From: Slingo, Julia (Chief Scientist) [[Redacted text]@metoffice.gov.uk]
Sent: 08 February 2010 19:34
To: Beddington MPST
Cc: Hirst, John; Julia Slingo
Subject: Various things!

Importance: High

Attachments: MetO_Comments_IPCC.doc; MetO Climate Science Briefing.doc; proposal_for_an_international_reanalysis_of_land_surface_air_temperature_data.doc

Dear John,

It was very good to have the opportunity to talk to you today and to know that we are in agreement on a number of things. In this email I'm sending some documents that may help your discussions over the next few days/weeks.

(1) I've attached a clean version of the Met Office Commentary on the IPCC debate which you have already seen. I gather this has been well received at DECC who have found it very helpful. Hopefully there will be some messages that you can pass on to Ed tomorrow.

(2) I've also attached a fairly extensive climate briefing paper which we've been working up recently. It contains a mixture of basic facts/science as well as tackling the usual sceptics' questions around climate change. It's really aimed at a more lay audience but it may also be useful for the CSAC briefing. There is a set of figures to accompany the text which include the latest results on global temperature changes (Figures 3, 4 and 8) which we discussed today. Please feel free to use them as you wish.

(3) As I said we have been working up an international project to reanalyse the land surface temperature data (see attached) and this is currently with the WMO for consideration. I'm hoping that they will endorse it and agree to lead it so that we have something positive to say when Muir Russell reports.

(4) I have also asked my staff to prepare a summary document on our recent work with releasing the surface temperature observations and the code, along with showing that the global warming signal is robust. I expect to send that on to you later this week. Hopefully that will be enough to convince Muir Russell not to call in statisticians to repeat the exercise. We would of course be happy to brief him on our findings.

I hope all this is helpful and do let me know if you need anything further. And I hope you are feeling better!

Regards,

Julia

Julia Slingo Chief Scientist
Met Office FitzRoy Road Exeter EX1 3PB United Kingdom
Tel: [Redacted text] Fax: [Redacted text]
E-mail: [Redacted text]@metoffice.gov.uk http://www.metoffice.gov.uk

Met Office commentary on the current debate on the IPCC and its future

Julia Slingo, Chief Scientist, and John Hirst, Chief Executive

7 February 2010

The claims against the IPCC of inaccurate and not properly assessed comments on the regional impacts of climate change continue. Last week it was reported that India will establish its own body to undertake a full, national assessment of the risks posed by global warming. There are two important lessons to be learned from the current debate around the efficacy of the IPCC.

First, none of the reported mistakes and discrepancies undermines in any way the fundamental science of human-induced climate change. That part of the IPCC Fourth Assessment Report was carried out in Working Group 1 which considered 'The Physical Science Basis' and drew on decades of research. There the peer-reviewed scientific literature is deep and extensive and the conclusions are robust – namely that global warming is occurring, is heading towards dangerous levels and is largely induced by human activity.

What is being called into question now is the degree to which the *regional and national assessments of the impacts* of climate change by the IPCC can be considered robust. These were mostly considered in Working Group 2. The science here was much less mature, and although the majority is sound and the core conclusions largely dependable, some aspects were more tentative. It is here that the report is vulnerable, and although not related to the Working Group 1 conclusions, the recent disclosure of mistakes is being used to undermine the whole report. This is both dangerous and unnecessary.

The question has to be asked whether the IPCC approach is the best way forward for national and regional assessments. Especially in parts of the developing world, the observational basis and the scientific literature to underpin regional and national climate change impact assessments remain sparse. Furthermore the evidence base is changing rapidly; by its very nature, the IPCC, which only reports every 5-6 years, cannot reflect those latest developments. Ultimately it will be national governments, with in some cases international support, who will need to make decisions. As India has concluded, these must draw on local knowledge and expertise, as well as on the international consensus on global climate change as represented by the IPCC.

Last September the WMO, through the 3rd World Climate Conference, established the Global Framework for Climate Services to provide all countries with access to the best possible climate science and information in a timely fashion, so that they can make national decisions around how to adapt to climate variability and change in the coming years to decades. Consequently, it could be argued that the IPCC should focus on scientific assessments of global and regional changes in climate, along with impacts on those key sectors, such as water and food availability, which have implications for global security. This is essentially what the first part of the IPCC Working Group 2 Report has done, and in those cases the peer-reviewed literature is more robust and extensive.

The second key point is that none of the current debate around the IPCC should undermine the very strong position that the UK has in regard to predicting climate change and assessing its impacts. In 1990 the Met Office Hadley Centre was

established to provide the UK with the best possible science and predictions to underpin decisions that must be made to protect society from climate change, and to drive national and international policies around emission reductions to limit the most dangerous effects of climate change.

Because of that foresight, the UK now has access to the best advice in the world, evidenced by the Hadley Centre achieving top spot in a recent poll of all geosciences research institutes in the world, conducted by the Times Higher Education Supplement and based on peer-reviewed science. We have used that expertise not only to give the UK access to the best possible advice, but to work with countries such as India and now Africa to build their own capabilities.

As India now recognises, national assessments of climate change and its impacts probably cannot be done adequately within the framework of the IPCC alone. In 1997, the UK Climate Impacts Programme was established to do just that for the UK, working with the Met Office Hadley Centre. Last year new UK climate projections were produced which are enabling many sectors to assess their risks and take appropriate actions. While this process draws strongly on the IPCC, the UK does not depend solely or critically on it.

Since its inception in 1988, the IPCC has played a vital role in world affairs. Without its process of drawing together and assessing critically all the evidence, the world's scientists would not be able to state that global warming is unequivocal and that they are 95% certain that it is due to human behaviour. And without those conclusions the compelling case for global agreements to limit emissions could not have been made.

This process of allowing all nations to have a voice in the scientific basis for global warming and consequent actions must not be jeopardised. The IPCC may need to reconsider its goals and to make its processes more robust and transparent, but the opportunity for all nations to participate in the science debate on climate change must continue. After all, it will affect us all in one way or another.

Climate Science Briefing

Met Office, February 2010

Executive Summary:

- Concentrations of Carbon Dioxide (CO_2) have increased by more than 39% since industrialisation began, from 280ppm to 390ppm (parts per million).
- Man-made greenhouse gases are altering the Earth's energy balance and causing climate change.
- Globally, the 17 warmest years on record have all occurred in the last 20 years.
- The UK has experienced 8 of the 10 warmest years on record since 1990.
- Natural variability will continue to bring warm and cool years, but, because of climate change, the warm years will get warmer and more frequent.

Basic Facts

- CO_2 continue to rise at a rate of 2ppm/year with emission rates tracking the A1B high emission scenario (Fig. 1).
- CO_2 levels have now risen by 110ppm (i.e. 39%) from pre-industrial levels of 280ppm. Two thirds of that increase has occurred in the last 50 years.
- CO_2 levels are now 30% higher than at any time over at least the last 650,000 years (Fig. 2).
- CO_2 is a potent greenhouse gas and the fundamental physics that links CO_2concentrations to temperature changes has been known since the 19th century.
- It is entirely consistent with this physics that global temperatures are increasing decade on decade since the mid 20th century (Fig. 3).
- The current decade is now the warmest on record despite a major La Nina event which temporarily cooled the global climate system.
- For the last 3 decades the rate of temperature increase is significant even when uncertainties in the observations are factored in (Fig. 3).
- New results from a synthesis of all observations suggest that recent warming may even be under-estimated (Fig. 4).
- Other evidence besides temperature increases tell us that the climate is changing. This includes rising sea levels, changes in the seasons, retreat of many glaciers, and shifts in rainfall patterns.
- No other scientifically defensible explanation has been found for the increases in temperature and the other supporting evidence.

The Fundamental Science

- The 'greenhouse effect' describes the way the atmosphere traps some of the energy we receive from the Sun and stops it escaping back out into space. This makes the Earth warm enough for life. Without the natural greenhouse effect, Earth would be 35^0C colder.
- The problem is that we are adding to the natural greenhouse effect with emissions from energy production, transport, industry and agriculture (chiefly carbon dioxide, methane and nitrous oxide). These gases trap more energy and hence increase the Earth's surface temperature.
- The overwhelming majority of leading climate scientists agree on the fundamentals - that the Earth is definitely warming and that this is very likely (95% certain) caused by increased greenhouse gases from human activities.
- Moving from the basic science of global warming to understanding the complexities of climate change requires a complete understanding of dynamics of the oceans and the atmosphere and how the biosphere will respond. Some regions may warm less than others and some regions may experience decreases in rainfall and others, increases.

Climate change also describes other effects like rising sea levels and increased frequency of extreme weather, such as heatwaves and flooding.

On recent cold weather

- The recent spell of cold weather in the UK and parts of Europe certainly does not mean that climate change has stopped. In the UK, 2009 was in fact the 15th warmest year on record; taking the globe as a whole, last year was the 5th warmest year on record.
- The period of cold weather in the UK is part of the normal regional variations that take place within the winter season and from year to year. It doesn't tell us anything about climate change, which has to be looked at in a global context and over longer periods of time (Fig. 5).
- Even in a warmer climate, cold winters will still occur but probably with decreasing frequency.

The IPCC

- The IPCC remains the most authoritative and comprehensive assessment process for information about climate-change science and is endorsed by 192 governments around the world. It covers all aspects of climate change science from the physical science basis, through sectoral and regional impacts, to socio-economic responses.
- None of the reported mistakes and discrepancies undermines in any way the fundamental physical science of human-induced climate change. That part of the IPCC draws on decades of research. The peer-reviewed scientific literature is deep and extensive and the conclusions are robust.
- The current debate focuses on details in the assessment of regional impacts. The science here was much less mature, and although the majority is sound and the core conclusions largely dependable, some aspects were more tentative.
- Especially in parts of the developing world, the observational basis and the scientific literature to underpin regional and national climate change impact assessments remain sparse. Furthermore the evidence base is changing rapidly; by its very nature, the IPCC, which only reports every 5-6 years, cannot reflect those latest developments.
- Since its inception in 1988, the IPCC has played a vital role in world affairs. Without its process of drawing together and assessing critically all the evidence, the compelling case for global agreements to limit emissions could not have been made.

The world isn't really getting warmer, some years are just hotter than others

- The 17 warmest years, globally, on record have all occurred in the last 20 years. This fact is based on recorded temperatures since 1850 (when reliable records began).
- Over the last 100 years the Earth has warmed by about 0.75 degrees Celsius and that warming is accelerating (Fig. 6).
- The UK Spring arrives about 10 days earlier than it did in the 1970s.
- Arctic sea ice is melting. The extent of summer sea-ice has shrunk by about 10% every 10 years since the late 70s. In a few decades, large parts of the Arctic Ocean are expected to have no late summer sea-ice (Fig. 7).

How can global warming be happening if Arctic Sea Ice has recovered in the last 2 years?

- The dramatic reduction in summer sea ice extents in 2007 was largely due to natural variations in the winds that move the ice around the Arctic Ocean.
- The subsequent recovery does not alter the long-term trend of declining ice extents (Fig. 7).

People say we've nothing to do with recent climate change

- Carbon dioxide (CO_2) levels in the atmosphere have gone up 39% since 1750 - the year the industrial revolution started. Rising levels of greenhouse gases are directly linked to human activity like burning fossil fuels and clearing forests. There is a clear link between more greenhouse gases in the atmosphere and global warming through fundamental physics.

Not all scientists agree

- The overwhelming majority of climate scientists agree that human induced climate change poses a huge threat to the world. The Intergovernmental Panel on Climate Change is not run by any government – 'intergovernmental' means it answers to all 192 governments signed up to it.
- Its reports are written by independent scientists. It is one of the most rigorous scientific bodies that exist. It brings together many thousands of scientists from countries all over the world to put together the best assessments of climate science available.

Hasn't the world cooled since 1998? (Lawson argument)

- This is a classic case of cherry picking data. 1998 is the warmest year on record but we know that this was due to the major El Nino event in the Pacific. The following year, 1999, was 0.35C colder and only the 19th warmest year on record. This was because El Nino events are followed by La Nina conditions which cool the planet. This emphasises the importance of not taking single years to defend or refute global warming. To see climate change we need to rely on long-term trends of 30 years or more (Fig. 8).
- Every year since 1998 (in fact every single year for the past three decades) has been significantly warmer than the temperatures you'd expect if there was no warming [*baseline of 1861-1900*]. The last ten years have all been among the 15 warmest in the historical record; it is just that these years have not been quite as warm as 1998.

Climate change varies across the world. Does this not allow climate-change 'proponents' to 'cherry pick' the examples they use to support their position? (Lawson argument)

- Climate change due to greenhouse gases is not expected to be uniform around the world. All the examples presented in Lord Lawson's book — including those that he presents as 'inconsistent' with global warming — are actually fully consistent with our understanding of how greenhouse gases affect climate.
- Specifically, the physics tells us that high latitudes should warm faster than low latitudes due to feedback effects associated with the retreat of snow and ice. This reduces how much solar energy is reflected back to space and means that the Earth absorbs even more energy. These changes are exactly what we are seeing.
- Some glaciers have advanced in some regions because glacier extent is determined by the balance between the snowfall and melting. For

example, snowfall has increased over the cold interior of the Greenland ice sheet because warmer air can hold more moisture. On the other hand, rising temperatures have also increased melting around the ice sheet's edge.

- Sea ice amounts and glacier extents do change naturally, but their current retreat is in line with what we would expect in a warming world. Recent work at the Hadley Centre confirms that the declining trend in summer sea ice in the Arctic is largely due to increases in greenhouse gases.

Haven't temperatures been higher in the past? Isn't the hockey stick graph flawed?

- In 2006, the US National Academies of Science carried out a full review of the evidence of past temperature—the so-called 'hockey stick graph'. They found that for the Northern Hemisphere at least, the rapid warming of the past half century has resulted in a level of warmth not seen in at least 500 years, and likely for at least the past 1300 years (Fig. 6).
- Natural processes including changes in solar output, volcanic eruptions and changes in the Earth's orbit can affect climate and have led to relatively warm and cold periods in the past.
- What matters now is that we're seeing warming that cannot be explained by changes in the sun's output or in the Earth's orbit (Fig. 9). Temperatures are rising rapidly, due to human activities and are set to increase by 2-4 deg C over the coming century (Fig. 6).

Satellite data do not support the theory of global warming.

- In the early 1990s initial estimates of temperatures in the lowest part of the earth's atmosphere, based on measurements taken by satellites and weather balloons, did not mirror the temperature rises seen at the earth's surface. However these discrepancies have been found to be related to problems with how the data were gathered and analysed and have now largely been resolved.
- A new synthesis of all observations, including satellite data, has shown that the recent warming based on surface observations alone may be an underestimate of the true warming (Fig. 4).

The CO_2 trend over the past century doesn't match the trend in global warming. How can it be a driver?

- Firstly, warming due to the enhanced greenhouse effect lags behind changes in CO_2 (and other greenhouse gases), due to inertia in the climate system. Secondly, greenhouse gases are not the only determinant of temperature. Aerosols, which are also emitted from human activities, are also important and can be shown to explain much of the cooling seen in the middle of the 20th century. Volcanic eruptions and small changes in solar output also complicate the picture.
- Two thirds of the increase in CO_2 has occurred in the last 50 years where we have observed the most significant warming trend.
- Models have been used that take into account all the factors that influence climate. These models have been able to simulate the historic changes in global and regional temperatures and have shown that most the warming

over the past half century has been caused by the rise in greenhouse gas concentrations (Fig. 10).

Human emissions of carbon dioxide are tiny in relation to natural flows of carbon dioxide, for example, the biosphere, the oceans and volcanoes. How then can humans be responsible for global warming?

- The human source is confirmed through the study of the isotopes of carbon in the atmosphere. This confirms that the amount of fossil carbon in the atmosphere is increasing.
- While human emissions are relatively small compared to natural emissions, e.g. from terrestrial ecosystems and the oceans, these natural flows are generally in balance (Fig. 11).
- Human emissions have tipped the balance leading to an accumulation of carbon in the atmosphere.
- In fact 50% of our emissions are currently taken up by the biosphere and the oceans, so that the Earth's natural systems are in fact buffering the true effect of our activities.
- Earth system modelling studies suggest that as the planet warms and the oceans become more acidic, that buffering will decline leading to an acceleration of the amounts of CO_2 in the atmosphere and consequently of global warming (Fig. 12).

Could water vapour be responsible for the atmospheric warming? Are the amounts of carbon dioxide being added really making a difference?

- While water vapour is the Earth's dominant greenhouse gas, it is only when humans have added carbon dioxide to the atmosphere that the energy balance of the Earth has started to shift. The effects of increasing carbon dioxide concentrations are magnified by feedback loops which allow more water vapour to be held in the atmosphere because the air is warmer. This exacerbates further the warming by enhancing the natural greenhouse effect.

Isn't climate variability shown to correlate with solar variability /sunspots?

- The sun's brightness varies naturally over an 11-year cycle and on longer timescales. Despite the recent decline in the sun's brightness, the long-term trend of global temperatures continues to rise (Fig. 9).
- Scientists are clear that there is strong evidence that changes in solar radiation could not have caused the rapid warming we have seen over the past fifty years.
- The Met Office has stated that since the Industrial Revolution, additional greenhouse gases have had about ten times the effect on the climate as changes in the Sun's output.

Isn't global warming caused by Cosmic Rays?

- The main hypothesis is that cosmic rays affect the formation of clouds. Because clouds act to both reflect and trap energy, changes in clouds can influence the Earth's energy balance.
- There is currently no evidence of systematic changes in cloudiness that could explain the observed changes in climate.

- Variations in cosmic rays over the past few decades cannot explain the long-term global warming trend. Some laboratory experiments have indicated their possible importance, but these have not been validated in the real world.

Isn't the apparent warming just due to urbanisation?

- Scientists have conducted rigorous tests to determine the effects of urbanisation on temperatures trends and found this to be negligible. The IPCC recently concluded that urban heat island effects have a negligible influence on the global scale, contributing less than 0.006°C per decade (<1%) to observed trends over land and zero over the oceans.

What about the Medieval Warm Period and Little Ice Age? We know that temperatures have varied in the past.

- We do know that the climate has varied naturally in the past and continues to do so today. But there is no evidence that natural forces can explain all of the warming being seen today. And there is strong and compelling evidence that the warming is linked to human activities.
- The Medieval Warm Period and Little Ice Age are often quoted as examples of past temperature change. The changes being observed today are global and are outside those during the past millennium (Fig. 6); there is also some evidence to suggest that neither of these periods of past temperature change were observed globally, just in parts of the northern hemisphere, especially the North Atlantic and Europe.

If we can't predict the weather next week, how can we predict the future climate?

- We know that the atmosphere is fundamentally a chaotic system, and that very small changes in the initial conditions of a forecast tend to grow with time – Lorenz's 'butterfly effect'. This means that beyond a few days our weather forecasts for a particular place have to be presented in terms of probabilities.
- Climate is about the statistics of the weather we experience over several years; it is not about saying what the weather will be like on a particular day at a particular place.
- When we make climate change predictions we look at how the statistics of the weather will change in response to changes in the long-term energy balances in the system. These are slowly varying and we are able to predict them with some confidence.

You talk a lot about uncertainty in your predictions so why should I believe anything you say?

- There are uncertainties in some aspects of our predictions but that does not mean that the fundamental science of global warming is uncertain or that we are not confident in some of the results.
- Uncertainties arise from two sources. Firstly the inherent, chaotic properties of the atmosphere and the oceans mean that natural variations in the climate system may influence the predictions of climate change at any time in the future. That is one of the reasons why we make a large

number of predictions so that we can say what the most probably outcome will be.

- Secondly, predictions of climate change are uncertain because our understanding of the full Earth system and how it will respond to global warming is incomplete. We still need to do much more fundamental research to reduce those uncertainties. What we can say is that most of the responses of the Earth system to rising temperature will make the warming worse.

FIGURES:

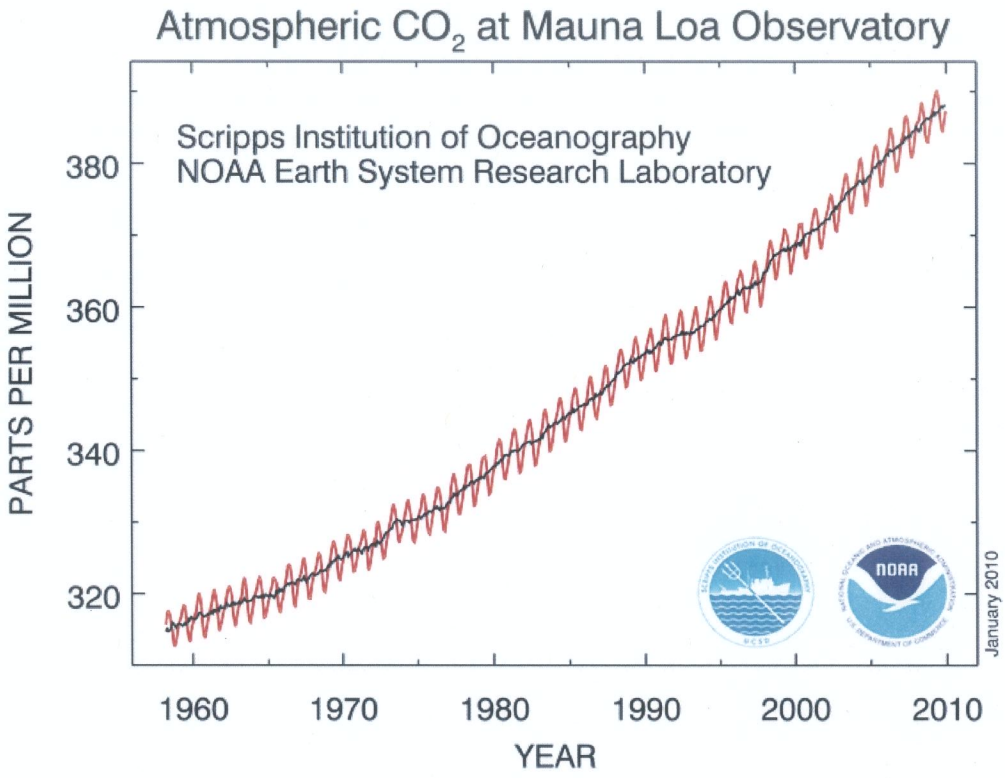

Figure 1: Observed trends in CO2 showing increases year on year of 2ppm.

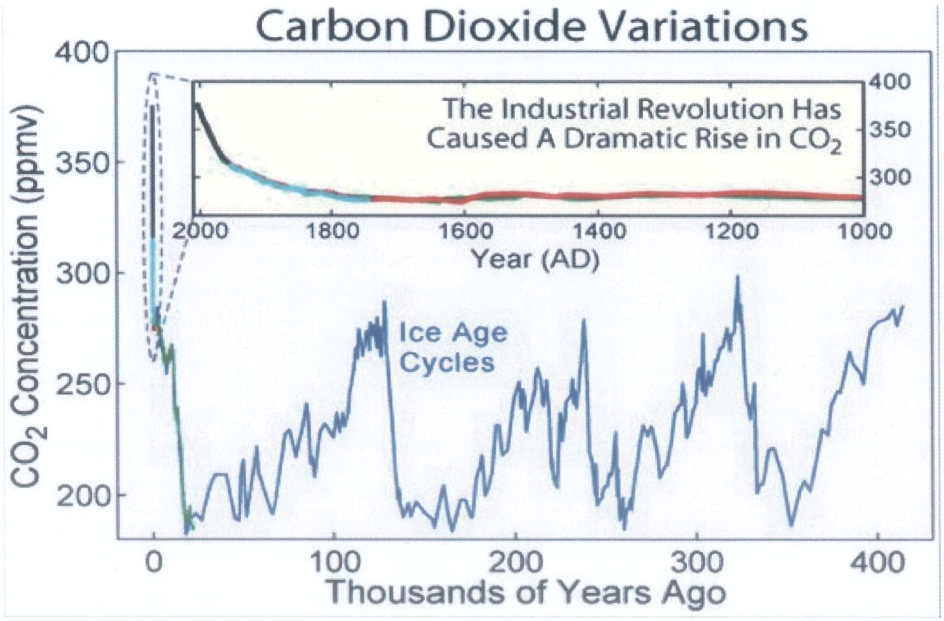

Figure 2: Records of past variations in CO2 concentrations from ice core records, showing that CO2 levels never exceeded 300ppm during previous warm periods. The insert shows that 2/3 of the recent increase in CO2 has occurred in the last 50 years.

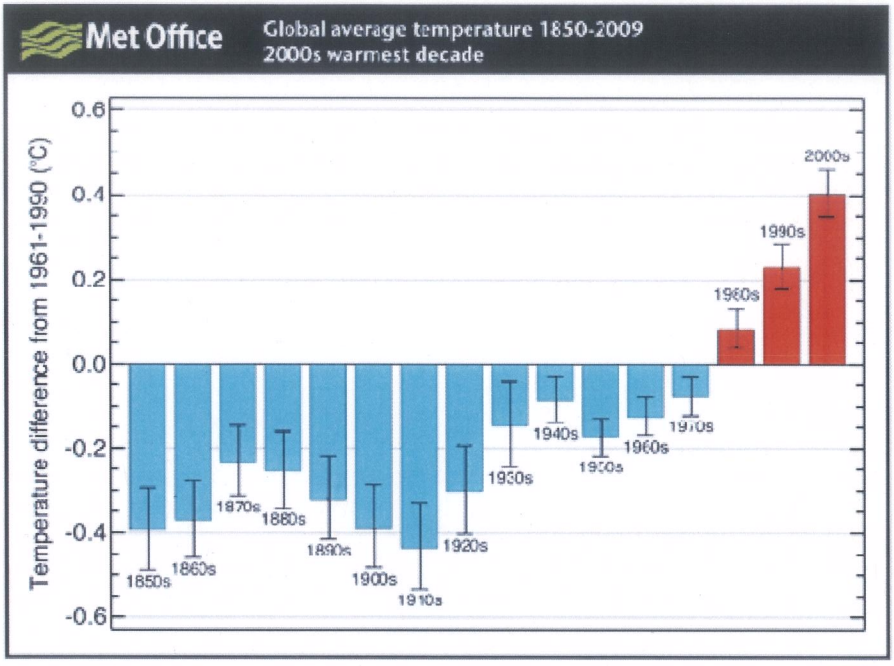

Figure 3: Decadal changes in global mean temperature. The error bars show the level of uncertainty in the observational base. From the 1980s onwards each decade has been significantly warmer than the previous decade. In other words, the coolest estimate for one decade is still warmer than the warmest estimate from the previous decade.

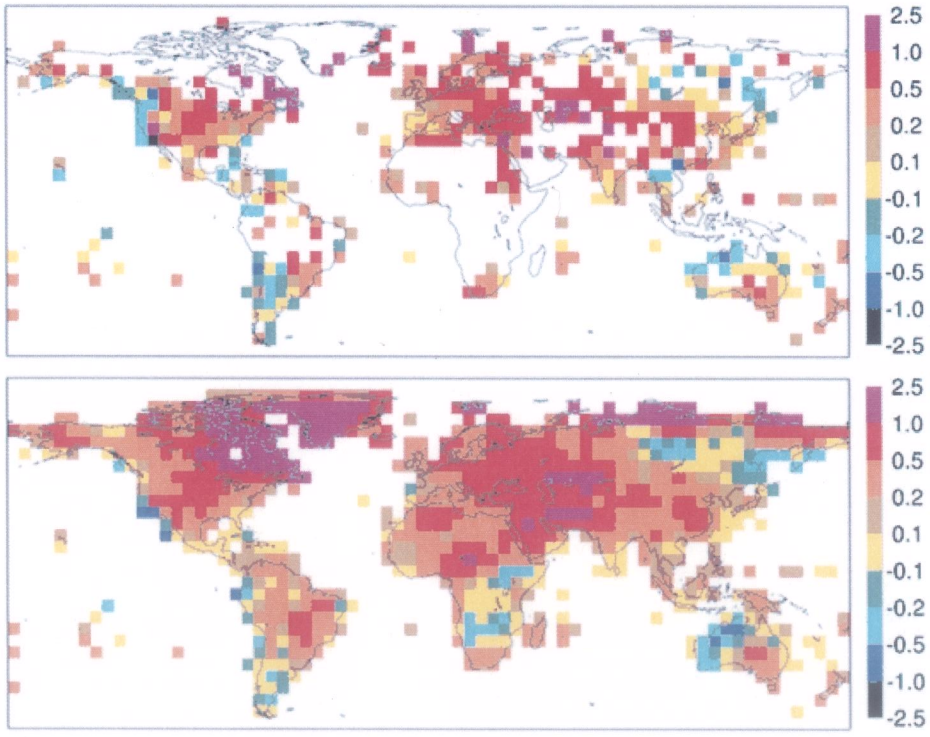

Figure 4: Increase in land surface temperatures (^{0}C) from (1989-1998) to (1999-2008) based on land surface temperature observations only (upper panel) and a new synthesis of all observations from satellites, surface stations, aircraft and radiosondes (lower panel). This shows that many of the un-sampled regions in the upper panel have warmed substantially especially in northern latitudes. From Simmons et al. (2010), Journal of Geophysical Research.

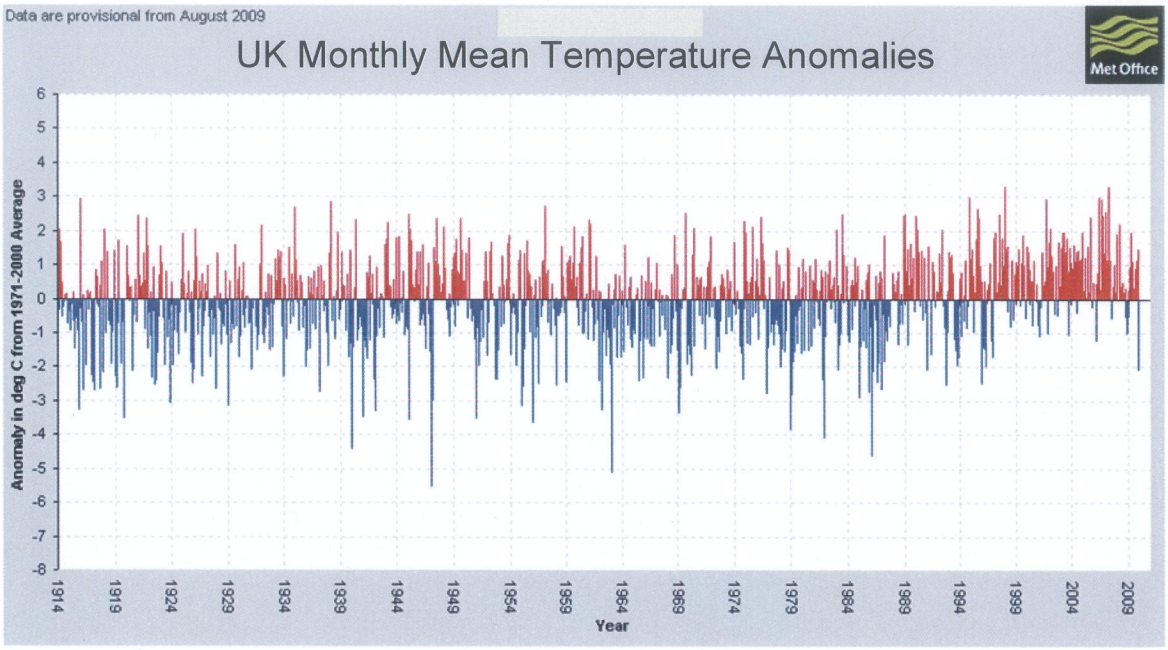

Figure 5: Monthly mean temperature variations for the UK showing that within year and from year to year large swings in temperature that exceed the global warming signal are part of the UK's climate. Since the 1980s a warming trend has begun to emerge from these natural variations.

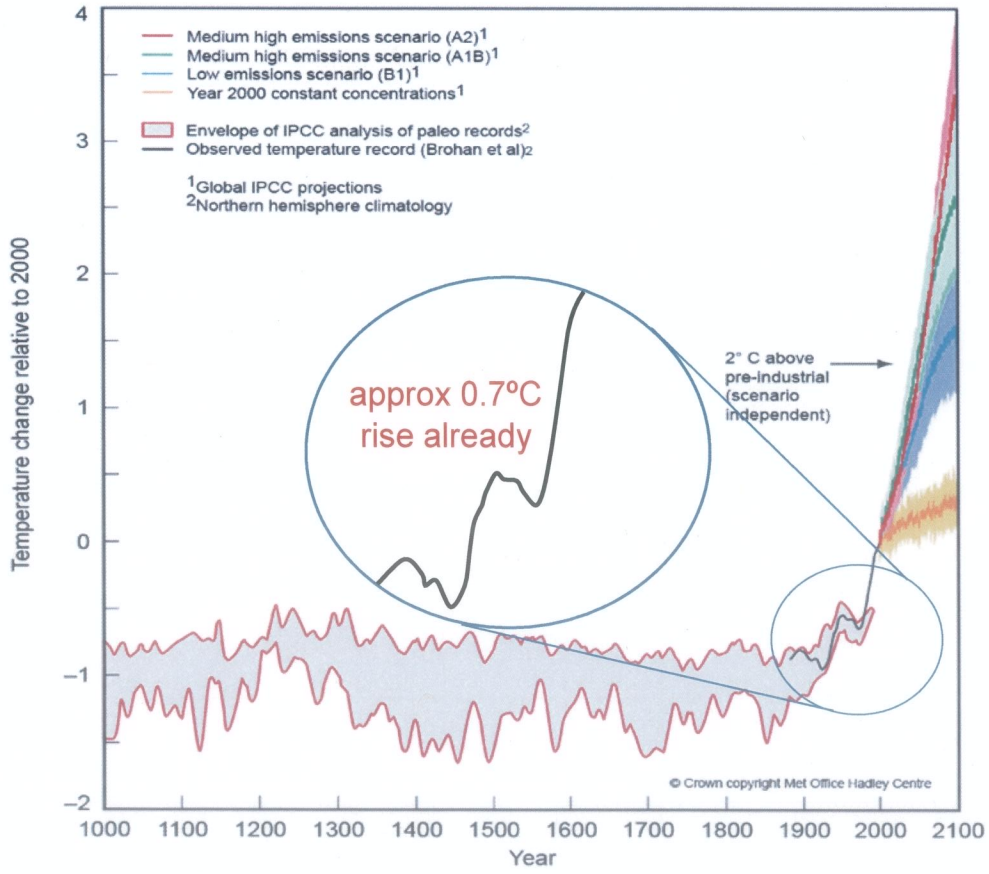

Figure 6: Past, current and future changes in northern hemisphere temperatures relative to 2000.

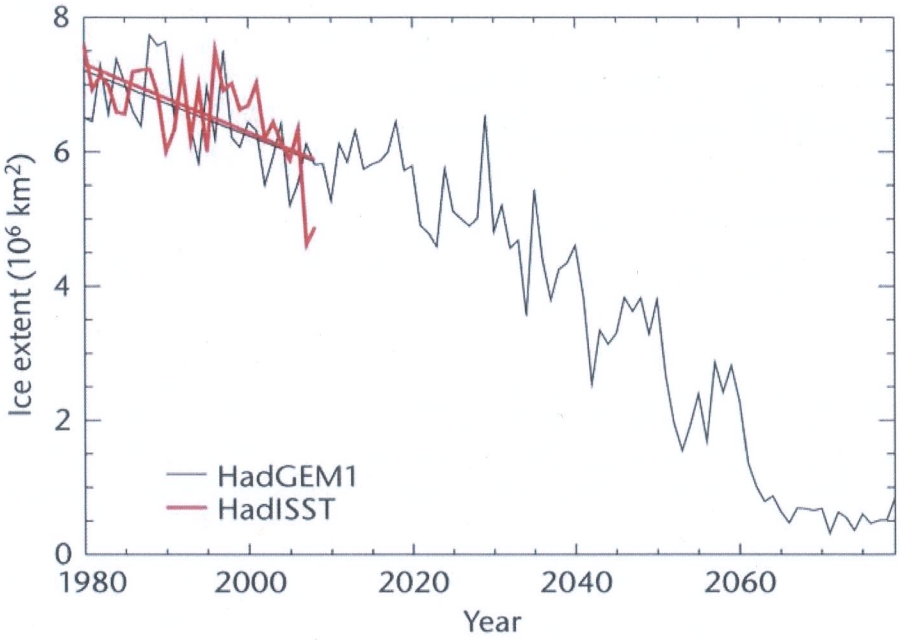

Figure 7: Observed and predicted Arctic summer sea ice extent showing the downwards trend and also that large year-to-year variations in extent are seen in the observations and captured by the model. Note also that rapid declines are also followed by some recovery.

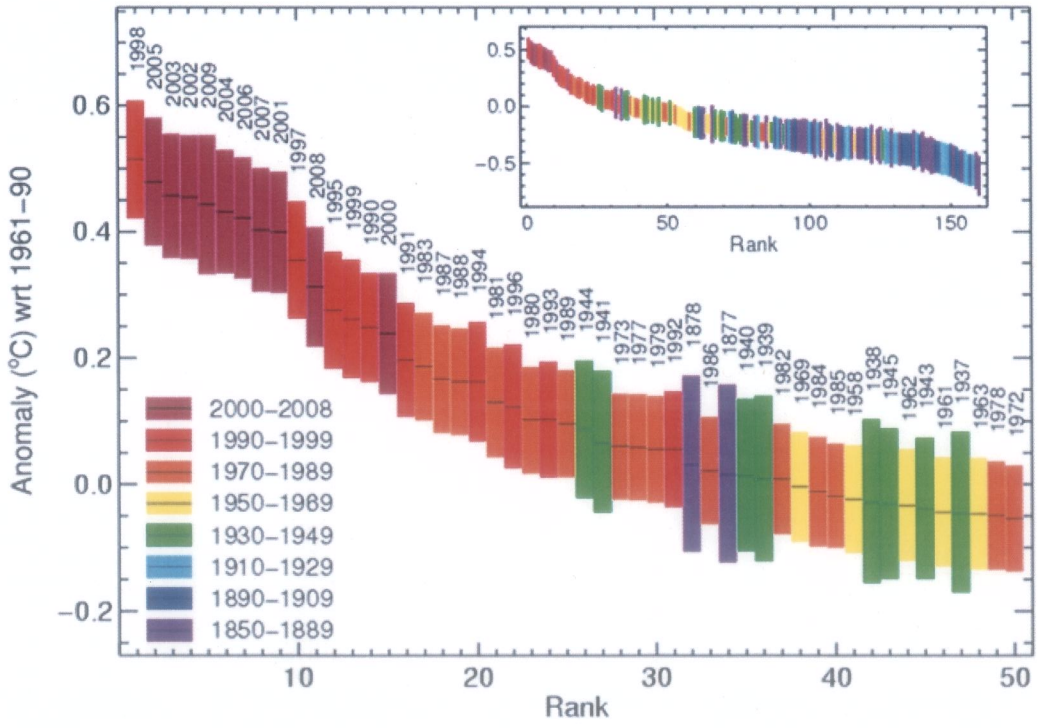

Figure 8: Ranked annual global surface temperature changes, colour coded by decade. The uncertainty in the observational estimate is shown in the length of the bars. 2009 was the 5th warmest on record. The warm years of 1877/1878 are due to the intense El Nino at that time which led to widespread famine in India.

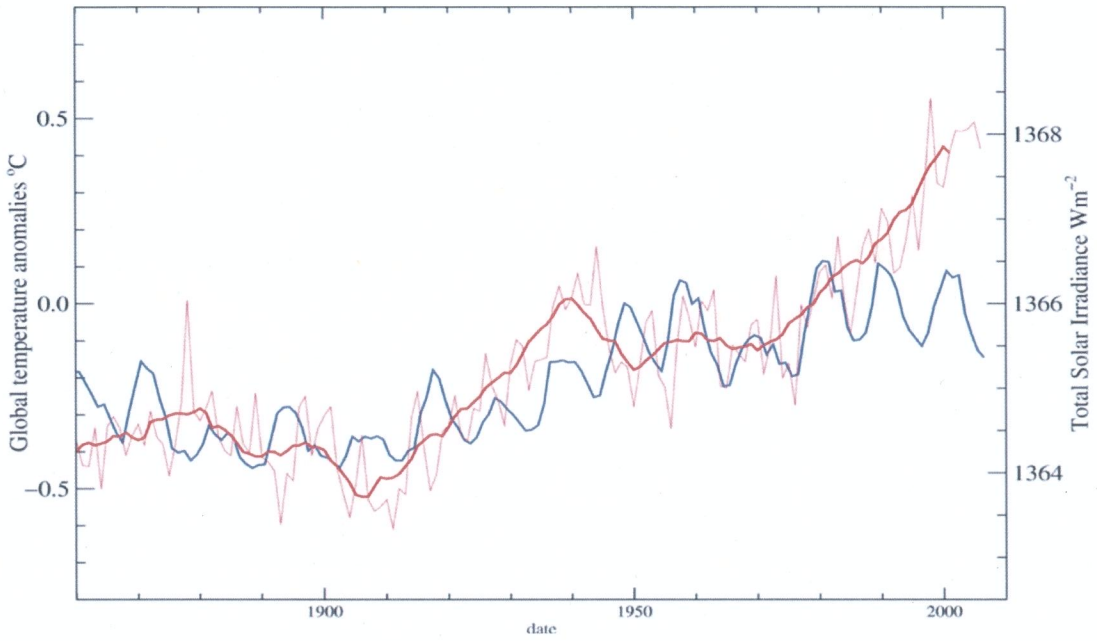

Figure 9: Variations in global mean temperatures (red lines) and total solar irradiance (blue lines).

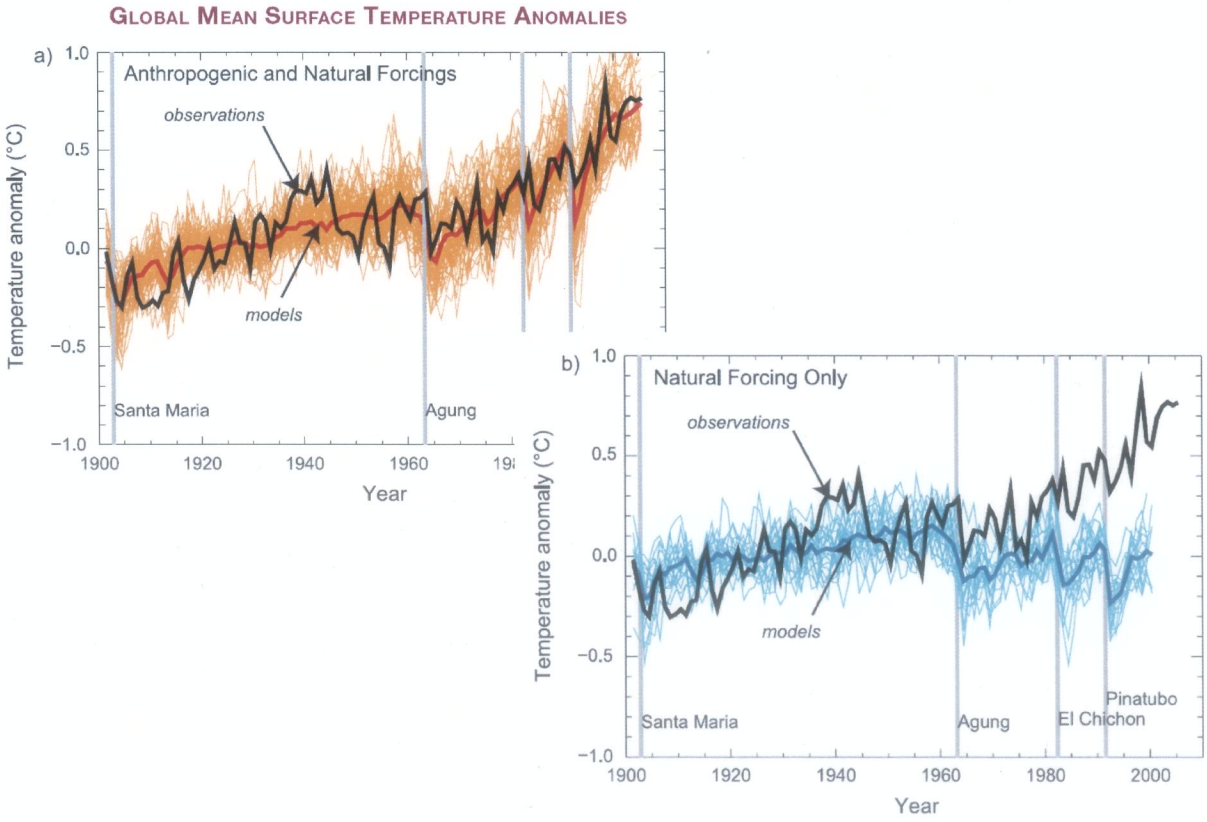

Figure 10: Simulations of the 20th century global mean temperature record from coupled climate models in which the only constraints are the external forcing from changes in total solar energy, volcanoes and increasing greenhouse gas concentrations. Left panel shows the simulations with all forcings, and the right panel the simulations in which greenhouse gas concentrations remain unchanged.

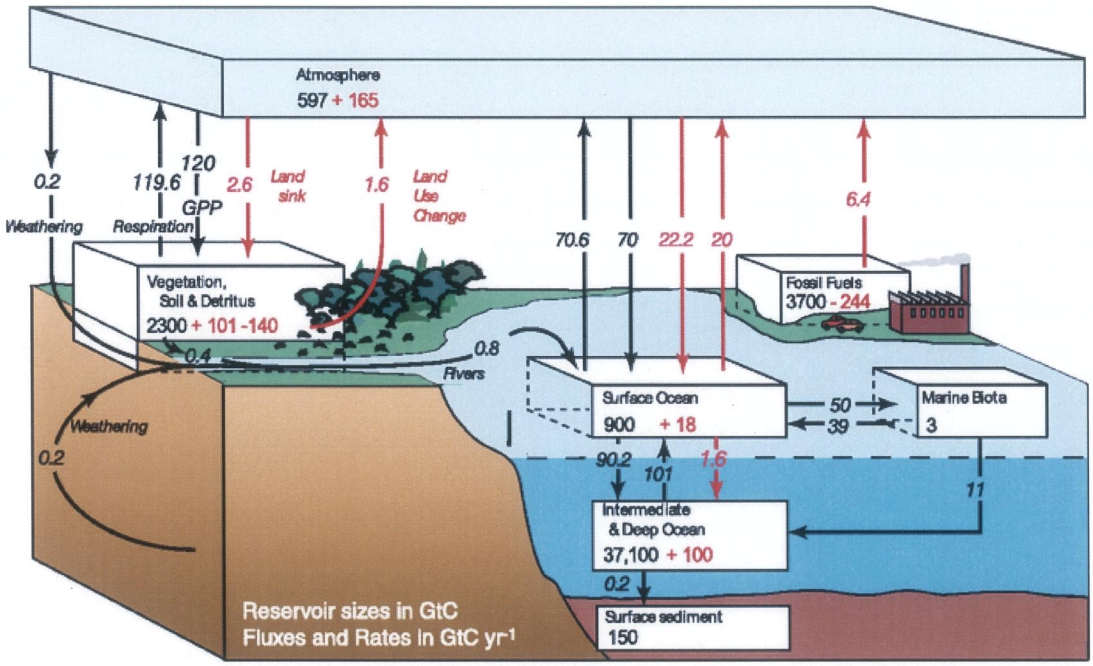

Figure 11: The global carbon cycle for the 1990s showing the mean annual fluxes in Gigatons of Carbon (GtC) per year: pre-industrial fluxes in black and anthropogenic fluxes in red (from IPCC AR4 WG1 Chapter 7).

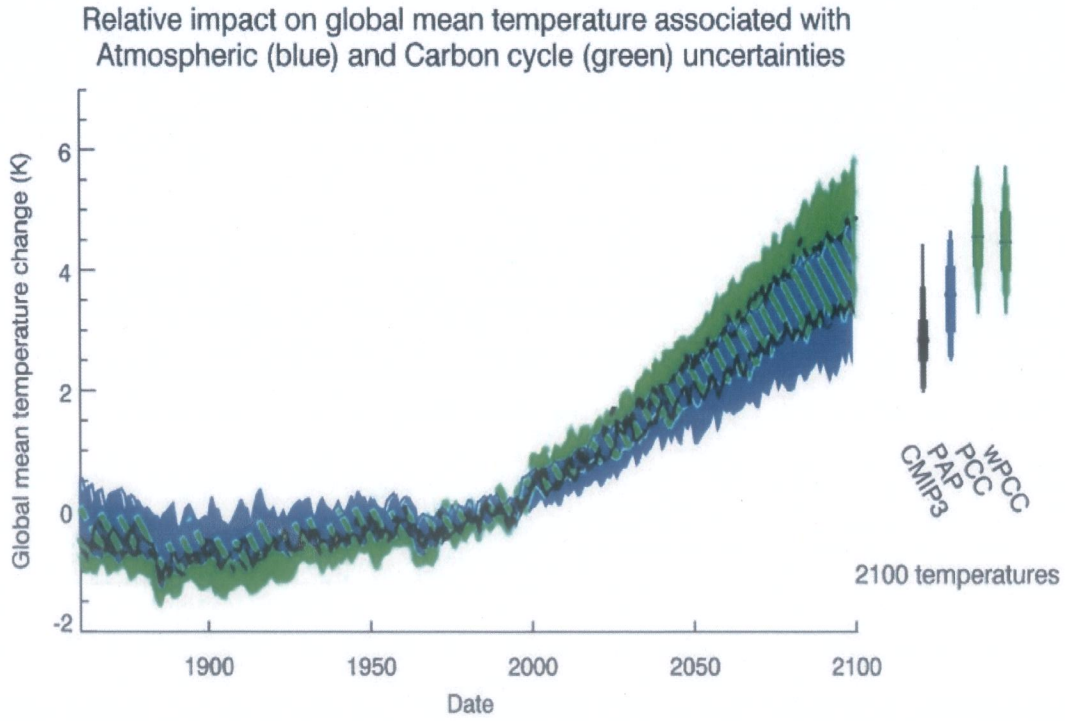

Figure 12: Recent ensemble predictions of climate change with (green) and without (blue/black) carbon cycle feedbacks.

Proposal for an international reanalysis of land surface air temperature data[2]

Executive summary

Surface temperature datasets are of critical importance for detecting, monitoring and communicating climate change. They are also essential for testing the validity of the climate models that are used to produce predictions of future climate change. The current datasets, constructed in the UK and US using different methodologies, agree in showing that the world is warming. Taken together these records provide a robust indicator of global change and form part of the evidence base that led the IPCC Fourth Assessment Report to conclude that "warming of the climate system is unequivocal".

To meet future needs to better understand the risks of dangerous climate change and to adapt to the effects of global warming, further development of theses datasets is required, in particular to better assess the risks posed by changes in extremes of climate. This will require robust and transparent surface temperature datasets at finer temporal fidelity than current products.

The current surface temperature datasets were first put together in the 1980s to the best standards of dataset development at that time; they are independent analyses and give the same results, thereby corroborating each other. However, they do not meet the expected standards of 2010 in respect to completeness of audit trail and transparency.

In the case of the CRU land surface temperature dataset (CRUTEM3, which forms the land component of the HadCRUT dataset) this is in part because there are substantial IPR issues around the raw station data that underpin the dataset; we are actively pursuing resolution of these issues so that the base data can be made openly available. We know that several stations have already been explicitly forbidden from release by the rights' holders so we will not be able to release all the under-pinning station data. The two further independent estimates produced by NOAA and GISS have other issues and are also regularly questioned.

Consequently we have been considering how the datasets can be brought up to modern standards and made fit for purpose in addressing 21st Century needs. We feel that it is timely to propose an international effort to reanalyse surface temperature data in collaboration with the World Meteorological Organization (WMO), which has the responsibility for global observing and monitoring systems for weather and climate.

The proposed activity would provide:

1. Verifiable datasets starting from a common databank of unrestricted data at both monthly and finer temporal resolutions (daily and perhaps even sub-daily).
2. Methods that are fully documented in the peer reviewed literature and open to scrutiny.
3. A set of independent assessments of surface temperature produced by independent groups using independent methods
4. Robust benchmarking of performance and comprehensive audit trails to deliver confidence in the results
5. Robust assessment of uncertainties associated with observational error, temporal and geographical inhomogeneities.

It is important to emphasise that we do not anticipate any substantial changes in the resulting global and continental-scale multi-decadal trends. This effort will ensure that the datasets are completely robust and that all methods are transparent.

Background

---

[2] Prepared by: Dr Peter Thorne (Met Office Hadley Centre)
Reviewed by: Dr Vicky Pope, Prof. Julia Slingo, Dr Peter Stott (Met Office Hadley Centre)

In many respects HadCRUT has been the default choice of surface dataset in all 4 IPCC Assessment Reports. However we must stress that other independent data sets are used which support the HadCRUT data. There are three centres which currently calculate global average temperature each month:

- Met Office, in collaboration with the Climatic Research Unit (CRU) at the University of East Anglia (UK)
- Goddard Institute for Space Studies (GISS), which is part of NASA (USA)
- National Climatic Data Center (NCDC), which is part of the National Oceanic and Atmospheric Administration (NOAA) (USA)

These groups work independently and use different methods in the way they process data to calculate the global average temperature. Despite this, the results of each are similar from month to month and year to year, and there is robust agreement on temperature trends from decade to decade.

All existing surface temperature datasets are homogenised at the monthly resolution, and are therefore suitable for characterising multi-decadal trends. These are adequate for answering the pressing 20th Century questions of whether climate is changing and if so how. But they are fundamentally ill-conditioned to answer 21st Century questions such as how extremes are changing and therefore what adaptation and mitigation decisions should be taken. Monthly resolution data cannot verify model projections of extremes in temperature which by definition are (sub-)daily resolution events.

Through collaboration with NCDC we have two quality controlled, but not homogenised products at the daily and sub-daily resolution (HadGHCND and HadISD – the latter about to be submitted to peer review), spanning 1950 onwards and 1973 onwards respectively. However, because these are not homogenised, they may retain time-varying biases. It is an open scientific question as to whether homogenisation is feasible at these timescales whilst retaining the true temporal characteristics of the record. In particular, seasonally invariant adjustments which are adequate for monthly timescale data will be grossly inadequate at the daily or sub-daily resolution. Clearly homogenisation of these data is highly desirable but some detailed research is needed to define the best approach.

The way forward

Recognising that no single institution can undertake such a fundamental data collection, re-analysis and verification process single-handedly, we would envisage this as a broad community effort – a 'grand challenge' so to speak - involving UK and international partners.

The Met Office would convene a workshop and invite key players who could plausibly create such datasets with the aim of initiating an agreed community challenge to create an ensemble of open source land temperature datasets for the 21st Century both at monthly temporal resolution and also at the daily and sub-daily timescales needed to monitor extremes. Such an approach would help distribute many of the basic tasks, ensuring that the most appropriate parties were responsible for each part as well as providing a focussed framework and timeline. Ideally this effort would have involvement from and possibly be coordinated under the umbrella of one or more of the Commission for Climatology, the Global Climate Observing System, or the World Climate Research Program, all part of the WMO.

Activities that would be required within any overall programme are:

1. Creation of an agreed international databank of surface observations to be made available without restriction, akin to the I-COADS databank in the ocean domain. Note that NCDC already have substantial efforts in this regard and would be a key participant and likely host as the designated world data bank. Data to be available at monthly, daily and sub-daily resolutions.
2. Multiple independent groups undertake efforts to create datasets at various temporal resolutions based upon this data-bank. Participants will be required to create a full audit trail and publish their methodology in the peer-reviewed literature. Strong

preference will be given to automated systems and creations of ensembles that reflect the uncertainties in the observations and methods.

3. One or more groups to create realistic test-cases of the spatio-temporal observational availability by sampling output from a range of climate simulations from a number of models, adding realistic error structures.
4. Groups to run their algorithms against the test-cases and one or more groups, preferably completely independent, to undertake a holistic assessment based upon the results of this verification exercise from all groups.