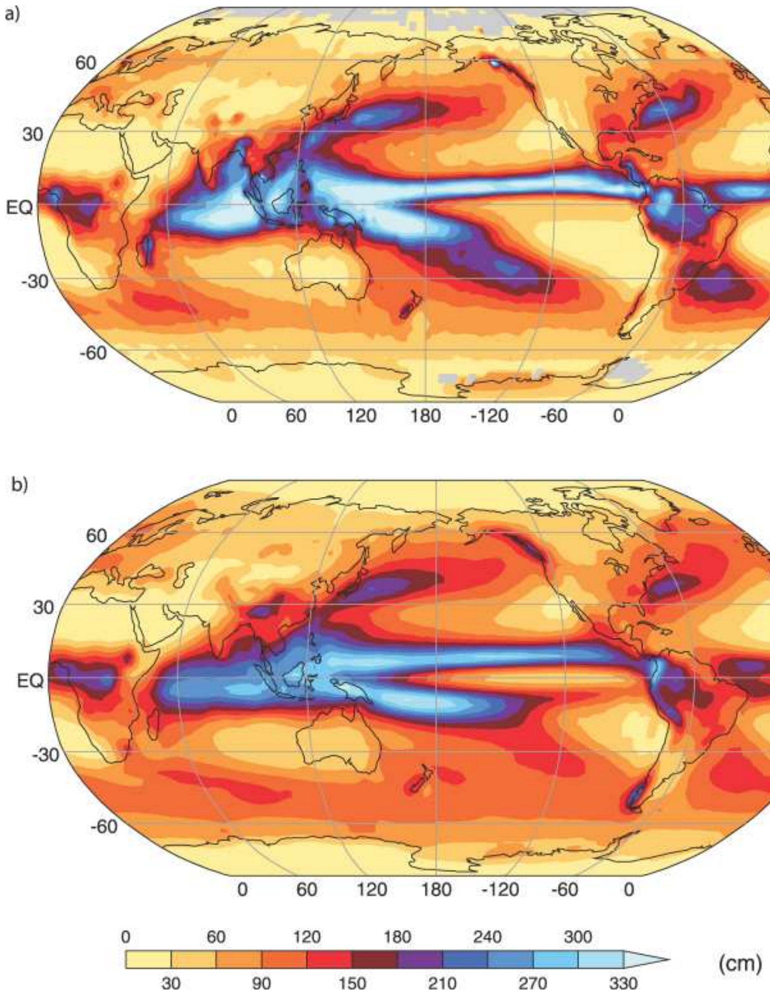

Figure 2.38 Annual mean precipitation (cm), observed (a) and simulated (b), based on the multimodel mean. The Climate Prediction Centre Merged Analysis of Precipitation observation-based climatology for 1980 to 1999 is shown, and the model results are for the same period in the 20th-century simulations in the MMD at PCMDI. In (a), observations were not available for the grey regions. Source: IPCC Fourth A*ssessment Report, Supplementary material to Chapter 8, Climate models and their evaluation*

Figure 38a shows observation-based estimates of annual mean precipitation and Figure 38b shows the multi-model mean field. In spite of discrepancies at southern latitudes, the models capture these large-scale zonal mean precipitation differences, suggesting that they can adequately represent these features of atmospheric circulation.

For other climate variables, comparisons between observational and simulated values are more difficult due to lack or uncertainties in the observational data. This is the case, for instance, for the sea ice variables. Here, the data about ice thickness are very scarce. More abundant, however, are the observational data about distribution and varying extent of sea ices, for which the multi-model mean yields values in good agreement.

Climate models can also be validated by their ability to simulate and predict irregular phenomena within the large scale climate variability, such as El Niño-Southern Oscillations (ENSO – see sub-section 2.3.2) or monsoons. Likewise, recent models begin to produce good statistical predictions of extreme events such as heat waves, droughts, persistent rainfalls or tropical cyclones. Occasional events, such as large volcanic eruptions, are a good testing ground for climate models (see G.A. Schmidt, *Physics Today*, January 2007, pp. 72-73)

As well as by their ability to predict the present from the past climate, models can be validated by their ability to simulate paleoclimates. In particular, much data about temperature and carbon dioxide levels in the far past are available through ice cores, vegetation and plankton fossils, geological records, etc. Therefore it is possible to compare the simulations performed by climate models with the known behaviour of paleoclimates.

Nevertheless, despite their good performances, the high computational costs of atmospheric and ocean GCMs (AOGCMs) make it difficult to carry out a sampling of parameter space to study their effects on large ensembles or long simulations. For these studies it is more convenient to use models with a reduced dynamical core or a lower resolution. These models, so called Earth Systems Models of Intermediate Complexity, or EMICs, cover a wide range between simple models, such as the above mentioned 1D and 2D models, and comprehensive GCMs [McGuffie and Henderson-Sellers,2005; Harvey *et al*.,1997]. Some EMICs deal only with specific processes, although at an improved dynamical detail. For instance, a 1D upwelling-diffusion model includes a detailed treatment of the atmospheric and ocean carbon cycles.

Other EMICs include most of processes represented by AOGCMs, but in a more parameterised form. These models are invaluable tools for understanding feedbacks acting within the climate system. Yet other EMICs strip out processes with short time-scales, thereby allowing simulations which span thousands of years or even glacial cycles.

The moral to draw from the above considerations is that comparatively simple models can be very useful to elucidate some important aspects of climate or simulate processes over very long time periods which would be inaccessible for more complex models requiring great computations resources.

Overall, the climate models, both GCMs and EMICs, are robust and their predictions are becoming closer and closer to observational data. Moreover, in some cases, discrepancies between predictions and observed values have been resolved in favour of the former, and errors in measurement have been detected.

In this sense, the IPCC Fourth Assessment Report (AR4) states:

> There is considerable confidence that climate models provide credible quantitative estimates of future climate change, particularly at continental scales and above. This confidence comes from the foundation of the models in accepted physical principles and from their ability to reproduce observed features of current climate and past climate changes. Confidence in model estimates is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation). Over several decades of development, models have consistently provided a robust and unambiguous picture of significant climate warming in response to increasing greenhouse gases.

2.5 Conclusion to chapter 2

Although many aspects of climate change may be the object of controversy, there are some basic facts that are considered well-established knowledge and on which rest the foundations of any argument in favour of global warming predictions:

1) It is well known from classical physics that certain gases (water vapour, carbon dioxide, methane and nitrous oxide, among others) do absorb and emit significantly within the thermal infrared range. As components of the atmosphere they do just that with the infrared radiation emitted from the Earth's surface. Part of this absorbed energy is re-emitted back into space, where it ultimately came from; but the other part is trapped in the atmosphere. These gases are naturally present in the atmosphere and help in maintaining the Earth's mean temperature. An increase in their concentrations has invariably a positive feedback on the atmosphere's temperature and thus on that of the Earth. Systematic instrumental measurements made all over the World in the last fifty years have detected a significant increase in the concentration of these gases in the atmosphere.

2) A trend towards a rise in the “atmosphere mean temperature” (0.4 to 0.8 ºC) has indeed been observed since the beginning of the instrumental record.

3) Since the beginning of the industrial revolution, more than 200 hundred years ago, huge quantities of carbon sequestered in fossil fuels have been released in the form of carbon dioxide into the atmosphere as a result of human activities, altering significantly the pre-existing natural carbon cycle. These emissions are presently of the order 7 Gt of carbon a year.

4) Human activities have also released into the atmosphere small particles (known as aerosols), essentially from burning fossil fuels. In the laboratory, some of these particles are known to reflect incoming radiation and it is reasonably presumed that a similar effect may happen when they are airborne, as far as the incoming solar radiation is concerned. Aerosols would thus have a cooling effect, something which is consistent with observed drops in temperature after volcanic eruptions.

All these four statement have negligible level of uncertainty and are subject to no debate. It also appears that the observed temperature rise is connected to human emissions and disruption of the pre-industrial carbon cycle, although the actual extent of the correlation is difficult to appraise, partly due to not well-assessed or yet unknown feedback processes in the climate system. What is subject to debate is the magnitude of the global warming and its impact on climate, not the fact that emissions of greenhouse gases lead to a temperature rise.

In order to apprehend both the relationship between the previous well-established facts and all the factors intervening in the climate system, climate scientist resort to what are known as climate models, which are essentially, computer-run, mathematical simulations of physical models. Most of the science on which these models are based is well-established. However, climate is an extremely complex system, with a high number of intervening variables and cross-effects, many of which are still poorly known, just plainly unsuspected, or imperfectly modelled due to the limitations of present computer power. Models are nevertheless continuously upgraded and sharpened and are presently able to represent fairly well, for example, the evolution of climate in the last 200 years. They do provide a powerful instrument in the hands of climate scientists for unravelling the mysteries of the climate machinery and its future evolution in response to the human alteration of nature of global proportions.

To conclude your study of Chapter 2 and for you to check your basic understanding of the science of climate change, turn to the Module 1 workbook activities 2.1–2.4.

FURTHER READING

In addition to the specific references to which we have alluded in the text and which can be found in the chapter References, we provide here additional sources for further study and/or clarification. The material cited bellow is at the general level, much in line with the present narrative. It contains both material covered here and topics which have not been covered, for example impacts of Climate Change:

Mainstream Climate Change science

Books and reports

Spencer Weart (2008). The Discovery of Global Warming, Harvard University Press, Revised and Expanded Edition (Partial view available on Google Books).

John Houghton (2009). Global Warming: The Complete Briefing, Cambridge University Press, 4th Edition (Partial view available on Google Books).

Mark Maslin (2007).Global Warming: Causes, Effects, and the Future. Voyageur Press, 2nd Edition.

Stephen Schneider (1990). Global Warming: Are We Entering the Greenhouse Century? Lutterworth Press (Partial view available on Google Books).

Internet resources

iTunesU: Apple provides a distribution system for everything from lectures to language lessons, films to labs, audiobooks to tours from more than 800 participating universities. The list of contributions on Climate Change issues is exhaustive and covers every aspect of the topic.

Website created by Spencer Weart. It supplements his much shorter book. http://www.aip.org/history/climate/index.htm

Government Office for Science, Department for Business Innovation & Skills of the United Kingdom, http://www.bis.gov.uk/go-science/climatescience

Met Office (UK) on Climate Science, web portal: http://www.metoffice.gov.uk/climatechange/

The US National Oceanic and Atmospheric Administration (NOAA) offers a comprehensive web portal on climate, http://www.climate.gov/#climateWatch. A page addresses FAQs on global warming at a basic level http://www.ncdc.noaa.gov/oa/climate/globalwarming.html

Climateprediction.net (http://climateprediction.net/) is a distributed computing project to produce predictions of the Earth's climate up to 2100 and to test the accuracy of climate models. To do this, it needs people around the world to give us time on their computers – time when they have their computers switched on, but are not using them to their full capacity. It offers an interesting section devoted to climate science as well as links to numerous scientific papers. It deserves a visit.

Sceptics

Use is made of the term "sceptics" to categorise those people who have an alternative view of global warming. We find some scientists among them (Fred Singer Richard Lindzen, Claude Allègre…). A list of some names endorsing views against mainstream climate change science can be found in: http://en.wikipedia.org/wiki/List_of_scientists_opposing_the_mainstream_scientific_assessment_of_global_warming. They are few and, not surprisingly, they certainly have more acclaim and cheers from their readers than what mainstream scientists receive from theirs. The Wikipedia page (http://en.wikipedia.org/wiki/Global_warming_controversy) gives a good account of the different points of view defended by sceptics on the issue of anthropogenic global warming. More on these ideas may be found in:

S. Fred Singer and Denis T. Avery (2007).Unstoppable Global Warming: Every 1,500 Years. Rowman & Littlefield Publishers, Inc., Updated Expanded edition (Partial view available on Google Books). S.F. Singer trained as an atmospheric physicist and is emeritus professor of environmental science at the University of Virginia while D.T. Avery is the director of the Centre for Global Food Issues at the Hudson Institute. The authors do not challenge global warming though they claim it is not as severe as asserted by mainstream scientists. They instead argue that present global warming is not something unusual (several periods in historical times have undergone warmer climate) but belongs to a natural 1,500 year cycle.

Bjorn Lomborg (2008).Cool It: The Sceptical Environmentalist's Guide to Global Warming, Vintage, Reprint edition. Lomborg is generally referred to as a statistician, but he can be better defined as a political scientist. He does not strictly deny global warming but criticises instead the overemphasis given to the topic. There are some videos presenting his views on YouTube.

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3. Economics matters in climate change

By Gordon Wilson

Before you start: the aim and learning outcomes of this chapter

Chapter 3 aims to introduce you to the central importance of economics and economic analysis to policy-making on climate change.

After studying Chapter 3, you should be able to:

1. Understand and engage critically with the conventional neoclassical approach to the economics of climate change, and the key concepts of market failure and innovation.
2. Engage critically with cost-benefit analysis in relation to climate change-related interventions
3. Have a basic understanding of alternative approaches to the economics of climate change.
4. Use your knowledge and understanding to engage with others on the assumptions behind a cost-benefit analysis of a project related to climate change.

3.1 Introduction: climate change, fossil fuel resources, technology and economic development

Climate change, energy, technology and the economy are closely related, whether we are referring to local, national or global scales. In a nutshell, the dominant model of the economy is predicated on growth of economic activity which requires energy and technology to enact transformations into useful goods and services.

The bulk of useful energy globally is generated through first burning fossil fuels (oil, coal, gas), which releases their stored energy as heat. Sometimes heat itself is useful energy as in the heat required to keep the insides of buildings at a given temperature, but it also is converted into electricity, light and mechanical energy. This interconvertibility of energy is enshrined in what is called the first law of thermodynamics. The second law of thermodynamics, however, tells us that it is impossible to convert all of the energy from burning fossil fuels into these other useable forms and much remains as heat, which is wasted unless it can be put to a use, such as in a combined heat and power station (CHP – see Box 3.1). However, although the second law of thermodynamics holds generally, there is still much that can be done to improve the efficiency of conversion which would mean that less fossil fuel has to be burnt to generate a given unit of useable energy.

Improving fuel efficiency is potentially an important part of climate change mitigation, as we shall see. The other important aspect is, of course, to switch from burning fossil fuels to forms of useful energy generation which do not involve the release of greenhouse gases.

Box 3.1 Combined Heat and Power (CHP)

A typical large power station or plant generates electricity by burning oil or coal, which turns water into steam at a high pressure and temperature. The steam then drives a turbine which generates the electricity. The first law of thermodynamics tells us that the total energy going into this system remains the same as that coming out. The second law, however, tells us that not all of the heat energy going in can be converted to useful energy (i.e. electricity) because we are limited by a) how hot we can operate the steam under pressure and b) the temperature of the ‘sink’ (what the condensed steam – water – is discharged into once it has done its job, typically a river).

Thus, even for a ‘good’ electricity generating power station, one will be lucky to obtain a 45% conversion from the heat energy supplied to electricity. Because the first law of thermodynamics still applies, this means that a lot of waste energy remains as heat and is discharged into the river.

A CHP station simply collects this ‘waste’ heat in pipes to warm nearby buildings, in addition to the electricity it uses. The overall proportion of useful energy (electricity plus useful heat) then rises typically to over 60% of the energy input from burning the fuel. Heat escape through pipes and the friction of the turbines are major sources of the remaining deficit of useful energy.

How does burning fossil fuels link to climate change? A simple chemical equation is at work. Fossil fuels basically comprise either carbon (coal) or carbon-hydrogen chemicals which we call hydrocarbons (oil and gas). The burning process causes carbon to react with the oxygen in the air to release carbon dioxide, and hydrocarbons to react likewise with oxygen to produce carbon dioxide again plus water vapour. In both cases heat energy is released. These chemical reactions can be expressed through simple chemical equations:

Carbon + Oxygen = Carbon Dioxide + Heat Energy

Hydrocarbons + Oxygen = Carbon Dioxide + Water + Heat energy

Chapter 2 of this module explains why carbon dioxide is described as a ‘greenhouse gas’ through trapping some of the sun’s radiation within the earth’s atmosphere. The above chemical equations make it clear that its production and release into the atmosphere is an inevitable by-product of burning fossil fuels, the heat energy from which is needed for economic and livelihood activity. Hence we witness a linear chain as shown in Figure 3.1.

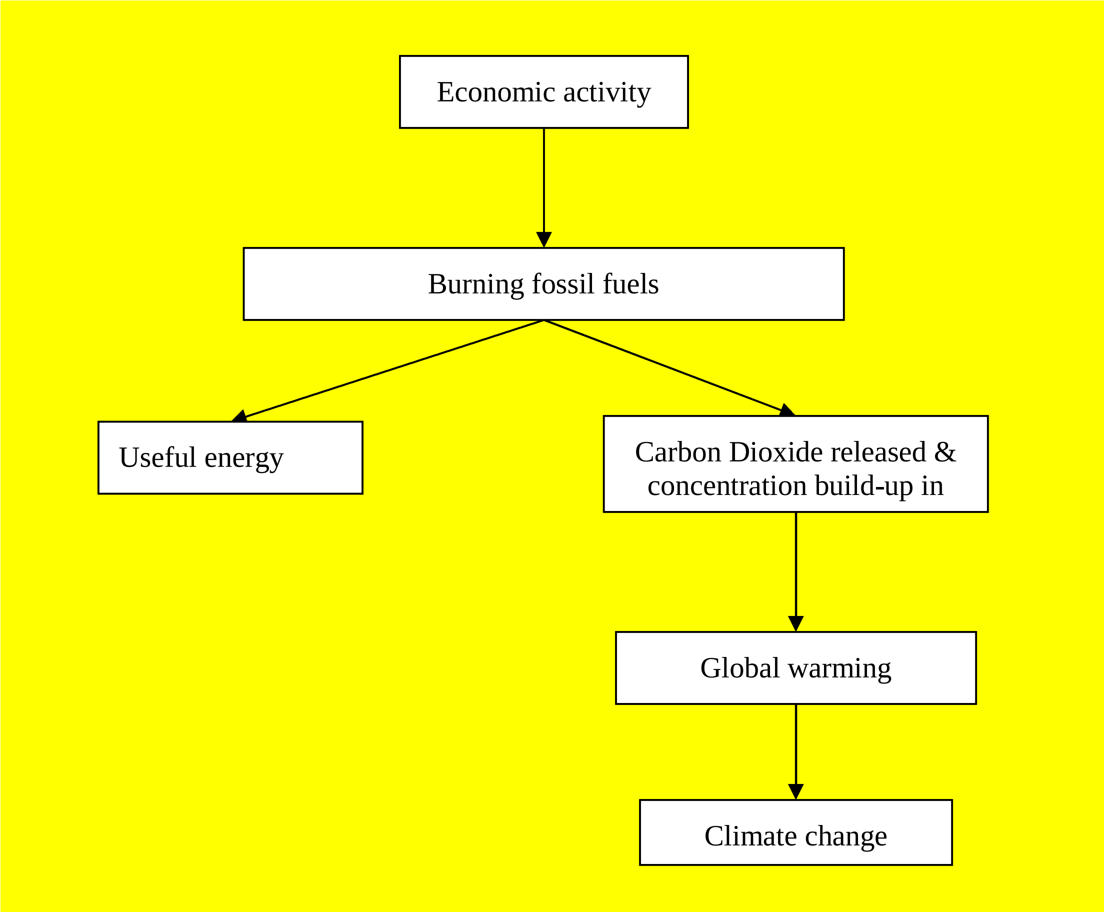

Figure 3.1 From economic activity to climate change through burning fossil fuels

Attempts to mitigate climate change attempt to break or at least curtail links in the chain. Thus, they focus on:

a) Moving to models of economic activity which are less energy intensive (breaking the link at source).

b) Improving the efficiency of conversion of heat energy released from burning fossil fuels to other forms of useable energy. As already stated, much can be done to improve the conversion efficiency despite the second law of thermodynamics holding true generally. This then allows us to burn less fossil fuel for the same amount of useful energy that it generates, and hence produce less carbon dioxide (curtailing the fossil fuel-carbon dioxide release link)

c) Direct saving of heat energy that is used to warm domestic and other buildings, through limiting escape by conduction and convection (Box 3.2) (curtailing the burning fossil fuel- carbon dioxide release link).

d) Developing and using alternative energy sources which don't release carbon dioxide. These include utilising various forms of mechanical energy to generate electricity such as wind, running water, sea waves and tides; direct heat energy from the sun; and nuclear power (breaking the economic activity-burning fossil fuel link).

e) Sequestering –or capturing – the carbon dioxide which is released (curtailing the carbon dioxide release-global warming link).

Box 3.2 Heat flows: conduction, convection and radiation.

Another formulation of the second law of thermodynamics tells us that, left to its own devices, heat will always flow from a higher to a lower temperature, until an equilibrium is reached.

This heat transfer from higher to lower temperature can occur via three routes: conduction, convection and radiation.

Conduction is the transfer of thermal energy between neighbouring atoms or molecules due to a temperature gradient. Everyday examples include what we observe as heat 'loss' (more accurately 'transfer') through pipes carrying hot water or through the walls and windows of buildings. Some materials such as metals are much better heat transfer agents (heat conductors) than others such as ceramics. Most Europeans will know this from practical experience. It is why we insulate buildings and lag pipes which carry hot water with materials which are poor heat conductors.

Convection is the main means of heat transfer in liquids and gases. It is literally the carrying of the heat from one place to another via the movement of the liquids and gases. In buildings we try and cut down on convection 'losses' (i.e. transfers to the outside or a cooler part of the building), by excluding draughts, i.e. air movement, as much as possible.

Radiation is the transfer of heat energy through electro-magnetic waves. It is how the sun's energy reaches the earth. Unlike conduction and convection, this energy is able to travel through the vacuum of outer space. Substances which absorb a wider range of the visible radiation spectrum appear to be dark in colour. Conversely substances such as snow and ice appear to be light in colour because they reflect a wider range of the visible radiation spectrum.

Several of these mitigation measures are referred to again in subsequent sections. We should note for the moment that all, except possibly a) which is of a different order, put their faith directly into technological solutions to the problem. Thus, while technology can be thought of as part of the problem of climate change in that it is a key ingredient of economic activity, including the technologies (power stations, internal combustion engines) that convert fossil fuels into useful energy, it is also perceived as part of the solution.

It is also worth pointing out here that increasing the concentration of carbon dioxide in the atmosphere has not always been thought of in negative terms. The science pioneers of the link between carbon dioxide concentration in the atmosphere and the earth's mean temperature – referred to in Chapter 2 – thought of it largely in positive terms. As recently as 1995, the physicist Freeman Dyson wrote an essay arguing that carbon dioxide is good for plant growth and hence potentially beneficial for agriculture (Dyson 1995: 492–494).

Dyson's argument was that plants absorb carbon dioxide from the air through the process of photosynthesis, which is the basis of plant growth and health. In doing so, they release oxygen into the atmosphere. In other words they reverse the process of humans and other animals that absorb oxygen and release carbon dioxide. Dyson's essay then further argued that the increasing concentration of carbon dioxide in the atmosphere is too small to be accounted for by increasing emissions from burning fossil fuels, and that the 'lost' carbon dioxide is probably accounted for by enhanced absorption by plants, which is good for them.

Whatever the merits or otherwise of this argument (for a critique, see chapter 2 section 2.2.8), it does point to another economic activity apart from useful energy generation, which can contribute to global warming and hence climate change. This is where vegetation cover is depleted, interrupting the natural sequestration of carbon dioxide that takes place through photosynthesis. It is one reason why there is so much concern about forest depletion in many regions of the world, particularly through logging, but also for direct fuel uses.

Dyson's argument also triggers a broader question concerning why there is so much fuss about climate change. From an economics perspective this question boils down to asking whether it is good or bad in economic terms. Note that economists usually have no truck with ethical concerns about the intrinsic rights of nature and all living things, whether human or not. Their starting point is a purely utilitarian view of nature in the service of human beings. Insofar as they have a concern for it, this is primarily about nature's continuing ability to service economic activity. Hence they speak of 'natural capital' and whether this is being depleted or not, or whether it can be replaced by other forms of capital, such as financial and human capital (Box 3.3).

Box 3.3 Capital, its various forms and their inter-changeability.

Capital, in its most general form, is any form of wealth that is able to be used to produce more wealth. There are many forms of capital, the most common being:

Financial capital, typically the money that is available to invest in productive activity, for example buying new machinery to produce the goods.

Physical capital, such as tools, equipment and machinery that are used in production

Human capital, which is the skills and abilities of the workforce.

Natural capital, for example natural resources such as soil, water, air, forests, oil, coal, natural gas etc.

Social capital, which is the ability to form networks with others for mutual economic gain.

Some economists claim that these different forms are inter-changeable and that you can substitute one for another. For example, if you have good machinery to produce your goods and a skilled workforce, perhaps financial capital is not so important in the short term. Much debated, however, is whether or not you can substitute natural capital by other forms of capital, for example by human capital (skills and abilities to innovate away from reliance on the natural resource as it becomes depleted) and physical capital (machinery to make more efficient use of the depleting natural resource). Obviously, some substitution of some natural resources in these terms is possible, but there are limits and we will always be dependent, for example on air and water.

So, is climate change good or bad in economic terms? You will probably have already gathered that this question provokes argument. I identify here two answers that are in direct opposition to each other, both of which accept the science arguments about anthropogenic global warming.

- *Scenario 1*. The release of carbon dioxide into the atmosphere is benign or even positive for economic activity and hence human welfare. For example, in addition to Dyson's arguments linking increased carbon dioxide concentration to agricultural production, some parts of the world which are currently cold and dry might benefit from becoming warmer and wetter. The melting polar ice caps might reveal new sources of oil.
- *Scenario 2*. While there may be some economic benefits, these will be far outweighed by the economic costs of the massive disruption that climate change will cause in many parts of the world. These include disruption caused by extreme and unpredictable weather patterns, rising sea levels displacing millions of people, and so on.

Economists have a well worn tool for weighing up the balance of benefits and costs of an activity. Unsurprisingly it is called cost-benefit analysis, and I examine it in some depth in relation to climate change in section 3.3 below.

Both of these scenarios, however, carry the same utilitarian assumption that economic activity is ultimately in the service of human welfare. It is why, in the words of Mike

Hulme (2009: 111, 146): 'Governments worry about climate change because of the risk to economic growth policy. Economic arguments carry weight.' Governments especially worry about the second scenario above. Even if a few countries might appear to benefit, even these cannot escape from the economic interconnection of the world, which is commonly referred to as 'globalisation (Box 3.4). Any benefits which accrue to a few countries will be an illusion if the rest of the world suffers economically and is not able to engage in trade with them.

Box 3.4 Globalisation and trade

This is the process of increasing interconnectedness of the world. In the realm of the economy, interconnectedness is viewed as integration necessitating trade across the globe, rather than purely internally within a single country or region. Globalisation is facilitated by modern communications technology and transport, and by the ability to produce different parts of the same product in different places. Optimistic views on globalisation claim that economic integration is overall a good thing which ultimately allows everybody to enjoy the fruits of market-based capitalism. Pessimistic views, however, argue that increasing integration reinforces existing global inequalities and power relations. A third view, the transformationalist view, argues that globalisation is creating a new world order, where new concentrations of power and inequality, wealth and poverty are forming in both the hitherto rich countries and the historically poor countries. (adapted from McGrew 2000)

However, this basic assumption that economic growth equals human welfare itself needs interrogating.

The rest of Chapter 3 unfolds as follows, elaborating on the economic ideas, issues and challenges which have been outlined in this Introduction:

Section 3.2 examines climate change from the conventional 'neoclassical economics' perspective, on which the assumptions about economic growth are predicated.

Section 3.3 interrogates the economic justification to intervene on the impacts of climate change that is provided by cost-benefit analysis.

Section 3.4 examines in detail how a broad cost-benefit approach has framed an influential analysis on the economics of climate change: the Stern Review.

Section 3.5 is on alternative economics which challenge the assumption of forever increasing human welfare resulting from economic growth. It raises questions of (in)equality and (in)justice, and the links between climate change and poverty.

Section 3.6 concludes the chapter by returning to the central questions of why:

Economics matters for climate change mitigation and adaptation

We have to treat the dominant global model of economics and economic growth seriously

We must nevertheless be constantly on the alert to challenge the dominant model's principles and assumptions, being informed by alternative models which stress justice.

Section 3.6 ends with a brief discussion about how we might use the dominant economic model's ubiquitous tool of cost-benefit analysis as a framing device for discussion and debate about climate change mitigation and adaptation options.

3.2 The economics of climate change through the dominant neoclassical lens

> 'The greatest market failure the world has seen.'
>
> *(Stern 2010: 11).*

Thus concluded the author of the influential UK Government Review into the economics of climate change, about global warming.

'Market failure' is part of the language of the neoclassical economics which is basically a theory of capitalism. An essential feature of capitalism, and many argue the basis of its pre-eminence as a form of economic organisation, is its ability to build continuously on itself and hence 'grow' wealth through a spontaneous and unconscious process from within. This process is called *immanent* development (Thomas 2000: 25) and is predicated on a self-regulating market, where goods and services are exchanged according to laws of supply and demand, and where the old is destroyed if necessary to create the new. Thus, if people are producing similar goods and services, there is competition between them for customers who choose according to a combination of price and quality of what is on offer. This in turn creates the incentives to innovate. Innovation can be described as:

- Process innovation, in which production processes are adapted or replaced to lower the cost of providing the product.

And/or

- Product innovation which can involve developing new products or improving the quality/reducing the material costs of existing products. (Forbes and Wield, 2002).

Thus the incentives provided by markets and the 'motor' of innovation drive the immanent process of capitalist growth. The process is elucidated if we contrast it with the command economies that characterised the ex-Soviet Union and its satellites. Command economies are those where production is planned in detail centrally by the state. 'There are many reasons why the command economies of the Soviet system collapsed, but perhaps the most important is that they failed to deliver the goods,' states Kaplinsky (2009: 150). In other words, these command economies lacked the self-regulating market system which provides the incentives to innovate and they stagnated as a result.

Thus neoclassical economics contends that self-regulating markets can correct just about everything according to laws of supply and demand. For example, if our lives are being degraded significantly through greenhouse gas emissions from industrial production, we will demand more carbon friendly products which will accordingly be supplied by, in the famous words of Adam Smith (1776/1996), the 'invisible hand' of the market. This is a view held by a few people who propose that the self-regulating invisible hand of the market will take care of climate change for us.

Even among conventional economists, however, very few claim that markets in practice conform more than approximately to this abstract ideal. Some obviously conform more closely than others and there is thus a spectrum of deviation from the ideal. The extreme deviation is of course 'market failure' as Stern, in the quotation at the start of this Section, contends is the case with respect to global warming.

Economists also generally agree that substantial deviations from perfect markets require a correcting factor. Here, I identify two broad categories. Both involve government intervention or intervention through an international agreement between governments

- Interventions which either establish or enable a market which functions correctly, through for example a robust legal framework which protects individual property rights (see below).
- Interventions which involve more directed action by government (or supra-government bodies such as the European Union).

Neoclassical economists tend to be happy with the first category of intervention, but ideologically opposed to the second, although most will accept in practice some form of directed intervention.

Only national Governments can command the resources and means to intervene in the market economy, promote desirable outcomes (Giddens, 2007: 91) and address real or potential market failures. The legitimacy of directed intervention in the economy by government, its extent and timing, is, however, highly contested, the debate being summarized historically under the heading, 'State versus Market'. Of course, states are not perfect either, which has led the Public Choice School of Economics (Box 3.5) to argue that government failures may be worse than the market failures they seek to correct.

Box 3.5 The Public Choice School of Economics

This concerns subjecting government, politicians and public sector officials to economic analysis, usually from a neoclassical perspective. It starts from the premise that politicians and public sector officials are no different from other individuals. They are driven by private self-interest which results in public sector bureaucrats attempting to expand their powers, budgets and privileges, and leads to over-powerful ('Leviathan' – a sea monster referred to in the Bible) states. Such individuals will also attempt privately to gain from opportunities created by state regulations (known as 'rent-seeking').

Thus, although public servants can be made by institutional norms, values and rules to act in the public interest, it is easy to see how public choice theorists are interested in the notion of 'government failure' when it attempts to intervene to correct 'market failure', and that the former can turn out to be worse than the latter.

(Adapted from Mackintosh 1992: 70–73)

3.2.1 A classic example of market failure: the tragedy of the commons?

Market failures represent the extreme of market imperfections, where the mechanisms have failed to deliver their self-correcting role. An apparent classic example in relation to 'free' natural resources – i.e. situations where markets for the natural resource don't exist -- was provided in 1968 with the publication of Garrett Hardin's 'The tragedy of the commons' (Hardin, 1968). Hardin explained his argument through the example of herdsmen sharing a common piece of land (the commons) for grazing their cattle. It is in the interests of each 'rational' herdsman, Hardin said, to keep adding cattle to his stock on the land. The benefits which accrue to him personally of doing so outweigh the costs of possible overgrazing, because the latter are shared by all herdsmen. Thus, he concluded:

> 'Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit – in a world that is limited. Ruin is the destination towards which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all.'
>
> *(ibid.)*

This analysis has been seized upon by many an economist (note that Hardin himself was a biologist) to argue for private property rights in natural resources, in order to provide the necessary incentives to conserve them. Private property rights form another basic tenet of neoclassical economics and market failures are deemed inevitable where they don't exist. They concern the private ownership of goods, services, intelligence (as in intellectual property rights), and so on where the owner's rights include:

- The right to use something (for example to farm land), and conversely the right to exclude others from using it
- The right to alienate it (to give it away, to sell or otherwise dispose of it)
- The right to transform it (for example, to use it as an input to a production process)
- The right to appropriate it (for example, to eat or sell farm produce).

(Bromley et al, 2001: 53)

Thus, to illustrate, I change Hardin's scenario to one where each herder has private property rights to (i.e. 'owns') a piece of land, and postulate that one herder wishes to add to his stock. The herder has two options:

1) He grazes the extra stock on the land that he owns. Here, however, he risks degrading his own land through overgrazing. The result may be no net gain and even a loss if cattle die prematurely because they are weak through lack of food.
2) He may therefore approach another herder to buy or rent land off him so that he can maintain his grazing resource at the appropriate level. In effect, the allocation of private property rights in this situation has established a market for land.

With option 2, the price that the herder may have to pay in rent or purchase is the result of a complex tacit calculation made by both parties and which appears as the invisible guiding hand of the market at work. Thus the prospective buyer/tenant has to calculate the maximum price he is prepared to pay in order for this option to be worthwhile. The seller/landlord has to calculate the price he needs to extract to make it worthwhile giving up herding the land himself. The really complicated bit, however, is that each must conduct his own internal risk analysis – again likely to be tacit and unconscious – of things not working out as planned. For example, for the buyer/tenant, what if there is a prolonged drought just after the deal is done and all the grass dries up? For the seller/landlord, what if a second herder is willing to sell or rent and undercuts him?

It is beyond the scope of this module to enter into the subsequent debate about the tragedy of the commons in relation to property rights and natural resource management, except to note that the commons are rarely free in Hardin's sense of unregulated access. Local institutional rules usually manage and regulate use (for a wide-ranging critique, see Ostrom, 1990).

In relation to atmospheric pollution by carbon dioxide and other greenhouse gases, however, establishing private property rights is clearly untenable. How could one establish private property rights over the air we breathe? How could we exclude others from its use and from polluting it with yet more greenhouse gases which know no boundaries? Thus, Stern concluded that global warming represents a market failure, unable to provide a self-correcting mechanism. However, intervention by government, or perhaps even a global coalition of governments, to correct for the failure requires an evidence base for the decisions taken, involving answers to some basic questions:

- What are the costs of the global warming market failure?
- What are the costs and benefits of different kinds of intervention and their timing?
- Is the net balance sheet positive or negative?
- Who bears the costs and who claims the benefits?

The answers to these questions inform the extent, content and form of the intervention, where to intervene, and who intervenes. As already noted, the most widely used tool in economics for informing such decisions is cost-benefit analysis (CBA) which, as the term indicates, weighs up the costs and benefits of this or that intervention, where a net benefit will support a decision to go ahead, and will represent value for the money that is spent.

3.3 Cost-benefit analysis and climate change

> 'A cost-benefit analysis purports to measure in money terms all the benefits and all the costs to be expected over the future of some mooted project, and to admit the project if the sum of the benefits exceeds the sum of the costs by a significant margin'.
>
> *(Mishan, 1970).*

There are several reasons why CBA has evolved into a standard economic tool to aid decision-making. Below are three of the most important:

- In theory, it is simple and neat. CBA reduces the complexities of decision making to a single number, the ratio of benefits to costs.
- Market failures can occur for many reasons, but of primary importance for this section is that they often occur because they have to deal with phenomena on which it is difficult to assign an economic value. Many government interventions fall into this category, and CBA provides a legitimate way of taking such *externalities* as they are called into account. CBA thus can take a wide view rather than a narrow view. An example of the latter would be a decision to invest in a new coal-fired power station that is based purely on an assessment of the costs associated with building, running and maintaining the power station, and the expected returns on this investment. Alternatively, additional consideration of the costs of emissions, including carbon dioxide emissions, and the adverse consequences for the wider population would constitute a wide view.
- Economic investment becomes even more uncertain as we project further into the future, which is why market capitalism is good at making short term decisions but often fails on the long-term. CBA specifically projects into the future to provide a longer-term view.

In practice, however, CBA is anything but simple, the main criticisms being:

- Assigning a monetary value to something where the market has already failed to do so is highly contentious. If, for example, people have to leave coastal homes because of rising sea levels, the cost of providing new homes inland is not hard to estimate. What value, however can be put on the wholesale disruption to the lives of these people? To cast the net wider, what value can be put on the lives of the people who already live inland and who might be disrupted by an influx of coastal dwellers? To take a different example, what value can be put on the disruption caused to a local community by erecting a wind farm literally next door as a contribution to reducing a country's carbon footprint?

- These problems are compounded when projecting into the future, which has to be done because climate change has a strong temporal dimension. Its impacts are already being felt today, but much of the prediction is about the probably greater impacts into the future. Put crudely, the issue concerns assigning a value to intervening today where the benefits are likely to accrue principally to future generations.
- A third issue relates to the claim that CBA offers a wide view of an intervention decision, beyond straightforward investment costs and returns. But, how wide is wide and conversely how narrow is narrow? In other words there can be a tricky decision on what to include and what to exclude in the CBA. To follow the example in the first of these criticisms, above, how is the decision taken whether to include or exclude the disruption costs to the lives of those inland dwellers who might have to absorb an influx of coastal ‘refugees’ into their communities?
- A further criticism of CBA which relates to the inclusion/exclusion issue is that often it only calculates the *net social benefit*. It does not discriminate necessarily in situations where some gain while others lose. To take a different example: a government decision to intervene to protect rain forests in Kenya might be a sound decision for the Government and the population as a whole, especially if it attracts money from the international Clean Development Mechanism (Box 3.6). Rain forest dwellers who depend on the forest for their livelihoods, however, might become worse off.
- The deepest criticism, however, is that CBA is not the neutral tool that it is claimed to be. The boundaries of what to include and exclude from the calculation, the values placed on different costs and benefits both now and in the future, reflect the interests and values of the most powerful stakeholders. This criticism has been expounded at length by Ranjit Dwivedi (2006) in a book about the Narmada Dam (Sardar Sarovar project) controversy in India (Box 3.7), where the CBA of building this dam has produced protest and counter-protest for around three decades. There has been particular controversy around valuing the costs of disrupting the lives of the people who will be displaced by the Dam.

Box 3.6 The Clean Development Mechanism (CDM)

The CDM is part of the Kyoto Protocol, the international trading regime designed to provide a market mechanism for countries to lower their greenhouse gas emissions by establishing a price on them (see Chapter 4 of this module). The Protocol expires at the end of 2012 when agreed 5.2% reductions in greenhouse gas emissions from their 1991 levels should have been met by the signatory countries. As this Box is being written there are ongoing negotiations to replace it.

The CDM derives from agreed exemptions to this ‘carbon trading’ regime, exemptions which apply to poor developing countries. Instead, the CDM allows development aid from rich, developed countries, which are part of the regime, to be used for ‘clean development’ – i.e. projects that help to mitigate global warming arising from activities in the receiving country. One example of a CDM project is to use development aid to halt deforestation in a country through providing alternative economic uses (e.g. tourism) which do not involve felling the trees. Another might be to sponsor re-forestation of areas. The point, however, is that the rich providing country can use such projects to count towards its own 5.2% reduction target.

Box 3.7 The Narmada Dam (Sardar Sarovar) project in India

This project, first mooted in 1946, has been the subject of huge controversy concerning its adverse environmental impacts and the displacement of a large number of people. It involves the construction of a series of domestic water, irrigation and hydroelectric generation dams along the Narmada River, which flows west through mostly the Indian State of Gujurat into the Indian Ocean. The largest, and most controversial, of these dams has been the Sardar Sarovar in Gujurat. The first landmark decision to go ahead with the project was in 1979 and at that time the Sardar Sarovar dam would have been – at 200km in length – the second-largest dam in the world.

Since 1979 there have been a number of decisions halting and resuming the project. The most recent was in 2000 with the Supreme Court of India decision that the project should go ahead. There are, however, continuing protests as I write this Box.

Although there are other, more recent, big dam controversies in India and elsewhere (for example, China), the Narmada Dam remains overall one of the most infamous and well-documented. It is particularly pertinent for Chapter 3 of this module because the main analytical tool by which experts reached their initial and subsequent decisions has been cost-benefit analysis. Moreover, this cost-benefit analysis has been subject to rigorous critical appraisal by Dwivedi (2006) in a substantial chapter – 'The gainers and losers: a cost-benefit analysis of the SSP [Sardar Sarovar Project]' –of his book.

For those interested more generally in the controversy around the project from a political science perspective, see also Wood (2007).

Below I deal with CBA – its uses and the formidable challenges that it faces -- in some detail in relation to the UK Government's 'Stern Review: the economics of climate change' which has attained international influence. Before then, however, I outline three different kinds of intervention related to climate change where CBA might apply:

1. Firstly, one might conduct a CBA of a policy which advocates acting only in response to climate-related events. One example would be to weigh up the financial costs and benefits of re-housing coastal dwellers as sea levels rise and flood their homes. Another would be to weigh up the costs and benefits of leaving the matter to individual house owners and their insurers. We refer to this as *reactive adaptation* to climate change
2. The converse of reactive adaptation is *proactive adaptation*. Here, for example, one might conduct a CBA of: erecting coastal or flood defences such as the Thames Barrier in London; or of withholding planning permission to build houses on flood plains of rivers; or of developing drought-resistant crops through genetic modification. Essentially, proactive adaptation involves reducing human and ecosystem *vulnerability*, or (to use the opposite term) increasing their *resilience* to climate-related impacts such as sea level rise and prolonged droughts. Resilience in turn depends on the *adaptive capacity* either of individuals, a community or the Government. Adaptive capacity is the capacity not only to cope in the face of climate-related events, but to be pro-active and pre-emptive (Giddens, 2007: 163).
3. Finally, there are the costs and benefits of *mitigation* – the attempts to at least stall global warming through stabilising, and preferably reducing, the concentration of greenhouse gases in the atmosphere. Examples include decreasing consumption of fossil fuels through behavioural change (consuming less), greater energy efficiency or changing to non-polluting fuel resources. 'The Stern Review: The economics of climate change' primarily concerned itself with stabilising the concentration of greenhouse gases in the atmosphere, and hence represents an economics of mitigation versus doing nothing. It is to this Review that I now turn.

3.4 The Stern Review: the economics of climate change

The Stern Review was commissioned by the Finance Ministry (the Treasury) of the UK Government and was led by senior economist Lord Nicholas Stern (Box 3.8). It reported in October 2006, to the approval of then Prime Minister Tony Blair. Its findings soon gained international prominence.

The Review was essentially conducted within a CBA framework, albeit a much more complex framework than is conventionally the case when used to provide economic evidence about projects, even large scale projects such as a new airport. Thus, it did not concern a project working within a defined national economic growth path, but strategic action at a global scale where growth or even decline are uncertain and the scale of possible climate-related damage is potentially high. In his later book, Stern (2010: 13) himself explicitly criticised the notion that decisions on climate change could be subject to standard cost-benefit analysis, stating: 'This is not an investment project like a new road or bridge.'

Thus, the Review took a very wide view, taking into account, for example, the costs and benefits to people in different parts of the world. It considered, in considerable depth, risk and uncertainty of the occurrence of climate change-related events. It made assumptions and ethical judgements which 'went beyond conventional economics' (Hulme 2009: 125, 126). As a result, although it gained much credence in national and international policy circles, it has been much contested, not least by other economists. Some have criticised it for being too conservative, others for being too radical.

The Review concluded that the benefits of averting climate change damage by taking immediate action to stabilise the concentration of carbon dioxide in the atmosphere greatly outweighed the costs. In Stern's (2010: 10) own words, 'the cost of action is much lower than the cost of inaction'. In other words, despite his own strong qualification, Stern conducted a general, albeit complex, CBA of mitigation, to stabilise carbon dioxide emissions.

Box 3.8. Nicholas Stern and the process of the Stern Review

Nicholas Stern is currently a professor of at the London School of Economics and Political Science (LSE). Formerly he was Chief Economist and Senior Vice President at the World Bank (2000–2003). In July 2005 he was asked by the UK Government to lead a comprehensive review of the economics of climate change. His team comprised Government economists at the UK Treasury, with some independent economists being involved as consultants.

The 700-page report was released in October 2006. UK Prime Minister Tony Blair hailed the report and stated that it would be 'disastrous' if the world failed to act in response to global warming. The European Commission said that doing nothing is no longer an option. It also received widespread positive reviews from business, senior politicians from several countries, and economists internationally (including Nobel prize-winning economist Amartya Sen). Hulme (2009: 126) claims, 'The Review seems at times to have carried the authority of an IPCC [the United Nations Inter-governmental Panel on Climate Change – see Section 4.2.2 of this module] report.'. And the Wikipedia entry on the Review has commented that 'although not the first economic report on climate change, it is significant as the largest and most widely known and discussed report of its kind'.

Perhaps as a result of its fame and immediate impact, the Review has also received many critical reviews, the most important of which are covered in the main text of this module.

Adapted from Wikipedia: http://en.wikipedia.org/wiki/The_Stern_Review (accessed 26th October 2010).

Let us now examine in greater detail, but without entering the actual calculations, how the Stern Review reached its conclusion. A large part of this exercise is to get behind the numbers to examine the assumptions and judgements that that lay behind them, and the trade-offs. Along the way, I highlight some of the issues by drawing your attention to critiques – both those that stated the Review was too conservative and those which stated it was too radical (following Hulme 2009: 125–132). You will see that these critiques illustrate the general critiques of CBA which I highlighted above.

I start by examining the goal which Stern set in terms of stabilising the atmospheric carbon dioxide concentration. Then I move onto valuing the potential damage to human welfare through not taking action which is encapsulated in the *social cost of carbon*. This valuation has a number of elements:

- measuring human welfare,
- the cost of the damage to human welfare,
- the capacity of human populations to adapt,
- the different levels of development of populations (the equity weighting factor),
- valuing the damage to the human welfare of future generations (discounting the future),
- issues of uncertainty and risk.

Finally, I value and compare the respective costs of doing nothing and of mitigating action.

3.4.1 The goal set by the Stern Review

The Stern Review's goal was to establish, at a global scale, the net benefit (in terms of damage avoided to human welfare) of investing promptly to stabilise greenhouse gas concentration in the atmosphere within the range 450–550ppm (parts per million) of carbon dioxide equivalent (CO_2 e)[32]

The concentration of greenhouse gases in the atmosphere at the time of the Review (2006) was about 430ppm CO_2e and climbing. It had risen to this level from the 1850 level of 285ppm, a 51% increase. According to 'middle of the range climate models' (Stern 2010: 26), and relative to the 1850 temperature:

- A concentration of 450ppm CO_2e will lead to a 78% likelihood of a 2ºC global average temperature increase and an 18% likelihood of a 3ºC increase. The likelihood of a 5ºC increase is 1%.
- A concentration of 500ppm CO_2e will lead to a 96% likelihood of a 2ºC global average temperature increase and a 44% likelihood of a 3ºC increase. The likelihood of a 5ºC increase is 3%.
- A concentration of 550ppm CO_2e will lead to a 99% likelihood of a 2ºC global average temperature increase and a 69% likelihood of a 3ºC increase. The likelihood of a 5ºC increase is 7%.
- A concentration of 750ppm CO_2e will lead to a 100% likelihood of a 2ºC global average temperature increase and a 99% likelihood of a 3ºC increase. The likelihood of a 5ºC increase is 47%. 750ppm CO_2e represents a 'cautious estimate' (ibid.) of the concentration that will be reached under a business-as-usual scenario (i.e. no action is taken to limit emissions).

Quoting the evidence from the United Nations Intergovernmental Panel on Climate Change (IPCC) reports, Stern (ibid: 29) states that a 2–3ºC temperature rise will cause 'severe dislocations' in many parts of the world, including dislocations resulting from

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32 Human activity releases greenhouse gases in addition to carbon dioxide: for example, methane from decomposition of wastes and nitrous oxide from agricultural chemicals. Carbon dioxide (CO_2) is by far the most important gas released, however, because of the sheer quantities involved compared with the others. Thus greenhouse gas emissions of all kinds are expressed in a single figure – CO_2 equivalent (CO_2e).

‘rising sea levels, a greater frequency of increased storms and hurricanes, the melting of glaciers and snows… , droughts…, and a high risk that the major rainforests will collapse’.

If a 2–3ºC rise is bad, a 4–5ºC rise could be catastrophic with the elimination of many species, much of Southern Europe reverting to desert, most of Bangladesh and Florida submerged, etc. Stern (ibid: 31) then concludes: ‘With temperature changes of this magnitude, the physical geography is rewritten. If the physical geography is rewritten then so too is the human geography of the world. There would be movement of people on an immense scale… [which] would plunge the world into massive and extended conflict.’

The Stern Review’s chosen goal of limiting atmospheric concentrations to 450–550ppm is therefore a judgement, informed by a combination of ethical and pragmatic considerations. Within this range there is a high chance of a 2–3ºC increase in global temperature, but only a low chance of a 5 ºC rise. 2–3ºC will cause massive dislocation in many parts of the world but not all-round calamity. To try and attempt reducing the chances of a 2 ºC rise to below 50%, however, would involving reducing the concentration to 350ppm CO_2e. Given that it is already at 430ppm, and given the current energy demands of rapidly developing countries such as China and India with their huge populations, this is considered politically impractical. For the Stern Review, and others, 450–550ppm is a compromise goal (he has also stated his wish for a long-term reduction to below 400ppm), and a matter of judgement. Stern, himself has since lowered the upper limit from 550 ppm to 500 ppm CO2e (ibid.)

3.4.2 Assumptions about, and measuring, human welfare

Human welfare is a combination of many factors – our material wealth, our health, education, spiritual well-being and so on. Capturing it by quantitative measurement is therefore problematic. One method is to compile a composite ‘Human Development Index’ (HDI) for each of the world’s countries (Box 3.9).

Box 3.9 The Human Development Index (HDI)

This index, developed originally by the United Nations Development Programme (UNDP), creates a single measure for each country in the world which serves as an indicator for social and economic development. It is a composite of three components: material wealth, health and education.

Material wealth is measured by the average national income per capita in US dollars at purchasing power parity (PPP – an adjustment for what a US dollar will buy in different countries).

Health is measured by the life expectancy in each country, measured in years. Life expectancy is the average number of years a person at birth is expected to live. It is called a ‘proxy’ indicator as it does not, of course measure a country’s health directly (which would be a much more complex, many argue impossible, task).

Education is measured as a further composite, combining the adult literacy rate of a country (the percentage over the age of 15 who can read and write to a basic standard), and the percentages of children in the relevant age groups who are enrolled in primary and secondary schooling.

These three components are combined in the HDI on a scale 0 to 1. Typically, rich countries of Western Europe, North America, Australasia and Japan have HDIs greater than 0.9, while poor countries in Sub-Saharan Africa and South Asia have HDIs around 0.5.

Other composite indices exist, but in policy and practice the most common method to measure human welfare – in a way that everyone can understand – is simply as one factor, economic performance. This is easily done through gross domestic product (GDP) where GDP is the total market value of all goods and services produced in a country (or other defined population) over a given period, usually a year. It is commonly expressed in US dollars per annum. Nevertheless, GDP obviously is not a direct measure of human welfare, but a 'proxy' indicator. Its proponents argue that it is a good proxy because, apart from its simplicity, many of the other factors that make up human welfare, such as health and education, are positively correlated with GDP.

The Stern Review used GDP, but the basic criticism remains: it does not, and cannot capture dimensions that do not have a market value. Examples related to climate change which do not normally have a market value include the natural environment and our spiritual welfare. This is not a criticism of CBA as such which was partly developed to include these non-market considerations (see above), but it does mean that equivalent market values have to be derived for these dimensions using some form of reasoning and assumptions which will almost certainly be questioned by others.

In 2010, the GDP of the entire world was around $50 trillion. Thus a loss of current global GDP in a single year of just 2% due to climate change would represent a large figure, $1 trillion. These are the kind of absolute figures that make news headlines. The Stern Review, however, was more concerned with percentages of GDP and how these change over time. He assumed a continuing rise in global GDP of 1.3% per annum over the next 200 years, which his analysis demonstrated would be more than wiped out by the costs of taking no action on climate change.

Thus Stern adhered to the economic orthodoxy that global GDP, the occasional blip caused by world recession notwithstanding[33], continues to rise, and implicitly so does human welfare. There are radical critiques of this orthodoxy and also the continuing association between GDP and human welfare (see Section 3.5 below). These critiques focus on the 'right of future generations to benefit from and appreciate the same natural assets and functions as do our own generation' (Hulme 2009: 131). They represent an ethical stance where it becomes impossible to put a market value on what might be lost through climate change. As two ecological economists put it:

> 'Climate change, at least above a certain temperature rise, violates fundamental principles of sustainable development, intergenerational stewardship and fairness and therefore violates the inalienable rights of future generations.' (Neumayer 2007: 299)
>
> 'The [Stern Review maintains] allegiance to an economic orthodoxy which perpetuates the dominant political myth that traditional economic growth can both be sustained and answer all our problems.' (Spash 2007: 706)

These are fundamental critiques of the ideology behind the Stern Review. By locating the investigation within a framework of continuing world economic growth, the Review essentially legitimised that framework. It was, however, commissioned by a western government, so it is difficult to see how it could avoid using a 'continuing economic growth' framework. The critiques do, nevertheless, accord with the general fundamental critique of CBA noted at the end of Section 3.3 which concerns whose interests and values such an exercise represents.

Stern himself has defended the assumption of continuing economic growth in terms of a 'win-win-win' for tackling global poverty and climate change simultaneously, and for making it politically acceptable to citizens throughout the world. Restating the well-rehearsed argument that economic growth correlates with increasing human welfare, he states (Stern 2010: 10):

> 'It is neither economically necessary nor ethically responsible to stop or drastically slow growth to manage climate change. Without strong growth, it will be extremely difficult for the poor people of the developing world to lift themselves out of poverty, and we should not respond to climate change by

33 The Stern Review was conducted before the world recession of 2008–20??,.

> damaging their prospects. Moreover, politically it would be very hard to gain support for action by telling people that they have to choose between growth and climate responsibility… [It would] be so politically destructive as to fail as policy.'

Stern's poverty claim represents a counter-attack on another line of argument from some development economists. This line uses the economic concept of opportunity costs, which are the costs of opportunities foregone by choosing a particular strategy or action, to argue that we might be wiser to invest more in lifting people out of poverty today (and hence reduce their vulnerability to climate change today) than invest in mitigating future climate change for the benefit of future generations (Hulme 2009: 122).

So, after the general justification for the necessity of continuing economic growth, the Stern Review gave it a value of 1.3% of global GDP per annum for the next 200 years. This was actually modest compared with a similar exercise conducted by IPCC economists, whose range for annual global GDP growth is 2.3–3.6%!

If we are to draw any general conclusion about the measurement of human welfare from this sub-section, it is that every assumption, every indicator we choose and every value that we derive will be challenged by others who are operating with different assumptions, promoting different indicators and deriving different values.

3.4.3 Valuing the damage of unmitigated climate change

This is encapsulated and given a monetary value through the concept of the *social cost of carbon (SCC),* defined by Hulme (2009: 117) as the 'worldwide incremental damage that would be caused by emitting one tonne of carbon dioxide (or the equivalent of other greenhouse gases) at a point in time and to express this value in monetary terms'. This appears relatively straightforward as a definition, but it is far from straightforward in practice. Again, assumptions and judgements play a big part in quantifying the figures. The following represents a short review (following Hulme 2009: 117–119) of the main elements in arriving at the SCC, but they do not do justice to the complexity of the issues. For a fuller review of these elements see Stern (2010).

The damage costs

Some costs of climate change are relatively easy to estimate as there already exist ways of expressing them in monetary terms. Thus one can work out by country or region the costs to agriculture, or even benefits in some northern latitudes, of a particular temperature rise. The aggregation across the world of these individual country/region costs and benefits can then easily be worked out for agriculture. The same exercise can be done for other sectors of the economy. The overall sum will represent the net cost aggregated across the sectors of the economy which are analysed and across the world.

Much more difficult – and we have been here before – is converting into money the damage costs that don't normally have a market value. For example, how does one value the trauma associated with losing your home and means of livelihood because of rising sea levels, or with flooding from excessive rainfall? How does one value the amenity loss associated with climate-related biodiversity changes? How does one aggregate these kinds of cost across locations – a species loss in one country might be an addition to another country, for instance? On a different scale, how might one value the damage done by a far-reaching, but relatively unlikely, abrupt climate change event? On this last, Hulme (ibid.) gives the hypothetical example of an irreversible change of the South Asian monsoon. A North European example would be an irreversible change in the gulf stream of the Atlantic Ocean which keeps the continent's North-Western countries temperate.

Adaptation

We should not assume that people and groups of people are passive in the face of climate change. Some damages will possibly be offset by local adaptation – for example a community of farmers in Sub-Saharan Africa selectively breeding drought resistant strains of their staple crop. As already noted, adaptation can be reactive or proactive, although these two dimensions are not easily separated in many circumstances. Is building a home on stilts in Bangladesh – which is an increasing practice – a reaction to past floods or a proactive measure against future floods? The answer is probably both. Adaptation can be from *within* individuals, organisations, businesses, communities and so on, but also of course it can be the result of top-down intervention from *above*, such as the Government. The latter type of intervention tends to comprise larger scale projects with their own high costs, and they invariably will have been the subject of separate cost-benefit analyses. Examples include flood defences, such as the Thames barrier in London, or agricultural research in East Africa.

We should also beware of treating adaptation as a kind of 'black box' where the broad challenges face everywhere in the world, even if the particular circumstances of adaptive practices differ. There are enormous differences between rich 'developed' countries and poorer 'developing' countries. For the latter, many adaptations will appear extreme compared with those in the former. Quoting Archbishop Desmond Tutu, Stern (2010: 68) for example compares climate-induced migration of families in poor countries with providing more air conditioning in a rich country. Both might be termed adaptation, but for poor countries this is an issue of development whereas in the rich country example it is adaptation to deal with an inconvenience.

Stern (ibid.) goes on to state that, in a poor country context, instead of adaptation he prefers to refer to the 'greater costs of development in a more hostile climate'. He quotes the United Nations Human Development Report (2007–2008) which argues that the extra costs of development as a result of climate change are $86billion per annum. Of this sum, $44billion is required to make development investments more resilient to climate change, $40 billion for strengthening poverty reduction strategies to compensate for the increased difficulties poor people will face in their everyday lives, and $2billion for additional disaster relief (ibid: 69–70).

Poorer countries might be located in areas where climate-induced changes are likely to be extreme – such as low-lying islands in the Pacific Ocean – and hence extreme adaptive responses such as migration are appropriate. A major factor, however, is the low capacity of these countries to take (especially proactive) adaptive measures from above, precisely because they are poor, and they lack the technological know-how.

The equity weighting factor

The discussion of adaptation in different parts of the world leads to a more general consideration of how we value the costs incurred by different groups of people, those who are poorer or richer than ourselves. This is where the equity weighting factor enters the calculation and, as previously noted, the Stern Review paid considerable attention to these issues.

Stern (2010: 4, 13, 28, 31 56, 57, 174) makes the following points to argue for rich countries seriously taking on board the climate-related impacts on poorer countries:

1) As stated above, these countries will be hit earliest and hardest by climate change, and they also have less capacity to adapt, at least institutionally. Stern refers repeatedly to vulnerable locations which are associated with poor countries – melting Andes and Himalayan glaciers, rising sea levels, hurricanes, ferocious storms, droughts.

2) This is a matter of ethics and associated rights – poorer people have equal rights as do richer people to human welfare.

3) It is also a matter of justice. Through their past industrialisation the rich countries have been historically responsible for the climate changes we are starting to witness.

4) Nevertheless, developing countries constitute the future major emitters through exercising their right to development and their growing populations. Because of its large population and rapid development, China is now the world's largest greenhouse gas emitter, having displaced the United States to second place, and the gap between the two countries is growing (Scientific American, 3rd February 2012). We have to face the fact that development requires energy, and the world's useful energy is mostly obtained through burning fossil fuels. China is particularly dependent on its coal reserves and increasingly has to import oil and gas (Gallagher 2009: 13–23). The poorer, developing countries have to be part of any deal to cut back on emissions.

5) Poorer countries will be the main sites of permanent displacement of millions, possibly billions, of people – or climate refugees. Displacement even on relatively small scales is a source of conflict and insecurity between migrating and receiving populations. On a large scale, human displacement induced by climate change is likely to affect world security.

For people in richer countries, 'equity weighting' might be partly a matter of ethical principles around rights, equity and justice. In large part, however, it is also a matter of self-interest as points 4 and 5 above imply. Nevertheless, all of the above points illustrate the argument that climate change and development are not separate issues, but are inextricably linked (Stern 2010: 89).

Stern (ibid.), himself, does not use the term 'equity weighting factor' (the term is from Hulme, 2009), but he makes it clear in his analysis that an important dimension of mitigation activity will involve resource transfers to the developing world. I reported above Stern's (2010: 68–71) support for the UNDP call for an extra $86 billion per annum in aid to cover the overall extra cost of development as a result of climate change. His 'key elements' of a global deal (ibid: 146–149; 178–179) include public money (less, however, than $86 billion per annum) to be provided by rich countries to developing countries to cover the extra costs arising from climate change (see below).

Discounting the future

In contrast to 'equity weighting', discounting the future is a standard feature of CBA where net benefits (or costs) extend some way into the future. In a straightforward investment CBA, such as a road or bridge, the future returns on investment are *discounted* to a 'net present value' (NPV). The *time discount rate* is expressed as a percentage, meaning the proportion by which the net future benefits decline in present value year on year. Thus, to give an illustrative example, a time discount rate of 5% will mean that a net benefit of one million Euros in year 15 of the project will have a net present value of about half a million Euros. This is because it decreases by 5% each year working back to the present in what is essentially the reverse of a compound interest calculation. If however the time discount rate is only 2%, the NPV of one million Euros in year 15 will be approximately 760,000 Euros, while if it is 10% it will be approximately 240,000 Euros. In sum, the higher the discount rate the lower the NPV of the net benefit accrued over time.

A very pragmatic approach is taken to assign the time discount rate for a conventional investment project. The reasoning is as follows: the highest risks of the investment will be in the present and these risks will diminish over time. Therefore the present returns on the investment should be weighted higher than the returns in the lower risk environment of the future. This is analogous to deposits of personal savings. The 'safer' (i.e. the lower risk) deposit in a trusted bank account attracts a lower rate of interest than a deposit in something riskier (e.g. share dealing). In fact, practically, discount rates are chosen in line with the rate of return that might be obtained by investing the money elsewhere, in another project, for example, The Stern Review effectively rejected this justification for discounting future returns in the context of the net benefits of climate change, arguing that it is tantamount to valuing the welfare of future generations less than our own. This is an issue of *inter-generational* equity, as enshrined in the oft-quoted definition of sustainable development of the United Nations World Commission on Sustainable Development in 1987 (WCED). Also known as the Brundtland Commission after the Norwegian Prime Minister who chaired it, the definition states that sustainable development is ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ (Brundtland 1987: 43).

Followed to this argument’s logical conclusion, the Stern Review should have assigned a value of zero to the time discount rate. In fact it chose a tiny, but measurable, value of 0.1%. Following our example above, the NPV of a net benefit of one million Euros in year 15 would then be approximately 986,000 Euros. The Review justified this slight increase on zero on the very tiny risk that future generations might not exist to experience the benefits – such as if a meteorite collided with the planet and destroyed all life (Stern 2010: 83).

There is, however, a further argument for discounting the future, which the Stern Review did accept in its essence. This is that future generations may be wealthier than the present generation, and will attach less significance to an extra dollar than we do today (as an aside, this argument also applies to the significance of an extra dollar to richer and poorer people in the present). Stern (2010: 81) refers to this as the ‘diminishing marginal utility of income’. To give it a discount rate value, the Review chose the assumed annual rise of global GDP with which we began this enquiry above: 1.3%. A simple aggregation with the time discount rate then provides the overall discount rate as used by the Stern Review:

$$1.3\% + 0.1\% = 1.4\%$$

To take our illustrative example again, a discount rate of 1.4% turns a one million Euros net benefit in year 15 into a NPV of approximately 823,000 Euros.

Some of the fiercest challenges from other economists have been over the Stern Review’s choice of discount rate, because it affects greatly the overall calculation of the social cost of carbon. As usual the challenges come from both radicals and conservatives.

The radical challenges are essentially critiques of the use of GDP to measure human welfare and I dealt with these above (and I will return to them again in Section 3.5). Although not directly aimed at the Stern Review (it in fact pre-dates it) a further radical challenge is more conventional in that it advocates the relative benefits of investing elsewhere – such as in fighting malaria, HIV/AIDS and more generally, poverty. I also referred to this issue above, using the concept of opportunity costs. Thus, Pearce (2003) argues that a low discount rate might result in a ‘sacrifice of resources today… at the expense of transfers to poor people today. If so, the poor today may bear sacrifices in the form of foregone benefits in order to benefit their rich descendants’. Stern (2010: 89–90) is somewhat dismissive of this line of argument, stating that a) it is wrong to separate climate and development in this way (see above); b) even in narrow economic terms Stern’s own analysis reveals a net benefit from climate change mitigation so it makes no sense to forego it; c) the challenges cannot be simply treated as alternative public investment choices.

Conservative critiques have challenged Stern more on his own ground, and particularly his precise figure of 1.4% for the discount rate, which is felt to be too low – i.e. it values future generations too highly relative to the present. Hulme (2009: 126) for example states that the conventional range is 3%-6%. Thus, Nordhaus (cited in Hulme 2009: 127–128; and in Stern 2010: 91–92; 150) argues that we should give much more weight to the value of a dollar (or Euro or pound, etc.) in the present than in a richer future. Empirically, he claims that the ways in which we act and the decisions we make today reveal that we simply *do not* value the welfare of future generations as much as our own.

Therefore we should adopt a higher discount rate. The contrast between Nordhaus' position and that of Stern then translates into quite different broad policy preferences. Stern's choice of a low overall discount rate ultimately translates into a policy for immediate action to protect future generations, while Nordhaus prefers a 'slow policy ramp' involving weak action (and relatively low costs) now followed later by stronger action as technological options and climate change damage are explored more closely (Stern, 2010: 91–92; 150)). In other words, Nordhaus prefers displacing substantial costs of action to the future in order not to place too great a burden on the present generation. Stern (ibid.) counter-argues that this would mean allowing CO2e concentrations in the atmosphere to rise to 650ppm or even 700ppm. Such concentrations would trigger a high risk of a 4ºC temperature rise which would be 'extremely dangerous territory from which it would be very difficult to extricate ourselves'. Elsewhere, Stern (ibid: 87) warns that neglect of the climate change problem by the current generation could make future generations poorer than the present, which would imply a negative discount rate where the net benefit of a dollar in the future would have a higher NPV.

Uncertainty and risk

At several points in the preceding discussion I have referred to the possibility or probability (I have also used the word 'likelihood' in similar vein) of a climate-related occurrence and also its possible/probable/likely impact. These and similar words take us into the realm of uncertainty – where we have some idea of possible outcomes but are unable to put a number on probability (Stern 2010: 18) – and risk. This is the cross-cutting context of climate change, a context which makes definitive statements well-nigh impossible and which is the source of much of the debate about economic assumptions and the numbers that flow from these assumptions.

At its simplest, Hulme (2009: 181) describes the risk of an event as the function of the probability of its occurrence and the magnitude of its impact. Stern (2010: 95) asserts that the more conservative economic analyses have ultimately got it wrong because they fail to take into account the scale of the risks (on both probability of occurrence and magnitude): 'Behind all the technical complexities of the [conservative] modelling were two simple assumptions: first that the risks are small; and second, that benefits in the far future matter very little.'

I do not have the space here to enter into the discussion in detail but it is worthwhile referring briefly to a related concept often invoked in environmental debates, the *precautionary principle*. In the words of Hulme (2009: 123–124), the precautionary principle states that 'if an action *might* cause severe or irreversible harm then, in the absence of a scientific consensus that harm would *not* ensue, the burden of proof falls on those who would advocate taking the action'. In the context of climate change, this would refer to action which allows greenhouse gas emissions to continue to rise. Hulme (ibid.) sums up the precautionary principle in the British aphorism, 'It's better to be safe than sorry.'

Clearly in this formulation, the precautionary principle places great emphasis on the magnitude of the impact of an event, such as climate change, basically stating that a high magnitude effectively trumps considerations of the probability of the event occurring. Application of the precautionary principle has become a statutory requirement in the Law of the European Union. In relation to the environment, the European Commission issued the following Communication in 2000: 'Union policy on the environment shall aim at a high level of protection taking into account the diversity of situations in the various regions of the Union. It shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay.'

Application of the Principle can be 'strong' or 'weak'. The former requires immediate regulation even if the evidence is weak and the costs of regulation are high. Weak application allows significantly more discretion – it allows measures to be taken without requiring them. The 'taking into account the diversity of situations in the various regions of the Union' in the above Communication can be viewed as endorsing a weak application.

Returning to climate change, application of the precautionary principle informs many of the radical critiques of the Stern Review, and of the notion that we should perform any kind of economic valuation of benefits and costs in relation to it.

The social cost of carbon and the costs of inaction

The start of this sub-section quoted Hulme in defining the social cost of carbon (SCC) as the worldwide incremental damage that would be caused by emitting one tonne of carbon dioxide (or the equivalent of other greenhouse gases) at a point in time and to express this value in monetary terms. Examining the above dimensions of the SCC, or variations of them, enabled the Stern Review to arrive at a SCC of $310 per tonne of carbon, which can be expressed alternatively as $84 per tonne of CO2e[34]. This is somewhat higher than most analyses, again reflecting the arguments over the different dimensions that I have outlined above. Hulme (2009: 130), for example, quotes a range from other economists of between $40 and $120/tC.

The Stern Review's estimate of the SCC at $310/tC in turn translated into a cost of *inaction* of 5–20% of global GDP per annum. The Review cautioned, however, against an over-literal interpretation of the results because of the background assumptions and judgements that had gone into the calculation. Nevertheless, it made clear that the economic risks of a 'business as usual approach' to climate change are very large (Stern 2010: 94). Of course, the conservative analyses put this cost much lower, with Hulme (2009: 127) citing Nordhaus who puts the annual cost of inaction at 0.5–2% of GDP, a full order of magnitude lower than that of the Stern Review.

In his later book, Stern (2010: 94) states that he now thinks the Stern Review led to an under-estimation of the costs of inaction: 'Current evidence is now showing that the Review was too cautious on the growth of emissions, on the deteriorating absorptive capacity of the planet, and on the pace and severity of the impacts of climate change.'

3.4.4 From the costs of inaction to the costs of action: technologies, policies and action to mitigate climate change

I stated in Section 3.4.1 that the mitigation target of the Stern Review was to stabilise CO_2e concentrations in the atmosphere at between 450 and 550ppm. In his later book (Stern 2010), and based on unfolding scientific evidence, Stern felt that the upper limit should be reduced to 500ppm CO_2e. He also expressed a desire for a long-term reduction to below 400ppm CO_2e, somewhat less than the present concentration of 430ppm CO_2e.

This sub-section seeks answers to the following questions:

- How does Stern envisage such stabilisation being achieved, at what cost, and who pays?
- How does the cost of mitigation compare with the cost of inaction? If the costs of the former are less than the latter then, through utilitarian economic eyes, the action is worth it. Conversely, if the costs of mitigation are more than the costs of inaction, it is not worthwhile taking action and we just have to muddle through.

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[34] The calculation is to divide the figure for carbon by 3.7 to arrive at the figure for CO2e. This represents the ratio of the relative molecular masses of carbon (12) and carbon dioxide (44).

Achieving stabilisation in atmospheric CO_2 concentrations: technologies

The Stern Review and his later book (Stern 2010, 41–48) assume continuing world economic growth and hence increasing world energy demand, especially in China. In other words, there is no challenge to the fundamental capitalist growth path for the world economy. The main reason why the Stern Review has attracted so much international attention is that it indicated that the global economy, and hence the world as we know it, would suffer if urgent action is not taken to mitigate climate change.

The proposals to meet the target are therefore, and unsurprisingly, mainly technological, where the costs of mitigation concern the transition to the better/newer technologies and achieving the conditions necessary for the whole world to join in. Nowhere in his analysis is a suggestion that we should consume less.

If the problem of climate change has, for many, been seen in terms of problems of the dominant model of the global economy and of its associated technology, in Stern's scenario they are viewed as part of the solution. The technological possibilities fall into the following main groups:

- *Energy savings through efficiency measures*. Improved insulation in buildings, energy-saving light bulbs, more efficient engines in road and air transport , etc. are examples of technological measures in this group. These efficiency gains concern energy savings in consumer use.
- *Low- or zero-carbon forms of useful energy generation*. Technologies which are already available and are either already in use on a major commercial scale or as substantial pilots include:

a) Nuclear energy, even when the economics are based on the lifecycle costs which include decommissioning

b) Wind power, both onshore and offshore, where Germany, China, India and the United States have made great inroads in recent years.

c) Coal or gas or biomass with 'carbon capture and storage' (CCS) which involves capture of CO_2 from the atmosphere and its storage underground.

d) Hydro-electric, which is popular in Brazil and some Scandinavian countries.

e) Solar energy, including electricity generation from photovoltaics.

f) Geothermal energy in, for example, Iceland.

- *Low carbon transport*, which includes:

a) Hybrid cars which switch automatically back and forth between conventional petrol and battery-electric engines, and which use every opportunity to re-charge the battery automatically while the car is moving.

b) All-electric vehicles, where breakthroughs are still required in battery technology

c) Alternative fuels with a strong power-to- weight ratio, especially in aviation. According to Stern (2010: 46), biofuels are the most promising in this regard, and they could reduce flight-related greenhouse gas emissions by 60–80%.

Some of these technologies are already competitive, depending on the price of oil. All become much more competitive if a price is placed on greenhouse gas emissions (see below). The costs are mainly those associated with a transition to a continuing growth economy which is low/zero-carbon in terms of its greenhouse gas emissions. In other words, for Stern (ibid: 47) the costs are those associated with a 'wave of innovation'.

A further positive aspect of developing and deploying these technologies concerns the problems into the future of securing energy supplies which are based on fossil fuels, and avoiding therefore the international disputes which already arise with respect to oil. According to Sachs and Santarius (2007: 88–89), the level of maximum oil output (referred to as 'peak oil') is likely to be reached before 2015 as old reserves dry up and new ones are not opened sufficiently quickly to keep pace. Unsurprisingly this date is disputed, with the International Energy Authority stating that peak oil is unlikely to be reached before 2030 (quoted in Giddens 2009: 39). Whichever of these figures is chosen, however, we shall witness a growing problem of energy security which will translate into problems of national, political security.

In should also be noted that most of the above technologies have their own social costs. Those of nuclear power have been well documented. They include the risks of radiation escape from accidents, and developing nuclear weapons. The problems of large-scale hydro-electric schemes associated with 'big dams' are also well-known, especially their displacement of many people (see Box 3.7 above). Wind farms experience local opposition on the grounds of visual intrusion and noise. The first generation of biofuels ran into controversy because they required good land which could be used for food. Stern (2010: 46) notes, however, that a second generation of biofuels, which can be produced from waste products or on marginal land, has strong potential

Meeting the cost of mitigation (1): putting a price on carbon

For Stern, public policies are needed to engineer the necessary transition to a continuing growth but low/zero-carbon economy. His favoured policy to correct the 'market failure' of greenhouse gas emissions is to establish market incentives for low/zero-carbon innovation alongside penalties for failing to do so. He thus maintains the ultimate faith of neoclassical economics that markets drive innovation:

> 'If public actions and policies give the right signals and rewards for cutting greenhouse gases, then markets and entrepreneurship will drive the response. The bulk of the action will be in the private sector – this is not about a return to government control and rigid planning: on the contrary it is about enabling markets and private-sector initiative to work well.'
>
> *(Stern 2010: 99).*

For Stern and his neoclassical approach, establishing a price on greenhouse gas emissions (the 'price of carbon') has to be at the heart of policy for two reasons. Firstly it provides incentives for consumers and producers to reduce emissions. Secondly, it provides incentives to keep the cost of action to reduce emissions low, which in principle means that many possible actions will be explored with the cheapest being selected. The price will influence to a large extent the trading schemes and technology options that are developed. More colloquially this is known as the 'polluter pays' principle.

This is an abstract formulation, when of course markets are not perfect arbiters of efficiency. Much depends on selection of the 'right' price of carbon, which should be the same everywhere. The obvious initial choice would be to base it on the social cost of carbon (SCC) as discussed above. Stern, who uses the equivalent term *the marginal social cost (MSC)* of greenhouse gas emissions in chapter 6 of his book, rejects this approach, however, on the grounds of the contested assumptions and judgements that go into the figure, grounds of which we are well aware from the discussion so far. His alternative method of establishing the price is to identify the appropriate targets and then establish the *marginal cost of abatement* (i.e. the cost of reduction of one additional tonne of greenhouse gas emissions at the target figure). For Stern, to achieve a 500ppm CO_2e atmospheric concentration target requires cuts in greenhouse emissions of 30Gigatonnes per annum by 2030. The price of carbon can be then based on an analysis such as that provided by international management consultants McKinsey which Stern uses in an earlier chapter of his book (ibid: 52). This suggests that the marginal cost of abatement at that level is \$26–33 per tonne of CO_2e. Stern rounds up this figure to around \$52 per tonne of CO_2e.

Stern (ibid: 102–107) goes on to identify three broad policy instruments for achieving a price for carbon of this order. All three of course require measurement of the CO2e emissions. They are:

- Taxes, especially on the use of carbon sources such as fossil fuels, where the emissions can easily be predicted. The drawback is that taxes are difficult to coordinate internationally. They also often lack legitimacy among citizens, who are prone to see them as 'stealth taxes' – i.e. ways of increasing general government revenue without being honest about them.
- 'Carbon trading' where the government (or governments acting together) sets the overall limit on greenhouse gas emissions and divides this into a fixed number of emission permits which it allocates initially. A private company, for example, cannot then break the limit on emissions that is set by its allocation, but it can increase its allocation by buying from another company. Thus, the permits can be traded between companies. They can also be traded at a grander scale between regions, for example between the Global North and Global South. The market for emissions trading sets the price according to supply of and demand for the permits. The instrument therefore provides certainty on the total quantity of emissions because this is set by government or governments, but uncertainty on price which is determined by trading and likely to fluctuate. There are many intricacies to this basic model. The original European Union Emissions Trading Scheme, for example, allocated the permits almost entirely free of charge but there was an over-allocation which resulted in the market price established through trading being too low. For this reason, Stern (ibid: 108) argues for not having free allocations of permits, but to auction them. Further issues concern: scaling up to an international deal, consistency to allow for trading between regions and for bringing the poorer countries of the Global South into the system. The Kyoto Protocol is, of course, an example of a deal, where international carbon trading is central (see Box 3.6 above and, for further elaboration see Chapter 4 of this module)).
- Regulations and technical requirements embodied in standards which can require more costly processes and equipment. The experience of the car industry and catalytic converters to meet standards against creating smog, and of unleaded petrol to meet standards on lead emissions, illustrate what can be done. A key to success seems to be industry knowledge that the standards are likely to be global and long-term.

Most countries and regions will use a combination of these instruments, with the exact composition of the mix varying. The European Union, for example, already has strong taxes on petrol, as mentioned above an Emissions Trading Scheme (EU ETS), and some tight regulations on equipment (ibid: 105). An 'equity' downside of establishing a price on greenhouse gas emissions, however, is that the costs will be passed to consumers, hitting poorer societal groups disproportionately in relation to their income. Nevertheless, Stern (ibid: 107) maintains that appropriate transfers can be made to the poor from carbon taxes and other instruments.

Meeting the costs of mitigation (2): publicly funded intervention to promote technology

Stern (Ibid: 111–115) argues that this be a policy in recognition that pricing of, and markets for, carbon will contain many imperfections. Although he terms policy to promote technology as government assistance for markets to work well, it is actually a directed intervention. In particular, he argues for government support in:

- Research and development (R&D) of low-carbon technologies, basically because patent protection of new ideas is inadequate. Anyone can gain from new ideas, essentially for free. There are therefore disincentives for people to develop their ideas. Stern thus laments global downward trends in both public and private R&D on energy, which should be reversed 'as an urgent priority'.

- Deployment of low-carbon technologies. If protection of new ideas can be inadequate, even more inadequate is protection of experience of deployment by early adopters of new technologies. Setting tariffs, which essentially fix the price of electricity from certain (e.g. low/zero-carbon) sources, have apparently worked well in Germany, Spain, Portugal and Austria, expanding the deployment of renewable energy sources. Removing or at least loosening ‘red tape’ can also encourage early deployment.

Meeting the costs of mitigation (3): publicly funded transfers to the South

Although not specified by Stern as such, a further technology policy is embodied in his recognition of the need for transfers to the South. Such a policy is not only about making the technologies in the form of hardware (machines, equipment, useful energy generation infrastructure) available for poorer countries, but additionally to develop their capabilities to produce and use them, adapt them to local contexts, and where appropriate develop their own technologies.

Also recognised by Stern, without having a specific policy for it, is the need for strong initiatives with public funding to halt deforestation (ibid: 147). Land-use change accounts for 18% of global greenhouse gas emissions according to the World Resources Institute, most of which is deforestation (and hence loss of CO_2 absorptive capacity) and peat burning (ibid: 42).

Meeting the costs of mitigation (4): funding and funding sources

One reason why Stern believes that climate change mitigation cannot be treated as a straightforward investment project requiring a standard CBA is that the costs will not simply be met out of an allocated budget of, say, a government department. Rather, the funding sources will be more widely spread throughout society and therefore in many ways will appear more diffuse. It is easy to identify, however, two broad funding sources from the discussion above:

The private sector and consumers. Making the private sector pay for its greenhouse gas emissions through one or more of the instruments for carbon pricing discussed above will partly be absorbed by firms, being seen as investment costs in the innovations required to lower their emissions. In great part, however, as also mentioned above, these costs will be passed onto citizen consumers in the form of higher prices.

Public funding. These sources will be from more than one government department, for example, for funding , international development transfers and public R&D. Of course, ultimately these public funding sources derive principally from taxation, and hence the individual citizen.

Stern (2010: 178) estimates that the following additional public funding per annum by rich countries will be required during the next decade:

- $15 billion to cut deforestation by half
- $40 billion for public energy R&D. This represents an increase from the current annual global figure of $10 billion to $50 billion. Part of this sum is for national R&D and part is a contribution to promoting R&D internationally.
- Approximately $75 billion in aid to pay for the extra costs of development arising from climate change in developing countries. This assistance will be contingent on developing countries agreeing to targets to reduce their greenhouse gas emissions.

The total global cost of mitigation compared with the cost of inaction

Described by Stern (ibid: 48) as ‘reasonable estimates’, the combination of costs borne by the private sector and consumers through carbon pricing, plus the costs identified above from the public purse, amount to:

- 1% of global GDP for the Stern Review upper CO2e atmospheric concentration limit of 550ppm
- 2% of global GDP for the revised upper CO2e atmospheric concentration limit of 500ppm which is contained in his 2010 book.

This compares with the costs of inaction – or doing nothing to mitigate climate change – of 5%-20% of global GDP per annum (see above). There is therefore a clear net benefit of taking immediate action to limit atmospheric concentrations of greenhouse gases to Stern's currently preferred upper limit of 500ppm. The reader should note, however, the constant challenge to Stern's estimates of costs of inaction from both conservatives and radicals. I have recorded many of the conservative challenges above which estimate the costs of inaction to be much lower than Stern, and in some cases they wipe out the net benefit of taking action. Stern, of course, has in turn counter-challenged, also recorded above.

I have devoted less space above, however, to the radical challenges to Stern. These are more deep-seated in that they question his underlying assumptions, even his ideology. The next section examines the radicals a little more thoroughly.

3.5 Alternative economic models and the radical critique

As previously indicated, alternative economic models usually challenge fundamentally the dominant neoclassical model. Beyond this commonality, however, there are several kinds of 'alternative'. Some of these – such as Marxian and institutional economics – represent in themselves generalised bodies of knowledge which might provide further insights into the economics of climate change. They do not, however, necessarily challenge notions of economic growth. They are also concerned with markets, property rights and innovation, but subject these core concepts to a much greater critical interrogation.

A body of knowledge has also evolved around 'ecological economics' which, at first sight, appears to offer a more directed approach to the economics of climate change. Ecological economists seek to consider the full range of environmental goods and services and the interdependence of the economy with natural ecosystems. To a large extent they are also concerned about 'justice' for both current and future generations.

Below, firstly I discuss briefly the potential relevance of Marxian and institutional economics to climate change. Then, I spend a little longer examining one model which broadly equates with ecological economics – the 'Contract and Converge' model. None of these sub-sections, however, pretend to be more than very preliminary tasters of their respective topics, and undoubtedly fail to do full justice to them. I introduce them to you to illustrate that counter-economics exist and perhaps whet your appetites to delve more deeply.

3.5.1 Marxian economics and climate change

As the name suggests, Marxian economics originated in the works of the German philosopher Karl Marx, especially his magnum opus *Das Kapital*. First published in 1867, this work was sub-titled 'A critique of political economy' which provides the clue to the substance of Marxian economics as an alternative to the classical and neoclassical economics embedded in the works of an earlier generation of British economists, among them Adam Smith, Thomas Malthus and David Ricardo (Box 3.10).

Box 3.10 Smith, Ricardo, Malthus and the critique of Marx

Adam Smith (1723–1790) is widely regarded as the person who first formulated modern economics through his work 'An inquiry into the nature and causes of the wealth of nations' (Smith 1776/1976) which is usually abbreviated as 'The wealth of nations'. He is often quoted for the concept (adapted from astronomy), 'the invisible hand' [of the market] guiding our private interests. He also claimed that following our private interests brings broader societal benefits, as in his dictum:

'It is not from the benevolence of the butcher, the brewer, or the baker, that we expect our dinner, but from their regard to their own interest. We address ourselves, not to their humanity but to their self-love, and never talk to them of our own necessities but of their advantages.'

(Adapted from Wikipedia: http://en.wikipedia.org/wiki/Adam_Smith – accessed 27 October 2010).

David Ricardo (1772–1823) systematised economics and is best known for his theory of 'comparative advantage' to bring mutual benefits through trade. In a simplified, stylised form comparative advantage states that if:

1. Countries A and B both manufacture aeroplanes and cars;

2. Country A is more efficient than country B in doing both;

3. Country B manufactures cars more efficiently than it manufactures aeroplanes.

4. Country A manufactures aeroplanes more efficiently than it manufactures cars,

Then, despite being more efficient than country B in both aeroplane and car manufacture, country A should concentrate on manufacturing and trading with country B in aeroplanes, while country B should concentrate on manufacturing and trading with country A in cars. This will be in the best interests of both countries.

Thomas Malthus (1766–1834) is most famous for his argument about population growth which he said would exceed the capacity of humankind to produce the necessities required to feed it (Kaplinsky 2009: 152). Contemporary Malthusians claim that the fundamental issue for saving the planet from environmental destruction (including climate change) is to limit population growth. He and his subsequent followers are often criticised on the grounds that the argument has not so far been supported by history, as people have innovated and become more productive.

Karl Marx (1818–1883) provided a critique of Malthus, accusing him of blaming poverty on nature rather than the injustice of the capitalist system. Mostly, however, he critiqued the 'political economy' of Smith and Ricardo. Marx's argument in Das Kapital ran as follows:

1. Smith's greater good of society which arises out acting in one's private interests, and Ricardo's theory of comparative advantage being for the mutual good, assume eventual full employment where 'all producers have a role to play, a product to produce which someone else wants and can afford to buy' (Kaplinsky 2009: 152).

2. This assumption does not hold. Technical progress is inherent to the capitalist production system and that, contrary to Smith and Ricardo, it is inherently labour-saving, leading to surplus (which Marx termed 'a reserve army of') labour. Thus the capitalist system has an inherent tendency towards unemployment and low wages.

A particular concern of Marxian economics is the social relations of production which Marx originally argued are mostly ignored by the neoclassical economists with their over-riding interest in markets for commodities. Although capitalism can be distinguished from coercive labour relations, such as slavery and feudalism, because it establishes a market for labour, an exploitative social relation still exists between those who own capital and those who sell their labour power to turn capital into profits for the owner. This relation is embedded in Marx's concept of surplus value as the difference between the value of a worker's labour power that goes into making a commodity and the value at which it sells in the market (i.e. its exchange value), which is a creative value added by the worker. Put colloquially, profits derive from the unpaid (creative) labour of the worker.

This basic critique by Marx of the early neoclassical economists and those who followed them can today also be applied to question a crucial assumption in the Stern prescription for mitigating climate change. It is worthwhile here quoting again Stern's comments about the key to mitigation being establishing a market for carbon:

> 'If public actions and policies give the right signals and rewards for cutting greenhouse gases, then markets and entrepreneurship will drive the response. The bulk of the action will be in the private sector – this is not about a return to government control and rigid planning: on the contrary it is about enabling markets and private-sector initiative to work well.'
>
> *(Stern 2010: 99).*

This, and subsequent words of Stern, say nothing about what might happen to employees during the period of transition while 'markets and entrepreneurship' are doing their job, and hence are open to a similar critique to that made of the early neoclassical economists. A Marxian economics will thus surely point to the relations of production to create an argument about who will bear the costs of this transition. These will not only be consumers and not primarily those who own the capital. Costs of production will be passed onto employees in the form of redundancies, changes in working patterns and pressure to be yet more productive in order to recoup the investment on low/zero-carbon technologies. Moreover, while in Marx's day the employees were the working class who created value with their hands, the last decades of the 20th century to the present have seen increasing anxiety about job security among the professional classes as they strive to make and exceed targets of productivity (Kaplinsky 2009: 152–153).

3.5.2 Institutional Economics

Whereas neoclassical economics abstracts markets from their social and political contexts, institutional economics argues that this is not possible and to do so misses much of the point about how markets work in practice. To illustrate the point, Karl Polanyi (1957) argued that capitalism actually necessitates commoditisation of everything, including people, so that the only thing that matters is the commodity's price in markets where everyone acts for individual gain, or to paraphrase the 19th century Irish playwright, poet and author, Oscar Wilde: to know 'the price of everything and the value of nothing'. Polanyi went on to argue that capitalism represents a struggle between pro-commoditisation and anti-commoditisation forces. He characterised the events leading to the industrial revolution in Britain as a transformation where land and labour were commoditised, having previously been embedded in social relations, institutions, beliefs and values. It was a transformation which did not take place without a struggle, involving among other things, enclosing common land and creating a large class of landless labourers who were often evicted by force, and who eventually became the industrial workforce.

This example of the commoditisation of land and labour in Britain as a precursor to the industrial revolution illustrates a basic tenet of institutional economics. It is is that markets are in fact 'made' out of a complex mix of government actions, social networks and power relations, and the institutional processes that shape behaviour. Their making often involves struggle, as the creation of a 'free' labour force, meaning free from the ties of the land, certainly did during the industrial revolution in Britain. Markets, in this view are themselves social institutions which regulate their practice in line with locally evolved 'rules', as opposed to the neoclassical view that they evolve naturally and are context-free as long as the prices are right (Bromley et al 2001: 39–49).

Institutions can be broadly defined as the behaviours and practices that relate to the overall 'rules of the game', which are enforced formally through the law or informally by expected norms of behaviour. They can be organisations (e.g. public organisations in

Europe which provide welfare services such as health for all) or established aspects of wider society which embody common values and ways of behaving (e.g. the institution of marriage) (Thomas 2009: 181). We can see here an institutional critique of the argument that Hardin's 'Tragedy of the Commons' (expounded in Section 3.2 above) requires the correcting factor of establishing private property rights to what was previously 'free'. Once you examine the 'Commons' as an institution you will find that they invariably are never 'free', but that access is regulated by (often informal) rules of behaviour to which everyone adheres. In other words, local institutional norms frame the access rights.

With respect to climate change, it is not difficult to see that institutional economists will criticise Stern for his belief that an appropriate self-regulating market for carbon can be established simply through a mix of taxation and trading schemes. This is because markets across the world vary a good deal according to their histories and current institutional contexts. Even in the rich countries, the ethos of 'free' markets is undermined by protectionist policies on many commodities, including agriculture in the European Union. Galbraith (1967) famously argued in 'The new industrial state' that international markets are often manipulated by large powerful corporations with the collusion of governments. At the other end of the scale, in rural markets in Sub-Saharan Africa and other regions of the Global South, rich farmers are able to manipulate local prices for food grains.

I end this sub-section with two contrasting examples related to climate change where institutional economists would argue that local or national institutional contexts have to be understood.

The first concerns deforestation and re-forestation of tropical forests. Much of the discussion in Stern (2010: 165–169) concerns placing a 'social value' on a forest which takes into account, for example, its value in controlling soil erosion or in absorbing carbon dioxide. For Stern, reversing deforestation then becomes a matter of creating 'incentive structures' for alternative uses. In all of this discussion, however, there is scant regard for forest dwellers whose relationship with the forest is governed by local institutional rules which cannot simply be superseded by commoditising it with a 'social value'.

The second is at a national level, and concerns the institutional arrangements for public sectors within governments. Some governments have specialist departments devoted to energy and climate change, where a mandate might be to promote transition to a low-carbon economy. Such departments nevertheless must compete with more established departments for their share of the public budget. Other governments do not have specialist departments but claim to embed climate change and energy concerns across all of their traditional sectors – education, health, finance, agriculture, industry and so on. In these situations the struggle for effective public resources to mitigate climate change is perhaps even more difficult.

While contrasting, both of these examples link the local or national to the global scale. The Clean Development Mechanism discussed in Box 3.6 is an early attempt within the international Kyoto Protocol to put a social value on forests in developing countries, while at world summits and negotiations on climate change, the public budget and how it is divided back home is an important backdrop to the bargaining positions of countries. Unilateral action on reducing greenhouse gas emissions is not an option moreover, if it is likely to reduce the competiveness internationally of the country taking such action

3.5.3 Ecological economics

For many people, ecological economics began with the publication in 1977 of Herman Daly's 'Steady State Economics' (SSE), the second edition of which was published (with updating and slight expansion) in 1991 (Daly, 1991). In this book he explored the economic system of human beings as a sub-system within a wider ecological system from which it extracts raw materials and to which it returns waste (pollution). He contrasted SSE with conventional economics, claiming that the latter treats economics as an isolated system from its wider environment, where extraction from the environment and pollution resulting from returning waste to it don't figure centrally. Questioning the sustainability of conventional economics in terms of the world's finite stock of physical resources and its continuing capacity to absorb waste, Daly defined SSE as an economy that recognises boundaries to growth. SSE is, he wrote:

> 'Constant stocks of people and artefacts measured at some chosen, sufficient level by a low rate of throughput.' (ibid: 53)

Daly elaborated on this definition in a later book, 'Beyond growth: the economics of sustainable development' (Daly, 1996: 31-44). There, he rejected the idea of indefinitely continuing growth which he defined as the increasing physical scale of the matter/energy throughput that sustains the economic activities of production and consumption of commodities. He also linked a constant level of throughput to long-term ecological sustainability 'for a population living at a standard or per capita resource use that is sufficient for a good life'.

Contemporary ecological economics has several variants, but they all tend to be influenced by Daly and SSE. Overall, ecological economics can be distinguished by its central concerns with preservation of nature (natural capital), justice, intergenerational equity and sustainable development (Faber 2008). Ecological economics also:

- Questions the assumption that, beyond a certain level, increasing per capita economic output (i.e. GDP per capita) is equated directly with human welfare.
- Tends to argue for stabilising population in order to curb absolute growth in economies.
- Rejects the notion that human capital (innovating for improved and new technologies, and substitution of say fossil fuel energy by wind energy, etc.) can forever substitute for natural capital. This rejection paves the way for calls to cut consumption by richer countries.

Ecological economics thus represents a critique of neoclassical economics. Insofar as the latter considers issues of nature, justice and intergenerational equity, they tend to be thought of as 'externalities' – where the actions of one person/group/country directly affect the prospects of another person/group/country. They need factoring in, but are not necessarily central. For ecological economics, however, these issues should not be 'external' but a core concern.

I am not sure that this critique is fair when applied to the Stern Review on the economics of climate change. Stern (2010) actually goes to great lengths to acknowledge that rich countries are responsible for past climate change while poor countries are being hit hardest. He has also made it clear that climate change is a development issue, while his choice of a time discount rate close to zero in effect is a statement of intergenerational equity and has caused much controversy.

Nevertheless, ecological economics does start from a different point and can come to somewhat different prescriptions regarding what should be done to mitigate climate change. Below is a particular manifestation of ecological economics which has made it more than a marginal concern in policy circles.

Contraction and convergence

> 'The future model of 'contraction and convergence'… combines ecology and justice. It begins with the insight that environmental space is finite, and it ends with a fair sharing of the environment by the citizens of the world.'
>
> *(Sachs and Santarius 2007: 153–154).*

Conceived by the Global Commons Institute[35], the Contraction and Convergence Framework has had some influence in the United Nations Framework Convention on Climate Change and the Intergovernmental Panel on Climate Change. One prominent proponent is Anthony Giddens (2009: 64–65). Applied to climate change, it states that rich countries should reduce their carbon emissions at a high rate initially while poor countries increase their emissions at an equivalent rate. Both the decreasing rich country emissions and the increasing poor country emissions will over time level off to the same ecologically sustainable level. Another prominent proponent of the framework is Wolfgang Sachs, who generalises it beyond climate change emissions, to contraction and convergence of resource use (Sachs and Santarius 2007: 152–153). Figure 3.2 indicates a possible contraction and convergence for energy consumption which would take place over the next eight decades. Do not read too much into the actual numbers, Figure 3.2 is reproduced primarily to show the curve shapes. Similar curve shapes would be produced if I used CO_2e emissions rather than energy consumption.

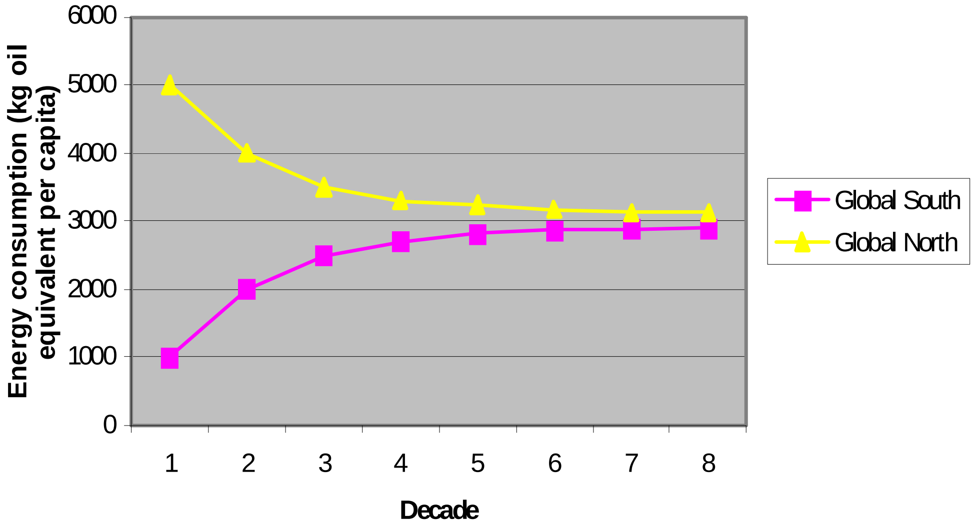

Figure 3.2 Energy contraction and covergence

Here we should note that, without using the term, Daly's original concept of SSE presaged contraction and convergence in that he advocated a distributive institution to set 'minimum and maximum limits on income and the maximum limit on wealth'. He added: 'Without some such limits, private property and the whole market economy lose their moral basis' (Daly, 1991: 53-56).

Fast-forwarding to the present, the Contraction and Convergence framework suggests policies and instruments that do not appear in the Stern Review, as well as strengthening some that do. For example:

Per capita emission rights. The basic policy is to establish and converge towards a standard per capita greenhouse gas emission right throughout the world, based on the principle that every citizen should have equal rights to the atmosphere (Sachs and Santarius 2007: 186–189). Carbon taxation is one instrument for achieving this, but more strongly used than Stern (2010) advocates. A new policy instrument, however, could comprise 'carbon rationing', whereby each member of the population would have an annual carbon allowance (equal for all adults and a lesser but equal allowance for all children) for energy use in respect of domestic consumption and travel, including air

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35 The Global Commons Institute was founded in 1990 as an independent body campaigning on climate change and fairness. It has several eminent people among its supporters and has provided evidence at the request of the United Nations Inter-governmental Panel on Climate Change in relation to the contraction and convergence model.

travel. It would be incorporated on a smart card which would be used every time domestic bills were paid or travel services used. It would be possible for individuals who have low carbon lifestyles to trade their excess allowance with those who are more profligate (Giddens 2009: 155–158).

Fair trade rather than free trade. A relatively narrow view of fair trade focuses on what is called the 'terms of trade' which comprise the relative prices of a country's exports and imports, expressed as a ratio of export prices index to import prices index. This ratio is invariably worse for poor countries, reflecting the fact that what they have to export commands a lower price than what they have to import. Fair trade then becomes a matter of ensuring greater equality in the terms of trade between countries. For Sachs and Santarius (2007: 144), however, fair trade also concerns ethically and ecologically responsible consumption by rich consumers. They state that, whatever is produced in poor countries and traded internationally, the principle is the same: '… a final higher price ensures a better income for the producer and – increasingly – a better ecological quality for the consumer. The strategy aims at breaking the disastrous tendency of profit-oriented markets to externalise as much as possible social and ecological costs: that is, to pile them on the shoulders of the weak'. A better 'ecological quality' of course includes, but is not restricted to, low/zero-carbon production of an item.

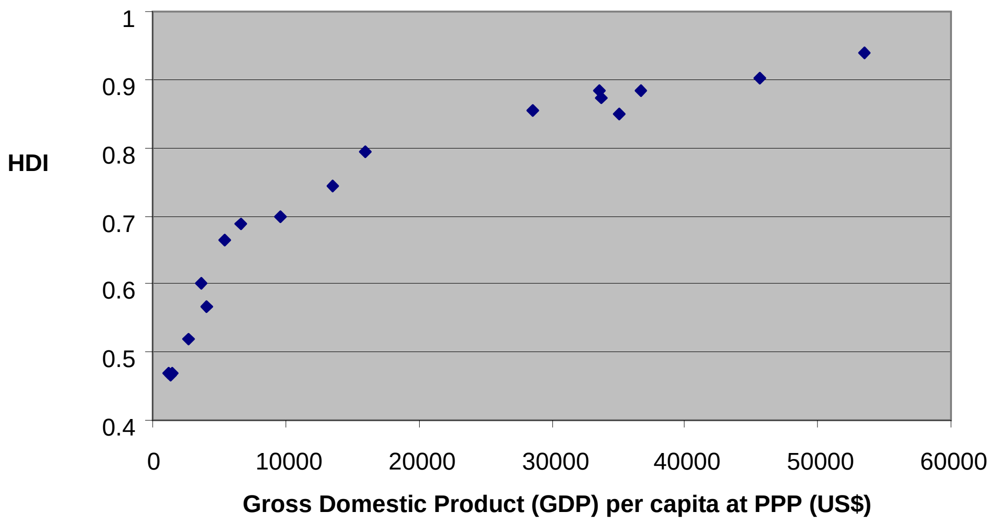
Earmarking of carbon taxes. Here, the principle is that tax revenues do not enter a general finance ministry pot to be distributed among receiving ministries. Rather, they are specifically and transparently earmarked for particular uses, for example to poorer sections of society who are bearing the brunt of carbon pricing or for ecological leapfrogging by poor countries. By 'ecological leapfrogging', Sachs and Santarius (2007: 166, 239) mean poor countries not following 'the false paths of industrial countries' for their development, and moving instead 'directly to modern renewable energies'.

The new imperative: lowering consumption in rich countries. For Sachs and Santarius. (2007), this imperative is in relation to resource use generally, in the name of justice for poor countries and sustainable development. The general argument applies equally, however, to climate change emissions, where it represents the contraction part of the Contraction and Convergence framework. It questions fundamentally the Stern (2010:99) assumption that, given the right signals, markets and entrepreneurship will drive the response. In the final analysis, the argument is that Stern is putting great faith in technological innovation in the context of continuing global economic growth, when instead we should be questioning that very model of growth if we are to achieve long-term sustainability. One powerful point here is that continuing growth will ultimately swamp any emissions/resource savings we make through deployment of new technologies. Thus, the overall signal that we are given by Stern -- that we can continue our economic growth pathway -- is highly dangerous for global warming. In the rich countries we cannot avoid having to cut emissions through lowering consumption and likewise lowering economic growth.

The difficulty of rich country contraction through lowering consumption and therefore economic growth is that, as it stands, it flies in the face of political acceptability in that it implies lowering the standard of living in these countries. Sachs and Santarius (and others) have therefore tried extremely hard to break the widely accepted meta-truth that economic growth and increasing human welfare go hand-in-hand.

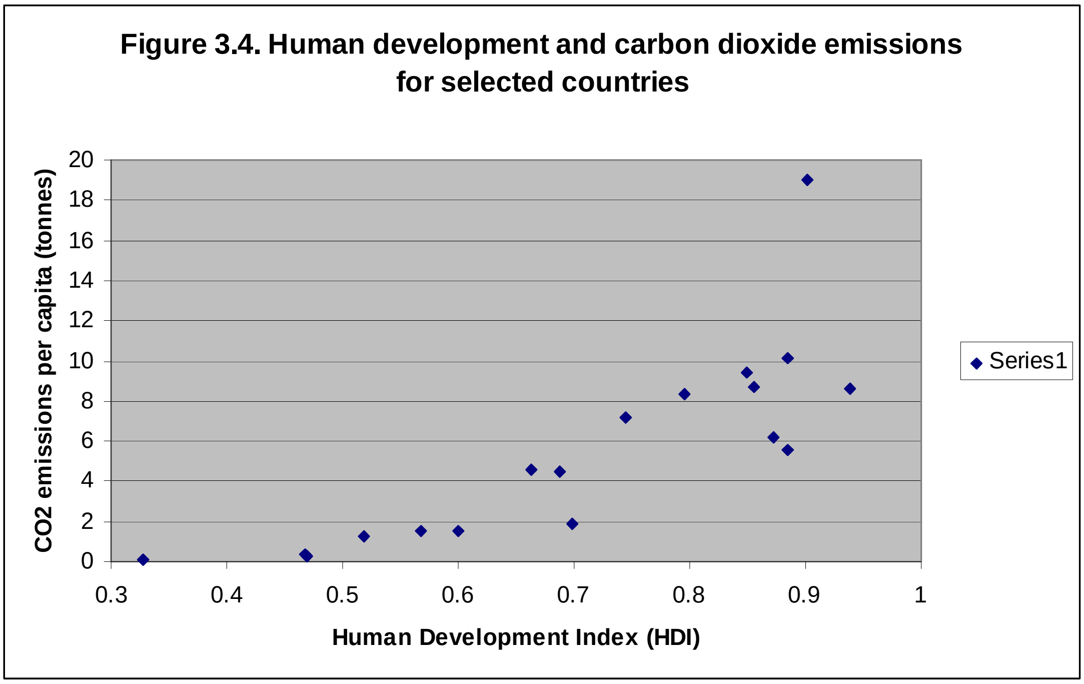
Thus Sachs and Santarius (2007: 156-158) devote a subsection of their book to the link between well-being and resource consumption, concluding that the 'quality of life has only a limited amount to do with standard of living'. Several studies have indeed shown that these links are not straightforward. For example, if we take the multi-dimensional Human Development Index (HDI – see Box 3.9 above) as a more accurate proxy for well-being/quality of life/human welfare (the terminology that is used can be confusing in its variations) and plot it against Gross Domestic Product (GDP) per capita at purchasing power parity, the result is shown in Figure 3.3. At low and medium levels, we can see that indeed HDI seems to rise significantly with increasing GDP per capita. Once an HDI of 0.8 is reached (corresponding to Poland), however, a law of diminishing returns applies and the curve flattens. For example, the GDP per capita of Norway ($53,433) is significantly greater than that of the United States ($45,592) but there is only a marginal difference between their HDIs (0.938 for Norway, 0.902 for the United States).

Figure 3.3. Economic output and human development for selected countries



Source: United *Nations Human Development Report 2010:*
http://hdr.undp.org/en/media/HDR_2010_EN_Tables.pdf *(accessed 8th November 2010). All data are for 2010.*

If, conversely, we plot human development against greenhouse gas emissions per capita, as shown in Figure 3.4, the shape of the curve is the opposite. At relatively low HDI, the corresponding emissions per capita do not change very much, but as the HDI rises to higher levels the relative per capita increases in emissions become much greater. Note however, that the trend is much more obvious in Figure 3.3 than it is in Figure 3.4. In particular the especially high emissions of the United States (19 tonnes of CO_2 per capita) distort the graph of Figure 3.4. Also, in Figure 3.4, two countries with high HDI have lower emissions than we might expect from the overall trend. These are France (HDI 0.872 and annual CO_2 emissions per capita 6.2 tonnes) and Sweden (HDI 0.885 and annual CO_2 emissions per capita 5.6 tonnes). Countries which don’t fit the general trend such as the United States, France and Sweden are called outliers to the graph. They are worthy of extra attention to discover why they don’t fit. For example, in the case of France, the relatively low carbon dioxide emissions for the country’s high HDI are almost certainly related to France’s heavy reliance on nuclear power.



Source: United Nations Human Development Report 2010:
http://hdr.undp.org/en/media/HDR_2010_EN_Tables.pdf *(accessed 8th November 2010). HDI data are for 2010.* CO_2 *emissions data are for 2006 (the latest available).*

The argument, therefore, reduces to this: richer countries can reduce their high greenhouse gas emissions through decreasing their economic output without it affecting significantly the quality of life/well-being/human welfare of their citizens. It must be said, that so far the argument has been listened to but has carried little weight with policy makers. One difficulty, which resonates with the Marxian critique of neoclassical economics, is that it pays little attention to the transition involved in the countries that are required to contract. We know, for example, that during periods of economic slowdown or recession, only a small percentage drop in GDP can mean many people losing their jobs. There is an issue, therefore, about who pays for the necessary transition, perhaps with their jobs. On this line of argument, we can also go further, and suggest that the concern of Sachs, Santarius, and others from the broad field of ecological economics, with justice and equity appears to apply mainly to North (rich country)-South (poor country) relations and ignores the unequal social relations and divisions between rich and poor *within* all countries.

3.6 Conclusion to Chapter 3: the challenges from an economics perspective

Picking up where we left off in the previous sub-section, and the discussion about the possibilities for rich country contraction of their greenhouse gas emissions (and resource consumption in general), it has to be acknowledged that individual citizens in richer countries can do much to mitigate harmful climate change through their lifestyle and consumer choices. For example, they might reduce the amount they travel and generally adopt simplified lifestyles which require less energy. Alternatively, they might try and maintain their lifestyle but are prepared to pay more for lower-energy alternatives, for example, build a low-energy home, own a hybrid car rather than a conventional car, and buy locally sourced food rather than food which has many air miles attached to it.

All of the above is significant. It does depend, however, on voluntary behaviour which runs contrary to normal expectations about lifestyle and incentives associated with economic behaviour. The stark reality is that most people will not voluntarily change their behaviour in the name of climate change without appropriate economic incentives and a reasonable assurance that their lifestyles will be maintained. ‘Voluntary simplicity’ as has been applied to some East European states (Jehlička 2009: 48–50) is significant but not sufficient.

This is why economics matters in climate change. It has a privileged role in policy-making. It sets incentives for behavioural change for both producers and consumers. It also provides warning about what is likely to happen to lifestyles if nothing is done at scale to meet the challenge.

Any deal on climate change, whether local, national or international, will be informed by the science, but ultimately will be based on some common ground of what we can afford in the present compared with the economic costs of not doing anything. As far as an international deal is concerned, finance ministers around the world will play a huge role. This is the reality and the most compelling reason for exploring ‘the dismal science’ – as the Scottish 19th century historian, Thomas Carlyle, described economics – in relation to climate change in this module.

Rather than go into the detailed calculations and an exercise in number crunching, this Chapter has critically examined the principles behind some of the concepts which are used in neoclassical economics: *market failure*, *discounting the future* and *opportunity costs* being prime examples. I have chosen these as the prime examples because they go to the heart of the neoclassical framework when used to examine the economics of climate change. Thus:

- Global warming conceptualised as market failure provides a strong conventional reason for intervening;
- Discounting the future is a key consideration because climate change, and hence its economics, stretches into the future and raises issues about the welfare of future human generations as well as about the present generation;
- Opportunity costs raise issues about choice of intervention between climate change and other pressing global problems.

From examination of the principles behind the concepts, I have explored critically the assumptions that inform the numbers that Stern and others have chosen to feed into their economic modelling. Thus, a discount rate of 1.4% or 3% matters, because the choice of one or the other affects hugely the headline figures of costs and benefits which emerge from the subsequent number crunching. Yet these numbers are a matter of judgement. The choice of discount rate is again a prime example of the background assumptions that go into the figure chosen. The Stern Review chose a time discount rate (0.1%) which was close to zero because it valued the lives of future generations as much as the lives of the current generation. This is a *normative* assumption about what is right or wrong. Others, however, have adopted a much higher time discount rate on the grounds of observed behaviour in the present which empirically does not seem to value the lives of future generations as much as those in the present. This is an *analytical* assumption concerning what is believed to be the case in practice. Thus, identifying and examining assumptions such as these is of prime importance, and it is well to note the adage as applied to computer modelling: feed garbage in and you get garbage out!

Why, however, has this Chapter concentrated on applying the neoclassical framework of economics to climate change, with only a single section to cover briefly the many other frameworks and approaches? This is a good question, but the answer has already been at least implied. Neoclassical economics has a global reach, even in China which is still under Communist Party control politically. It speaks the economic language that policy makers throughout the world understand and take notice of. Its importance in this regard should never be underestimated by anybody who is concerned with coordinated action on climate change at both national and international scales.

Academics and students have, of course, a responsibility to subject neoclassical economics to fierce critical examination, rather than simply accept it as the dominant framework for examining climate change, and much else besides. In doing this, it is also our duty to bring to wider attention the other frameworks and approaches covered in the previous sub-section, and do probably more justice to them than I have done because of my page constraints. Critique and promotion of alternatives, however, have to be grounded in a good understanding of the current dominant framework, its strengths as well as its weaknesses and, to repeat myself for emphasis, the simple empirical observation that neoclassical economics is dominant, frames the analyses of those with the power to do something about climate change, and cannot be wished away.

Many of the alternative economic approaches, generally as well as specifically in relation to climate change, stress strongly issues of justice, equity, and rights of both individuals and nations, in the present and in the future. As I have illustrated above, however, neoclassical economics does not necessarily ignore these issues either. The Stern Review certainly didn't, although the alternative approaches can legitimately question the extent of its commitment to them. The word 'commitment' has a strong normative dimension – this is what a person, a group, a country, the world *should* be doing in an ethical sense, because of values that we are all one human race (and I note that others will go further and cover all life forms). To take one example from Daly's 'Steady State Economy' he prescribes three institutions that are needed to achieve the transition to the SSE. These necessary institutions, according to Daly, respectively address:

- Distribution (and hence inequality)
- Stabilising population
- Stabilising 'the stock of physical artifacts and keeping throughputs below ecological limits'. (Daly, 1991: 53-75),

Daly (ibid: 70-75) accepts that in the short term people will not accept either the steady-state idea or these particular institutions, while claiming some political support (in the United States) for his arguments. His overall tenor, however, is to treat policy that is needed in order to create these institutions as something that follows simply from logical, economic prescription and ignores the realpolitik of interests and power which benefit from the status quo.

In contrast to Daly and other ecological economists, neoclassical economics is more comfortable with the analytical concept of *incentives*. It will therefore take on board issues of equity, justice, rights and so on if it is in one's self-interest to do so, such self-interest forming the incentive to act on these matters. Thus we return to an analytical justification in neoclassical economics rather than the normative justification that is generally found in alternative approaches. This would hardly matter if they achieve the same result, except that the former appears to have a distasteful connotation of pragmatism in contrast to the 'pure and lofty' thoughts of the latter.

Of course, I must qualify. The normative and analytical represent two extremes of a spectrum and most people combine the two. Thus Stern, in his 2010 book, did express strong normative alongside analytical preferences.

Nevertheless, many will have difficulty reconciling the neoclassical economic approach to climate change with your own normative values. There is, however, a different way of dealing with the neoclassical approach which involves being creative about how we use its ubiquitous tool – cost-benefit analysis. As a general framework, cost-benefit analysis (CBA) has evolved as a major tool for adapting neoclassical economics to a world of market imperfections and even failures, because it can be stretched to take a wide range of factors into account. These are factors on which, in other circumstances, we often do not attempt to place a market value, and this apparent weakness of CBA in attempting to do so can be turned into a strength.

Ultimately, however, CBA is a tool to aid analysis. Like all tools it can be treated literally or roughly, and be put to unexpected uses. It does not have to be envisaged as a CBA expert judging for him/herself the market values, inputting the data and bringing the results to the decision-making committee or other forum. It does not even have to be envisaged as a small group of like-minded economists – experts – doing much the same thing, a possible example being the team of UK government economists which created the Stern Review (Box 3.8). CBA and its data inputs can, instead, be used as a basis for discussion among a much wider group of stakeholders, including non-economists, about the principles behind the key concepts and the assumptions behind the numbers on which the CBA computer programme is based. Used in this *processual* way CBA then has potential to a) be a source of learning about climate change out of our differences; b) produce a result that has a broad legitimacy beyond a narrow band of professional policy makers. In other words, CBA can be democratised!

In the final analysis, however, economic analysis does not have the last word. Many of its judgements concern 'PPP' – politics, policy and people. Politics and policy in relation to climate change form the subject of Chapter 4, while the often inequitable impacts on different groups of people and how they respond are analysed in Chapter 5.

To conclude your study of Chapter 3 and for you to reflect on the issues raised by the economics of climate change, turn to the Module 1 workbook activities 3.1–3.4.

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4 The Politics of Climate Change: a political science perspective

By Daniel Otto and Helmut Breitmeier

Before you start: aims and learning outcomes of this chapter

The purpose of this chapter is to introduce you to the politics of climate change.

After studying the chapter about "The Politics of Climate Change" you should:

a) Know and be able to reflect on the main aspects of the development of international climate politics:

You should understand how the climate change issue has come onto the political agenda and be informed about the milestones and main conflicts that have determined international negotiations.

b) Know the leading and important actors in the climate change debate and be able to identify their interests and aims in the political process.

You should know that states are the most important, but not the only, actors at the international level. Climate change politics is determined by well-organised interest-groups and science-based institutes as well as by national and international organisations. Economic considerations have become a very important factor (see chapter 3) and the different interests of economic actors reflect the costs and benefits expected by them from far-reaching global policies for the reduction of greenhouse gases. Various players are involved in the politics of climate change and they all have different interests and goals.

c) Understand the main reasons which explain the difficulties and conflicts, combined with the process for achieving an effective and binding agreement at the global level.

You should be able to exemplify the main conflicts among opposing groups in the climate change debate. This involves knowing the major lines of conflict and about the complexity of climate change as a global political issue.

4.1 Overview of chapter 4

Chapter 4 familiarises you with the evolution and process of the politics of climate change. We hope to raise your awareness of the problems and focal points of the climate change debate. We do this through examination of the politics of climate change in an international context. You will learn about the milestones -- the big climate conferences, which have been crucial in bringing the climate change issue to the international agenda. The evolution of the climate change regime (UNFCCC) from the United Nations Conference on Environment and Development (UNCED) in 1992 to the Kyoto Protocol in 1997 will also be described, as will the process for the development of a new post-Kyoto Protocol.

Furthermore, we introduce the various actors at the different – local, national, international – scales, which are relevant to the politics of climate change. Thus, a brief overview about the relevant actors, their origins, their development and their main interests will be provided. Not only will states and domestic units that belong to the realm of the state be conceived as important actors, but also international organisations, non-governmental organisations (NGOs) and transnational companies. The growing importance of NGOs in climate change politics suggests a sociological view of global politics. In this regard, the traditional view of world politics as the result of an international community of states has become out of date. It has been replaced by a model of transnational politics where states are still highly relevant as political units but where social actors such as NGOs or transnational companies exert pressure on states or on other non-state actors, or where these private actors follow their own political or economic interests and form coalitions with other actors in global politics. Furthermore, this contemporary model of world politics allows us to disaggregate the state itself into different relevant units (e.g., cities and federal states) which have become important actors in transnational climate politics.

The politics of climate change does not only contain a high degree of uncertainty but poses problems that make it difficult to achieve cooperation. We will inform you about theoretical approaches which are used in the social sciences for explaining the success and failure of global policies – and we will apply these approaches to the empirical evidence about global climate governance. Thus, we will provide an insight into the methodological approach of social scientists who develop, use and test theory-driven explanations in empirical analysis. We will illustrate the obstacles for collaboration and demonstrate the main causes as to why existing cooperation is deficient. We will also describe the relevant areas of conflict which have determined negotiations within the framework of the climate change regime. The conflict between North and South will be described in more detail. However, it will also become obvious that other lines of conflict existing among industrialised or between developed and rapidly developing countries make it difficult to achieve effective solutions.

4.2 The history of international climate change politics

4.2.1 Introduction

The natural sciences have considered the issue of climate change as a main topic of interest for many decades, but the issue has been politicised on the international agenda only since the 1980s.

In this section we will illustrate the main steps which brought the issue onto the political agenda and we will analyse the progress made and the agreements reached so far.

We explore the evolution of the politics of climate change through the application of theoretical concepts from political science. First of all, the protection of the global climate is among the most complex tasks faced by 'global governance' (see box 4.1). James Rosenau defined global governance as "systems of rules at all levels of human activity – from the family to the international organisation – in which the pursuit of goals through the exercise of control has transnational repercussions" (Rosenau 1995: 13).

Box 4.1 Governance is a relatively broad concept and can be best understood by distinguishing it from government. Whereas government involves the existence of a central political authority in political decision-making and implementation, governance involves the use of more non-hierarchical forms through the control and coordination of bargaining processes between different actors. Governance refers to processes at different levels (local, regional, national or global) which drive decisions and the actors involved in them, whether they belong to the state, to civil society or to the economy.

In *political science*, in particular in the discipline of *International Relations*, the term governance is closely related to international or transnational institutions. The traditional realm of international politics is focussed primarily on the creation and implementation of so-called international regimes which intend to achieve collective goals through intergovernmental institutions. In addition, new forms of semi-private or private institutions have been established by private actors or public-private networks aiming to implement global norms and to contribute to collective problem-solving. Governance on the level beyond the nation-state includes mechanisms and arrangements which enable transnational cooperation and stability in the international system. This is secured through formal or informal, institutional or non-institutional organisations and contracts. These transnational forms of cooperation allow the integration of non-state actors such as NGOs or economic actors and thus enable what Rosenau and Czempiel (1995) call "Governance without Government".

Global governance has long been understood primarily as a domain of governments. Intergovernmental institutions were considered as the most important instrument for collective problem-solving until the 1990s. In particular, the research of international relations has primarily focused on exploring the evolution and effectiveness of so-called "international regimes" as a specific type of international institution (see Box 4.2). International regimes (see Box 4.3) can be considered as "social institutions created to respond to the demand for governance relating to specific issues arising in a social setting that is anarchical in the sense that it lacks a centralised public authority or a government in the ordinary meaning of the term" (Breitmeier/Young/Zürn 2006: 3).

International regimes are a part of global governance. But they can hardly be considered as a synonym which can replace the term of 'global governance'. Rather, global governance encompasses more than intergovernmental institutions. (Semi)-private institutions and the potential for citizen self-regulation have responded to efforts at global, regional or national levels to complement international policies through additional private activities. Policymakers, the people and private business have come to realise more and more after the aforementioned United Nations Conference on Environment and Development – the 'Earth summit' – in Rio de Janeiro in 1992 that activities by the international community alone will not be sufficient enough for achieving significant improvements in the state of the global environment. The UN-Global Compact launched in July 2000 represents one of the most prominent efforts to align private companies with ten universally accepted principles in the areas of human rights, labour, environment and anti-corruption[36] (Flohr et al 2010).

Box 4.2 Institutions and norms. Institutions are social systems based on norms and rules which structure the behaviour of individuals or collective actors. They can be formal or informal. Political science research has long focused on formal institutions like governmental bodies or international regimes. Transnational institutions that exist between societal or economic actors have become relevant more recently. Recent research pays attention to the social embeddedness of institutions. These **social institutions** integrate a set of social norms organized around the preservation of basic societal values. They can be informal and composed of groups of roles or expected behaviour. Thus they shape and constrain codes of behaviour and cultural norms. The discipline of International Relations puts a special focus on analysing how norms of institutions affect the behaviour of states and other actors. In this context several types of institutions are considered relevant: international organisations such as the UN or the European Union, nongovernmental organisations and their networks, economic actors, or institutions which combine public and private actors. *See also chapter 3 for more discussion of institutions.*

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36 For more information about the UN-Global Compact consult http://www.unglobalcompact.org/docs/news_events/8.1/GC_brochure_FINAL.pdf.

Norms are general prescriptions or guidelines which structure appropriate and adequate social behaviour. Social norms are specific values derived from common socio-cultural expectations. Norms can be classified in terms of their claim of validity, extent of formalisation, the level of engagement and the sanction for breaching the rules. In political science they are especially relevant in the form of legal norms (codified law or common law) and non-codified norms. Norms are normally operationalised into rules that describe their meaning and content more concretely and in detail. In international politics, norms are a central object of investigation. In particular, research focuses on processes of norm-generation, and the implementation of, or compliance with, international norms. In addition, constructivist approaches explore whether behaviour of different actors in world politics is the result of a "logic of appropriateness" where norms structure the behaviour of these actors accordingly (March/Olsen 1998).

Box 4.3 International Regimes is a special concept in International Relations. Regimes are a specific type of institutions that were established at the intergovernmental level. International regimes are social institutions which were created to respond to the demand for governance relating to specific issues arising in a transnational social setting determined by anarchy in the sense that it lacks a centralized public authority or a government (Breitmeier/Young/Zürn 2006: 3). They are based on principles, norms, rules, decision-making procedures or programmatic activities which affect the behaviour of actors in a given problem area (Krasner 1983, Breitmeier/Young/Zürn 2006). Regimes are institutionalised systems of cooperation for problem-solving in a special issue-area. Regimes provide a framework for negotiation among states. Their function reaches from the provision of a framework for cooperation which: a) reduces transaction costs among parties (Keohane 1984); b) produces new consensual knowledge about causes and effects of a problem and about possible solutions (Haas 1992); c) provides mechanisms that prevent cheating and free-riding by parties (Downs/Rocke/Barsoom 1996); d) establishes mechanisms for dispute-settlement in the issue-area; d) provides financial or technology transfers to support the implementation by developing countries. Examples of regimes in international politics are the World Trade Organization, the nuclear non-proliferation regime, the climate change regime, and the regime on long-range transboundary air pollution in Europe.

In the following text, another concept of political science – the policy cycle -- shall be used to structure the policy process. Each form of political management in global governance is normally determined by this process. This process will be divided into different stages of the policy cycle, each of which is connected with specific assumptions and propositions.[37]

The "policy cycle" (Fischer 2007) is one appropriate model that can be used for analysing the politics of climate change.[38] It is a tool that makes it possible to understand the historical development and dynamics of a political issue.

The basic policy cycle contains four major steps:[39]

1) Agenda setting (problem identification)
2) Policy formulation (negotiations and decision-making)
3) Implementation

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37 We cannot discuss this issue in detail. For detailed information see for example: Schram S F, Caterino B (Ed) (2006). Making political science matter: debating. Knowledge, research and method, New York [u.a.]: New University Press.

38 There are also other models that exist beside this particular model on the policy cycle.

39 There are also alternative models, which comprehend for example eight steps, e.g. Bridgman P, Davis G and Althaus C (2007). The Australian Policy Handbook (4th ed.). Sydney: Allen & Unwin.

4) Evaluation

During agenda-setting as the first stage of the policy cycle, an issue is considered as relevant, for example by civil society, the media, political parties, science or other organisations. Once the issue has entered the political agenda, its real meaning and content have to be defined by politics or public discourse. This complex process clarifies and determines a number of relevant issues: Who is responsible for causing the problem? What are the impacts of the problem? How will possible measures for problem-solving affect consumers, the economy or the state-budget?

Science can play an important role in shaping the issue through the provision of knowledge and expertise (Ascher/Stealman/Healy 2010, Barkenbus 1998, Keller 2010).[40] This influence of scientists on the global agenda or on the shaping of the preferences of policymakers in international negotiations has been explored by Peter M. Haas. He identified the influence of so-called ‘epistemic communities’ which consist of networks of “professionals with recognised expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain or issue-area” (Haas 1992: 3).

At the end of agenda setting, the nature of the problem has to be defined more concretely. A broad number of issues demand access to the global political agenda, but only a few of them are finally recognised as important. Thus, there is strong competition between social actors for placing their own specific issue on the global agenda.

The second stage, policy formulation, contains negotiations and decision-making. When an issue has reached this stage, the agenda has been set and the definition of the problem has been developed. The public and political decision-makers have a relatively clear understanding about the problem as such. But actors dealing with the problem face the challenge to develop norms and rules that contribute to solving the problem effectively. This process takes place in negotiations between relevant parties where a decision has to be negotiated. International institutions are strongly determined by bargaining processes.

A number of theoretical approaches – e.g., power-based approaches, game-theory, cognitive approaches – deal with the dynamics and results of bargaining or – more specifically – with the shaping of preferences and interests in international institutions (Barnett, Duvall 2004, Breitmeier 2006, Miles et al 2002, Wagner 2008). These theoretical approaches identify the factors which enable or constrain the achievement of bargaining solutions in international negotiations. The asymmetries regarding differentiated responsibilities for a problem, or uneven capabilities or resources available for problem-solving between states in an issue-area can be obstacles to achieving an agreement (Yang 2008). Furthermore, justice has become a prominent issue in the global debate about climate change. Many developing countries are especially affected by climate change but are lacking resources to adapt to its impacts. On the other hand, developed countries have contributed substantially to rising concentrations of greenhouse gases in the global atmosphere (Vanderheiden 2008).

Policy formulation is followed by the implementation phase which involves translation of agreed commitments into concrete action by those actors who agreed to the outcomes of negotiations. This process includes the development of tools which can be used to implement the measures which have been agreed. The options that are chosen during this stage will be assessed in terms of costs and benefits, expenditure of time, or other consequences arising for the actors in the issue-area.

The implementation of policies raises the question whether intended goals of the policies have been achieved and whether decision-making during implementation has been effective and efficient. The issue of compliance is closely related to this stage. States which have ratified an international agreement have to take steps for national

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[40] http://www.bismanualz.com/blog/policy/the-policy-cycle.html

implementation in order to comply with international commitments. Students of global governance have put special emphasis on the issue of compliance. The international system lacks a central authority which can enforce compliance with international norms. Accordingly, the central question raised by this strand of literature focuses on the conditions which facilitate or guarantee compliance with international norms in a global political system which is lacking a central authority (Beyerlin/Stoll/Wolfrum 2006, Breitmeier 2008: 101–128, Mitchell 2009).

An evaluation of policies and continuous monitoring of the process after the decision-making and implementation are necessary for national implementation and for securing compliance. If the outcomes of a policy are assessed as negative or if the targets have not been achieved, this may result in a policy reform. Reforms could involve the modification of a policy or, in the worst case, the replacement of the entire policy. In this latter case, the policy cycle will start again.

The adaptation of the policy cycle to the issue of climate change leads us to identify four different stages in the evolution of climate change politics, which form the next five sub-sections.

Firstly, we discuss how the issue of climate change was politicised. Science, the media and environmentalists contributed to bring the problem of global warming onto the international agenda. These actors raised political attention and a need for action.

Secondly, we discuss the process of policy formulation which achieved initial results at the Rio World Summit in 1992. Thirdly, we discuss the post-Rio negotiation process and the binding commitment which resulted in 1997 in the form of the Kyoto Protocol. Furthermore, we discuss the implementation of the Protocol and the mechanisms which were developed.

Fourthly we assess the attempts at a post-Kyoto (the Kyoto Protocol ends in 2012) agreement. Finally in this section we consider the results of the later international UN gatherings in Cancun Mexico and Durban South Africa.

4.2.2 From Science to Politics: How the climate change issue became politicised

The issue of climate change was ignored by political actors for a long time. But in the mid 1980s, it increasingly reached the attention of natural scientists, environmentalists and the media (Weingart 1999). The first international conference on climate change was initiated by the *World Meteorological Organisation (WMO)* in 1979. The issue was only weakly recognised, however, by politicians or the public at that time.

In contrast, a series of global conferences took place in the mid and late 1980s which addressed the depletion of the ozone layer in the upper atmosphere, biodiversity, desertification and climate change as new global challenges. For example, NGOs, scientists and national policy-makers participated in an international climate conference in Toronto in 1988 and agreed on a non-binding recommendation that emissions should be reduced.

What reasons and driving factors led political actors to engage in the issue of climate change? Warnings from scientists about global warming were not new; more than hundred years ago the Swedish physicist Svante Arrhenius (1896) had posited a connection between human activities and the observed greenhouse effect of global warming (Bolin 2007; see also chapter 2 section 2.1 of this module). He argued that the burning of fossil fuel released carbon dioxide (CO_2) and that this mechanism was responsible for the warming of the global atmosphere. It took nearly a hundred years before these findings were taken seriously by scientists and global policy-makers.

Several factors explain why political mobilisation on climate change began exactly in the mid-1980s. The societies in western industrialised countries had increasingly developed a growing interest in environmental issues. Environmental disasters such as oil-tanker accidents, the damaging effects of chemicals on human health, and the explosion of major chemical plants (for example, Bhopal in India) contributed to the development of environmental consciousness in many countries. The growing concern about the depletion of stratospheric ozone as a result of the production and use in aerosol sprays of the group of chemicals called chlorofluorocarbons (CFCs), and other substances, led to a global debate about the need for new global environmental regimes. In 1987 the United Nations *World Commission on Environment and Development (WCED)* published the Brundtland Report (named after the Norwegian prime minister who chaired the WCED – see also Chapter 6) which had one central goal: the propagation of *sustainable development* as a fundamental principle for future social and economic development in industrialised and developing countries. This awareness for environmental protection was encouraged by a series of extreme weather phenomena in the late 1980s, especially in the United States (US). These weather events were interpreted by scientists and environmentalists as possible harbingers of climate change and massive media coverage increased political pressure to initiate concrete action in response.

The creation of new scientific evidence about the human influence on the warming of the global climate was another important factor which contributed to agenda-setting. Bores in the ice layer in Greenland revived the presumed correlation between the global temperature and the concentration of emissions in the atmosphere. This new perception induced the *United Nations Environment Programme (UNEP)* and the *WMO* to put this issue on the international agenda. Several workshops in Villach (1985) and in Bellagio (1987) held by climate scientists discussed the effects of increased emissions of carbon dioxide, CFCs, methane and other substances on the global climate.

All these events contributed to bring the issue onto the political agenda and evoked pressure to deal with the rising threat of climate change. Even though there was an international discussion about the causes and consequences of global warming, knowledge about its human influence was incomplete at that time. Thus it was agreed to collect data for an international literature review on the state of climate change science. As a consequence, the UNEP and the WMO founded the *Intergovernmental Panel on Climate Change (IPCC)*, which was legitimised through the consent of the United Nations General Assembly. Although the IPCC contributed to coordinate research findings on climate change, the topic itself was still not considered as a priority on the political agenda. Only 28 countries actively participated in the IPCC when it was founded in 1988 and only eleven of these were developing countries (Bolin 2007: 49). One central aim of the IPCC was to assess the impacts and consequences of climate change and to produce relevant expertise to enhance policy-makers' understanding. Since then, the IPCC's frequently published assessment reports (1990; 1993; 2001; 2007) have in many cases attracted the attention of the global public and political decision makers.

The IPCC was recognised as the central body for scientific knowledge about climate change. Since its establishment, however, it has also been constantly under attack from diverse groups and individual governments, challenging its findings. A detailed discussion about the influence and impacts of these groups on the IPCC cannot be carried out here. For further reading we recommend Oreskes and Conway who offer a state of the art (2010). The IPCC presented its first assessment report in 1990 at the second world climate conference in Genève. The report stressed the emerging threat of anthropogenic (human-induced) climate change. The participants of the conference agreed on an appeal to start international negotiations on climate change. Three years after the founding of the IPCC a UN General Assembly resolution resulted in a *UN Framework Convention on Climate Change (UNFCCC)*, which– until today – has had the task of coordinating international negotiations.

4.2.3 The Creation of the International Climate Change Regime – the Earth Summit in Rio de Janeiro

International public attention to a political issue does not automatically lead to political action by governments.

In the view of political scientists, the interests of different actors are an important motivation for political action (Prittwitz 1990). Here we suggest three broad categories of interest.

Causers of environmental problems normally have an interest in maintaining their practices in a *business as usual* scenario. In contrast actors who are affected adversely by a problem, or who have developed an environmental consciousness, focus on the development and propagation of solutions. These are the *concerned* actors. Others, the so-called *helpers*, have an interest in supporting the process of problem solving to achieve maximum benefit to themselves.

The adaptation of this theory to the interests of the main actors in the early phase of the political process on climate change allows us to identify the specific types of coalitions of interests that were involved.

The group of causers was dominated by the United States (US). This group had a low interest in the development of binding emission targets. The US was the largest global producer of coal and the second largest of oil and gas. A similar constellation could be found with the *Organisation of Petroleum Exporting Countries* (OPEC – mainly the oil-rich states of the Middle East), which, as the largest producer of oil, had no interest in reducing emissions. They feared that reducing emissions could reduce international demand for oil and gas. The interests of Russia and the former states of the Warsaw pact were comparable with those of the US and the OPEC.

The *Alliance* of *36 small and non-industrialised island states* (AOSIS) is an example of concerned countries. The island states feared that a possible sea level rise resulting from global warming could threaten their existence. Therefore, they strongly favoured binding targets for the reduction of emissions. The AOSIS was accompanied by some European countries, the Netherlands and Denmark especially, who wanted to lead the way in this area. These two European countries are also especially affected by climate change because of predictions of sea-level rise.

The *helpers* were mainly from European countries, especially Germany, Denmark and the Netherlands called the “green troika”. The oil crisis of the 1970s and the publication of the report “The limits to growth” by the Club of Rome (1972) had soon raised the willingness for a change in national energy politics as a matter of self-interest. As a consequence, the costs of addressing climate change and its impacts were estimated lower and more resolvable than in the US or Russia.

Other countries like Japan, the G77 plus China (an alliance of originally 77, but had grown to 132 by 2011, developing countries), were rather undecided and had no clear position at that time.

An international negotiation process was started in 1990 to establish a framework for a binding convention on emissions and to open that convention for signature at the Earth Summit in Rio de Janeiro in 1992. The negotiating parties had only 15 months, however, in which to develop such a framework convention for this ‘earth-summit’. In the event, five negotiation rounds were conducted in advance of the Summit in an attempt to produce a rough agreement. If we take the constellation of the divergent interests into consideration, it is not surprising that an agreement seemed to be hard to reach.

The main conflict line existed between industrialised and developing countries. While industrialised countries argued for the need for a comprehensive convention, the developing countries opposed this aim. They blamed the industrialised countries as the main causers of greenhouse emissions and emphasised the historical responsibility of these countries for the climate problem. They also refused the intent of the industrialised countries to reduce emissions because they saw it as a danger for their own socio-economic development. Some even suspected the whole issue could be a complot to constrain the progress of the developing countries (Grubb/Vrolijk/Brack 1997). As a consequence, the developing countries sought to obtain at least a technology transfer or funding to ensure their own progress on the matter. The OPEC in particular was critical about reducing emissions. These countries worried that this could result in a lower demand for energy imports by industrialised countries. The AOSIS meanwhile feared for the survival of their own territories and voted for binding reduction targets. But their influence was too weak and they had no real impact on the results of the negotiations.

It was uncertain for considerable time whether the negotiations would lead to a concrete outcome that could lead to an agreement at the Earth Summit. In the end, a document was produced a few weeks before the start of the conference. It combined the opposing positions into an appropriate outline that contained core principles, procedures, institutions and commitments, which formed the framework for the Earth Summit negotiations.

This Earth Summit – officially titled the United Nations Conference on Environment and Development (UNCED) -- in 1992 was not merely a conference about climate, its main topic being “Environment and Development”. Alongside climate change, biodiversity, desertification and forests were also discussed. An innovation was the invited participation of civil society groups. These actors included environmental groups as well as representatives of industry and lobbyists, who all tried to influence the outcome of the conference. One influential lobby group was the *Global Climate Coalition (GCC)*, an association of companies that operate in the automobile, coal and oil industries. Altogether 2400 representatives from NGOs and over 17.000 people were engaged in parallel forums.

Despite all the challenges and diverging interests, a *UN Framework Convention on Climate Change (UNFCCC)* was signed.

One key element of the convention was the industrialised countries’ commitment to implement policies and measures which “will demonstrate that developed countries are taking the lead in modifying longer-term trends in anthropogenic emissions consistent with the objective of the Convention, recognising that the return by the end of the present decade to earlier levels of anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol[41] would contribute to such modification” (Article 4 (2a) of the UNFCCC). This was a relatively weak commitment by industrialised countries which included only a declaration of intent (but no formal binding legal commitment) to reduce emissions back to the level of 1990 by the year 2000. The convention contained no binding commitment, mainly because the US had opposed clearly defined reduction targets. On the other hand, the European Union and the AOSIS had argued for binding targets. The developing countries also supported this idea, but only if they would be released from obligations (Bodansky 2001: 19).

Another important point was the principle of *common but differentiated responsibilities* expressed in Article 3 of the agreement. While all signatories accepted their responsibilities, they stressed that these responsibilities had to be seen in connection with their individual capabilities to fight climate change. Furthermore, in article 4 it was mentioned that developing countries should be supported in their efforts to reduce emissions with financial, technological, research and educational aid (Quennet-Thielen 1996: 79).

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41 The Montreal Protocol is the name of the Protocol signed in 1987 to address the issue of damage to the ozone layer.

The 50 ratifications, which had been necessary for entry-into-force of the convention, were easily achieved one year after the summit. The Earth Summit had gained wide public interest and great attention in the media. On one hand, this public pressure had accelerated the process towards an agreement. On the other hand, the convention remained vague with respect to all the issues related to the achievement of reductions in greenhouse gas emissions. While this undermined attempts to establish clear instructions and targets, it reflected the diverging interests during the negotiation process.

4.2.4 The reinforcement of Climate Change: the Kyoto Protocol

The climate change negotiation process following the Earth Summit was difficult. Notwithstanding that the Rio convention had been signed by 50 countries in December 1993, the atmosphere for environmental concerns, especially climate change, was inauspicious (Grubb/Vrolijk/Brack 1997 et al: 44). Mainly, the perceived costs of reducing emissions were big obstacles for further and deeper agreements. Most of the industrialised countries feared competitive disadvantages for their domestic economies.

This tendency could be observed in political events outside of the international negotiations. In the US, domestic resistance against international environmental commitments was high. The newly elected President Clinton had sent out signals during his election campaign to advance climate protection, but political blowbacks prevented the project. An initiative for an energy tax failed in 1994. This collapse was also advanced by intensive lobbying by the US industry (Paterson 1996: 87). Even more effort was put by lobbyists into blocking environmental initiatives after the success of the Republican Party in congressional elections in 1994.

Even the EU had its difficulties with furthering its environmental proposals. The EU's carbon tax, which had been on the agenda since 1990, was rejected by the UK in 1993 but had also little support in other European member countries.

Another aspect was scientific scepticism over climate change, which emerged for the first time after the Earth Summit. Furthermore, the interest of the media and public attention for climate change waned.

Despite all these failed initiatives and problems on the international agenda, the approved evolution of the Climate Change Convention agreed at the Summit moved to the next step. The first *Conference of the Parties (COP)* to the convention in Berlin 1995 was a bad omen. Although Germany, the host of the conference, promoted new commitments, this was never seen as a realistic proposition (Grubb/Vrolijk/Brack 1997: 45).

The Berlin conference agreed a few resolutions. Some were institutional (e.g., that the secretariat will be moved from its interim base in Geneva to Bonn). The financing of the regime was secured and left under the control of the *Global Environmental Facility* (GEF) (see Box 4.4). Two new bodies were established under the Convention: first the *Subsidiary Body for Scientific and Technological Advice (SBSTA)* and second the *Subsidiary Body for Implementation.*

Box 4.4 The Global Environment Facility (GEF) was established in 1991. It is the largest funder of projects for the protection of the global environment. It has 182 member countries and it also cooperates with international institutions, non-governmental organizations and the private sector. The GEF is an independent financial organization and provides grants to developing countries and countries with economies in transition for projects related to biodiversity, climate change, international waters, land degradation, the ozone layer and persistent organic pollutants. Currently, the GEF is active in more than 165 developing countries and has allocated about $9.2 billion. The GEF partnership includes 10 agencies: the UN Development Programme; the UN Environment Programme; the World Bank; the UN Food and Agriculture Organization; the UN Industrial Development Organization; the African Development Bank; the Asian Development Bank; the European Bank for Reconstruction and Development; the Inter-American Development Bank; and the International Fund for Agricultural Development. The Scientific and Technical Advisory Panel of UNEP provides technical and scientific advice on the GEF's policies and projects.

The COP in Berlin made it obvious, however, that most of the industrialised OECD countries (see Box 4.5) could not fulfil the non-binding targets that they had indirectly (but not explicitly) accepted at the Earth Summit. Virtually none of the signatories would be able to reduce its emissions by 2000 to the level in 1990. Most countries therefore articulated that the targets were inadequate and poorly conceived. While the US and the OPEC still opposed binding targets, the developing countries refused any commitments. Finally it was agreed in Berlin to declare the current Convention as inadequate and to develop a new agreement on reducing emissions for the time beyond the year 2000. The industrialised countries especially were considered to be under obligation to support and contribute to these goals.

Box 4.5 The Organisation for Economic Cooperation and Development (OECD)[42] is an international economic organisation which was founded in 1961 by 20 industrialised countries, which has since expanded to 34. It originated from the 1948 *Organisation for European Economic Co-operation (OEEC)*, which was founded to help administer the Marshall Plan for the reconstruction of Europe after the Second World War. The main purpose was to promote world trade and economic progress. Basic principles of cooperation are democracy and market economy. The self-declared mission of the OECD is to promote policies that will improve the economic and social well-being of people around the world.[43] Therefore, the OECD provides a forum in which governments can cooperate and share experiences about common problems. The OECD also analyses and compares data for the evaluation of policies or economic issues. One famous example is the Programme for International Student Assessment (PISA), which is an assessment that allows for a comparison of educational performances between countries.

This decision, named the *Berlin Mandate*, specified that the commitments for industrialised countries should be revised, while new commitments would not apply to developing countries. Furthermore, the Berlin Mandate provided that a Protocol with binding reduction targets and a concrete timeline should be negotiated for the third Conference of the Parties in Kyoto, Japan 1997. For this purpose, an *Ad Hoc Group on the Berlin Mandate (AGBM)* was established.

The second Conference of the Parties in Geneva was also influenced by the second IPCC assessment report, which approved the scientific findings of the first report. The US administration showed its willingness to cooperate with binding targets but voted for market-based and flexible solutions. While the EU agreed on the US approach to specific commitments, OPEC, Russia and Australia opposed binding targets for reducing emissions. In the end a Ministerial Declaration was passed, in accordance with the

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42 http://www.oecd.org

43 http://www.oecd.org/pages/0,3417,en_36734052_36734103_1_1_1_1_1,00.html

second IPCC assessment report, which renewed the Berlin Mandate, proposed legally binding targets and reiterated the need for technology transfer to developing countries. Although this was not an official document, it set the guidelines for the following meetings and the conference in Kyoto.

The Kyoto conference in 1997 was the biggest environmental conference since the Earth Summit in 1992. It gained strong attention by the media, the public, industry and environmental NGOs. Almost 10 000 people attended the conference. The crucial issue during negotiations was the development of concrete commitments, mechanisms for action and of instruments for monitoring and implementation.

Three active and two passive groups determined the negotiations at Kyoto (Sprinz 1998: 33). The active parties which promoted the development of concrete solutions were the EU, the US and Japan. The G77, which consisted of 132 countries including China and the AOSIS, emphasised the commitments of the Berlin Mandate but neither actively participated in the conference nor tried to work for a consensus

The US argued for limiting emissions but only from 2012. It also argued for commitments, which included emission reductions, by developing countries. The US pushed the idea of market-based approaches as a possible mechanism for reductions. In contrast, the EU emphasised strong reduction targets with a first subordinated target to be reached by 2005. The G77 refused all commitments. Due to its special role as the host of the conference, Japan had a strong interest in completing negotiations in Kyoto with success. Thus, it tried to mediate between the different groups.

Despite all of the divergent interests and conceptions about procedures, rules, aims and targets of the conference, the secretariat and the Chairman of the Kyoto Conference committee, Raul Estrada, managed to merge the different proposals into an appropriate document that formed the basis for the final Protocol. This constituted a compromise on the main issues. But some issues remained unresolved and had to be resolved by the next conferences of the parties.

The outcomes of the Kyoto Protocol, which was adopted by the Third Conference of the Parties in December 1997, can be divided into two main parts.

The first and most important part comprised the emission targets which were distributed individually between the Parties. In Annex B of the Protocol, the industrialised countries agreed to reduce emissions by a total of five percent in the period from 2008–2012 with reference to 1990 as the base year. While the US had to reduce its emissions by seven percent, the EU had an eight percent reduction target. For this purpose each reducing country was allocated an emissions allowance[44].

The EU was perceived in the Protocol as a single actor, which involved the creation of a special mechanism that was called the *EU bubble*. The EU had the overall aim to cut emissions by eight per cent, but it was allowed to achieve this aim through an individual burden sharing system. Thus Germany, for example, had to reduce emissions by 21 per cent, while countries like Greece or Ireland were allowed to increase their emissions. This arrangement took into account the different economic capacities in the member countries of the EU.

China, Brazil, India and other developing countries were not required to commit to any reductions. Most of the Eastern European countries like Russia and the Ukraine were subsumed under the category of “economies in transition” and therefore also excluded from binding commitments.

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44 **Emissions allowance** is an authorization to emit a fixed amount of pollutants. Mostly it describes a unit of greenhouse gas emissions (GHG) covered by a certain emission trade system. The allowances under the Kyoto Protocol were fully marketable. This means they were approved to be bought, sold or traded for use by entities covered by the program.

The other important aspect of the Protocol was the mechanism for achieving emission targets for those required to do so. While each country had to take domestic measures to reduce emissions, the Kyoto Protocol also provided for three international transfer mechanisms. The first mechanism was *emissions trading* which was designed to enable countries to exchange their emission allowances for attaining their targets. The trading of emissions was allowed only in 'Annex I' states and between members of the EU – i.e. those countries that would be required to reduce their emissions. The second mechanism provided for a system within the EU. It permitted companies which could not reach their individual reduction targets alone to buy emission certificates from other companies, which exceeded their own individual targets. The governments of the EU member states are responsible for allocating certificates. Both trading systems should in the first instance allow a market based reduction of emissions.

The second transfer mechanism was *The Clean Development Mechanism (CDM)*, defined in Article 12 of the Kyoto Protocol, which allows committed countries to accomplish emission reductions in developing countries and to offset these against their domestic targets. Because the global climate is considered to be a public good it was agreed by the parties that it is unimportant where the emissions reductions are made and this provided the rationale for the CDM. Furthermore, the Protocol intended the CDM to advance investments and modernisation in developing countries.[45]

The third mechanism *was Joint Implementation (JI)*. This mechanism was defined in Article 6 of the Kyoto Protocol. It permitted parties of Annex I to initiate attainments in other Annex I countries and to take them into account for their own emission reduction or limitation commitment. This made cross-border investments between countries possible. Project-based approaches, which allow actors to earn emission reduction units (ERUs) from investments in other Annex I countries, set incentives for collaboration.

The Kyoto Protocol included many compromise solutions. Some decisions remained unresolved. The market-based approach, which was a core provision of the Protocol, was a concession to the US government. Almost all states and observers were aware that a Protocol without participation of the US would be ineffective. NGOs criticised the Protocol, however, claiming that the specified reduction targets were not sufficient to prevent global warming. On the other side, many interest groups feared the high costs and investments that emerged from the implementation of the Protocol.

One has to admit that many experts had long been more than sceptical that negotiations could lead to binding reduction targets (Grubb/Vrolijk/Brack 1997: 150).

4.2.5 Towards a Post-Kyoto Agreement?

The Kyoto Protocol had to be ratified by member states before its provision could become effective. The criteria for entry-into-force required a double majority. At least 55 states had to ratify the Protocol, representing more than 55 per cent of the global carbon emissions of the year 1990. The required number of states was achieved with the ratification by Iceland on May 23rd, 2003. The second criterion was harder to achieve, because the US dropped out of the Protocol as it had not passed the US-Senate. In June 1997, the US-Senate had passed the so called *Byrd-Hasel resolution* with 95:0 votes, which declared that no contract would be ratified without participation of developing countries. The new President George W. Bush made clear that he would not ratify Kyoto unless amendments were made, especially regarding the involvement of developing countries. The US accounted for 35 per cent of global carbon emissions and its failure to ratify was a major blow. Nevertheless, the Protocol finally entered into force through the ratification by Russia on 16th February 2005.

Since the Kyoto Protocol, no additional major agreement has been achieved to date which contributes to preventing climate change. Because the Protocol expires in 2012

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[45] http://unfccc.int/kyoto_Protocol/mechanisms/clean_development_mechanism/items/2718.php

(and may already have done so for those reading this from 2013) and many matters have not been settled by it, further negotiations were needed for a post-Kyoto agreement.

The *Buenos Aires Plan of Action (BAPA)*, agreed in Buenos Aires in 1998, was supposed to develop further steps for negotiations until the year 2000. During the two conferences in The Hague in 2000 and Bonn 2001 political conflict intensified along the persistent major conflict lines. While the EU propagated stronger policies and procedures, the US, Japan and Russia voted for more flexibility and more exceptions from rules. The other conflict line existed between developing and industrialised countries. It focussed mainly on the issues of participation in agreements by the former and financing. The situation was further aggravated by the declaration of President Bush that the US would withdraw from the Kyoto Protocol (see above).

While progress was poor, the 7th COP in Marrakesh in November 2001 was expected to resolve open questions concerning the Protocol. The importance of the conference was underlined by participation of over 170 government representatives and several non-state actors. During the negotiations, a framework and rules for the parties were elaborated. Nevertheless, it was apparent that, at the current level, the agreed commitments of Kyoto could hardly be achieved (Babiker et al 2002) (See Figure 4.1). Major concessions were made to states, especially to Russia, to offer incentives for the ratification of the Protocol. The US, however, was absent during the negotiations.

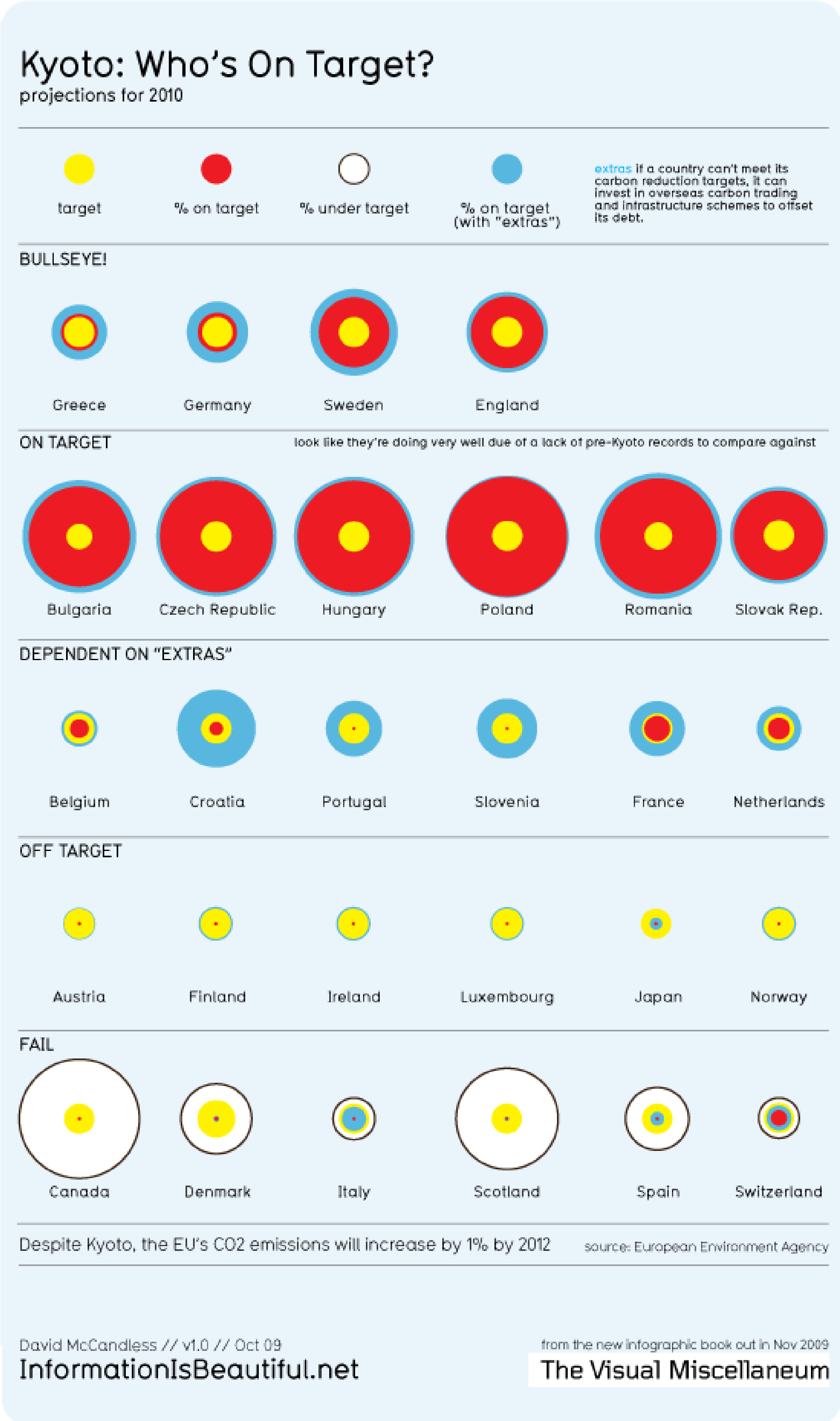

Figure 4.1 Kyoto: Who's on target? Projections for 2010 which were made in 2009

At the eighth COP in New Delhi, little progress was made. While Canada ratified the Protocol, the US and the OPEC pursued a political blocking tactic. At the ninth COP in Milan in 2003 the focus was on Russia, which had given signals to possibly ratify the Protocol. It was also specified how, under the CDM, the reduction of emissions through *carbon sinking (see Box 4.6)* would be organised and credited. The tenth COP in Buenos Aires in 2004 was a success mainly because the Russian President Putin signed the Kyoto Protocol enabling it 90 days later to come into force.

Box 4.6 Carbon sinking means that an entity absorbs more carbon than it releases. In contrast a **carbon source** can be defined as anything that releases more carbon than it absorbs. Most common resources for carbon sinking are soils, forests, oceans and the atmosphere, which all store carbon.

The first meeting of the member states of the Kyoto Protocol, called the *Meeting of the Parties (MOP)*, took place in Montreal in December 2005. The main task of the conference was to coordinate the forthcoming negotiations to strengthen and deepen its agreed targets and mechanisms. The second MOP in Nairobi 2006 decided to create a fund to support the African countries. At the third MOP in Bali 2007, parties planned to agree on a procedure for the development of a new Protocol. But again the divergent interests and conflict lines were severe obstacles. The US again refused the application of binding targets and it proposed instead voluntary agreements that each country would develop itself. The EU on the contrary tried to integrate the developing countries by offering them financial and technological aid in return. Because in the end, the US abandoned the option of blocking the process, an informal agreement was achieved in Bali. However, the overall results of the new "Bali roadmap" brought little progress (Haas 2008: 1). The main outcome was the commitment to create a post-Kyoto convention in the following three years. After a phase of negotiations the convention was to be signed in Copenhagen at the end of the year 2009.

Global attention thus focused on the 15th COP in Copenhagen in December 2009. The purpose of the conference was to design a new legal framework for climate change. 120 heads of states and governments attended the conference. The general participants of the conference included 10,500 delegates, 13,500 observers, and coverage by more than 3,000 media representatives.[46] Beyond that, over 220 exhibits from political parties, the UN, NGOs and civil society were registered.

Although there was enormous pressure on the Copenhagen participants, even before the conference had started, it was clear that it would be nearly impossible to reach an agreement and that further negotiations would be needed to achieve binding targets (Dröge 2010b: 11). Nevertheless, the context of the negotiations was highly complex. One big task was to integrate the US into the negotiation process. New hope had emerged since the election of the new US President Barack Obama in 2008 (Dröge 2010a: 5). Although Obama seemed willing to cooperate, he still had to take domestic concerns into consideration, where there was strong resistance to an international convention. Another crucial actor was China as a rising economic power. China had, close to the start of the conference, unveiled commitments on its part and renewed the demand that the US should ratify Kyoto and the other industrialised countries should aim for their committed targets. The EU on the contrary had signalled that it would commit itself to unilateral targets from 20 to 30 percent by 2020. Developing countries like India and Brazil voted for a further development of Kyoto without being committed to reducing their own emissions. China in particular took a leading position in stressing that no convention would be supported which burdened developing countries.

46 http://unfccc.int/meetings/cop_15/items/5257.php

Because the conference raised great international attention, numerous NGOs, lobbyists, organisations and representatives from many areas of society tried to influence the negotiation process.

Despite these efforts, it soon became apparent that the big gaps between developing and industrialised countries could not be bridged. Major tensions and mistrust between these two groups could be observed. Europe and the US were seeking market based approaches and emphasised the responsibility of developing and newly industrialising countries like China. A new bloc emerged including, Brazil, South Africa, India and China (BASIC), which sought to represent the interests of developing and newly industrialising countries vis-à-vis industrialised countries (Dubasch 2009: 8).

With all these conflicts and fault lines, no consensus text was available for signature even during the last few days of Copenhagen. Thus, the heads of states entered into intensive negotiations to achieve at least a minimum accord.

The results of the Copenhagen conference were assessed as the lowest common denominator. No binding targets under international law could be established. Instead, a paper was agreed, called the *Copenhagen Accord*, where it was decided that global warming should be limited to a maximum of two degrees above that which existed in the preindustrial age of the 17th century.[47] The Accord can be understood as a political declaration of intent rather than a definite goal. Beyond that, a paragraph to the Accord – which was declared an external document – was negotiated by the parties including the US and China. In that document, the industrialised countries committed themselves to supply new and additional resources to address climate change. These resources will be provided through international institutions such as the Global Environment Facility (GEF) or the UN Environment Programme and will approach USD 30 billion for the period 2010 – 2012.

Given the aims of the 2007 Bali COP-13 (see above) the overall goal of establishing a process in Copenhagen to replace the Kyoto Protocol from 2012 when it expires failed. Experts who were directly involved in negotiations as government delegates also classified the conference as the worst case scenario (Radoslav 2010).

Nevertheless, it is often argued that it is firstly the UN climate process that has been damaged, while a summative climate policy beyond the UN is making progress (Radoslav 2010). Even if the big conferences have failed, progress can be made outside such events at other levels. Thus one can distinguish between a stagnant UN process and a multilevel approach which might be assessed in a more positive way.

For all that, a discussion has since started on how to deal with the collapsed post-Kyoto Protocol and how to move forward international climate change policy.

In the meantime, the UN negotiation process has continued. The 16th and 17th COPs took place respectively in Cancun Mexico (2010) and Durban South Africa (2011). But even if the UN negotiations are continuing, one may legitimately ask how the important cornerstones for a new convention could be set.

In this vein, the journal *Nature Climate Change (2010)* interviewed several researchers who have observed the climate negotiation process from an academic point of view, especially the development of perspectives since Copenhagen.

- Mike Hulme, a British geographer and climatologist, advances the opinion that one should not only focus on the structured UN process, but pursue progress outside of it. He proposes to split the treaties and establish one for short-lived gases and another one for carbon dioxide only.

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[47] UFCC: Copenhagen Accord (http://unfccc.int/files/meetings/cop_15/application/pdf/cop15_cph_auv.pdf)

- Jonathan Lash, president of the World Resources Institute[48], a global environmental think tank, assesses the Copenhagen Accord as better than is often reviewed. Agreements were made, which structured the negotiation process until the next conference in Cancun at the end of 2010. Especially the US and China have been challenged to expedite this process.
- David G. Victor is professor at the School for International Relations and Pacific Studies at Stanford University in the United States. He has a moderate position concerning the outcomes of Copenhagen. Not convinced that Mexico would produce further results, he conceived the next milestone to be the expiration of the Kyoto treaty in 2012. For a new convention he argues that the private sector should be taken more into account. According to Victor it is essential to establish a convention which is acceptable for countries such as the US and China. Generally speaking, a basic effective agreement by governments should be a role model for people to get involved with the issue of climate change.
- John Schellnhuber, climate advisor to the German government and director of the Potsdam Institute for Climate Research, thinks Copenhagen is a landmark event. On the one hand policymakers accepted the majority scientific findings and now conceive them as the point of reference. On the other hand the conference demonstrated in no uncertain terms that, after 20 years of negotiations, states are still not able to agree on a common course of action.
- Finally, Roger Pielke Jr. from the University of Colorado considers it apparent that there exists no possible coordination between states for binding targets and timetables for emissions reduction. He recommends focusing more on technology, innovation and economics for example the decarbonisation of the global economy than on international treaties.

We can see that there are several ideas and forecasts of what a potential climate policy may look like beyond Copenhagen. The opinions mentioned here are just outlines of a broader academic and political discussion.

However, the politics of climate change do not only contain negative aspects, but must also be perceived as a chance to reconsider the current action (Prins 2010).

First of all it seems obvious that the primary target, the reduction of emissions, cannot be achieved by focussing alone on the classical approach of interstate negotiations under the UN.

If we look at the level of states, we still find the old fault lines of interests illustrated by the concept of Prittwitz (see section 4.2.3 above).

The US is still not willing to sign clear binding targets regarding the reduction of emissions. Although President Obama has sent signals for a more cooperative course of action, resistance at the domestic level is strong. Despite that, the US is still seeking to commit developing countries to contribute to the reduction of emissions.

The EU has tried to take a leadership role regarding climate change and attempts to bring negotiations forward. But this has to go beyond indentifying new ambitious goals. Concrete action is needed.

Most attention has to be paid to the new major emitters and rising economic powers such as China, India and Russia. These states have become key actors in international negotiations because of their rapid economic growth. They also perceive themselves to be international leaders (Dröge 2010a).

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48 http://www.wri.org/

One potential solution might be to loosen the strict framework of the UN negotiation process and to follow other paths to reach agreements concerning the protection of the climate.

As experts suggest, one is often too focused on the big negotiations in which many states are involved, and many interests and preferences have to be taken into account. Often it seems overambitious and unrealistic to try to achieve commitments when more than 20 nations are involved in the negotiating process (Dubash 2009). On the other hand, many global negotiations – e.g., negotiations on the Law of the Sea (see Box 4.7) –were eventually successful. Thus, it is still possible that new rules for global emission reductions could emerge from climate negotiations in the near future.

Box 4.7 The United Nations Convention on the Law of the Sea (UNCLOS) is an international agreement which defines the rights and responsibilities of nations regarding their use of the oceans.[49] It establishes rules for governing the collective use of the oceans and their resources. Since the UNCLOS came into force in 1994, 158 countries have joined the Convention.

We cannot deny that states are the most important actors in climate change politics. But approaches other than interstate negotiations should be taken into consideration as well.

For example, in the run-up to Copenhagen, China initiated its own climate protection programme which it presented as a *green revolution*. While economic growth still has the highest priority, Chinese political leaders have gradually paid more attention to energy efficiency and protection of the environment. China is willing to reduce emissions aside from commitments at the international level at its own speed and following its own rules. China is already a world leader in investing in renewable technologies. The Chinese government supports this with the objective of a 20 percent share of renewable energies by 2020 (Hilton 2009). Concerning Kyoto, China is not obliged to reduce emissions, yet China has – as self-obligation – the aim to stabilise emissions by 2020.

At the international level a joint effort by China and the US seems improbable because of their rivalry for international leadership. While the EU has taken a leading role in former times, it has often seemed inflexible – because of its political structure – to respond to recent dynamic international events (Dröge 2010a: 7). However, China's new role as a pioneer of the so called domestic green revolution may encourage other states to follow.

In this context, we can observe that the political discussion has turned away from the simple approach of mitigation against climate change and focuses more on adaption as a chance for technological and economic modernisation.

Meanwhile, a study realised by the University of Oregon and private economists in 2009 indicates that if the international community fails to reduce emissions significantly, this will incur billions of dollars each year (Niem 2009). Technological responses have to be developed to manage these impacts.

These estimates of the costs of inaction on climate change follow the earlier work by Nicholas Stern which also took a worldwide, economic perspective. The *Stern Review on the Economics of Climate Change* was published in 2006 by the World Bank's chief economist Nicholas Stern. In this report, initiated by the British government, the economic impacts of a change in global climate were analysed (Stern et al 2006). This report gained worldwide attention and is often instanced as a reason for action. The Stern Review and his more recent consideration of the matter in a book published in 2010 is analysed in detail in Chapter 3 of this module.

It has become more and more apparent, therefore, that climate change is not only a threat to the environment but also to security and the economy.

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49 http://www.un.org/Depts/los/convention_agreements/convention_overview_convention.htm

Some political scientists predict a new threat to the human race caused by what Welzer calls “Climate Wars” (Welzer 2010). Welzer forecasts that climate change will result in floods of refugees, wars for drinking water, civil wars etc. The possible relevance of environmental deterioration, or of access to resources, as factors accounting for violent conflict management has been debated in peace and conflict studies since the early 1990s (Homer-Dixon 1999, Bächler 1999, Kahl 2006) [50]. Special emphasis has been put on this presumed causal link in the context of global environmental change in general, or climate change more specifically (Matthew et al 2010). Growing concern has been raised in different reports of political think tanks that the impacts of climate change can lead to more violence on sub-national, national or international levels (Campell et al 2007). It is difficult, however, to establish always a direct causal link between climate change and violent conflict.

The negative impacts of climate change will occur primarily in developing countries. Water shortage, drought, flooding, extreme weather events – to mention only a few of these impacts – will deteriorate the living conditions of poor people and thus increase political frustration and the likelihood of political unrest. In many cases, the impacts of climate change bear the potential to strengthen the intensity of existing conflicts. The prevention of such possible climate-induced conflicts can possibly be achieved, however, by a combination of policies for mitigation and adaptation (Breitmeier 2009).

Existing studies already demonstrate that conflict over access to shared resources such as drinking water do not inevitably lead to violence but can be managed by international institutions. For example, conflict over access to drinking water or over water quality of rivers which cross more than one country is frequently managed peacefully by international river regimes (Wolf/Yoffe/Giordano 2003; see also The Water Case Study in this series). This demonstrates that special emphasis must be paid by policymakers and research to various types of governance systems as possible instruments for peaceful management of conflict arising from the impacts of climate change (see Box 4.8).

Box 4.8 Address to the UN International School-UN conference on ‘Global warming: confronting the crisis’, by the UN Secretary-General

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Secretary-General Ban Ki-moon

General Assembly

01 March 2007

Address to the United Nations International School-United Nations Conference on “Global Warming: Confronting the Crisis”

Welcome to the United Nations. It is immensely gratifying for me to see so many young faces in this General Assembly Hall. Here in this building, there is often talk about future generations and how best to serve them. Yet, it is a rare pleasure to actually welcome some of tomorrow’s leaders to today’s United Nations.

Walking into this Hall right now, I felt the sense of possibility and openness that all of you breathe into this space. You are unburdened by political agendas. You are free of restrictive governmental mandates. Indeed, your gathering symbolizes much of what is best about the United Nations: people of all nations and varied viewpoints coming together to deliberate and deliver on the foremost issues confronting the world.

50 Criticism, however, has also been raised against this hypothesis (See Gleditsch 2007).

Over these two days, as you consider the challenge of climate change, I am confident that your discussions will benefit from the sense of history and consequence permeating this chamber. But, I also believe that your energy can help inspire your older counterparts -- such as myself.

As you know, I am somewhat new to the United Nations system, having taken over as Secretary-General at the beginning of this year. In fact, I must confess to you that this is my first address on this podium as Secretary-General of the United Nations since I was elected. I have been waiting already two months, but there has been no General Assembly officially, and I am still waiting for an official General Assembly presentation in this august body. But, believe it or not, after two months, this is my first time to address any group of people on this podium since I was sworn in on 14 December.

Yet, like you, I started to identify with this Organization and its ideals at a very early age. A child of the Korean War, I grew up viewing the United Nations as a saviour; an organization which helped my country, the Republic of Korea, recover and rebuild from a devastating conflict. Because of decisions taken in this building, my country was able to grow and prosper in peace. This prosperity, in turn, helped a boy from rural Korea to rise up through his country’s diplomatic ranks and eventually become Secretary-General of the United Nations.

So, dear delegates, you may say that I not only believe passionately in the mission of the United Nations to “save succeeding generations from the scourge of war”, I have benefited directly from it.

Yet, if there is one crucial difference between the era I grew up in, and the world you inherit, it is of the relative dangers we face. For my generation, coming of age at the height of the cold war, fear of a nuclear winter seemed the leading existential threat on the horizon.

Today, war continues to threaten countless men, women and children across the globe. It is the source of untold suffering and loss. And the majority of the UN’s work still focuses on preventing and ending conflict. But, the danger posed by war to all of humanity -- and to our planet -- is at least matched by the climate crisis and global warming.

By now, I believe that the world has reached a critical stage in its efforts to exercise responsible environmental stewardship. Despite our best intentions and some admirable efforts to date, degradation of the global environment continues unabated, and the world’s natural resource base is being used in an unsustainable manner.

Moreover, the effects of climate change are being felt around the world. The latest assessment by the Intergovernmental Panel on Climate Change has established a strong link between human activity and climate change. The Panel’s projections suggest that all countries will feel the adverse impact. But, it is the poor -- in Africa, small island developing States and elsewhere -- who will suffer most, even though they are the least responsible for global warming.

That is why action on climate change will be one of my top priorities as Secretary-General. I am encouraged to know that, in the industrialized countries from which leadership is most needed, awareness is growing. In increasing numbers, decision makers are recognizing that that the cost of inaction or delayed action will far exceed the short-term investments needed to address this challenge.

The success of *An inconvenient Truth* suggests that, even amongst the broader public, climate change is no longer an “inconvenient” issue, it is an inescapable reality. As participants in the global carbon-based economy, all of us are part of this grave and growing problem. Now, each one of us also needs to commit to the search for solutions. We have to change the way we live, and rethink the way we travel and transact business.

By your presence here, you are clearly ready to take up this challenge. I know that your discussions will consider ways to mitigate global warming, and I am confident that you will take those lessons to heart.

One of the issues I hope you will consider is the urgent need to reframe the debate on climate change. Till now, this phenomenon has largely been viewed in isolation as an environmental issue. Yet, it is fast becoming increasingly clear, in North and South alike, that there is an inextricable, mutually dependent relationship between environmental sustainability and economic development.

Global warming has profound implications for jobs, growth and poverty. It affects agricultural output, the spread of disease and migration patterns. It determines the ferocity and frequency of natural disasters. It can prompt water shortages, degrade land and lead to the loss of biodiversity. And, in coming decades, changes in our environment and the resulting upheavals -- from droughts to inundated coastal areas to loss of arable lands -- are likely to become a major driver of war and conflict.

These issues transcend borders. That is why protecting the world's environment is largely beyond the capacity of individual countries. Only concerted and coordinated international action -- supported and sustained by individual initiative -- will be sufficient. The natural arena for such action is the United Nations.

I am strongly committed to ensuring that the United Nations helps the international community make the transition to sustainable practices. We are preparing for a United Nations Framework Convention on Climate Change conference in Bali in December. More broadly, the UN family is mobilizing all its efforts to address the many challenges posed by global warming. I plan to strengthen this work further.

Much more must also be done by Governments, business and civil society. This June, I plan to attend the summit meeting of the Group of 8 (G-8) industrialized nations, known as the G-8, where I shall discuss the issue of climate change with global leaders. The world needs a more coherent system of international environmental governance. We need to invest more in green technologies and smarter policies. And we need to do far more to adapt to global warming and its effects. There are growing opportunities for innovative businesses to spur progress and innovation through products that push all of us onto more sustainable paths. But, our efforts should focus particularly on the needs of the poor, who already suffer disproportionately from pollution, disasters and the degradation of resources and land. In particular, plans to implement the Millennium Development Goals should address the added risks posed by climate change.

We are all complicit in the process of global warming. Unsustainable practices are deeply entrenched in our everyday lives. But, in the absence of decisive measures, the true cost of our actions will be borne by succeeding generations, starting with yours.

That would be an unconscionable legacy; one which we must all join hands to avert. As it stands, the damage already inflicted on our ecosystem will take decades -- perhaps centuries -- to reverse; if we act now.

Unfortunately, my generation has been somewhat careless in looking after our one and only planet. But, I am hopeful that is finally changing. And I am also hopeful that your generation will prove far better stewards of our environment; in fact, looking around this hall today, I have a strong sense that you already are.

In that spirit, let me wish all of you a very successful and informative Conference.

UN Daily News

4.2.6 Back on track: The 16th COP in Cancun

The 16th COP took place in Cancun, Mexico, in December 2010, one year after the frustrating outcome of Copenhagen. In the run-up to Cancun expectations were kept deliberatively low and nobody made any claims that participants would produce a binding agreement.

The purpose of the summit in Cancun was not the development of a final and binding agreement, but it was expected that states would give clear signals of intent to establish further steps in the process. The Mexican host and foreign secretary Patricia Espinosa underlined this in her opening statement: “We need to send a clear sign of our desire to meet this global challenge. We must set the stage for further significant steps in Durban and beyond.”[51]

The outcome of Cancun was assessed more positively by participants and the global public than expected. The main issue was to attain a consensus about the future procedures regarding policies about climate change. One option was to amend the only legally binding agreement, the Kyoto Protocol, which requests countries to cut down emissions. Excluding developing countries and expiring in 2012, a number of countries stated that sticking with the Kyoto Protocol could be a burden for further developments. A new contractual framework was requested to follow the Protocol, including all countries.

As so often before in climate conferences, the final agreement called the “Cancun agreement” left this door open and postponed binding agreements to further negotiations. Thus, the Cancun Agreement contains mostly indefinite statements without concrete decisions for implementation. Nevertheless it is the first agreement accepted by all countries (with one objection) since the Kyoto Protocol in 1997. Only Bolivia objected, because it considered the Agreement to be not strong enough to mitigate global warming. The mutual consent was possible because Chairman Patricia Espinosa focused on reaching a consensus, leaving out objections or caveats during the final session in the early hours of the morning (Gray 2010). Thus she ignored the objections of Bolivia although these were incorporated into the Agreement in form of a footnote.

The Cancun Agreement signed by all 193 members (including Bolivia) was the first one in almost 15 years that was accepted by all countries. Especially the participation of the US, China and India was an important step. However, the core elements of the Cancun Agreement are mostly non-binding declarations of intent.[52] All in all it was a signal to keep climate change on the political agenda without making great efforts regarding implementation or binding obligations. Concrete actions and compromise were referred to the next COP (COP17) in Durban, South Africa in 2012.

Reactions of environmentalists and NGOs after the summit were fairly optimistic. Progress made in Cancun was appreciated and signals of support were sent concerning the final agreement (Usi 2010). More critical observers argued that the outcomes are indeed sufficient to keep the process alive but not effective enough to combat climate change. Espinosa, asked about her evaluation of Cancun, said it was “the best we could achieve at this point in a long process” (Carrington 2010). Nonetheless the documents provided in Cancun could be the basis for further efforts to establish a framework for a climate change convention after the Kyoto Protocol expires in 2012.

The most important consent reached in Cancun is the acceptance of the intention to restrict global warming and to cut greenhouse gas emissions by 2020. While this was already in the Copenhagen accord, it was incorporated in Cancun into the official UN process. For the first time developing countries also agreed to contribute to cutting emissions according to their resources and potentials.

Although these intentions were registered, they are not legally binding. Temperatures may still increase by more than 2 degrees – which the IPCC considers as the maximum acceptable threshold – beyond pre-industrial levels.

General consensus was reached by the partners that emission cuts will be monitored. It was agreed that a mechanism will be established for the monitoring of countries’ mitigation policies.

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51 http://unfccc.int/files/meetings/cop_16/statements/application/pdf/101208_cop16_st_espinosa.pdf
52 An overview of all elements of the Cancun agreement is available at the UNFCCC http://unfccc.int/files/press/news_room/press_releases_and_advisories/application/pdf/pr_20101211_cop16_closing.pdf

Concerning the financing of climate aid, a new climate green fund was agreed. The fund will transfer money from developed to developing countries to reduce the impacts of climate change. The board of the fund is to be made up of an equal number of representatives from developed and developing countries. No concrete financial promises were made by developed countries for the fund, which was left to the next COP (see Section 4.2.7 below).

The developed countries agreed in a separate decision to support climate action in developing countries with 30 billion dollars up to 2012. The intention to raise this amount up to 100 billion dollars in long-term funds by 2020 is included in the decisions.

Furthermore knowledge transfer of clean technology was discussed. A climate technology centre including a technology executive committee is to be set up, but no details were agreed as to how it will be funded.

Another key outcome was the adoption of the Cancun Adaptation Framework (CAF) where equal weight is given to adaptation and mitigation efforts.

A significant way to stabilise emissions, recognised by the parties, is the UN´s scheme to address deforestation. Known as REDD (Reducing Emissions from Deforestation and Degradation). The governments agreed to support developing countries with technological and financial aid to reduce emissions through curbing deforestation and forest degradation. Details about a timeline and concrete forms of action have still to be established.

4.2.7 The latest 17 COP conference in Durban

According to the UNFCCC, Durban in December 2011 "delivered a breakthrough on the international community's response to climate change." Even though most observers find this to be something of an overstatement, few deny that some wide-ranging decisions have been made. The most crucial issue that could be solved in Durban was the question of whether and how to proceed with the expiring Kyoto Protocol. All participants accepted the "Durban Platform for Enhanced Action" to prepare a legally binding agreement by 2015, which is intended to come into force in 2020. Unfortunately, the understanding to reach an agreement by 2015 is non-binding! Because the date and scope of the new agreement are still uncertain, the question remained of how to proceed with the Kyoto Protocol on its expiration at the end of 2012. To fill this gap, members of the Protocol proposed a second commitment period which will start on 1 January 2013 and run until 2017 or 2020. AS I write (March 2012) the exact end date of the second Protocol commitment period will be decided upon at the 18th COP in Qatar in November/December 2012. Meanwhile the current procedure guarantees the continuation of steps undertaken so far. Unfortunately, some countries of the Protocol namely Canada, Russia and Japan have indicated that they will not participate in the second commitment period. Also the US is still not involved in the second period as it was not in the first one.

While the organizers around the President of the Durban conference, Maite Nkoana-Mashabane, classified the agreement as a big step to "develop a protocol, another legal instrument or an agreed outcome with legal force under the convention applicable to all parties", most observers criticised it as being too vague and without enough progress. The phrasing in the agreement can be seen as ambiguous. On one hand, there is a lack of clearness and explication of how a future roadmap might look. On the other hand, this imprecision might have been the reason that all participants agreed to it.

In addition to the huge obstacle of Post-Kyoto, a bundle of open questions were closed that had remained from the previous year's meeting in Cancun. The most urgent issue was the final design of the Green Climate Fund for developing countries. The GCF was operationalized and is the major supplier of financial assistance with about 100 billion dollars. This private and public fund will be subsidized for adaptation and mitigation activities – which will be given equal weight – by developed countries annually until

2020. The completion of the GCF also included the establishment of new bodies and mechanisms which support climate adaptation, financing and technology.

Other less important decisions were made in Durban including among other things:

- A new market-based mechanism for cost-effective ways to reduce emissions;
- To enhance transparency in addressing the emissions of the different countries;
- The consideration of agriculture as an issue relating to climate change.

4.3 Actors in global climate change politics

In the previous section, we described negotiations about regulations for the mitigation of climate change. In this section, we focus on the main actors who determined this process and on their interests and goals.

As we have already indicated, world politics is more than interstate relations. States are certainly the dominant actors in international negotiations because they make decisions, lead negotiations and finally sign and implement legal agreements. This has also been the case with respect to climate change. States have lost their monopoly, however, as the only representatives of the will of their peoples at the global level. The arena in which global governance takes place has experienced the growing relevance of political actors other than the state. In the following we differentiate and examine five main types of actors and their networks: nation states, international organisations, NGOs, transnational companies, and scientific and technical experts.

4.3.1 Nation states

A review of the literature concerning global politics still shows that nation states are the most important authority in the international system. As a consequence they remain the most common object of analysis in international politics, and climate change politics is no exception.

Governments are the only actors who are able to sign or to vote for international treaties. States can draw on diverse resources such as economic or military power, political and/or social legitimacy, which empower them to meet their respective goals (O´Neill 2009: 49). In addition, states are the only actors which are able to declare war, impose trade barriers or set economic regulations.

Beyond these resources, states have specific powers that characterise them as nation states. They have jurisdiction over their territory and a broad political and administrative apparatus. States have unchallenged rights in international society. The norm of non-intervention posits that states are not allowed to interfere with the national politics of other states. This right is based upon the principle of state sovereignty.

In the field of political science, especially in international relations, we can observe a long lasting debate about the character of the state. According to Kenneth Waltz and the theory of *Realism*, states can be perceived as homogenous units (Waltz 2008).[53] Thus they are treated as a monolithic block whose interests have to be analysed. Because states act in an international system which is characterised by ‘anarchy’, meaning that there is no centralised, global coordinating power, they strive for their own power to maintain their position or to expand it. Many theories emphasise that the state is the central actor in explaining international politics. *Neorealism* (Morgenthau 1954) considers states as the relevant actors in international politics, but there is no analysis in *Neorealism* about the attributes of a state and how these attributes affect the process of interest formation within the state.

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53 For an overview about theories in international relations see for example (Dunne 2007).

In contrast, *liberal* theories highlight the role of different actors *within* the state, which compete in the process of interest formation (Moravcsik 1998). While the realism approach emphasises that the international system is the centre of analysis, liberal theories focus on the role of different groups and actors within states. They argue that states have no fixed interests. There are several actors in a state which try to influence interest formation. This is the case in many environmental issue-areas where the position of governments is simply the outcome of a process in which domestic groups such as private firms, environmental organisations, experts, the media etc. are involved.[54] In summary, we should keep in mind that states are not 'black boxes', but that they are under the influence of endogenous factors such as different domestic groups on one hand, and exogenous factors such as international governmental organisations on the other hand. This will be discussed in the following section.

The discussion about the changing role of the nation state is closely connected to a broader debate about the impact of globalisation. Many theorists of globalisation argue that the impacts of globalisation are resulting in the reduced ability of individual states to influence world politics and to govern social, economic or other affairs at the domestic level. This enhances the influence of other actors in world politics: NGOs, global civil society movements, international organisations, transnational companies, scientific experts etc. Yet, despite the effects of globalisation, we can still claim that states are the only actors able to negotiate and agree on international treaties, establish international organisations, provide financial resources, and the only actors that act on a relatively broad, democratically legitimate basis.

Unsurprisingly, we observe many of these functions of states in international climate change politics. Although other actors have increased their engagement, it is the state which is the only actor able to set binding commitments on greenhouse gas emissions and provide the appropriate resources. In addition, it is the nation state which can guarantee domestic implementation of international norms and rules.

4.3.2 International Governmental Organisations (IGOs)

Inter-governmental Organisations (IGOs), which by definition are 'international', are set up by states. Their foundation is mostly the result of interstate negotiations.

After the Second World War states were confronted with many international problems because of their increasing interdependence. This process often labelled 'globalisation' has produced a need for international coordination as it does not fit easily with the notion of 'anarchy' in the system. Thus one of the primary tasks of IGOs is to manage international problems, which would less effectively be managed by independent state action (Haas 1990).

Thus IGOs coordinate and contribute to collective problem-solving in international environmental regimes. These regimes are social institutions (see Box 4.2 earlier in this chapter) which consist of principles, norms, rules, decision-making procedures and programmatic activities (Breitmeier/Young/ Zürn 2006). The broad majority of transnational environmental problems are managed in these governance systems. Most problems are caused by multiple factors, which are not all situated within the states, for example problems of the international economy such as trade, foreign direct investment, capital flow etc. This means that several actors at different levels are part of the problem. This is also true for climate change where countries which are mainly responsible for causing the problem are not identical with those who are mostly affected. IGOs provide a forum where negotiations take place and collectively binding decision can be made.

Although IGOs depend on the financial and political support, and hence tend to reflect the interests, of their member states, they can establish an autonomous character. The prime example is the UN which has its own apparatus including an autonomous staff.

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[54] See also Prittwitz (1990) and the triangle of interest.

Sometimes, IGOs such as the UN develop political initiatives independently of states and bring issues to the global agenda. This frequently results from the work of scientific and technical experts or networks which collaborate in programmatic activities established by IGOs for the purpose of improving knowledge about the causes and consequences of an environmental problem. For example, the World Meteorological Organisation (WMO) and UN Environment Programme (UNEP) have jointly contributed to the broadening of the knowledge-base about climate change since the 1990s and created the Intergovernmental Panel on Climate Change (IPCC). They have offered scientific experts an arena in which they could coordinate national climate research programmes. But IGOs also lack democratic legitimacy and are frequently criticised on these grounds.

A special kind of IGO is the European Union (EU). Although it consists of individual and sovereign member states, it often acts like a unitary actor in international politics and has the authority to sign international binding agreements (see section 4.2.4 about the Kyoto Protocol). The EU is an important regional key player in climate negotiations.

4.3.3 Non-Governmental Organisations (NGOs)

International regimes function as arenas for state negotiations. But non-state actors can influence the development or implementation of transnational policies within these arenas (Breitmeier 2008: 40). The number of non-state-actors has risen dramatically since the end of the Second World War, especially in the field of environmental politics. Because of the increasing importance of international politics, more and more actors organise themselves on the transnational level. The most important and most numerous actors are Non-Governmental Organisations (NGOs), which try to shape the international system.

Predecessors of what are today generally known as NGOs existed in the 19th century. Environmental NGOs gained relevance, however, only during the second half of the 20th century. When we consider NGOs as a category, we have to take into account that a clear definition of NGO has not been agreed in the literature (Yaziji/Doh 2009: 4). The term “non-governmental organisation” was established by the UN in 1950, which wanted to consult organisations which were independent of government influence. Criteria for being accredited as an NGO differ widely. For example, the Union of International Associations (UIA – a research institute and documentation centre under UN mandate, based in Brussels) has a narrow concept of NGOs. The UIA accepts associations as NGOs if they meet the following criteria:[55] They:

- Are founded as a result of a private initiative
- Have a headquarters with a permanent staff
- Have an international membership
- Are active in at least three states
- Obtain funds in at least three states
- Are independent from the influence of states
- Have an election mechanism for their governing body and officers

The total number of NGOs increased rapidly at the end of the 1980s with almost 5000 being registered. Especially within the framework of the big international UN conferences in the 1990s, for instance the Earth Summit of 1992, the acceptance and

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55 For other definitions of NGOs see for example: http://library.duke.edu/research/subject/guides/ngo_guide/igo_ngo_coop/index.html

influence of NGOs increased. According to the UIA, 7628 NGOs were registered in 2007 worldwide.[56]

NGOs are associations acting on behalf of, or in connection with, civil society (see Box 4.9.). If individuals in civil societies centre on a common idea or interest they tend to organise themselves to take collective action. This often results in the form of a social movement. When different groups in civil society come together to form a more organised relationship, the emerging entities are often labelled NGOs (Yaziji/Doh 2009:4). One elementary characteristic that distinguishes NGOs from IGOs is that that they are independent of direct state influence, theoretically at least, and therefore are self-governing. They act on a non-profit base and their activities are mostly not driven by commercial interests. Mtypes of organisations are subsumed under the term NGO, and they all reflect different interests.[57] Furthermore, NGOs differ in their organisational structure and follow different strategies and goals. Within NGOs there is a great variety of stakeholders such as financial contributors, executives, board members, staff and beneficiaries.

Box 4.9: Civil society is a concept introduced by Alex Ferguson in the 18th century. Civil society can be understood as a sphere between state and privacy. This sphere is occupied by several organized groups which autonomously pursue material and immaterial interests. Often identified with NGOs, civil society encompasses all organized activities like for example citizens groups, religious associations and various interest groups. The existence of civil society presupposes an efficient state of law including individual and civil rights.

In contrast to states, NGOs lack formal resources for influence, for example voting rights in international organisations, the ability to sign treaties etc. However, they can act independently from state interests or other forms of interference (Scheppers 2006: 284). This independence is guaranteed, for example through excluding government representatives from membership in their organisations.

One role that NGOs often play comprises direct aid in the form of providing assistance where nation states lack willingness or resources to fulfil their responsibilities. Thus, NGOs are especially active in regions where nation states cannot provide social needs because of corruption, unwillingness, low capacity or externalities like war or natural catastrophes which require emergency assistance. This is often called the “service” function of NGOs (Yaziji/Doh 2009: 8). The second, and more prevalent in the case of climate change, is their role as “advocacy” NGOs, where their main intent is to influence the social, political or economic system to promote/advocate an interest or concern. In this, they try to persuade governments or other actors in the international system in the process of policy formulation. Thus NGOs are engaged in processes of monitoring, they are advisory experts, organisers of conferences, of symbolic action and so forth. In practice, individual NGOs can provide both services and play an advocacy role.

Thus, NGOs are an important element of the contemporary international system. They enhance the legitimacy of climate change issues at the international level and try to assure that the interests and needs of civil society are taken into account.

4.3.4 Expert groups

The influence of expert advice has risen during recent decades. Although there is a broad discussion about the influence of expert advice, a prevailing enhanced need for scientific knowledge can be observed in nearly all parts of society (Nelkin 1975; Resnik 2009). In a complex and sophisticated world, more and more decisions rely on the advice of experts. This expertise, especially that of the scientific community, is conceived as

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56 Union of International Associations (UIA), Yearbook of International Organisations: Statistics on international organisations.

57 For a further explanation see (Yaziji, Doh 2009: 6 ff.)

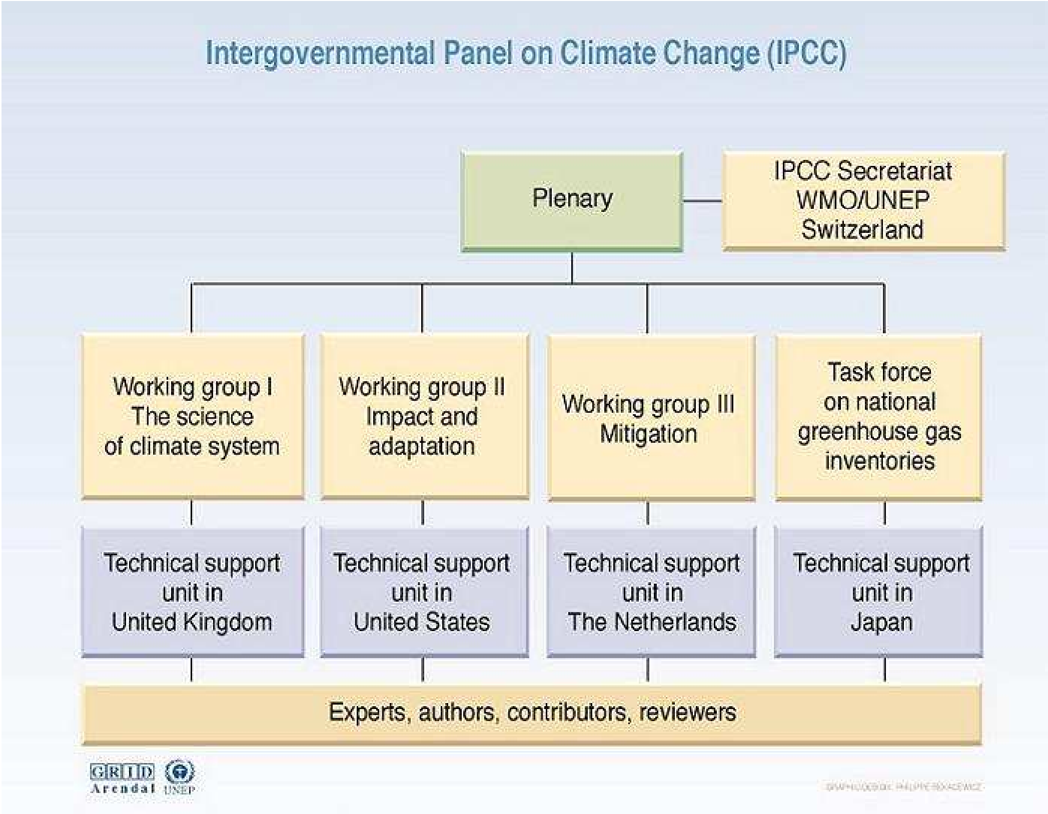
advanced knowledge, which is objective and reliable. Thus it is often conceived to be recognised above other forms of knowledge and therefore privileged. However, although in an ideal model experts should be free from political influence, states often provide a significant part of the infrastructure for scientific research. A famous example in climate change is the IPCC, which serves as a body for scientific advice, but was established by states within the UN system. As well as the IPCC, several forms of international cooperation have emerged to provide scientific or technological expertise.

Scientific and technical service organisations can carry out various functions (Breitmeier 2008: 44ff). They collect knowledge about the causes and effects of environmental problems. The production of assessment reports helps decision makers to identify their interests concerning a global problem. This function has been (and is still) carried out by climate scientists and through interdisciplinary collaboration between scientific disciplines. Many global research programmes that are carried out by international organisations strengthen this function of climate scientists. Scientific and technical service organisations produce expertise for single states, international institutions or other non-state actors. For example, they support multilateral organisations such as the World Bank in the assessment of possible projects designed for the financing of global warming mitigation measures or for the preservation of carbon sinks (i.e. forests which absorb carbon dioxide) in developing countries. In addition, they provide the expertise for the implementation of these projects.

In the area of climate change a major discussion has evolved about the role and influence of science in international climate change negotiations (see for example Mitchell et al. 2006, Skodvin 2000, Agrawala 1998 and 1999). Especially in the beginning of the climate change debate, there was much uncertainty regarding the causes and impacts of a change in climate. In 1988, the two UN agencies WMO and UNEP set up the Intergovernmental Panel on Climate Change (IPCC), to which we have referred several times already in this chapter. The IPCC's task was to ascertain scientific data about the state of climate change, to assess critically scientific, socio-economic and technical information as well as potential impacts and options for adaptation and mitigation.

The IPCC itself does not do research on climate change, it collects and evaluates scientific data. On this basis it regularly publishes assessment reports about the likelihood and impacts of climate change. The latest (4^{th}) report (at the time of writing) was released in 2007 (IPCC 2007). Although it has been, and still is, often under attack by the media and political decision makers, the IPCC has gained and maintained its influence in climate change negotiations (Beck 2009). Its assessment reports have often provided the stimulus for international agreements, for example the second assessment report in 1995, which provided key input for the negotiations leading to the Kyoto Protocol (Bolin 2007). Critics often argue that the IPCC is not a scientific body and moreover under political influence. The IPCC itself, however, claims to be a scientific body where peer-reviewed research is evaluated according to scientific criteria. As this chapter is being written its 5^{th} Assessment Report is being prepared for publication in 2014.

The institutional structure of the IPCC clearly attempts to demarcate between scientific independence and political engagement. Thus, it is divided into three working groups (see Figure 4.2). Working Group (WG) I and II are exclusively science-based and address scientific questions, the former assessing the science of the climate system, the latter impacts and adaptation. In contrast, WG III assesses policy options for the mitigation of climate change through a kind of forum where science and politics interact. As raw scientific facts are complex and abstract (see chapter 2 of this module) they have to be transformed into policy relevant knowledge.



Source: United Nations framework convention on climate change (UNFCCC).

Figure 4.2 Intergovernmental Panel on Climate Change (IPCC)

Following Beck, the IPCC has maintained its authority and independence by putting emphasis on drawing clear lines between science and politics (2009: 87 ff.) Refusing to be drawn into the political process the IPCC might have missed opportunities to be influential, but has earned a high reputation. The highlight was the award of the Nobel Peace Prize in 2007 to IPCC and to ex-US Vice-President Al Gore, “for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change”.

4.3.5 Multinational firms and business associations

As the above sub-sections demonstrate, evolution of the social order in world politics is not only dependent on states. Global governance in issues such as security, the environment, or social and economic welfare requires the participation of non-state private actors (Wolf 2008: 225). The role of business actors and their influence on interstate negotiations has long been obscured by political science, but this view has changed in the last decades (Breitmeier 2008: 45). The relevance of national as well as transnational firms, and of industrial associations, has constantly grown in the context of climate change negotiations.

These groups are motivated to engage in international climate change politics for several reasons. The creation and implementation of effective policies to mitigate or adapt to climate change affect the activities of private businesses in various ways. Thus they can constrain business actors as climate policies often involve requirements which lead to government regulations and costs, potentially reducing the profits of these actors. Some businesses can even be so affected by these regulations that their existence will be threatened in the long-term.

Climate policies, however, can also provide new opportunities or prospects for economic profits. For example, a broad range of economic actors, which is focusing on the development of new energy-efficient technologies, can benefit from structural technological change that is caused or reinforced by climate policies. This change involves the creation of improved global market conditions for these firms which make their technologies competitive vis-à-vis traditional facilities or ways of production. As a consequence, firms form national and transnational business associations which try to influence decisions of states or negotiations according to their own interests. A famous example of one such business association is the Global Climate Coalition (GCC) which was set up in 1998 and dissolved four years later. The GCC was an association of mostly American business groups whose goal was to oppose international efforts to reduce greenhouse gas emissions. It consisted of large transnational firms such as British Petroleum (BP), Daimler Chrysler, Exxon, the Ford Motor Company and so forth. Their main strategy to prevent political action for the reduction of emissions was to deny that the problem even exists (Menestrel, Hove, Bettignies 2002: 256). Therefore they mainly challenged climate science, especially that which emanated from the IPCC.

The GCC was also active domestically in the US. For example, it lobbied against the ratification of the Kyoto Protocol by the US Senate, asserting that targets for greenhouse gas emissions would damage economic growth in the country and lead to rising energy prices for consumers. To illustrate the dramatic impacts of a ratified Kyoto Protocol on energy prices, the GCC published a report in May 2002 (GCC 2002). The report summarised the major findings from four studies about the impact of Kyoto on the US economy. Although the organisation was dissolved in 2002 it is a good example of the influence of economic actors.

Research has demonstrated that private actors cannot be reduced to business activities which are only commercially-driven (Wolf 2008: 234). Alternatively, business activities can also be understood as a form of norm generation (see Box 4.2 earlier in this chapter) and implementation, trying to foster international commitments.

Under the surveillance of NGOs, consumers, politicians and the media in recent years, business actors have made considerable efforts to demonstrate their sense of broader social responsibility, being aware that they could face a consumer backlash if they do not do so. Thus business actors have become increasingly aware that aspects of environmental protection must be integrated into their economic activities (Breitmeier 2008: 45). They often use the international attention that is given to climate change as an opportunity to show their commitment to solving environmental problems.

During climate negotiations, business actors will often contribute their knowledge and experiences to assess policy options. These reviews can help politicians to calculate better the consequences of their agreements for the economy. International environmental institutions also often collaborate with firms to facilitate the implementation of agreements in developing countries.

As we have seen in the example of the GCC there is frequently a tension between economic and environmental interests. But this tension is not inevitable and international environmental policies or changing consumer patterns can change market conditions substantially so that the prospects for environmentally sound technologies are improving on global markets. Some business actors have reacted to the challenge by reducing their emissions unilaterally. Others fear competitive disadvantages because of their energy-intensive methods of production and/or other high costs of change to help mitigate climate change.

In summary, business actors can have an influence on environmental politics in several ways. They follow the international debate about environmental issues and thus try to support or prevent agreements according to their own interests. It is already possible that those business sectors which are focusing on new environmentally sound technologies are lobbying together with environmental NGOs for stricter climate policies. In such a changing context, new coalitions emerge between NGOs and environmentally focused industrial sectors. In contrast, life might become harder for traditional sectors whose business is heavily dependent on energy-intensive ways of production or on the trading and sales of fossil fuels.

4.4 The actors in international climate change: pushers and laggards

In the previous section we conceptualised the different types of actors. In this section we identify the main conflict lines in international climate change politics. This inevitably moves us towards a focus on interstate relations again, although we do not ignore other actors and the roles that they play in the conflict lines.

We categorise actors by their general attitudes and roles towards climate change into two groups: *pushers* and *laggards*. Empirically, however, we can easily identify actors who have changed their interests or represent a more moderate position. Thus the distinction between pushers and laggards is always a dynamic one. In one phase of a negotiation a state can be a pusher whereas in another it might be a laggard or vice versa.

The distinction between pushers and laggards includes what Paterson calls the "two great conflicts" (1996: 73) in international climate change politics. The first is between the US and the rest of the world. More precisely Paterson identifies opposing perceptions about the extent to which greenhouse gases should be limited and what instruments should be used for this purpose. The second more pervasive conflict is between countries from the North (developed or industrialised countries) and countries from the South (developing or industrialising countries). Although a clear separation between North and South has become more difficult during the development of climate change politics, this conflict can still be observed in every aspect of it (Timmons/Parks 2007; see also Section 4.4.5 below).

If we examine the beginning of international climate change politics (see section 4.2), we can easily identify actors belonging to the groups of pushers and laggards. Because political actors were not involved until the Toronto Climate Conference in 1988, it was mainly natural scientists who applied the pressure for action on a changing climate (Okerkeke 2010). One example is Bert Bolin, a Swedish climate scientist who was acclaimed several times for his research on climate change. Bolin was one of the founders of the IPCC and its first chairman. During his term of office, and beyond the IPCC, he strongly called on states for action on climate change and for binding commitments to mitigate its impacts. Bolin was therefore a pusher and, with its published assessment reports, the IPCC has taken a leadership role, gaining scientific credibility and political legitimacy until the present day, as previously noted. Thus scientists and their organisations provided intellectual leadership for climate change politics (Andresen, Agrawala 2002).

As well as science, other organisations also have provided leadership in climate change politics. The United Nations Environmental Programme (UNEP) established in 1972 is not a scientific community but funds research and enhances its policy relevance. When scientists raised concerns about the impacts of climate change it was UNEP which strongly advocated the development of mitigation policies (Agrawala 1999). It was UNEP which combined with the WMO to create the IPCC.

4.4.1 States take over the lead

Although the IPCC is an important player it is not directly involved in the negotiation process. It provides scientific knowledge which serves as an epistemic basis for conferences (e.g., its second assessment report before the Kyoto conference in 1997). From this point, states are mainly responsible for the progress or failure in establishing climate change policies. Paterson even asserts that the IPCC, because of its intergovernmental character, was a manoeuvre by states to obtain control over the scientific community and its advisory process (Paterson 1996: 124).

Nevertheless, the IPCC has remained an important pusher and is still raising its voice for reducing emissions. Single states like the US under the Presidency of George W. Bush have, however, tried to undermine its credibility and legitimacy, through raising serious doubts about the causal connection between carbon-emissions and the greenhouse effect.

Using, and sometimes sponsoring, the work of a small number of sceptical scientists, they have tried to erode the IPCC and the scientific consensus it has established. The ultimate intention has been to erode the arguments used by pushers for strong measures to reduce greenhouse gases.

4.4.2 Pushers: the European Union and the Alliance of Small Island States

According to most observers, the European Union (EU) is one of the most important pushers for mitigating climate change. Since the beginning of negotiations it has taken a self-declared leadership position.

Andresen and Agrawala (1999: 45) argue that the EU wanted to fill the leadership vacuum which the US had left in climate change politics. They also claim that this was a chance for the EU to present itself as a strong and unified block. This becomes understandable if one examines the political situation of the EU in the early days of the climate change regime. At the end of the 1980s, the so-called European Community (EC) was not a homogeneous actor and had no coherent foreign policy. Most of the members tried to follow their own political interests and developed individual positions in international negotiations. The issue of climate change was conceived to be an opportunity to overcome these tendencies.

Right from the beginning the EU emphasised its obligations not just to formulate a common strategy within its territory but to recognise the responsibility to help poorer countries (Giddens 2009: 193). Beyond that, climate change was seen as an opportunity for ecological modernisation (Box 5.0), which had already been initiated in Germany and the Scandinavian countries. Renewable energies especially were supposed to take a leading role, with an ambitious goal to increase their share in the EU's energy mix to up to 20 per cent.

Box 5.0. Ecological modernisation is an approach which has its roots in the discipline of environmental social science. Ecological modernisation has gained growing attention in research as well as among policymakers, especially in Europe, North America, and Japan. The concept was first introduced in an article by Spaargaren and Mol in 1992. One key characteristic of the theory is that most proponents see continuous technological development as the best option for escaping the ecological crisis of the developed world (Fischer/Freudenburg 2001: 702). In contrast to many other theorists who criticise the over-reliance on ongoing technological development alone, ecological modernisation highlights its potential benefits in dealing with the ecological crisis. Nevertheless, to date the concept of ecological modernisation is limited by inconsistencies and incompatibilities in the interpretation of the theory.

In climate change negotiations the EU often follows the strategy of leading by example. For example, at Kyoto the EU agreed on an internal burden-sharing arrangement and presented itself as a unified block. This ambitious action, which was acclaimed by civil society environmental movements, put pressure on other more reluctant parties (Andresen/Agrawala 2002: 47). Thus, throughout the international negotiation process, the EU has consistently announced ambitious targets to cut emissions and reduce the global temperature rise. In January 2007, the European Commission formulated a strategy to mitigate climate change and reduce the temperature increase to 2 degrees compared to pre-industrial levels. According to this strategy industrialised countries are supposed to reduce emissions by 30 per cent compared to 1990 levels by 2020.

In trying to reach the announced targets, the EU has put special emphasis on its local market. It has established the European Emissions Trading Scheme (ETS), which allows the trading of emission certificates within the EU market.[58] Although the European Union is often treated as a single actor, it obviously consists of a number of member states, all of which have individual preconditions and interests. If there is for example, a

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[58] http://ec.europa.eu/environment/climat/emission/index_en.htm

debate on the role of renewable energies, states start from different positions and backgrounds. Economic circumstances may also play an important role. Countries from the south of Europe put more effort into achieving economic growth and less attention to emission reduction than countries such as Germany, which, for example, benefit from exporting solar energy technologies. In contrast, French ex-president Sarkozy refused to accept emission targets by arguing that France, through its use of nuclear power, had already lowered emission levels (Giddens 2009: 194).

Strong pushers in the early phase of climate change politics inside the EU were countries like Germany, the Netherlands and Denmark who were called the rich and green EU countries during the negotiations at the 1992 Earth Summit (Ringius 1999). They either adopted their own targets to halt emissions (an interesting example being Norway which is a non-member-state) or to reduce them (Germany and the Netherlands). It soon became apparent, however, that these targets were too ambitious, although it underlined their commitment to climate change politics. Moreover, these same countries have been strong advocates of binding targets in international climate change negotiations. Under the EU bubble negotiated in Kyoto in 1997, Germany and the Netherlands committed to reducing emissions by 21 per cent, which was the most far-reaching obligation within the EU.[59]

Another – less influential, but often relying on its symbolic power – pusher is the Alliance of Small Island States (AOSIS), which is a coalition of 43 low-lying and small island countries drawn from all oceans and regions of the world. They are also members of the G77 developing countries group. The AOSIS states are united by their vulnerability to sea-level rise and extreme weather events resulting from climate change. IPCC reports suggest that the very existence of some is threatened. As a result they demand compensation as well as advocate a significant and binding reduction of emissions. They were first to propose a draft text during the Kyoto Protocol negotiations, which called for cuts in carbon dioxide emissions of 20 per cent compared to 1990 levels by 2005.

4.4.3 Laggards: the United States, JUSSCANNZ, OPEC, the G77 and others

The US can be seen as the crucial actor in the group of laggards. This becomes obvious if we look back on the behaviour of the US in climate negotiations.

The reasons are not hard to find. The energy system of the US depends heavily on oil. In addition, the extensive use of energy by the US economy and domestically, and comparatively cheap energy prices, serve as structural constraints to a rapid transition to an environmentally sustainable energy system.

Thus, the US consumes the most oil per capita (head of population) and overall the second most fossil energy (coal, gas and oil combined) in the world behind China. Today (2012), it accounts for 20 per cent of greenhouse gas emissions, again the second behind China.[60] As a result, the scepticism towards action in climate politics can be observed at an early stage. Presidents Bush senior and junior were sceptical about the scientific evidence and even questioned the existence of global warming while simultaneously advocating more research.

One important reason for the laggard role of the US is the strong influence of domestic interests, which shape the action of the US government on the international level. At the domestic level, the potential costs of reducing greenhouse emissions were considered to be extremely high. In contrast to other countries like Germany the need for green technological and sustainable development was not an important topic on the political and public agenda for a long time. Some researchers also see a cultural aspect in the

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[59] Only Luxembourg was committed to reduce emissions by 28 per cent.

[60] http://www.bp.com/assets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2011/STAGING/local_assets/pdf/statistical_review_of_world_energy_full_report_2011.pdf

mindset against climate change action. In the US low energy prices are essential for mobility especially in rural areas.

All this can help explain why the US has been a laggard in climate change politics. Even when political leaders like Presidents Clinton or Obama seemed to have a more cooperative position towards international binding agreements, they always had to take the strong opposition from domestic groups into account. One severe institutional hurdle is the US Senate which has to ratify international legal agreements with a two-thirds majority. For example the ratification of the Kyoto Protocol was rejected by the US Senate, emphasising that it would be a great threat to the US economy and its competitiveness. Furthermore senators argued that developing countries should also be obliged to reduce emissions. Here the conflict between North and South becomes observable. In general, even though the rejection of the Kyoto Protocol by the US was more than ten years ago, no fundamental changes have been made concerning these objections.

To enhance their influence states also form groups to gain a stronger position in negotiations. A good example of a strong group of laggards is the JUSSCANNZ. The JUSSCANNZ was a group of states which aligned in the run-up to the Kyoto conference as a loose coalition of non-EU, developed countries. It consisted of Japan, United States, Switzerland, Canada, Australia, Norway (see Section 4.4.4 below) and New Zealand. Although they all had different approaches to a concrete course of action they had a common interest to prevent binding commitments to mitigate climate change (Oberthür/Ott 1999: 18). The main reason behind this was that they discovered that the cost of emissions reduction would be much higher than expected. The JUSSCANNZ was not based on any formal rules; instead it can be understood as a group united by a common motivation. Because their members were influential states like the US, they were able to prevent strong commitments in the Kyoto negotiations (Oberthür/ Ott 1997). After the adoption of the Kyoto Protocol the JUSSCANNZ transformed into the UMBRELLA Group, additionally including the Russian Federation, Ukraine and Iceland.

We can also find other laggard groups working together to enhance their influence in negotiations because they have congruent interests. Examples are the Organisation of Petroleum Exporting Countries (OPEC), a group of countries of Central Asia, the Caucasus, Albania and Moldova (CACAM), and countries that are members of organisations such as the League of Arab States and the Agence Intergouvernementale de la Francophonie.[61]

An influential group representing the interests of the developing countries is the G77. The G77 was founded in 1964 by 77 developing countries in the context of the UN Conference on Trade and Development (UNCTAD) and now operates throughout the UN system to establish a common position in international negotiations. It has since expanded to 130 countries. It includes China and is one of the biggest groups in climate politics. The chair of the G77 is held by one state and rotates every year. Because of the great number of members, the G77 has been able to make itself heard in climate change negotiation processes and to criticise industrialised countries for their insufficient action while simultaneously refusing binding commitments for its own members. However, because the G77 reflects diverse countries and different interests, some members tend to voice individual positions regarding climate change. China especially often intervenes in debates regardless of the common position of the G77 (Oberthür/Ott 1997). Although the G77 is a clear laggard in terms of emission reductions, in recent years it has been engaged in pushing for adaptation measures.

Beside laggard states we can also find a number of non-state groups and consortia acting at both the international and the state levels to prevent international commitments in climate change politics. These groups predominantly represent economic interests of the

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[61] See http://unfccc.int/parties_and_observers/parties/negotiating_groups/items/2714.php

private sector and seek to avoid competitive disadvantages resulting from climate agreements. They often assert that if they are constrained by rules and regulations they will shift production to countries without these restrictions. Another strategy is that, instead of shifting production, they claim compensation from states to balance the competitive disadvantages.

As already noted, the EU is predominantly a pusher for commitments against climate change. However, within the EU there are strong laggard groups which try to influence the EU´s policy or national policies of its member states. Again, private sector groups often fear a competitive disadvantage resulting from climate change obligations. This could for example be observed during the German struggle to reduce CO_2 emissions from new cars. The EU tried to set a maximum limit of 120 grammes of CO_2 emissions per driven kilometre for every new car from 2012. In Germany particularly there was a strong lobby against such binding limits, especially for high class cars. Because there are many producers of these cars in Germany who form the lobby, the government strongly resisted all commitments which might restrict the competitiveness of the German car industry. This example illustrates the duality which often occurs because of the tension between preventing climate change on one hand and the resulting economic disadvantages or other drawbacks on the other hand (see also chapter 3 of this module).

In general, emission targets often seem to lose priority when they overlap with other problems that are higher on the political agenda. This could for example be observed throughout the crisis of the international financial markets in October 2008 when the heads of government from Italy and Eastern European countries voted for a deferment of the EU´s plans for emission targets (Giddens 2009: 195).

4.4.4 From pusher to laggard and vice versa

Although we use the distinction between pushers and laggards we have to take into consideration that this classification cannot be applied to all actors involved with the climate change challenge. While some states like the US or Germany can obviously be categorised into one or the other of these groups over the whole period of climate change negotiations, in other cases the classification is not so clear.

Norway constitutes a good example of a complete turnaround of one country’s position in climate change politics. Andresen and Butenschøn (2001) have analysed the reasons.

In the early days of international negotiations Norway acted as a clear pusher in international climate conferences. In the 1980s Prime Minister Brundtland was the chair of the United Nations Commission on Environment and Development whose report was named after her. In addition, she was the only head of government who participated in the Toronto climate conference in 1988. Furthermore Norway was the first country to adopt self-obligations in stabilising emissions and to introduce a CO_2 tax (1991) (Andresen/Butenschøn 2001: 339). Hence the Norwegian government was originally a leading proponent of establishing an international climate change regime.

Thus Norway could be categorised as an early pusher. While this position was maintained during the 1992 Earth Summit process, a change could be observed in the pre-Kyoto conference (1997) process and beyond. Norway called for joint international efforts to integrate most developed countries into the Kyoto Protocol. In the run-up to the conference, Norway joined the JUSSCANNZ negotiation group, which was against binding commitments and hence a laggard (see above). After the Kyoto conference, Norway joined the UMBRELLA successor of the JUSSCANNZ.

Taking all this into account we can ask how such a reversal happened in Norway and what the main reasons were. Although Andresen and Butenschøn try to explain this reversal there is no easy answer and several factors have to be considered. One major reason was the waning of “public environmental enthusiasm” which had developed during the 1980s (Andresen/Butenschøn 2001: 343). After that early period of enthusiasm, however, the approach was soon questioned by several actors within the state, the private sector, research institutions and among key policy makers. As a result, an initiative to replace coal by gas to reduce emissions failed. Besides, the public was not so alarmed about environmental issues anymore. Taking this special situation into consideration in the Kyoto Protocol, Norway was allowed to increase emissions by 1 percent. Nevertheless latest data shows that Norway will not be able to accomplish this target (see Figure 4.3). To reach it Norwegian companies had to purchase certificates on the emission market. Only in this way can Norway's obligations under the Kyoto Protocol be fulfilled.

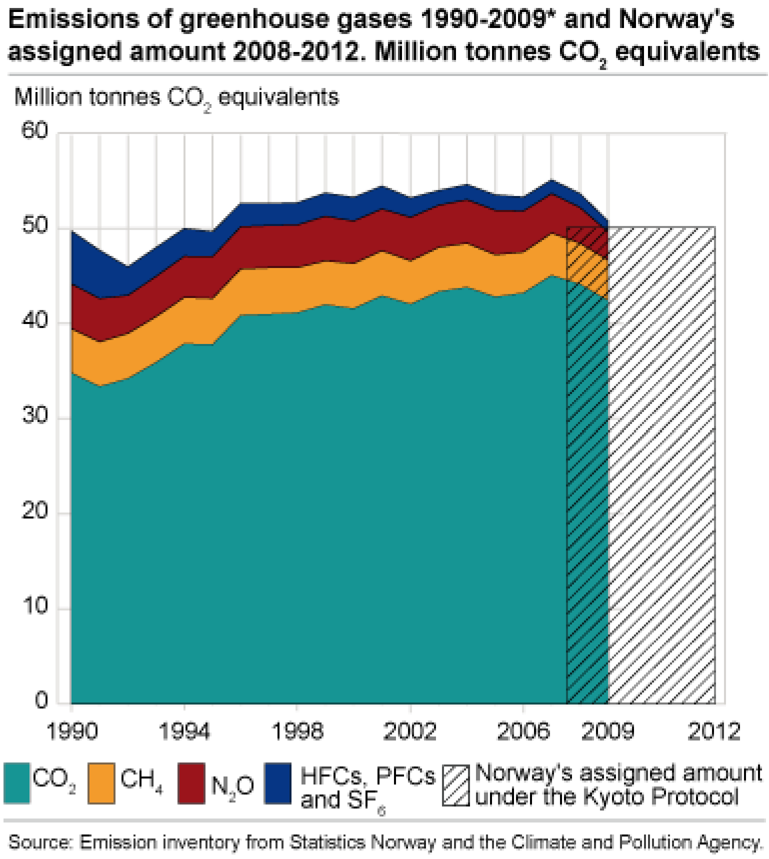

Figure 4.3 Emissions of greenhouse gases 1990–2009 by Norway and Norway's assigned amount 2008–2012. Million tonnes CO2 equivalents

Emission reductions in Norway are considered to be possible only at a high price (Andresen, Butenschøn 2001: 345). Because Norway is without major influence at the international level these tendencies were noticed quite late by other states. Even the change of government in 1997 had no notable effect on the international negotiation position. Although only few points of a comprehensive explanation can be addressed here, one can ascribe the turnaround of the Norwegian international negotiating position mainly to events on the domestic level. Norway is a leader in many other environmental cases where low costs of the agreements were expected. But because of perceived economic disadvantages the Norwegian interest in the success of the climate change regime was low.

While we have only discussed the case of Norway in detail we can also find other examples for changing positions in climate change politics. While the UK had long been a cautious actor regarding climate change and rather a laggard, the situation changed in the late 1990s. While an increased awareness of environmental issues may have been a reason for this change, Agrawala and Andresen assert that the motivation had little to do with climate policy (2002: 47). The restructuring of energy supplies inspired by economic concerns had significantly reduced CO_2 emissions. Therefore the UK was in a more cooperative position, which helped the EU to agree on a common position and as a result facilitated negotiations in the Kyoto conference.

4.4.5 The conflict between North and South

In the early days of climate change politics the conflicts between countries from the North and the South concerned mainly the assignment of responsibility for the climate problem and the efforts to reduce emissions (Biermann 1997: 187ff.). Thus, developing countries of the South called on the developed countries of the North to acknowledge their full responsibility for having created the problem through their historical industrialisation (see Figure 4.4), and to make concrete endeavours to reduce the impacts of climate change. This argument was grounded in what was claimed to be the "historical responsibility" of the industrialised countries.

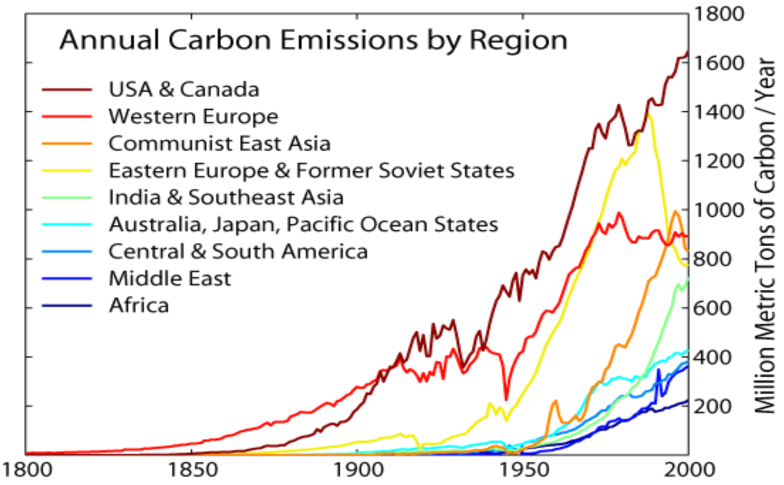

Figure 4.4 Annual carbon emissions by region

Also, while industrialised countries today have reached a high standard of living, some developing countries face urgent problems of poverty and slow socio-economic development. Thus the fight against climate change is not a priority for developing countries and as a consequence they neither feel a moral obligation nor do they have appropriate resources to reduce emissions.

As a result, during the interstate negotiation process, assistance offered (especially by the US) to developing countries to reduce emissions was refused. Most countries of the South suspected the North of trying to establish a mechanism to prevent their economic development. Some countries even saw this as an attempt to establish new colonial patterns.

Another argument was voiced by India which questioned negotiating targets in terms of a country's total emissions. If one takes the per capita emissions as a point of reference instead of country-wide total emissions, the data offer a very different picture (see Figure 4.5). While India is the fourth largest large total emitter in the world because of its huge population, its per capita emissions are low. A similar picture applies to China. Thus, India asserts that it should not be states that are the units of comparison but individual people and this will warrant equal treatment of each participant.

Despite these arguments the industrialised countries insisted on their approach that requests efforts from all countries to prevent climate change. Arguing that poverty in developing countries is predominantly a result of mismanagement and lack of fiscal discipline, a sole transfer of money and technology aid outside of existing rules and market conditions would be unfair and would not lead to effective environmental governance (Okereke 2010: 50). Instead every country should contribute according to its individual capability and resources. The US especially insisted on binding obligations for developing countries. The preliminary outcome of this debate can be observed in the concept of 'common but differentiated responsibility' (CDdR), which is integrated in the 1992 Earth Summit Convention on Climate Change as the basis for cooperation between developing and industrialised countries.

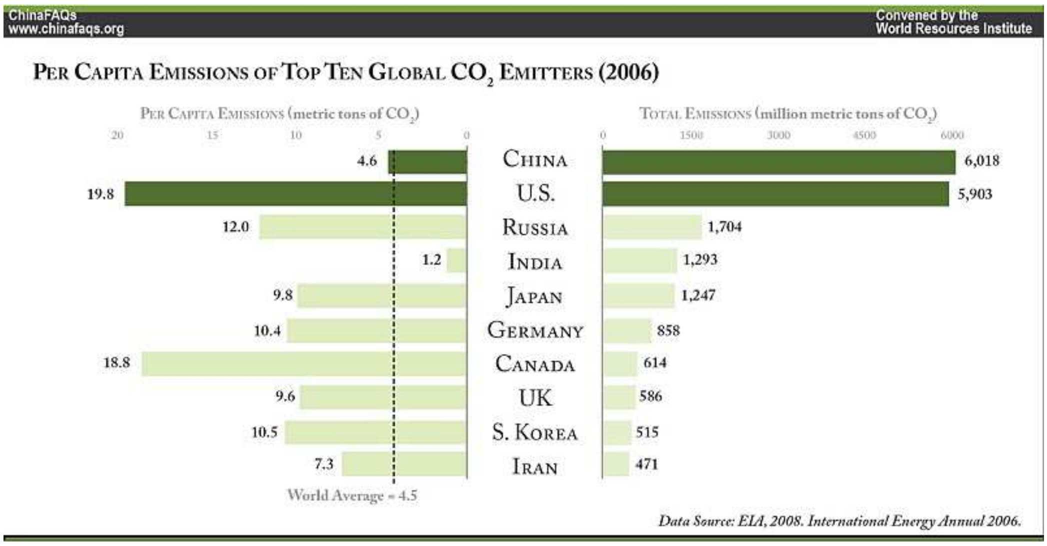

Figure 4.5 Per capita emissions of the top ten global emitters (2006)

It should be stressed, however, that the conflict line between North and South has become more blurred in recent years. While in the beginning of climate change negotiations it seemed fairly obvious which country belonged to which group, in later years the roles and preferences of some countries have changed significantly. Because of their rapid economic growth and their increasing political influence, countries such as China, India, Brazil and South Africa are no longer easily categorised as developing countries. As the general perception of these countries has changed because of their economic growth, increasing military power etc., so has their role in climate negotiations, and they are now major players.

Economic growth and political influence have especially enhanced the self-confidence of China and India. Because China has already overtaken the US as the number one emitter of greenhouse gases (Figure 4.6) it has gained a central position in negotiating further commitments.[62] While the US has sought especially to hold China responsible for reducing emissions, some observers argue that the future conflict line in negotiations will not be, as Paterson suggests between the US and the rest of the world, but between China and the US as the largest economies of the world and thus the most significant greenhouse gas producers.

62 US-Today (2007):China to top USA in greenhouse emissions (http://www.usatoday.com/weather/climate/globalwarming/2007–04–24-china-emissions_N.htm)

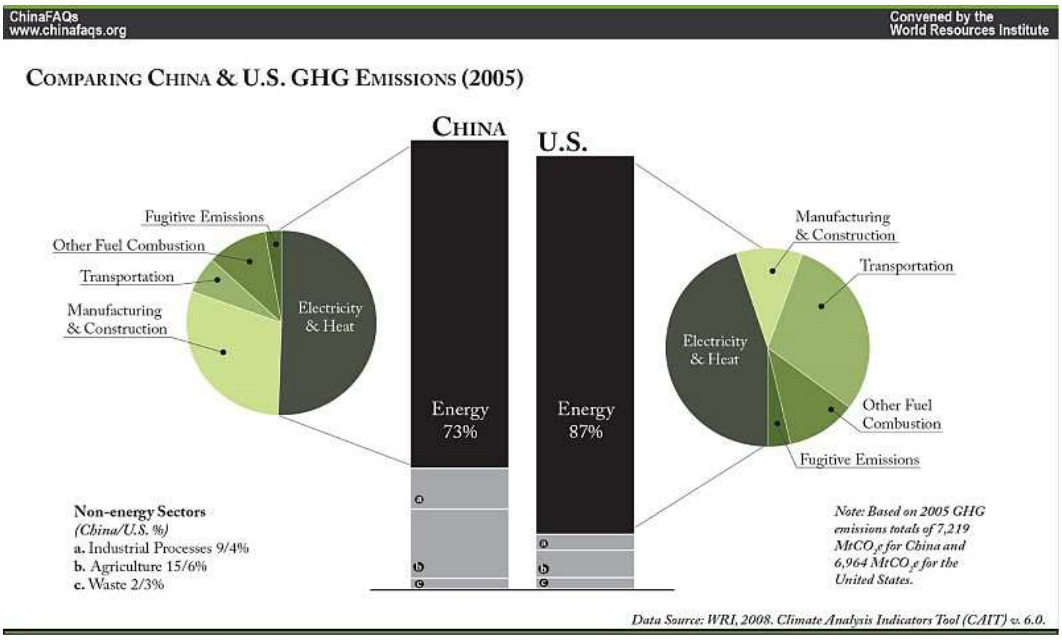

Figure 4.6. Comparing China and United States greenhouse gas emissions

Yet China, India and Brazil are themselves also threatened by the impacts of a changing climate. In China dramatic environmental degradation has taken place, in India monsoon rainfall patterns are changing, while Brazil suffers because of massive deforestation which is a contributory cause of climate change. Nevertheless, the dominant line of argument remains that the problem should be solved by the developed, industrialised countries. "The industrialised countries have created the dangers, the leaders of the developing countries tend to say; let them be responsible for reducing them – especially where measures taken might inhibit economic growth" (Giddens 2009: 186). Overcoming this tension might be the biggest challenge in North-South relations and climate change politics in general.

4.5 Conclusion to Chapter 4

In this chapter we have introduced what we call the "Politics of Climate Change". The overall goal of this chapter was to give an impression of the current political situation regarding international agreement on climate change, the main actors in this process and the dominant conflict lines between them.

We have covered a wide range of topics by reconstructing the history of the climate change debate from its scientific emergence at the First World Climate Conference in 1979 until the state of negotiations after the conference in Durban in 2011. Another important aspect is the players involved in this process. There are several actors in the arena of climate change negotiations, all with diverse interests and goals. Not only can individual states be conceived as actors, albeit the most influential ones, but also intergovernmental organisations, non-state organisations, business actors, and other special interest groups which try to shape the international agenda.

Following this introduction of actors we showed their main conflict lines and the main challenges for international cooperation. Instead of analysing each of the actors in isolation we established mindsets towards climate change under which actors can be classified. Pushers and laggards are two main categories which can be used to describe the current antipodes in climate change. Although a definition of groups can reduce complexity it can never be appropriate to every single group or actor involved in this process. Therefore we gave examples of actors who changed their positions throughout the negotiations. This emphasises the dynamic component in the process.

After we identified the groups of pushers and laggards and the tension between them, we analysed another prevalent conflict: the conflict between North and South. Of course categories which geographically divide states are difficult in many ways, but they offer an idea as to where the origins of this conflict are rooted. We argued that recent economic development in countries such as India, China and Brazil especially might supersede the old debate and produce a new constellation regarding climate change.

Many topics were discussed or at least touched upon in this chapter, but you should be aware that only small extracts of the whole issue of climate change politics could be offered. This becomes especially apparent if you keep in mind the different levels on which the climate change debate takes place: internationally, nationally and regionally. The main focus of this chapter has been on the international level. The politics of climate change nonetheless have important implications at the national and domestic levels, where commitments in the form of treaties or conventions need to be implemented. We could not discuss this issue here in depth. You should be aware, however, that the international level is only one – although an important – component for understanding the politics of climate change.

To conclude your study of Chapter 4 and for you to reflect on the issues raised by the politics of climate change, turn to the Module 1 workbook activities 4.1–4.3.

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5 A sociological perspective on climate change

By Dina Abbott

Before you start: the aim and learning outcomes of this chapter

Chapter 5 aims to introduce you to a sociological perspective on climate change.

After studying this chapter, you should be able to:

1) Understand how sociologists, whilst taking much note of scientific analysis, essentially regard climate change (as with other environmental issues) as a social construct.
2) Critically evaluate climate change as a social construct through relationships of power and inequality evident in local and global structures.
3) Consider the relationship between agency and structure in addressing climate change issues and actions.
4) Recognise the growing importance of a sociological interpretation of climate change.

Thus far in this module you have been introduced to various aspects of a scientific, economic and political analysis of climate change. This chapter of the module now offers you another dimension to build towards a more holistic understanding, that of a sociological perspective. Essentially a sociologist perspective considers how any given phenomenon (in this case climate change) is mediated through social relations of power and inequality embedded in local and global social structures. Whilst acknowledging the place of agency to change things, a sociologist perspective focuses on how social relationships, shaped by discriminators such as class, gender and race, influence ways in which individuals mediate the impact of climate change. And, although the sociological perspective recognises the enormous contribution of science to the debate, it nevertheless regards climate change (as with other environmental issues) as fundamentally a social construct.

To discuss this, chapter 5 begins with a fuller account of what is meant by a sociological perspective and where it is in relation to the current discourse on climate change. It will then go on to consider the ways in which power and inequality embedded in local and global social structures helps or hinders individuals in the way they respond to climate-led disasters as well as everyday changes that affect their lives and livelihoods.

5.1 The interrelation of individual behaviour and social structures

A sociologist perspective, as the name suggests, arises from sociology which is a systematic study of society and societal relationships. As a discipline it can be grouped under the general umbrella term of "social sciences" and shares various conceptual, theoretical and methodological tools with other disciplines within this band, for example human geography and anthropology.

Sociology in itself is a broad discipline spanning a wide range of subjects based on patterns of human interaction with society. These include, for instance, various dimensions of economic, cultural, political and religious life, both at a local and global scale. This leads sociologists to analyse the complexities of human interaction at both a micro- and macro- level. For instance in relation to climate change, sociologists would want to consider at least a three-way analysis: (i) of individual behaviours and attitude, (ii) set within specific local societal contexts, and (iii) within a global context reflecting global structures, issues and actions. Sociology is therefore a distinct social science subject in that it considers the analysis of individual behaviour primarily through a critical understanding of social structures within societies, whether in the immediate locality of the individual or within a worldwide context. Much of its theoretical and conceptual analysis is thus around deciphering the everyday relationship between these (structures) and individual behaviour (agency) as discussed in more detail below.

In these interactions, sociologists regard our daily lives and interaction with each other as patterned, and generally revolving around various organisations, institutions and structures in our immediate and wider society in a predictable manner. These predictions and patterns are defined by the expectations of the roles and status that each of us have within society and are important to its functioning – otherwise interaction in a random manner is often counterproductive and confusing! As humans, therefore, we require relative stability to function every day and the framework for this is located within structures embedded in social institutions[63] and organisations which are an essential part of any society. These structures include families (represented through the institution of marriage), religion (represented through churches, mosques, etc.), culture (through everyday norms, practices, values), education (through schools, universities) and organisations (through employment, official bureaucracies). Such structures are crucial within our everyday lives which they shape and hold together. In fact, the importance of these structures can be compared to the rafters and steel girders that hold up buildings, supporting the overall frame upon which the foundations and future construction of the structure are based. At the same time, the rafters and girders provide an overall, overarching influence on the construction and overall future functioning of the building!

Sociologists are therefore certainly interested in what is upfront (i.e. the building), but are fascinated by what underpins societal behaviour (i.e. the rafters and the girders). Thus they attempt to identify those often taken-for-granted and sometimes invisible structures that are most influential in shaping human interaction in relation to various social issues (of which climate change is one). As societies have many layers through which both individual and societal behaviour is defined, a sociologist perspective will unpack these systematically in order to understand what lies behind individual behaviour. So whilst the individual is important, the society within which the individual lives and functions is even more so! This relation between the individual and society, however, is not always immediately apparent as individual behaviour is in fact often internalised or aspects of it are given, or hidden from a public view. To unpack and explore what lies beneath the surface requires a "sociological imagination". This is a term associated with C. Wright Mills, an American sociologist (1959) who suggested that there is a relation between individual biographies and historical change embodied in global and local societal events. Read the extract in Box 5.1 below to help you understand a fuller argument on this relationship.

In Box 5.1, Mills demonstrates that even if we do not acknowledge it, or understand it, our individual biographies are not simply about ourselves or how we shape them, but an interplay of our individual selves and historical change that is embedded and manifest within societal structures as described at the start of this section, and well illustrated in the second paragraph of the extract. One way to assess this interplay is to consider how historical processes and change affect individual responses. Thus, for instance, India is undergoing transition from what was essentially a closed society based on internal markets towards trade liberalisation and wider engagement within global markets. In turn this has created a climate of institutional, ideological and structural change which can enable businesses and entrepreneurs to thrive. Opening up to external global markets has also created a significant group of rich and super-rich Indians, and amongst these, a large number of rising middle classes whose behaviour has changed in that they are more demanding of "western" style consumption such as large cars, fridge/freezers, gadgets and are acquiring a "throw-away" attitude that is challenging to the environment. In fact, today in India this has raised many controversies regarding the effect of such large-scale consumption with respect to climate change issues. If you wish to further explore the

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[63] For a definition of social institutions see Chapter 4, Section 4.2 of this module (The history of international climate change politics).

interrelationship between historical change and individual behaviour, particularly with reference to climate change, in greater depth, please turn to Activity 5.1 in the Module 1 workbook.

Box 5.1 On interaction between individual biographies and historical change

Nowadays people often feel that their private lives are a series of traps. They sense that within their everyday worlds, they cannot overcome their troubles, and in this feeling, they are often quite correct. What ordinary people are directly aware of and what they try to do are bounded by the private orbits in which they live; their visions and their powers are limited to the close-up scenes of job, family, neighbourhood; in other milieux, they move vicariously and remain spectators. And the more aware they become, however vaguely, of ambitions and of threats which transcend their immediate locales, the more trapped they seem to feel.

Underlying this sense of being trapped are seemingly impersonal changes in the very structure of continent-wide societies. The facts of contemporary history are also facts about the success and the failure of individual men and women. When a society is industrialized, a peasant becomes a worker; a feudal lord is liquidated or becomes a businessman. When classes rise or fall, a person is employed or unemployed; when the rate of investment goes up or down, a person takes new heart or goes broke. When wars happen, an insurance salesperson becomes a rocket launcher; a store clerk, a radar operator; a wife or husband lives alone; a child grows up without a parent.

Neither the life of an individual nor the history of a society can be understood without understanding both. Yet people do not usually define the troubles they endure in terms of historical change and institutional contradiction. The well-being they enjoy, they do not usually impute to the big ups and downs of the societies in which they live. Seldom aware of the intricate connection between the patterns of their own lives and the course of world history, ordinary people do not usually know what this connection means for the kinds of people they are becoming and for the kinds of history-making in which they might take part. They do not possess the quality of mind essential to grasp the interplay of individuals and society, of biography and history, of self and world. They cannot cope with their personal troubles in such ways as to control the structural transformations that usually lie behind them. (Source: Mills (1959) Chapter 1, *The Promise* p5, cited in Mills, 2000).

Through all this, as I mention in the paragraphs above, sociologists attempt to identify patterns of social and casual relationships. For instance, in Section 5.5 I illustrate a socially constructed view of disaster-related deaths in Bangladesh. I suggest that it is possible to analyse why there are more female than male deaths during crises such as floods. I do this by showing a direct causal link between deaths and death patterns with strict gendered roles and codes of behaviour within that society. Identification of such patterns thus allows sociologists to address the problem at the core, i.e. not one that is about the number of deaths, but about the relationship between the “inequality” in disaster-led death and the social reasons for this.

Yet this is not enough. Sociologists also seek to find that which deviates from these patterns and explore what it is in society that makes them deviate. To do that, as suggested by a contemporary British sociologist, Anthony Giddens (2001: 699), we need to apply imaginative thought to the asking and answering of sociological questions. The sociological imagination involves one in “thinking oneself away” from the familiar routines of day-to-day life. It is only when we explore beyond the familiar patterns of everyday life that we begin to discover what underlying forces shape our behaviour as individuals. The process of uncovering the deviant thus ignites imagination further, and becomes even more alive as it allows sociologists to consider what is happening not only in the mainstream, but on the margins of society. For instance, take the notions of adaptation and vulnerability that are often used in discussions of climate change impacts, as defined in Box 5.2 below.

Box 5.2. Definitions of adaptive capacity and vulnerability

Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Source: Intergovernmental Panel on Climate Change, Climate Change 2002: Impacts, adaptation and vulnerability, p21. (http://ncseonline.org/2008conference/Resources/IPCC%20WG2-4%20Summary.pdf)

The above definitions of "adaptive capacity" and "vulnerability" are somewhat generalised and, arguably, built on underlying assumptions which may undervalue or misjudge those invisible and silent processes that go into decision making on adaptation action and policy. For instance, the definitions here refer to "systems" with an assumption that these treat everybody equally. However, both adaptation and vulnerability are negotiated within the boundaries of their own, specific social contexts which include cultural and social identities, societal economic capacity and limits, and the values that underpin decision-making processes (more often than not influenced by those with the strongest voices). For example, at an individual level, richer people are more likely to have the capacity to tap into a range of adaptation strategies such as air conditioning for their cars and homes, or migration to selective "green" neighbourhoods. On the other hand, poor people may experience a further downward spiral into poverty. They will intensify last-resort coping strategies such as cutting down on or adjusting food intake, working in unsafe environments, enforced migration -- all of which may not necessarily be good for them as individuals or good for the general environment in the long term. In that too, the individual's capacity to mitigate adaptation and vulnerability will depend on their age, gender, race and other factors that determine their overall social status and social positioning. Adaptation and vulnerability therefore depend on both specific individual and overall societal contexts.

In looking for the "deviant", sociologists would question what is missing rather than what is apparent – in this case, adaptive capacity and the vulnerability of those people whose voices have not been included in the decision-making processes, but are nevertheless important and have the potential to throw light on new ways of thinking. Take for instance, the issue of waste and recycling and its impact on climate change. Whilst many "experts" and vocal citizens have contributed to the wider debate, many others who are in fact actively minimising the damage (even if they are not always aware of it), are often not consulted over climate change. These include the "informal sector" urban poor who work the rubbish heaps of cities across Asia, Latin America and Africa everyday and are regarded as "scavengers" and "undesirables" in their association with dirt and poverty, thus not being seen as worthy of consultation. They are in fact providing an enormous service in recycling products, cutting down on waste and gas emissions and helping cities to survive. In a case study of Delhi (India), for example, the Chintan Environmental Research and Action Group identifies that, by 2020, municipal solid waste in Delhi will reach up to 23,000 metric tons per day. However, within this, the waste pickers of Delhi are estimated to collect and recycle 15–20% of total waste, where glass, metals, plastics and paper alone will reduce Greenhouse gas emissions by an estimated 962,133 tonnes of carbon dioxide equivalent (TCO2e) each year (equivalent to United States estimates of removing 176,215 road vehicles or providing electricity to 133,444 homes for a year) (Kholsa and Chatruvedi, 2010 p97–98).

Sociologists also question the wider context of climate change, for example, the processes of economic and trade liberalisation, within which individuals will have a limited choice in how they adapt to and mitigate climate change. Food production, for instance, is affected by changes in seasonality, temperature and rainfall, which may result in drought or flooding. Farmers all over the world increasingly have to create adaptation strategies in relation to these changing local food growing conditions. However, they also have to respond to the demands of a wider world, the context of which includes urbanization, globalization, and fluctuations of food prices in international markets. An evident example is the hunger faced by many African farmers at the global fall in commodity product prices such as coffee as well as an increase in international food imports (Swan, Hadley and Cichon, 2010). This often spells disaster at an individual level both in the short term and the longer term, but also at a global level as agri-business and large-scale technology-led farming is a key contributor to emissions of the greenhouse gases methane (CH_4) and nitrous oxide (N_2O) (Gregory, Ingram and Brklacich 2005 p2139; see also chapter 2 Section 2.2.8 of this module).

5.2 Whose influence counts: individual agency or structure?

An important question for sociologists is that of establishing the relative significance and nature of individual agency in relation to social structures in influencing behaviour and actions.

Thus the conceptual and theoretical debate on what is more influential in determining individual behaviour, structure or agency, is fundamental to a sociologist analysis of understanding of individual/societal interaction. This is a similar dualistic mode of argument to that posed by the nature versus nurture arguments in the study of human behavioural development[64]. The question that arises from a structure/agency debate primarily asks, “Are individual life choices shaped by our capacity to make independent, free, controlled choices (agency), or are they bound within the constraints and limitations defined by social structures and the social context that the individual inhabits?” For a succinct definition of these terms, see Box 5.3.

Box 5.3: Concepts of structure and agency

Structure: The pattern or framework of relationships between social institutions such as markets, families, class, and political factions. It includes rules of behaviour associated, for example, with moral norms and hierarchies.

Agency: The actions of individuals or groups, and their capacity to influence events.

In practice, social analysts combine both concepts, although some tend to favour one over the other. (Allen and Thomas 2000 p189)

See also Box 3.2 in Module 2 of this series.

Take for example the issue of fuel wood, the everyday consumption of which contributes significantly to deforestation and ultimately climatic consequences in developing countries (Agarwal 1986, 2010). People in many developing countries use fuel wood for two main purposes (i) domestic, such as for cooking, and (ii) for marketing and trading purposes. Depending on the number of people who cut down forests to obtain the wood, deforestation often occurs fairly rapidly and soon starts to become visible. Yet people go further and further into the forest to obtain the wood, causing increasing pressure on the forest.

Arguably, in this example, the individual has choices and can exercise agency on whether to cut the wood or not. They may not want to do so as often poor, landless people (particularly women whose responsibility it is to gather wood) rely on common resources such as forests and are very aware of their value and the cost of deterioration and loss of these. Yet, especially those in developing countries carry on because they have limited

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[64] The “nature versus nurture” debate goes back to Darwinian times of evolutionary theories and questions what determines an individual’s character and behavioural traits, heredity “nature” and biological characteristics people are born with, or the acquired ones from their “nurtured” environment and personal experiences.

agency to make other choices as they experience structural poverty in two ways: (i) through national poverty and low GDP/GNP per capita, and (ii) as individuals bound within power and unequal relationships within society which constrain and determine their choices.

If you wish to explore the concepts and relation between structure and agency in further depth, please now turn to Activity 5.2 in the Module 1 workbook.

Do note, however, that although the structure and agency argument above appears dualistic, this is for explanatory purposes only and it would be incorrect to see them as separate and compartmentalised. Giddens (1993), for example, refers to a "duality of structure" in arguing that individuals are constrained by society, but at the same time they make it. The two are inexorably interlinked. As he suggests, "social structures are both constituted by human agency, and yet at the same time are the very medium of this constitution" (ibid, p169). However, he notes that, "The realm of human agency is bounded. Individuals produce society, but they do so as historically located actors, and not under conditions of their own choosing."(ibid, p168, but note that Giddens is also borrowing from a phrase of Karl Marx here, over 100 years earlier).

Note also that although primarily setting explanations of events within societal structures, a sociological analysis inevitably draws on individual agency as well. For example two other prominent sociologists, Peter Berger and Thomas Luckmann (1967) suggest that reality, as understood by the individual, is in fact based on the societal structures within which each person interacts. This argument may appear in the first instance as structurally bound in that individuals are seen as limited or constrained by societal structures and social forces which ultimately influence and therefore define the individual. However, in developing their argument, both Berger and Luckmann are also careful to acknowledge the importance of individuality, individual uniqueness and the ability of some to exercise a degree of independent agency.

Thus whilst sociologists may initially appear to lean in one direction or the other (as illustrated above), generally there is underlying recognition that structure and agency are closely intertwined and inexorably bound. For example, whilst taking note of individual characteristics such as ability and capacity that may enhance an individual's life chances, sociologists, nevertheless seek a social explanation that is based on general social patterns rather than that of particular individuals for explanation of individual action and behaviour. Thus an individual might have particular characteristics which define them (e.g. entrepreneurship, determination), but essentially it is the general social discriminators of age, gender, and social class which have a bearing on their behaviour and life chances.

Take for example, small women farmers in The Gambia, West Africa, who are often very poor, and responsible for feeding their families. Many are also responsible for domestic, subsistence cropping and attempt to grow the staple, rice, in swamp water. These women farmers usually work very hard carrying out the various processes of "stoop" labour[65] required in rice farming, namely sowing, transferring, weeding and harvesting the crop. Disentangling what is happening at the societal level, however, reveals a number of structural events that force the women to work so hard. For instance, the women rarely own their own land and are pushed onto the margins where their access to land is limited to the swamps which do not have the most fertile and advantageous characteristics for rice growing. The end crop is therefore never sufficient and women are forced to enter into seasonal, waged labour, relying on male farmers who may own land. They may also diversify into other activities such as vegetable growing. Here too they are limited to doing so within the boundaries of the household compound land. Essentially, therefore, no matter how hard the woman works or how determined she is, in a heavily patriarchal

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[65] So-called because they have to stoop to carry out the work.

society, the structural barriers which deny her land ownership, curtail her chances of making an adequate livelihood.

Whilst the above example focuses on local structural constraints, as noted earlier, sociologists go beyond the local and consider the location of the individual within wider, global structures of markets, trading and inequality between sovereign nations. The ideological context within which global societies operate is clearly important in analysing the relationship between structure and agency. For example, in “western” societies where a neo-liberal and free-market ideology dominates and where individuality and individual entrepreneurship are particularly valued, the notion that our lives are shaped by predictable, patterned behaviour determined by social structures is not something that is readily acceptable to many. However, whilst recognising that some individuals are by nature more entrepreneurial, more determined to take part in competing within markets, sociologists place the question within (i) local structures where class, gender, race may help or hinder individuals as well as (ii) the overall positioning of the country and individual within global structures which may do the same. This is not to say that other disciplines do not also consider the importance of the global, but for a sociologist perspective which focuses on social structures, this is particularly important. An underlying reason for this is that sociologists want to explore how societal structures generate, manifest and reinforce power and inequality in mediating social relations, and use the findings to direct policies and actions which can effectively address this imbalance.

If you wish to explore the point regarding how global structures such as trade shape social interaction and inequality between more and lesser economically developed countries, please try Activity 5.3 in the Module 1 workbook..

5.3 Mediating social relations: power, powerlessness and knowledge

Underlying sociological debates on what shapes individual actions are the notions of “power” and “powerless” as embedded in social structures. In fact, for sociologists, “power” is central to the understanding of everyday social relations. They ask who the powerful are, what gives them “power”, and how the powerful may influence individual behaviour. For the study of this module too, “power” is a central concept, especially if we are to understand how climate change mediation is negotiated. Sociologists are also interested in the shift from “power” to “empowerment”, and conversely the related issues of “powerlessness” and “disempowerment” which make climate change mediation an enhanced struggle for lives and livelihoods.

Factors such as money, the class or caste you are born into, the race and gender that you belong to, more often than not influence how powerful (or powerless) you feel within a given society. In turn, the more powerful you are, the more you are likely to influence the dominant structures of your society (for example, through religious, education, and family institutions). To analyse actions and how they interact with each other and the wider society, sociologists dig below the surface-level to explore and identify what shapes power within a given society and how this enables or constrains the individual. This analysis is embedded in notions of equality and inequality. To explore social relations of power and equality/inequality, you may like to do Activity 5.4 in the Module 1 workbook to reflect on your own positioning in society and what has influenced your behaviour and life chances.

As mentioned in the introductory paragraphs of this chapter, sociologists view social issues, including the way we think about climate change as framed within existing societal knowledge. As Pettenger argues in her book (2007: 2), “We are seeking to understand the interpretations of climate change, vis à vis the social processes of climate change conceptualisation, i.e. what it is and how its causes and consequences and the planned responses to it, are constructed”. Thus the emphasis is not on climate change per se, but on how this is interpreted and presented as “knowledge” in public spaces. For instance, many sociologists argue that in the public sphere, “knowledge” of climate change and the future of people is currently dominated by a scientific leaning underpinned by a supposed “objective” approach to data which in turn generate assumptions of threats from climate change[66]. There is a sense of authority in this interpretation as it is filtered through the media and other cultural institutions which dissipate information in a knowledgeable manner to many of the public debates and decision-making bodies. This in turn reinforces the authoritative position of scientists, giving them power over what interpretation of climate change is considered important and valid.

Invariably, this can sometimes lead to imperfect intervention that is led by science and technology. An example is that of technological intervention in unpredictable rainfall via seed cloud technology designed to modify and increase precipitation in many parts of the world, including China and India (Nelson 2009). However research suggests that this technology, once thought to be the answer to water variability, has several problems, for example seeding with materials such as silver iodide and frozen carbon dioxide is not entirely effective (Sciencedaily 2010). The problems are compounded as there is unpredictability in the quantity and quality of the rain. Furthermore, it is not clear exactly when and where the clouds will bring rain, sometimes causing political strife between regional and district boundaries who feel their rain has been “stolen” and so forth.

Conversely, in contrast to scientific knowledge, other knowledge such as indigenous knowledge[67] that is not backed up by scientific data and which relies on tacit learning often appear less authoritative. Whilst generations have, for instance relied on indigenous knowledge as a form of mitigating and adapting to climate variability, historically it has been undermined. This was particularly so throughout the colonial period when there was systematic undermining of voices from Africa, Asia and Latin America because of paramount notions of superiority and whose knowledge should reign. Nevertheless in recent years, as discussed below, public spaces for indigenous voices have no doubt opened up. Yet overall, a historical undermining has resulted in powerlessness both within a local context where new technologies have been introduced amongst other things, and a wider context where forces of globalisation, conflict and so forth may bring extreme changes to local situations.

All the same, people are not passive victims and demonstrate empowerment in voicing concerns of climate change, especially where this affects livelihoods of the poor. Action often involves, however, collaborating with others to attain goals, where fundamentally collaboration provides a collective power which is stronger than individuals acting in isolation. To take just two examples: (i) through mass social movements, people have forced environmental concerns (e.g. deforestation, damming of waters) onto policy agendas, and (ii) through working in partnerships with academics and other institutional agencies, people have ensured that indigenous knowledge is integrated into mainstream policy and planning. Box 5.4 is an example of how individuals gain empowerment by coming together through community organisations.

From both of these examples, it is clear that there is a need to develop partnerships which respect all facets of knowledge in the struggle to manage climatic change. Thus there has been a radical shift nowadays in the attitude towards indigenous knowledge and there are several strategies to incorporate it into the mainstream, and also to ensure that it is preserved. For example, The Geometrics and Cartographic Research Centre, Carleton

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66 See Module 3, Chapter 3 for a critique of a scientific “objectivity” and scientific assumptions.

67 Indigenous knowledge is that which is passed on from one generation to the next and is learnt through observations and experimentation to connect to local environments. It often provides the cultural foundation of many communities and is drawn upon for local decision making, particularly in rural village communities of the developing world.

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University has attempted to develop an electronic and hard-copy dictionary (The Kingikmiut 'Sea Ice Dictionary') of over one hundred terms for the types of sea ice (sigu) and the local climate knowledge this reflects, which are used in the Kingikmiut dialect of the Iñupiaq language, Wales, Alaska. If you wish to explore further examples of how it has become important for "mainstream" science and social scientists to work together with indigenous knowledge, please turn to Activity 5.5 in the Module 1 workbook. Also, you might note that 'indigenous knowledge' bears some resemblance to the 'lived experience of climate change' that is expounded in Module 2 of this series. The latter, however, is a more dynamic entity where human agency and engagement interact with local and broader societal contexts to create evolving experiential knowledge that is a shifting hybrid of the indigenous and external (see also section 5.4 below).

To end, from a sociologist perspective, any social issue (such as climate change) is a matter of interpretation and recognition of from where the issue is arising, and who has the power to voice it loudly!

5.4 Social context, embeddedness and climate change

A question you might ask at this point is how does a sociological perspective throw light on the lived experiences of climate change? Firstly, a sociologist perspective takes account of several explanations in order to build a holistic, fuller understanding of climate change, including those identified earlier in this module. From this, it examines how interpretations regarding climate change as a topic and climatic events as individual experiences can be interpreted within a societal context within the framework of structure/agency and power/powerlessness as discussed in the preceding sections.

For instance, take the negative effects of climate-led events including dramatic climate chaos events (such as floods and hurricanes) of which the general public is made aware as these soon hit the media. What usually happens is that the television and radio report the event, where it is happening and offer some (often disturbing) images of its impacts on people, perhaps followed by an appeal for assistance from neighbouring and other

Box 5.4: From individual to community empowerment

Demanding justice in El Salvador Evangelina González deMarías, 59 years old, lives in the community of San José with her husband, three children and a grandson aged 4. They earn their living from farming and when they can they sell their labour in local large private farms. They face many challenges relating to changing weather patterns. Droughts and floods are regular occurrences, as well as increasing heat and more frequent storms. In the past few years, the problem of access to water has become more acute in the community of San José. There are severe water shortages due to the fact that droughts are more frequent and longer now, and also as a result of deforestation occurring in the area.

Evangelina takes part in her community organisation and is a member of the Environmentalist Network in Action (Red Ambientalista en Acción). This is a nationwide grassroots organisation that lobbies municipal governments, the central government, and private enterprises to promote adequate policies and laws for the protection of the environment, for fair and equitable use of the natural resources, especially water, and for the prevention and attention to disasters. The communities that belong to this network have become familiar with the problem of climate change and its impact on the life of the country and its communities, as well as how to face it, mitigate it, and become more adaptable to it. In the past 10 years Evangelina's community has fought for the removal of a number of companies that were causing environmental problems in the area. One of the companies which they were successful in removing was carrying out large-scale deforestation in the area and affecting the water volume of the nearby rivers, making them more vulnerable to the effects of climate change.

For Evangelina it is very important to be part of the Environmentalist Network in Action and participate actively in it. About her participation in the network she says: "One enjoys everyone's support…we are all very attentive to one another and, additionally, we are all together in the fight for our rights and to defend nature". The communities' success in stopping the destructive activities of companies has confirmed for Evangelina that the only way of confronting and overcoming the problems that make them more vulnerable to climate change is the organisation and participation of the communities affected.

Source: http://www.trocaire.org/sites/trocaire/files/pdfs/policy/ChangingLives.pdf

(P28 - accessed 9 March 2012)

well-off countries. There is also somewhere an analysis, perhaps a scientific one, provided in lay terms for general public consumption. We may even be told the type of people who are affected, such as poor African Americans who were caught up in Hurricane Katrina which hit New Orleans in the United States, or the poor in a Bangladeshi cyclone.

A sociological analysis, however, usually begins much after the initial events when, for example, Government, aid agency or other institutional responses are analysed to address the effectiveness of policy and response. Often this is done by academic communities in partnership with politicians, economists and a variety of civil society groups. As discussed above, sociological analysis does not focus on the individual but on embedded social structures in society. In analysing climate chaos, therefore, sociologists would consider how climate has historically influenced the vulnerable, and who is most likely to suffer when extreme events occur.

Here, for example is an insight into a sociologist's analysis of Hurricane Katrina. I begin with some scientific and economic facts.

Hurricane Katrina was reported by the US National Oceanic and Atmospheric Administration (NOAA), which supplies satellite weather and other environmental information as being in the Gulf of Mexico where:

> "On August 28, 2005, it powered up to a Category 5 storm on the Saffir-Simpson hurricane scale, packing winds estimated at 175 mph[68]. At 7:10 a.m. EDT[69] on August 29, Hurricane Katrina made landfall[70] in the southern Plaquemines Parish Louisiana, just south of Buras, as a Category 3 hurricane. Maximum winds were estimated near 125 mph to the east of the centre."

The ferocity of Hurricane Katrina made it one of the five deadliest and costliest ever to hit the US as nearly 2,000 people died and damage ran to many billions of US dollars, with NOAA guesstimates of $125 billion for the Gulf Coast states. The massive impact of this event has since then, of course, generated many studies of what happened both in terms of the disaster occurrence itself, but also the management of it.

I now turn to the sociological analysis. As suggested in the previous paragraphs, a sociologist perception is interested in locating what happened in a historical social context, and interprets disaster management, responses and human behaviour within the setting of "multiple locations" and "embeddedness". Thus Iversen and Armstrong (2008: 4) argue that studies which followed the Hurricane Katrina disaster have only been able

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68 Mph = miles per hour. 1 mile = 1.6km.

69 North American Eastern zones daylight saving time.

70 A meteorological term signifying the time when a tropical cyclone (hurricane) passes from over the waters to the land.

to offer a disjointed analysis of the societal reaction and response to the event. They therefore critique the:

> '"Traditional" systems analysis[71] which does not include local knowledge and participatory planning in that epistemologically and practically, it maintains the fiction that "events" and social actors are at the same time bound together and yet independent of each other—a view that is paralleled by the structure of autonomous government departments and funding streams that provide institutionally separate prevention, response, or recovery efforts. For example, the Federal Emergency Management Agency (FEMA) addresses temporary housing concerns in New Orleans and the US Department of Housing and Urban Development (HUD) addresses longer-term concerns, but neither concern has been addressed effectively, even 3 years after Katrina'

Based on a participatory study of low-income families in New Orleans, Iversen and Armstrong (ibid) thus suggest that a sociological perspective is likely to offer a fuller, more inclusive insight into individual and societal interaction during disaster events and their consequent management. They continue:

> 'The Hurricane Katrina and New Orleans situation was commonly called a "natural disaster"—an anomalous "event" that disrupted lives, spaces, and organizations. Research and planning attention then focused on particular aspects of the event and on restoring order. In contrast, sociologists and similar-thinking scholars have increasingly viewed disaster situations from multiple locations and histories. Here, reanalysis of empirical material from ethnographic research in New Orleans pre-and post-Katrina suggests that a sociological embeddedness perspective illustrates the dynamic seamlessness of past, present, and future economic contexts and social actions. The perspective's constitutive concepts of weak, strong, and differentiated ties highlight the role of local knowledge, intermediary-led workforce networks, and sustained participatory planning in creating a robust economic environment. Toward this end, disaster research, planning, and theory building could incorporate network tie assessments into social vulnerability protocols, compare embeddedness with other perspectives, and learn from related international experiences.' (ibid.).

The above example shows the richness of a sociological enquiry and how this can add to existing knowledge of social inaction and post-disaster management. A sociologist perspective thus has the capacity to contribute to a deeper understanding of climate change through an analysis of embedded social structures. Yet this is not necessarily at the expense of other accounts such as the scientific/economic account as discussed earlier in this module, but complementary to these.

5.5 Social embeddedness and consequences of climate chaos

Other studies support Iversen and Armstrong's emphasis (previous section) that individual actions during and after a disaster cannot be understood as isolated from their social context. Take for example gendered behaviour in times of disaster. There is increasing evidence that disasters affect women more than men in rigid patriarchal societies, both during and after the event. For instance, Chowdhury et al (1993) show that, during the Bangladesh Cyclone of 1991, more women than men died. Whilst some

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[71] Systems analysis is frequently used by large corporations and organizations such as educational bodies, social services, regional and urban planning to make informed decisions through a formal enquiry. Systems analysis draws on both technological (computer) and other forms of interdisciplinary research to gather data on the various systems and processes used by the corporation or organization.

people (including those in authority) may take these findings as a given, sociologists will question why certain individuals died whilst others survived, and what the underlying reasons for more female than male deaths are. Were these skewed ratios a result of greater individual (biological) male capacity to challenge the cyclone through sheer determinism and strength (i.e. pure agency), or were they the result of something else embedded in the local context?

For instance, Chowdhury et al (ibid.) identify several reasons for the female: male death ratio in this particular cyclone, reasons that are primarily bound within the societal structures and context of a Bangladeshi society, which in turn is influenced by Islamic religious norms and codes of behaviour. They argue that, for a start, women were constrained by societal norms governing their dress and public behaviour which prevented them from responding to the crisis as quickly as the men. Many of the women could not swim as this is a public activity, not generally appropriate to female modesty. They were further restricted by clothes that covered them from head to toe, with some wearing the outer veil of a "burqa" which hampered their survival efforts. Because they were isolated and unable to move freely in public spaces, women were also reliant on men to both supply them with information as well as accompany them to a place of safety. In addition, women were not able to access public spaces as readily as the men and it took them longer to get to safety. In fact many of the women left their homes too late because they waited for a male relative to accompany them. This kind of evidence suggests that the structural constraints for women in Bangladeshi society are so strong that they are sometimes rendered powerless to exercise agency, to the point of death.

There are several other factors besides fatality that also reflect powerlessness for women in Bangladesh, with this being exacerbated when climate chaos occurs. Flooding, for instance, puts a halt to any agricultural or livestock activity. It brings lack of shelter and dependency on relief. As men are also left homeless they are reported to vent their anger increasingly on women. Thus it is common that physical, sexual and emotional violence increases during and after a disaster. Flood and cyclone shelters along with any relief centres throw women (used to sexual segregation) into sharing spaces with strangers where the men are more likely to sexually harass them. In addition, because they might find it more difficult to protect themselves, these shared spaces are particularly difficult for vulnerable women such as disabled women and nursing mothers.

Taken as a whole, it would appear that the underlying reason for greater female deaths during the 1991 Bangladeshi cyclone, as an example of climate chaos, is that of the social context rather than of individual incapacity to deal with the challenge. To back this statement, I can cite further studies, for example, a 2006 study of 141 natural disasters suggests that when men and women's economic and social rights are more or less equal, there is little or no difference between male and female deaths related to a disaster event. Female mortality is higher, however, where women have fewer rights than men (Neumayer and Plümper 2007). This type of conclusion can only be drawn by analysing underlying social structures (in this case, gendered behaviour of individuals) through a sociological perspective that looks for causal explanations in terms of social contexts.

5.6 Social embeddedness, inequality and climate change

Fortunately, climate chaos does not happen everyday. However, the invisible, slow but gradual degradation of the environment affects men and women, rich and poor, alike. But, if we take a closer look, it is the vulnerable, especially women in poverty who are more likely to be threatened by this. We therefore need to look at why this group is particularly vulnerable and why social differentiation affects the way individuals respond to climate change. (Dankelman 2010).

In the case of women in poverty all over the world, there are several commonalities which manifest themselves in powerlessness for the individual in their everyday lives. These include:

i. Poor women are less likely to own land or property yet are more dependent on natural resources for their livelihoods. Thus as ‘free’ (communal access) natural resources diminish, their chances of making a living are also threatened;

ii. Their power in society is limited by social, economic and political structures that constrain their capacity to cope as illustrated in the Bangladesh cyclone example above;

iii. They are often directly responsible for finding basic fuel, food and water supplies for their family in spite of limited mobility, particularly in the rural areas.

Continuing with the example of Bangladesh, women suffer large-scale social inequalities in terms of both material and non-material matters. The former include inequalities in land and property ownership, and inheritance rights. The latter include issues of decision-making within households, reproductive health, education and general human and political rights. Yet the roles and responsibilities defined by their societies mean that women are often responsible for meeting the food and water requirements of their families and caring for their children whatever the circumstances. In circumstances where they do not own property, many women in Bangladesh rely on common resources such as forests. As climate-related change and climatic variability affect activities based on common natural resources, their dependency on these activities and a lack of technical capacity make women in poverty even more vulnerable. Climate change thus affects their everyday capacity for food production and foraging as well as water scarcity due to changes in hydrological cycles. Water salinity, which accompanies climate variability especially in coastal areas, is another huge problem particularly in southwest Bangladesh. When nearby potable water is affected, women have to travel further distances often on rough terrain in search of alternative supplies (WEDO 2008).

Power and powerlessness are thus embedded in societal structures and influence the everyday worlds which individuals inhabit. Thus, individual actions and reactions to climate change are shaped according to their age, gender, class and other discriminatory factors that enable or constrain them.

Within a local structure, there is also the global context of the wider world. For instance, we are increasingly aware of the global interconnectedness of climatic impacts (such as evapotranspiration, desertification). Changes to climate and climate-dependent environments are nowadays hard facts of everyday reality, but they are increasingly a pressing issue for developing countries throughout the world. In fact, it seems almost inevitable that the more economically poor a country, the more it is likely to be affected adversely as it has a lower capacity to cope with this change (IPCC 2007).

I do, however, want to end this section with a note of caution. As mentioned earlier, it is important to remember that neither the poor generally nor women in poverty specifically are passive victims. A very strong global fight-back is evident in the way social movements around green issues have evolved. These include, to give a developed country example, the Environmental Justice movement which began in 1982. Hundreds of activists and local residents began to protest against the expansion of a chemical landfill in poor communities of Western Country, North Carolina, USA. The movement has since opposed and stopped many plans to turn communities into “waste incinerator dumps” and “toxic doughnuts” where communities are surrounded by a full circle of toxins (Pellow and Brulle, 2009 p435). Another historical example is from a developing country where the “Chipko”, tree-hugging women, led a huge protest against the Indian government and private firms wanting to destroy forests in the North of India in order to make profit from logging – a movement that has now spread beyond India (Shiva 1989, p67).

5.7 Climate change as remapping equality and inequality

Through lessons learnt from disasters such as floods, hurricanes, and the predictions made by climatologists, a sociological stance is concerned with social disintegration and increasing inequality that accompanies climate change. Sociologists speculate that, as vulnerability increases, societal chaos results, exemplified by mass migration, disruption of kinship and peer support systems, displacement, loss of subsistence economies, conflict and warfare. Examples are found in instances of migration arising from the recent drought and related conflict which have afflicted thousands from Somalia to Kenya (see also the Water Case Study in this series), or the millions who try to escape rural poverty, which has been intensified by environmental changes, in South America, Asia and Africa, by joining the ever-growing numbers in mega-cities. Therefore, the consequences of climate change and increasing inequality are far-reaching, not only across immediate neighbourhoods and localities, but also across wider geographical spaces and boundaries. It is important to note, however, that sociologists do not just attribute this bleak future scenario to climate change alone as they are always concerned with a multi-variable rather than a single variable explanation. However, climate change as an analytical indicator in environmental sociology is becoming more and more important.

Thus a sociological perspective inexorably links climate change to notions of inequality, and its counterpart, equality. Whilst I have focussed thus far on *inequality* and who is likely to suffer most, intriguingly for sociologists, climate change is also capable of providing new opportunities to bring nations and individuals together to create *equality* which will ultimately challenge existing inequalities. This is because in climate change everyone, rich and poor alike, is affected and we cannot escape our interdependence on the challenge that faces us[72]. A famous proponent of this view is a German Professor, Ulrich Beck (1944-) who has brought the issues of societal behaviour and future global sustainability to the forefront. He argues:

> 'Climate change globalises and radicalises social inequality; it exacerbates inequalities of rich and poor, core and periphery, and at the same time dissolves them in the face of a common threat to humanity. Climate change combines with the inequalities arising from globalisation, decoupling the producers and subjects of risk. Remapping inequality in the age of climate change and globalisation therefore requires taking account of the unbounding of both equality and inequality, and an awareness of the end of the opposition between society and nature, one of the founding principles of sociology". (Beck 2010:165).

He further argues (ibid) that whilst climate change has the potential to increase gaps and lead to social disintegration, a move away from nationalist principles and solidarity has the potential to create a global transnational solidarity in the face of climate change scenarios that impacts all humans. Uniting to tackle this has the potential to close divides and create global equality.

Propositions as those of Beck above (see also Wilson 2009: 274–280), suggest that sociologists can make an important contribution to both the understanding of the concepts and theories of climate change, but also discuss new ways of acting upon it that may unite rather than divide humans.

5.8 A place for sociology in debating climate change?

Arguably, science has the first claim on the study of climate change. Scientists from several disciplinary backgrounds for a long time have been able to advise the rest of us in an authoritative manner on greenhouse gases, the ozone layer and so on. In recent times, this authority has been reinforced, for example by the IPCC reports (1990–2007) which have been legitimatised by global approval and state backing in many countries around the world (see earlier chapters of this module). Secondly, popular science programmes on television and publicly accessible news and media reports have also brought the scientific

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[72] Interdependence is also an important backdrop to chapters 3 and 4 of this module.

interpretations of climate change to the forefront of the public imagination, particularly in the economically developed world which has connected economic activity with climate consequences. The latter is, of course, supported by the UK Government's influential 2007 Stern Review (*The economics of climate change*) which clearly identified the economic impacts of climate change and reflected on the benefits of management, adaptation and mitigation and a transition to a low-carbon economy (see Chapter 3 of this module).

It is difficult to trace a sociology of climate change through similar important reports. Essentially about society, sociology (as with other disciplines such as economics) offers varied ways of interpreting climate change. For instance, a Marxist sociological perspective would blame the economic system of capitalism and its unsustainable behaviour over a long period of time for environmental degradation. It would blame global inequality and western hegemony for continuing degradation. Production methods related to greed and profit would also enter the equation. Negative *externalities,* meaning the wider costs of production such as social and environmental costs which are not reflected in pricing mechanisms, are thus incurred. Those with a leaning towards the French philosopher, Michel Foucault (see also Module 2 of this series), may regard climate change as a social construction and in their analysis there would probably be something about how fears of climate change may be related to moral panics. Eco-centred or alternative sociologists would also construct climate change through its association with technology as well as global capitalism.

In fact, historically, a sociologist perspective on climate change has been closely associated with a long interest in environmental issues and the underlying relationship of societal behaviour to the natural and physical world. Over at least the last four decades (and with an ever growing literature), environmental sociology has given us insights into a range of human activity and interaction with nature, including the correlation between environmental degradation and climate change. These include how men and women, rich and poor, relate to the environment according to five important areas which determine societal behaviour and without which societies would not exist. Each society will, of course, emphasise these areas differently according to their needs and capacity. Generally, however, they represent how a society is engaged in:

- Social relationships of production (e.g. industrialisation, resource extraction, use of technology, externalities);
- Consumption (e.g. food, fuels, high resource commodities, luxuries);
- Biological and daily reproduction (e.g. through its population trends and consequences on environments, socialisation of children into awareness of the environment, public opinion of the environment);
- Spiritual leaning (e.g. cultural and religious understanding and relationship with nature);
- Action (e.g. Environment Impact Assessment (EIA), tradeoffs between environment protection and growth activities such as 'Recovery for Debt Programmes', social movements, social mobilisation).[73]

Nowadays, however, sociologists have shifted climate change from under the general umbrella of environmental concerns to specifically arguing for its place in sociology. Beck (2010), for example, makes a strong argument for inclusion of a sociological perspective as a complement to the natural scientific one in order to give us a fuller understanding of 'the environment' and climate issues:

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[73] For a fuller discussion on sociology's measured entry to the climate change specifics, see for instance Lever-Tracy (2008).

> "The discourse on climate politics so far is an expert and elitist discourse in which peoples, societies, citizens, workers, voters and their interests, views and voices are very much neglected. So, in order to turn climate change politics from its head onto its feet you have to take sociology into account. There is an important background assumption which shares in the general ignorance concerning environmental issues and, paradoxically, this is incorporated in the specialism of environmental sociology itself – this is the category of 'the environment'. If 'the environment' only includes everything which is not human, not social, then the concept is sociologically empty. If the concept includes only human action and society, then it is scientifically mistaken and politically suicidal." (Beck 2010: 254).

Urry (2010: 1), in using a carbon-based systems analogy, adds a further argument for a recognition of societal contribution to climate change. He states:

> "During the last few centuries and especially in the twentieth century various high carbon systems were established within various societies of the 'west', so much so that some refer to this as a new geological era of the 'Anthropocene' [see Chapter 2 of this module]. Societal changes brought about high carbon forms of life, as well as high population growth and growing greenhouse gas emissions. Especially important in this patterning from the twentieth century were interlocking carbon interests, what we might call the "carbon military-industrial complex" in many societies and around the globe. This seeks to extend major carbon-based systems including electric power and national grids; the steel-and-petroleum car system; suburban housing filled with household consumption goods; technologies for networking; distant, specialized leisure sites; and aero mobility.
>
> And in order to overcome the problems of this high carbon world it is necessary to bring about a wholesale shift to an interlocking set of low carbon systems – this involves establishing and examining the sociological characteristics of such a low carbon 'economy-and-society'. It is necessary to develop not post-modern, but what we could call 'post-carbon' thinking and practice. Thus there is the utterly crucial need for social science analysis of how to move to interlocking low carbon systems which on the face of it will provide lower levels of measured income, economic wellbeing and population. This is not at all simply a matter of policy prescription or of transformed economic incentives, but of transformed patterns of social life within most domains that especially counter the power and embedded interests of the carbon-military-industrial complex"

Thus while Urry acknowledges that scientific knowledge is essential for understanding climate change, so too is the knowledge of human behaviour which sociology can offer.

Another highly influential sociologist, Giddens (2009), emphasises the 'political will' issues which concern action on climate change. He asks why, in the face of growing scientific evidence that anthropogenic climate change is occurring to our planet through our actions, do we continue to behave complacently in the same manner. In view of this paradox, Giddens asks whether we, as humans, are waiting for the dangers of global warming, which are currently largely invisible to us (even though we know about them), to become visible before we act (although by that time there will be nothing that can be done about it). He points therefore to the issue of political will, and argues that, whilst politicians too are aware of the climate change threat to our planet, their action remains a gesture, and there will be little resolve unless there is genuine, concrete action and intervention at local, national and global levels. Giddens also has little faith in the precautionary principle (see chapter 3 of this module) and the notion of sustainable development (chapter 6 of this module). He considers the latter to be incoherent and therefore calls for systematic political change and coordinated action.

To note an additional point, it is not just sociology but other disciplines that are highly concerned about why we as human beings are not acting fast enough in view of the growing evidence and warnings of climate change. Unlike Giddens who locates his argument within structures in society (i.e. governance and political will), psychologists for instance, whilst not necessarily disregarding structures, turn to the individual. An important report based on various studies conducted for the American Psychological Association Task Force (*Psychology and global climate change Addressing a multifaceted phenomenon and a set of challenges 2008-9*), articles from which were later reproduced in the journal *American Psychologist* (2011), identifies several psychological barriers in individual perceptions of climate change.

This report (amongst a growing literature) suggests that individuals are often guided by emotional rather than scientific evidence into how climate changes poses risk to themselves or to a collective humanity. Their personal assessment is built up from various aspects and a diverse range of personal experiences and emotions. These include underestimation of events when people live a more or less comfortable lifestyle (as in economically developed countries) or an overestimation in the face of recent or localised disasters. Emotions also govern perceptions about the level at which an individual acts or engages in action related to climate change. Perceptions of climate change timeframes as something distant in space and geographical location often cause conflicting emotions about how much responsibility for action can be taken, especially when systems and natural processes appear to be beyond the individual's control.

As suggested in Section 5.2, the much varied social and cultural contexts in which we live and the everyday social pressures we face shape our environmental practices. If an individual is poor they will justify environmentally unsound practices within the context of survival. On the other hand, a carbon-dependent lifestyle, an overload of consumption together with media representation may also create conflict within individuals who are aware of their unsound practices but want to fit in with their social peers.

In addition, many people feel unaware of the actual problem and unsure of what to do about it to determine what makes sense to them in terms of individual risk management and action. Thus they may "scapegoat" others, for example, overpopulation in developing countries, or trans-national corporations for polluting. As Lorenzoni et al (2007) argue, this emotional reaction can lead to a fatalistic attitude resulting in individual lack of political engagement and even believing that arguments on climate change are "greenwash" and a marketing ploy. Thus they often turn to governments or other agencies to solve problems that they cannot see themselves able to act on.

From a psychology point of view, emotions, uncertainty, confusion, lack of knowledge, personal social contexts, culture, personal capacity and competence amongst other variables all shape perceptions of individual risk management and action. The knowledge we gain from this view also makes a valuable contribution in analysing individual and collective complicity towards the issue of climate change. We clearly cannot leave this to natural science alone. And, together with disciplines such as psychology, recent literature suggests that sociology (in spite of the slower entry) has quickly made serious inroads into the climate change debate. Further examples include:

(i) Evidence based arguments on the value of sociology to the debate (Yearley 2009),

(ii) Development of conceptual and theoretical analysis to pose climate change as a social construct (Beck 2010, Giddens 2009, Urry 2010);

(iii) Development of specific case studies related to sociology (Frumkin, Hess and Luber 2008, J Bicknell, Dodman and Satterthwaite 2009, Urry 2008).

To end this section, sociology has thus come a long way. As Hulme (2009) argues, rather than view climate change as a "problem" waiting for a "solution", we should begin to explore the diverse ways we have come to know and understand it as a social construct from differing standpoints (environmental, cultural, political). It can then act to make us reassess how we view our place in the world.

5.9 Conclusion to chapter 5

In conclusion, I want to recap the important contributions sociology can and has made in enhancing our understanding of climate change. In presenting climate change in a social context, it has given us a powerful insight into many aspects of societal relationships and responses to the phenomenon which are very different and perhaps more intricate than those of natural scientific research. These stem from a growing debate on individual, national and global interrelationships in connection to climate change and its very many associated issues. With such a broad subject range, sociology has thus been able to contribute to several strands of debate on climate change.

Thus for example, sociology’s existing voluminous research into culture has paved a path towards a cultural meaning of climate change, with the main question being how societies and individuals construct such meaning through an internalisation of values. Thus what we understand as the reality of climate change and how we react to global climate change issues – in other words, whether we accept the change (and therefore do something about it) or dismiss it mentally (as not really happening) –, depends partially on the meaning we attribute to it. As a result, some individuals and some societal groups will forge ahead with the idea of “going green” whilst others may feel that their personal contribution will remain so insignificant within the context of the huge issues that meaningful action is impossible.

Culture and meaning also shape our responses to consumption and production, two essential facets which allow our society and world at large to function. Whilst these processes clearly have economic and even political meanings, sociology has contributed to a deeper understanding of the making of consumption habits and production mechanisms. For instance, it has traditionally explored the relationship between consumerism and advertising and how this is reinforced through “popular culture”. It provides insights into how consumption, and related production methods, which forever seek new designs and sellable models, are determined and by whom. By analysing these processes, profit motives and behaviours of advertising companies, particularly those of transnational corporations, sociology explains how institutional, processes and national governments which support such processes advertently or inadvertently, in turn, present barriers to “green economies”. In order to support profit-making (particularly capitalist ventures), institutions, organisations and government bodies therefore may not be able to develop alternative, sustainable habits and a change in individual attitudes to consumerism and production.

Further, as suggested in the text above, an important notion in all sociological analysis is that of inequality and the role of power and powerlessness in the way climate change affects different nations and different people. There is, for instance, strong evidence that climate change will probably impact most negatively on countries which have been least responsible for creating the problem. Climate change, it is predicted, will manifest itself in many walks of life, including the environment, health, weather and disaster-related responses. Yet whilst we may all be affected by these to varying degrees, we will not be able to respond to and mitigate changes in the same way. In this, an analysis of equality and inequality is critical to the understanding of the varying capacity that people have in responding to change and the consequences of this varying capacity for developing countries in particular.

In fact an analysis of equality and inequality has also allowed sociology to enter strongly into debates on environmental justice. This is manifested, for example, through its focus on the interrelation between gender, class and race dimensions in society and its analysis of the aftermath of disasters where inequalities are exacerbated (as with the Hurricane Katrina example in section 5.4 above). As discussion and analysis without action is fairly meaningless, sociology has also begun to examine the multi-dimensional and multi-level (global, national, local) processes of how climate change policy is made and implemented. In considering the effectiveness of these policies, it considers the political processes that allow representation of pluralist interest groups, advocacy groups, governmental and non-governmental organisations and so forth. In this way, it has been partly instrumental in moving the climate change debate to the public sphere. This has been an important move as it has shifted the image of "climate change" as a looming but distant threat and a scientific problem to a public problem to be resolved through effective public policy and action.

Sociology, as a discipline, may therefore have made a later entry into the climate change debate, but its contributory value has already made a mark into several disciplinary areas, including natural science which is starting to recognise the value of interdisciplinarity. Thus even the Philosophical Transactions of the Royal Society, a renowned UK-based science body, has increasingly begun to look to a society-based analysis for complex climate change issues. For instance, after examining the shift of climate change from a "scientific" to a public sphere space, Corfee-Morlot, Maslin and Burgess (2007: 2772) confirm that there is an:

> "Intimate relationship between science and society, especially on complex issues such as global environmental change. The interactions between science and society argue for a hybrid model of social theory on the environment where the power and influence of scientific discovery and developments are mediated through social means. Tracing the emergence of climate change in the public sphere supports the notion of co-production of knowledge and understanding, a process which combines the strengths of realist, scientific discovery with contextual insights and knowledge, where society and science co-construct meanings of global warming" (p2772).

They add that:

> "Although a global environmental problem is initially identified and advanced by science, it inevitably becomes intertwined with society, with politics and policy. Scientific research is also inevitably shaped by society" (ibid: 2768).

A sociological perspective is instrumental in raising that awareness.

If you have not done so already in the places indicated in the text, to conclude your study of Chapter 5 and for you to reflect on the issues raised by the sociological perspective on climate change, turn to the Module 1 workbook activities 5.1–5.5.

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6: Conclusion: integrating the perspectives within the paradigm of sustainable development

By Gordon Wilson and Carolien Kroeze

We start this final chapter of Module 1 by firstly reviewing the main messages of the preceding main chapters 2–5. Then we describe how scientists have brought some (but not all) of the concerns of chapters 2–5 into what are called Integrated Assessment Models. Finally, we act as a critical friend to these models and extend them into the concept of sustainable development, a concept which we also interrogate.

6.1 The main messages of the disciplinary inputs to Module 1

The different disciplinary inputs in chapters 2–5 are rich and go into considerable depth. They illustrate, if nothing else, what a rigorous application of disciplinary knowledge can bring to a subject such as climate change.

Summarising the main messages, therefore, involves inevitably a process of selection. Those that we have chosen here have been selected because they fit our purpose for the final chapter of the module. You may have obtained other insights which you think are important, and the authors of these modules may also think that we have not quite done justice to them. Nevertheless, we must make a start:

Chapter 2: What science can tell us about climate change. We are often told that climate is a complex system, but chapter 2 demonstrates just how complex it is. This is not so much a matter of understanding the mechanisms of how the so-called greenhouse gases can lead to global warming, or of understanding the many factors at play. More important is the way these factors interact in a systemic manner (which is why the chapter refers to the climate *system*), with multiple feedback effects. Some of these feedbacks are ‘positive’ (reinforcing the global warming effect) while others are ‘negative’ (mitigating the global warming effect). Understanding the importance of systemic feedbacks is crucial to understand the modelling of the climate by scientists. However, modelling the future is highly uncertain, not only because of the complexity of the physical system, but also the big unknown concerning future human behaviour.

Thus, the key message of chapter 2 is the explanation of climate in terms of the complex interactions and feedback in a dynamic system

Chapter 3: Economics matters in climate change. This chapter starts the exploration of how human beings affect climate. It links our ability to labour – economic activity – to the release of greenhouse gases, and how mainstream economists strive to reconcile continuing economic growth, which they argue is essential for human welfare, with mitigation of this release. In doing so we are introduced to the tool of cost-benefit analysis and enter the economists’ world of climate change in relation to markets, prices, incentives, technological innovation, and gross domestic product. While the chapter outlines alternative perspectives, the key message of this chapter is that climate change will cost the world dear if we don’t act. However, through incentives and human ingenuity we can create an inclusive global green economy, which brings mutual prosperity.

Chapter 4: The politics of climate change. While chapter 3 tries to account within a cost-benefit framework different impacts on, and capacities to act, between the global North and the global South, chapter 4 takes on board much more thoroughly the different interests of countries, and regional blocs of countries, and how these different interests represent serious obstacles to an international climate change deal. The key message of the chapter, therefore, is the understanding it offers of the ‘realpolitik’ of climate change policy-making and why, in the face of the scientific evidence, an international deal is a long process.

Chapter 5: The social impact of climate change. From this chapter, we gain a sense of the differentiated impacts a changing climate is having, and is likely to have, on different groups of people. The key message is that impacts and our ability to respond are highly differentiated and structured by our social contexts. These social contexts also structure our commitments to action.

You should further note three general points about chapters 2-5:

1 *They operate at different, albeit overlapping, scales*. Chapter 2 operates unashamedly at a global level, because that is the state of the science, but also because science tends to deal in universals. The main part of the analysis in chapter 3 is also carried out in relation to the overall global economy. It does, however, start to differentiate, and takes into account, structural economic differences in the world between the global North and the global South, as mentioned above. Chapter 4, too, is ostensibly about negotiations at the international scale, but now the world is differentiated into regional blocs of interests (and not just North-South regional blocs). Even individual countries that are crucial to climate change negotiations, or are exemplars in good/bad practice, are covered by the analysis. It is finally left, however, to chapter 5 to deal with the impacts on people and social groups at a range of scales, but especially the local.

2. *Inter-scalar connections are also signalled within the chapters*. In chapter 3, it is necessary for the rich countries of the North to make transfers to the poor countries of the South in order to transform towards the vision of a 'green' global economy. In chapter 4, domestic politics influences strongly the international bargaining positions of, for example, the United States and Norway on climate change. In chapter 5, of course global phenomena such as droughts, floods, sea level rise impact on localities, but individuals through their 'cultures of consumption' also impact on the global.

3. *The chapters overlap with each other in terms of covering the same or similar content*. Thus the anthropogenic global warming referred to in Chapter 2 is, to a significant extent, the result of economic activity (chapter 3), while national and regional economic interests inform international climate change negotiations (chapter 4). These national interests are in turn informed by the social impacts and cultural preferences of their populations.

We can appreciate in general the power of disciplinary analyses offered by chapters 2-5, and their depth. Such analyses are, however, by definition bounded (disciplined) by their core concepts and each is therefore also limiting. Once we note their inter-scalar connections, and the interfaces between them, we start to explore the possibilities of a deeper understanding of climate change through integration. This is the starting point for an interdisciplinary inquiry, while hitherto we can only claim a multidisciplinary one.

Scientists of all persuasions (natural and social scientists) too have noted the added value in terms of integrating different disciplinary perspectives, especially when they wish to provide scientifically credible answers to policy-relevant questions [Leemans, 2008]. It is to these attempts to provide such integration that we now turn.

6.2 Integrated Assessment Models

These models were introduced in chapter 1 as an advance on the environmental assessments that are made from different disciplinary perspectives. Only by combining these perspectives can we identify the best options to approach future climate change. An important question when considering options concerns whether we should focus on adaptation to climate change, or whether we should focus on reducing greenhouse gas emissions in order to mitigate future climate change, or both.

Integrated Assessment (IA) Models are therefore environmental models that integrate information on the causes, effects and possible solutions of environmental problems. The IMAGE model is an example of an IA model (Figure 6.1). It integrates knowledge on the drivers of global changes including demographic and economic trends, with terrestrial, ocean and atmospheric sub-models in order to explore future trends in greenhouse gas emissions and their impact on ecosystems and society [Strengers et al., 2004]. IA models typically are meta-models, aggregating detailed information from disciplinary models of the atmosphere, or of terrestrial or aquatic systems. They are primarily developed to explore future trends on the basis of assumptions about future human activities.

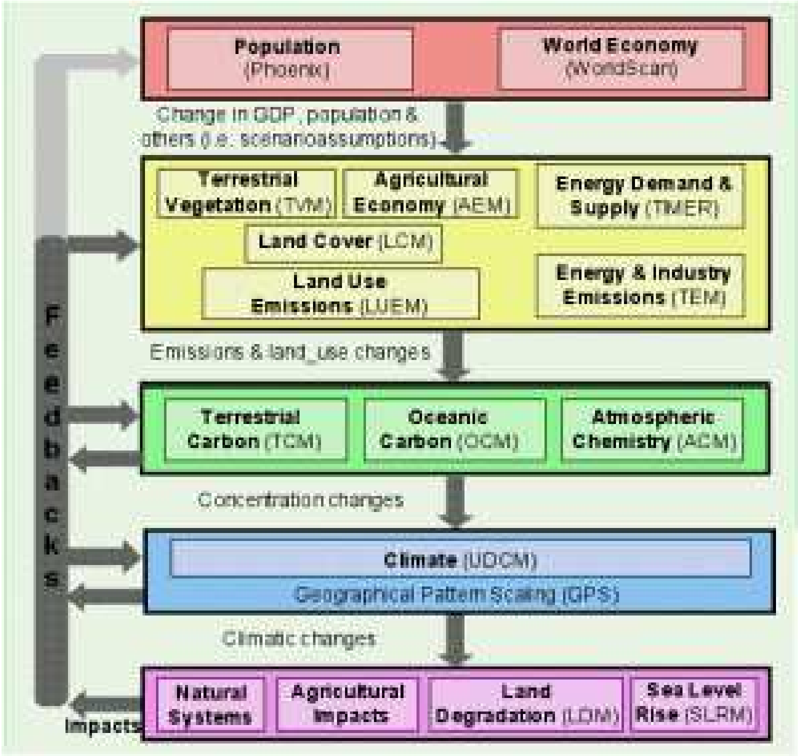

Figure 6.1 The IMAGE model [Strengers et al., 2004]. For higher resolution, see: http://www.lenntech.com/greenhouse-effect/ipcc-scenarios.htm (accessed 12th March 2012)

The future of the climate

To explore possible future trends, the IPCC developed the so-called Special Report on Emissions Scenarios (SRES) that describes possible future worlds without explicit climate policies (see Figure 6.2). These scenarios differ with respect to assumed global socio-economic developments (globalization or regionalization[74]) and with respect to attitudes towards economic development (a focus on economic growth or sustainable development). Based on these general assumptions, storylines of how the world might develop were written. The resulting scenarios are identified as A1, A2, B1 and B2 (Figure 6.2).

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74 Globalisation here refers to the integration of the world economy, facilitated by information and communication technologies and rapid transport systems. Individual countries are often taken as the building blocks for globalisation (although it often transcends national borders too) and the efforts of bodies such as the World Trade Organisation are aimed at removing barriers for free trade between them. Regionalisation is not a new idea, but is coming to the foreground again as an antidote to some of the excesses of globalisation and its inherent tendency to build in structural inequality between and within countries. In regionalisation, identified groups of countries come together to form internal trading blocs while retaining the national political sovereignty of each. Within these blocs they set their own, regionally appropriate, rules for trade. You might like to consider regionalisation in terms of how it applies to the European Union.

Summary for Policymakers — IPCC WGI Fourth Assessment Report

The Emission Scenarios of the IPCC Special Report on Emission Scenarios (SRES)[18]

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.

The SRES scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

Figure 6.2 Description of IPCC SRES Scenarios, copied from the IPCC Summary for Policy Makers [IPCC, 2007c]. For higher resolution see: http://www.grida.no/publications/other/ipcc_sr/?src=/climate/ipcc/emission/ (Click on 'Summary for policy makers-What are the main characteristics of the new scenarios second page) (Accessed 12th March 2012).

Using multiple climate models, including IA models, the implications of these scenarios were analysed (Figure 6.3) [*IPCC*, 2007a]. In all scenarios, global greenhouse gas emissions increase until the year 2050. After that year, some scenarios show continued increasing emissions, while in other scenarios emissions start to decrease. These trends are the net effect of assumptions on population growth, economic development and environmental concerns. The effect on the global climate is also shown in Figure 6.3. In all scenarios the temperature continues to increase. By 2100 the global warming amounts to 1–6 degrees Celsius in these scenarios. It should be noted that these numbers reflect the global average warming, and that there are large regional differences. Generally, the warming will be larger at the poles, and smaller at the equator.

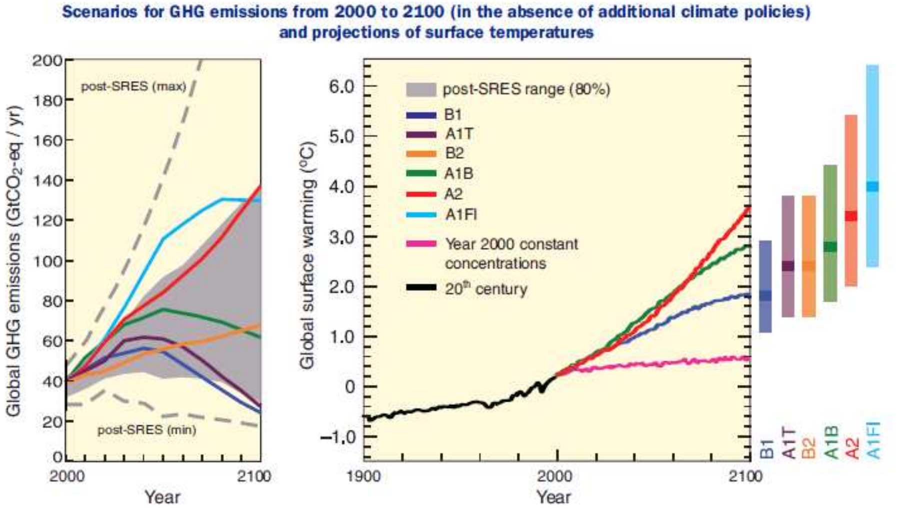

Figure SPM.5. ***Left Panel:*** *Global GHG emissions (in $GtCO_2$-eq) in the absence of climate policies: six illustrative SRES marker scenarios (coloured lines) and the 80th percentile range of recent scenarios published since SRES (post-SRES) (gray shaded area). Dashed lines show the full range of post-SRES scenarios. The emissions include CO_2, CH_4, N_2O and F-gases.* ***Right Panel:*** *Solid lines are multi-model global averages of surface warming for scenarios A2, A1B and B1, shown as continuations of the 20th-century simulations. These projections also take into account emissions of short-lived GHGs and aerosols. The pink line is not a scenario, but is for Atmosphere-Ocean General Circulation Model (AOGCM) simulations where atmospheric concentrations are held constant at year 2000 values. The bars at the right of the figure indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios at 2090-2099. All temperatures are relative to the period 1980-1999. {Figures 3.1 and 3.2}*

[8] For an explanation of SRES emissions scenarios, see Box 'SRES scenarios' in Topic 3 of this Synthesis Report. These scenarios do not include additional climate policies above current ones; more recent studies differ with respect to UNFCCC and Kyoto Protocol inclusion.

[9] Emission pathways of mitigation scenarios are discussed in Section 5.

Figure 6.3. Future projections of climate change, copied from the IPCC Synthesis Report [IPCC, 2007a]. For higher resolution of right panel, see: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/figure-spm-5.html (accessed 12th March 2012)

For the next two decades a warming of about 0.2°C per decade is projected. Model runs, assuming that concentrations of all greenhouse gases and aerosols will stay constant at the level of the year 2000, indicate a further warming of about 0.1°C per decade. If greenhouse gas emissions in the future are at or above current rates, the warming will be higher. This could induce many changes in the global climate system, including sea level rise, changes in precipitation, wind patterns, etc. These changes, in turn, could have important impacts on water availability, ecosystems, food production, coast lines, and human health (Figure 6.4).

In March 2009, scientists met in Copenhagen a few months before the Copenhagen Conference of Parties to the UN Framework Convention on Climate Change (the much-maligned Copenhagen Summit). This scientific climate change congress formulated a number of messages from science: (1) climate trends are visible, (2) there may be social and environmental disruption when global warming exceeds 2 degrees, (3) a long-term strategy is needed with firm 2020 targets as first steps, (4) equity dimensions are important, (5) inaction is inexcusable, and (6) the focus needs to be on meeting this challenge (http://climatecongress.ku.dk).

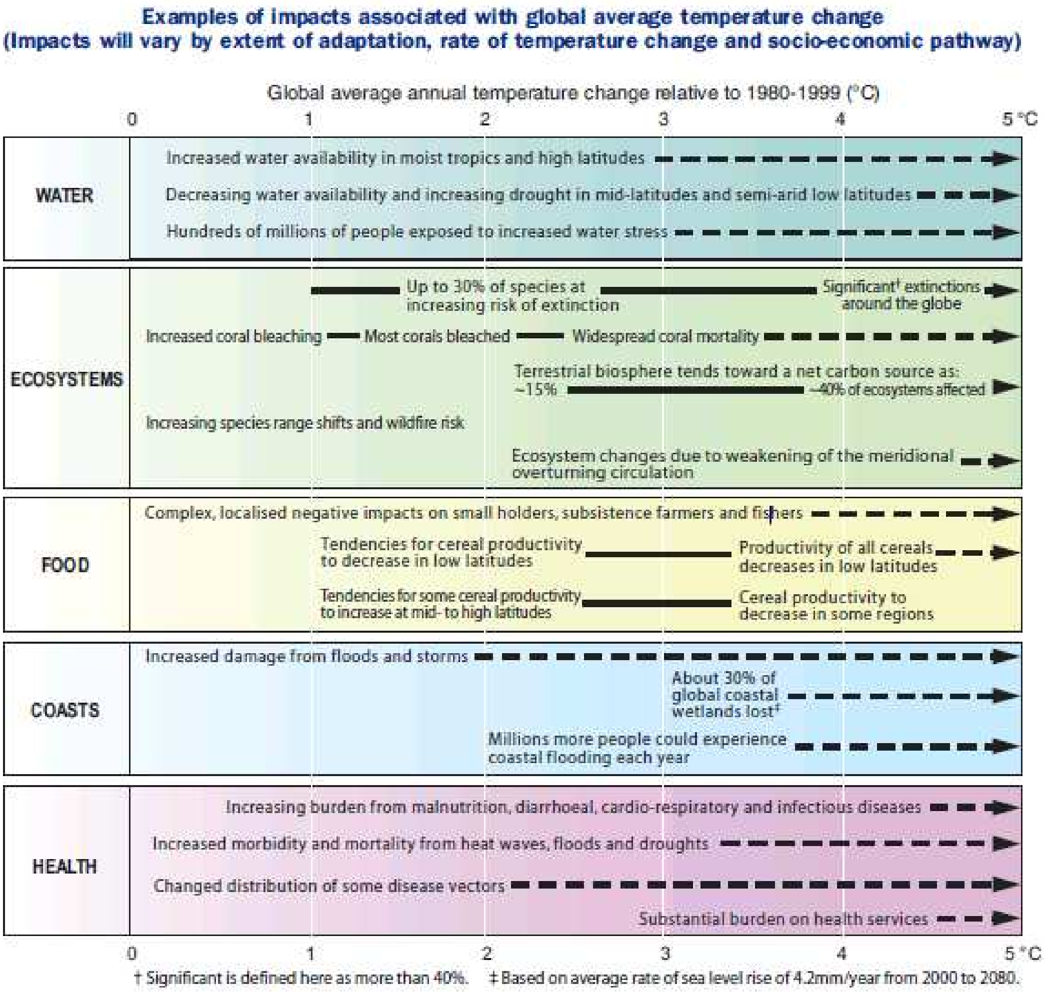

Figure 6.4 Examples of the impacts of global warming [IPCC, 2007a]. For higher resolution, see: http://www.ipcc.ch/graphics/syr/spm7.jpg (accessed 12th March 2012)

6.3 From integrated assessment models to sustainable development?

Between them, Figures 6.1–6.4 cover the actual or potential environmental, economic and social impacts of climate change. As such they represent a serious attempt by scientists to map, through integrated assessments, their concerns onto what are commonly referred to as the three pillars of sustainable development – environment, economy and society.

At this point we ask you to put aside for the moment any one of the 100-plus definitions of sustainable development that you may have encountered. Instead, we return to first principles about the meanings of each of these pillars.

Environment refers to our ability to sustain the natural environment over time. This, however, is not simply a quantitative time issue. We might be able to sustain most things over time, but only if we allow (or force) them to exist in a degraded form. There is also, therefore, a dimension to sustainability whereby we expect 'quality' to be maintained and even improve. We might further add the dimension of robustness – the ability to withstand and recover from shocks (for example, extreme weather events). These dimensions of sustainability apply to the other pillars as well, but we can easily apply them to the environmental sustainability of climate change. In a generalised sense, climate change starts with the degradation of our atmosphere through greenhouse gas emissions. This in turn impacts on our climate, and on our water, ecosystem services, landscape and biodiversity, which become increasingly vulnerable to shocks.

Economy is broadly viewed in terms of providing our means of livelihood. Following environment, this is the ability to sustain an economy that is robust and improves over time. It raises issues, however, of inclusion in this sustainable economy – is it for all of us to realise secure livelihoods, or just a few? Is its main measure our economic output – gross domestic product – or employment rate or some other measure that relates the economy to our quality of life?

Society concerns our ability to play a full, satisfying and sustained part in social life, where we are able to recover from shocks to social systems (the most extreme example being a war). Generally it is assumed that inclusion should apply to everybody and that issues of social exclusion of some groups (poor people, women in some societies, ethnic and religious minorities) raise serious challenges for the sustainability of society.

Many countries have expressed a commitment to sustainable development. For a few it is even written into the country's constitution, and sustainable development indicators have been developed. These indicators invariably draw on the three pillars.

One example is Wales, a small nation with devolved government within the United Kingdom. The Welsh Assembly Government environment indicators include emissions of greenhouse gases, percentage of waste recycled, air quality, river quality and wildlife. Economic indicators include employment and economic growth rates. Social indicators include crime, housing and education. The problem is that these sustainable development indicators can be, and often are, used simply as a check list of boxes to tick without thought given to what they mean or how the different indicators interact. For example, an indicator that includes economic growth will almost certainly be in tension, in many views, with environmental indicators (Thomas 2009: 178).

Other examples of tensions between and within the pillars can easily be found. We provide here just two, respectively from India and the United States (US).

- Mumbai, that great sprawling city on the west coast of India, is known both for its extremely rich people and the largest slum in Asia (Dharavi). Abbott (2009) reports on the contrasting agendas of the rich and poor in Mumbai. The rich are concerned with preservation of large open spaces where wild animals can roam, the poor, who often set up squatter settlements in these open spaces, are concerned with environmental health concerns such as clean water and adequate housing.
- The US is the richest country in the world. Environmentalism in the US has classically been associated with preservation of wilderness and the frontier ideology of the 'Wild West'. It has given rise to the great national parks of the US. Environmentalists, however, have been accused of being concerned to a much lesser degree with issues of people's jobs (the economy) or the siting of toxic waste dumps next to poor communities (society), and this has led to major debate (Crow 1999).

To turn to the definitions of sustainable development that we have put to one side until now, the 'classic' and most-quoted remains that developed by the World Commission on Environment and Development in 1987, which was chaired by the then Norwegian Prime Minister, Gro Harlem Brundtland. It subsumes the three pillars within a generalised definition, where sustainable development is 'development that meets the needs of present generations without compromising the ability of future generations to meet their own needs' (Brundtland 1987: 43).

As with all general definitions, this one is very abstract, and the three pillars were developed subsequently in part to make it more concrete, but also to deal with the criticism of the definition that it pays explicit attention to 'inter-generational equity' (the well-being of future generations) but does not refer to 'intra-generational equity' (the inequalities in well-being that exist between countries and social groups in the present).

These issues of intra-generational equity go to the core of the debate about which countries are historically responsible for global warming (see chapter 4).

It should be fairly obvious from the above that, taken seriously, sustainable development requires the integration of these pillars. The Integrated Assessments (IAs) of climate change described in the last section should be applauded, therefore, as they often go some way towards this. They certainly represent an advance on indicator checklists. There are, however, issues concerning many IAs, no matter how sophisticated they might become in the future. These are not so much issues of the IAs themselves, but more about what might be needed to complement them. We outline three:

1. As they freely acknowledge, the IAs are typically developed at a high level of aggregation. Questions we ask of climate change in the context of sustainable development, however, especially in relation to the economy and society pillars, force us to disaggregate beyond the capabilities of IAs.
2. While the IPCC process promotes the involvement of users (policy makers) in the production of IAs, many have not actually involved them in a substantive way. Models like the IMAGE discussed above are developed by scientists, while the interactions with policy makers help to shape the model and decide on what model runs to analyse. But there are many examples of models and assessments where policy makers have played a minor role in their creation. Thus, some IAs tend to ignore the ***process*** of making policy on climate change, their job, as they see it, being to provide scientifically derived knowledge inputs into that process, rather than concern themselves with the messy politics. They do this by providing scenarios of climate impacts under different socio-economic assumptions, but with no judgement as to which is preferable. Their job is then done. It is up to the politicians to choose the scenario and make policy accordingly. Chapter 4, however, illustrates that making policy on climate change has to deal with competing interests, where knowledge inputs become highly politicised. This criticism that IAs ignore process regarding how climate change policy made can also be levelled at our discussion of sustainable development so far and its three pillars. Here, however, it is interesting that an alternative model of sustainable development introduces a 4th pillar – that of policy – because of this issue (O'Donoghue, cited in Hewat and Banda 2009: 229)).
3. IAs that do not consider the users of the results, are by themselves, ultimately limiting, precisely because they are purely scientific and bounded by their ways of thinking. Again, it is not their function to be otherwise so this is not a criticism of them for what they are. The fundamental assumption behind sustainable development, however, is that it is inclusive. In terms of the three pillars: environment is for all, the economy is for all and society is for all. The logical extension of this, and especially with regard to climate change, is that we are all included in the process of addressing the challenge, and for that to happen the knowledge derived from our experiences has to be acknowledged and taken on board. In sum, climate change is too important to be left to scientific knowledge (even when broadly defined to include both natural and social sciences) and politicians alone.

The third issue identified above extends the second about process into a general domain. To many it may seem like a frightening thought. If politicians engaged in formal processes of policy making are structured by self-interests and power, what happens if we expand the process beyond them? Don't the same issues apply, but now multiplied beyond imagination?

However, and especially with respect to climate change, there is hope, because, despite our conflicts of interest, we are also fundamentally interdependent, and we have seen examples throughout this module. Thus, the mainstream analysis in chapter 3 concerns the continuing development of a world economy where we are all interdependent for production and trade in their broadest senses. Politicians have to agree some global deal and action because climate change recognises no borders (chapter 4). Huge human migrations resulting from climate change impact on and could put other societies at risk (chapter 5).

Rather than despair, therefore, our interdependence means that we can also tap into our different experiences positively where difference is a source of learning from and with each other, new knowledge and ultimately action. This is fundamentally a different approach to knowledge to that provided by the sciences, not necessarily in contradiction, but complementary to them. To use our difference in this way, however, is predicated on our human ability to engage with each other, to discuss and debate. These matters are discussed further in modules 2 and 3 of this series.

As already noted, interdependence is particularly appropriate to a phenomenon such as climate change which acts at a global scale and recognises no territorial borders. It echoes a process of around 150 years ago in Europe which led to the great public health initiatives such as provision of clean drinking water. Then, the interdependence between scientists, politicians and citizens was encapsulated in the phrase, 'germs recognise no borders'.

What we can learn from the historical example of public health in Europe, and from the nature of climate change today, is that any analysis that ignores the process by which things actually happen is by definition incomplete. Thus, we conclude that, yes, it is useful to think of climate change in the context of sustainable development. But climate change also requires us to rethink what sustainable development means. To many it is a grand vision towards which we strive and that is good. We should not confuse vision, however, with end point. Our analysis leads us to the conclusion that it is better to think of sustainable development as an ongoing process of learning through our engagements with each other on the subject, both formally as when negotiating policy and informally as citizens. In this view of sustainable development, seeming 'end points' such as an action on greenhouse gas emissions are also important points in the process, and more often than not triggers for further engagement and learning. Nor are they the only triggers – any idea or action you hear of that is related to climate change can be a trigger .They include, for example reports, such as the Integrated Assessments discussed above, or even this and the other modules in this series.

Viewing climate change in the context of sustainable development as a process of learning might seem a much more modest goal than achieving the grand vision, but with a bit more modesty and respect for our differences, we might actually achieve more.

Thus, valuing our human interdependence requires thinking about our different interests and the things in which we believe – our different knowledges – in a different way, as a source of learning and joint new knowledge which in turn creates a 'background consensus' (Habermas, cited in Fischer, 2003: 199) for policy and action on climate change. We have also argued that, if we are to take sustainable development seriously, the range of knowledges that we take into account must expand beyond those conventionally defined by the sciences (natural and social) to include the experiential knowledges of citizens.

Thus we conclude Module 1 by introducing the main focus of this series – the concept of the lived experience of climate change. The whole of Module 2 is devoted towards developing this concept, while Module 3 focuses on the methodological challenges of capturing it and making it useful. To end Module 1, however, we simply flag the lived experience of climate change as an important different kind of knowledge, but a knowledge which, like those that derive from the sciences, we must scrutinise critically for the influences on it that stretch back in time, as the word 'experience' implies. Such a scrutiny will reveal not only its potential contribution to knowledge for climate change policy and action, but also its limitations.

To reflect further on chapter 6 and the module as a whole you might now wish to turn to Activity 6.1 in the Module 1 workbook.

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