Climate Change: A Guide for the Perplexed

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NewScientist.com news service
Michael Le Page

Our planet's climate is anything but simple. All kinds of factors influence it, from massive events on the Sun to the growth of microscopic creatures in the oceans, and there are subtle interactions between many of these factors.

Yet despite all the complexities, a firm and ever-growing body of evidence points to a clear picture: the world is warming, this warming is due to human activity increasing levels of greenhouse gases in the atmosphere, and if emissions continue unabated the warming will too, with increasingly serious consequences.

Yes, there are still big uncertainties in some predictions, but these swing both ways. For example, the response of clouds could slow the warming or speed it up.

With so much at stake, it is right that climate science is subjected to the most intense scrutiny. What does not help is for the real issues to be muddied by discredited arguments or wild theories.

So for those who are not sure what to believe, here is our round-up of the 26 most common climate myths and misconceptions.

There is also a guide to assessing the evidence. In the articles we've included lots of links to primary research and major reports for those who want to follow through to the original sources.

Climate Myths 1: Human CO_2 Emissions Are Too Tiny to Matter

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Catherine Brahic

Ice cores show that carbon dioxide levels in the atmosphere have remained between 180 and 300 parts per million for the past half-a-million years. In recent centuries, however, CO_2 levels have risen sharply, to at least 380 ppm (see *Greenhouse gases hit new high*)

So what's going on? It is true that human emissions of CO_2 are small compared with natural sources. But the fact that CO_2 levels have remained steady until very recently shows that natural emissions are usually balanced by natural absorptions. Now slightly more CO_2 must be entering the atmosphere than is being soaked up by carbon "sinks".

The consumption of terrestrial vegetation by animals and by microbes (rotting, in other words) emits about 220 gigatons of CO_2 every year, while respiration by vegetation emits another 220 Gt. These huge amounts are balanced by the 440 Gt of carbon absorbed from the atmosphere each year as land plants photosynthesize.

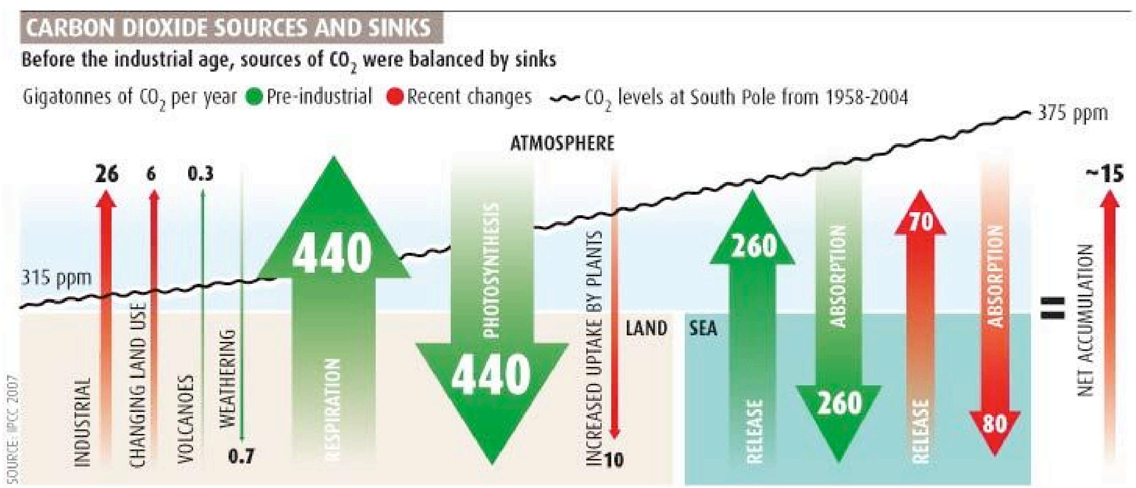
Similarly, parts of the oceans release about 330 Gt of CO_2 per year, depending on temperature and rates of photosynthesis by phytoplankton, but other parts usually soak up just as much – and are now soaking up slightly more.

Ocean sinks

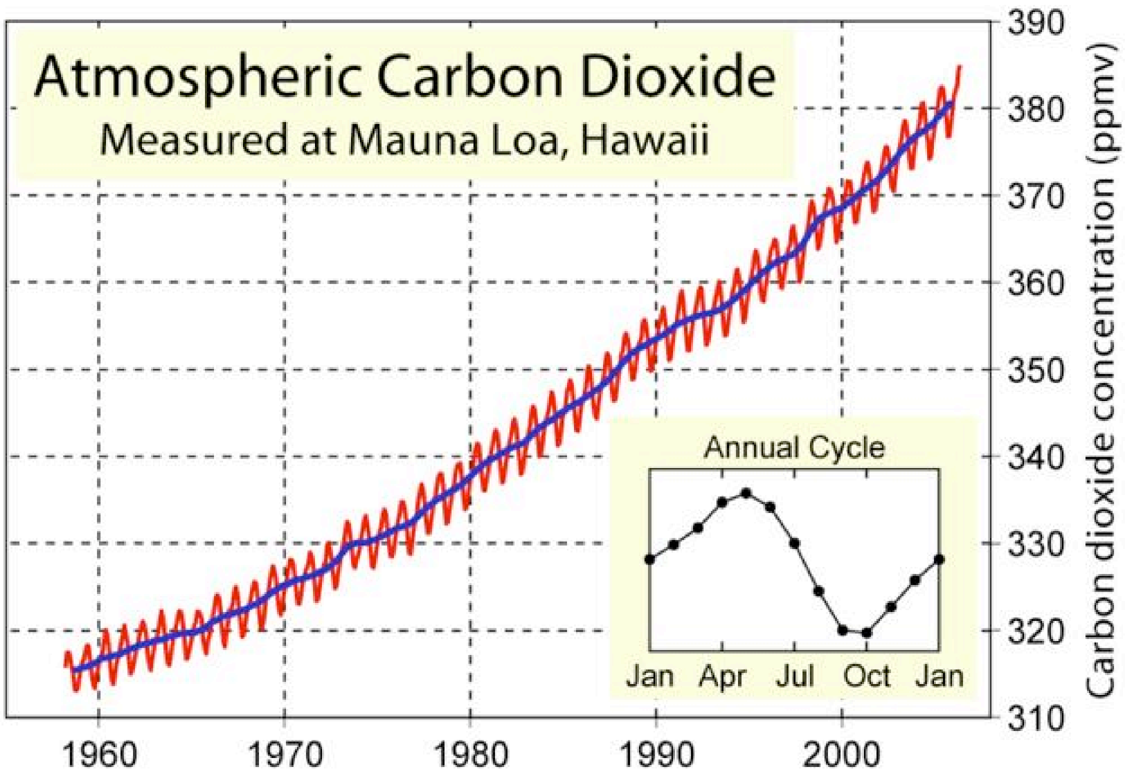
Human emissions of CO_2 are now estimated to be 26.4 Gt per year, up from 23.5 Gt in the 1990s, according to an Intergovernmental Panel on Climate Change report in February 2007 (pdf format). Disturbances to the land – through deforestation and agriculture, for instance – also contribute roughly 5.9 Gt per year.

About 40% of the extra CO_2 entering the atmosphere due to human activity is being absorbed by natural carbon sinks, mostly by the oceans. The rest is boosting levels of CO_2 in the atmosphere.

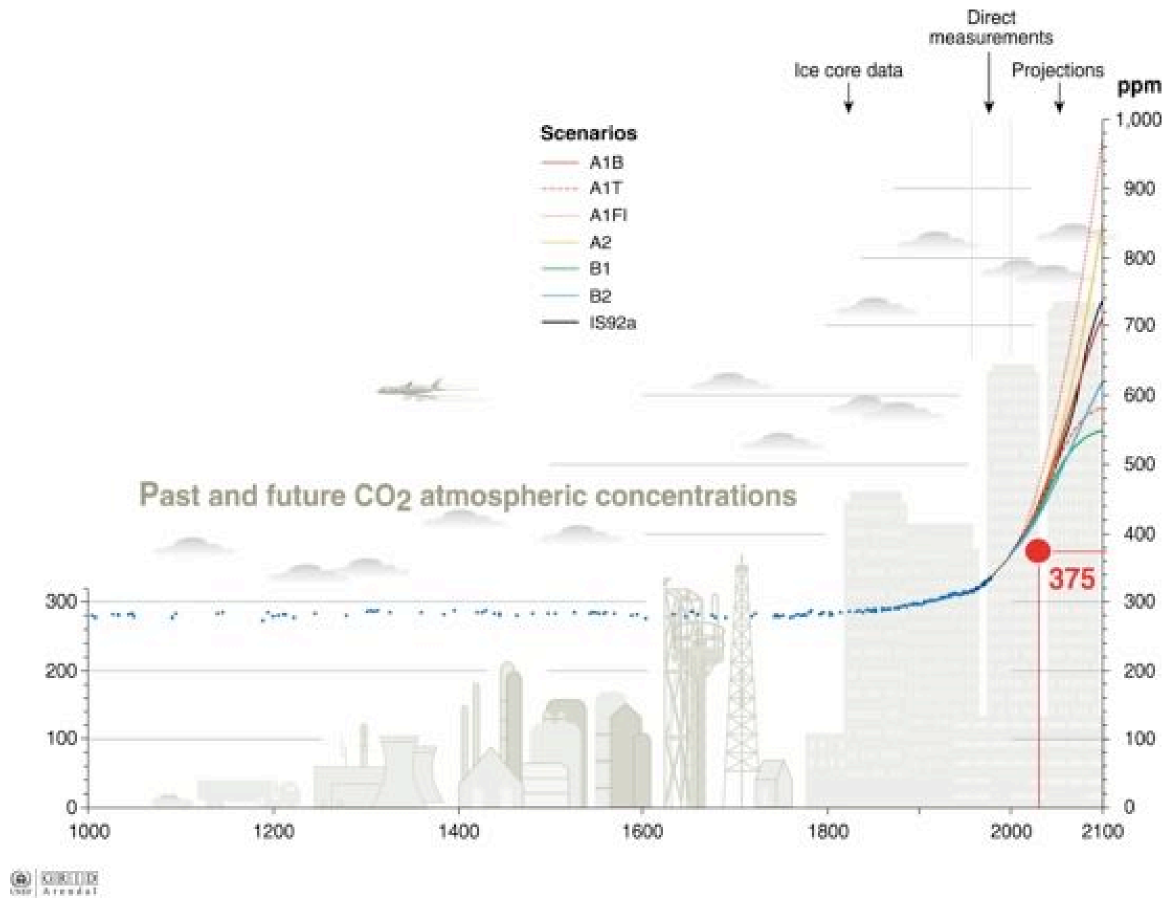
How can we be sure that human emissions are responsible for the rising CO_2 in the atmosphere? There are several lines of evidence. Fossil fuels were formed millions of years ago. They therefore contain virtually no carbon-14, because this unstable carbon isotope, formed when cosmic rays hit the atmosphere, has a half-life of around 6000 years. So a dropping concentration of carbon-14 can be explained by the burning of fossil fuels. Studies of tree rings have shown that the proportion of carbon-14 in the atmosphere dropped by about 2% between 1850 and 1954. After this time, atmospheric nuclear bomb tests wrecked this method by releasing large amounts of carbon-14.



Carbon dioxide sources and sinks.



Carbon dioxide increase since 1959.



Past and future carbon dioxide concentration for certain scenarios. IPCC 2007

Volcanic misunderstanding

Fossil fuels also contain less carbon-13 than carbon-12, compared with the atmosphere, because the fuels derive from plants, which preferentially take up the more common carbon-12. The ratio of carbon-13 to carbon-12 in the atmosphere and ocean surface waters is steadily falling, showing that more carbon-12 is entering the atmosphere.

Finally, claims that volcanoes emit more CO_2 than human activities are simply not true. In the very distant past, there have been volcanic eruptions so massive that they covered vast areas in lava more than a kilometre thick and appear to have released enough CO_2 to warm the planet after the initial cooling caused by the dust (see *Wipeout*). But even with such gigantic eruptions, most of subsequent warming may have been due to methane released when lava heated coal deposits, rather than from CO_2 from the volcanoes (see also *Did the North Atlantic's 'birth' warm the world?*).

Measurements of CO_2 levels over the past 50 years do not show any significant rises after eruptions. Total emissions from volcanoes on land are estimated to average just

0.3 Gt of CO_2 each year – about a hundredth of human emissions (pdf document).

While volcanic emissions are negligible in the short term, over tens of millions of years they do release massive quantities of CO_2. But they are balanced by the loss of carbon in ocean sediments subducted under continents through tectonic plate movements. Ultimately, this carbon will be returned to the atmosphere by volcanoes.

Climate myths 2: We can't do anything about climate change

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Fred Pearce

It is certainly too late to stop all climate change. It is already under way, much in line with model predictions. And there are dangerous time lags. There are already several decades of warming in the pipeline. The lags in organizing effective initiatives to reduce greenhouse gas emissions are also long.

But climate change is not an on-off switch. It is a continuing process. The sooner we stabilize atmospheric concentrations of greenhouse gases, the sooner we can reduce our impact on the climate and minimize the risk of reaching tipping points that will make preventing further warming even harder. Even if we only manage to slow warming rather than prevent it, societies will have more time to adjust to the changes.

It is true that the action taken so far, such as the Kyoto Protocol, will only have a marginal effect. The protocol's authors have always described it as a first step. But even before it came into effect in 2005, the protocol has triggered some profound thinking among governments, corporations and citizens about their carbon footprint and how to reduce it. Industrialized countries such as the UK are planning for emissions reductions of 60% or more by mid-century.

We may find that once the process has begun, the world loses its addiction to carbon fuels surprisingly quickly. Natural scientists fear "tipping points" in the climate system. But there are also tipping points in social, economic and political systems. Once under way, things can happen fast.

Political issue

The great majority of the extra carbon dioxide in the atmosphere was put there by the developed world, with the US alone responsible for an estimated quarter of emissions since 1750. Future emissions may be dominated by large developing countries like China and India. While neither can be blamed for climate change so far, they clearly have to be part of the solution. That is probably the biggest challenge.

But this is primarily a political issue. The industrialized nations have already emitted enough carbon dioxide to trigger significant warming. Humanity cannot afford for the developing world to take the same path. So a deal has to be done to prevent that. But today the technology to develop on a low-carbon path is much further advanced. And costs are coming down fast.

A new deal to save the world from climate change will probably involve large flows of technology and cash to the developing world. There are precedents for this. Developing countries are already being paid in cash and technology for not using ozone-destroying chemicals in refrigerators and air-conditioning systems. The same must be done on a bigger scale to halt climate change.

To repeat, this is not primarily a technological or even an economic problem, as huge as these challenges are. It is a political problem. And in politics, most things can be done if there is the will.

Climate myths 3: The 'hockey stick' graph has been proven wrong

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Michael Le Page

The "hockey stick" graph was the result of the first comprehensive attempt to work out the average northern hemisphere temperature over the past 1000 years, based on numerous indicators of past temperatures, such as tree rings. It shows temperatures holding fairly steady until the last part of the 20th century and then suddenly shooting up (see graphic, right).

It was published in a 1999 paper (pdf) by Michael Mann and colleagues, which was an extension of a 1998 study in *Nature*. The graph was highlighted in the 2001 report of the Intergovernmental Panel on Climate Change (IPCC).

Since 2001, there have been repeated claims that the reconstruction is at best seriously flawed and at worst a fraud, no more than an artifact of the statistical methods used to create it (see *The great hockey stick debate*).

Details of the claims and counterclaims involve lengthy and arcane statistical arguments, so let's skip straight to the 2006 report of the US National Academy of Science (pdf). The academy was asked by Congress to assess the validity of temperature reconstructions, including the hockey stick.

"Array of evidence"

The report states: "The basic conclusion of Mann et al. (1998, 1999) was that the late 20th century warmth in the Northern Hemisphere was unprecedented during at least the last 1000 years. This conclusion has subsequently been supported by an array of evidence that includes both additional large-scale surface temperature reconstructions and pronounced changes in a variety of local proxy indicators, such as melting on ice caps and the retreat of glaciers around the world".

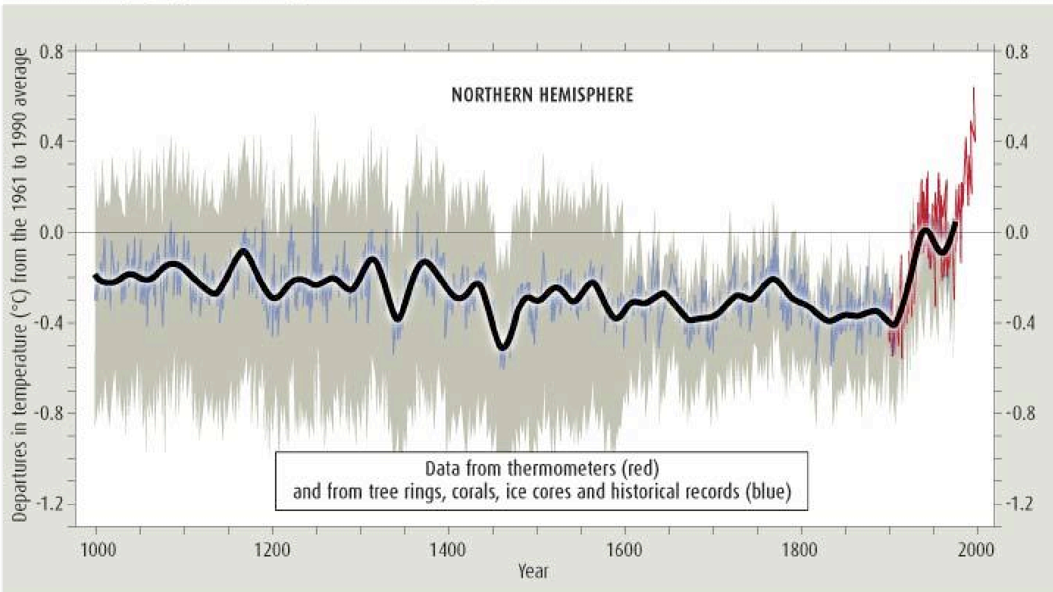
Most researchers would agree that while the original hockey stick can – and has – been improved in a number of ways, it was not far off the mark. Most later temperature reconstructions fall within the error bars of the original hockey stick. Some show far more variability leading up to the 20th century than the hockey stick, but none suggest that it has been warmer at any time in the past 1000 years than in the last part of the 20th century.

It is true that there are big uncertainties about the accuracy of all past temperature reconstructions, and that these uncertainties have sometimes been ignored or glossed over by those who have presented the hockey stick as evidence for global warming.

Climate scientists, however, are only too aware of the problems (see *Climate myths: It was warmer during the Medieval period*), and the uncertainties were both highlighted by Mann's original paper and by others at the time it was published.

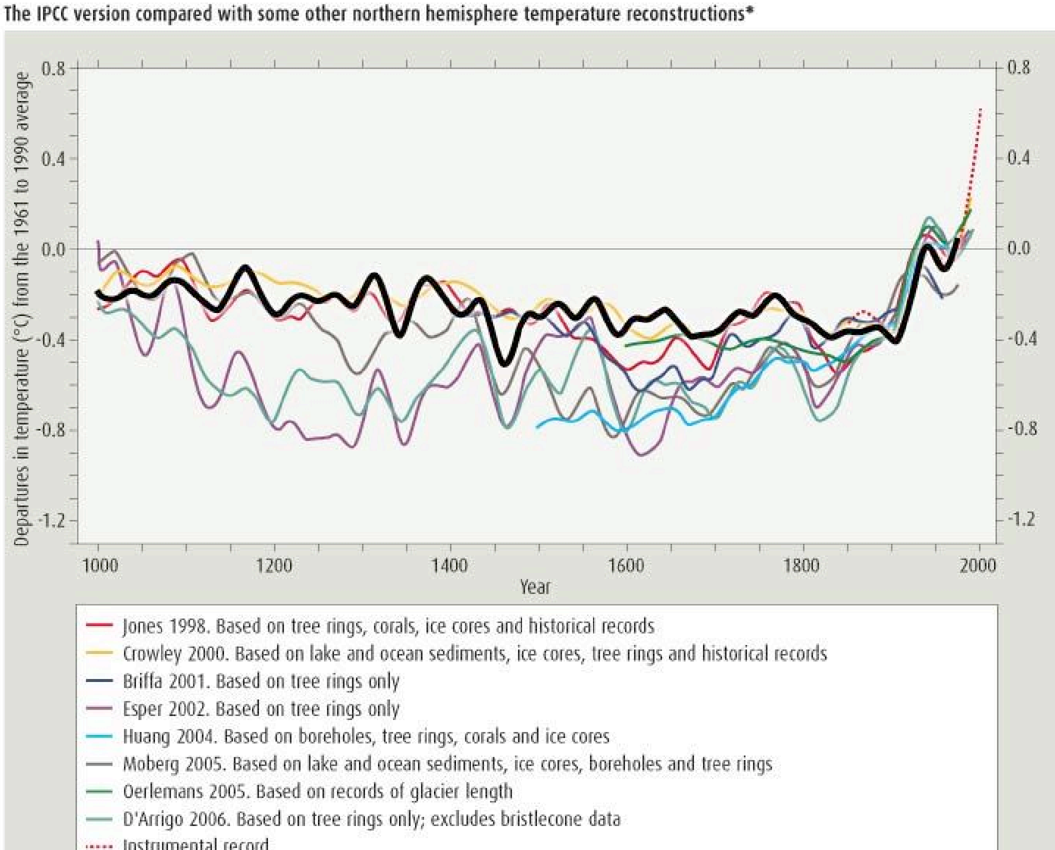
THE HOCKEY STICK: THE ORIGINAL AND LATER VERSIONS

The 2001 IPCC version: "Variations of the Earth's surface temperature over the past 1000 years"
The error bars (in grey) show the 95 per cent confidence range



SOURCE: IPCC, MANN 1999

The IPCC version compared with some other northern hemisphere temperature reconstructions*



*Compiled for *New Scientist* by Rob Wilson of the University of Edinburgh, UK.
For each reconstruction, the original raw measurements were decadally smoothed with a 50-year splicing spine. Each reconstruction is aligned so that its mean during the period of overlap, 1856 to 1979, matches that of the instrumental record (apart from Briffa 2001, which extends only to 1960) The mean and variance of the Esper 2002 series has been adjusted

The Hockey Stick: The original and later versions. Temperature reconstructions of the past 1000 years.

Climate myths 4: Chaotic systems are not predictable

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Michael Brooks

You cannot predict the exact path a ball will take as it bounces through a pinball machine. But you can predict that the average score will change if the entire machine is tilted.

Similarly, while we cannot predict the weather in a particular place and on a particular day in 100 years time, we can be sure that on average it will be far warmer if greenhouse gases continue to rise.

While weather and to some extent climate are chaotic systems, that does not mean that either are entirely unpredictable, as this demonstration neatly illustrates.

The unpredictable character of chaotic systems arises from their sensitivity to any change in the conditions that control their development. What we call the weather is a highly detailed mix of events that happen in a particular locality on any particular day – rainfall, temperature, humidity and so on – and its development can vary wildly with small changes in a few of these variables.

Climate, however, is the bigger picture of a region's weather: the average, over 30 years (according to the World Meteorological Association's definition), of the weather pattern in a region. While weather changes fast on human timescales, climate changes fairly slowly. Getting reasonably accurate predictions is a matter of choosing the right timescale: days in the case of weather, decades in the case of climate.

Dynamic interactions

Climate scientists sometimes refer to the effects of chaos as intrinsic or unforced variability: the unpredictable changes that arise from the dynamic interactions between the oceans and atmosphere rather than being a result of "forcings" such as changes in solar irradiance or greenhouse gases.

The crucial point is that unforced variability occurs within a relatively narrow range. It is constrained by the major factors influencing climate: it might make some winters bit a warmer, for instance, but it cannot make winters warmer than summers.

Put the other way round, two or three warmer winters in a row could be due to unforced variability rather than global warming, just as two or three high scores in pinball do not necessarily mean the table is tilted. But the more warmer winters there are, or more high scores there are on a certain pinball machine, the less likely it is to be due to the chaos inherent in the system.

To account for the influence of chaos, climate scientists run the models repeatedly, with slightly different starting conditions. The difference in outcomes gives scientists an indication of the uncertainty in any given prediction, of the range of possible outcomes.

Climate myths 4: We can't trust computer models

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Fred Pearce

Even though the climate is chaotic to some extent, it can be predicted long in advance.

Climate is average weather, and it can vary unpredictably only within the limits set by major influences like the Sun and levels of greenhouse gases in the atmosphere. We might not be able to say whether it will rain at noon in a week's time, but we can be confident that the summers will be hotter than winters for as long as the Earth's axis remains tilted.

The validity of models can be tested against climate history. If they can predict the past (which the best models are pretty good at) they are probably on the right track for predicting the future – and indeed have successfully done so.

Clouded judgment

Climate modelers may *occasionally* be seduced by the beauty of their constructions and put too much faith in them. Where the critics of the models are both wrong and illogical, however, is in assuming that the models must be biased towards alarmism – that is, greater climate change. It is just as likely that these models err on the side of caution.

Most modelers accept that despite constant improvements over more than half a century, there are problems. They acknowledge, for instance, that one of the largest uncertainties in their models is how *clouds will respond to climate change*. Their predictions, which they prefer to call scenarios, usually come with generous error bars. In an effort to be more rigorous, the most recent report of the IPCC has quantified degrees of doubt, defining terms like "likely" and "very likely" in terms of percentage probability.

Given the complexity of our climate system, most scientists agree that models are the best way of making sense of that complexity. For all their failings, models are the best guide to the future that we have.

Finally, the claim is sometimes made that if computer models were any good, people would be using them to predict the stock market. Well, they are!

A lot of trading in the financial markets is already carried out by computers. Many base their decisions on fairly simple algorithms designed to exploit tiny profit margins, but others rely on more sophisticated long-term models.

Major financial institutions are investing huge amounts in automated trading systems, the proportion of trading carried out by computers is growing rapidly and some individuals have made a fortune from them. The smart money is being bet on computer models.

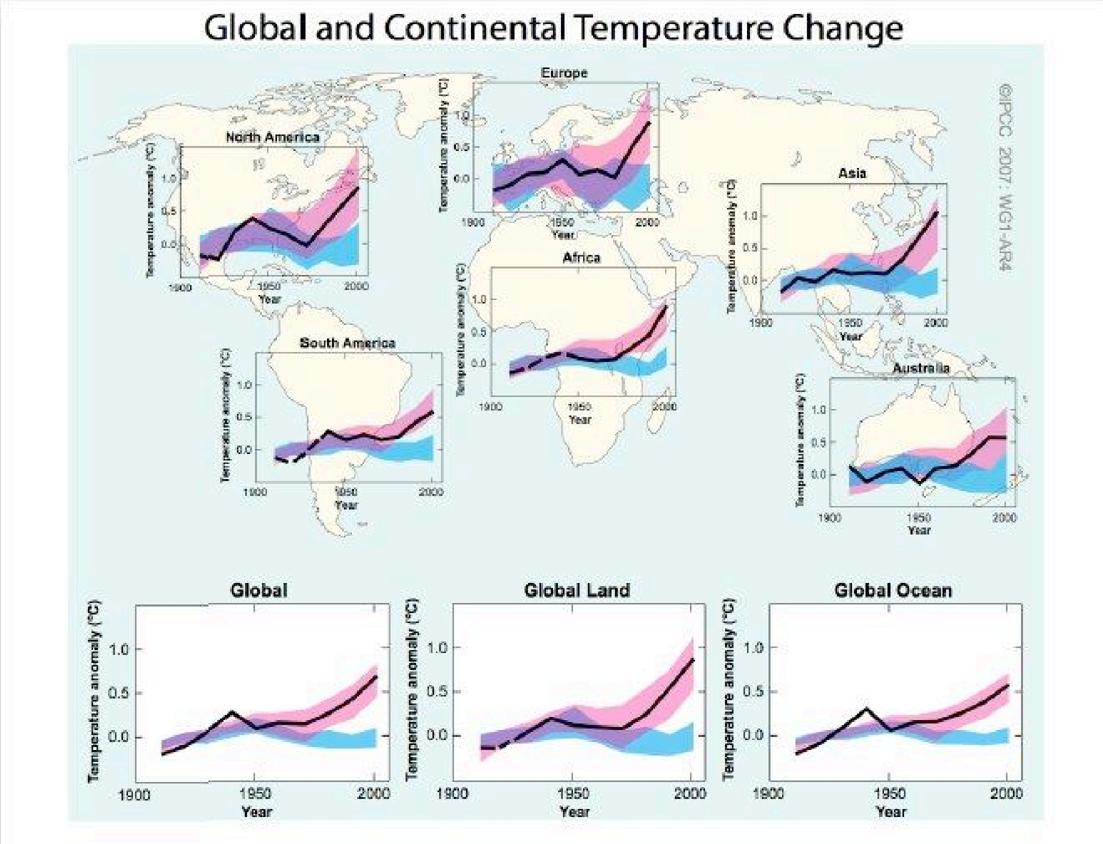

FIGURE SPM-4. Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906–2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901–1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5–95% range for 19 simulations from 5 climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5–95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings. {FAQ 9.2, Figure 1}

Climate myths 6: They predicted global cooling in the 1970s

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Michael Le Page

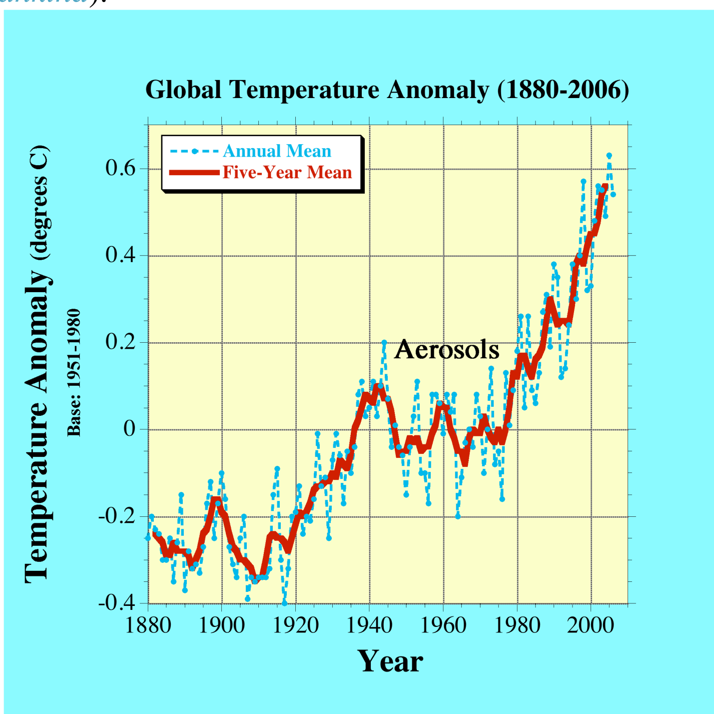
Indeed they did. At least, a handful of scientific papers discussed the possibility of a new ice age at some point in the future, leading to some pretty sensational media coverage (see *Histories: The ice age that never was*).

One of the sources of this idea may have been a 1971 paper by Stephen Schneider, then a climate researcher at NASA's Goddard Space Flight Center in Maryland, US. Schneider's paper suggested that the cooling effect of dirty air could outweigh the warming effect of carbon dioxide, potentially leading to an ice age if aerosol pollution quadrupled.

This scenario was seen as plausible by many other scientists, as at the time the planet had been cooling (see *Global temperatures fell between 1940 and 1980*). Furthermore, it had also become clear that the interglacial period we are in was lasting an unusually long time (see *Record ice core gives fair forecast*).

However, Schneider soon realized he had overestimated the cooling effect of aerosol pollution and underestimated the effect of CO_2, meaning warming was more likely than cooling in the long run. In his review of a 1977 book called *The Weather Conspiracy: The Coming of the New Ice Age*, Schneider stated: "We just don't know...at this stage whether we are in for warming or cooling – or when." A 1975 report (pdf format) by the US National Academy of Sciences merely called for more research.

The calls for action to prevent further human-induced global warming, by contrast, are based on an enormous body of research by thousands of scientists over more than a century that has been subjected to intense – and sometimes ferocious – scrutiny. According to the latest IPCC report, it is more than 90% certain that the world is already warming as a result of human activity (see *Blame for global warming placed firmly on humankind*).



The cooling after 1940 was due to human-caused emission of aerosols that cool the climate.

Climate myths 7: It's been far warmer in the past, what's the big deal?

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David L Chandler

First of all, it is worth bearing in mind that any data on global temperatures before about 150 years ago is an estimate, a reconstruction based on second-hand evidence such as ice cores and isotopic ratios. The evidence becomes sparser the further back we look, and its interpretation often involves a set of assumptions. In other words, a fair amount of guesswork.

It is certainly true that Earth has experienced some extremes that were warmer than today, as well as much colder periods. In some cases the main factors that caused these past warm periods – and the ebb and flow of ice ages over recent millennia – are well understood, though not in all. Many of the details remain unknown.

Within the past billion years, there may have been one or more periods when the whole planet was covered in ice. This "snowball Earth" phenomenon remains controversial, with some evidence suggesting that there were at least some areas of unfrozen land and water even at the height of the freezing (read more here, here and here). It is clear, though, that from about 750 million to 580 million years ago, the Earth was in the grip of an ice age more extreme than any since.

Why did it happen? The spread of ice produces further cooling by reflecting more of the Sun's energy back into space. But ice on land blocks the chemical weathering of rocks that removes CO_2 from the atmosphere, which leads to warming as levels rise.

Snowball Earth may have been possible only because the continents were clustered on the equator, meaning CO_2 removal would have continued even as ice sheets spread from the poles. Only when most of the land was covered would greenhouse gases have started to build up to levels is high enough to overcome the cooling effects of the extensive ice cover.

Mass extinctions

After this deep freeze, there were several periods when the temperature exceeded those we experience today. The warmest was probably the Paleocene-Eocene Thermal Maximum (PETM), which peaked about 55 million years ago. Global temperatures during this event may have warmed by 5°C to 8°C within a few thousand years, with the Arctic Ocean reaching a subtropical 23°C. Mass extinctions resulted.

The warming, which lasted 200,000 years, was caused by the release of massive amounts of methane or CO_2. It was thought to have come from the thawing of methane clathrates in deep ocean sediments, but the latest theory is that it was caused by a massive volcanic eruption that heated up coal deposits. In other words, the PETM is an example of catastrophic global warming triggered by the build-up of greenhouse gases in the atmosphere.

Since then, the Earth has cooled. For the past million years or so, the climate has switched between ice ages and warmer interglacial periods with temperatures similar to those of the past few millennia. These periodic changes seem to be triggered by oscillations in the planet's orbit and inclination that alter the amount of solar radiation reaching Earth.

However, it is clear that the orbital changes alone would not have produced large temperature changes and that there must have been some kind of feedback effect (see the section on Milankovitch cycles in this article).

Inundated cities

In between ice ages, some lesser peaks of temperature have occurred a number of times, especially around 125,000 years ago. At this time, temperatures may have been about 1°C to 2°C degrees warmer than today. Sea level was 5 to 8 meters higher than today – a rise sufficient to inundate most of the world's coastal cities (IPCC report, pdf format). This peak was triggered by the orbital cycles.

After the last glaciation ended, global temperatures appear to have peaked around 6000 years ago, called the Holocene Climatic Optimum. The warming appears have been largely localized, concentrated in the northern hemisphere in summer, and average global temperatures did not exceed those of recent decades by much, if at all. Again, orbital variations were the trigger, but these led to changes in vegetation and sea-ice cover that produced marked regional climatic alterations.

From about AD 800 to AD 1300, there was a minor peak called the medieval warm period, but it was not as warm as recent decades (see *Climate myths: It was warmer during the Medieval period*)

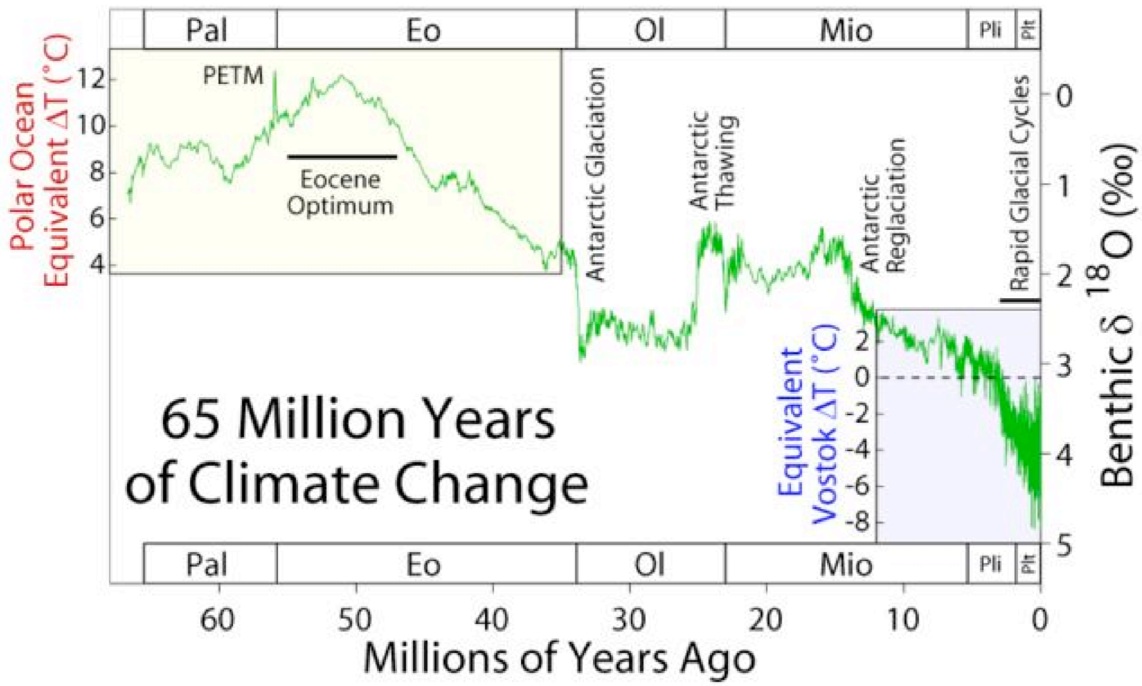
Thermal insulation

What is clear from the study of past climate is that many factors can influence climate: solar activity, oscillations in Earth's orbit, greenhouse gases, ice cover, vegetation on land (or the lack of it), the configuration of the continents, dust thrown up by volcanoes or wind, the weathering of rocks and so on.

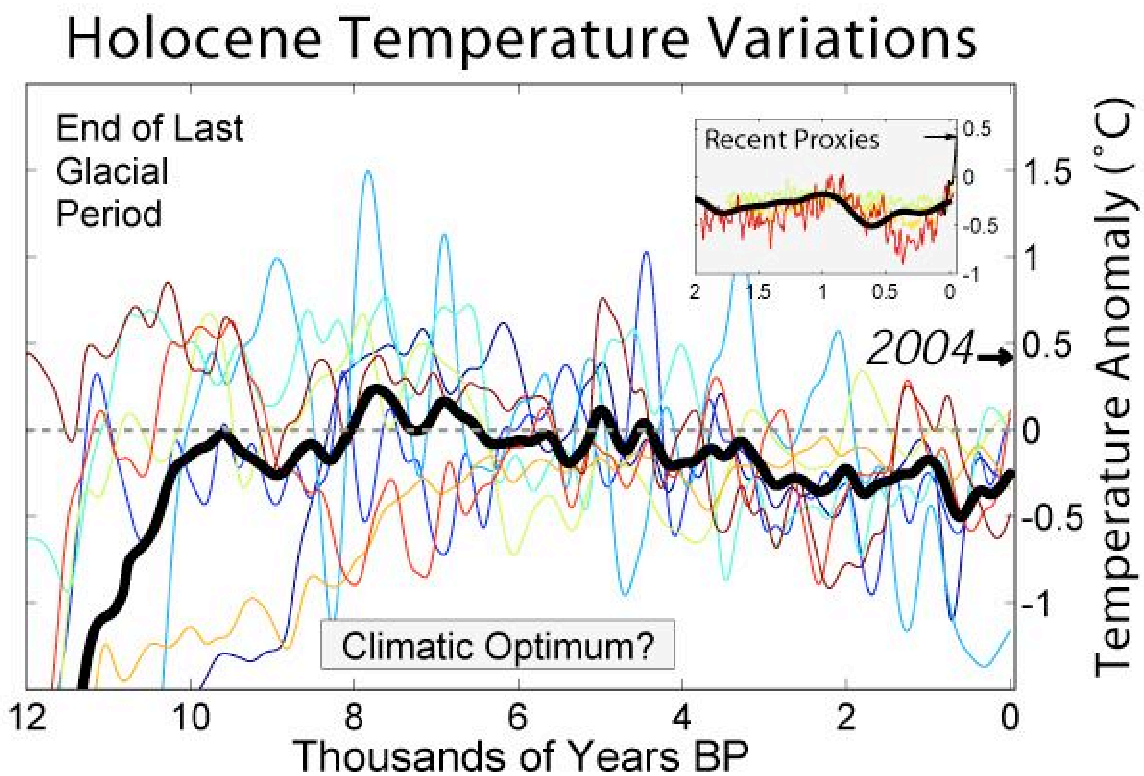
The details are seldom as simple as they seem at first: sea ice reflects more of the Sun's energy than open water but can trap heat in the water beneath, for example. There are complex interactions between many of these factors that can amplify or dampen changes in temperature.

The important question is what is causing the current, rapid warming? We cannot dismiss it as natural variation just because the planet has been warmer at various times in the past. Many studies suggest it can only be explained by taking into account human activity.

Nor does the fact that it has been warmer in the past mean that future warming is nothing to worry about. The sea level has been tens of meters higher during past warm periods, enough to submerge most major cities around the world.



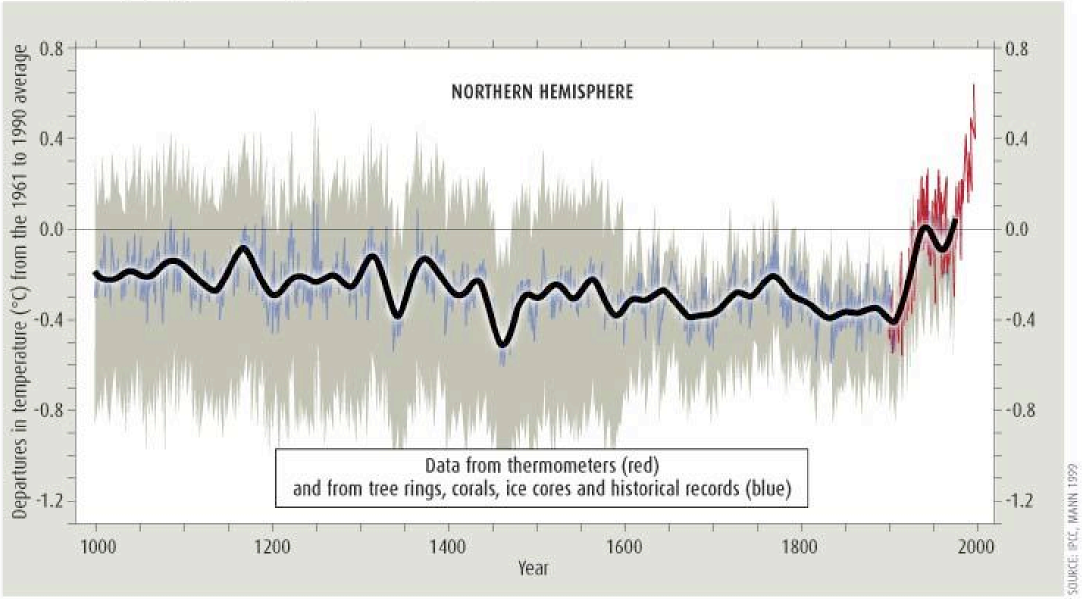
Temperature changes during the past 65 million years. Higher level is warmer.



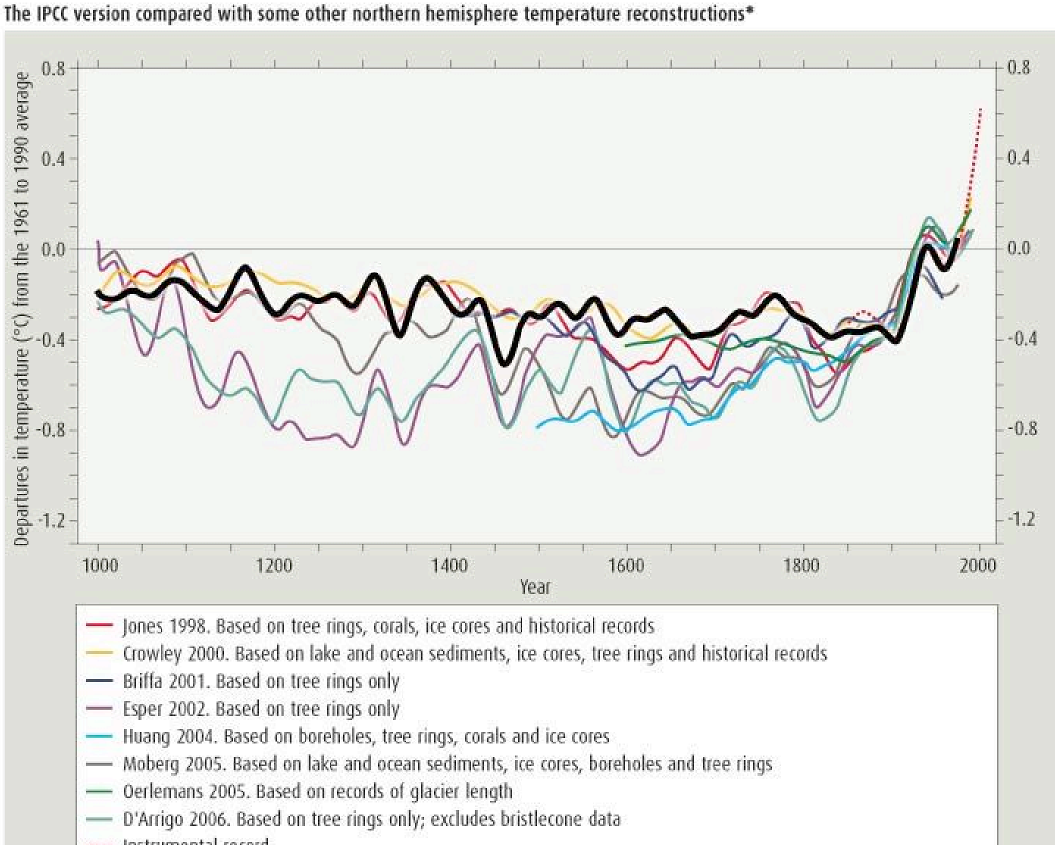
The Holocene Climate Optimum was probable less than today's warming.

THE HOCKEY STICK: THE ORIGINAL AND LATER VERSIONS

The 2001 IPCC version: "Variations of the Earth's surface temperature over the past 1000 years"
The error bars (in grey) show the 95 per cent confidence range



The IPCC version compared with some other northern hemisphere temperature reconstructions*



*Compiled for *New Scientist* by Rob Wilson of the University of Edinburgh, UK.
For each reconstruction, the original raw measurements were decadally smoothed with a 50-year splicing spine. Each reconstruction is aligned so that its mean during the period of overlap, 1856 to 1979, matches that of the instrumental record (apart from Briffa 2001, which extends only to 1960) The mean and variance of the Esper 2002 series has been adjusted

Climate myths 8: It's too cold where I live - warming will be great

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Michael Le Page

How climate warming will affect you? It depends on where you live, how long you will live, what you do for a living and for fun - and whether you care about the future of your children or humanity in general.

Global warming is already happening. Just about every part of the planet, except for Antarctica has warmed since 1970. Glaciers are melting, spring is coming earlier and the ranges of many plants and animals are shifting polewards (see the IPCC's 2007 report on impacts, adaptations and vulnerability).

For most people, this has made little difference. We may have sweltered through more heatwaves but winters have been milder. The next decade or two will bring a similar mix of upsides and downsides. Heating bills will go down but air conditioning bills will go up. Heatwaves may cause some deaths but this will probably be outweighed by fewer cold-related deaths.

This does not sound too bad, and for many people it won't be. Wealthy individuals and countries will be able to adapt to most short-term changes, whether it means buying an air conditioner or switching to crops better suited to the changing climate. Rainfall will fall in mid-latitudes but rise in high latitudes, and initially agricultural yields will probably increase (see *Higher CO_2 levels will boost plant growth and food production*). Some regions will suffer, though. Africa could be hardest hit, with yields predicted to half in some countries as early as 2020.

Frequent bleaching

Wildlife will also be in trouble. Some plants and animals will thrive as CO_2 rises but at the expense of others. Coral reefs, which are already suffering frequent bleaching episodes, could be particularly hard hit. Many species, like the polar bear, will suffer as their habitat disappears.

As global temperature climbs to 3°C above present levels - which is likely to happen before the end of this century if greenhouse emissions continue unabated - the consequences will become increasingly severe. More than a third of species face extinction. Agricultural yields will start to fall in many parts of the world. Millions of people will be at risk from coastal flooding. Heatwaves, droughts, floods and wildfires will take an ever greater toll.

There are two factors should borne in mind when thinking about the impacts. Firstly, even countries that escape the worst of the direct effects will feel the economic effects of what happens elsewhere. There may be social and political problems too, as migration increases and water becomes increasingly scarce in some regions.

Time lags

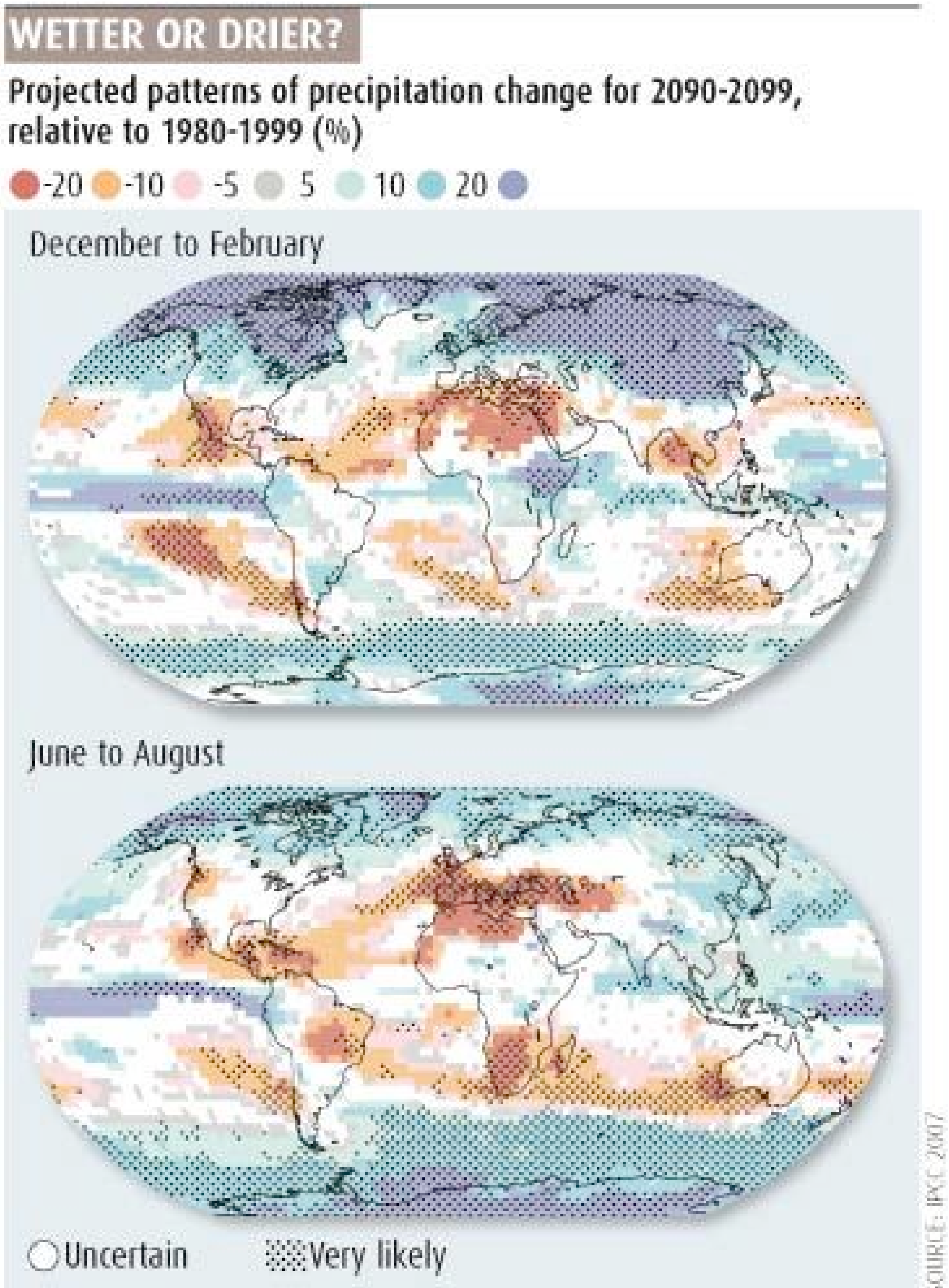
Secondly, there are time lags between rises in CO_2 and their impact on climate. These lags mean that the longer we delay effective action, the more severe the impacts will eventually be.

There is a lag between CO_2 rises and their full effect on global temperature. Even if we made the drastic cuts necessary to stabilize CO_2levels tomorrow, the world would continue to warm for decades.

There is an even longer lag between any increase in temperature and the resulting rise in sea level. The IPCC is predicting a rise of 0.6 metres at most by 2100 but this will just be the start.

The IPCC predicts a minimum temperature rise by 2100 of 1.8°C. About 120,000 years ago, when it was 1 to 2°C warmer, the sea level was 5 to 8 meters higher - more than enough to inundate many major cities around the world, including New York, London and Sydney. Three million years ago, when the temperature was 2 to 3°C higher, it was 25 meters higher.

There is no doubt that similar temperature increases will eventually lead to similar rises in sea level. The assumption is that it will take many centuries, as the Greenland and Antarctica ice caps slowly melt and the oceans expand as the waters warm. But some researchers think it could happen much sooner due to the sudden collapse of ice sheets.



Climate myths 9: Global warming is down to the Sun, not humans

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NewScientist.com news service
Fred Pearce

Switch off the Sun and Earth would become a very chilly place. No one denies our star's central role in determining how warm our planet is. The issue today is how much solar changes have contributed to the recent warming, and what that tells us about future climate.

The total amount of solar energy reaching Earth can vary due to changes in the Sun's output, such as those associated with sunspots, or in Earth's orbit. Orbital oscillations can also result in different parts of Earth getting more or less sunlight even when the total amount reaching the planet remains constant – similar to the way the tilt in Earth's axis produces the hemispheric seasons. There may also be more subtle effects (see *Climate myths: Cosmic rays are causing climate change*), but these remain unproven.

On timescales that vary from millions of years through to the more familiar 11-year sunspot cycles, variations in the amount of solar energy reaching Earth have a huge influence on our atmosphere and climate. But the Sun is far from being the only player.

How do we know? According to solar physicists, the sun emitted a third less energy about 4 billion years ago and has been steadily brightening ever since. Yet for most of this time, Earth has been even warmer than today, a phenomenon sometimes called the faint sun paradox. The reason: higher levels of greenhouse gases trapping more of the sun's heat.

Amplified effect

Nearer our own time, the coming and going of the ice ages that have gripped the planet in the past two million years were probably triggered by fractional changes in solar heating (caused by wobbles in the planet's orbit, known as Milankovitch cycles).

The cooling and warming during the ice ages and interglacial periods, however, was far greater than would be expected from the tiny changes in solar energy reaching the Earth. The temperature changes must have been somehow amplified. This most probably happened through the growth of ice sheets, which reflect more solar radiation back into space than darker land or ocean, and transfers of carbon dioxide between the atmosphere and the ocean.

Analysis of ice cores from Greenland and Antarctica shows a very strong correlation between CO_2 levels in the atmosphere and temperatures. But what causes what? Proponents of solar influence point out that that temperatures sometimes change first. This, they say, suggest that warming causes rising CO_2 levels in the atmosphere, not vice versa. What is actually happening is a far more complicated interaction (see *Ice cores show CO_2 only rose after the start of warm periods*).

Sunspot trouble

So what role, if any, have solar fluctuations had in recent temperature changes? While we can work out how Earth's orbit has changed going back many millions of years, we have no first-hand record of the changes in solar output associated with sunspots before the 20th century.

It is true that sunspot records go back to the 17th century, but sunspots actually block the Sun's radiation. It is the smaller bright spots (faculae) that increase the Sun's output and these were not recorded until more recently. The correlation between sunspots and bright faculae is not perfect, so estimates of solar activity based on sunspot records may be out by as much as 30%.

The other method of working out past solar activity is to measure levels of carbon-14 and beryllium-10 in tree rings and ice cores. These isotopes are formed when cosmic rays hit the atmosphere, and higher sunspot activity is associated with increases in the solar wind that deflect more galactic cosmic rays away from Earth. Yet again, though, the correlation is not perfect. What is more, recent evidence suggests that the deposition of beryllium-10 can be affected by climate changes, making it even less reliable as a measure of past solar activity.

Recent rises

Despite these problems, most studies suggest that before the industrial age, there was a good correlation between natural “forcings" – solar fluctuations and other factors such as the dust ejected by volcanoes – and average global temperatures. Solar forcing may have been largely responsible for warming in the late 19th and early 20th century, leveling off during the mid-century cooling (see *Global temperatures fell between 1940 and 1980*).

The 2007 IPCC report halved the maximum likely influence of solar forcing on warming over the past 250 years from 40% to 20%. This was based on a reanalysis of the likely changes in solar forcing since the 17th century.

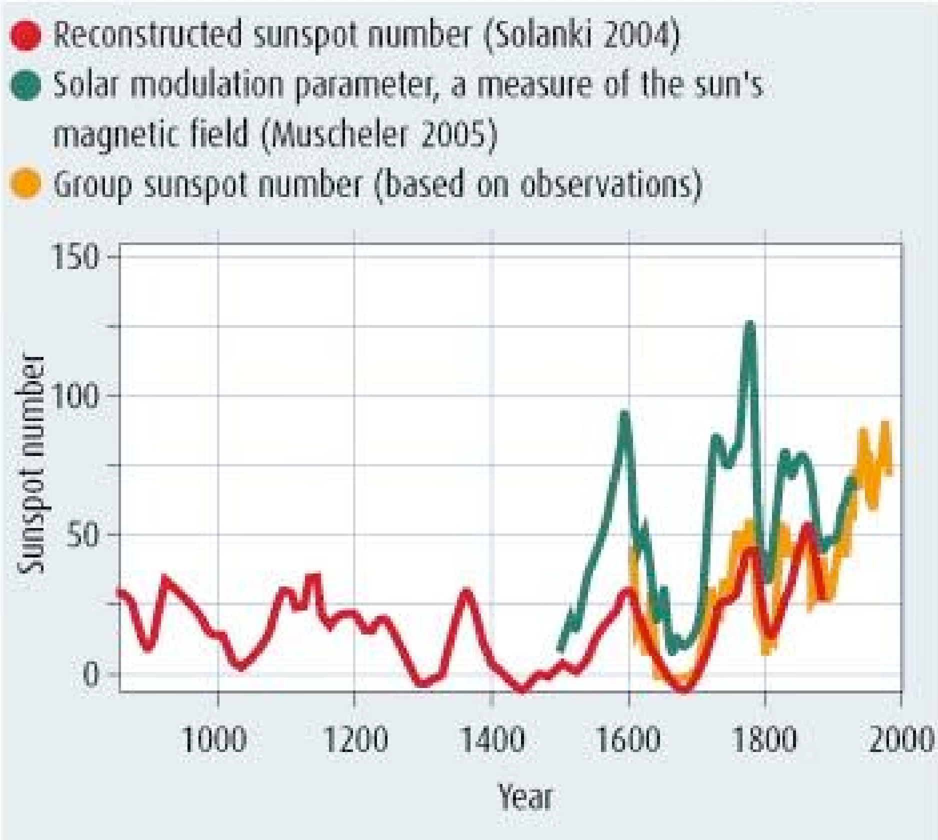
But even if solar forcing in the past was more important than this estimate suggests, as some scientists think, there is no correlation between solar activity and the strong warming during the past 40 years. Claims that this is the case have not stood up to scrutiny (pdf document).

Direct measurements of solar output since 1978 show a steady rise and fall over the 11-year sunspot cycle, but no upwards or downward trend .

Similarly, there is no trend in direct measurements of the Sun's ultraviolet output and in cosmic rays. So for the period for which we have direct, reliable records, the Earth has warmed dramatically even though there has been no corresponding rise in any kind of solar activity.

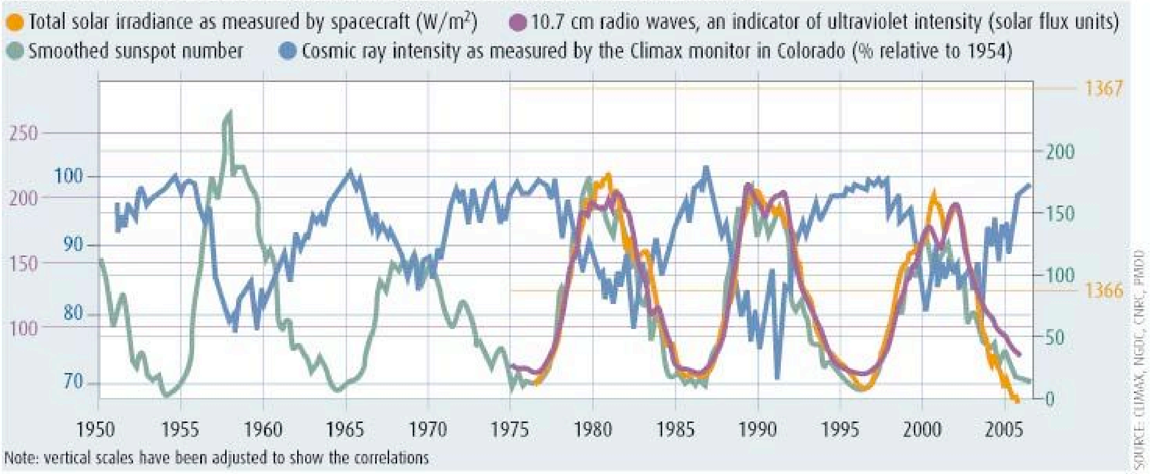
PAST SOLAR ACTIVITY

Two recent estimates of past solar activity based on carbon-14 levels in tree rings. Carbon-14 is formed when cosmic rays hit the atmosphere and its levels are approximately inversely proportional to solar activity. Even if solar activity has been exceptionally high over the past century, as the reconstructed sunspot number suggests, this still cannot account for the recent warming



RECENT CHANGES IN SOLAR ACTIVITY AND COSMIC RAYS

Direct, accurate measurements of cosmic ray intensity and various forms of solar activity began only in the late 20th century. None of these measures shows any long-term trends that can explain the recent warming



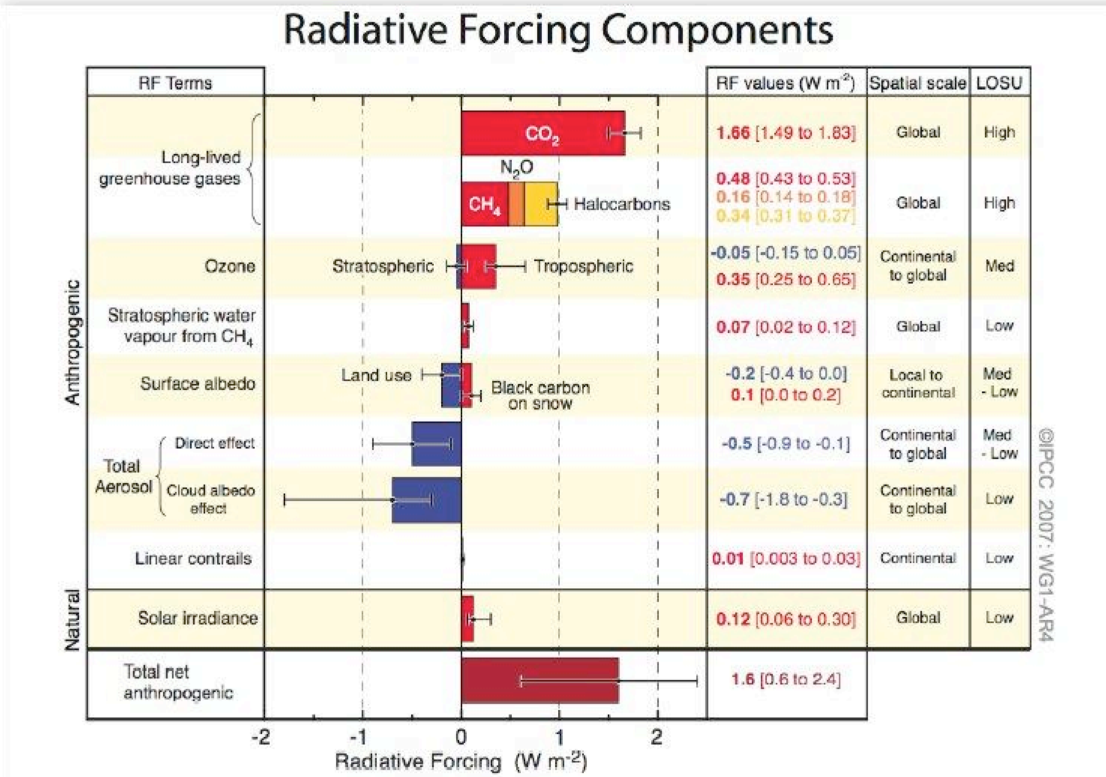


FIGURE SPM-2. Global-average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. Range for linear contrails does not include other possible effects of aviation on cloudiness. {2.9, Figure 2.20}

Climate myths 10: It's all down to cosmic rays

17:00 16 May 2007
NewScientist.com news service
Fred Pearce

The variation in the total amount of energy reaching Earth from the Sun is one of the main factors determining our planet's climate (see *Climate myths: Global warming is down to the Sun, not humans*).

However, this factor alone cannot explain the recent warming nor, indeed, can it fully explain many past changes such as Earth's ice ages. But what if changes in the Sun's activity have larger-than-expected effects on the climate?

There are plenty of ideas about how this could happen. For instance, one as-yet-unproven idea is that changes in the relative amount of ultraviolet light emitted by the Sun might affect the ozone layer, heating the stratosphere and altering circulation patterns in the lower atmosphere.

In the late 1990s, some Danish scientists revived another idea, proposed decades earlier, that cosmic rays might be able to amplify small changes in solar activity by ionising the atmosphere and triggering cloud formation.

Chilling idea

Increased sunspot activity is known to strengthen the Sun's magnetic field, which deflects more of the galactic cosmic rays entering the solar system and thus reducing the number hitting Earth. The argument championed by Henrik Svensmark is that this would reduce cloud formation in the atmosphere – warming the Earth – and that this effect explains the recent global warming.

The case has been made at greater length in a book Svensmark wrote with science journalist Nigel Calder (who edited New Scientist from 1962 to 1966), called *The Chilling Stars*.

There are at least three separate issues here. First, do cosmic rays really trigger cloud formation? If so, how do the resulting changes in cloud cover affect temperature? Finally, does this explain the warming trend of the past few decades?

Far-fetched concept

There is no convincing evidence that cosmic rays are a major factor determining cloud cover. The ionising of air by cosmic rays will impart an electric charge to aerosols, which in theory could encourage them to clump together to form particles large enough for cloud droplets to form around, called "cloud condensation nuclei".

But cloud physicists say it has yet to be shown that such clumping occurs. And even if it does, it seems far-fetched to expect any great effect on the amount of clouds in the atmosphere. Most of the atmosphere, even relatively clean marine air, has plenty of cloud condensation nuclei already.

A series of attempts by Svensmark to show an effect have come unstuck. Initially, Svensmark claimed there was a correlation between cosmic ray intensity and satellite measurements of total cloud cover since the 1980s – yet a correlation does not prove cause and effect. It could equally well reflect changes in solar irradiance, which inversely correlate with cosmic ray intensity.

Furthermore, this apparent correlation depended on adjustments to the data, and it does not hold up when more recent cloud measurements from 1996 onwards are included.

Beguiling fit

Svensmark and others then pointed to an apparent correlation between low-altitude cloud cover and cosmic rays. But after 1995, the beguiling fit of Svensmark's graph depends on a "correction" of satellite data, and the satellite scientists say this is not justified. "It's dubious manipulation of data in order to suit his hypothesis," says Joanna Haigh, an atmospheric physicist at Imperial College London, UK.

Then there is the question of how changes in clouds will affect climate. Svensmark claims the overall effect of less cloud cover is a warmer world, with less heat loss due to reflection off clouds during the day outweighing higher loss of heat at night.

Yet even during the day, many clouds in the upper atmosphere can have a warming effect. Not all scientists agree that reducing cloud cover would warm the planet.

In fact, clouds are one of the greatest uncertainties in climate science. It is not even clear whether the satellite measurements of changes in cloudiness are correct or how these changes have affected temperature, let alone what will happen in the future. Clouds might mitigate global warming or amplify it.

No trend

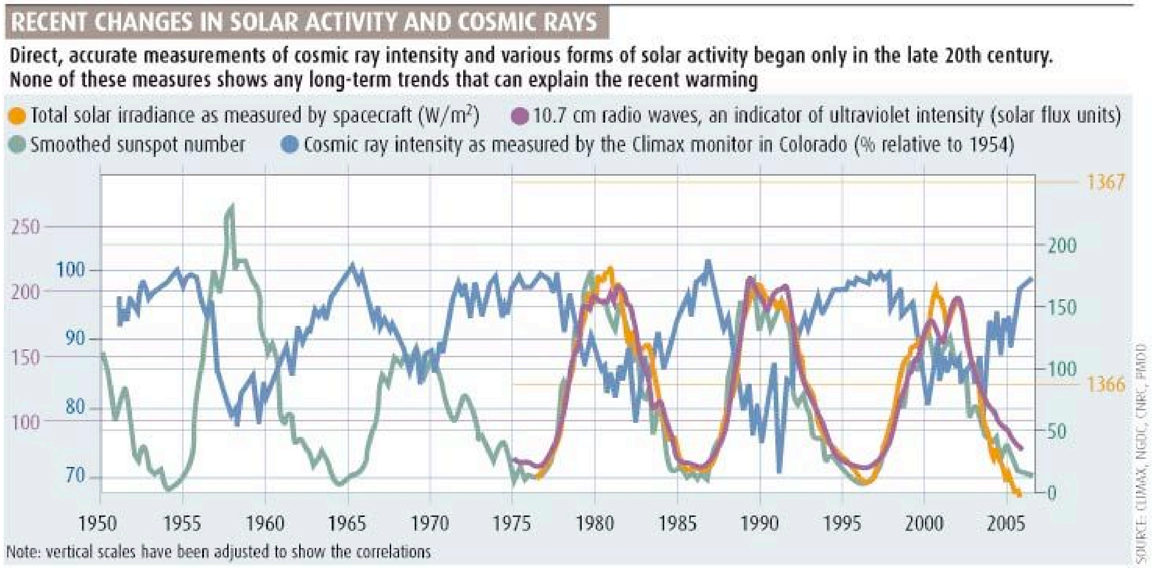
Finally, and most importantly, even if cosmic ray intensity does turn out to influence cloud cover and temperature, it cannot explain the warming trend of the past few decades. Direct measurements of cosmic ray intensity going back as far as 50 years show no downward trend coinciding with the recent warming.

Indirect measurements of cosmic rays, based on the abundance of certain atmospheric isotopes formed by them, suggest that intensity fell between 1900 and 1950. Yet while there can be a lag between a sudden jump in a climate "forcing" and its full effect on temperature, most warming should occur within a few years and taper off within decades..

The wild claims of Svensmark do not mean that the idea of a link between cosmic rays and clouds is nonsense. It is taken seriously by a small number of scientists. A handful of studies using different methods hint at a very tiny effect, though more have found none.

Experiments now underway at the European Laboratory for Particle Physics (CERN) should settle the issue of whether cosmic rays can trigger the formation of cloud condensation nuclei, though this will not reveal whether it matters in the real world.

The bottom line is that whether or not cosmic rays have affected the climate in the more distant past, they cannot explain our planet's recent warming.



Climate myths 11: CO_2 isn't the most important greenhouse gas

17:00 16 May 2007
NewScientist.com news service
David L Chandler

Is water a far more important a greenhouse gas than carbon dioxide, as some claim? It is not surprising that there is a lot of confusion about this – the answer is far from simple.

Firstly, there is the greenhouse effect, and then there is global warming. The greenhouse effect is caused by certain gases (and clouds) absorbing and re-emitting the infrared radiating from Earth's surface. It currently keeps our planet 20°C to 30°C warmer than it would be otherwise. Global warming is the rise in temperatures caused by an increase in the levels of greenhouse gases due to human activity.

Water vapour is by far the most important contributor to the greenhouse effect. Pinning down its precise contribution is tricky, not least because the absorption spectra of different greenhouse gases overlap.

At some of these overlaps, the atmosphere already absorbs 100% of radiation, meaning that adding more greenhouse gases cannot increase absorption at these specific frequencies. For other frequencies, only a small proportion is currently absorbed, so higher levels of greenhouse gases do make a difference.

This means that when it comes to the greenhouse effect, two plus two does not equal four. If it were possible to leave the clouds but remove all other water vapour from the atmosphere, only about 40% less infrared of all frequencies would be absorbed. Take away the clouds and all other greenhouses gases, however, and the water vapour alone would still absorb about 60% of the infrared now absorbed.

By contrast, if CO_2 alone was removed from the atmosphere, only 15% less infrared would be absorbed. If CO_2 was the only greenhouse gas, it would absorb 26% of the infrared currently absorbed by the atmosphere.

A simplified summary is that about 50% of the greenhouse effect is due to water vapour, 25% due to clouds, 20% to CO_2, with other gases accounting for the remainder.

Water cycle

So why aren't climate scientists a lot more worried about water vapour than about CO_2? The answer has to do with how long greenhouse gases persist in the atmosphere. For water, the average is just a few days.

This rapid turnover means that even if human activity was directly adding or removing significant amounts of water vapor (it isn't), there would be no slow build-up of water vapour as is happening with CO_2 (see *Climate myths: Human CO_2 emissions are tiny compared with natural sources*).

The level of water vapor in the atmosphere is determined mainly by temperature, and any excess is rapidly lost. The level of CO_2 is determined by the balance between sources and sinks, and it would take hundreds of years for it to return to pre-industrials levels even if all emissions ceased tomorrow. Put another way, there is no limit to how much rain can fall, but there is a limit to how much extra CO_2 the oceans and other sinks can soak up.

Of course, CO_2 is not the only greenhouse gas emitted by humans. And many, such as methane, are far more powerful greenhouse gases in terms of infrared absorption per molecule.

While methane persists for only about a decade before breaking down, other gases, such as the chlorofluorocarbons (CFCs), can persist in the atmosphere for hundreds or even tens of thousands years. Per molecule, their warming effect is thousands of times greater than carbon dioxide. (Production of CFCs in now banned in most of the world, but because of their ozone destroying properties, not greenhouse properties.)

Double up

But the overall quantities of these other gases are tiny. Even allowing for the relative strength of the effects, CO_2 is still responsible for two-thirds of the additional warming caused by all the greenhouse gases emitted as a result of human activity.

Water vapour will play a huge role in the centuries to come, though. Climate models, backed by satellite measurements, suggest that the amount of water vapor in the upper troposphere (about 5 to 10 kilometers up) will double by the end of this century as temperatures rise.

This will result in roughly twice as much warming than if water vapor remained constant. Changes in clouds could lead to even greater amplification of the warming or reduce it – there is great uncertainty about this. What is certain is that, in the jargon of climate science, water vapor is a feedback, but not a forcing.

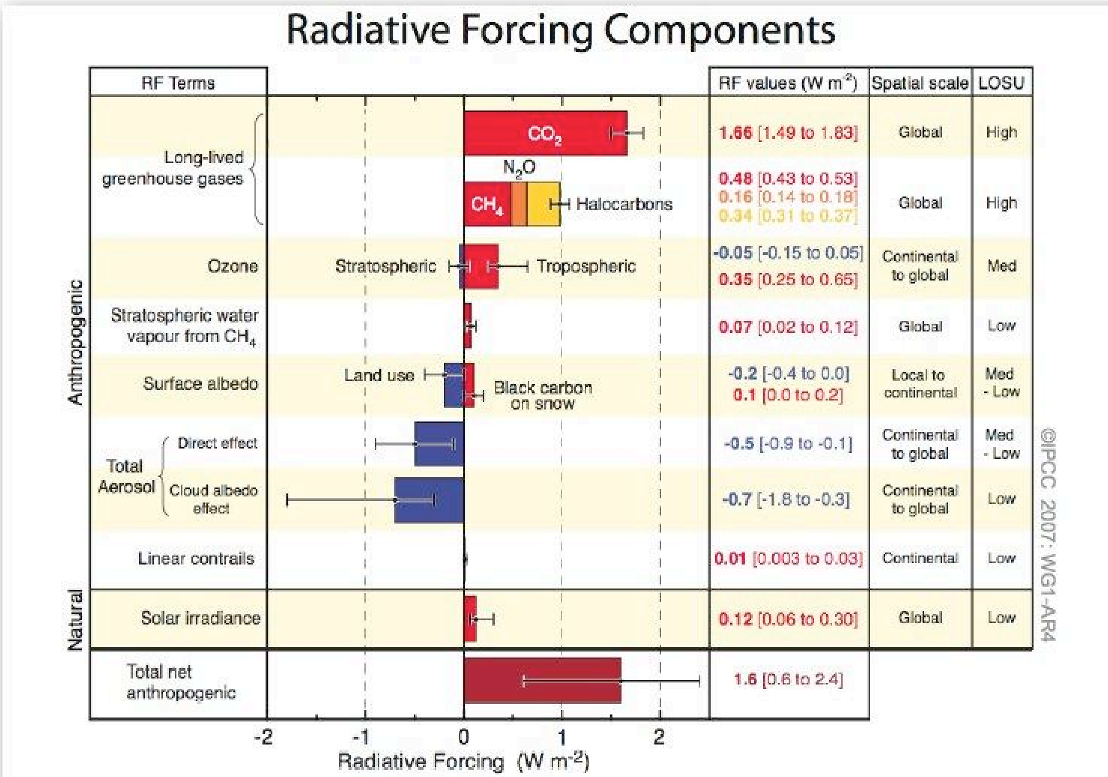


FIGURE SPM-2. Global-average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. Range for linear contrails does not include other possible effects of aviation on cloudiness. {2.9, Figure 2.20}

Climate myths 12: The lower atmosphere is cooling, not warming

17:00 16 May 2007
NewScientist.com news service
Phil McKenna

Increasing levels of greenhouse gases should warm the Earth's surface and the lower atmosphere, and cool the upper layer. So is this happening as the theory and models predict?

Satellites and weather balloon measurements show that the stratosphere, the layer from 10 to 50 kilometers above the Earth, is indeed cooling (although this is partly due to the depletion of the ozone layer).

In 1992, however, an analysis of satellite data by John Christy at the University of Alabama in Huntsville, US, concluded that the lower part of the troposphere – the first 10 kilometers of atmosphere – had cooled relative to the surface since 1979, when the first satellites capable monitoring temperature measurements were launched. This trend seemed to continue into the late 1990s and also seemed to be supported by balloon measurements.

This was not quite the "nail in the coffin" for global warming that some skeptics claimed. If the satellite data was correct, it meant there was something wrong with the existing models of climate change. But it made little sense for the lower atmosphere to be cooling even as the surface warmed, suggesting the problem lay with the data. The jury was out until the issue could be resolved one way or another.

Slowing satellites

The answer came in a series of studies published in 2005 (see *Sceptics forced into climate climbdown*).

One study in *Science* revealed errors in the way satellite data had been collected and interpreted. For instance, the orbit of satellites gradually slows, which has to be taken into account because it affects the time of day at which temperature recording are taken. This problem was always recognized, but the corrections were given the wrong sign (negative instead positive and vice versa).

A second study, also in *Science*, looked at the weather balloon data. Measurements of the air temperature during the day can be skewed if the instruments are heated by sunlight. Over the years the makers of weather balloons had come up with better methods of preventing or correcting for this effect, but because no one had taken these improvements into account, the more accurate measurements appeared to show daytime temperatures getting cooler.

The corrected temperature records show that tropospheric temperatures are indeed rising at roughly the same rate as surface temperatures. Or, as a 2006 report by the US Climate Change Science Program (pdf) puts it: "For recent decades, all current atmospheric data sets now show global-average warming that is similar to the surface warming." This one appears settled.

There is still some ambiguity in the tropics, where most measurements show the surface warming faster than the upper troposphere, whereas the models predict faster warming of the atmosphere. However, this is a minor discrepancy compared with cooling of the entire troposphere and could just be due to the errors of margin inherent in both the observations and the models.

Climate myths 13: Antarctica is getting cooler, not warmer, disproving global warming

17:00 16 May 2007
NewScientist.com news service
Phil McKenna

There is much uncertainty over exactly how Antarctica's climate is changing. There are few weather stations, most are on the edge rather than in the interior of the continent and records go back just a few decades.

It is clear that the Antarctic Peninsula, which juts out from the mainland of Antarctica towards South America, has warmed significantly. The continent's interior was thought to have warmed too, but in 2002 a new analysis of records from 1966 to 2000 concluded that it has cooled overall.

This study was promptly seized upon as proof that the world is not warming, but a single example of localized cooling proves no such thing, as the lead author of the 2002 study has tried to point out.

Climate models do not predict an evenly spread warming of the whole planet: changes in wind patterns and ocean currents can change the distribution of heat, leading to some parts warming much faster than average, while others cool at first. What matters is the overall picture, and global temperature maps show far more areas are warming than cooling.

Blowing in circles

So what is happening in Antarctica? The cooling is due to a strengthening of the circular winds around the continent, which prevent warmer air reaching its interior. The increased wind speeds seem to be a result of cooling in the upper atmosphere, caused by the hole in the ozone layer above the pole, which is of course the result of chlorofluorocarbon (CFC) pollution.

Confusingly, it appears that one human impact on the climate – the Antarctic ozone hole – is currently compensating for another, global warming. If the ozone layer recovers over the decades as expected, the circular winds could weaken, resulting in rapid warming.

This raises the question of what is happening to Antarctica's ice sheets, which hold enough water to raise sea level by a catastrophic 61 metres, should it all melt. Contrary to what you might expect, the third IPPC report predicted that global warming would most likely lead to a thickening of the ice sheet over the next century, with increased snowfall compensating for any melting cause by warming.

Gravity revelations

Finding out what is actually happening to the ice is not easy. Radar measurements of the height of the ice over parts of the continent suggest that the huge East Antarctic ice sheet grew slightly between 1992 and 2003.

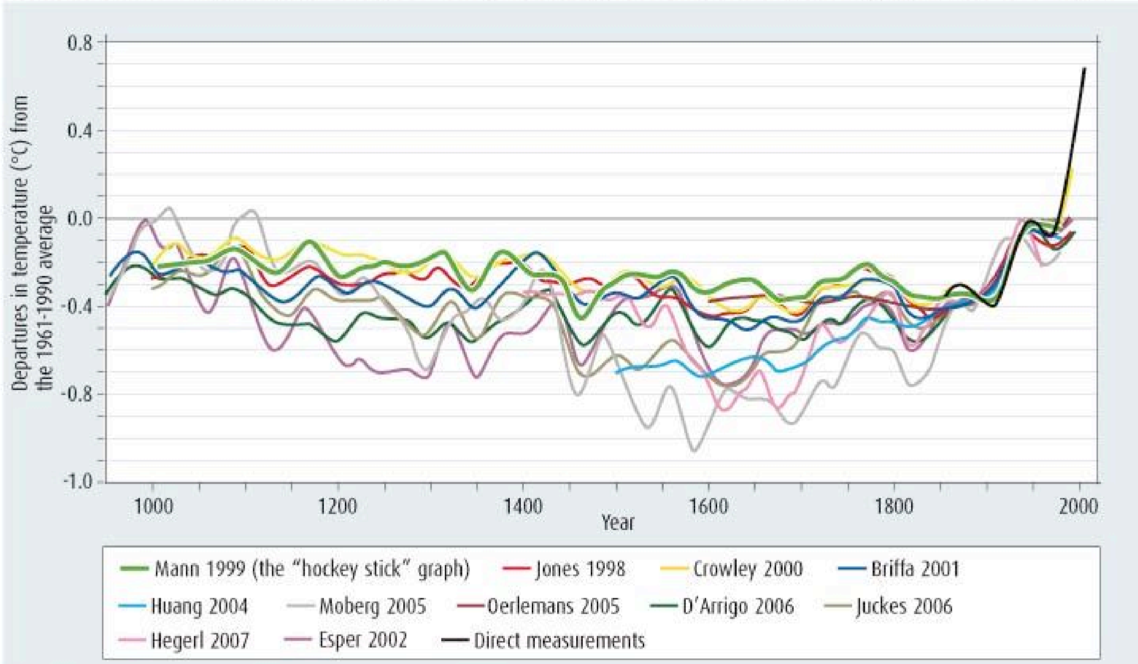
A more recent study based on satellite measurements of gravity over the entire continent suggests that while the ice sheets in the interior of Antarctica are growing thicker, even more ice is being lost from the peripheries. The study concluded that there was a net loss of ice between 2002 and 2005, adding 0.4 millimetres per year to sea levels (see *Gravity reveals shrinking Antarctic ice*). Most of the ice was lost from the smaller West Antarctic ice sheet.

Greenland, whose ice cap holds enough water to raise sea levels by 7 meters, is also losing ice overall. Small amounts of meltwater appear to be lubricating the base of glaciers, speeding the flow of ice into the sea.

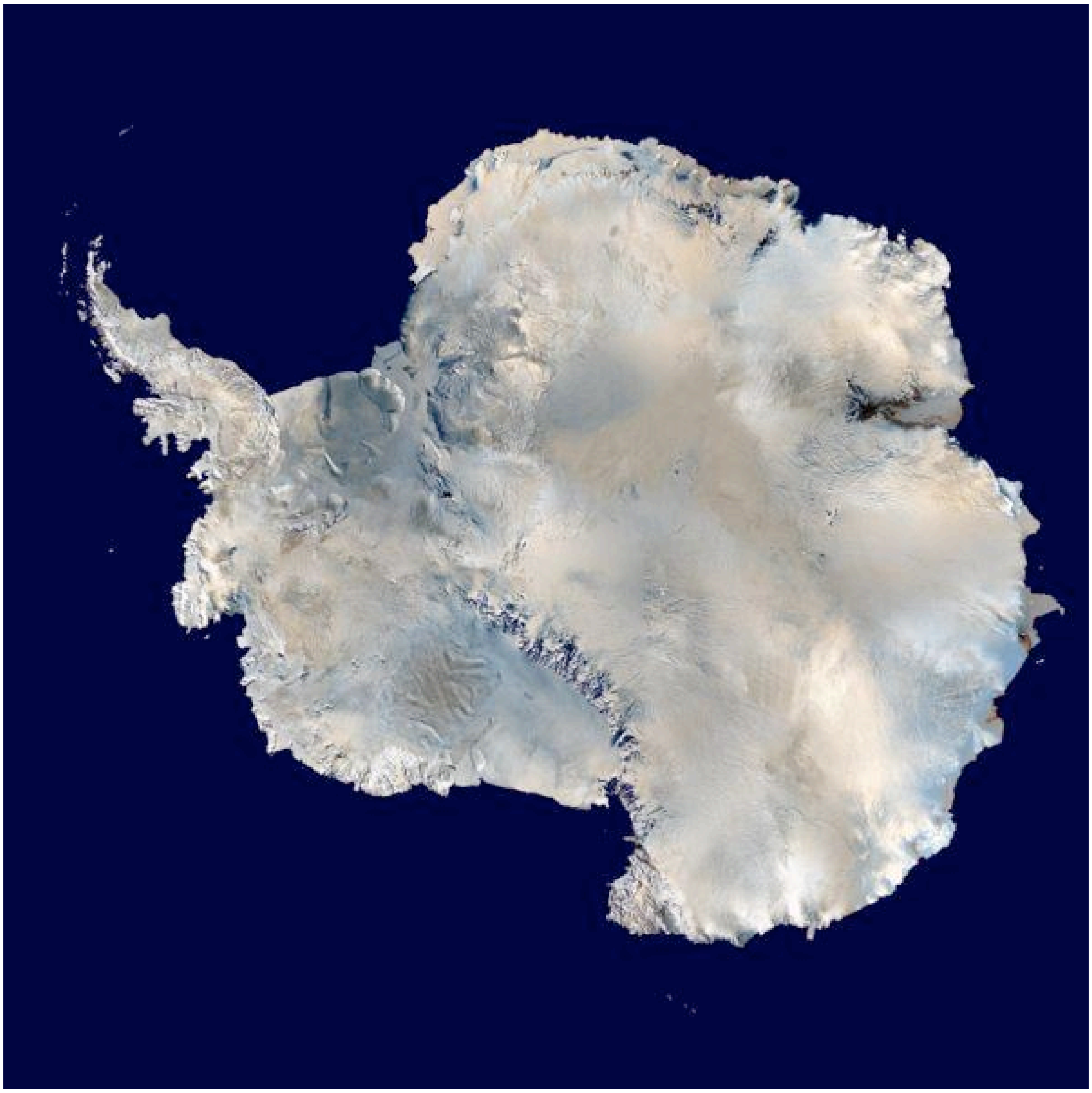
The IPCC's latest prediction for sea level rise – 0.2 to 0.6 meters by 2100 – takes this ice loss into account but it is based on the assumption that the rate of ice loss will remain constant. Many researchers think this is unrealistic and that the rate of ice loss will accelerate, which means that sea level could rise much faster than predicted. But no one knows for sure what will happen and the prediction of a net gain of ice in Antarctica could yet turn out to be correct.

TEMPERATURE OVER THE PAST 1000 YEARS

Reconstructions of northern hemisphere temperature vary but all suggest it is warmer now than at any time in the past 1000 years



Compiled for *New Scientist* by Rob Wilson of the University of Edinburgh, UK



Antarctica

Climate myths 14: The oceans are cooling

17:00 16 May 2007

NewScientist.com news service

Michael Le Page

One study in 2006 suggested that the upper layers of the ocean had cooled between 2003 and 2005. The apparent cooling was very slight – just 0.02°C – but needless to say, this should not be happening if the planet is getting warmer (see *Cooling oceans buck global trend*).

The study was based on measurements taken by a worldwide array of floats (the Argo Network) that monitor the upper 2 kilometres of the ocean. The finding was surprising because other studies have concluded that the oceans are warming very much as predicted.

Now the authors of the 2006 study have submitted a correction (pdf format). It turns out that a fault in the software on some of the floats led to some temperature measurements being associated with the wrong depth.

Meanwhile, work by other teams suggests that the past warmth of the oceans has been overestimated. The problem was due to expendable sensors that are thrown overboard and take measurements as they sink. Some did not sink as fast as expected.

While there is still some doubt about precisely how much the oceans have warmed, they *are* warming. In particular, there is a strong warming trend from the 1990s onwards – just as the models predict.

Climate myths 15: The cooling after 1940 shows CO_2 does not cause warming

17:00 16 May 2007
NewScientist.com news service
Catherine Brahic

After rising rapidly during the first part of the 20th century, global average temperatures did cool by about 0.2°C after 1940 and remained low until 1970, after which they began to climb rapidly again.

The mid-century cooling appears to have been largely due to a high concentration of sulphate aerosols in the atmosphere, emitted by industrial activities and volcanic eruptions. Sulphate aerosols have a cooling effect on the climate because they scatter light from the Sun, reflecting its energy back out into space.

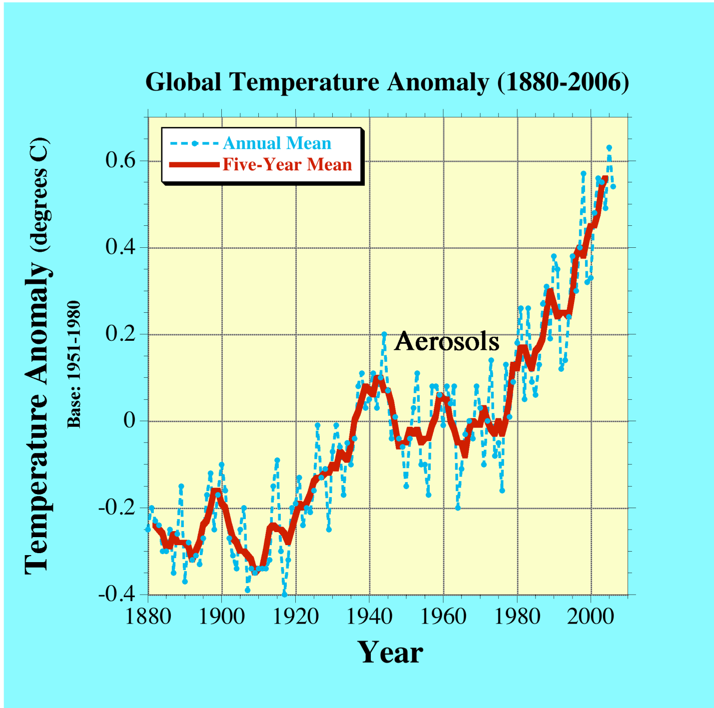
The rise in sulphate aerosols was largely due to the increase in industrial activities at the end of the second world war. In addition, the large eruption of Mount Agung in 1963 produced aerosols which cooled the lower atmosphere by about 0.5°C, while solar activity levelled off after increasing at the beginning of the century

The clean air acts introduced in Europe and North America reduced emissions of sulphate aerosols. As levels fell in the atmosphere, their cooling effect was soon outweighed by the warming effect of the steadily rising levels of greenhouse gases. The mid-century cooling can be seen in this NASA/GISS animation, which shows temperature variation from the annual mean for the period from 1880 through 2006. The warmest temperatures are in red.

Climate models that take into account only natural factors, such as solar activity and volcanic eruptions, do not reproduce 20th century temperatures very well. If, however, the models include human emissions, including greenhouse gases and aerosols, they accurately reproduce the 1940 to 1970 dip in temperatures.

How aerosols will influence the climate over the coming century is unclear. While aerosol emissions have fallen in Europe and the US (and in the former Soviet Union after 1991), they are now rising rapidly in China and India.

The picture is complicated because different kinds of aerosols can have different effects: black carbon or soot has warming rather than a cooling effect, for instance. Then there is the question of how all the different aerosols affect clouds. Climate scientists acknowledge that the aerosol issue is one of the key uncertainties in their understanding.



The cooling after 1940 was due to human-caused aerosols.

Climate myths 16: It was warmer during the Medieval period, with vineyards in England

17:00 16 May 2007
NewScientist.com news service
Michael Le Page

English wine production is once again thriving and the extent of the country's vineyards probably surpasses that in the so-called Medieval Warm Period. So if you think vineyards are an accurate indicator of temperature, this suggests it is warmer now than it was then.

The point is that historical anecdotes about the past climate, such as the claim that Greenland used to be green, or that Newfoundland (Vinland) was full of grapes, have to be treated with caution.

For starters, the accuracy of some historical claims is questionable: it is not clear that Vinland of Viking sagas refers to modern-day Newfoundland, or even that there really were grapes, for instance.

Even when historical records are accurate, their interpretation is not as straightforward as many assume. Take the frost fairs held when the River Thames in England froze over, which are sometimes hailed as proof of how cold it was during the so-called Little Ice Age (see *We are just recovering from the Little Ice Age*). The slowing of water flow by the old London Bridge is now seen as a crucial factor in the freezing of the river, which explains why the river did not freeze in 1963 even though it was the third-coldest winter in England since 1659.

Growth bands and coral

To work out how the average global temperature has changed over the centuries, climate scientists need long-term records from as many different parts of the world as possible. Historical records do not provide this, which is why they have turned to other indicators such as growth bands in trees and corals.

These proxy records have their problems too: tree rings can reflect the effects of rainfall as well as temperature, for instance. The uncertainties also become greater the further back you look, as the evidence becomes sparser. And there are also very few proxies from the southern hemisphere, so most reconstructions are of northern hemisphere temperature only.

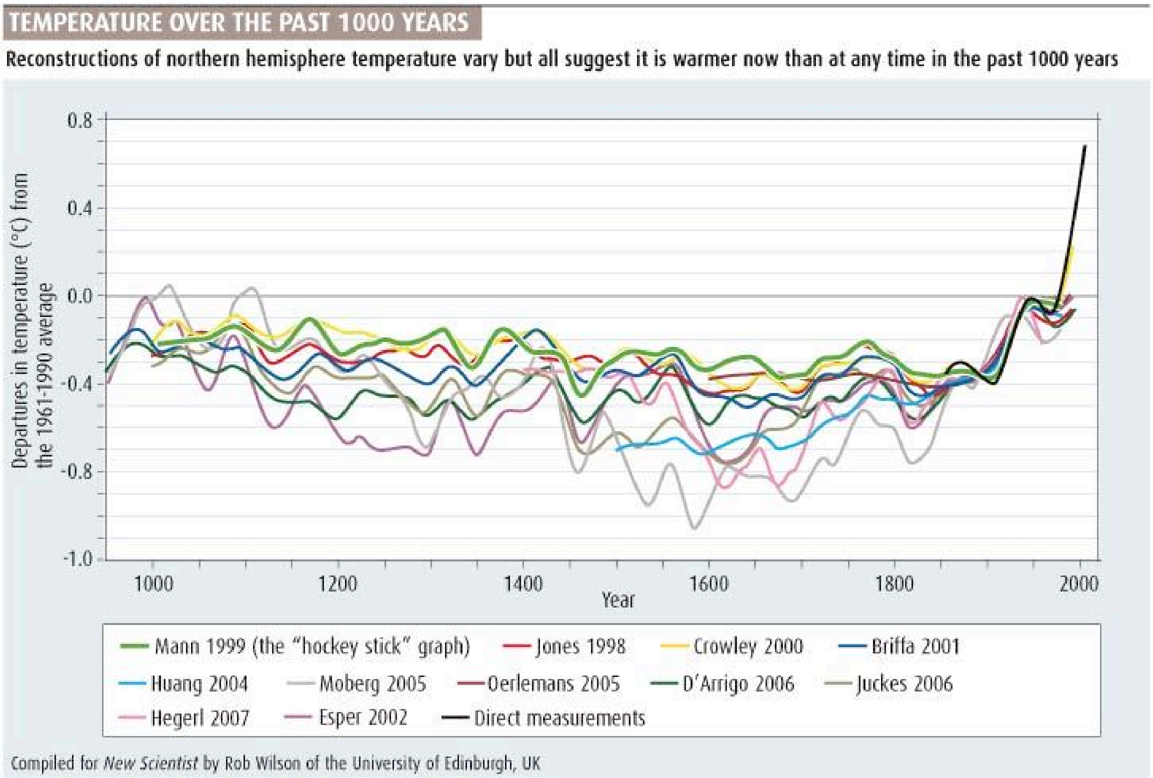
There are a dozen or so temperature reconstructions for the northern hemisphere that go back beyond 1600, including the so-called "hockey stick" (see *Climate myths: The 'hockey stick' graph has been proven wrong*). These studies suggest there were periods of unusual warmth from around AD 900 to AD 1300, but details vary widely in each reconstruction.

What matters most

In the southern hemisphere, the picture is even more mixed, with evidence of both warm and cool periods around this time. The Medieval Warm Period may have been partly a regional phenomenon, with the extremes reflecting a redistribution of heat around the planet rather than a big overall rise in the average global temperature.

What is clear, both from the temperature reconstructions and from independent evidence – such as the extent of the recent melting of mountain glaciers – is that the planet has been warmer in the past few decades than at any time during the medieval period. In fact, the world may not have been so warm for 6000 or even 125,000 years (see *Climate myths: It has been warmer in the past, what's the big deal?*).

What really matters, though, is not how warm it is now, but how warm it is going to get in the future. Even the temperature reconstructions that show the greatest variations in the past 1000 years suggest up until the 1980s, average temperature changes remained within a narrow band spanning 1ºC at most. Now we are climbing out of that band, and the latest IPCC report (pdf format) predicts a further rise of 0.5ºC by 2030 and a whopping 6.4ºC by 2100 in the worst case scenario.



Climate myths 17: Warming will cause an ice age in Europe

17:00 16 May 2007
NewScientist.com news service
Stephen Battersby

While the rest of Earth swelters, might Europe and parts of North America freeze? This scenario was always unlikely, and the latest findings largely rule it out.

Europe and parts of North America are kept milder than other northerly parts by warm water flowing north from the Caribbean in an ocean current called the North Atlantic Drift. If climate change broke this heating system, European temperatures could drop by up to 5°C or more within decades.

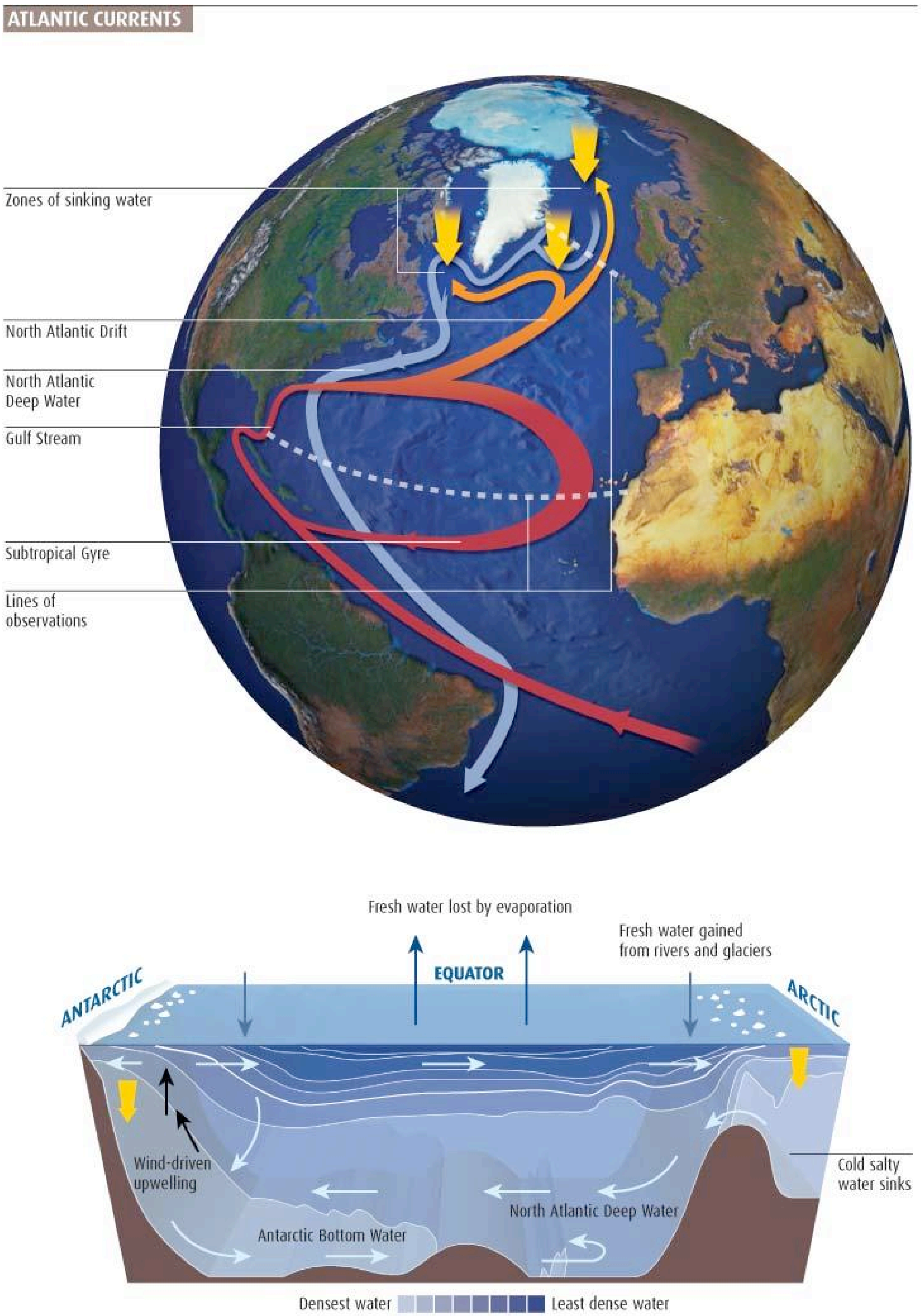
Some have even talked of a new ice age, of tundra spreading across the continent, while the film *The Day After Tomorrow* depicted the Earth plunging into a super ice age within weeks (see *Scientists stirred to ridicule ice age claims*).

Well, global warming certainly could disturb ocean currents. They are largely driven by the sinking of cold, salty water in the Arctic, but melting glaciers and swollen rivers are now pouring more fresh water into the surface of the Arctic ocean than before. Fresh water is less dense than salty, so it weakens this "pump". Enough could hinder ocean circulation, or even cut it off, as may have happened in the past.

In 2005, climatologists were shocked by evidence that it was already happening. A team of oceanographers led by Harry Bryden of Southampton University, UK, claimed there was a 30% reduction in the vital Atlantic current. But subsequent measurements by the team show no clear trend.

Few scientists think there will be a rapid shutdown of circulation. Most ocean models predict no more than a slowdown, probably towards the end of the century. This could slow or even reverse some of the warming due to human emissions of greenhouse gases, which might even be welcome in an overheated Europe, but the continent is not likely to get colder than it is at present.

A slowdown in circulation would affect many parts of the world by disrupting global rainfall patterns. But these effects will be insignificant compared with the much greater changes global warming will cause (see also *It's too cold where I live. A bit of warming will be great*).



Thermohaline circulation in the Atlantic Ocean.

Climate myths 18: Ice cores show CO_2 increases lag behind temperature rises, disproving the link to global warming

17:00 16 May 2007
NewScientist.com news service
Catherine Brahic

Ice cores from Antarctica show that at the end of recent ice ages, the concentration of carbon dioxide in the atmosphere usually started to rise only after temperatures had begun to climb. There is uncertainty about the timings, partly because the air trapped in the cores is younger than the ice, but it appears the lags might sometimes have been 800 years or more.

This proves that rising CO_2 was not the trigger that caused the initial warming at the end of these ice ages – but no climate scientist has ever made this claim. It certainly does not challenge the idea that more CO_2 heats the planet.

We know that CO_2 is a greenhouse gas because it absorbs and emits certain frequencies of infrared radiation. Basic physics tells us that gases with this property trap heat radiating from the Earth, that the planet would be a lot colder if this effect was not real and that adding more CO_2 to the atmosphere will trap even more heat.

What is more, CO_2 is just one of several greenhouses gases, and greenhouse gases are just one of many factors affecting the climate. There is no reason to expect a perfect correlation between CO_2 levels and temperature in the past: if there is a big change in another climate "forcing", the correlation will be obscured.

So why has Earth regularly switched between ice ages and warmer interglacial periods in the past million years? It has long been thought that this is due to variations in Earth's orbit, known as Milankovitch cycles. These change the amount and location of solar energy reaching Earth. However, the correlation is not perfect and the heating or cooling effect of these orbital variations is small. It has also long been recognized that they cannot fully explain the dramatic temperature switches between ice ages and interglacials.

So if orbital changes did cause the recent ice ages to come and go, there must also have been some kind of feedback effect that amplified the changes in temperatures they produced. Ice is one contender: as the great ice sheets that covered large areas of the planet during the ice ages melted, less of the Sun's energy would have been reflected back into space, accelerating the warming. But the melting of ice lags behind the beginning of interglacial periods by far more than the rises in CO_2.

World warmer

Another feedback contender, suggested over a century ago, is CO_2. In the past decade, detailed studies of ice cores have shown there is a remarkable correlation between CO_2 levels and temperature over the past half million years (see *Vostok ice cores show constant CO_2 as temperatures fell*).

It takes about 5000 years for an ice age to end and, after the initial 800 year lag, temperature and CO_2 concentrations in the atmosphere rise together for a further 4200 years.

What seems to have happened at the end of the recent ice ages is that some factor – most probably orbital changes – caused a rise in temperature. This led to an increase in CO_2, resulting in further warming that caused more CO_2 to be released and so on: a positive feedback that amplified a small change in temperature. At some point, the shrinking of the ice sheets further amplified the warming.

Models suggest that rising greenhouse gases, including CO_2, explains about 40% of the warming as the ice ages ended. The figure is uncertain because it depends on how the extent of ice coverage changed over time, and there is no way to pin this down precisely.

Biological activity

The source of this extra carbon was the oceans, but why did they release CO_2 as the planet began to warm? Many factors played a role and the details are still far from clear.

CO_2 is less soluble in warmer water, but its release as a result of warming seawater can explain only part of the increase in CO_2. And the reduction in salinity as ice melted would have partly counteracted this effect.

A reduction in biological activity may have played a bigger role. Tropical oceans tend to release CO_2, while cooler seas soak up CO_2 from the atmosphere as phytoplankton grow and fall to the ocean floor. Changes in factors such as winds, ice cover and salinity would have cut productivity, leading to a rise in CO_2.

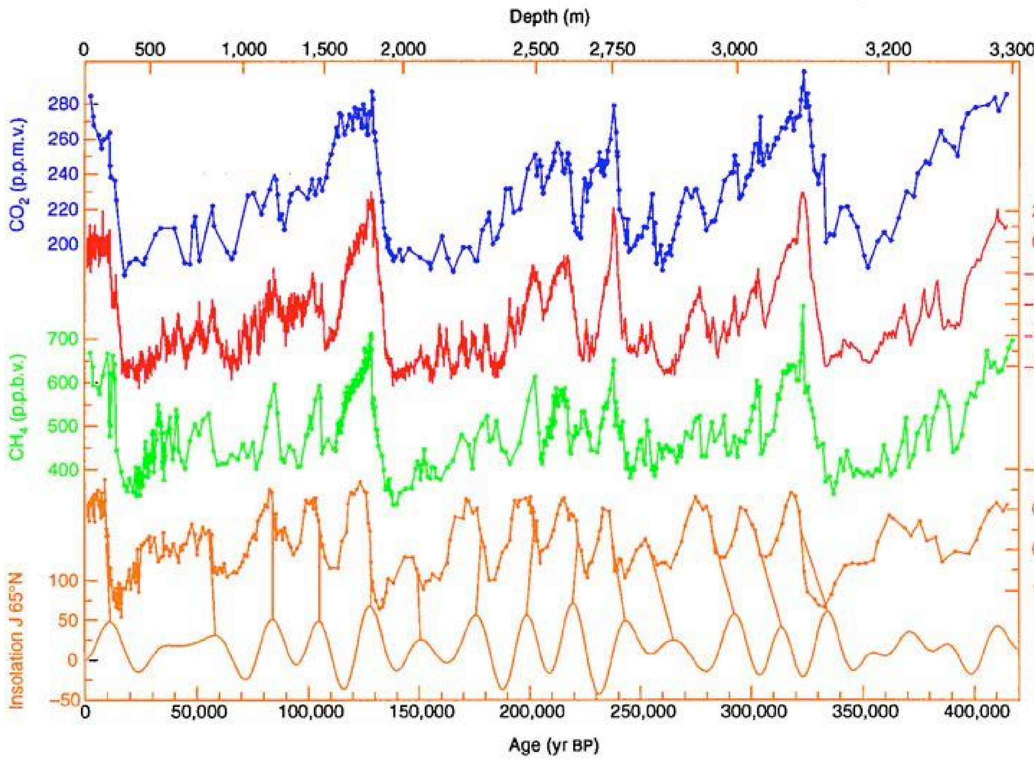
Runaway prevention

The ice ages show that temperature can determine CO_2 as well as CO_2 driving temperature. Some sceptics – not scientists – have seized upon this idea and are claiming that the relation is one way, that temperature determines CO_2 levels but CO_2 levels do not affect temperature.

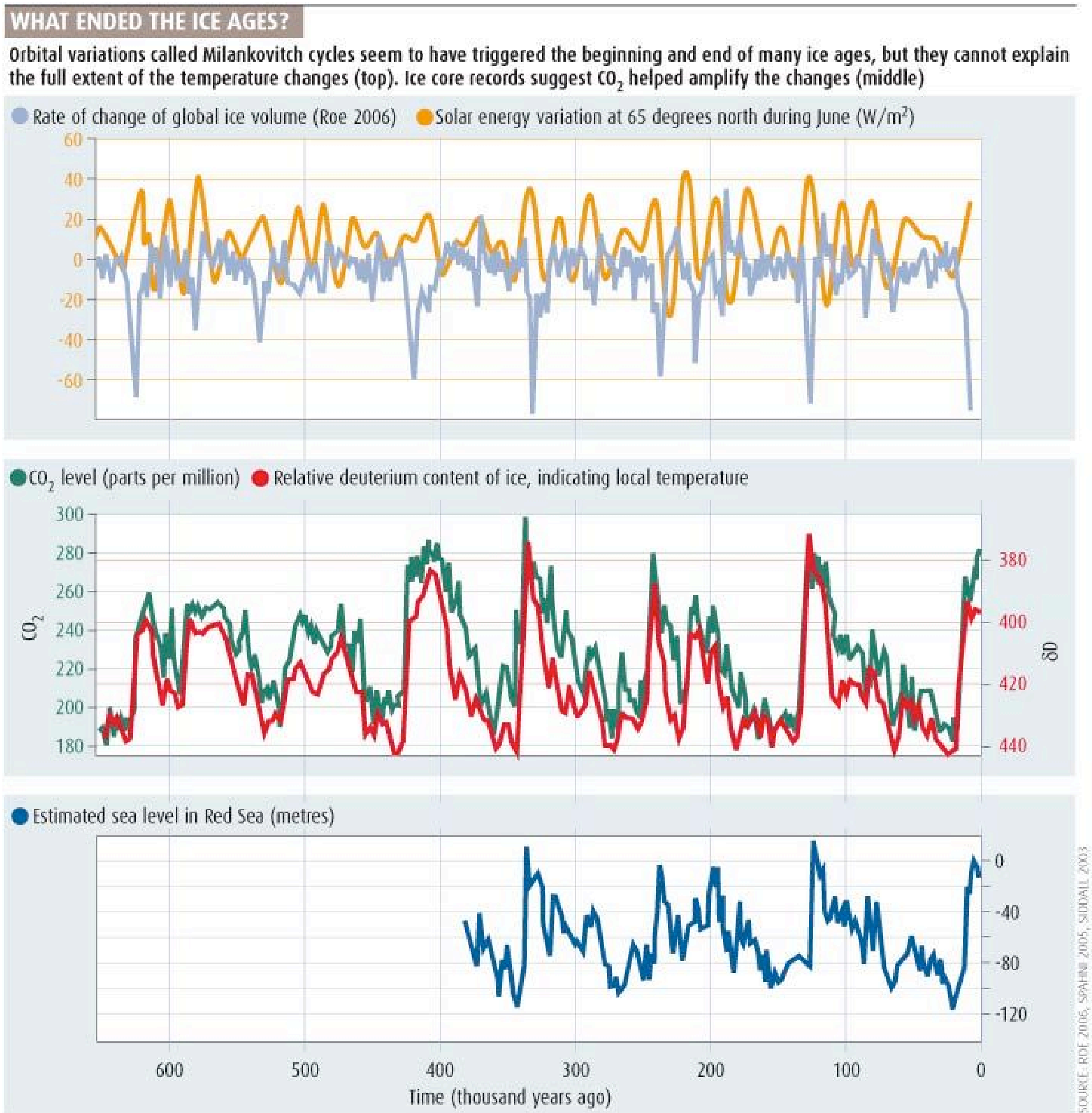
To repeat, the evidence that CO_2 is a greenhouse gas depends mainly on physics, not on the correlation with past temperature, which tells us nothing about cause and effect. And while the rises in CO_2 a few hundred years after the start of interglacials can only be explained by rising temperatures, the full extent of the temperature increases over the following 4000 years can only be explained by the rise in CO_2 levels.

What is more, further back in past there are examples of warmings triggered by rises in greenhouse gases, such as the Palaeo-Eocene Thermal Maximum 55 millions years ago (see *Climate myths: It's been far warmer in the past, what's the big deal?*).

Finally, if higher temperatures lead to more CO_2 and more CO_2 leads to higher temperatures, why doesn't this positive feedback lead to a runaway greenhouse effect? There are various limiting factors that kick in, the most important being that infrared radiation emitted by Earth increases exponentially with temperature, so as long as some infrared can escape from the atmosphere, at some point heat loss catches up with heat retention.



Temperature and CO2 variation in the Vostok ice core compared with changes in solar irradiance due to orbital variations.



What ended the Ice Ages?

Climate myths 19: Ice cores show CO_2 rising as temperatures fell

18:00 16 May 2007
NewScientist.com news service
Michael Le Page

How should past CO_2 levels compare with past temperatures? If there is no relation between CO_2 and temperature, there should be no correlation at all. If CO_2 is the only factor determining temperature, there should be a very close correlation.

If CO_2 is just one of several factors, the degree of correlation will depend on the relative importance of CO_2 and will vary depending on how much other factors change.

So what has actually happened? The best evidence comes from ice cores. As the snow falling on the ice sheets in Antarctica or Greenland is slowly compressed into ice, bubbles of air are trapped, making it possible to work out the concentration of CO_2 in the atmosphere going back hundreds of thousands of years.

There is no way to work out the global temperature at the time the ice formed, but clues to the local temperature come from the relative amount of heavy hydrogen (deuterium) in the water molecules of the ice compared with seawater, or from the amount of oxygen-18.

It takes more energy to get heavier water molecules into the atmosphere and to keep them there. What this means is that the isotopic content of water falling as rain or snow depends on the temperature of the sea from which it evaporated and on the air that carried the water vapour, and is thus related to local temperatures.

Observations show for any particular region there is usually a strong correlation between the average annual deuterium content of rain or snow and average annual surface temperatures: the higher the deuterium content, the warmer the year. So the deuterium content of ancient ice provides a rough measure of past changes in temperature.

Global thermometer

However, there are numerous problems with relying on the relative deuterium content as a "palaeothermometer". To mention just one, if changes in air circulation bring water from a different source region to the Antarctic, there may be a change in the deuterium content of snow even though there was no change in the local temperature.

Comparing this temperature record with the CO_2 level in trapped bubbles brings another problem: the air in the bubbles can be hundreds or even thousands of years younger than the ice in which it is trapped. Air is trapped in a layer only after the snow above it has built up to a thickness of 70 metres or more, and the time this takes can vary greatly as the climate changes.

Despite these issues, ice cores from Greenland and Antarctica show that the local temperature as measured by the deuterium content correlates remarkably well with atmospheric CO_2 levels going back hundreds of thousands of years.

This correlation alone does not establish cause and effect. In fact, there is evidence that temperature can determine CO_2 levels to some extent by affecting natural sources and sinks (see *Ice cores show CO_2 only rose after the start of warm periods*).

But together with the indisputable fact that CO_2 absorbs infrared radiation and thus acts as a greenhouse gas, the close correlation is strong evidence that CO_2 levels were one of the major factors determining global temperature during the past half million years, although they were not the trigger that started or ended the ice ages.

Mismatch issues

There are some mismatches though. Besides lags at the end of ice ages, cores taken from the ice overlying the famous lake below Vostok in Antarctica seemed to show that about 120,000 years ago, the temperature plummeted sharply while CO_2 levels remained high for many thousands of years.

The question is whether this is real or just a reflection of the problems with working out the age of the trapped air and with deuterium as a temperature indicator. Many researchers are working on ways to independently date the air and the ice, and to improve temperature reconstructions based on relative deuterium content. One involves working out what is called the deuterium excess by comparing the relative amounts of deuterium and oxygen-18 in the ice.

The deuterium excess reflects the temperature at the sea surface where the water that later fell as snow evaporated, rather than the surface temperature where the snow fell. It helps to reveal whether variations in the relative deuterium content of the ice are a result of water coming from a different source region rather than changes in local temperature.

In 2001, researchers used the deuterium excess to correct for some of the problems with the temperature record of the Vostok ice core. Their results produce a much closer fit between temperature and CO_2 levels and reduces the mismatch around 120,000 years ago to a few thousand years.

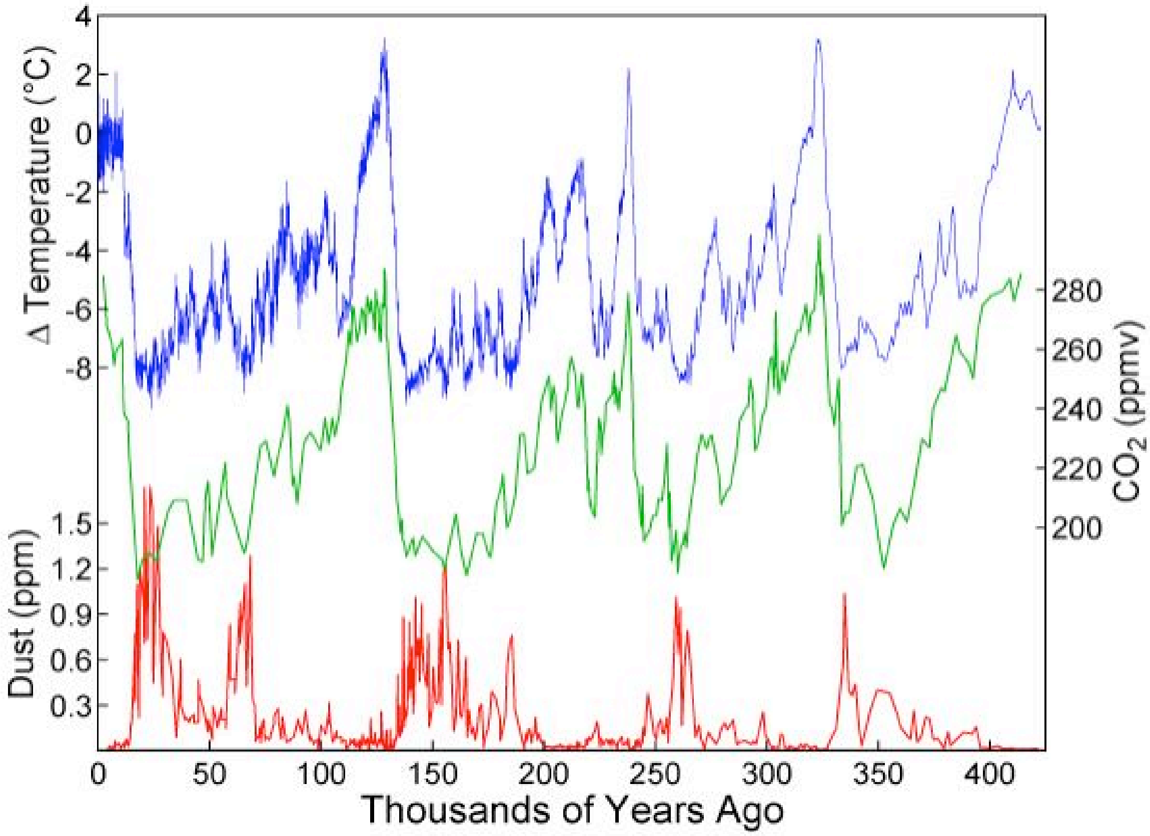
The existence of such mismatches is not surprising given all the problems with interpreting the deuterium record, the possibility of errors in measurements and the fact that CO_2 level is not the only factor affecting temperature. After all, the correlation between CO_2 and temperature over the past century is not that close (see *Global temperatures fell between 1940 and 1980*).

Jury still out

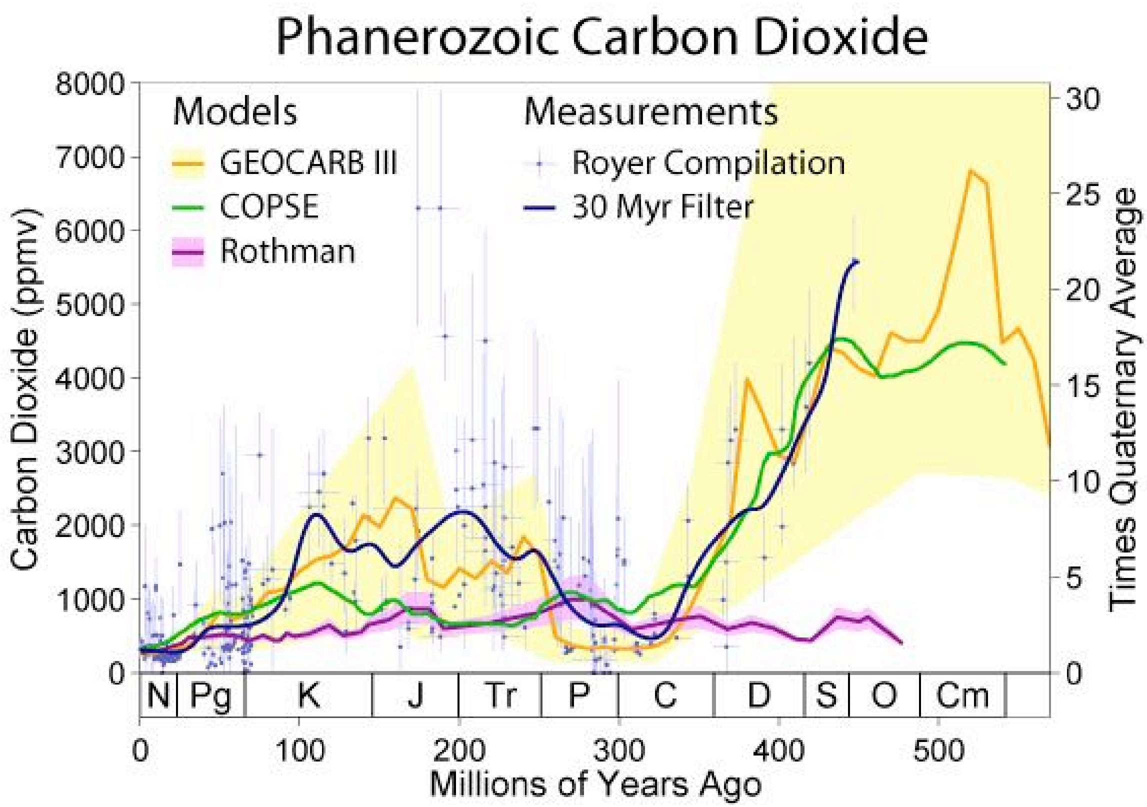
On a much bigger timescale, looking back 600 million years or more – when CO_2 levels may have been as high as 5000 parts per million at times – there are substantial questions about whether the CO_2-temperature correlation holds up. Some studies suggest that there are major discrepancies during at least two periods. Others claim the relationship holds up fairly well (pdf document), including this recent study.

The jury is still out because the reliability of estimates of temperature and CO_2 levels so long ago is extremely questionable. For instance, estimates of past CO_2 levels based on isotopic ratios in carbonates in fossil soils can differ substantially from those based on the density of pores in fossil leaves. These pores, called stomata, let in CO_2, so fewer are needed when CO_2 levels are high.

As with the warming in recent decades, to understand the causes of climate changes in the distant past we have to look at all the factors involved, from the steady increase in the Sun's luminosity to the dust thrown up by volcanoes. If one or more of these factors had a much bigger impact than CO_2 at certain times during the past, then the link between CO_2 and temperature will be obscured.



Vostok ice core data showing temperature (blue), dust (red), and CO2 levels (green).



Various estimates of CO22 levels over the past half billion years.

Climate myths 20: Mars and Pluto are warming too

17:00 16 May 2007
NewScientist.com news service
Michael Le Page

There have been claims that warming on Mars and Pluto are proof that the recent warming on Earth is caused by an increase in solar activity, and not by greenhouses gases. But we can say with certainty is that even if Mars, Pluto or any other planets have warmed in recent years, it is not due to changes in solar activity.

There are two big problems with the idea: the evidence for warming on Mars and Pluto is sketchy, while the Sun's energy output has not increased since direct measurements began in 1978 (see *Climate myth special: Global warming is down to the Sun, not humans*). If increased solar output really was responsible, we should be seeing warming on all the planets and their moons, not just Mars and Pluto.

Our solar system has eight planets, one dwarf planet and quite a few moons with at least a rudimentary atmosphere, and thus a climate of sorts. Their climates will be affected by local factors such as orbital variations, changes in reflectance (albedo) and even volcanic eruptions, so it would not be surprising if several planets and moons turn out to be warming at any one time.

However, given that a year on Mars is nearly two Earth years long, and that a year on Pluto lasts for 248 Earth years, it is rather early to start drawing conclusions about long-term climate trends on the outer bodies of the Solar System.

What do we know? Images of Mars suggest that between 1999 and 2005, some of the frozen carbon dioxide that covers the south polar region turned into gas (sublimated). This may be the result of the whole planet warming (see *Mars images hint at recent climate swings*).

Dwarf planet

One theory is that winds have recently swept some areas of Mars clean of dust, darkening the surface, warming the Red Planet and leading to further increases in windiness – a positive feedback effect (see *Dust blamed for warming on Mars*).

There is a great deal of uncertainty, though. The warming could be a regional effect. And recent results from the thermal imaging system on the Mars Odyssey probe suggest that the polar cap is not shrinking at all, but varies greatly from one Martian year to the next, although the details have yet to be published.

Observations of the thickness of Pluto's atmosphere in 2002 suggested the dwarf planet was *warming even as its orbit took it further from the Sun*. The finding baffled astronomers, and the cause has yet to be determined.

It has since been suggested that this is due to a greenhouse effect: as it gets closer to the sun Pluto may warm enough for some of the methane ice on its surface to turn into a gas. This would cause further warming, which would continue for a while even after Pluto's orbit starts to take it away from the Sun.

Climate myths 21: Many leading scientists question climate change

17:00 16 May 2007
NewScientist.com news service
Michael Le Page

Climate change sceptics sometimes claim that many leading scientists question climate change. Well, it all depends on what you mean by "many" and "leading". For instance, in April 2006, 60 "leading scientists" signed a letter urging Canada's new prime minister to review his country's commitment to the Kyoto protocol.

This appears to be the biggest recent list of skeptics. Yet many, if not most, of the 60 signatories are not actively engaged in studying climate change: some are not scientists at all and at least 15 are retired.

Compare that with the dozens of statements on climate change from various scientific organizations around the world representing tens of thousands of scientists, the consensus position represented by the IPCC reports and the 11,000 signatories to a petition condemning the Bush administration's stance on climate science.

The fact is that there is an overwhelming consensus in the scientific community about global warming and its causes. There are some exceptions, but the number of skeptics is getting smaller rather than growing.

Even the position of perhaps the most respected skeptic, Richard Lindzen of MIT, is not that far off the mainstream: he does not deny it is happening but thinks future warming will not be nearly as great as most predict.

Of course, just because most scientists think something is true does not necessarily mean they are right. But the reason they think the way they do is because of the vast and growing body of evidence. A study in 2004 looked at the abstracts of nearly 1000 scientific papers containing the term "global climate change" published in the previous decade. Not one rejected the consensus position. One critic promptly claimed this study was wrong – but later quietly withdrew the claim.

Climate myths 22: It's all a conspiracy

17:00 16 May 2007
NewScientist.com news service
Michael Le Page

Conspiracy (*noun*): a secret plan by a group to do something unlawful or harmful.

If you believe that tens of thousands of scientists are colluding in a massive conspiracy, nothing anyone can say is likely to dissuade you. But there are less extreme versions of this argument.

One is that climate scientists foster alarmism about global warming to boost their funding. Another is that climate scientists' dependence on government funding ensures they toe the official line (pdf).

It has taken more than a century to reach the current scientific consensus on climate change (see *Many leading scientists question the idea of human-induced climate change*). It has come about through a steadily growing body of evidence from many different sources, and the process has hardly been secret.

Now that there is a consensus, those whose findings challenge the orthodoxy are always going have a tougher time convincing their peers, as in any field of science. For this reason, there will inevitably be pressure on scientists who challenge the consensus. But findings or ideas that clash with the idea of human-induced global warming have not been suppressed or ignored – far from it.

Cosmic rays

In fact, many of the better arguments seized upon by skeptics have been based on contradictory findings published in prominent journals, from the apparent cooling of the lower atmosphere (see *The lower atmosphere is cooling, not warming*) to the apparent cooling of the oceans (see *The oceans are cooling*).

Millions will be spent testing whether cosmic rays can form cloud condensation nuclei, even though some regard this as a waste of money (see *Cosmic rays are causing climate change*).

As for funding, the US spends billions of dollars on climate science and this increased by 55% from 1994 to 2004. However, an increasing portion of this is spent on mitigation technology rather than pure research. Climate scientists point out that if they were after a bigger chunk of that money, their best bet would be to stress the uncertainties of climate change and call for more research, rather than call for action.

Under pressure

As for the idea that scientists change their tune to keep their paymasters happy, under the current US administration many scientists claim they have been pressurized to tone down findings relating to climate change (see *US fudging of climate science details revealed*).

Indeed, those campaigning for action to prevent further warming have had to battle against huge vested interests, including the fossil-fuel industry and its many political allies. Many of the individuals and organisations challenging the idea of global warming have received funding from companies such as ExxonMobil.

That in itself does not necessarily mean that the skeptics are wrong, of course. Nor does the fact that most scientists believe in climate change necessarily make it true. What counts is the evidence. And the evidence – that the world is getting warmer, that the warming is largely due to human emissions, and that the downsides of further warming will outweigh the positive effects – is very strong and getting stronger.

Finally, perhaps the most bizarre conspiracy-related claim is that the journalists covering science have an interest in promoting global warming.

Journalists do have an interest in promoting themselves (and their books), while their employers want to boost their audience and sell advertising. Publicity helps with all these aims, but you get far more publicity by challenging the mainstream view than by promoting it. Which helps explain why so many sections of the media continue to publish or broadcast the claims of deniers, regardless of their merit.

Climate myths 23: Hurricane Katrina was caused by global warming

17:00 16 May 2007
NewScientist.com news service
Emma Young

The chaotic nature of weather makes it impossible to prove that any single event such as Hurricane Katrina is due to global warming. It is also impossible to prove that global warming did not play a part, so debates about the causes of individual events are futile.

It is possible, however, to determine whether global warming is increasing the frequency or intensity of extreme events. It is a bit like throwing dice: getting one six proves nothing, but if sixes keep coming up more often than the other numbers, you know the dice is loaded.

So is global warming loading the dice when it comes to tropical cyclones (also known as hurricanes and typhoons in different parts of the world)? A host of atmospheric factors have to be just right for a cyclone form and grow. Sea surface temperatures play a big role and they are steadily increasing.

But the temperature difference between the sea surface and the air also matters, and global warming might have little effect on this. Then there is the question of how warming will affect factors that weaken storms such as high level winds that chop off the top of developing hurricanes, an effect called wind shear (see *Wind shear may cancel climate's effect on hurricanes*).

Increasing intensity

General climate models are not detailed enough to accurately predict the effects of warming on hurricane activity. Instead, modelers have tried to feeding in predictions from general models to detailed regional models of hurricanes. This has produced some widely varying results, but the consensus among experts is that global warming will not lead more hurricanes overall, but will increase the average intensity of storms.

A growing number of studies of hurricane records suggest this trend can already be seen. In 2005, for instance, Kerry Emanuel at MIT published a research suggesting that tropical cyclones in the West Pacific and Atlantic have become more powerful over the past 50 years. That same year, another study concluded that the frequency of the strongest tropical cyclones has almost doubled globally since the early 1970s.

There are problems with such studies. For starters, tropical cyclone activity in some regions seems to rise and fall in cycles lasting many decades. "This variability makes detecting any long-term trends in tropical cyclone activity difficult" concluded the 125 members of a World Meteorological Organization international workshop on tropical cyclones and climate change, held in December 2006 (see pdf report).

Researchers studying past activity are also only too aware of the shortcomings of the databases. For example, the techniques for measuring storm intensity have changed dramatically over the past 30 years. On the fundamental question of whether global warming is affecting tropical cyclones, the WMO group decided: “no firm conclusion can be made at this point".

Stalagmites and coral

More data is needed settle the issue. Some are looking to natural records of past hurricane activity in stalagmites, lake deposits and coral rubble. Others are re-analyzing existing databases. In February 2007, one such re-analysis concluded that over the past two decades, hurricane intensity has increased in the Atlantic but not in other parts of the world (pdf format).

Yet another complicating factor is that changes in climate can also change the paths that tropical cyclones tend to take, determining whether they remain over oceans or strike land.

What every one agrees on is that over the past few decades there has been a huge rise in the number of people being killed or injured by hurricanes, and in damage to infrastructure, and this trend looks set to continue. The main reason for this, however, is that more and more people are living and building in hurricane zones.

Climate myths 24: Higher CO_2 levels will boost plant growth and food production

17:00 16 May 2007
NewScientist.com news service
David Chandler

According to some accounts, the rise in carbon dioxide will usher in a new golden age where food production will be higher than ever before and most plants and animals will thrive as never before. If it sounds too good to be true, that's because it is.

CO_2 is the source of the carbon that plants turn into organic compounds, and it is well established that higher CO_2 levels can have a fertilising effect, boosting growth by as much as a third. Higher temperatures can boost growth even further. Plants also lose water through the pores in leaves that let CO_2 enter, so higher CO_2 can decrease water loss in plants as they do not need to open these pores as much.

But it is extremely difficult to generalize about the overall impact on plant growth. Numerous groups around the world have been conducting experiments in which plots of land are supplied with enhanced CO_2, while comparable nearby plots remain at normal levels.

While these experiments typically have found initial elevations in the rate of plant growth, these have tended to level off within a few years. In most cases this has been found to be the result of some other limiting factor, such as the availability of nitrogen or water. (See also *Climate change warning over food production*.)

Actual yields do always not rise as much as overall growth, as the ratio of seeds to overall biomass tends to fall. The regional climate changes that higher CO_2 will bring, and their effect on these limiting factors on plant growth, such as water, also have to be taken into account.

Levelling off

Some have suggested that the increase in plant growth due to CO_2 will be so great that it soaks up much of the extra CO_2 from the burning of fossil fuels, significantly slowing climate change. But the leveling-off effect means that plants will not simply soak up ever more CO_2. Furthermore, studies of past climate suggest that as the planet warms, the land and oceans will start emitting more CO_2 and other greenhouse gases than they absorb.

Another complicating factor is ground level ozone due to air pollution, which damages plants. This is expected to rise in many regions over the coming decades and could reduce or even negate the beneficial effects of higher CO_2.

As for food crops, the factors are more complex. The crops most widely used in the world for food in many cases depend on particular combinations of soil type, climate, moisture, weather patterns and the infrastructure of equipment, experience and distribution systems. If the climate warms so much that crops no longer thrive in their traditional settings, farming of some crops may be able to shift to adjacent areas, but others may not. Rich farmers and countries will be able to adapt more easily than poorer ones.

Predicting the world's overall changes in food production in response to elevated CO_2 is virtually impossible. Global production is expected to rise until the increase in local average temperatures exceeds 3°C, but then start to fall. In tropical and dry regions increases of just 1 to 2°C are expected to lead to falls in production. In marginal lands where water is the greatest constraint, which includes much of the developing world but also regions such as the western US, the losses may greatly exceed the gains.

Biodiversity loss

Even if plant growth does rise overall, there could be a decline in biodiversity. Species that thrive on higher CO_2 will drive others to extinction. In the long run, this might limit the resiliency of some ecosystems.

In addition, fertilization is just one of carbon dioxide's effects. Increased CO_2 causes acidification of water, especially in the oceans. Recent research has shown that the expected doubling of CO_2 concentrations could inhibit the development of some calcium-shelled organisms, including phytoplankton, which are at the base of a large and complex marine ecosystem (see *Ocean acidification: the other CO2 problem*). That may also result in significant loss of biodiversity, possibly including important food species.

Climate myths 25: Polar bear numbers are increasing

17:00 16 May 2007
NewScientist.com news service
Phil McKenna

Polar bears have become the poster children of global warming. The bears spend most or all of the year living and hunting on sea ice, and the accelerating shrinking of this ice appears to pose a serious threat. The issue has even become politically sensitive.

Yet recently there have been claims that polar bear populations are increasing. So what's going on? There are thought to be between 20,000 and 25,000 polar bears in 19 population groups around the Arctic. While polar bear numbers are increasing in two of these populations, two others are definitely in decline. We don't really know how the rest of the populations are faring, so the truth is that no one can say for sure how overall numbers are changing.

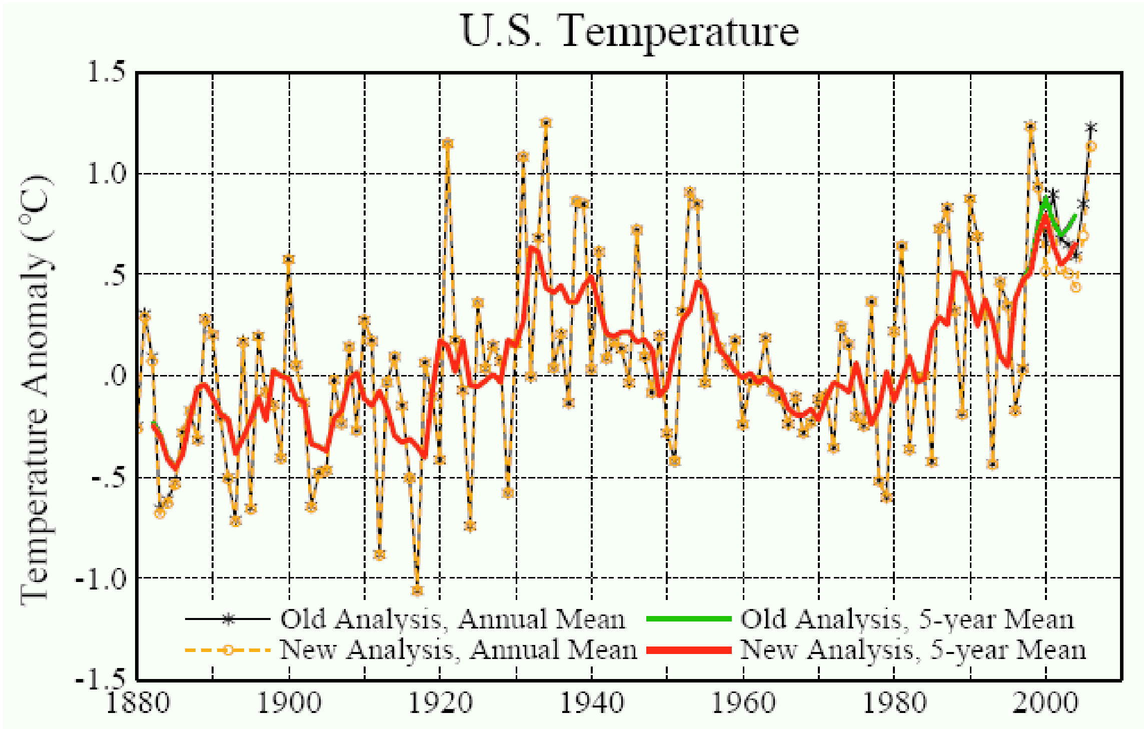
The two populations that are increasing, both in north-eastern Canada, were severely reduced by hunting in the past and are recovering thanks to the protection they and their prey now enjoy.

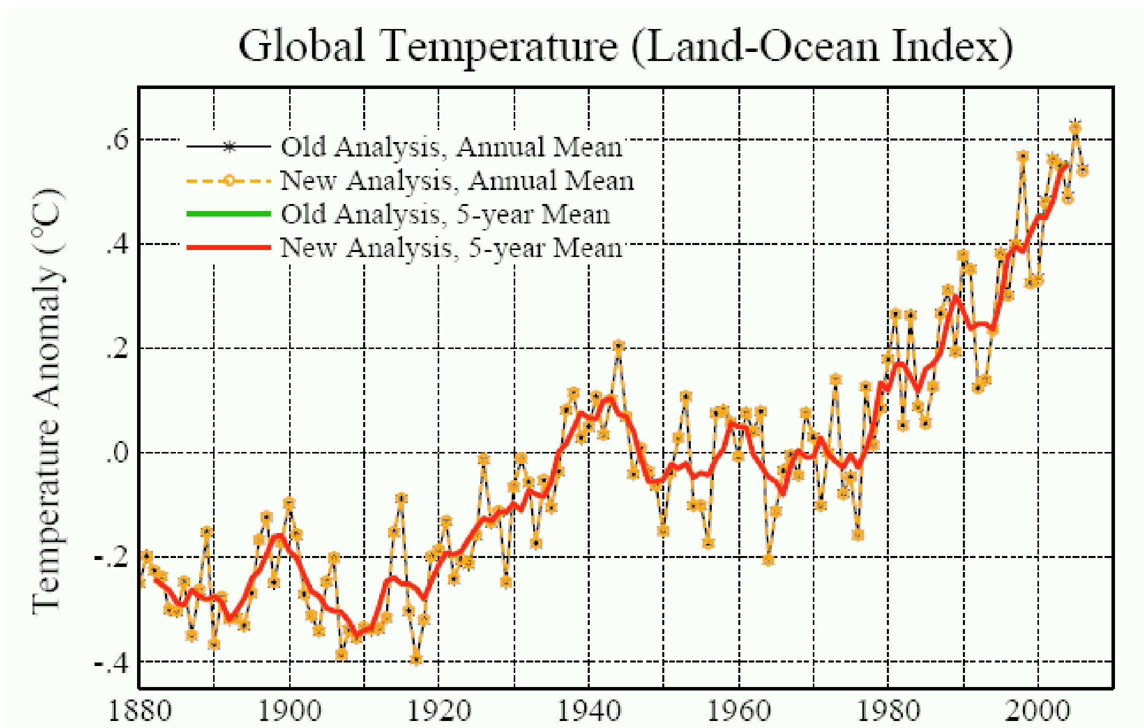
The best-studied population, in Canada's western Hudson Bay, fell by 22% from 1194 animals in 1987 to 935 in 2004, according to the US Fish and Wildlife Service. A second group in the Beaufort Sea, off Alaska's north coast, is now experiencing the same pattern of reduced adult weights and cub survival as the Hudson Bay group.

A comprehensive review (pdf) by the US Fish and Wildlife Service concluded that shrinking sea ice is the primary cause for the decline seen in these populations, and it recently proposed listing polar bears as threatened (pdf) under the Endangered Species Act. The International Conservation Union projects the bears' numbers will drop by 30% by 2050 (pdf) due to continued loss of Arctic sea ice.

Climate myths 26: Recent re-evaluation of the U. S. temperature data shows that global warming is not happening.

The revaluation by James Hansen only changed the U.S. temperature by 1 tenth of a degree C, and the world temperature by 1 thousandth of a degree C. The two figures below show the change for the U.S. temperature anomaly and the global temperature anomaly. There is virtually no difference. For the global temperature anomaly the change is undetectable on the graph.


U.S. Temperature
Temperature Anomaly (°C)
1.5
1.0
.5
.0
-.5
-1.0
-1.5
1880
1900
1920
1940
1960
1980
2000
Old Analysis, Annual Mean
New Analysis, Annual Mean
Old Analysis, 5-year Mean
New Analysis, 5-year Mean


Global Temperature (Land-Ocean Index)
Temperature Anomaly (°C)
.6
.4
.2
.0
-.2
-.4
1880
1900
1920
1940
1960
1980
2000
Old Analysis, Annual Mean
New Analysis, Annual Mean
Old Analysis, 5-year Mean
New Analysis, 5-year Mean