

# ***The Science of Global Warming***

Report of a seminar organised by the  
Royal Society of Chemistry

**19 October 2005**

# The Science of Global Warming

“Even if we ceased producing greenhouse gases today, the temperature in the UK will continue to rise for 100 years”

The warming of the Earth by human activity and its consequences are of intense concern to scientists, policy-makers and citizens. The amount of carbon dioxide in the atmosphere has soared by 34 percent since the Industrial Revolution due to our use of fossil fuels. Even if we ceased producing greenhouse gases today, the average temperature in the UK would continue to rise for 100 years. Although the majority of scientists agree that there is a link between fossil fuel use and climate change, a vocal minority continues to question both the evidence and predictive modelling of global warming.

In light of the highly charged political debate surrounding the issue, an understanding of the basic scientific principles is crucial. On 19 October 2005, the Royal Society of Chemistry held a seminar to discuss the evidence and modelling of climate change. The seminar was chaired by the writer and broadcaster **Vivienne Parry**.

**Professor Keith Briffa** of the Climate Research Unit, University of East Anglia gave an account of the evidence for global warming and the link to atmospheric carbon dioxide levels. **Professor John Mitchell**, Chief Scientist at the Met Office explained the methodology, results and reliability of climate modelling and **Professor Colin Prentice** of the University of Bristol covered what these predictions will mean for our planet. Finally **Andy Rowell**, writer and investigative journalist, shed light on the powerful lobbies who still deny that global warming is occurring.

has been instrumentally recorded since the 1850s but there is also high resolution ‘proxy’ evidence from studying tree rings, corals and ice-core compositions. These allow us to infer global temperature changes further back in time.

Tree ring studies are particularly important as they allow us to align temperature data with time. By combining information from many trees we are able to extend records back hundreds of years and produce a year-to-year chronology. For climate records, measurements are usually restricted to trees that grow mainly in the summer. Once calibrated from modern records, the size of each tree ring can be used to indicate annual temperatures. Over the last 10 years researchers have built up year to year temperature data in this way. This method has been particularly useful for Europe, where we now have the longest homogenised temperature records, going back to the sixteenth century.

“Our temperature proxy records do not as yet give a comprehensive view”

## Measuring temperature

Professor Keith Briffa explained that the evidence attributing recent global warming to increased greenhouse gas levels needs to be seen in the context of global temperature changes over the last two thousands years. Temperature data

## Proxy evidence

Climate scientists are also collecting proxy evidence from ice core samples, taken from deep inside glaciers. The composition of air bubbles trapped in the ice hundreds or even thousands of years ago gives an indication of the climate at the time the air

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was trapped. This can give data for the past 160,000 years, but will obviously only tell us about the climate in high latitude polar areas where glaciers are found.

Corals from the depths of tropical waters have also recorded the Earth's climate over thousands of years. The chemistry and density of coral skeletons, primarily made of calcium carbonate, can indicate past temperature conditions.

Professor Briffa acknowledged that our temperature proxy records do not as yet give a comprehensive view. Proxy records are mostly from the northern hemisphere and records from before 1820 are scant, with only a handful of tree ring records by 1400. We are deficient in records from the tropics, the oceans, and in general from the southern hemisphere. Winter temperature records are also scarcer than those taken in summer. This lack of complete regional and seasonal coverage causes problems as warming effects vary seasonally and geographically, usually being stronger at high latitudes.

There has always been variability in climate. Century long periods of relative warmth have occurred and there have been periods of cooling due to volcanic action. We need to be aware of this variability to understand the context of present warming trends.

## The IPCC hockey stick curve

In their last report, the Intergovernmental Panel on Climate Change (IPCC) have attempted to integrate all Northern Hemisphere records and come up with temperature measurements which acknowledge the uncertainty and error of the data. The IPCC measures temperature in terms of a base mean value, the average temperate value from 1961. All other values are quoted as an increase or decrease in comparison to this temperature.

The key evidence for global warming over the last 50 years is shown in the IPCC graph,

known as the hockey stick graph. This name refers to its shape - with the blade representing the sharp temperature rise during the late 20th century, in marked contrast to the relatively small temperature fluctuations over the previous six centuries.

Even allowing for the fact that the data are not complete, the trend is indisputable. There has been a rapid and unusual acceleration in global temperature from the mid 1980s.

Critics have argued with the quality and distribution of the data in the original IPCC hockey stick graph, and in response the IPCC has introduced new data and statistical techniques. This new hockey stick graph actually shows a more exaggerated upturn in temperatures. It shows modern temperatures lie even further outside the previous trends. Even conservative estimates show past temperatures are well below recent readings.

Those not convinced that the modern warming trends are man-made, point back to the medieval era where there was also a period of warming. But it is clear that this period does not replicate what we are seeing today. There was no extended period of constantly increasing temperature. A 'little ice age' also took place in the 17<sup>th</sup> century - but again, this does not match the unprecedented continuous changes we are now experiencing.

## The greenhouse effect

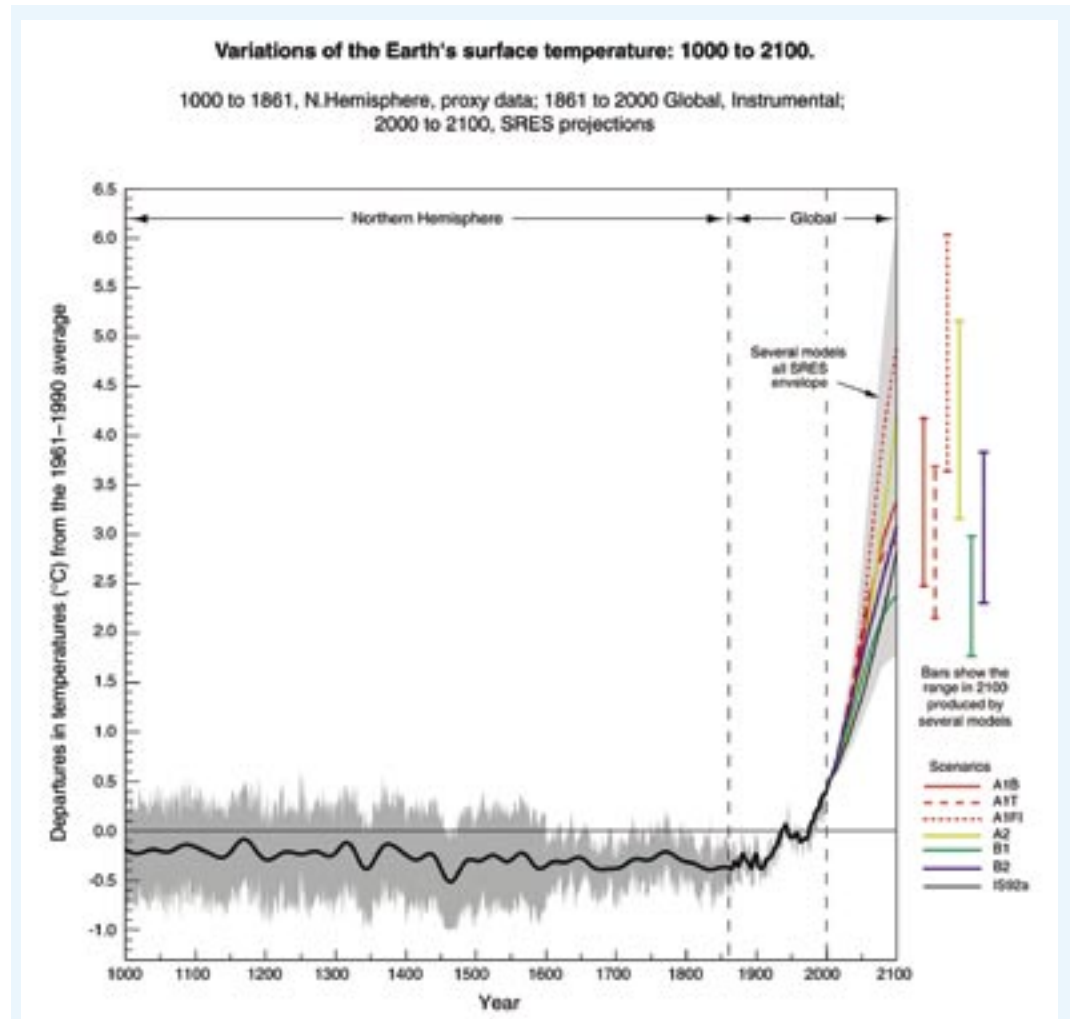
Can today's unusual period of warming be linked to human activity? Professor John Mitchell, Chief Scientist at the MetOffice, explained how a causal link between increasing temperature and increasing levels of atmospheric carbon dioxide has been established. Since the industrial revolution there has been a 33 percent rise in the amount of carbon dioxide in the atmosphere and a 100 percent rise in the amount of methane.

**"There has always been variability in climate"**

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The hockey stick graph. Both proxy temperature reconstructions and instrumental data including several models from IPCC (Special Report on Emissions Scenarios) predicting temperature to 2100. Source: IPCC Special Report on Emissions Scenarios <sup>1</sup>

**“Since the industrial revolution there has been a 33 percent rise in the amount of carbon dioxide in the atmosphere”**

The greenhouse effect is not a new idea. It was first recognised a hundred years ago by the Swedish scientist, Svante August Arrhenius.<sup>2</sup> The warming mechanism is comparable to the trapping of heat that occurs in a greenhouse.

Long-wave solar radiation re-emitted from the earth's surface is absorbed by greenhouse gases in the atmosphere and then re-radiated back down to the earth, causing warming. This process is crucial in keeping our planet warm – without greenhouse gases our planet would be much colder (around 20°C colder) and it is unlikely that there would be any life on Earth! However, when the levels of

greenhouse gases start to increase, so will the amount of heat trapped by the atmosphere and this is what we now see occurring.

## Climate modelling

This simple model underpins the fundamental principles of global warming. But predictive modelling of the relationship between climate and the composition of the atmosphere is not so simple.

Other atmospheric constituents such as methane, nitrous oxide, and fluorinated gases have an effect on climate. There

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are also feedback processes that need to be included in any model. For example, when the temperature of the atmosphere increases so does the amount of water vapour it contains. Water vapour is itself a strong greenhouse gas and so will cause further warming. Increases in temperature also accelerate the liberation of more carbon dioxide and methane from the sea beds and oceans which then contribute to further warming.

Clouds also have complex effects on our climate. They trap heat from the atmosphere but also reflect sunlight away from the Earth. In addition, volcanoes, solar output, smog and the effects of the oceans must all feature in climate models. Ironically, actions in the developed world to improve air-quality and reduce smoke emissions may actually accelerate global warming by allowing more solar radiation to reach the surface of the Earth.

Some sceptics have argued that fluctuations in the amount of energy emitted by the Sun can alone account for climate change over the last 50 years. But Professor Mitchell stated that the solar variability detected correlates only with climate change up to the 1970s. After this date it is impossible to explain the record-breaking acceleration of global temperature using the Sun alone. Even when all feed-backs are included, climate models can only account for today's temperatures when increases in carbon dioxide levels are factored in.

Can we use climate models to predict how changing carbon dioxide levels will affect future climate? Professor Mitchell explained that there is a significant amount of uncertainty in such modelling, making accurate prediction a difficult task. But even the most conservative models predict a significant temperature increase over the next century.

Present climate models used by the Met Office predict a warming of 1.5 – 5.5°C

by 2100. This would cause sea levels to rise 0.1 – 0.8m. Such severe changes to the hydrological cycle are likely to lead to frequent and extreme storm surges.

The warming predicted is likely to be irreversible as cycles of melting and heating are set up. Snow and ice usually form a protective, cooling layer over the Arctic, but as the Arctic ice cap contracts, the earth absorbs more sunlight and gets hotter, causing the ice to melt still further. Most of the models predict that the Greenland ice sheet will have totally disappeared within 3,000 years. Modellers have speculated that this would lead to a 5m increase in the average sea level.

## Predicting the consequences

Professor Colin Prentice continued the theme of how climate change will affect our planet. Professor Prentice is a pioneer in the field of earth systems science, which takes a holistic view of the Earth and the organisms that inhabit it, examining the ways that the physical and natural worlds interact. Professor Prentice leads the QUEST programme (Quantifying and Understanding the Earth System) at Bristol, a £21m programme to improve scientists' ability to predict environmental change and to assess the implications for the sustainable use of resources.

Understanding the impact of climate change is now crucial. His group are developing a risk analysis approach to predicting the effects of global warming. For a range of climate change predictions, bespoke models looking at individual climate change indicators such as water supply, fire danger and vegetation are being devised. From these models the group can set thresholds for 'extreme events'. The probable time until these events will occur can be calculated.

Professor Prentice is plotting his data on probability maps. These maps give an

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indication of some of the consequences over time for a given temperature rise. Climate change will affect water, crops, fisheries, forestry, biodiversity and human health. Not all of the effects will be adverse, but the greater the degree of global warming the greater the risks of adverse effects.

An example of this is the modelling of freshwater supply. The model predicts that if the temperature rises by 3°C the Americas will be at risk of droughts. The UK will also experience problems in the South East during the summer. (In fact, problems are already apparent with the South East experiencing drought conditions over the last 18 months.) Ecological changes are also being mapped. In harsh warming scenarios, there is a risk of forest dieback in Amazonia, southern Africa and Siberia.

The QUEST programme has not completed its analyses of the implications of climate change and is working to produce better models. However, it is clear that human populations will vary greatly in their capacity to cope with warming scenarios. Richer countries are likely to cope better than those in the developing world. But even local changes to the physical and natural environment will have a global impact. There is the potential for refugee problems and changes in world trade will create knock-on effects.

## Time to act

Although there are uncertainties in the present models, Professor Prentice stresses that we know enough to act now. If we continue to emit carbon dioxide into the atmosphere, the concentration of carbon dioxide will continue to increase, and global warming will proceed unchecked. Stabilization of the global climate will only be possible if carbon dioxide emissions are progressively reduced, and ultimately cease.

In 1995 the IPCC Second Assessment Report stated the '*balance of evidence suggests*' a human influence on climate. The Third Assessment Report in 2001 changed its emphasis stating that there was '*new and stronger evidence*' that climate change is largely caused by human activity. A Fourth Assessment Report is due in 2007 and the climate modelling community waits to see what conclusion the IPCC will now draw.

## Climate change scepticism

The majority of scientists agree that global warming is a direct consequence of the burning of fossil fuels and release of carbon dioxide and other greenhouse gases into the environment. Keith Briffa likened the certainty of this causal relationship to the link between smoking and cancer. But there is still a small and vocal minority who do not accept this interpretation of the evidence. The very political nature of this debate has brought a new level of media spin to the otherwise sedate world of climate science.

Andy Rowell, writer and investigative journalist reviewed some of the strategies that are employed by some global warming sceptics. In particular, large oil corporations are funding policy organization and think tanks to publish work questioning the link between climate change and fossil fuel emissions.

Companies, such as Shell and BP have a different approach and now accept the evidence for global warming. They are looking at future strategies where emissions can be reduced or new technologies developed. But this strategy has not been universally adopted. Some oil companies are funding third parties to put the case that global warming is not related to the burning of fossil fuels.

In 2004 Exxon Mobil made donations to a variety of organisations who are skeptical of global warming, including a \$115,000

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donation to the Washington branch of the UK-based International Policy Network<sup>3</sup>. Such organisations make a variety of claims. Some say climate change is not man made and some claim it is, but it will actually have positive consequences. Some say it is already too late or too expensive to intervene so there is no point in trying. The science to back up much of this political scepticism comes from voices marginal to the scientific community.

## A challenge to scientists

It is clear that there are still many areas of debate within climate science. There are uncertainties in climate modelling and in the consequences of global warming and what should be done about it. There is however a broad consensus on the link between carbon dioxide levels and global warming. The debate now needs to move on to consider some of the uncertainties. Can we quantify the effects of climate change? Is there an 'acceptable' level of warming? Will there be a catastrophic point of no return?

Whilst we continue to burn fossil fuels, the possibility of removing carbon dioxide from the atmosphere and pumping it into underground storage sites is also a major research focus.

The scientific community must take up the challenge of developing more successful low carbon energy technologies. The policy community must engage the public so that they understand the consequences of their energy use. The overwhelming evidence for climate change exists – can we afford to ignore it?

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