25. PREDICTIONS OF CLIMATE CHANGE

Vicky Pope[1]

Figure 25.1 *An example of negative feedback. Low-lying cumulus cloud reflects sunlight which cools the Earth's surface. We can improve mathematical models used to predict long-term climate change by understanding the Earth's climate system.*

The only way to predict day-to-day weather and changes to the climate over long timescales is to use computer models. These models solve complex mathematical equations that are based on well-established physical laws that define the behaviour of the weather and climate.

Two critical factors have helped to improve these computer models over the years. First, our knowledge of the real world has improved, and second, the speed and power of computers has increased dramatically, allowing us to represent more detail in the models.

Improvements in the science

The climate system is highly complex with many potential interactions and feedbacks. More of this complexity has been included in the models. Our current 'state of the art' climate models now include fully interactive clouds, oceans, land surfaces, and aerosols; as well as detailed chemistry and carbon cycle calculations. It is worth thinking about why these processes are important and a few examples are highlighted here:

1. *Clouds affect the heating and cooling of the atmosphere.*

   On a cloudy day less radiation (heating) from the sun reaches the Earth's surface, but on a cloudy night the heat generated during the day is trapped and the temperature near the surface remains relatively warm. The detailed properties of the clouds are also important. Cirrus cloud high up in the atmosphere lets sunlight through but traps infra-red radiation, which stops heat escaping from the surface. Low-level clouds reflect sunlight and trap little infra-red radiation and so result in a cool surface climate.

2. *The oceans take much longer to warm up than the land.*

   They also move heat around the globe. For example, the gulf-stream brings warm water from the tropics up to northern Europe, and has a strong effect on our temperatures.

3. *The land surface influences how much radiation is absorbed at the surface.*

   Land that is covered in trees will be dark and will absorb more radiation, whilst areas that are covered in ice, or by desert, will both reflect more radiation and absorb less heat.

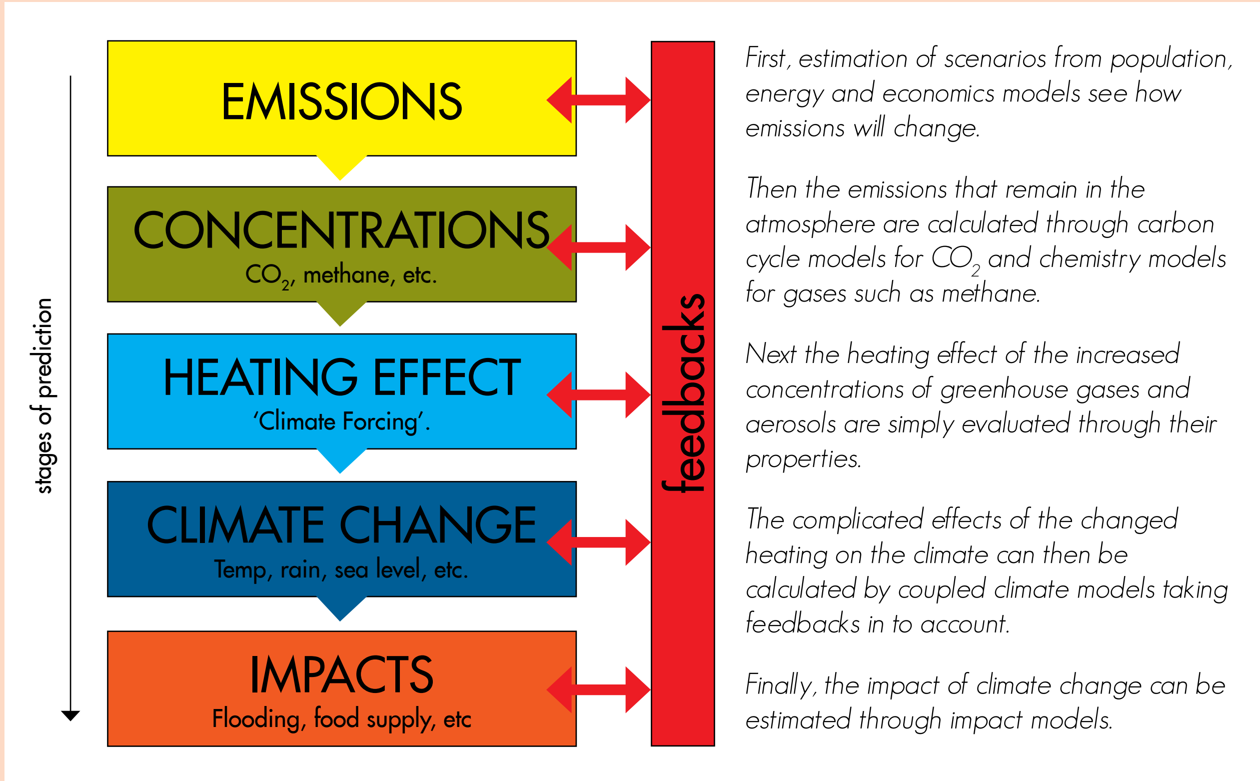
4. *Aerosols.*

   These are atmospheric particles, such as sulphate and black carbon that are produced naturally from volcanoes and forest fires, as well as by humans from fossil fuel power stations and other industrial activity. These have a short term cooling effect by reducing the amount of sunlight reaching the surface (the so-called dimming effect).

5. *The chemistry and carbon cycle determines how much carbon dioxide remains in the atmosphere.*

   Currently the biosphere (plants, soils, and phytoplankton) absorbs half of the carbon dioxide that man produces. However, this will not continue indefinitely as soils could start to release carbon if temperatures rise too much.

Figure 25.2 Stages in predicting climate change



Adapted from Hadley Centre for Climate Prediction and Research.

The Results

The latest computer models predict similar possible global average temperature changes to models used five or ten years ago, but we are much more confident that they are correct because they are based on so much more information.

Now that man-made climate change is established beyond reasonable doubt and further global warming is inevitable, it is even more important to improve our climate predictions.

References

1. Dr Vicky Pope is head of the climate predictions programme at the UK Met Office's Hadley Centre, which provides independent scientific advice on climate change.

26. CLIMATE CHANGE SCENARIOS FOR GUERNSEY

Peter Cox[1]

Global average temperatures have risen by about 0.7°C over the last 100 years, and most of this change is likely to have been caused by the burning of fossil fuels. We also know that temperatures in Guernsey have risen by more than that, particularly in the past few decades.

Climate models predict a rise of between 1.5°C and 5.8°C in the global annual average temperatures between 1990 and 2100, taking account of both the range of predictions of future emissions of 'greenhouse gases' and different climate models. These models are based on the following emissions and social scenarios:

1. High Scenario - rapid economic growth, continuously increasing populations peaking in mid-21st century and a reliance on fossil fuels (the business as usual scenario);
2. Medium-High Scenario – more self reliance, continuously increasing populations, economic growth;
3. Medium-Low Scenario – Population peaks mid-21st century, clean and efficient technologies, reductions in material use, social and environmental sustainability, improved equity;
4. Low Scenario – Local solutions to sustainability, increasing population but at a lower rate, less rapid technological change.

The climate consequences, in terms of global average temperature, of these four emissions scenarios calculated by the Hadley Centre global climate model is shown in Figures 26.1 – 26.3. Despite the immediate and rapid divergence of future emissions paths, the warming over the next 40 years or so is predicted to be much the same. This is mainly due to the very long effective lifetime of CO_2 in the atmosphere and the inertia of the climate system. Warming over the next few decades is already built into the climate system from current emissions and those over the past few decades. On the other hand, warming by the end of the century does depend on how emissions change in the future; roughly 2°C for the lowest emissions scenarios and 5°C for the highest.

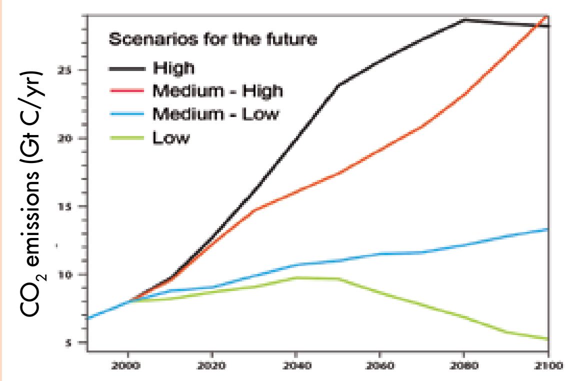


Figure 26.1 *Emissions of carbon dioxide, 1990-2100, in the four SRES emissions scenarios.*

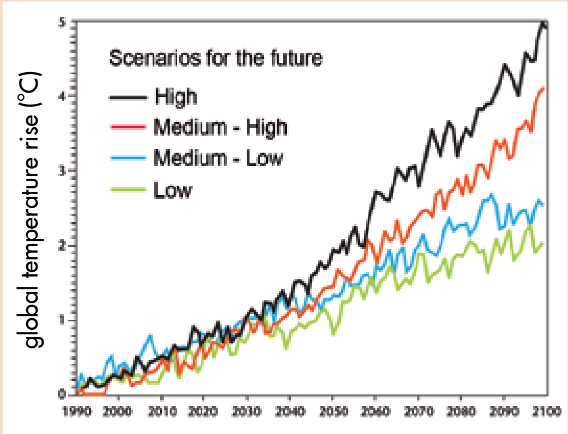


Figure 26.2 *Global mean temperature change, relative to 1990, predicted by the Hadley Centre global climate model (HadCM3), for each of the four SRES emissions scenarios.*

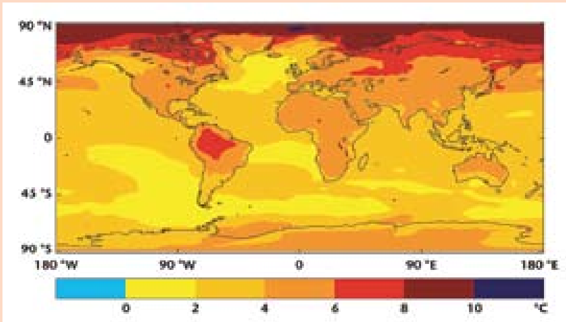


Figure 26.3 *Temperature rise between 1961-90 and 2071-2100 predicted by the Hadley Centre global climate model with Medium-High emissions.*

Seasonal Scenarios for Guernsey (the Channel Islands)

The scenarios of temperature (maximum and minimum) and precipitation (rainfall) are presented in map form (Figure 26.4 - 26.7). Maps are shown for all four emissions scenarios, and for all three 30 year time periods - 2020s (2011 – 2040), 2050s (2041-2070), and 2080s (2071-2100). The maps that follow identify by their box outline a grid square covering the land and sea area of the islands. A single 25km grid square, located for the purposes of the map mid-way between the two islands, has been taken to represent both Jersey and Guernsey.

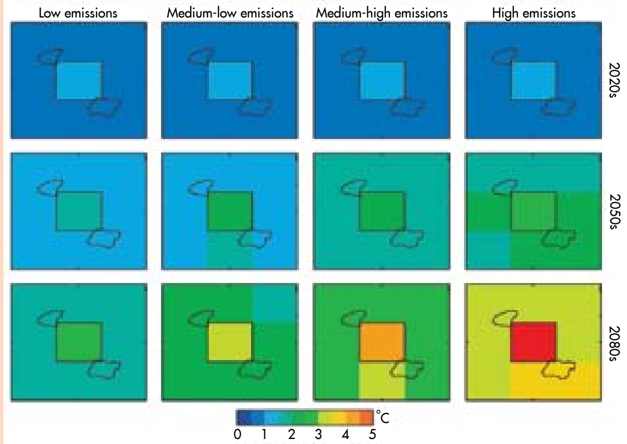


Figure 26.4 *Change in summer-average maximum temperature.*

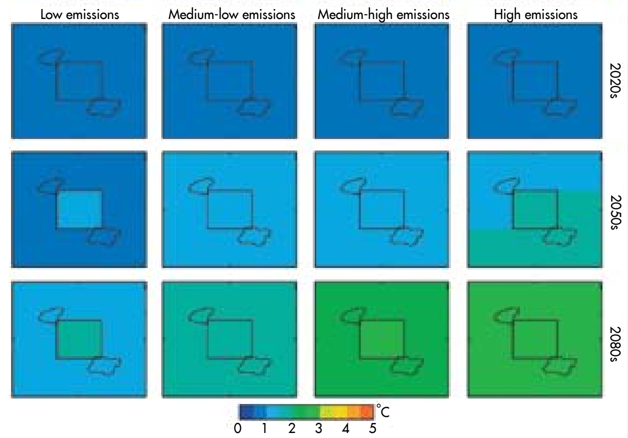


Figure 26.5 *Change in winter-average minimum temperature.*

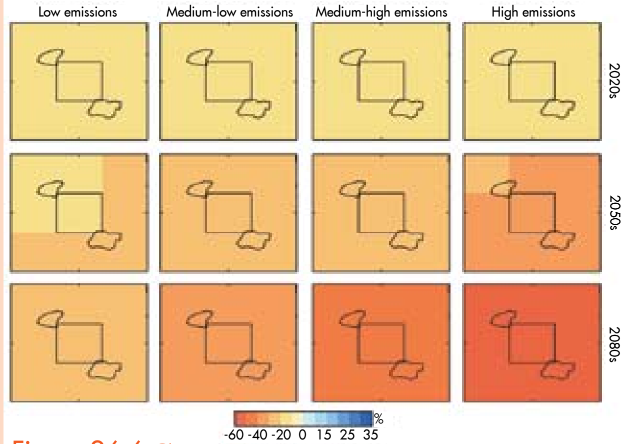


Figure 26.6 *Change in summer-average precipitation.*

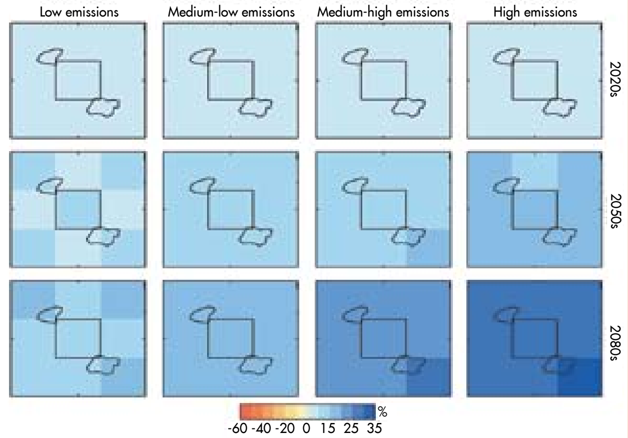
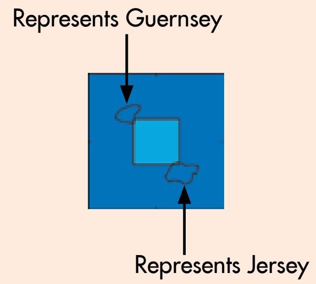


Figure 26.7 *Change in winter-average precipitation.*

Under the medium-high scenario of climate change the average annual temperature in the Channel Islands will increase by 3°C by 2080, but this masks a seasonal change from an average of 3.8°C in the summer to an average of 2.4°C in the winter. A similar seasonal difference is likely to be seen in rainfall (precipitation) that shows a modest 4% annual reduction, but this masks a dramatic 45% reduction in summer rainfall and a 24% increase in winter rainfall.



The frequency of hot days in the Channel Islands is expected to increase 4 or 5 fold by the 2080s under the medium-high emissions scenario, with a 70-85% reduction in frosts. The number of heavy rainfall days is expected to increase by 30-50% in winter but to decrease by 40-50% in summer.

Sea level is expected to increase by between 9 and 69cm by the 2080s; taking account of the different future emissions. When the effect of land movement is added the net rise varies from 14 to 74cm. With a sea level rise of 30cm the change in height of a once-in-50-years storm surge is predicted to be up to 0.5m.

The North Atlantic Ocean circulation, which includes the gulf stream, is predicted to decrease in strength by about 20% over the next 100 years, but not to switch off during that period. The temperature predictions above take account of the reduced heating due to these gulf stream changes.

Use of Climate Change Scenarios

The main use of climate change scenarios is in carrying out assessments of the impacts that climate change may have on socio-economic sectors such as infrastructure, agriculture, water resources, and coastal and river flood defences. In this way, adaptation can be planned well in advance, so that damages and costs can be minimised, and perhaps some potential benefits realised.

References

1. Dr Peter Cox is Director of the UK Met Office's Hadley Centre, which provides independent scientific advice on climate change.

Predictions: how it could affect your family

0°c - 1°c Guernsey temperature increase, assuming high CO_2 emissions

2025

In your lifetime

- Water bills double as new reservoirs commissioned for Guernsey
- Malaria pills needed for most south European destinations
- Air transport quotas introduced
- Pistachio and olive trees become garden centre favourites
- Flash floods devastate communities

1°c - 2°c

2050

In your children's lifetime

- Malaria pills imported on mass after major outbreak
- Environmental refugees arrive in strength at St Peter Port
- Flying becomes a luxury for the super rich
- London downsizes as summer temperatures become unbearable for millions
- Permanent island wide hosepipe ban

4°c - 5°c

2080

In your grandchildren's lifetime

- New northern sea wall barriers fail after storm surge
- First case of elephantiasis, caught from infested doult
- Light crude oil becomes more expensive, litre for litre, than claret
- Many west coast beaches disappear because of sea level rises

Source: Hadley Centre, Energy Saving Trust, World Resources Institute, Intergovernmental Panel on Climate Change, Worldwatch Institute, Energy Information Administration, UK Climate Impacts Programme, Arctic Climate Impact Assessment, UNEP

Life in 2050

Sea-level rise

Predicted to rise by up to 36 cm by 2050 and by 69 cm by 2080. Stabilising emissions by the year 2025 could cut the rate of sea level rise in half

Deforestation

Could account for 15 per cent of the CO_2 in the atmosphere by 2050, mostly from the Amazon. After 2050, this contribution will decline because there will not be many forests left. 73 per cent of the world's tropical forests will have been felled by the year 2100. The last tropical evergreen tree will fall before 2045

Crops collapse

By 2050, current crop yields must double in order to keep pace with increasing populations. Research suggests a 50 percent loss in crop yield under constant 2050 levels of CO_2

Water conflict

Humans are already using more than half the planet's fresh water. By 2025, this could be more than 70%. Some of the fastest growing human populations live along rivers shared between two or more countries –the Nile, the Ganges, the Jordan and the Tigris–Euphrates

Tropical storms

Around 50 tropical storms reach hurricane status each year. Warmer oceans mean that figure could double. Tropical atolls like the Maldives – which rise less than 1.8m above sea level – could disappear forever

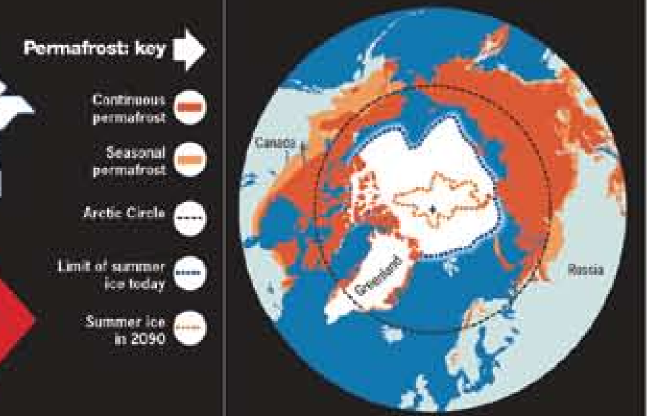
Fishing

Two–thirds of fish species, including cod and haddock, in the North Sea have moved north in search of colder waters as temperatures rise – average surface temperatures of the North Sea could rise by up to 4°C by 2080

Disease

The percentage of the earth where mosquitoes transmit malaria is likely to rise from 45% today to about 60% sometime after 2050. Increases in cholera, salmonellosis. Increased asthma, allergic disorders, and cardiorespiratory diseases

Permafrost: the world's CO_2 store



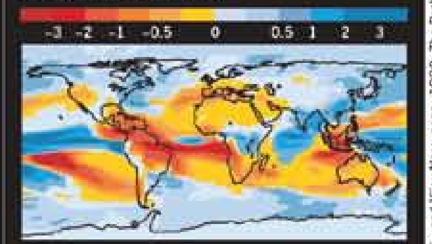
What is permafrost?
It's the name given to frozen soil, which occurs in Arctic regions and on high mountain ranges – and it can contain over 30% ice, or practically no ice at all. It covers 27% of the world's land surface and can be as much as 1000 metres deep. It contains 14% of the world's carbon trapped in the frozen soil and a minimum of 100,000 trillion cubic feet of methane

What happens when it melts?
Across much of Canada, Alaska, Russia, Norway, China and Greenland permafrost is melting with alarming results. Houses, roads, pipelines and railways built on the assumption that permafrost was permenant are collapsing. In Switzerland some mountain tops are literally crumbling. The melting releases vast quantities of carbon and methane into the atmosphere

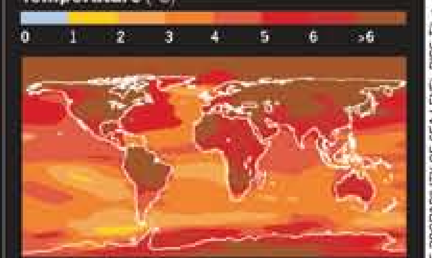
2080 the weather

Annual changes from the present day to the 2080s with the continuation of fossil fuels as the main source of energy

Precipitation (mm/day)



Temperature (°C)



THE PROBABILITY OF SEA LEVEL RISE Titus, James G., and Vijay Narayanan. 1998. The Probability of Sea Level Rise. Environmental Protection Agency, Washington, D.C..

Adapted from Guardian News and Media Ltd 2007.

28. MODELS OF PROJECTED SEA LEVEL RISE IN GUERNSEY

Andrew Casebow

Sea levels appear constant to us during the course of our lives but, as John Renouf showed in chapter 5, the sea level around the coast of Guernsey has risen by over 100 metres in the last 20,000 years. Against such a backdrop the sea level rises that are now being predicted appear small, but they could have a dramatic effect on the island and on the lives of the inhabitants.

The recent Intergovernmental Panel on Climate Change report states that "Observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000m and that the ocean has been absorbing more than 80% of the heat added to the climate system."[1] Heated water expands and, as a consequence, sea levels are projected to rise as water temperatures increase. This will occur even without any increase in glacial melting. Information from Cherbourg suggests that sea level rise is already happening in this part of the Channel, and that the sea level has risen by over 40 mm in the thirty years to 2004.

Future projections of sea level rise suggest that the Channel Islands are in one of the worst regions of the British Isles, with a potential sea level rise of up to 0.7 metres by 2080 (see Figure 28.1).

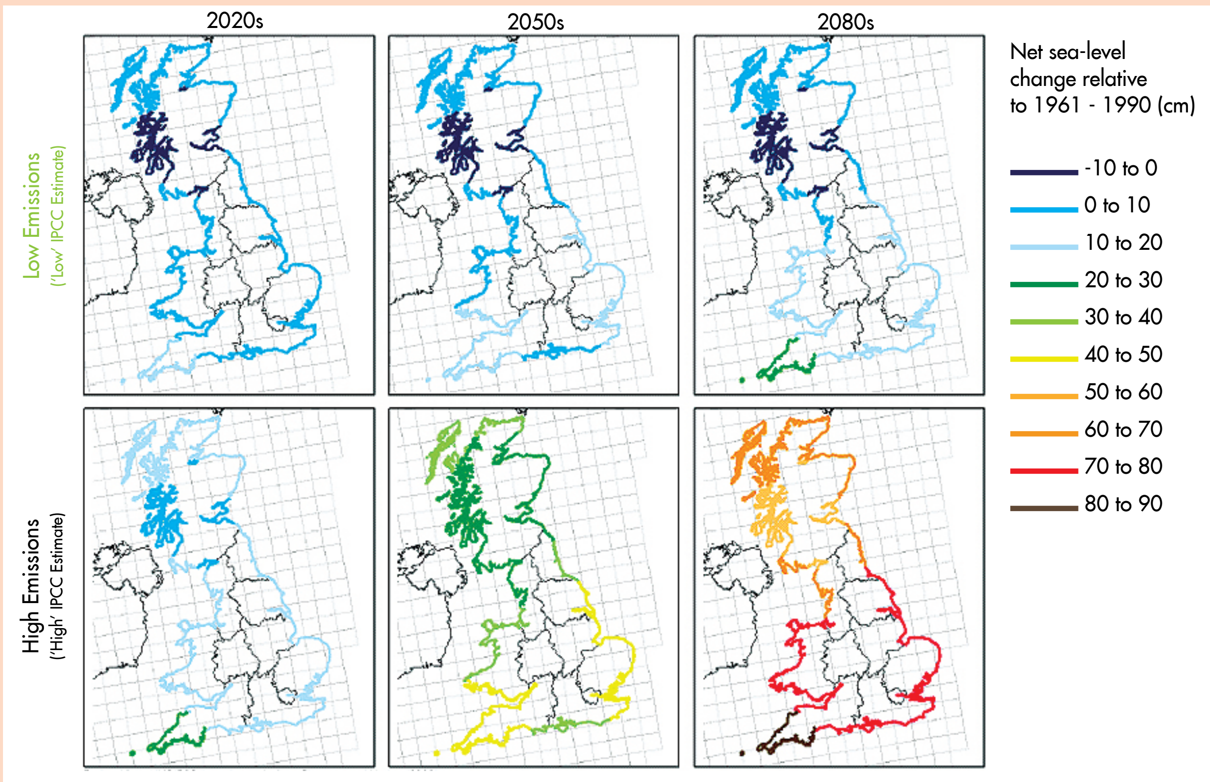


Figure 28.1 *UKCIP 2002 Projected average sea level rise under different SRES scenarios (mm)* [2].

Some individual scientists suggest that if glaciers melt more quickly than predicted then sea levels will be higher, whilst if appropriate action to curb carbon dioxide emissions can be taken then potential sea level rise might be considerably less. In the longer term sea level rise could be substantially more than this and 'business as usual' predictions suggest that a level about 10 metres higher than the present might be expected within 1000 years following the melting of the Greenland ice cap and expansion of the world's oceans (Chapter 29).

It will be noted in the following Digimap representations that a considerable area of the island would already be subject to flooding at high water spring tides if it were not for the island's existing sea defences. As a consequence, a small rise in sea levels might make little difference to the current situation; whereas if sea levels rose further than predicted, possibly in a longer time frame, or during the occasional (once in 50 year) storm surge, then there might be more extensive flooding. Fortunately the most adverse effects can be avoided if timely actions are taken in anticipation of sea level rise. Where appropriate, actions can be initiated to strengthen sea defences and protect vulnerable areas, at least for the foreseeable future.

A rising sea could also increase the salinity of coastal marshes and aquifers, disrupt marine life and threaten some private drinking water supplies.

In addition to the 'headline' risk of inundation by sea-water, there is a risk of greater flooding in low lying areas of the island due to the higher winter rainfall that is predicted. Considerable areas of open agricultural land already flood following prolonged heavy rainfall. This could be particularly important in the future as urban and infrastructural development (sewage, roads, housing and educational facilities) have been undertaken in low-lying areas, and greater areas of roofs, paved areas and tarmac roads lead to more rapid run-off. Flooding in some of these areas is already mitigated by pumping, and flooding has occurred in the past when remedial pumping of water has not occurred.

Figure 28.2 shows 'Digimap' representations of Guernsey areas that would currently be vulnerable to flooding at high water if it were not for the existing sea defences. The map showing potential flooding if the sea level was up to one metre higher is little changed, but a more substantial sea level rise could affect greater areas, particularly in the north of the island. Fortunately this is unlikely to occur this century, although as sea levels rise these areas will become more vulnerable to flooding following a storm surge.

References
1. Summary for Policymakers: IPCC Fourth Assessment report of the IPCC, Working Group 1, 2007.

2. M Hulme et al (2002) Climate Change Scenarios for the United Kingdom: UKCIP 02 Scientific Report. Tyndall Centre for Climate Change Research, UEA, Norwich.

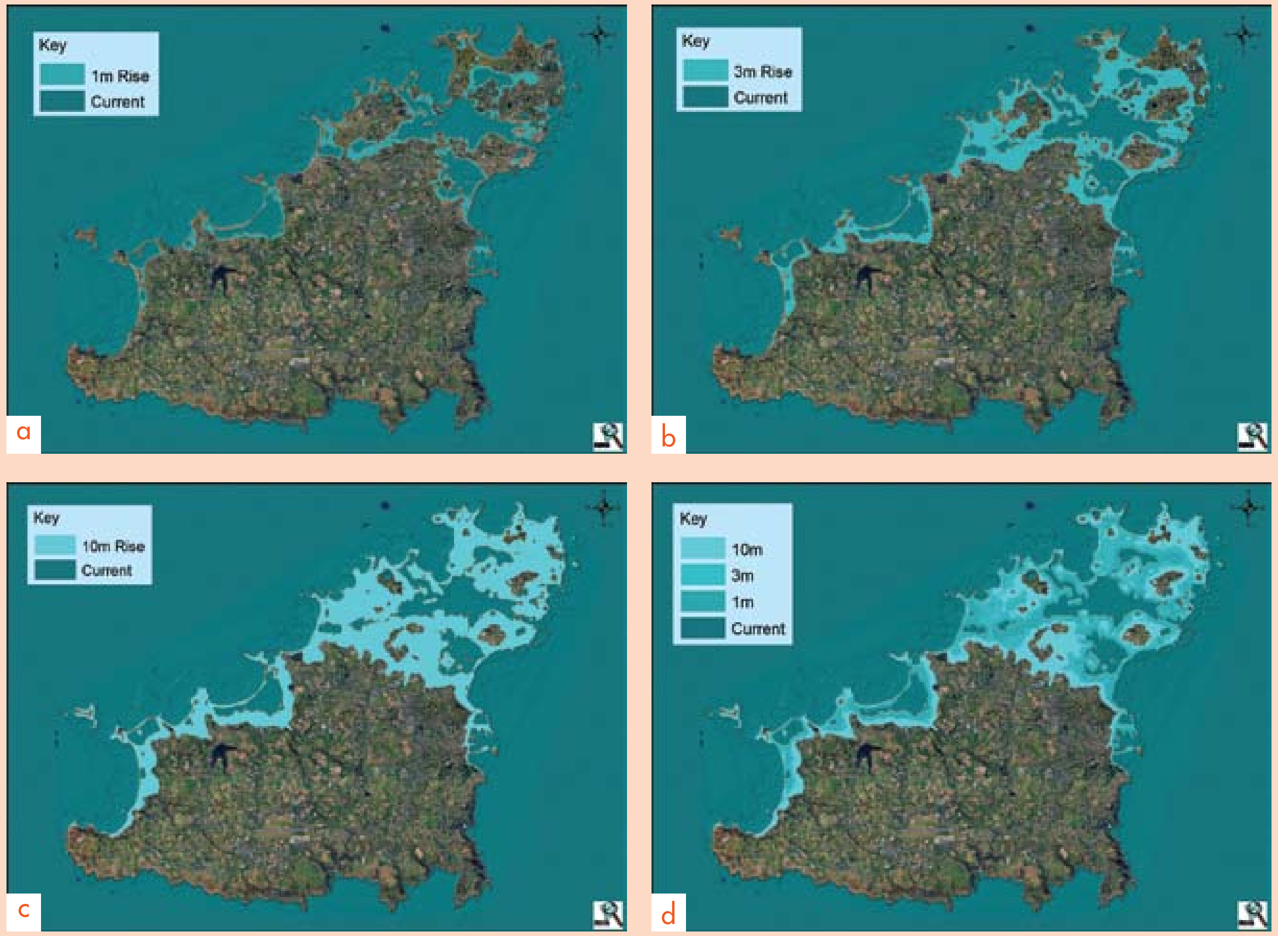


Figure 28.2 *Representations of potential flooding in Guernsey if it were not for our existing sea defences; (a) after 1m sea level rise, (b) after 3m sea level rise, (c) after 10m sea level rise, and (d) all three levels superimposed on top of each other.* "Mapping © States of Guernsey 2007, supplied by Digimap".

29. CLIMATE CHANGES OVER A MILLENNIAL TIMESCALE

Andrew Casebow

Figure 29.1 *Continual increase in emissions could lead to total depletion of ice in the Northern Hemisphere.*

Most projections of future climate change focus on this century. The obvious reason for this is that beyond this period relatively accurate predictions become more and more difficult. They also become less meaningful to most of us when the predictions are for a period of time beyond human contemplation, and beyond the possible lifetimes of our immediate descendants.

Projections for the period 2080 – 2100 leave the near surface air temperature and sea level still rising, and in some models the rate of change seems to be still increasing. However, climate changes will not stop occurring. If, as many predictions indicate, greenhouse emissions are still increasing, albeit at a slower rate, and temperature increases are still occurring, then where will all this lead?

The Tyndall Report

The UK Environment Agency commissioned a report into climate change over the next 1000 years from the Tyndall Centre for Climate Change Research.[1] This shows that decisions over the next few years by the major greenhouse gas emitting nations (and by us all), will leave a legacy of increasing climate change over the next millennium unless there is a major reduction in emissions.

Obviously the storylines, or possible scenarios, that lie behind the climate change models will vary enormously, and as a consequence the change in the earth's climate could be quite minimal if appropriate long term action is taken immediately, or severe if humanity adopts a 'business-as-usual' approach. The report notes that:

"The most important potential contributor to the long term forcing of the climate system by human activities is the amount of fossil fuel carbon we emit to the atmosphere as the greenhouse gas carbon dioxide (CO_2). The reasons are that the potential emissions of CO_2 are huge and it has a long lifetime in the atmosphere; even after ~1000 years, at least ~15% of CO_2 emitted will remain in the atmosphere."

The report says that by the year 3000:[2]

- Temperatures could rise from 1.5°C if emissions are minimised to as much as 15°C if we continue burning fossil fuels, which is more than double what the IPCC predict on the centennial timescale.
- Only the minimum emissions scenario can prevent global temperatures from rising more than 2°C above pre-industrial levels. This is thought to be the maximum warming acceptable without the risk of long-term dangerous consequences (defined in the report as 'a global sea level rise of 2m, because it would flood many low lying cities and displace hundreds of millions of people').
- Sea levels will still be rising at the end of the millennium and could reach 11.4m above the pre-industrial level by 3000. Low lying areas of Guernsey and the UK, including London and many major cities, could be threatened by sea level rise.
- Ocean pH is predicted to fall dramatically (increasing acidity), posing a threat to marine organisms.
- Abrupt climate change events could occur (see Figures 29.2 and 29.3). Business-as-usual emissions could lead to "*a rapid climate change event in the 22nd century.*" One model predicts a southward shift in a diminished gulf-stream caused by the melting of the Greenland ice sheet, that might result in a reduction in the surface temperature of the Atlantic Ocean. Another prediction suggests that a rapid increase in global temperature could occur in the 2600s / 2800s. Arctic ice could disappear all year round with the "*thermo-haline circulation (the gulf stream) becoming very vigorous*" causing North Atlantic seas to heat by up to 8°C, accompanied by UK land temperature increases of up to 5°C. However, the Report notes that "*This should not be treated as a prediction but rather as an indication that continual increase in emissions could lead to an event of this type*".

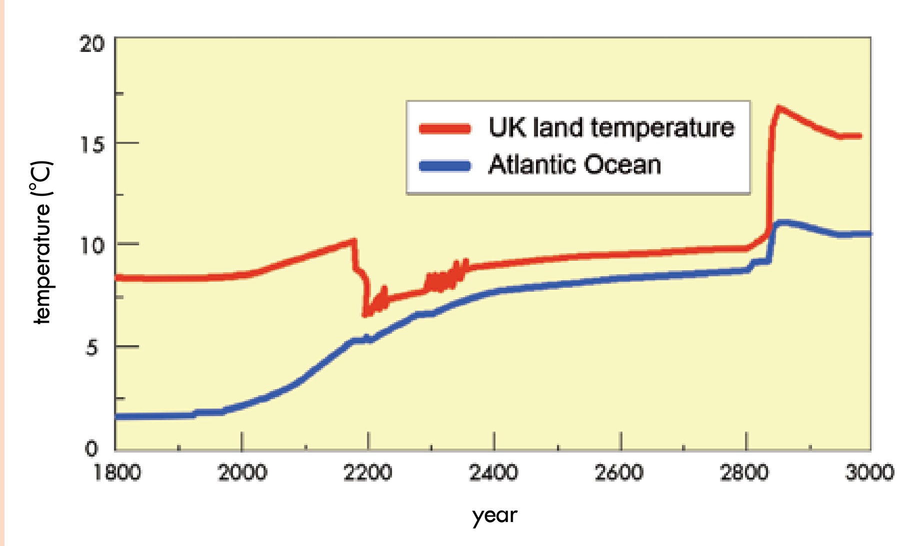


Figure 29.2 *Abrupt climate change events as seen in the North Atlantic region. Surface temperatures drop about 3°C at around 2200 as the Greenland ice sheet completely melts. At around 2800 Arctic ice disappears and the gulf stream becomes vigorous causing North Atlantic seas to heat by up to 8°C.*

('UK' refers to continent at UK latitude).

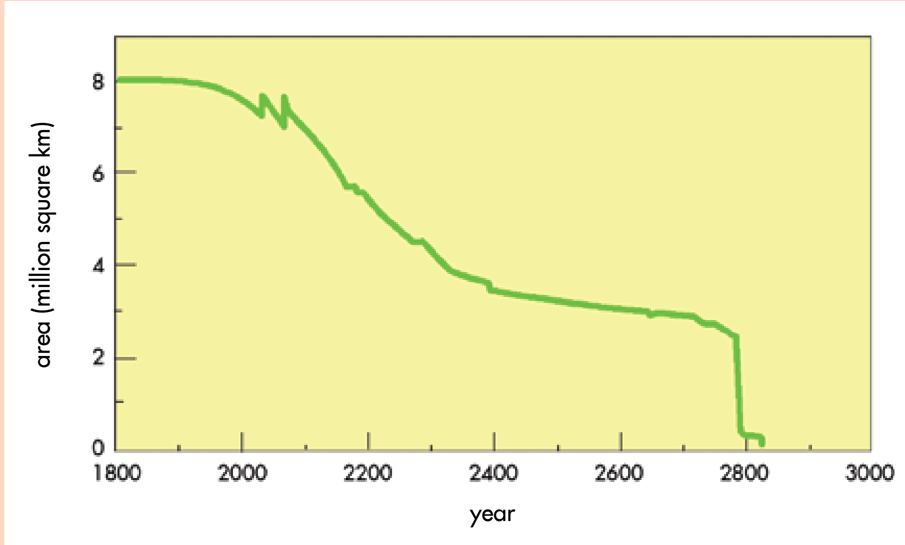


Figure 29.3 *Northern Hemisphere sea-ice area in million square km. Sea-ice rapidly retreats from the Arctic Ocean and at around 2800 it disappears completely. For recent reduction in the extent of sea ice in 2007 (see page 25).*

"Only by minimising emissions can dangerous climate change be avoided: in all except the most stringent emissions reduction scenario, Greenland ice sheet melt begins between the early 22nd and early 23rd century".

Conclusion

"We have presented a sobering picture of potential climate change on the millennial timescale. Whilst great uncertainties remain, our relatively conservative assumptions still produce the result that only by starting to reduce CO_2 emissions in the very near future, and continuing to reduce them so that they are zero by 2200, can we avoid dangerous climate change on the millennial timescale."

References

1. Climate Change on the Millennial Timescale (2006). Tyndall Centre for Climate Change Research, Norwich, UK. (www.tyndall.ac.uk).

2. Environment Agency: http://www.environment-agency.gov.uk/news/1299456.