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RAPID CLIMATE CHANGE

Climate change is a widely debated issue and was a key focus of the UK's joint presidency of the EU and G8 this year. Policy responses so far have focused on steady changes in climate. Now growing evidence suggests that increases in global temperatures may lead to more rapid and irreversible shifts in the climate system. These could produce large changes in global weather patterns in only a few decades. The likelihood of such an event occurring this century is thought to be low, but the potential impacts are too high to ignore. While the uncertainties remain high, some evidence suggests that if emissions growth continues unabated, abrupt changes could be seen by the middle of this century. This POSTnote summarises current knowledge of rapid climate change and reviews possible policy options.

Background

Climate change and greenhouse gases

In June 2005, the national science academies of the G8 nations and India, China and Brazil issued a statement affirming that "climate change is real". Global average temperatures rose by 0.6°C over the last century. There is consensus that much of this warming is human-induced, linked to a build-up of greenhouse gases (GHGs) in the atmosphere. The level of carbon dioxide (CO_2) has grown from 280 parts per million (ppm) to 380 ppm since pre-industrial times (pre-1800s), largely due to fossil fuel burning. Rising levels of other GHGs have added another 45 ppm, giving a total equivalent of 425 ppm of CO_2, the highest CO_2 level for more than 400,000 years. CO_2 emissions have been projected to rise by a further 60% by 2030[1]. What is less certain is how the climate system will respond to these increases.

The Intergovernmental Panel on Climate Change (IPCC) gives the best synthesis of current knowledge. Its 2001 report predicts a "steady" global change in climate: a warming of 1.4°C to 5.8°C during this century; rising sea levels; and changes in regional weather patterns. The predicted impacts are discussed in previous POSTnotes[2].

'Rapid' climate change

The IPCC report also highlights the possibility of "rapid" climate change: an accelerated change or abrupt shift in climate over only a few decades (Box 1). The potential impacts include abrupt regional changes in rainfall, temperature, sea levels and storm patterns. This scenario is not unrealistic: evidence suggests that rapid changes in climate have occurred frequently in the past (Box 1).

Box 1. How can climate change abruptly?

The climate system is an intricate balance of billions of inter-linked processes involving the atmosphere, cryosphere (ice), oceans and ecosystems. This complexity makes the system chaotic: even small stresses (whether slowly building or sudden, like a huge volcanic eruption) can destabilise the system, leading to abrupt shifts as the climate adjusts to balance the new conditions. Much of human civilisation has occurred during a relatively stable climatic period, but data, reconstructed from ice cores and ocean sediments, show that abrupt climate shifts have occurred repeatedly in the past. The effects can persist for centuries. One major event, the Younger Dryas (see figure), saw some regions switch to near-glacial conditions (cold, dry and windy) in only 20 years. This event has been linked to a shift in ocean currents induced by the melting of large ice sheets (Box 2). It is likely that another natural event will cause an abrupt shift at some point in the future, but scientists believe that a build-up of stress from escalating atmospheric GHG levels may trigger rapid changes at some time in the next few hundred years.

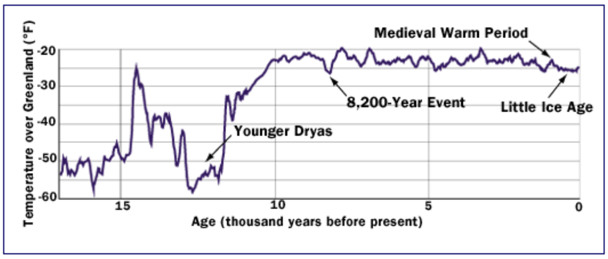

Figure 1. Past temperature changes over Greenland. *Source: R. Alley (Pennsylvania State University, USA), using data from Grootes, Stuiver, Cuffey and coworkers.*

Box 2. The thermohaline circulation (THC)
The THC is a global ocean current system. In the North Atlantic, warm surface waters (commonly called the Gulf Stream, part of the Atlantic THC) transport vast amounts of heat from the equator towards the Arctic. Some of this heat is released into the atmosphere and has a significant warming effect on the climates of much of Europe and North America. Without this, the UK might have a climate similar to parts of Norway. The Atlantic THC is partly driven by the sinking of dense (cold and salty) water in the northern Atlantic seas. This process may be disrupted by global warming as the sea surface warms or if more fresh water from rain, rivers and melting ice overlaid the salty sea water. Disruption to the driving mechanism may weaken or even collapse the Atlantic THC. If it did collapse, it might remain in an 'off' state for several centuries and average temperatures in the UK could fall by 5°C in a few decades.

The severity of the potential impacts has attracted considerable attention in recent years. For example, in 2003, a study commissioned by the Pentagon, recommended that the "risk of abrupt climate change, although uncertain and quite possibly small, should be elevated beyond a scientific debate to a US national security concern"[3]. Most scientists agree that the likelihood of rapid changes in the next few decades is probably low. More steady changes in climate, on the other hand, are now palpable and may have equally widespread and severe impacts.

Avoiding 'dangerous climate change'

In mid-2005, leaders of the G8 industrialised nations reached agreement on the link between climate change and GHG emissions from human activities. They agreed that there is a need for resolve and urgency in cutting GHG emissions. No specific commitments were made. In February, as a prelude to the UK's presidency of the EU and G8, the Prime Minister invited scientists and policy makers to an international conference at the Met Office, to discuss what actions may be needed to avoid "dangerous climate change". Rapid climate change featured strongly in the discussions. This briefing draws upon some of their conclusions in this area.

Potential mechanisms

Based on current understanding, Box 3 describes the key mechanisms that may cause rapid changes. A great deal of research is focused in this area, but there are still large uncertainties. It is difficult for scientists to find clues from recent, natural, climate events as the current rate of GHG build-up is unprecedented, and making predictions by computer modelling is challenging as these mechanisms involve many sensitive links between several parts of the climate system. In particular, mechanisms may interact in ways that are difficult to model. For example, if global warming were to accelerate due to weakening of carbon sinks, the likelihood of a collapse of the Atlantic THC may increase. In general, there is a good understanding of how these mechanisms might work, but scientists are uncertain of the likelihood of changes in the near future. It does seem likely that any changes would be irreversible within a human life time. In most cases, some important changes have already been observed (Box 3).

Box 3. Potential mechanisms: key findings

Disruption to the Atlantic THC
The Atlantic THC (Box 2) is projected to weaken with rising global temperatures, although there is little consensus on the size or rate of the weakening. Any weakening would have a cooling effect around the North Atlantic, principally during winter. This would be superimposed on GHG warming. Only relatively simple models predict a total collapse, giving likelihoods as high as 20% for collapse by 2050. Complex models, similar to those used in weather forecasts, indicate a slow weakening rather than a total collapse. The UK Met Office model predicts a 20% weakening by 2050. In this case, the UK is likely to experience a net warming, but there may be an impact on rainfall. Some observations suggest that a large weakening has already taken place, but the time period of these observations is too short to be conclusive.

Melting or collapse of ice sheets
Observations indicate some recent thinning in parts of both the Greenland and West Antarctic ice sheets. Of the large ice sheets, Greenland is thought to be most vulnerable to global warming. Several models indicate that the projected Arctic warming will cause significant melting in this century. This could increase the IPCC-projected sea level rise (9−88 cm by 2100) by over 50%. It may take over a 1000 years of warm conditions to melt completely, giving a rise of 7 m. The West Antarctic Ice Sheet (WAIS) could be inherently unstable. If it collapsed, sea levels may rise by 5 m over a few centuries. There is no conclusive link between global warming and the stability of the WAIS, but a few studies suggest a higher risk of collapse if GHG levels were to double (to 560 ppm).

Shifts in atmospheric circulations and variability
There are concerns that climate change could lead to abrupt shifts in regional weather by altering natural patterns of circulation in the atmosphere. For example, a shift over equatorial Africa may cause rapid changes in local rainfall patterns. Some models predict changes in the frequency of natural climate shifts, such as the El Niño (a periodic change in atmospheric circulations over the Pacific that occurs as part of a natural cycle). The strong El Niño in 1997/1998 had severe impacts around the Pacific and Indian Oceans, causing 23,000 deaths and costing around £50 billion globally. Some studies have indicated shifts in storm patterns in Europe and changes in monsoon systems. The latter could have disastrous effects on rainfall in Asia.

Weakened natural carbon 'sinks'
Currently, half of all GHG emissions are taken up by the land and oceans. As the world warms, scientists suggest that these processes may weaken. For example, key forests may dry out and die, becoming an additional source of carbon. This problem is exacerbated by direct deforestation. The net effect is more emissions remaining in the atmosphere and contributing to global warming. Most models agree that some sizeable weakening may occur around 2050 and may be irreversible. Some models show a strong effect, with a rate of global warming 50% faster than currently predicted. Changes in ecosystems and ocean acidity (as more CO_2 dissolves into seawater) may also have severe effects on terrestrial and marine biodiversity.

Release of natural GHG stores
Huge quantities of GHGs are stored in wetlands, peat bogs, permafrost and in deep oceans (particularly methane, a GHG 20-times more potent than CO_2). Small amounts are already being released from melting permafrost around the Arctic and from peat bogs and wetlands due to changes in land use, but this may increase in the future. If the deep ocean stores destabilise, huge amounts of methane could be released, catastrophically and irreversibly accelerating global warming. While the probability of such an event is thought to be low, there is evidence that it has happened in the past.

Critical thresholds

At the Met Office conference, scientists endeavoured to find consensus on a series of critical global temperature levels, above which the risk of triggering rapid climate change may increase. It was suggested that:

- a rise of about 2°C above the pre-industrial level may trigger significant melting of the Greenland ice sheet;
- a rise of more than 3.5°C could give a more serious risk of large-scale, irreversible system disruption, such as major weakening of carbon sinks or possible destabilisation of the Antarctic ice sheets;
- no clear threshold was agreed for a collapse of the Atlantic THC, but the risks were shown to increase with temperature and the rate of warming[4].

Thresholds give an idea of the likelihood of changes, but should be treated with caution: an unexpected event may be triggered at a lower threshold or an unknown process could slow the changes. These thresholds must also be kept in perspective: some serious impacts from steady climate change are expected for a rise of just 1°C (we are now nearing a 0.7°C rise). The chance of crossing a threshold rests on the sensitivity of global temperatures to GHG levels. This is not known precisely. Recent studies indicate that doubling of the pre-industrial GHG level (to 560 ppm CO_2 equivalent) may lead to a long-term warming of between about 2°C and 5.5°C, with a lower probability of a rise of up to 9°C. Assuming GHG levels are likely to double by 2050, at the bottom end of this range the risk of rapid changes by 2050 may be low. At the top end, the risk could be more acute. Scientists cannot currently discount either scenario.

Policy issues

All current policy assumes that any changes in climate will be steady; the risk of rapid changes is not explicitly included. The fourth IPCC report, due to be published in 2007, will be critical in informing policy makers of what further actions may be needed to tackle rapid climate change. As with steady changes in climate, there are two options: mitigation (minimising the risk) and adaptation. This section discusses what new challenges rapid climate change may bring for policy in these two areas.

Reducing the risk of rapid climate change

While some future changes in climate are now probably inevitable, the risk of rapid changes might be reduced by curbing GHG emissions. Under the 1992 UN Framework Convention on Climate Change (UNFCCC), it was agreed that the atmospheric GHG level should be stabilised at a point sufficient to prevent "dangerous" human-induced climate change. Due to disputes over uncertainties in the science and what constitutes dangerous climate change, a suitable global target has never been defined. It has been suggested that rapid climate change thresholds may provide the most unequivocal definition of what level of warming needs to be avoided. There are dangers in this definition: these thresholds may not be definitive and policies must also reflect the more certain thresholds in social vulnerability linked to steady changes in climate. For example, in Europe, falling crop yields are expected at a 2°C warming. Nevertheless, rapid climate change may increase the impetus for emissions reductions as:

- the cost of impacts may be much larger and more widespread than previously thought (Box 4), tilting cost-benefit analyses in favour of mitigation;
- adaptation may be more difficult (see later section).

Box 4. Potential impacts of rapid climate change

Impacts: The predicted impacts can be divided into:

- accelerated warming (with sea level rises and shifts in regional weather patterns) linked to weakening of carbon sinks and increased natural GHG releases;
- accelerated sea level rise from loss of land ice;
- falling temperatures around the North Atlantic, further warming in Africa and global shifts in weather patterns, including droughts in parts of the Central and South America, linked to a collapse of the Atlantic THC;
- shifts in the frequency of some extremes for all cases.

It is thought that damage would be far more severe than is predicted for steady changes, as the rate and size of impacts may outstrip a society's capacity to adapt. Damage would be more acute where capacity is lower like, for example, Africa, where resources are stretched. There is little research on specific impacts of rapid climate change. One study suggests severe impacts in health, infrastructure, food and water availability and ecosystems (food, biodiversity and forestry)[5].

Costs: No calculations of the costs of climate change include extreme events or rapid and irreversible changes. However, it has been suggested that these costs would be prohibitive. For example, a recent study found that, under a high emissions scenario and with no adaptation, the annual UK cost of flooding could reach £20 billion by 2080[6]. With extreme events, this would rise even further. Significant melting of the Greenland ice sheet could accelerate the risk, meaning that, with less time for adaptation, this cost may be seen in 40 rather than 80 years. In a worse-case scenario, if London were flooded, over a million people could lose their homes and direct damage could be in excess of £80 billion[7].

The 2°C stabilisation target

Based on current understanding of 'steady' and 'rapid' impacts, organisations such as the International Climate Change Taskforce[8] suggest a long-term target to prevent global average temperatures rising more than 2°C above the pre-industrial level. While some impacts are expected below this level, above it impacts on ecosystems, water, and food may rise dramatically. To inform policy, targets must be translated into emissions reductions but science can not link these precisely. The 2°C target has guided EU policy since 1996, when it was linked to a CO_2 level stabilised at 550 ppm. This level was thought to give an optimum balance between costs. Although the EU has no official target, the 550 ppm level is now embedded in EU policy. The UK's domestic 2050 target (a 60% cut in CO_2 emissions below 1990 levels) is consistent with that calculated as the UK's contribution to the overall global emissions reductions required to stabilise at 550 ppm.

Recent evidence indicates that CO_2 levels need to be kept below 400 ppm to be fairly certain of limiting warming to 2°C. As the CO_2 level is now nearing 380 ppm and rising at over 1.5 ppm per year, this cannot be done without urgent, vigorous global action to cut emissions. The UK would have to cut CO_2 emissions to over 80% below 1990 levels by 2050. Many studies demonstrate that cuts on this scale are achievable, but costs remain contentious. The Kyoto Protocol alone can not notably reduce the risk of rapid changes. Without effective global action, the world could exceed a 2°C warming by 2050.

Adapting to rapid climate change
The high-impact, low-likelihood scenarios linked with rapid climate change bring new challenges for adaptation strategy. Given the range of projected impacts, it may be financially and technically difficult to begin adapting now. Many agree that such measures are not justified unless uncertainties are reduced. Others stress that if thresholds are passed, it may be too late to implement the most effective solutions, making the impacts more costly. A few studies have begun to assess the ability of society to adapt to abrupt events; some of their recommendations are outlined in Box 5[9]. One study found that paralysis of decision making could be a critical factor in whether societies can cope[10]. Integral in this were the need for public engagement and the inclusion of high-impact, low-likelihood events into long-term decision making. Some future studies are already planned, for example:

- the Government-funded UK Climate Impacts Programme (UKCIP), which provides scenarios to help organisations adapt to climate change, is planning a study to explore low-likelihood, high-impact events;
- the Environment Agency is working with the Met Office Hadley Centre on the Thames 2100 project. This will include an analysis of policy responses to worse-case scenarios of sea level rise in the Thames region.

Box 5. Adapting under uncertainty
Given the uncertainty, studies suggest that the most effective action now is to instigate win-win policies that will reduce the vulnerability of society for all scenarios. For example:

- instigate coordinated research to improve climate prediction and monitor key climate system components to detect early onset of changes; in many areas, data are too scarce to detect rapid changes conclusively;
- identify vulnerabilities and increase adaptive capacity. For example, by developing financial risk transfer instruments markets can be more resilient to extreme events or by improving the management of resources, such as water, society can better cope with shortages;
- where possible, consider potential extreme impacts when planning long-term infrastructure and changes in land use (such as avoid building on high-risk flood plains: over the past 20 years, 350,000 properties have been built on floodplains; over 100,000 more are planned, 10,000 in areas of significant flood risk[11]);
- develop strategies for making effective policy decisions under uncertain conditions and over long-time periods.

Forthcoming opportunities
The climate change discussions at the G8 Summit in July 2005 focused heavily on energy. Over the next 25 years an estimated $16 trillion must be invested in the energy sector to meet growing demand; the International Energy Agency believes that there are significant opportunities to invest this cost-effectively in cleaner and more efficient technologies[1]. Many argue that this alone is not enough to prevent dangerous changes in climate and that defined targets are needed. The UNFCCC meeting in Montréal in November 2005 provides an opportunity to begin talks towards post-2012 commitments. The inclusion of developing nations will be critical. At present, developed nations still contribute the majority of emissions but, developing nations are projected to account for nearly 70% of emissions growth to 2030[2]. One-quarter will come from China alone, where there are plans to build over 500 new coal-fired power stations by 2030.

The UK has set some of the most ambitious domestic targets. However, it now seems unlikely that the UK will achieve its 2010 CO_2 emissions target (a 20% cut below 1990 levels) based on current policies[12]. This year the UK Government will publish a review of the UK Climate Change Programme, which is expected to launch a new wave of domestic policy to put the UK back on track to achieve the 2050 target. There are also opportunities for action within the EU: the first phase of the EU Emissions Trading Scheme began in January. The second phase, which is hoped will facilitate larger emissions cuts, will be negotiated over the coming year, for launch in 2007.

Overview
There is growing evidence that stress put on the climate system by rising atmospheric GHG levels might trigger rapid, irreversible changes in climate. While uncertainties remain high, at the current rate of emissions growth, it is possible that some rapid changes may occur within this century. The uncertainty and low-likelihood, high-impact nature of rapid climate change presents new challenges for conventional policy making. Studies suggest that the most effective actions now are to: instigate coordinated research; install monitoring systems; implement win-win strategies to reduce vulnerabilities; and ultimately stabilise atmospheric GHG concentrations at a level that would lower the risk of rapid changes in the future.

Endnotes
1 International Energy Agency (2004) *World Energy Outlook 2004.*
2 POSTnotes 232 (2004), 161 (2001), 121 (1998), 61 (1995).
3 Schwartz & Randall (2003) *Imagining the Unthinkable.*
4 Report of the International Steering Committee. May 2005.
5 Arnell et al. (2005) *Vulnerability to Abrupt Climate Change in Europe.* Tyndall Centre for Climate Change Research.
6 OST Foresight Programme (2004) *Future Flooding.*
7 Parker & Penning-Rowsell (2002) *The Case for Flood Protection for London and the Thames Gateway.* Flood Hazard Research Centre.
8 The taskforce was established in 2004 by three leading policy think tanks. Chaired by Stephen Byers MP and Senator Olympia Snowe.
9 This includes a series of new ESRC-funded studies investigating rapid climate change and human behaviour. The recommendations are largely taken from: The National Academy of Sciences (2002) *Abrupt Climate Change: Inevitable surprises.*
10 A study conducted by the Stockholm Env. Inst. as part of the EU-funded “Atlantis” project to explore responses to rapid sea level rise.
11 Association of British Insurers (2005) *Making Communities Sustainable: Managing flood risks in the government’s growth areas.*
12 EFRA Committee, Ninth Report of Session 2004−2005, *Climate Change: Looking forward,* HC 130, para 25.

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