Module 1:
An Introduction to Climate Change

Lesson 1:
An Introduction to Climate Change: The Science behind the Phenomenon

UNEP Finance Initiative (UNEP FI) e-Learning Course on
Climate Change: Risks and Opportunities for the Finance Sector

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Lesson 1: An Introduction to Climate Change: The Science behind the Phenomenon

Lesson 1 Contents:

Objectives

This lesson has three main objectives:

- To show why scientists believe the Earth's weather system is changing
- To detail how these changes affect natural systems and human society
- To explain why this is relevant for business as a result of changes in the natural environment, in regulation, and in customer behaviour.

1.1 Introduction

The climate has always changed due to natural variations in the Earth's orbit. What is new is that human activities are altering the natural pattern, and this phenomenon is accelerating. Section 1.2 explains how manmade climate change is due to greenhouse gases, which are by-products of economic and land-use processes. By storing the Sun's energy, the gases raise the Earth's temperature and alter the weather and the oceans.

The detailed effects of global warming are predicted from complex computer programmes (General Circulation Models, or GCMs). Section 1.2 describes how their results are validated and assessed by the Intergovernmental Panel on Climate Change (IPCC). The results depend not just on the model specifications, but also on assumptions about future social and economic trends.

The GCM's predict large changes in weather systems and a steadily rising sea level in coming decades. The GCM predictions are reviewed in Section 1.3, focussing on vulnerable sectors (like water and insurance), and regions (coastal zones and developing countries). If we continue "business as usual" those changes will become even greater, and could overstep critical thresholds leading to destabilisation of some components of the climate system and possibly rapid climate change.

Section 1.4 deals with the critical question of timescales. Climate change is not a far-distant problem. Already the frequency of historically rare events is rising fast. Since extreme events do a disproportionate amount of damage, this has serious implications for infrastructure with a lifetime of decades, and also insurers of course. It takes decades for greenhouse gases to fade. This means that we need to plan for worsening impacts for at least 40 years. But, the lag effect also means that emission reduction policies are required now to avoid greater impacts after mid-century. That means new technologies for key economic activities which are energy-intensive, like electricity production and distribution, or transport systems, and new markets in carbon reduction. The Stern Review reinforces the case for strong, early action to modify energy use and limit the atmospheric accumulation of greenhouse gas emissions.

1.2 What is Climate Change?

The Earth has an inhabitable climate because it has an atmosphere of greenhouse gases that trap energy from the Sun's rays, raising the temperature by about 32^{o}C (Figure 1). There are natural variations in the climate due to subtle variations in the Earth's orbit around the Sun. These create seasonal patterns like monsoons, and winters, as well as much slower shifts like Ice Ages. Superimposed on these there are random fluctuations, which create the daily weather. What is new is that human activities are strongly altering the natural pattern, and the changes are accelerating.

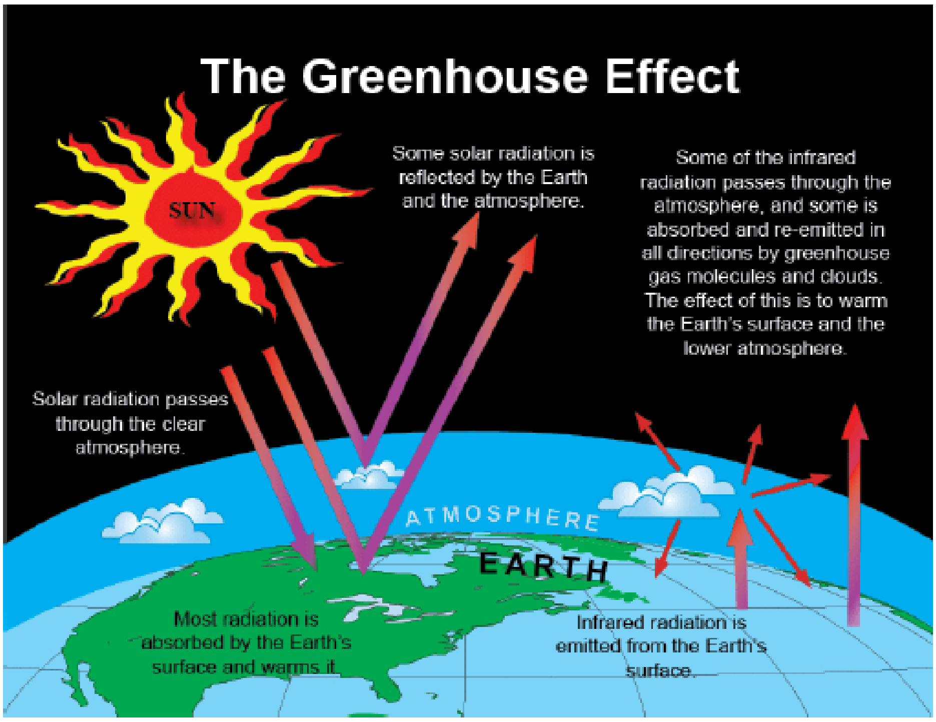


Figure 1: The Greenhouse Effect.

Source: IPCC AR4 Working Group I, Chapter 1

Manmade or anthropogenic climate change is due to the fact that energy consumption and changes in land use produce large quantities of greenhouse gases as byproducts. (see Box 1). The principal greenhouse gas is carbon dioxide, but methane, and certain industrial gases are also powerful. The volumes of them in the atmosphere have risen swiftly (see Figure 1), and they remain there for decades. The quantities emitted into the atmosphere are huge. For example, currently the annual emissions of anthropogenic carbon dioxide are around 25 billion[1] tonnes (gigatonnes), of which the active component , carbon, amounts to about 6.5 gigatonnes, or roughly 1 tonne per person on Earth, though of course the emissions are predominantly from developed countries. The key issue is what proportion of the atmosphere is composed of greenhouse gases. The level of atmospheric concentration is measured in parts per million by volume (ppmv) , or parts per billion (ppbv). In 2008 carbon dioxide (CO2) reached 386 ppmv, compared to its natural level between Ice Ages, of around 280 ppmv.

When the climate system is in balance, the amount of carbon released from sources like plants as they grow, is absorbed in a variety of natural sinks, such as oceanic water, marine organisms like shellfish, mature forests, and bogs. This is called the carbon cycle.

[1] US billion i.e. thousand million, or milliard

Box 1: Greenhouse gases

A large number of natural and artificial gases store energy from solar radiation. Each gas has a different strength, or global warming potential (GWP) based on its capacity to absorb energy and its lifetime in the atmosphere. Conventionally, they are rated by reference to carbon dioxide, which is given a GWP of 1.0. Six of the gases are regulated under the Kyoto Protocol (see Lesson 3). Others deplete natural ozone, and are regulated under the UN's 'Montreal Protocol on Substances that Deplete the Ozone Layer'.

The six main 'Kyoto' greenhouse gases, and their sources, are:

- CO_2 – Carbon dioxide – mainly from fossil fuel combustion; [GWP: 1*]
- CH_4 (Methane) – agriculture, waste management processes, fossil fuel extraction; [GWP: 23]
- N_2O – Nitrous oxide – agriculture, fossil fuel combustion in transport sector; [GWP: 298]
- PFCs – Perfluorocarbons – alternative to ozone depleting CFC's and HCFC's; aluminium production, and semi-conductor manufacturing; [GWP: 5,900-12,200]
- HFCs – Hydrofluorocarbons – substitutes for CFCs and HCFCs; refrigeration, foam blowing, air conditioning equipment; [GWP: range 124-14,800, the latter for HFC-23]
- SF_6 – Sulphur hexafluoride - insulator for electrical equipment; also semi-conductor manufacturing processes. [GWP: 22,800]

The Montreal protocol gases are:

- CFC's and HFC's – Chlorofluorocarbons and Hydrochlorofluorocarbons- refrigeration and other industrial processes [GWP: 5.0 – 10.800]

The most common "greenhouse gas" is water, which has a short lifetime in the atmosphere, and so is generally ignored in terms of global warming. There are also various emissions which reflect solar radiation and so cool the Earth. The most powerful one is sulphur dioxide (SO_2) - see Figure 1. These are short-lived in the atmosphere, and are often associated with poor air quality.

* *GWP is for 100 year lifetime of the gas in the atmosphere, based on IPCC AR4*

By storing the Sun's energy, the gases raise the Earth's temperature and that in turn alters the weather and affects glaciers and the oceans. The most obvious effect is to warm up the atmosphere, which is why the term "global warming" is often used. Figure 2 shows how the anthropogenic warming effect has developed since the Industrial Age began. Scientists estimate that in the last 100 years the Earth has warmed by 0.74^{o}C. Every year since 2001 inclusive has ranked in the top nine warmest years since 1850. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR4) states that the evidence for this is "unequivocal", that this warming is "unusual" and "very likely due to anthropogenic greenhouse gases" i.e. with a probability of over 90%.

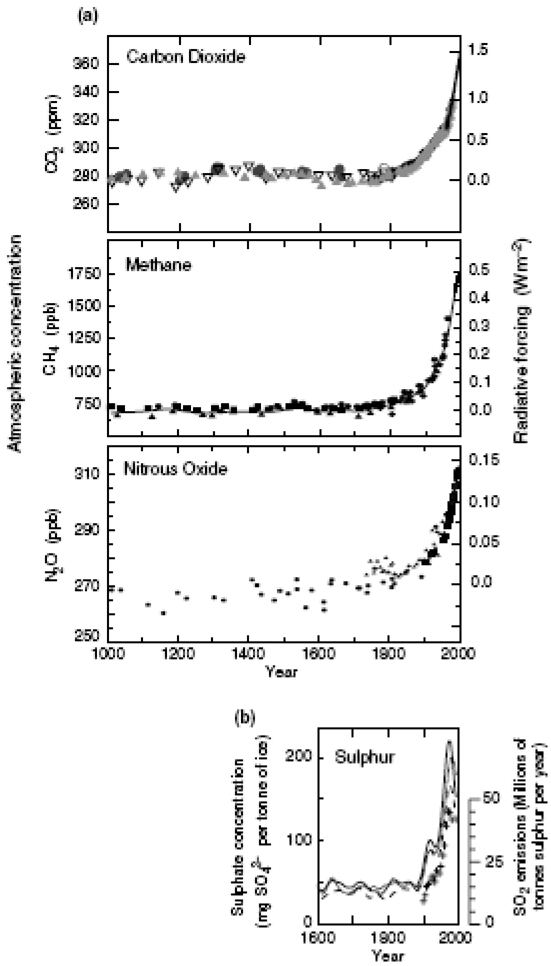


Figure 2: Growth of greenhouse gas concentrations in the atmosphere.

Records of changes in atmospheric composition.

(a) Atmospheric concentrations of CO_2, CH_4 and N_2O over the past 1,000 years. Data for several sites in Antarctica and Greenland (shown by different symbols) are supplemented with the data from direct atmospheric samples over the past few decades (shown by the line for CO_2 and incorporated in the curve representing the global average of CH_4). The estimated radiative forcing from these gases is indicated on the right-hand scale.

(b) Sulphate concentration in several Greenland ice cores with the episodic effects of volcanic eruptions removed (lines) and total SO_2 emissions from sources in the US and Europe (crosses).

Source IPCC TAR

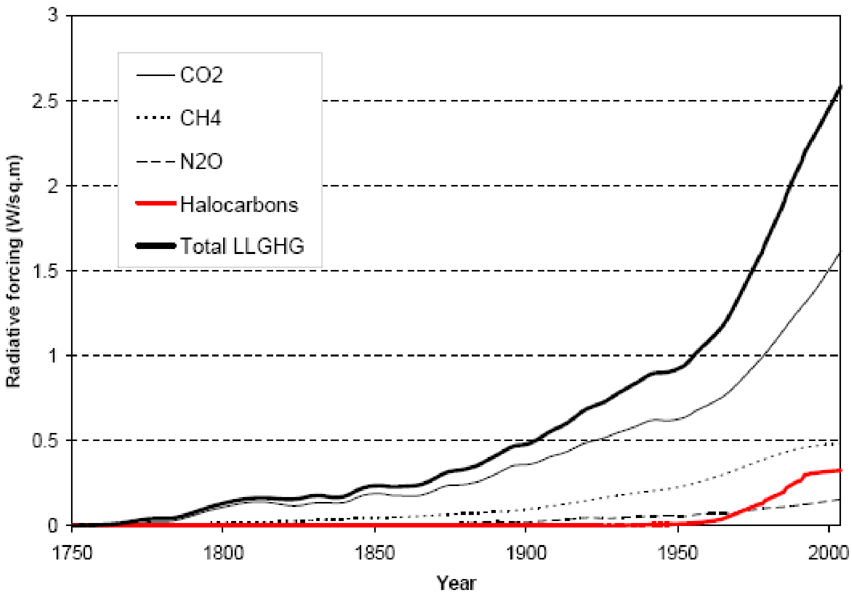


Figure 3:

Growth of greenhouse effect from long-lived greenhouse gases (LLGHG).

Effect on global warming measured in radiative forcing of Watts per square metre at Earth's surface

Source IPCC AR4 Chapter 2

To calculate the effect of the greenhouse gases, scientists construct immense computer models called General Circulation Models (GCM's). Essentially, GCM's are gigantic weather forecasting programmes, which work by calculating the conditions at thousands of grid-points in the air, on the surface, and beneath the sea, at 5- minute intervals for the next 100 years or more! The specific prediction for any particular future date is not a forecast; instead the predictions are averaged across time to provide a view of the future climate. Also, since the predictions only apply to specific points, they have to be interpreted to give a view of the conditions over the areas of interest.

There are over 20 principal GCM's , and they give quite consistent results for predictions of temperature and sea-level rise predictions. The results are less consistent for precipitation and other climatic variables like cyclones, or large-scale patterns like the El Nino Southern Oscillation (ENSO) which periodically warms up the East Pacific and causes widespread disruption to weather globally. To assess the results from these models, and work based on their output , the IPCC (Intergovernmental Panel on Climate Change) was founded (see Box 2).

Box 2: The Intergovernmental Panel on Climate Change (IPCC)

IPCC was formed in 1988 by the World Meteorological Office (WMO) and United Nations Environment Programme (UNEP) . Its purpose is to provide policymakers in the UNFCCC (United Nations Framework Convention on Climate Change) with ongoing comprehensive, objective asssessments of the scientific, technical and socio-economic information relevant to understanding climate change, its potential impacts, and the options for adaptation and mitigation. IPCC reports are based on existing high-quality scientific and technical literature; IPCC does not itself carry out research. The IPCC reports are compiled by leading experts nominated by governments, and selected to ensure balance and expertise. Currently there are about 2,500 authors in the project.

Quality control is a central feature of the IPCC process. The basic literature is usually peer-reviewed, the assessments or summaries of them are reviewed by external experts and stakeholders (including lobbying groups of all views as well as governments), and there is a strict internal review also. Control of the final text remains with the authors, except in the case of the Summaries for Policymakers, which are agreed unanimously by government delegates.

The IPCC published its first assessment report in 1990, a supplementary report in 1992, a second assessment report (SAR) in 1995, and a third assessment report (TAR) in 2001. The fourth assessment report (AR4) is currently underway. Since 1995, each of the assessment reports is in three volumes from Working Groups I (Science of Climate Change), II (Impacts and Adaptation) and III (Mitigation), with a Synthesis Report by the IPCC secretariat. The fourth assessment report (AR4) appeared during 2007.

It is sometimes thought that because scientists do not know the full details of climate change, that there is major disagreement among them. This is absolutely untrue. A survey of all 928 papers on climate change published over a period of ten years in the scientific literature showed that not one of them rejected the reality of man-made climate change (Oreskes, 2004). In 2005 the national science academies of the G8 nations, plus Brazil, China and India, the largest emitters of greenhouse gases in the developing world, signed a statement that confirmed that the scientific understanding of climate change is clear enough for nations to take prompt action, explicitly endorsing the IPCC consensus. A tiny number of non-expert dissenters receive big media attention and carbon industry funding, but cannot demonstrate the credibility of their position to other scientists.

The results from GCM's depend not just on the model specifications, but also on assumptions about future socio-economic trends. To provide a consistent base, IPCC commissioned a Special Report on Emission Scenarios of the future (SRES) – see Box 3. This report results in a wide range of predictions regarding the future developments of global temperatures and other variables - these scenarios imply different levels of future CO_2 emissions over the coming decades.

Box 3: The Emissions Scenarios of the Special Report on Emissions Scenarios (SRES)

A1. The A1 storyline 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 globalisation, 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: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).

A2. The A2 storyline describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Population continues to grow in developing countries. 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 describes a convergent world with the same population trends 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 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 describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. There is 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 A1 and B1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

Working Group I reported on February 2, 2007. Its key conclusions were:

1. Warming of the climate is "unequivocal". The rise in temperature within the last century has been of 0.74^{o}C.

2. Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values over the last 650,000 years.

3. Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to anthropogenic greenhouse gases.

4. Higher temperatures and rises in sea level "would continue for centuries" no matter how much emissions are limited.

5. The probability that this is caused by natural climatic processes is less than 5%.

6. During the 21st century world temperatures will probably rise by 1.1 to 6.4°C and sea levels will probably rise by 18 to 59cm.

7. It is more than 66% certain that there will be an increase in droughts, tropical cyclones and extreme high tides.

Figure 4 shows the key temperature predictions from IPCC AR4 and the recent observed rise. Under the fossil-fuel intensive scenario A1F1 the temperature could increase by as much as as 6.4°C by 2100. Apart from scenario B1, in every case the expected temperature increase is over 2°C, the EU's threshhold to avoid dangerous climate change.

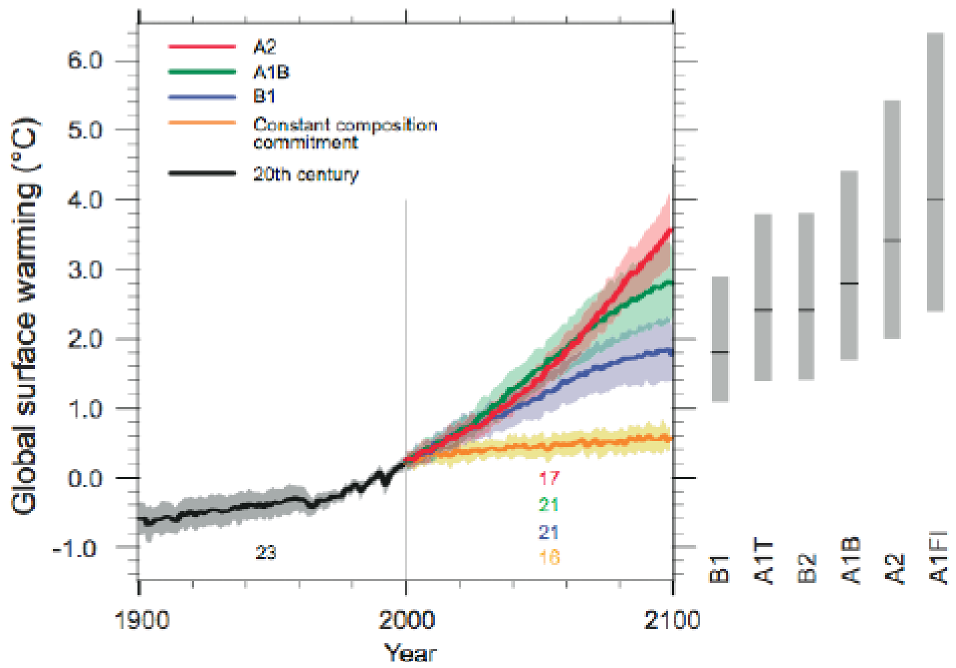


Figure 4: Predictions of Future Temperature.

The solid lines are multi-model global averages of surface warming (relative to 1980-99) for the scenarios A2, A1B and B1. Shading denotes the plus/minus one standard deviation range. The number of model runs for a given time period and scenario is indicated by the coloured number at the bottom part of the panel. The orange line is for the experiment where concentrations were held constant at year 2000 values. The gray bars at right indicate the best estimate (solid line within each bar) and the likely range for the six SRES base-line scenarios at 2100.

Source IPCC AR4

Many experts believe that the IPCC AR4 understates the dangers of climate change. The cut-off for the underlying research was December 2005, and there are several lines of work that indicate that global warming could be much worse. The International Alliance of

Research Universities convened the International Climate Change Congress in Copenhagen in March 2009 to address this issue. Many interesting papers not yet published are available on the website, and a summary report is expcected in June 2009. Among the key findings were:

Climatic Trends

Recent observations confirm that the worst-case IPCC scenario trajectories (or even worse) are being realised. For many key parameters, the climate system is already moving beyond the patterns of natural variability within which our society and economy have developed. These parameters include global mean surface temperature, sea-level rise, ocean and ice sheet dynamics, ocean acidification and extreme climatic events. There is a significant risk that many of the trends will accelerate, leading to an increasing risk of abrupt or irreversible climatic shifts.

1.3 Impacts of a changing climate

GCMs predict large changes in weather systems and a steadily rising sea level in coming decades. This entails many risks: serious threats to human health, costly disruption of economic activity, significant destruction of material assets, and irreversible damage to natural ecosystems (see Figure 5). The diagram shows a spectrum of risk (from white /no risk to red/high risk) for five major aspects of concern: large-scale breakdown or “discontinuities” in the climate system (see Figure 11 for more information), global size of economic impact, regional spread of impacts, extreme events, and loss of biodiversity or unique systems. Up to about 2^{o}C, the economic effects may be moderate at a global scale, but most of the world’s population will be adversely affected, while extreme events are expected to be significantly worse, and many ecosystems will be at risk or even lost. Above that level the risks rapidly deteriorate.

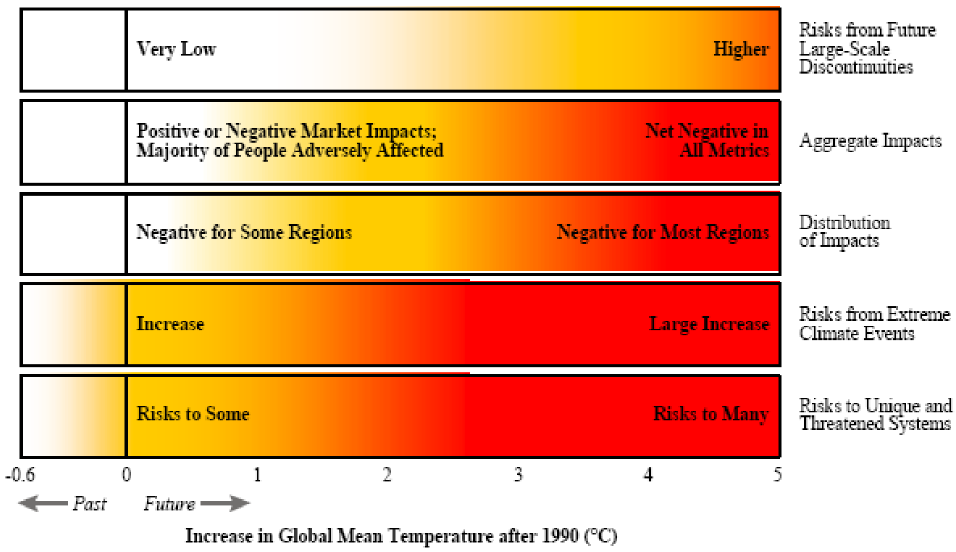


Figure 5: The risks from climate change. *Source IPCC TAR*

These shifts could occur within a project planning life-span i.e. before 2050. Next in this section we consider the GCM predictions for a number of key climatic variables: sea-level rise, river flood, drought, ENSO, NAO, European storms, tropical storms (including hurricanes), ice-cover, heatwaves and daily weather. The section concludes with a look at the possibility of rapid climate change. It is important to remember that apart from the direct implications of these factors, the degree of their likelihood could have a major bearing on consumer behaviour and political decisions.

a) Sea level rise (SLR)

Global sea level has been rising over the last century at rates of 1.5 to 2.0 mm/yr, although much higher rates exist in subsiding regions. The upper limit of SLR predicted for 2100 by IPCC AR4 is lower than previous reports, but is already under strong criticism for review, since SLR has been accelerating. A rise of up to 1.4m has been suggested (Rahmstorf, 2007). One surprising point is that SLR will not be uniform (see Figure 6), because of regional currents and the different rigidity of the continental shelfs. Many areas with large population centres will experience higher SLR, though wealthy regions like the Thames Estuary and Netherlands will remain viable for centuries. Deltas are highly sensitive to SLR, because the ground is also sinking for two reasons, ground water extraction and construction of upstream dams which depletes the supply of sediments to deltas, with increased coastal erosion. Rates of relative SLR are double or more over the global average in many heavily populated deltaic areas, including the Chao Phraya, Mississippi , and Yangtze Rivers, greatly increasing the potential for inundation of cities like New Orleans, Bangkok, and Shanghai. For detailed information see the latest IPCC Report (Working Group 2, regional chapters) and Box 4 on North America.

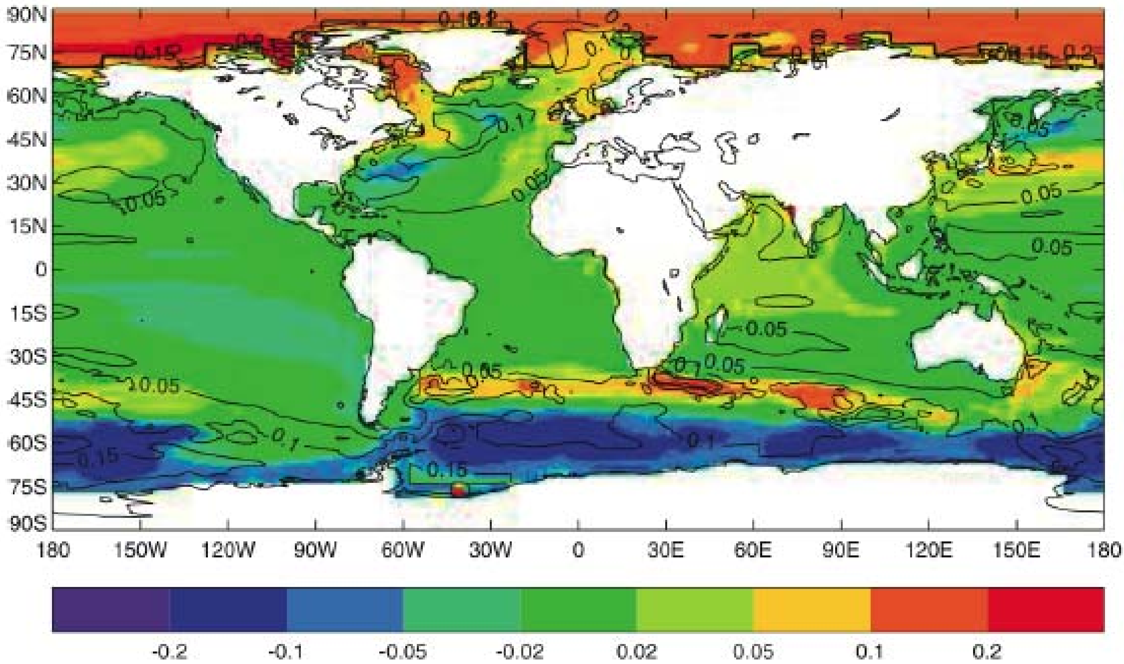


Figure 6: Variation in SLR from the global mean by 2100, in metres. *Source IPCC AR4 First approximation, includes only ocean density and circulation changes.*

Box 4: SLR in North America

Extraordinary rates of relative SLR in Louisiana (10 mm/yr at Grand Isle) and Texas (7 mm/yr at Galveston) reflect factors like oil and gas extraction. For Los Angeles, by 2090, in the worst-case scenario, a 100-year flood could occur as frequently as every 3-4 years, and 500-

year floods could be as frequent as every 50 years, putting dozens of the region's most significant infrastructure features at increased risk. This means an escalation of 2.5 to 4 percent per year in the associated risk.

About 60,000 km^2 of land along the U.S. Atlantic and Gulf Coasts lies less than a metre above high tide. The facilities at risk include surface roads and rail lines, bridges, tunnels, marine and airport facilities, and transit stations. An additional hazard during coastal flooding is the release of hazardous materials from industrial facilities into the environment. As sea ice vanishes, storms will cause accelerated shoreline retreat in the Arctic, because the protection of the pack ice has gone.

b) River floods

River flood patterns will not be uniform, because floods have different causes, in particular snow-melt versus rainfall, and because some areas are becoming drought-prone. A study by Dai *et al.*, 2004 found that global land areas in either very wet or very dry conditions increased from 20 to 38% of land area since 1972. Noticeable change is expected by 2010-2039 for high latitude regions throughout the whole year and the monsoon periods in Southern and Eastern Asia. Many semi-arid regions such as Southern Africa, Australia, and the Mediterranean are likely to suffer from decreased precipitation due to changes in wind patterns, and increased temperatures. It is very likely that heavy precipitation events will increase over many areas of the globe (Figure 7), because warm air can carry more moisture. One study of a high emissions future (Milly *et al* 2002) found for some areas that what is given as a 100-year flood in the control run will become much more frequent, even as often as every 2 to 5 years, and particularly strong increases are projected in Northern Asia.

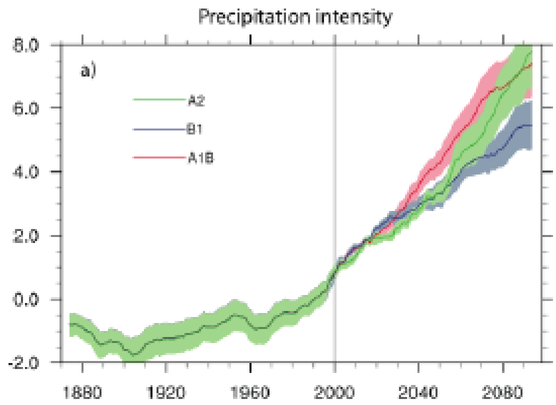


Figure 7:
Increase in heavy rainfall days.

Globally averaged changes in precipitation intensity (defined as the annual total precipitation divided by the number of wet days) for a low (B1), middle (A1B), and high (A2) scenario.

c) Drought

The 21st century will be the age of water scarcity. Even though total global rainfall will increase as the climate warms (see Figure 8), the proportion of land in drought is projected to rise throughout the 21st century because some areas are likely to experience less rainfall. Also, areas with rain will receive less benefit, as evaporation will be enhanced in a warmer climate. Without significant mitigation of emissions, by 2100 the area affected by drought is projected to double in extent from 25% to 50%.

The number of drought events are projected to increase only slightly but they will last much longer (Hadley Centre, November 2006, COP12 Report).The IPCC AR4 gives many historical examples of the costly effects of drought- see the regional chapters in Working Group 2).

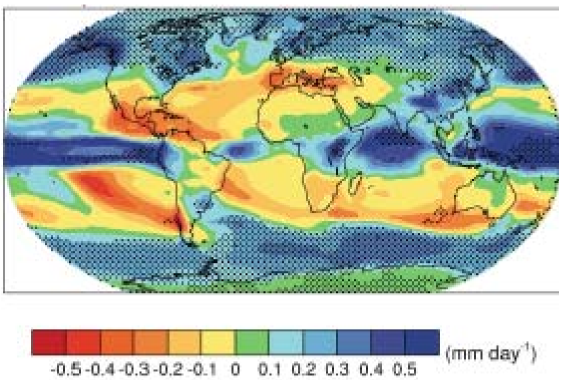


Figure 8:
Late 21st century changes in rainfall.

Multi-model mean changes in precipitation (mm/day). Changes are given as annual means for the scenario SRES A1B, for the period 2080–2099 relative to 1980–1999. Stippling denotes areas where the results are most reliable.

Source IPCC AR4

d) ENSO (El Niño Southern Oscillation)

Changes in climate variability at the annual and decadal scales like ENSO are still uncertain. For the time being, the warm (i.e. El Niño) phase shows a tendency to be more frequent, long-lasting, and intense. If this persisted it would favour less frequent (but possibly more intense) Atlantic hurricanes. Strong El Niño events are associated with increased precipitation and severe storms in some North American regions, such as the U.S. southeast, but warmer temperatures and less precipitation in areas such as the Pacific northwest, western Canada, and parts of Alaska and Australia.

e) NAO (North Atlantic Oscillation)

A positive NAO index is associated with low winter precipitation in Southern and Central Europe and above average precipitation in Northwest Europe, and also with extreme rainfall in Europe. The NAO leads to fewer storms and calmer conditions southward and into the Mediterranean. Most climate models predict a positive NAO beyond 2050. The NAO also has a strong influence on SLR, with a positive NAO raising sea levels over Northern Europe and lowering them over some parts of the Mediterranean.

f) European storm

Windiness projections typically increase in Northern Europe by about 8% and decrease in the Mediterranean region, but there is not overall consistency. The increase in windiness in Northern Europe is largest in winter and early spring.

g) Tropical storm- global view

Overall numbers of tropical cyclones have shown little variation over the past 35 years. However, there is a shift to stronger tropical storms globally (Webster, 2005) though the data quality has been queried for regions other than the Atlantic. Globally sea surface temperature (SST) has risen strongly over last 35 years in almost every hurricane-forming basin, which is an expected feature of climate change and is strongly correlated with storm formation and intensity (Emanuel 2005).

h) Tropical storm- hurricanes

Before Katrina, analyses of the historical record suggested that tropical cyclones were becoming more intense and frequent (Emanuel, 2005; Webster et al., 2005). The records broken in 2005 Atlantic hurricane season seem consistent with this: historically, this season featured the highest number of storms (27), the highest number of hurricanes (13), the highest number of strong US-landfalling hurricanes (4), the highest overall costs ($200billion+), the single most expensive event (Katrina), and the strongest ever (Wilma). The Atlantic season also had three of the six strongest hurricanes recorded (Wilma, Rita, Katrina) and continued a very active phase (most storms, hurricanes, and strong hurricanes ever in a two-year or three-year period). There were five major hurricanes in 2008, twice the long-run average.

In terms of future developments, all observers concur- there will be more storms in the coming decades. The climate change sceptics base this on natural cycles over the next 20 to 30 years (Goldenberg et al., 2001; Chelliah and Bell, 2004; see also Mayfield, 2005). Climate change scientists predict that global warming will make tropical storms more intense i.e., stronger winds, heavier rain, and higher sea-surges (Knutson and Tuleya, 2004; Emanuel, 2006; Munich Re, 2006a.

Projections for future activity under climate change suggest potentially large increases in storm energy and the proportion of hurricanes that become intense, with stronger increases expected under those scenarios of higher emissions: **between a doubling and trebling in the numbers of intense hurricanes is seen as likely.**

i) Asian tropical storms

Recent studies indicate that the frequency and intensity of tropical cyclones originating in the Pacific have increased over the last few decades. In contrast, cyclones originating from the Bay of Bengal and Arabian Sea have been less frequent but the intensity has increased. There is no evidence to suggest that cyclone frequencies or locations may change in the future. An increase in cyclone intensity of 10-20% for a rise in sea surface temperature of 2 to 4^{o}C relative to the current threshold temperature is very likely. Greater storm surge heights should result from the stronger winds resulting in an enhanced risk of coastal disasters for East, South and Southeast Asian countries.

j) Ice cover

Climate change will cause enormous changes in the cryosphere i.e. the part of the Earth system that is frozen, like glaciers, ice-caps, and tundra. Figure 9 shows how the Arctic sea-ice has shrunk since 1975. That trend is expected to continue under every emission scenario; it could only stabilize if emissions stopped, as shown by the uppermost projection line in Figure 9. Some research even suggests that Arctic sea-ice might disappear in summer by mid-century. This opens up new economic possibilities in the Arctic region, for transport and mining. On the other hand ecosystems could be destroyed, and infrastructure will be vulnerable to storm damage and ground subsidence.

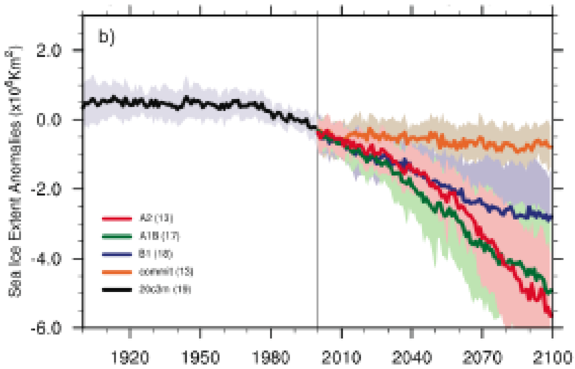


Figure 9: Extent of Arctic sea ice in summer.

Source IPCC AR4

k) Heatwaves

Cold spells will disappear in many regions, while heatwaves will become frequent. In the tropics they could become the norm by 2100, and in mid-latitudes, two years in five might be hot. Figure 10 shows that the expected change for average temperatures in the Amazon Basin is around 5°C (blue bars) for a doubling of carbon dioxide. However, the peak temperatures in heatwaves are expected to rise by around 11°C (red bars), which is much more critical for ecosystems and economic activity also.

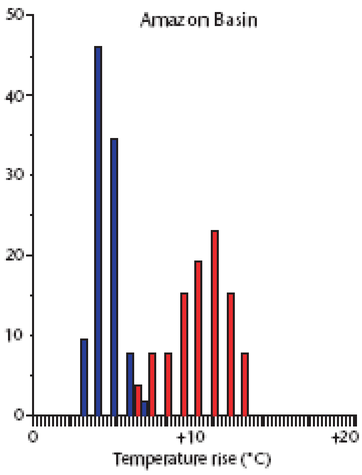


Figure 10: Change in temperature extremes.

Blue relates to expected average conditions, red relates to expected peak temperatures.
Source

Hadley Centre , December 2004

Box 5: The European heatwave of 2003

Severe heat waves occurred in Europe in 2003. It was the hottest summer for at least 500 years, possibly 1000 or more, coming on the back of the ten hottest years since mid-19century. It is very likely that human interference has doubled the chance of such an event (Stott et al, 2004). The probability will increase 100 fold in the next 40 years. **i.e. an annual increase in risk of 12%!** The impacts of 2003 are well summarised by Munich Re. – *Property damage*, especially in agriculture and as a result of forest fires: **US$ 13bn**; other grave effects on the economy: *Industry, power plants* (river water too warm, problems with cooling: production bottlenecks); *reduction in worker efficiency* (resulting in economic loss that is difficult to quantify); *retail and amusement sector* - open-air entertainment and tourist attractions suffered a shortfall in daytime receipts; cafés, ice parlors, garden restaurants, beer gardens, and swimming baths did a roaring trade though. *Death toll* -now revised by an EU report to over 70,000.

I) Extreme climate change ("discontinuities")

Climatic changes will accelerate if emissions continue on a "business-as-usual" path. Figure 5 indicated that one of the risks could be discontinuities in the climate system. Because the system is complex, with interactions between land, sea, atmosphere, cryosphere, and biosphere, there are many possible ways in which a breakdown could occur (see Figure 11). We shall discuss three of the factors, and one which has recently come to prominence and so is not featured in Figure 11, oceanic acidity.

Ice sheet collapse: The eventual sea level rise would be 7m and 4.6m for the deglaciation of Greenland and West Antarctica, respectively. Our ability to adapt would depend crucially on the rate of deglaciation, which is estimated as ranging from rapid (a few centuries) to slow (a few millennia). Recent observations indicate acceleration in the rate of sea level rise (Rahmstorf, 2007); the danger is that we may reach a point of no return by mid-21st century and it may be impossible to save the ice-caps.

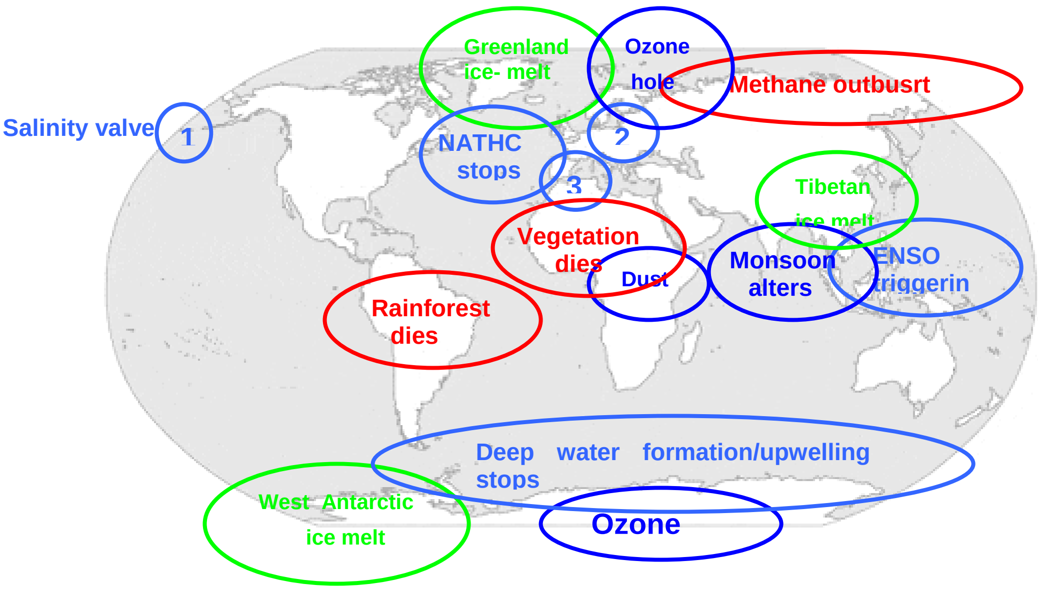


Figure 11: Schellnhuber's choke points.

NATHC (North Atlantic thermohaline current i.e. the Gulf Stream): A slowdown of NATHC is likely to occur during the 21st century, but subsequent behaviour is unclear. If it stopped flowing, then impacts would likely occur on a global scale. IPCC AR4 views this possibility as remote. However, the very latest observations challenge this comforting position: the NATHC appears to have weakened by 30% in recent decades (Bryden, 2005). As we cannot explain it, this surprising result indicates the need for caution.

Destruction of Amazonia The Brazilian rainforest is “the lungs of the planet”. It is a critical part of the carbon recycling system. Yet, Hadley Centre predicts that it could die back under water stress by 2060, due to lack or rainfall and heatwaves (see Figure 10).

Ocean acidity The acidity of the oceans is increasing as it warms and is able to absorb more atmospheric carbon dioxide. This is damaging for shellfish and other marine organisms, because their shells are sensitive to the acid content of the ambient water. Since these organisms are a major sink for carbon dioxide, this could accelerate climate change, but it has not been factored in to IPCC AR4.

1.4 The link between the science, the effects and business

Climate change is not a far-distant problem. It already affects key sectors and the frequency of extreme events is rising fast. That has serious implications for infrastructure with a lifetime of decades, and also insurers of course. It takes decades for greenhouse gases to decay (an example of a lag effect). This means that we need adaptation policies to cope with worsening impacts for at least 40 years. Within that timeframe, the cost of disasters may reach one trillion USD in a single year.

Figure 12 gives an overview of the key issues on a regional basis. Over 25% of the world's population and economic activity is located in vulnerable coastal zones. A second issue is the shrinking of glaciers, which could lead to water shortages as seasonal river-flows disappear, but also to more rapid sea-level rise, as glacial water enters the oceans.

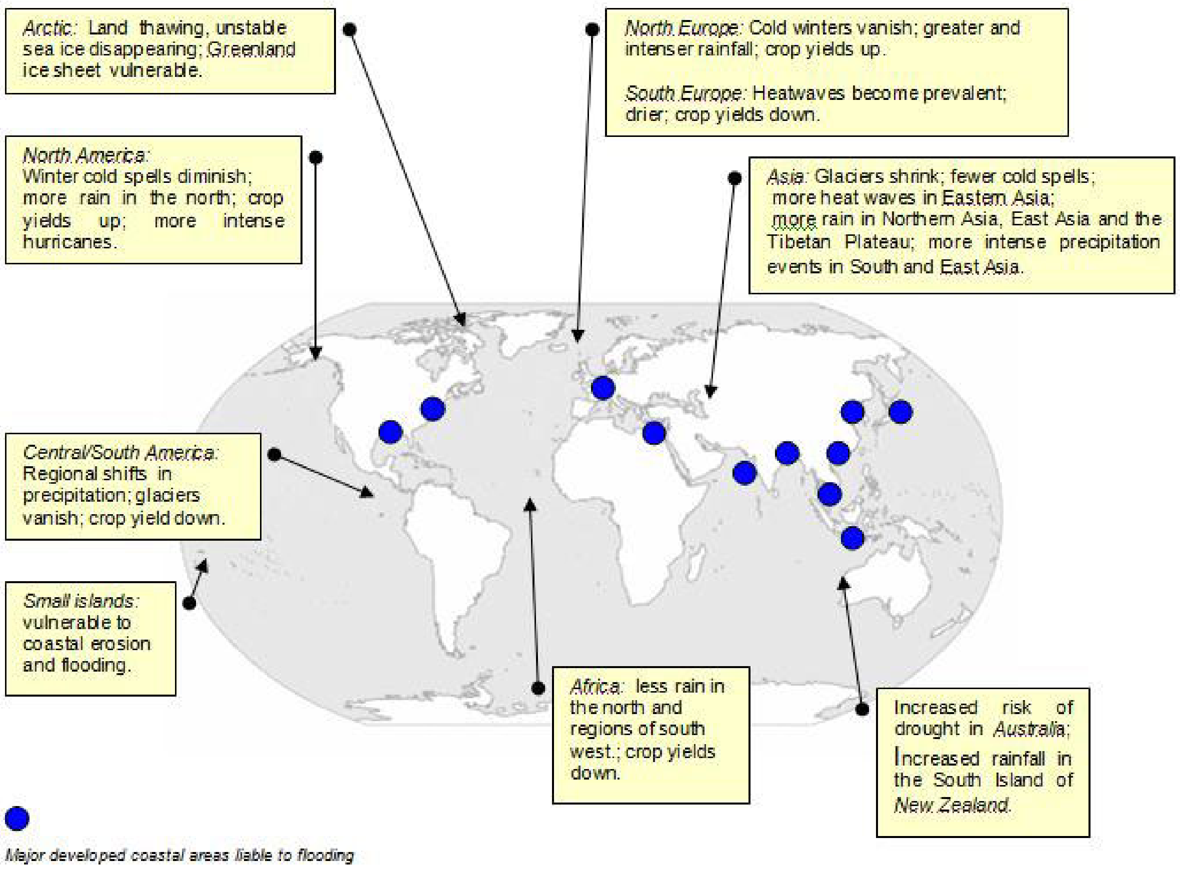


Figure 12: Major changes expected at regional level.

Source UNEPFI 2006

Key economic impact issues

Up to a rise of 1°C, global GDP might benefit from climate change, due to an aggregate increase in primary food and forestry. Pluses would also include access to polar minerals and waterways. However, there would be serious negative effects for vulnerable regions like Africa and the Pacific islands and Arctic peoples even at low increases. The number of people adversely affected would outweigh those benefiting directly, and inequity would increase in all societies, as the less wealthy or weaker would be disadvantaged.

Coastal Cities

This is a key area of concern. Twelve of the world's 16 megacities (over 10 million inhabitants) are coastal, and all are growing rapidly. The impacts of climate change will compound with other stresses like resource scarcity, insecurity, poverty, congestion, and pollution. In the short term, extreme events are the chief threat. Floods affect more people than any other natural disaster. Longer term, coastal cities are vulnerable to SLR, storms, water temperature and quality, and inland runoff.

Without enhanced flood defences, there will be a rapid increase in numbers permanently displaced worldwide, from less than 1 million today, to about 100 million by 2060, almost entirely in developing countries. Developed countries are strengthening defences for cities like Tokyo, Rotterdam and London, or installing new ones, like Project "Moses" for Venice. However, building similar protections for all threatened regions would be impossible, and protecting coastal aquifers is difficult.

Water

Globally, only 2% of water is taken for domestic use. The bulk is for agriculture, with other major uses for power generation, industry, transport and leisure. Two billion people live in water-stressed regions like the Mediterranean, Sahel and West Australia. More than 1 billion people in South America and Asia will be deprived of water as glaciers shrink. Some Himalayan glaciers may vanish by 2035. Water scarcity is the major long-term risk facing mainland Asia, compounded by seawater intrusion coastally.

Water systems in developing countries are already strained - less than half of urban water supply in Asia is reliable. Warmer weather will mean higher demand for water, and higher costs to purify water. By the 2020's over 500 million more people may be short of water. Demand management will be increasingly important, as well as planning for new levels of high and low extremes. Egypt faces typical problems- the water supply is inadequate, the agricultural sector is important (20% of GDP) and uses 85% of the water, albeit very inefficiently. SLR could cause saltwater intrusion, and temperature rise will increase irrigation demand. Plans include reuse of wastewater and improved irrigation, and reviewing the Nile Waters agreement of 1959 that apportions flow among countries.

Food and forests

Until 2050, overall food supply will be sufficient, but imbalances will increase. Drought will be the main risk for agriculture in developed regions like Australia and Europe.

Scientists expect declining yields in tropical regions, due to higher temperatures, and insufficient water. On average, 21% of Africa's GDP is in the agriculture sector, up to as much as 70% in some nations. Forests are important for biodiversity, as a source of primary materials, and for their capacity to store carbon. To mid-century, northern forests will benefit from a longer growing season, despite more pests and fires. However some tropical rainforests could suffer extinction from drought.

Energy

Climate change affects demand and supply. Heat waves in Europe and USA in 2006 forced power producers to reduce output and ration power to industrial clients, and power prices soared. Water supply will be problematic. Thermal and nuclear power stations need water for steam to drive the turbines and for cooling. Hydropower is even more sensitive, and is particularly important in many developing countries.

Tourism

This climate-sensitive sector is critical in many developing countries and big business in developed ones. 39% of Bahamas GDP is tourism. It is one of Australia's highest export earners. The Great Barrier Reef alone supports a AUD1.5 billion industry. By 2040, 60% of the coral could be regularly bleached.

Vulnerability and coping with impacts

Natural systems and less wealthy populations are vulnerable to climate change, being exposed directly to impacts, but unable to respond well, particularly if changes occur very rapidly. However, there is limited scope for financial sector involvement unless eco-benefits can be monetized or the poor have access to finance. According to the World Bank, 1.3 billion people live on less than $1 per day, and three-fourths depend on agriculture for their livelihood. Disasters have a strong impact on agriculture, ruin households, and can cost well over 100% of GDP for small nations.

We can get a feel for the costs by looking at the statistics on damage that are published by Munich Re and Swiss Re. For example, Figure 13 shows the Munich Re figures for large weather disasters from 1950 to 2005. The data does not include "small" incidents, which are reckoned to be as costly in aggregate as the great disasters. Yet, even then, the cost reported in 2005 came to 165 billion USD, of which half was insured. (Some experts consider that the indirect costs of Hurricane Katrina in 2005 amounted to $300 million - not included here). The underlying trend in the costs is shown as 6 percent per year. Recent analysis of similar costs trends by RMS suggests that there is an underlying "climate change" trend of 2 percent per year, and the remainder is due to the fact that modern economies are more vulnerable to climatic variability. The events come in clusters, creating "peak years" like 1993 (79 billion USD), 2004 (81 billion USD) and 2005 (165 billion USD). If this trend continues, then it is probable that a peak year cost of 1 trillion USD will occur by 2040.

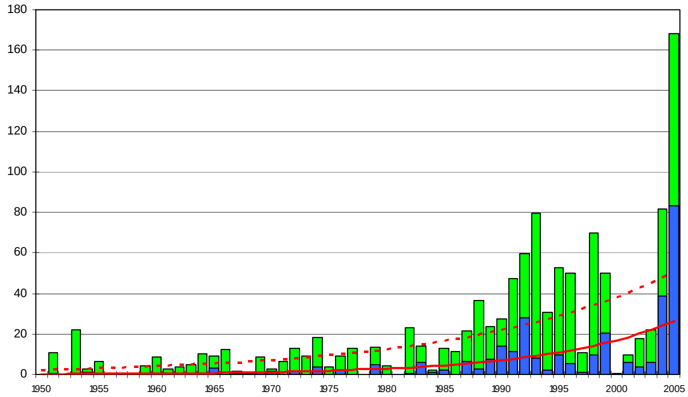


Figure 13:
Cost of great weather disasters 1950-2005.

(Source: Munich Re) Costs in USD billion,2005 values

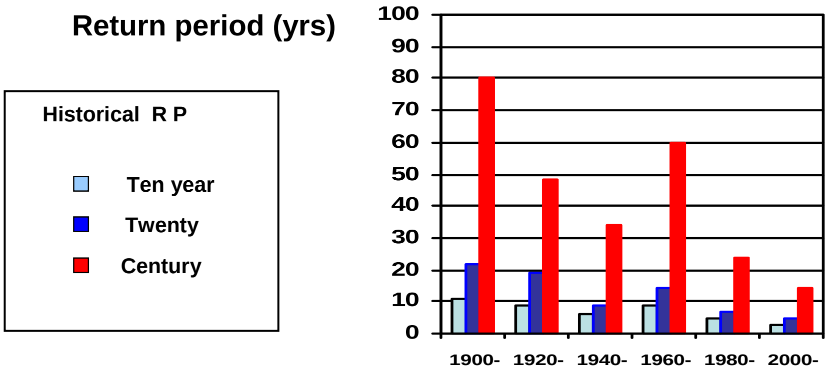
insured cost

uninsured

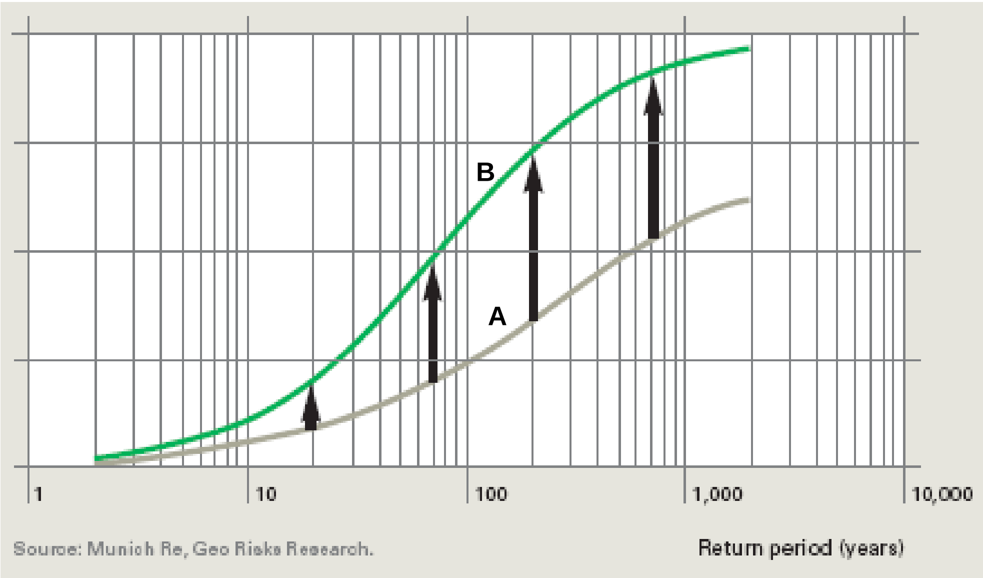
A key issue is <u>the rate of change of extreme events.</u> The extreme heatwave that struck Europe in 2003 will be simply a normal summer occurrence by the 2060's, and "cooler than average" by the 2080's, according to the respected Hadley Centre. This reflects a well-known statistical phenomenon: When the average value of a factor changes, then the risk of extreme values shifts much faster. In this case, the risk of severe summers will rise by a factor of 200 times within decades- this means that the risk is rising at an annual rate of over 5% conservatively. If ignored, this quickly results in gross errors in terms of risk management. The rarer the event, the faster the change in its frequency.

This problem is often discussed in terms of **<u>return periods</u>**. In the case of European summers, the heat seen in 2003 happened only once in 400 years of observations- it was a 400 year event, or an event with a 400 year return period i.e. expected to happen only once in 400 years. By 2060 it will be expected every second year, a return period of just two years. (In terms of probability, the chances shift from 0.0025 to 0.5 on a scale of zero to 1.0). Figure 14 shows it is already happening. Extreme monthly temperatures that used to occur once every 100 years in UK, now happen every 14 years. Twenty-year events have become five-year ones, and ten year events recur every three years.

Figure 14: Shrinking return periods: hot UK months.
Environmental Finance, October 2006



Since damage usually responds in a non-linear way to the intensity of the weather, this has serious implications for infrastructure with a lifetime of decades. This is shown by Figure 15, which Munich Re uses to plot the expected cost of a hurricane versus its severity. The curve was re-assessed after the 2004 and 2005 hurricane seasons, to reflect a trend to more costly experience. Line A is the original relationship, and Line B is the revised one. However, some experts argue that hurricane Katrina shows that the recovery system cannot cope with very large events, and the costs spill over into other systems due to global shortages, labour unavailability, and competitors in unaffected regions taking away customers.



- *Munich Re states that historical data (Line A) understates the potential present-day risk by up to 60%*

- *Line B shows the adjustment of the loss distribution proposed by Munich Re, including the following factors:*
  - *– Higher hurricane frequency*
  - *– Higher intensities*
  - *– Re-evaluation of the storm surge and flood risk*
  - *– Loss-aggravating factors in connection with mega-catastrophes*

- *Line B gets relatively closer to Line A in percentage terms as the return period lengthens.*

Figure 15: Recalibrating loss curves. *(Source Munich Re)*

Box 6: Hurricane Katrina

Even developed countries are susceptible to climate disasters. Katrina revealed some weaknesses in the public and private sector approaches, and in their collaboration. By learning from previous experiences, private insurers coped quite well, but other stakeholders suffered heavily. Many were under- or un-insured, because they did not appreciate the need for insurance or could not afford it. Banks have survived the first effects, but there may be local issues if recovery falters.

In 2005, New Orleans was a major port of 500,000 people on the Mississippi delta, with 4,000 oil and gas installations in the nearby Gulf of Mexico. As well as being in the hurricane belt, the area is subject to subsidence in excess of 10mm per year. Urban development in low-lying areas had increased the exposure. In August 2005, Hurricane Katrina struck, with a storm surge of up to 8.5 metres. Up to 80% of the city was flooded, with 55% of the properties over 1.2 metres deep. The total number killed probably exceeded 2,000. Due to pollution from leaking sewage, chemical and oil facilities, the entire city was compulsorily evacuated. It was early December before access to the city was completely restored, but a large number may never return. Just 25,000 children are registered at school now, compared to 65,000 before. Employment is 30% down.

The effects were far-reaching. Areas that housed refugees had to provide services, damage to offshore installations drove up global energy prices, construction teams left other areas, and federal funding elsewhere was reduced to cope with the emergency relief. Currently, quality of life is poor for the residents. Recovery was complicated because repairs to hurricane damage in Florida in 2004 were still incomplete, and the record 2005 season included three major storms: Katrina (total economic damage: 125 billion USD), Rita (16 billion USD) and Wilma (18 billion USD). Together they bankrupted the federal National Flood Insurance Program (NFIP), and created “demand surge”, when recovery costs rocketed due to labour and material constraints.

Katrina cost insurers over 40 billion USD, excluding 15 billion USD against the National Flood Insurance Program (NFIP), and 2 billion USD in offshore energy. Some commentators put the total cost at 350 billion USD. Perhaps 35,000 homes were uninsured, because they were outside the government-defined flood zone. Reinsurers bore 45% of the private market costs, as opposed to 20% in the 2004 hurricane season, because their contracts are intended to respond more when events are very large. Although insurers deployed thousands of adjusters, they were denied access by the emergency. This allowed damage to deteriorate, and complicated the attribution of damage between flood and storm. (In the US, the private market excludes flood cover, which is available through NFIP). The delays increased living costs for consumers, and reduced business profits. Other aggravating factors were public disorder (theft, looting and arson), and fraud.

Important issues were identified by this disaster:

“Worst case” scenario. Storm surge risk has been underestimated, with important implications for rebuilding and siting facilities like oil refineries. The zoning maps used by NFIP may need to be updated. Reinsurers raised their charges in 2006 by around 25% for hurricane risk, but for some risks e.g. less-sturdy drilling rigs, rates rose by 300%.

Munich Re has identified eight other possible sites for catastrophic flood.

Risk transfer products: Great hardship resulted from the absence of flood cover, and compensation is complicated by the existence of several different mechanisms. Only 3% of businesses had contingent business interruption coverage, which allows claims for economic losses, even if a business is not itself affected directly.

Macro-economic risk: The financial impacts extended into the wider economy, especially energy markets. Two airlines sought bankruptcy protection.

The private sector can only participate in large-scale adaptation initiatives on a commercial basis. Image and corporate responsibility are not sufficient. By working in partnership with the public sector, the barriers to entry can be overcome, and many advantages can accrue to the public sector and those at risk, because of the private sector's inherent need to innovate and be efficient. For that reason, the UNEP FI's CCWG has strongly advocated an aggressive policy of mitigating greenhouse gases. But, even if such a policy were agreed, we cannot avoid further warming, due to the thermal inertia of the oceans. This will be at least 0.6^{o}C, or the equivalent of all the warming we have seen already. The benefits of new emission cuts will not be felt until after 2040. That is why we must adopt vigorous measures to adapt to climatic change even as we strive to cut emissions. Adaptation is a vital complement to mitigation.

A key issue is that adaptation has to be integrated with development policy and disaster management. It is clear that damage from climatic disasters already threatens economic growth in many areas in various ways, and that these stresses will accelerate in coming decades. Even major public insurance schemes have faced technical insolvency, in France from subsidence claims, and in the US from flood claims following Hurricane Katrina. Developing countries require input from other nations to build capacity and finance infrastructure.

The intensive review of the economics of climate change by Sir Nicholas Stern concluded that the cost of climate change could be 14% or more of annual global GDP for the next 200 years, whereas taking action to avert it could cost around 1% of global annual GDP by 2050 (with a range between a cost of 5% and a benefit of 2% due to e.g. gains in efficiency). On that basis, it is clear that mitigation policies to limit greenhouse gases will be adopted. Policymakers will promote this variously with subsidies, taxes and performance standards, and greater reliance on 'flexible mechanisms' like emissions trading. Consumers will translate their growing concerns about global warming into preferences for climate-friendly products and services, and will favour companies that are seen to be active in that direction. Huge new markets will develop for technologies, processes, products and services that are less greenhouse-gas intensive.

1.5 Conclusion

Scientists have become increasingly confident over the last 20 years that greenhouse gases produced by human activity are altering the Earth's climate. If we continue 'business as usual', they predict very large changes in weather systems and a steadily rising sea level in coming decades. This would result in serious risks to human health, costly disruption of economic activity, significant destruction of material assets, and irreversible damage to natural ecosystems.

Because of the inertia in the climate system, the impacts of climate change will continue to worsen until at least 2040. Almost every sector has facilities, products or services that are vulnerable to weather impacts, and therefore this risk needs to be re-assessed in the light of scientific projections. Firms that provide services or facilities connected with weather risk (e.g. insurers) are particularly vulnerable.

There are many uncertainties, but inaction will compound the risks to companies, communities and individuals. The rest of this course provides decision-makers with more information in key areas. Lesson 2 takes a closer look at the political background and Lesson 3 considers the risks and opportunities of global warming for the financial sector. Lessons 4 to 7 examine the implications for the energy sector and its financiers. The evolving carbon markets are investigated in Lessons 8 to 10. Finally Lesson 11 reviews related issues that may become important as the political framework develops.

Key Terms (see also Lesson 1 Glossary)

- Adaptation
- GCM see General Circulation Model
- GWP see Global Warming Potential
- Greenhouse gas
- LLGHG see Greenhouse gas
- IPCC see Intergovernmental Panel on Climate Change
- Mitigation

1.6 Lesson Review

This lesson had three objectives:

- To show why scientists believe the Earth's weather system is changing
- To detail how these changes affect natural systems and human society
- To explain why this is relevant for business

What is Climate Change? Section 1.2 explained that the Earth's climate system works by trapping energy from the Sun's rays. The climate changes naturally due to subtle variations in the Earth's orbit around the Sun. These create seasonal patterns like monsoons, and winters, as well as much slower shifts like Ice Ages. What is new is that human activities are altering the natural pattern, and this phenomenon is accelerating.

Manmade or anthropogenic climate change is caused by excess greenhouse gases that are by-products of economic and land-use processes. The principal greenhouse gas is carbon dioxide, but methane, and certain industrial gases are also powerful. The volumes of them in the atmosphere have risen swiftly, and they remain there for decades. By storing the Sun's energy, the gases raise the Earth's temperature and that in turn alters the weather and affects glaciers and the oceans. The most obvious effect is to warm up the atmosphere, which is why the term "global warming" is often used. Scientists estimate that the Earth warmed by 0.74^{o}C in the period 1906-2005. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change states that this warming is "unequivocal", "unusual" and "more than 90% likely to be due to anthropogenic greenhouse gases".

How will global warming change things? The detailed effects of global warming are predicted from complex computer programmes (General Circulation Models, or GCMs). They predict large changes in weather systems and a steadily rising sea level in coming decades. Section 1.3 shows that this entails many risks: serious threats to human health, costly disruption of economic activity, significant destruction of material assets, and irreversible damage to natural ecosystems. Vulnerable areas include coastal zones, poor countries, and some Asian "tigers" which are growing fast economically, like China and India. Serious heatwaves and water shortages will be widespread. Extreme weather events are also more likely to occur. Potentially, some components of the climate system could be destabilized.

The business relevance of climate change. The intensive review of the economics of climate change by Sir Nicholas Stern concluded that the cost of climate change could be 14% or more of annual global GDP for the next 200 years, whereas taking action to avert it could cost around 1% of global annual GDP by 2050 (with a range between a cost of 5% and a benefit of 2% due to e.g. gains in efficiency). On that basis, it is clear that mitigation policies to limit greenhouse gases will be adopted. Policymakers will promote this variously with subsidies, taxes and performance standards, and greater reliance on 'flexible mechanisms' like emissions trading. Consumers will translate their growing concerns about global warming into preferences for climate-friendly products and services, and will favour companies that are seen to be active in that direction. Huge new markets will develop for technologies, processes, products and services that are less greenhouse-gas intensive.

Because of the inertia in the climate system, the impacts of climate change will continue to worsen for several decades after emissions stabilise. Every sector has facilities, processes, products or services that are vulnerable to weather impacts, and therefore these risks need to be re-assessed. A key issue is that as the climate changes, the frequency of historically rare events shifts dramatically. The regional and global disruption caused by Hurricanes Katrina and Rita in 2005 provide a good case study of what can happen.

Further Reading/Related Links

Note to Participants: *Links to websites mentioned in this section can be easily accessed from the EXTERNAL LINKS panel of the course.*

Hadley Centre (UK Meteorological Office GCM centre)
website http://www.metoffice.gov.uk/climatechange/science/hadleycentre/

- Annual reports at Conferences of the parties to UNFCCC
    - 2003 Climate change observations and predictions
    - 2004 Uncertainty, risk and dangerous climate change
    - 2005 Climate change, rivers and rainfall
    - 2006 Effects of climate change in developing countries
    - 2007 Biodiversity – Climate interactions

Intergovernmental Panel on Climate Change (IPCC)
website www.ipcc.ch

- *Fourth Assessment Report Working Group I (Summary for policymakers) 2007*
- *Third Assessment Report (2001), Working Group I*

International Energy Agency
http://www.iea.org/

- Implications of climate change for energy industries, especially World Energy Outlook series

International Scientific Congress on Climate Change- International Alliance of Research Universities (IARU)
Vast collection of current work in progress accessible at http://climatecongress.ku.dk/

Miscellaneous

- Hohenkammer seminar on Climate Change and Disaster Losses Workshop: Understanding and Attributing Trends and Projections. Joint Munich Re Foundation and Colorado University, June 2006. http://sciencepolicy.colorado.edu/sparc/research/projects/extreme_events/munich_workshop/index.html
- Bjørn Lomborg's book *The Sceptical Environmentalist* (2001), which dismisses climate change as an overstated threat. There is an excellent analysis and rebuttal on the Pew Center website.
- Mayfield, M. Testimony of the Director, National Hurricane Center, National

Oceanic and Atmospheric Administration (NOAA), to Hearing on NOAA Hurricane Forecasting before the Science Committee, House of Representatives, October 7, 2005.

- National Academies joint statement on climate change http://nationalacademies.org/onpi/06072005.pdf
- Lenton, T. M., Held, H., Kriegler, E., Hall, J. W., Lucht, W., Rahmstorf, S. and Schellnhuber, H. J. *Tipping elements in the Earth's climate system*, Proceedings of the National Academy of Science, 12 February 2008 http://www.pnas.org/cgi/reprint/105/6/1786.pdf
- Kemp,M. *Inventing an Icon* Nature 437 p1238 27 October,2005

Munich Re publications from website www.munichre.com

- Annual review of catastrophe losses, particularly for the years 2003 and 2005.
- Hurricanes: more intense, more frequent, more expensive: insurance in a time of changing risks, 2006.

Reports

Stern Review on the economics of climate change. London, The Treasury, 2006. http://www.occ.gov.uk/activities/stern.htm

Technical scientific papers

- Bryden, H.L., Longworth, H.R. and Cunningham, S.A. (2005). *Slowing of the Atlantic meridional overturning circulation at 25° N.* Nature, 438, (7068), 655-657. (doi:10.1038/nature04385)
- Chelliah, M., and Bell, G. (2004). *Tropical multidecadal and interannual climate variability in the NCEP-NCAR reanalysis*. Journal of Climate, 17, 1777–1803.
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- Elsner, J. (2006). *Evidence in support of the climate change: Atlantic hurricane hypothesis.* Geophysical Research Letters, 33, L16705, doi:10.1029/2006GL026869.
- Emanuel, K. (2005). *Increasing destructiveness of tropical cyclones over the past 30 years.* Nature, 436, 686–688.
- Emanuel, K. (2006). *Environmental influences on tropical cyclone variability and trends*. Proceedings of 27th AMS Conference on Hurricanes and Tropical Meteorology, Paper #4.2. http://ams.confex.com/ams/pdfpapers/107575.pdf.
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- Knutson, T., and Tuleya, R. (2004). *Impact of CO_2-induced warming on simulated hurricane intensity and precipitation: sensitivity to the choice of climate model and convective parameterization*. Journal of Climate, 17, 3477–3495.
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- Oreskes, N. *Beyond the Ivory Tower: The Scientific Consensus on Climate Change*. Science 3 December 2004: 306. no. 5702, p. 1686 DOI: 10.1126/science.1103618
- Rahmstorf, S. *A Semi-Empirical Approach to Projecting Future Sea-Level Rise* Science 19 January 2007: Vol. 315. no. 5810, pp. 368 – 370 DOI: 10.1126/science.1135456
- Rahmstorf, S., Cazenave, A., Church, J.A., Hansen, J.E., Keeling, R.F., Parker,

D.E., and Somerville, R. C. J., 1 Feb 2007, *Recent climate observations compared to projections*, Science Express

- Webster, P., Holland, G., Curry, J., and Chang, H.-R. (2005). *Changes in tropical cyclone number, duration and intensity in a warming environment.* Science, 309**,** 1844–1846.

UNEPFI publications see website www.unepfi.org

- CEO Briefing: Adaptation and Vulnerability to Climate Change: The Role of the Finance Sector. Climate Change Working Group, 2006. Author A. Dlugolecki.
- Climate Change and the Financial Services Industry: Module 1. Threats and Opportunities. Module 2 A. Blueprint for Action. Climate Change Working Group, 2002. Author, Innovest Inc.

Websites

- An excellent one on the science of climate change is http://www.realclimate.org/
- Another is http://www.climate.org
- From a US sustainable business perspective- Pew Center http://www.pewclimate.org/
- EU projects: MICE (Measuring the Impact of Climate Extremes), and STARDEX (Statistical and Regional Dynamical Downscaling of Extremes for European Regions).
- OECD has some good items on climate change, but they are scattered across categories, so you need to search inside the site for them. http://www.oecd.org/

World Business Council for Sustainable Development (WBCSD) www.wbcsd.org
A range of useful reports, though in the past has rather emphasized heavy industry concerns over environmental precautions, and not geared to FSS issues directly. A selection is:

- Policy Directions to 2050: A business contribution to the dialogues on cooperative action, 2007
- Energy and Climate 2006
- Facts & Trends to 2050: Energy & Climate Change, 2004.

Warning on climate change sceptics
There are many websites and publications that are sceptical of climate change, some apparently genuine and plausible, some slightly crazy. If a fresh piece of apparently contradictory evidence appears, check out what realclimate.org or climate.org say, or email them for a comment.

Web Links

Hadley Centre (UK Meteorological Office GCM centre)
http://www.metoffice.gov.uk/research/hadleycentre/index.html
Annual reports at Conferences of the parties to UNFCCC, including: (a) 2003 - Climate change observations and predictions; (b) 2004 - Uncertainty, risk and dangerous climate change; (c) 2005 - Climate change, rivers and rainfall; (d) 2006 - Effects of climate change in developing countries; and 2007 – Biodiversity – Climate interactions.

Intergovernmental Panel on Climate Change (IPCC)
http://www.ipcc.ch
Contains Assessment Reports of Workshop Groups and Summaries.

International Energy Agency
http://www.iea.org/
Implications of climate change for energy industries, especially World Energy Outlook series.

Hohenkammer Seminar on Climate Change and Disaster Losses Workshop
http://sciencepolicy.colorado.edu/sparc/research/projects/extreme_events/munich_workshop/index.html
Understanding and Attributing Trends and Projections. Joint Munich Re Foundation and Colorado University, June 2006.

Munich Re Publications
http://munichre.com
Annual review of catastrophe losses and information on hurricanes and insurance in a time of changing risks.

Stern Review on the economics of climate change
http://www.occ.gov.uk/activities/stern.htm
Office of Climate Change, UK.

Real Climate
http://www.realclimate.org
Climate Science from Climate Scientists.

Pew Center
http://www.pewclimate.org
From a US sustainable business perspective.

Climate and Life on Earth
http://www.climate.org/climate_main.shtml
A project of the Climate Institute.

Organization for Economic Cooperation and Development (OECD)
http://www.oecd.org
Contains some good items on climate change, but they are scattered across categories, so you need to search inside the site for them.

World Business Council for Sustainable Development (WBCSD)
http://www.wbcsd.org
Contains a range of useful reports, though in the past has emphasized heavy industry concerns over environmental precautions, and not geared to FSS issues directly.

UNEP Finance Initiative (UNEP FI)

e-Learning Course on

Climate Change: Risks and Opportunities for the Finance Sector

in collaboration with:

UNEP FI Climate Change Working Group | United Nations Institute for Training and Research | UNEP FI Australasian Credit Risk Advisory Committee | EPA Victoria | Bank of America