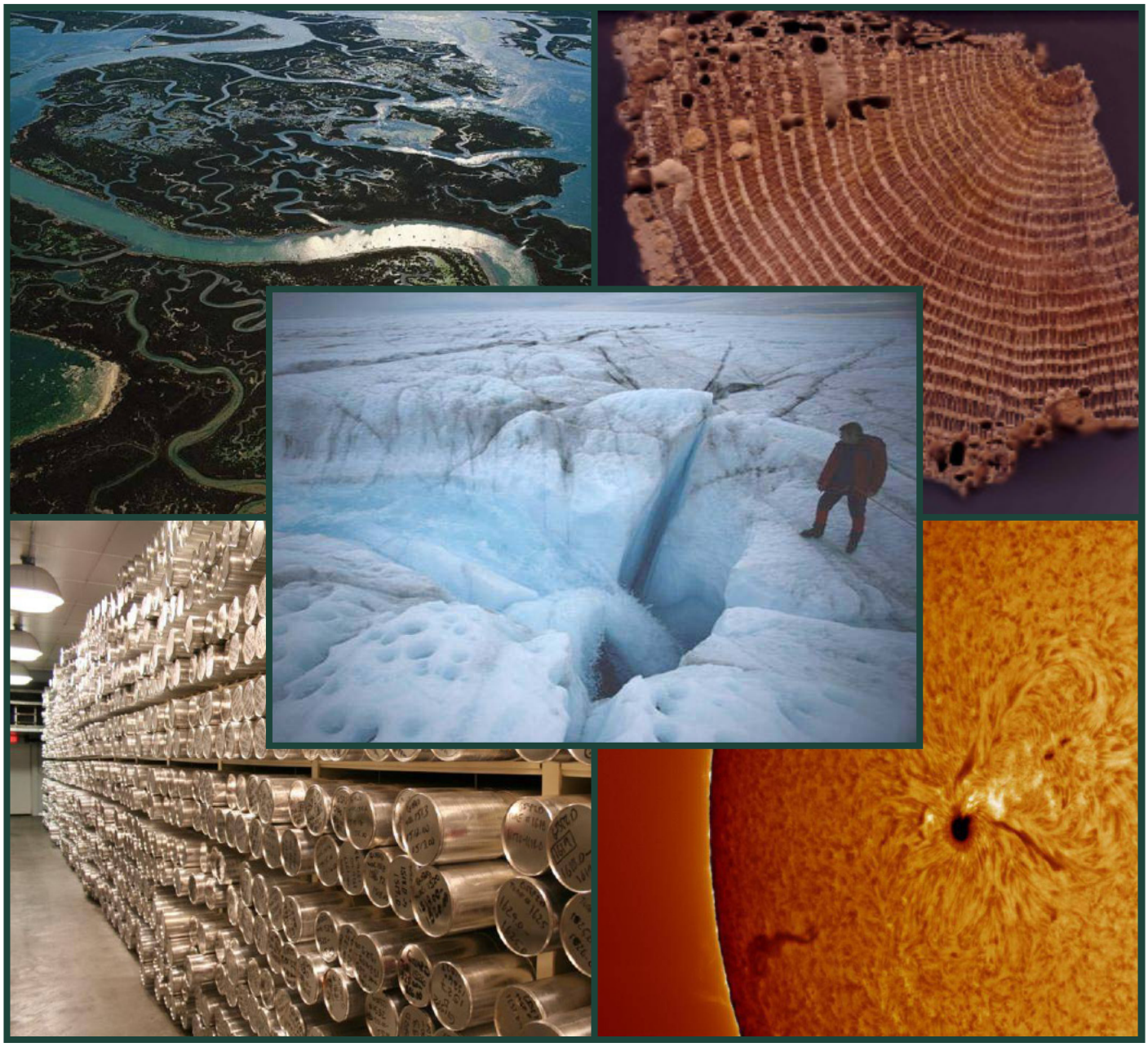
environment link Northern Ireland

RIA ROYAL IRISH ACADEMY

Conference Proceedings

April 2009

Climate Change: *Dealing with the Reality*



Foreword

Scientific and international political opinion agree that climate change is happening, that it is largely caused by human activities and that the implications are far ranging and very serious. Although there are uncertainties around the speed of change, the severity of that change and the nature and extent of its impacts, we cannot delay action to address the issues.

An internationally renowned group of scientists assembled in W5 (Odyssey Complex), Belfast for *Climate Change: Dealing with the Reality* on 20th January 2009 to discuss the issues; this document is a summary of their thoughts.

There are opportunities for Northern Ireland to be in the vanguard of both adaptation and mitigation technologies, bringing strong economic benefits to local companies. There are also opportunities to adopt policies and programmes that address the social and economic consequences of climate change while bringing benefits to Northern Ireland's citizens.

Grasping these opportunities requires strong and mature political leadership and offers Northern Ireland an opportunity to establish itself as a serious international leader. Climate change is just one of the many challenges facing Northern Ireland at this time and therefore cannot be dealt with in isolation. It provides a context within which specific issues — such as the increasing role of local authorities, tackling waste, changes in agriculture and the economic recession — can be better understood and more effectively addressed.

Acknowledgements

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We would like to thank all of the speakers at the conference both for the time and effort they put into producing their presentations and for writing their subsequent articles. We would also like to thank everyone who participated in the organisation and running of the event, the staff of Northern Ireland Environment Link, Royal Irish Academy and W5, and all conference delegates.

Northern Ireland Environment Link (NIEL), April 2009

Contents

1 KEY POINTS

2 ABSTRACTS

PUBLIC LECTURE

4 Earth: The Power of the Planet
Professor Iain Stewart, University of Plymouth

CONFERENCE PRESENTATIONS

5 Climate Change in Northern Ireland
Professor Sue Christie, NI Environment Link

Setting the Scene: Where We Are and How We Got Here

6 Climate Wars
Professor Iain Stewart, University of Plymouth

7 Ice, Mud and Blood: Lessons from Climates Past
Professor Chris Turney, University of Exeter

8 Events in Tree-rings Expose our Poor Understanding of Past Environmental Change
Professor Mike Baillie, Queen's University Belfast

Meeting the Challenges: Causes, Adaptation and Mitigation

9 Can we Predict the Impact of Climate Change to our Environment?
Professor Mike Ellis, British Geological Survey

10 Human-Induced Climate Change and Projections for the British Isles
Professor John Mitchell, Met Office

11 Could the Sun be Responsible for Climate Change?
Professor Joanna D. Haigh, Imperial College London

12 The Oceans – Recent Changes and Their Effect on Long-term Climate Forcing
Professor Ric Williams, Liverpool University

13 Sea Level and Climate Change: 21st Century (Un)Certainties for the Coast
Professor Julian Orford, Queen's University Belfast

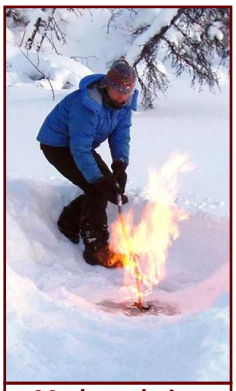
14 Carbon Capture and Storage in Ireland: Reasonable Reality?
Dr Garth Earls, NI Geological Survey

15 Good for the Climate, Good for Business
Mark Ennis, Airtricity

16 SPEAKER BIOGRAPHIES

Key Points from the Conference

Because you don't know something exactly doesn't mean you can't plan for it. **John Mitchell**



Methane being ignited on release from a Siberian lake.

- The overwhelming scientific consensus is that **climate change is happening and that human activity plays a major role**. Uncertainties exist in the timescale and magnitude of the impacts.
- **We must act now**, both to adapt to the unavoidable impacts and to mitigate against further increases in atmospheric greenhouse gases. In terms of the need to take action the finer details are irrelevant.
- Roughly two-thirds of carbon dioxide emissions result from the use of fossil fuels and one-third from land-use change and agriculture; both must be tackled as a matter of urgency. If we stopped emitting all carbon immediately, **the carbon already in the atmosphere commits us to 2–3.5°C warming by 2100**.
- Weather is short-term and highly variable whereas climate is long-term. Although we will still have colder years, the **general trend is one of warming**. Extreme weather events will not only occur more frequently, they will also often be more acute.
- Climate change cannot be dealt with just as a local issue. **A global perspective is required**. Social and economic impacts are hard to predict in detail, but will be hugely significant. The absolute rate of change is less important than society's ability to respond.
- To date, most carbon has been emitted by the developed world, but **developing countries are becoming increasingly significant contributors**. A concerted global effort with the developed world encouraging the developing world to do so in a sustainable manner is required.
- The **communication of science to both politicians and the public must be improved**. The differences between theory, fact and belief are not well understood by non-scientists.
- Past records show that the Earth's **climate can change rapidly over a small number of years** (not decades). There are a number of feedback systems and critical levels that can cause the climate to 'flip'. These are not considered within Northern Ireland's current policies and plans. As a society, Northern Ireland is not prepared for such changes.
- **Complex and interrelated factors and their impacts** are often poorly understood, but potentially highly significant on a local and global scale.
- There are **many interacting factors and potential 'tipping points'**. Understanding the complex results of such interactions requires a **multidisciplinary approach**. This is difficult to achieve but is vital to understanding the intricate relationships and improving the accuracy of climate models.
- The **oceans play a key and highly complex role in climate**. Our understanding of these impacts needs to be enhanced and communicated effectively.
- **Business is seeing the opportunities** presented by moving towards a low carbon economy and adapting to a changing climate, recognising the benefits of acting and the costs of not acting. This can only be good for society, especially in the current recession in Northern Ireland.
- **The cost of acting now will be much less than the cost of acting later**. We need to consider where we spend the money and how society will determine what actions are given priority.

Abstracts

Professor Iain Stewart – Earth: The Power of the Planet

Professor Stewart discussed Earth's processes relating to the carbon cycle and the impact of greenhouse gases on the atmosphere. He then examined events in the past where the climate 'flipped' over a short period of time, and how human activities have contributed to the current climate change.

"Society, rather than nature, decides who is more likely to be exposed to dangerous geophysical agents."

"If you were having brain surgery would you want a brain surgeon or a dentist?
The same applies to climate change science, would you believe a climate scientist or a philosopher?"

Professor Sue Christie – Climate Change in Northern Ireland

Professor Christie discussed why Northern Ireland should act on climate change and the business opportunities presented therein. She stressed the need for a concerted global effort and explained the role played by science in predicting future impacts.

"...if we do not address the issues, we risk being left behind as the rest of the world changes the way it works, acts and consumes"

"The Assembly can establish the framework and provide the equivalent leadership locally to ensure that Northern Ireland as a whole and each of us as individuals play our part."

Professor Iain Stewart – Climate Wars

Professor Stewart summarised the data demonstrating climate change; rising temperatures, loss of sea ice, sea level rise and increasing atmospheric CO_2. He also addressed the IPCC vs Non-governmental International Panel on Climate Change debate and examined the 'science communication stream.' He summarised the current problems, and ways of addressing them.

"Few scientists are trained in communications…few communicators are trained in science"

"All scientific work is incomplete — whether it be observational or experimental. All scientific work is liable to be upset or modified by advancing knowledge. This does not confer upon us a freedom to ignore the knowledge we already have, or to postpone action that it appears to demand at a given time."

Professor Chris Turney – Ice, Mud and Blood: Lessons from Past Climates

Professor Turney explained that we are entering into unprecedented times and presented scientific evidence to support this. For example the Northwest Passage opened last year for the first time in almost 9,000 years!

"55 million years ago, huge amounts of greenhouse gases were dumped in the atmosphere. The world warmed up 5–9˚C, and it was tens of thousands of years before conditions returned to what was then 'normal'."

"By 2020, 75–220 million Africans will suffer from drought; there's no precedent for the scale of future migration."

Professor Mike Baillie – Events in Tree-Rings Expose our Poor Understanding of Past Environmental Change

Professor Baillie discussed his global tree-ring records and how dendrochronologies are constructed. He illustrated that the science is coherent in terms of trends, it is the finer details that are still being investigated.

"It is a very bad idea indeed to tinker with the system. It might just 'flip.'"

Professor Mike Ellis – Can we Predict the Impact of Climate Change on our Environment?

Professor Ellis explained the uncertainties in global climate models, such as feedbacks, impacts and thresholds. He stressed the need for improved understanding of global processes and local variability caused by internal forcing, and varying levels of sensitivity of different landscapes.

"The absolute rate of change is missing the point. More critical is the rate of change to which societies can respond."

Professor John Mitchell – Human Induced Climate Change and Projections for the British Isles

Professor Mitchell discussed the variation in global climate model projections and made it clear that even when the models are deliberately 'untuned' to show variability, they still show the same trend. On average, the UK is getting hotter and dryer with more frequent extremes. He also discussed the need for higher levels of model resolution.

"Current CO_2 concentrations exceed those of the past 400,000 years. This is not a natural cycle."

"Warming will not happen smoothly. Extreme warm events will become commonplace by the second half of the century."

Professor Joanna D. Haigh – Could the Sun be Responsible for Climate Change?

Professor Haigh examined theories that cite the Sun as the cause of climate change and finds that sunspots, changes in orbits or other proposed factors cannot explain the current period of global warming. The short-term sunspot cycles do not correlate, and the major cycles related to the Earth's orbit and axis tilt are on a much longer scale than recently observed climatic trends.

"Although of course the Sun has a major impact on the Earth's climate, there is no scientific evidence that the current trends relate to any of the solar cycles."

Professor Ric Williams – The Oceans: Recent Changes and their Effect on Long-term Climate Forcing

Professor Williams discussed the impacts of climate change on the oceans. As the ocean holds approximately 50 times as much carbon as the atmosphere, it is important that we understand the relationship between the two and what climate change will cause.

"Oceans have absorbed more than 80% of the heat added to the climate system."

"One-third of the recent industrial emissions of carbon has gone into the ocean…long-term uptake is inhibited by rising acidity."

Professor Julian Orford – Sea Level and Climate Change: 21st Century (Un)Certainties for the Coast

Professor Orford looked at sea level rise predictions and considered the impacts of a rising sea level for Northern Ireland, including for iconic areas such as the Giant's Causeway, Strangford Lough and Murlough Bay. He also discussed the necessary actions and potential costs to society.

"By 2050 current 1:100 year events could become 1:20 or even 1:5 year events. By 2100 they might even become annual events. Do we prop up the banks, or do we prop up the banks?"

Dr Garth Earls – Carbon Capture and Storage: Part of the Solution

Dr Earls explored the feasibility of using this innovative technique as a transition technology to see us through until renewable energy technology is at a suitable level to supersede. He explained how the technique works, the risks involved, current knowledge and potential sites in Ireland.

"The fraction retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 1,000 years."

Mark Ennis – Good for the Climate, Good for Business

Mark Ennis discussed the predicted consequences of climate change and the business opportunities presented; mainly in terms of energy procurement, energy efficiency and waste. He also suggested the need for business and university collaboration to ensure sufficient and appropriate knowledge, skills and expertise for a sustainable future.

"Under business as usual…Europe will be importing 94% oil, 84% gas and 59% coal."

"Changing behaviour = Business opportunity for NI...Embrace a sustainable future."

Points Raised During Discussion Session

1) Communication of risk is something that scientists do not do well. It is hard for people and politicians to understand.

2) People who fund science are usually politically driven. We need to find a way to show politicians that opportunities are there. There is a lot that can be done, but it requires political will: framework, funding and incentives.

3) The EU has said we could achieve targets for CO_2 emission reduction without carbon capture and storage. *Closing the Energy Gap* (WWF and Greenpeace, 2008) — UK could reduce CO_2 emissions by 36%. CCS is a bridging technology until renewable energy production is more efficient. The CO_2 could be used in biofuel production (for example, through producing algae).

4) The Northern Ireland energy grid is inefficient and wastes 80% of energy, therefore we need to improve the system dramatically. This will require more scientific research into the processes and the political framework to implement the changes. UCD are doing some work, pushing the boundaries and feeding into government policy.

5) Scientists have shown that climate change is happening and have a role in tackling it, but politicians must provide the framework. Science is 'the easy bit' compared to the social change that is now required. Northern Ireland has the opportunity to take a lead. One-third of needed carbon savings could come from changing people's 'norms'. This shift is starting, albeit slowly, but the trajectory is in the right direction.

6) Translink are going to take another look at their sea defence plans on the basis of the information shared at the conference.

7) It is difficult to get funding for the research that goes into improving and building on our existing knowledge. However, such funding is vital to ensure that the money and effort involved in adaptation is spent appropriately. Getting co-operative programs funded is very difficult, but essential. In particular we need to look at ecosystem impacts.

8) The level of public acceptance of human-induced climate change is high. A public survey in USA in 1990 found that 70% of people agreed, whereas a survey in Northern Ireland last year found that 92% of people agreed, with 25 out of 27 MLAs also agreeing.

EARTH: THE POWER OF THE PLANET

Professor Iain Stewart, University of Plymouth

When the 'hockey stick' first appeared, many people were sceptical and it proved to be very controversial. It encouraged a flurry of climate change research which, when amalgamated, led to very conclusive results; the 'hockey stick' became the 'hockey team' (Fig. 1). Regardless of the proxy used (ice cores, tree-rings, coral), the climate is, on average, warming and we are in unchartered territory from the past 700,000 years.

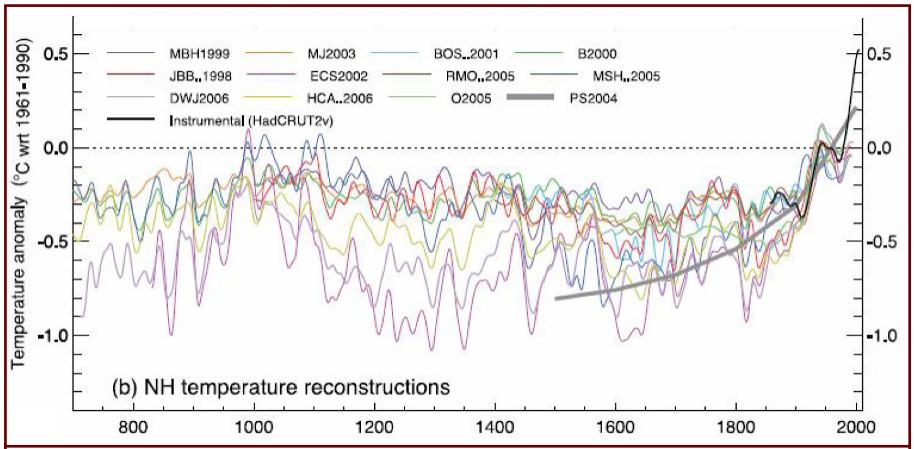


Fig 1: 'Hockey Team' showing changes in global temperatures over the past 1,300 years using a variety of proxys.

The Earth's climate appears to have a cyclic warming and cooling. However, the current rise in global average temperatures is out of sync with the norm and can only be explained by including the impacts of industry. One worrying aspect is that while some carbon is released directly into the atmosphere, there is also a huge amount that lags behind — it goes through a cycle before being released *en masse*. This means that it may already be too late to stop any major tipping points being reached as action taken now to combat climate change will "only start taking effect in about 30 years". What we must do, is assume that it is not too late and do everything within our capabilities to change behaviour and advance through sustainable development.

TIPPING POINTS

When a tipping point is reached it starts a chain of events that causes an unavoidable increase in atmospheric carbon by releasing stored carbon. The frozen lakes in Siberia contain a huge amount of methane. If the permafrost melts, it will release vast quantities of this highly potent greenhouse gas into the atmosphere, thus accelerating global warming.

The Earth's climate has 'flipped' before and over a very short period of time (Fig. 2). We do not have the infrastructure or knowledge to be able to cope with what the climate has the potential to throw at us. Take for example food production. The agricultural output of most countries would have to change markedly due to the growing requirements of different food crops. We don't have the expertise to address this potentially rapid transition.

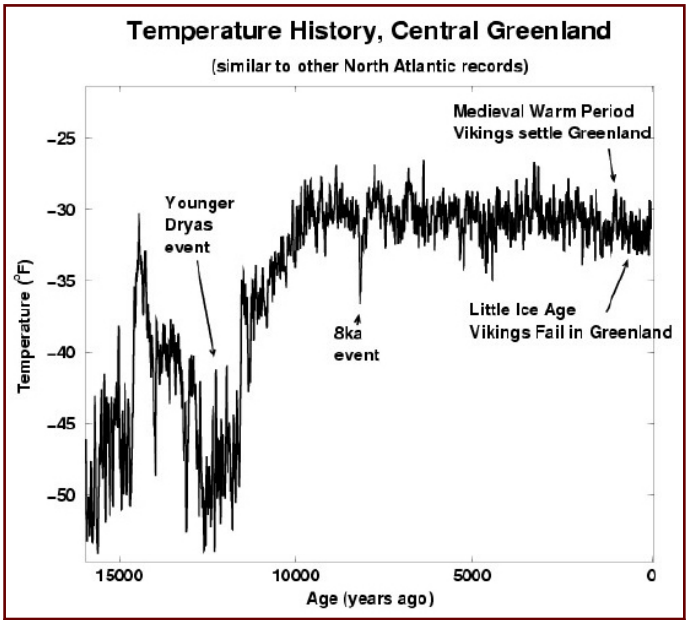


Fig 2: Graph showing the change in temperature over the past 15,000 years with extreme events clearly visible.

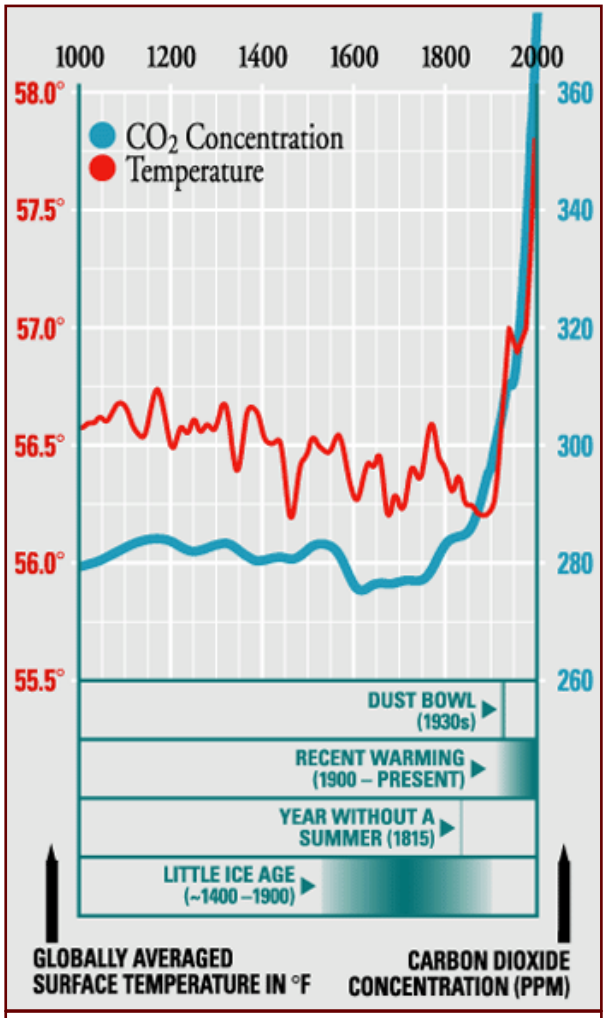
UNNATURAL DISASTERS

We are becoming more vulnerable to natural disasters because of the trends in our society, rather than those of nature. Although climate change is not predicted to increase the frequency of inclement weather, it will increase the ferocity of it. As a society we do not take natural disasters seriously enough. Hurricane Katrina wasn't the strongest of the three storms that reached Category 5 intensity during the 2005 Atlantic hurricane season, but its strength on landfall near New Orleans made it the most devastating disaster in US history. An area the size of the United Kingdom was impacted, displacing more than one million people, claiming over 1,000 lives, and exceeding $80 billion in costs. Yet not only was this event foreseen, but forecasts of the storm track were accurate and gave three days warning to authorities. By disregarding scientific knowledge we leave ourselves unnecessarily exposed. Instead we should take heed of scientific advice and warnings and take appropriate action.

Climate Change in Northern Ireland

Professor Sue Christie, Northern Ireland Environment Link

There are many factors that contribute to climate change, but there is only one that we can address: our own contribution. Science is not about personal belief or political opinion. It is based on knowledge and the testing of hypotheses by trained professionals. Science can provide us with informed calculations of what may happen under various circumstances, and develop a variety of scenarios of what will happen if we carry on as we have been, showing us the consequences of existing behaviour. But that does not mean these scenarios are inevitable. **Science can give us the information we need to take judicious and timely action, which can help us avoid the worst consequences**.



This graph is based on data from tree rings, coral and ice cores, and historical records. It represents only the Northern Hemisphere. Since the 1900s global average temperature and atmospheric CO_2 concentration have increased dramatically.

Only by understanding the problem can we identify the solution. The more we learn, the more it is obvious that we face a crisis. The destruction of tropical forests, land-use changes and agriculture account for over a third of greenhouse gas emissions. Therefore, addressing biodiversity aspects is key to addressing climate change. Waste is a massive problem in Northern Ireland, with huge adverse climatic impacts, so tackling this could contribute significantly to reducing our emissions. Peak oil, pollution, agriculture and land use, economic recession and fuel poverty are all linked with carbon emissions. Whatever you want to call it — low carbon economy, green collar economy, sustainable development — it is all about the same thing: **changing the way we live to use less of the Earth's resources and reduce the amount of greenhouse gases we produce**. And it is not an 'option'. If we do not do it voluntarily and gradually, more severe changes will be forced upon us. **We now have an addressable crisis: if we do not act very soon — in years, not centuries or decades — we will be facing a catastrophe**.

Addressing the diverse and multitudinous aspects of climate change will not be simple, but it is possible. The science, technology and research are available to tackle it. What is less clear is if there is the political commitment and public willingness to change our current unsustainable lifestyles. And these are crucial. **Science and technology can provide the tools to solve the problem, but they can not solve it by themselves**. It is a global problem requiring global solutions, and action by all of us.

Wishing something isn't happening won't stop it. Recognising it, seeing the threats and opportunities, and moving in the directions those solutions point to will address the issue. The UK has led the way with the Climate Bill, and it is now time for Northern Ireland to play its part. **The local politicians can establish the framework and provide the local leadership to ensure that Northern Ireland as a whole and each of us as individuals can take effective action**.

Climate Wars

Professor Iain Stewart, University of Plymouth

Evidence for Climate Change

Global temperature trends can be monitored using a variety of indicators, including actual temperature, tree-rings, ice cores (Fig. 1) and Arctic sea ice. No matter which method is used, they all show a similar trend; one of a warming climate that is unprecedented in over 700,000 years and that can only be explained by human activities.

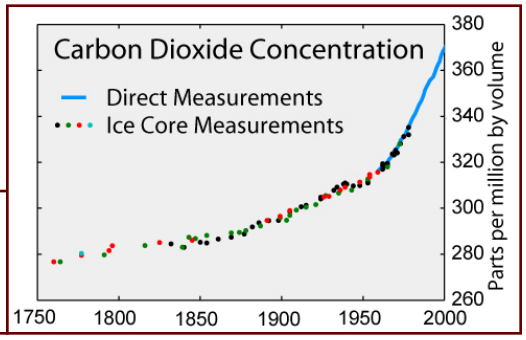


Fig 1: Graph showing CO_2 concentrations in the atmosphere since 1750, based on ice core and atmospheric measurements.

Evidence: Glaciers

Glaciers and ice caps reached their Holocene maximum extent in most mountain ranges throughout the world towards the end of the Little Ice Age, between the 17th and mid-19th century (Fig. 2). Over the past one hundred years a trend of dramatic shrinking is apparent over the entire globe, especially at lower elevations and latitudes. In this trend, strong glacier retreat is observed in the 1930s and 1940s, followed by static conditions around the 1970s and then increasing rates of glacier wasting after the mid-1980s. There are short-term regional deviations from this trend, and intermittent re-advances of glaciers in various mountain ranges occurred at different times. The trend of worldwide glacier shrinking since the end of the Little Ice Age is consistent with the increase in global mean air temperature. The decline in solar radiation at the Earth's surface in the second half of the 20th century and the transition from decreasing to increasing solar radiation in the late 1980s may be due to the industrial pollution of the atmosphere and the more effective clean-air regulations, together with the decline in the economy in Eastern European countries, respectively. This might explain some of the glacier mass gains around the 1970s and the subsequent strong mass losses.

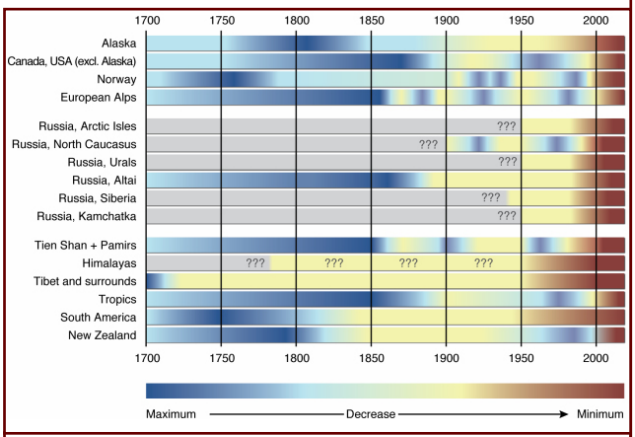


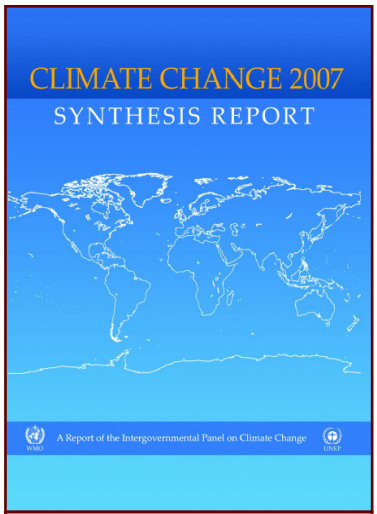
Fig 2: Glacier Loss Since 1700.

Uncertainty

Uncertainty plays a key role in science, as it drives debate. However, this has been misconstrued by the media and politicians and used as an excuse for inaction and to create doubt in the minds of the general public. We do not have time for inaction; we know that climate change is happening. What we are not 100% sure about is the scale of the impacts. To make a difference, we need to both adapt to the unavoidable change and mitigate against further change.

Communicating Science

With regards to the communication of science, we have two problems. Firstly, there is the problem of interdisciplinary communication within the scientific arena. We need to encourage networking, information sharing and multidisciplinary studies. Secondly, there is the problem of communicating science to the public. There is a clear division between where scientists publish their findings (journals, professional meetings and technical reports) and where the public obtain their information (media, public meetings and internet). There is also the problem that few scientists are trained in communication skills and few communicators are trained in science. One solution could be to ensure scientists obtain communication skills and make scientific findings available to the public in ways that will be easily understood.



The IPCC 4th Assessment Report (2007) is "the best piece of peer-reviewed science ever".

Conclusion

We need to address climate change now by ensuring that the public and key decision makers, both in policy and business, are well informed. Only by taking a global, coherent approach can we tackle this issue. The implementation of legislation and codes of practice are essential to encourage the behavioural changes that are necessary to make a difference.

Ice, Mud and Blood: Lessons from Climates Past

Professor Chris Turney, University of Exeter

In an uncertain world, the past gives us the opportunity to reflect and learn from what has gone before. It is pretty clear that we are on thin ice. The air we breathe contains a level of carbon dioxide not seen for at least 650,000 years, and may be unprecedented for as long as 3 million years. Our seemingly insatiable need to dump vast amounts of carbon dioxide and other greenhouse gases into the atmosphere is taking our planet out of its comfort zone. The past tells us of the risks we face. A little more greenhouse gas in the air does not cause just a little change in climate. Our planet has one set of feedbacks built on another. A 'bit' of warming can cause a cascade of unintended consequences. With an ever-warming planet, the Earth's ability to soak up greenhouse gases is already lessening, causing yet more warming. If there is one thing we can learn from the past, it is that the world can change at a moment's notice. When we will reach the tipping point is anyone's guess, but we must be getting close.

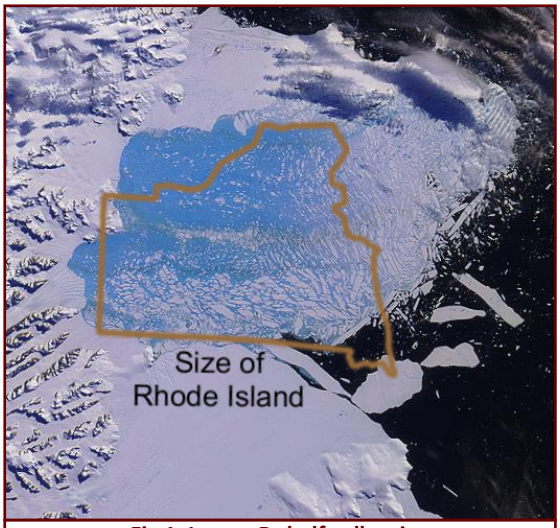


Fig 1: Larsen B shelf collapsing into the Weddell Sea.

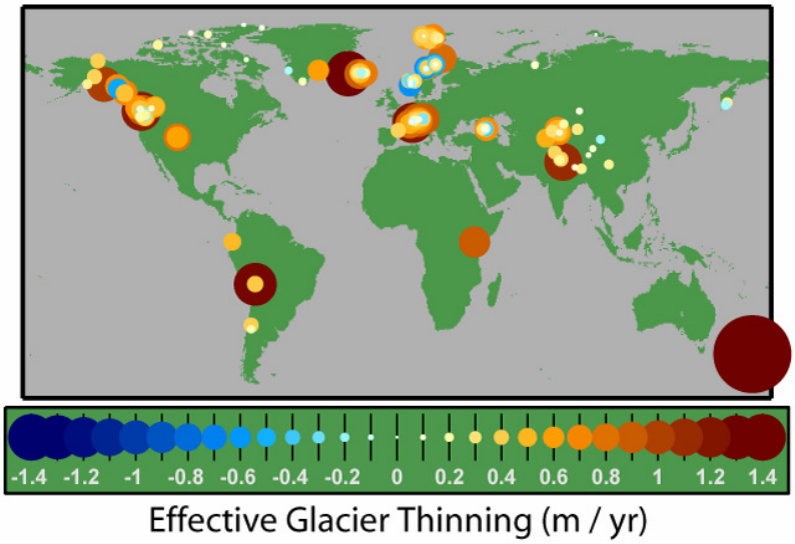


Fig 2: Mountain glacier changes since 1970.

We are now seeing changes that are without precedent for thousands of years. In 2002, a piece of Antarctic Peninsula ice, known as the Larsen B shelf, collapsed into the Weddell Sea (Fig. 1). It might not sound that exciting, but this piece was 3,200 square kilometres — a chunk equivalent to the size of Rhode Island. This is not something that happens periodically — the researchers who went into the area afterwards were able to show that this was a one in 12,000-year event.

This was just an opening shot. Other dramatic changes are taking place: glaciers in the Andes and Europe are falling back to a size not seen for 5,000 years (Fig. 2); the Northwest Passage opened up in 2007 for the first time in what looks like 9,000 years (Fig. 3). Meanwhile, temperatures across the northern hemisphere are the highest they've been for at least 1,000 years. We know from 55 million years ago that putting large quantities of greenhouse gases into the air can lead to catastrophic warming. As other parts of the world get warmer, we will start to see more of these events.

But there is one big difference from the past. Although many changes have happened in our planet's history, they had natural causes. We are now the cause. As such, we have a choice: we can change the future. We do not have to go down the ill-fated road before us. We can still turn back. The longer we leave cutting emissions, the worse the problem will become. We need to start thinking the unthinkable and change our ways.

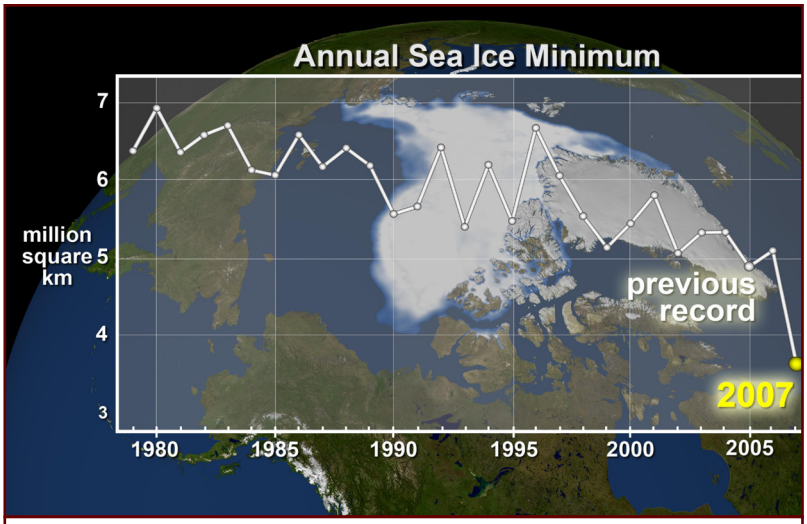
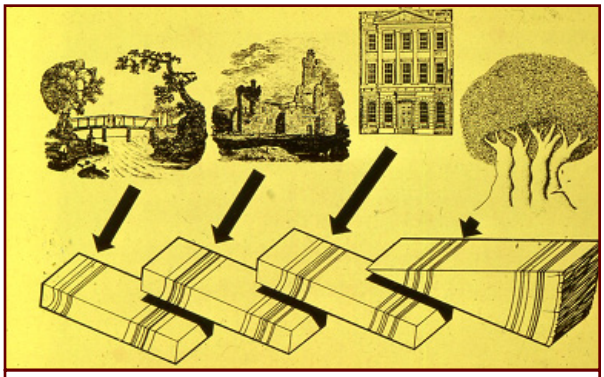


Fig 3: Graph showing annual sea ice minimums since 1980.

Events in Tree-rings Expose our Poor Understanding of Past Environmental Change

Professor Mike Baillie, Queen's University Belfast

Since the 1970s tree-ring chronologies have been constructed in many areas of the world. For example, in Ireland an oak chronology exists back to 5,400 BC. If we look at a number of independent oak chronologies across Europe from Ireland to Poland we can trace what European oaks 'thought' of their growth conditions each year. From the perspective of the trees, wide growth-rings are 'good' and narrow are 'bad'. As we look back from the present there are some surprises. Between 1816 and 1834, average ring width across Europe increases by around 50%. This implies that vast numbers of oaks were growing well, presumably stimulated by a change in climate. Further back, across the years 1740–1742, there is a dramatic reduction in oak growth across Europe. This coincides with the coldest year in Manley's Central England temperature record — the coldest year from AD 1659 to the present. In Ireland, some estimates put the death toll from famine for those years at around 300,000.



Tree-ring chronologies are constructed by overlapping and matching samples of increasing age.

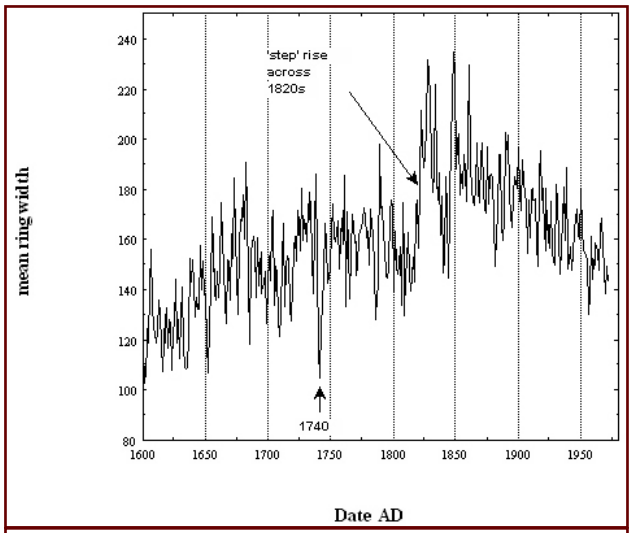


Fig 1: Graph showing the reduction in growth of European oaks (1740) and the increase in growth (1820s).

Whether it is the general growth enhancement across the 1820s, or the dramatic cold event in the 1740s, the actual physical causes are not known. Separating out the effects of the sun, volcanoes, earthquakes, ocean circulation and cosmic impacts — even in recent centuries — is fraught with difficulty. But some occurences are more straightforward; human records of a dust veil that dimmed the sun in 1601 coincide exactly with effects in trees from Eurasia to America and with volcanic acid in Greenland ice records.

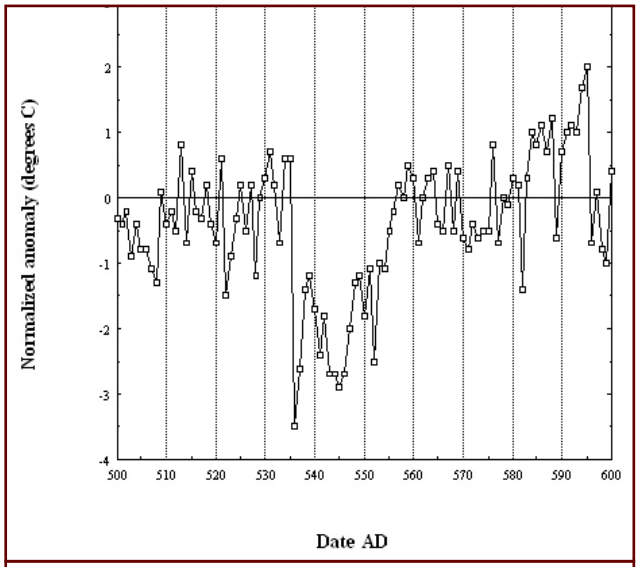


Fig 2: Graph showing the 'two stage' event that occurred between 535AD and 545AD.

However, once we move back beyond 1600, most ancient environmental events — some of them very severe, global, and involving famine and plague (such as the extreme episode between AD 536 and 550) — are not well understood. As a result, we live in a world where we do not fully understand what nature can do. Tinkering with a planetary system that you do not understand — as humans are now doing with gases in the atmosphere and pollution everywhere — is an activity that carries with it a level of risk that may be ill advised. The reason why none of this was a problem in the past is that never before has the Earth so dramatically exceeded its carrying capacity. If the 540 event (which we are only now beginning to understand may have been due to more than one large volcanic eruption in a short period of years) were to be repeated today, it is likely that it would result in the deaths of at least two billion people.

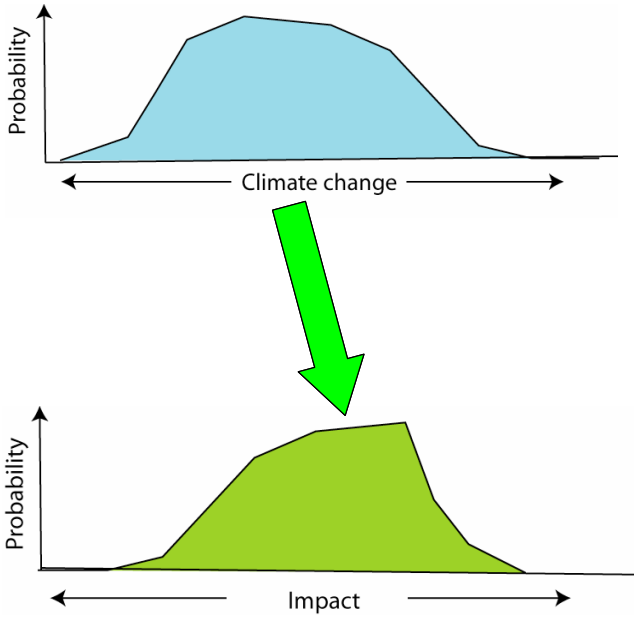
Given our poor understanding of cause and effect in environmental changes in the past, and given how hard it is to monitor the Earth system at present, there is a real need to avoid tipping the system into a new state. Given this poor understanding, if anyone tells me that they "Do not think humans are affecting the climate", my reply has to be "How can you possibly know?"

Can we Predict the Impact of Climate Change to our Environment?

Professor Mike Ellis, British Geological Survey

Climate change science is composed of a number of components: carbon emissions, impacts, adaptation to changes and mitigation against future change. Global climate models (GCMs) are used to predict the potential impacts of climate change, giving us a better understanding of the process. Uncertainties in the models arise from poorly understood sources and sinks of carbon, as well as feedbacks into the system and tipping points. Uncertainties early in the chain of events propagate to increasingly greater uncertainties further down the chain.

We already know some of the impacts of climate change including landslides, floods, debris flows and coastal erosion, but what we really need to know are the probabilities of these impacts. This requires an intricate knowledge of the climate change scenario probabilities and an area's sensitivity to the impact. It also requires an understanding of the impact of cumulative change. For example, a river course that has been altered by a one in 10 year storm will likely respond very differently to a subsequent storm.



Fort Kent, Maine (2007) - The raging St.John River spilled its banks, flooding more than 100 homes as emergency management officials feared the region could face its worst flooding in modern history.

It is imperative that we improve our understanding of the Earth's climate to make us more prepared, both for adapting to the unavoidable rise in temperature over the coming years and to mitigate against further rises in atmospheric GHGs. Concentrating on the absolute rate of change is missing the point, more critical is the rate of change to which societies and nations can respond. We only have to look at the severe flooding in the UK in 2007 to illustrate the fact that we are not prepared for what nature has the potential to throw at us.

Human-Induced Climate Change and Projections for the British Isles

Professor John Mitchell, Met Office

Given the recent winter's snow in Northern Ireland, and more generally in the British Isles, people question whether or not climate change is really happening. However, we must clearly distinguish between 'climate' (long-term trends) and 'weather' (short-term variation). We must therefore trust the climate science as opposed to relying solely on what we can see outside.

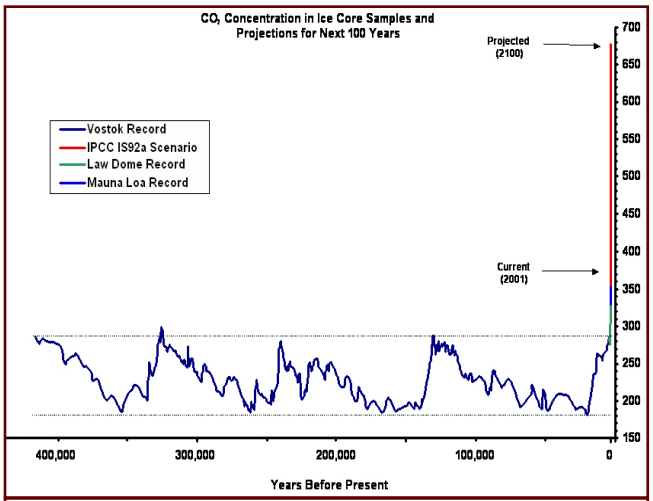


Fig 1: Graph showing the atmospheric CO_2 levels for the past 400,000 years.

The current and projected future CO_2 concentrations exceed those of the past 400,000 years (Fig. 1). Atmospheric CO_2, which remained below 300 ppmv for thousands of years, has now reached 380 ppmv (caused mainly by Western countries) and is projected to reach 500–900 ppmv by 2100 (due to the industrialisation China and India). This has been associated with a temperature rise of 0.8°C over the past 50 years. Regardless of the action taken now to reduce GHG emissions, there is a 'lag' phase in the cycle and we face an unavoidable temperature rise of 2–3.5°C by 2100. This warming will not happen smoothly; extreme warm events will become commonplace by the second half of the century (Fig. 2).

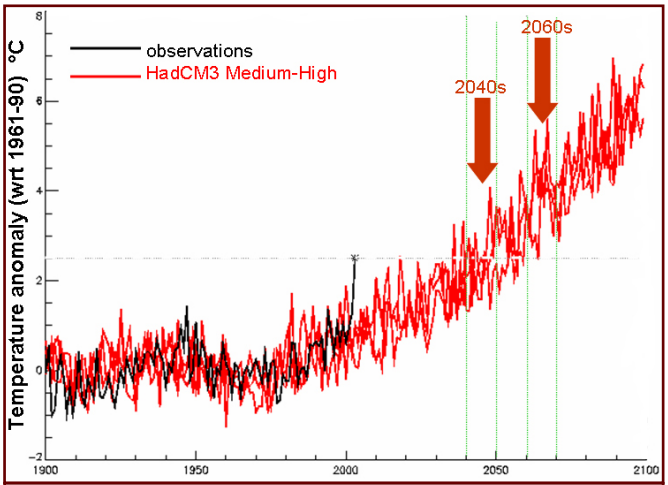
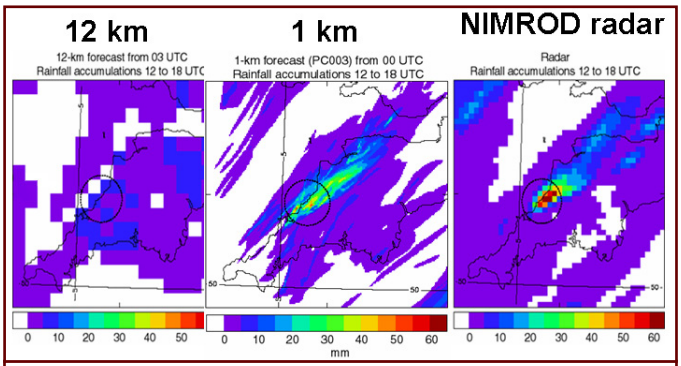


Fig 2: Graph showing the temperature change since 1900 and predicted future change with annual fluctuations.

Regional predictions of climate change, using models, contain a large degree of uncertainty. Emissions scenarios and natural (sometimes chaotic) variations in weather can lead to inaccuracies. Wind direction and cloud profile play an important role in determining temperature and must be factored into the models. The models are very accurate at predicting winter temperatures, but aren't as accurate for summer predictions due to the influence of wet surfaces, clouds, etc. Projected patterns of precipitation change are more difficult to predict. The models show the UK getting drier on average, but with annual fluctuations. There will also be a decrease in the number of rainy days, but an increase in their intensity.

To deal with the uncertainties, we need to look at a series of models, both global and regional, and decide on critical parameters. We also need to examine feedbacks into the climate to allow any new models to accurately take these into account. It is worth noting that current models have also been deliberately 'untuned' to show variability, yet they still show the same trends.



Model resolution is vital for making regional predictions, as illustrated by the Boscastle 'flood' predictions, 1994. The black circles represent a 20km radius around Boscastle. As you can see, the forecast using 12km² resolution missed the event, whereas that which used the 1km² resolution successfully predicted the event, which was captured using the NIMROD radar. To put this into perspective, doubling the resolution of a climate model requires an eight-fold increase in computer power.

To conclude, we must keep in mind that there is a contribution from a number of global variables, with temperature being important regionally. Uncertainties are larger at a regional scale due to the role played by mountains, oceans, etc. Major efforts are being made to quantify and reduce uncertainty in model predictions by increasing resolution and improving our understanding of climate processes.

Could the Sun be Responsible for Climate Change?

Professor Joanna D. Haigh, Imperial College London

Do changes in the Sun affect the Earth's climate? Variations in Sun–Earth geometry clearly have a major effect, controlling diurnal and seasonal cycles, as well as the onset of ice ages, but what about the impact on climate of intrinsic variability within the Sun? Observations of sunspots date back to at least the 2nd century BC, and so have speculations that sunspot numbers are related to weather. In 1801, for example, William Hershel claimed to have found a relationship between solar activity and wheat prices on the London Stock Exchange. During the 19th century, many other serious scientific attempts were made to establish such a link, but when 'sunspottery' became popular and was adopted by various astro-meteorologists (who predicted the weather based on the Sun and the planets), the embryonic UK Met Office established a distance between itself and such supposed quackery. Unfortunately, a lot of pseudo-science remains in this area. One example was shown during a TV broadcast in March 2008 (Channel 4's *The Great Global Warming Swindle*), whose description of the processes of cloud formation (as the action of solar-modulated cosmic rays on water vapour in the atmosphere) would have been laughable had it not been such an unashamed attempt to manipulate the audience.

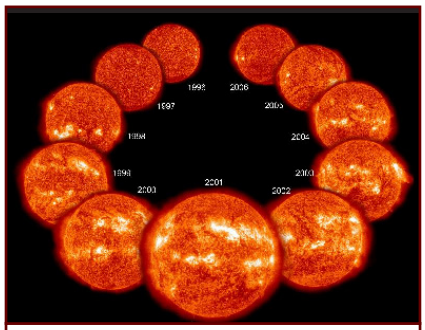


Fig 1: 11-year sun spot cycle.

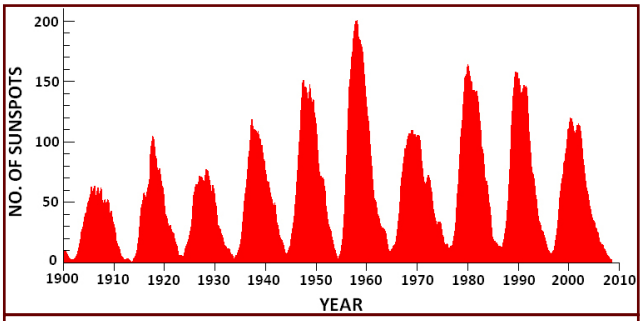


Fig 2: Graph Showing Annual Sun Spots Since 1900.

Undeterred, we in the Imperial Physics Department have been studying the effects of variations in solar irradiance on the atmosphere. We have found, from meteorological records, that mid-latitude storm tracks are positioned slightly further towards the poles when the Sun is more active, and that the response in temperature is not the warming concentrated in the tropics that might be anticipated as a response to a higher input of solar energy, but is concentrated in mid-latitudes. Thus solar activity plays a more significant role in climate in some geographical regions than in others. We have used computer models to investigate how these responses arise and found that the absorption of solar UV radiation in the stratosphere is an important factor. Our current research is concerned with the mechanisms whereby these effects take place and our studies are leading to a new understanding of climate variability in general.

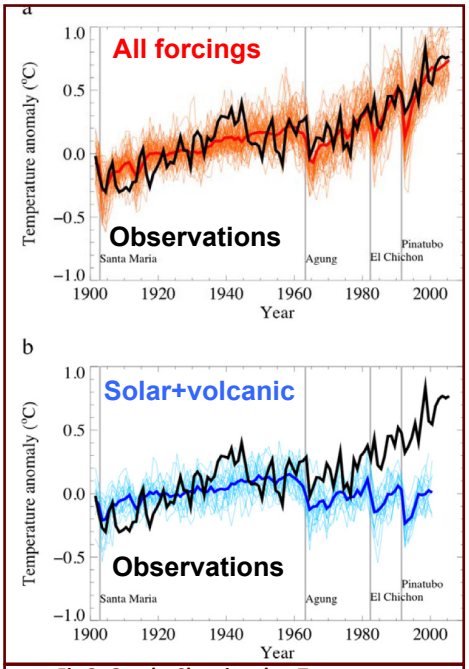


Fig 3: Graphs Showing that Temperature Predictions from Global Climate Models Only Hold True When Industrial Output is Included.

However, in terms of the global surface temperature record, none of our work suggests that solar variability could have been responsible for all the warming seen over the past century. We do not have measures of the Sun's historical energetic output, but we do have indicators of solar activity in isotope records (for example, in ice cores, tree rings and ocean sediments) and we can calibrate these 'proxy' measures to derive a solar radiation dataset dating back hundreds of years. Using this, together with information on volcanic activity, our computer models are successful in reproducing the gross variations in global mean temperature over the thousand years before the industrial era. However, we are not able to simulate recent global warming without including the effects of the greenhouse gases introduced by human activities. It might reasonably be argued that we have missed some (as of yet unidentified) process and thus underestimated the effect of the Sun on the climate over the past 50 years or so, but if this were the case it would then be necessary to explain why it did not have a much larger impact in the past.

Increasing solar activity over the first half of the 20th century might have contributed up to 25% of the observed rise in global temperatures, but the evidence for human-induced warming over the past 50 years is now incontrovertible.

The Oceans: Recent Changes and Their Effects on Long-term Climate Forcing

Professor Ric Williams, Liverpool University

The ocean plays a central role in the climate system, holding roughly 50–60 times as much carbon as the atmosphere. In addition, the upper 2.5m of water typically holds as much heat as the whole of the atmosphere. How is the forcing of the climate system changing over our lifetime and what is the response of the ocean? Atmospheric records of carbon dioxide reveal rising concentrations, which imply a radiative heating of typically 1 W/m^2 over the past 50 years from the extra absorption and emission of long wave radiation in the atmosphere. How significant is this extra heating? Over an individual year, this extra heating is a minor term compared with the amount of heating received from the Sun. However, over several decades this extra heating can accumulate and warm the climate system. For example, if this extra heating is applied to the ocean over a depth scale of 1 km, then the upper ocean would warm by typically 0.4°C over 50 years. This warming signal is broadly comparable with the surface warming of 0.6 °C measured over the globe since the 1950s, as reported in the IPCC (2007) report.

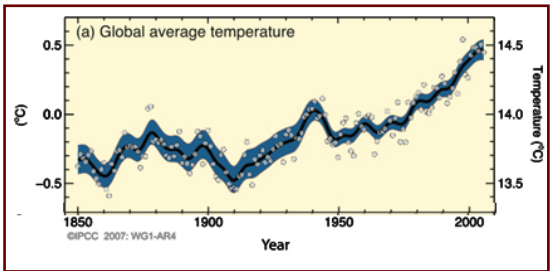


Fig. 1: Graph showing the increase in ocean temperatures.

Consider the case of the North Atlantic Ocean, rather than the response over the whole globe. Lozier et al. (2008) compared the heat stored in the North Atlantic Ocean over the whole water column between two periods 1980–2000 and 1950–1970. They found that there was an overall gain in heat content over the entire basin equivalent to a heating of 0.4 ± 0.05 W/m^2 over this time period. However, this overall gain in heat content is made up of a much larger warming in the tropics and mid-latitudes, and a reduction in heat content over the high latitudes. These regional changes in heat content are equivalent to a heating/cooling of ± 4 W/m^2. This ocean pattern of warming and cooling is probably due to changes in atmospheric winds and air–sea heat fluxes, associated with variations in the strength and path of the atmospheric Jet Stream (as measured by the North Atlantic Oscillation index). Hence, for the North Atlantic, the change in ocean heat content has a more complex pattern than a simple background warming and, at present, the pattern reflects the strong contribution of inter-annual or decadal variability.

The ocean is presently estimated to have taken up one-third of the anthropogenic carbon emitted to the atmosphere. The ocean has a huge store of carbon in the forms of aqueous carbon dioxide (1%), bicarbonate (90%) and carbonate ions (9%), collectively referred to as dissolved inorganic carbon. As carbon dioxide is added to sea water, there is an increase in acidity, which alters the partitioning of the dissolved inorganic carbon in sea water. With increasing acidity, more aqueous carbon dioxide is formed at the expense of the carbonate ions. This change in partitioning with increasing acidity acts to inhibit the further uptake of carbon dioxide from the atmosphere.

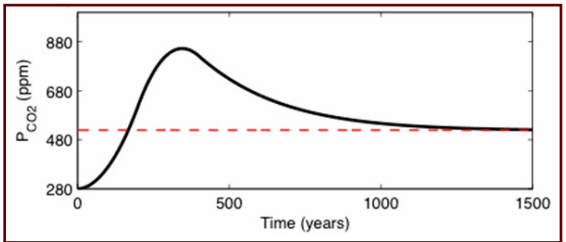


Fig. 2: Graph showing atmospheric CO_2 reaching equilibrium.

How about the distant future? As a pulse of carbon is emitted to the atmosphere, the atmospheric concentrations will initially rise and peak, but eventually should diminish from this peak as the ocean and terrestrial ecosystems take up some of this excess carbon (with the atmosphere having a higher final concentration than in the initial state). On a millennial timescale, the atmosphere, ocean and terrestrial ecosystem should move towards an equilibrium state over the globe. For this equilibrium state, the extra radiative heating from carbon dioxide is proportional to the size of the carbon emissions. If our conventional carbon reserves are consumed (estimated as 5,000 PgC) without any carbon capture, our simple model predicts an extra heating of 7.5 W/m^2, five times the size of the current anthropogenic heating. This estimate of extra heating is without taking into account any additional possible climate feedbacks, which could amplify the forcing. To understand the size of this effect, heating of 7.5 W/m^2 applied to a 20m x 30m lecture theatre is equivalent to 45 100W light bulbs being left continuously on and heating the room for millennia!

In summary, the increase in atmospheric carbon dioxide is providing an increase in radiative heating over the globe. This extra heating is expected to increase at least fivefold as conventional carbon reserves are consumed. In the present day, the global ocean does seem to be warming. Over regional scales, such as the North Atlantic Ocean, there is a complex pattern of warming and cooling over the past 50 years, reflecting the large inter-annual and decadal variability in the atmosphere and ocean.

Sea Level and Climate Change: 21st Century (Un)Certainties for the Coast

Professor Julian Orford, Queen's University Belfast

The global mean temperature is forecast to increase by 2–4°C over the next century. This is likely to lead to accelerating sea level rise (SLR), expanding sea volumes and melting of land-based glaciers. Coastal flooding will become more prevalent and will affect millions of people annually. The scientific analysis carries considerable uncertainty because of the range of models and conditions used. That stated, the consensus of scientific opinion identified by the latest IPCC report (2007) still holds that sea levels are likely to rise by 0.6m by the end of the 21st century. Figure 1 is an attempt to show what the future rates of SLR would be for Northern Ireland if the estimate is achieved. The uncertainty is not only about the emission scenario, but also because this IPCC model does not take into account the potential rapid melting of land-based ice, which could add several metres to the sea level sooner than expected — by the end of the 21st century, rather than the end of the 22nd century.

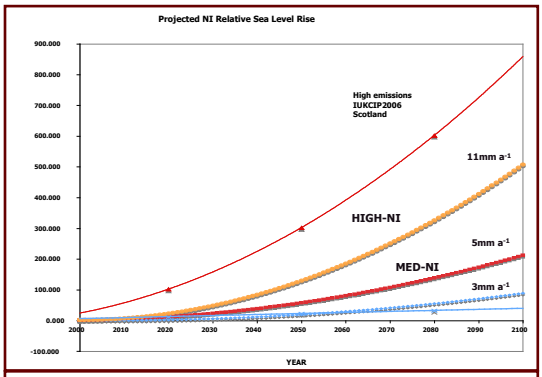


Fig 1: Estimates of future NI Sea Level Rise for varying emission scenarios. Rates of SLR are identified to show how rates must radically exceed contemporary rates to achieve end of century levels in SLR.

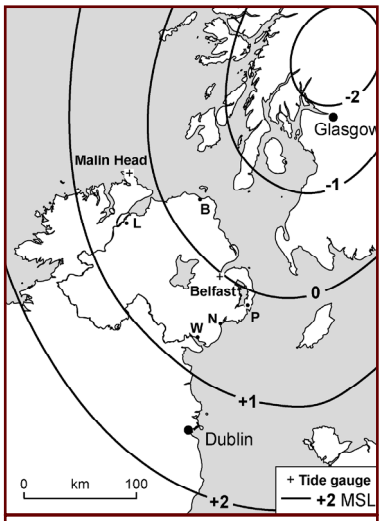


Fig 2: Modelled rates of contemporary relative SLR for Northern Ireland. Based on UK tidal variation during the 20th Century.

SLR has to be adjusted for the rate of crustal change, which in Northern Ireland could be between –1 and +1.5 mm/yr, to give the relative sea level change (RSLC). Figure 2, based on recent modelling of UK tide gauge variations, shows the most likely range of RSLC around the Northern Ireland coast at the moment. The north-east coast is still rising relative to sea level (RSLC is zero or negative), whereas the north-west and south-east coasts are still sinking (positive RSLC). If the future estimates of SL change are valid both Malin Head and Belfast Harbour are likely to be recording positive RSLC within a few years, and even the last bulwark of rising land (north-east Ulster) will be likely to be receiving rising RSL around its shoreline by 2020.

The second element of concern is the possibility that there will be more frequent and more intense coastal storms in the future. Severe coastal storms induce temporary (hours) rises in sea level, known as surges, which can result in flooding. Building coastal defences is a risk-based business — building defences is exponentially expensive and has to be balanced against the small probability of extreme storms reaching these higher levels. In the future, due to climate change around the Northern Ireland coast, such surges are thought to be increasing by about 40cm (for the north coast). Assuming the predictions of Northern Ireland sea level change indicated by DEFRA (Fig. 1), then the contemporary 1:100 year extreme sea-level during a storm surge could, by 2050, reoccur on a 1:5 year basis under a high emissions scenario, and a 1:20 year basis under the medium emissions scenario. By 2100, the contemporary 1:100 year extreme sea-level during a storm surge might occur on a yearly basis and could reach 0.2–0.7m (medium emissions scenario) or 0.7–1.1m (high emissions scenario) higher than that of previous surges.

During the 20th century the main human response to coastal erosion was to seek engineering protection in the form of sea walls. The cost of such ventures has proven to be exhaustive of available resources (Table 1). Judging by past experiences, it is expected that low quality agricultural land would not be defended, whereas valuable infrastructure (high density urban areas, ports and power stations) might well be defended. This is going to be the theme of many coastal problems in the future. Society has to identify cost for the individual, as opposed to the community, to bear. DEFRA (2001) has accentuated the likelihood that by the middle of the 21st century, holding-the-line will be acceptable only for high-value situations, with the general response being a strategic withdrawal from shorelines of vulnerability.

Table 1: Projected Costs of Maintaining Existing Coastal Defences Based on Devoy (1990) and Adjusted for Current Costs.

	Coast (km)	Defence (km)	Cost to Raise Defences to Meet 1m RSL Rise (£ million)				Total (£ million)
			Low Coast	Urban Coast	Harbour	Beach	
Britain	15000	5500	3900	5072	1248	2328	12548
Ireland	6500	200	124	672	80	0	876

Carbon Capture and Storage in Ireland: Reasonable Reality?

Dr Garth Earls, Northern Ireland Geological Survey

Northern Ireland has highly diverse geology, both onshore and offshore, which offers opportunities to make a significant contribution to mitigating and solving a range of 21st century issues. Carbon Capture and Storage (CCS) represents one of these.

CCS is a three-phase process (see diagram below). CO_2 is captured from a combustion source (such as power stations) and compressed to become a fluid. It is then transported, usually by pipeline, to a storage site and injected to rocks at depths of at least 750m.

The suggested locations for capturing CO_2 in Ireland are power stations in the Belfast, Shannon and Cork areas (see Fig. 1). Possible storage areas offshore include the Kinsale gas field off the south coast, the Clare Basin off the west coast and the Portpatrick Basin off the east coast. Considerable geological work remains to be completed to assess the suitability of these sites for CCS.

The geological conditions necessary to store carbon include exploited oil and gas fields and salt water aquifers. Oil and gas reservoirs are generally considered better options for CCS as there is a greater knowledge of their geological structure, as well as having engineering infrastructure in place.

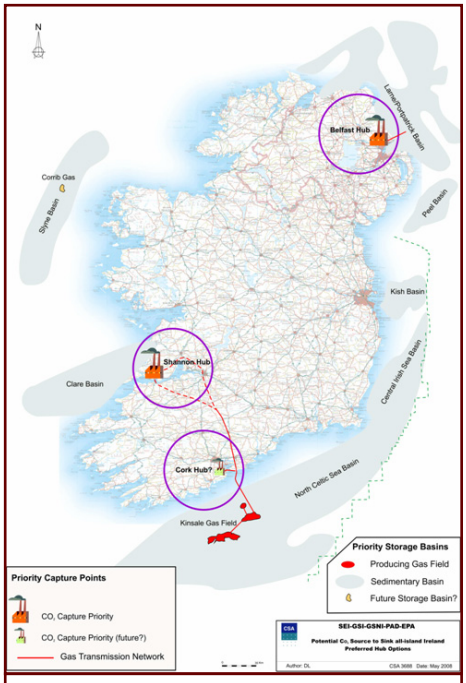
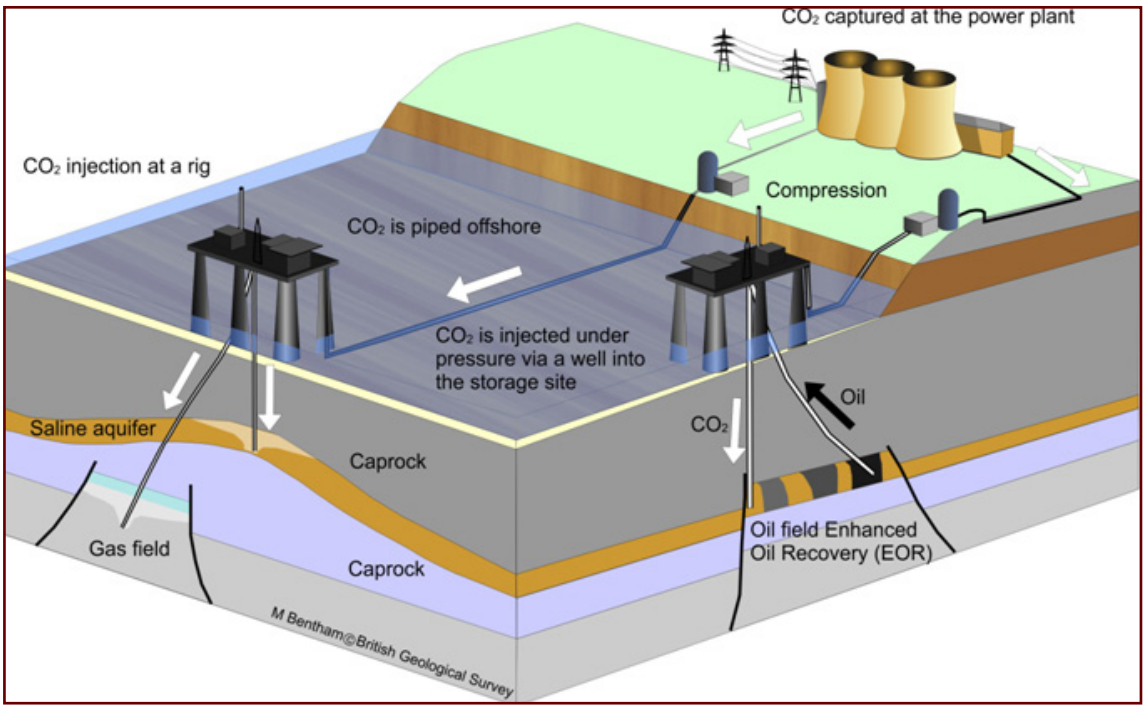


Fig 1: Preferred CCS Hubs in Ireland.

Carbon storage is the key phase of the process as leakage back into the atmosphere lowers the effectiveness of the technology and presents a number of risks. Consequently, for regulation, safety and public confidence the monitoring of CO_2 underground and the ability to detect potential leakages is important.

CCS is considered to have market potential in the UK and could play a key role in reducing global GHG emissions. European CO_2 reduction targets rely heavily on CCS and it has been suggested that the 2020 target cannot be met without CCS technology. It is now moving up the political agenda in many countries with Norway, UK, Germany, Australia and North America leading the way. Moreover, the UN, IEA, and EU are actively researching CCS as an option to significantly reduce carbon emissions.



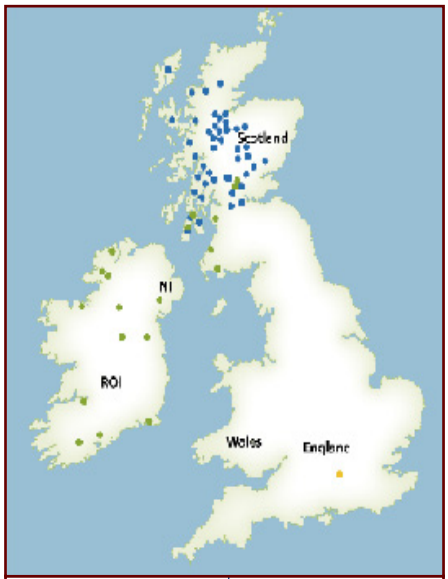
Good for Climate, Good for Business

Mark Ennis, Airtricity

Airtricity is the renewable energy development division of Scottish and Southern Energy (SSE). We are the UK and Ireland's second largest utility with over 10,000 MWs of generation capacity and the leading renewable generator with over 2,300 MWs of renewable generation (both wind and hydro) in operation and 1,500 MWs under development. We take climate change and the need to develop a sustainable future seriously — we have made a public commitment to reduce the carbon emissions from our electricity generation fleet by 50% by 2020.

Addressing climate change at the same time as securing energy supplies represents a huge challenge, but also a huge opportunity for businesses and countries that recognise the issue and are prepared to be part of the solution. Even allowing for the current recession, the world energy needs will increase by 45% by 2030 (International Energy Agency, IEA). While world demand grows Europe's exposure will increase; within 20 years Europe will be importing 94% of its oil, 84% of its gas and 59% of its coal. The IEA has just carried out a comprehensive study of the world's oil fields and found that they are depleting at an average rate of 8% per annum. This means we will have to find the equivalent of four Saudi Arabias if we are to meet world demand by the middle of the century. The increasing exposure to diminishing fossil fuel supplies will lead to increasingly volatile global prices. Northern Ireland, with no natural fossil fuels and situated at the end of a 4,000 mile pipeline from Russia, the nearest source of gas or oil, is particularly exposed. We have only to witness the recent events between Russia and the Ukraine to understand how important that exposure is. If Russia turned the gas tap off completely, it is likely that Northern Ireland would suffer rolling blackouts within 72 hours. No politicians should allow their country to be that vulnerable.

Climate change represents the biggest threat to humanity today. If the world carries on with 'business as usual', with energy demand fed by fossil fuels, it will result in atmospheric CO_2 of 1,000 ppm, which will lead to a 6°C temperature increase by the end of the century. This will have catastrophic implications for our grandchildren as they will be confronted with a world in which there is upheaval and anarchy, as those faced with starvation, drought and disease fight with those who still have resources. This is not Africa we are talking about. This will be the Western world, particularly central USA and the Mediterranean regions.



Wind	653MW
Hydro	1,356MW
Biomass	80MW
Total	2,089MW

Airtricity's Current UK Renewable Portfolio.

The UN's Intergovernmental Panel on Climate Change (IPCC) suggest that a 450 ppm CO_2 maximum is necessary to prevent any major tipping points being reached. This would have a corresponding 2°C temperature increase, but to achieve this requires political leadership, a global approach and rapid deployment of low-carbon technologies. We are not responding quickly enough to meet this, and the most likely scenario is that we will reach CO_2 levels of 550 ppm. This will result in a 3°C temperature increase, leading to four billion people suffering water shortages, 500 million going hungry and 170 million being affected by coastal flooding, including many in Belfast and Dublin. All leaders across the globe — in business, politics and science — must unite to stop this.

At Airtricity, we see climate change as a business opportunity, not a business hindrance. Opportunities will be created in many sectors, including energy procurement, efficient building and insulation technologies, and innovations in transport and engine efficiencies. Northern Ireland needs to embrace a sustainable future by utilising the skill sets of our young people, having industry-led research in our universities and exploiting our natural resources for a competitive advantage, wind and tidal power. By taking a leadership role we can also benefit from the financial support available from Europe for such activities.

Speaker Biographies

Iain Stewart is a Senior Lecturer in the Dept. of Geology at the University of Plymouth. He graduated with a degree in Geology & Geography from Strathclyde University and moved to the University of Bristol to carry out doctoral research on the geology of earthquakes in Greece and Turkey. After finishing his PhD, Iain lectured at Brunel University, then left to take up an Honorary Research Fellow post at Glasgow University while getting the *Journeys...* series off the ground. His main research interests are in the broad area of Earth hazards and natural disasters, particularly in terms of identifying past major earthquakes, tsunamis and volcanic eruptions in the Mediterranean region. Iain's geological research has featured in two BBC Horizon specials — *The Search of Ancient Helike* and *Earthquake Storms* — and he was the geology member of the science team in the BBC Two series *Rough Science*. His most recent TV series have been the highly acclaimed *Earth: The Power of the Planet* and *Climate Wars*.

Sue Christie has been the Director of NIEL, the networking and forum body for voluntary environmental organisations in Northern Ireland, since 1993. She is an ecologist, originally from the USA, with an MSc and PhD in Ecology and Behavioural Biology. She has been involved in a number of voluntary organisations, government committees and working groups on a variety of environmental matters. She is currently an independent member of the Strategic Waste Board, on the NI Climate Change Impacts Partnership and the Boards of Action Renewables, Sustainable NI and Tidy NI. She is Visiting Professor at the Dept. of Environmental Sciences at the University of Ulster and a tutor in environmental planning at Queen's University Belfast. She is a Member of the Institute of Ecology and Environmental Management and a Chartered Environmentalist and was awarded an OBE in December 2008 for services to the environment.

Chris Turney is a British geologist and currently holds a Chair in Physical Geography at the University of Exeter, UK. He received a BSc (Hons) in Environmental Science from the University of East Anglia in 1994 and a PhD in past climate change from the University of London in 1998. He did the radiocarbon dating on the 'Hobbit' fossil of Flores, Indonesia that hit the headlines worldwide in 2004. In 2007 he was awarded the Sir Nicholas Shackleton Medal for outstanding young Quaternary scientist for his pioneering research into past climate change and dating the past. In 2008, he received a 2008 Philip Leverhulme Prize for contributions to understanding the evolution of the Earth's climate over the last 50,000 years. Chris is the author of *Bones, Rocks and Stars: The Science of When Things Happened*. His most recent popular science book *Ice, Mud and Blood: Lessons from Climates Past* looks at what the past can tell us of the future and the risks facing us as we continue to drive our planet to new extremes. Chris' popular science website is www.christurney.com.

Mike Baillie is Emeritus Professor of Palaeoecology at Queen's University Belfast. His original degree was in Physics, before moving to Palaeoecology where he was one of the team responsible for the construction of Ireland's long oak dendrochronology and the calibration of the radiocarbon timescale. His interest in high resolution chronology prompted an interest in catastrophic environmental events, and he has spent many years attempting to reconstruct the effects of volcanic eruptions and extraterrestrial impacts. He is internationally recognised as an expert in tree-ring studies and chronology, and was elected to the Royal Irish Academy in 1990 and the Society of Antiquaries of London in 2006.

Mike Ellis joined the British Geological Survey as Head of Climate Change Science in May 2008, after three years as the founding Program Director of Geomorphology and Land-use Dynamics at the National Science Foundation in the USA. Dr Ellis was also the principal Program Director for the Community Surface Dynamics Modelling System and for the Critical Zone Observatory at Boulder Creek, Colorado. He serves on the Executive Advisory Board for the National Center for Earth-surface Dynamics, University of Minnesota. He has served on the National Oceanographic Partnership Program panel for Arctic coastal research and on the European Science Foundation TopoEurope panel. In 2007, he initiated a National Research Council study and a series of parallel workshops in Earth surface processes (particularly in connection with climate processes), and is the founding Chair of the American Geophysical Union's new Focus Group in Earth and Planetary Surface Processes. Dr. Ellis was a Professor of Geology at the University of Memphis from 1990 to 2005. He received a BSc in Geology from the University College of Wales and a PhD in Geology from Washington State University. He is a Fellow of the Geological Society of London, a Member of the American Geophysical Union and the Geological Society of America.

John Mitchell gained a BSc (Hons) in Applied Mathematics and a PhD in Theoretical Physics from Queen's University Belfast. He joined the Meteorological Office in 1973, and in 1978, took charge of the Climate Change group in what is now the Met Office's Hadley Centre for Climate Prediction and Research. His main speciality is the study of the climatic effects of increases in greenhouse gases and related pollutants. John has been a lead author in the last three IPCC Working Group I reports. He is currently chairman of the WMO JSC/CLIVAR Working Group on Climate Modelling. In 1997 and 1998 he shared the Norbert Gerbier–Mumm Prize with other colleagues, and in 2004 received the Hans Oeschger medal from the European Geophysical Union. He was made a member of the Academia Europaea in 1998, and a Fellow of the Royal Society in 2004. He is currently Director of Climate Science at the MetOffice and a member of NERC Council.

Joanna Haigh has published widely in the area of radiative transfer in the atmosphere, climate modelling and radiative forcing of climate change. She has been Vice-President of the Royal Meteorological Society, Editor of Quarterly Journal of the Royal Meteorological Society, a Lead Author of the Intergovernmental Panel on Climate Change Third Assessment and acted on many UK and international scientific panels. She is currently the UK representative to the International Association of Meteorology and Atmospheric Sciences, Editor of the American Meteorological Society's Journal of the Atmospheric Sciences and a Member of the Royal Society's Climate Change Advisory Group and Geoengineering Working Group. In 2004 she received the Institute of Physics Charles Chree Medal and Prize for her work on the influence of solar irradiance variability on climate.

Ric Williams obtained a BSc in Physics from Bristol, an MSc in Atmospheric Dynamics from Imperial College and a PhD in Physical Oceanography from University of East Anglia. He worked as a researcher at Imperial College and as a Research Fellow at MIT, USA before taking up a Lectureship at Liverpool University in 1993. In 2004, he was promoted to a Professor with a Chair in Ocean Dynamics and Biogeochemistry. At Liverpool, he is Director of a Research Centre in Marine Sciences and Climate Change. Recently, his work has addressed how changes in heat content in the North Atlantic Ocean vary with wind forcing, why phytoplankton growth is greater than expected in the North Atlantic and how radiative forcing from carbon dioxide is affected by ocean uptake of carbon.

Julian Orford is the Head of the School of Geography, Archaeology and Palaeoecology at QUB. He has undertaken research on the dynamics and development of gravel beaches and barriers around the North Atlantic, to ascertain how coasts 'behave' with respect to changing sea level, storms and sediment supply. This research has stimulated collaboration with NIEA, Environment Agency, DEFRA and Natural England over the organisation and evolution of the UK coastline. He was the only coastal geomorphologist on the expert panel by which FutureCoast (DEFRA 2001–2003) was established. His formulation of 'coastal behaviour' is now the core approach for Shoreline Management Planning, which forms the official governmental basis for coastal zone management in the UK. He has been a coastal consultant on the EUROSION programme that developed best practice towards the management of coastal erosion within the EU; a consultant to the central UK Foresight Flooding programme; and a member of the Governor of Louisiana's Working Party on the coastal science of the post-Katrina Mississippi Delta.

Garth Earls is a geology graduate of Queens University Belfast. He has been involved in natural resources exploration and development for 30 years, working internationally in industry, academia and government positions. Since becoming Director of the Geological Survey of Northern Ireland, Garth has become increasingly involved in geoscience communication and was part of the BBC NI Advisory Panel for the *Blueprint* series and also contributed to the 2008 series *Britain from Above*. Garth is the Chair of the Geosciences Committee of the Royal Irish Academy and a member of both the regional UK and Republic of Ireland Carbon Capture and Storage Working Groups.

Mark Ennis was appointed as main Board Director of Airtricity in 2003. He is currently Director of Communication & Strategy with responsibility for overseeing the development of Airtricity's strategy across all operational and geographical areas. His responsibilities also include Public & Regulatory Affairs and Public Relations. Mark has a particular interest in climate change and has addressed audiences as far afield as China, Abu Dhabi and Amsterdam. He has been an advisor to a number of businesses and has served as a Non-Executive Director on several boards. He is currently a Non-Executive Director of Invest Northern Ireland and a number of small start-up companies. In addition, Mark is a member and past Chairman of CBI Northern Ireland and is currently Chairman of the Management Leadership Network. He is also a member of the Chartered Institute of Management.

Climate Change:
Dealing with the Reality

Produced by

Northern Ireland Environment Link is the forum and networking body for organisations interested in the environment of Northern Ireland. It assists members to develop views on issues affecting the environment and to influence policy and practice impacting on the natural and built environment of Northern Ireland.

This report is a compilation of articles representing the views of the authors and the opinions expressed do not necessarily reflect the views of NIEL or any of its members organisations.

If you have any comments on this issue or would like to contribute to future issues, please contact us.

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