PIRC

PUBLIC INTEREST RESEARCH CENTRE

CLIMATE FACTSHEETS

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WELCOME

Climate change research encompasses tens of thousands of peer-reviewed studies, decades of observations and the work of thousands of scientists. But too often this valuable knowledge doesn't reach the people who need it most: climate change communicators & campaigners.

This document takes the latest scientific research and translates it into practical factsheets on a wide range of climate change topics, ensuring that those responsible for communicating it to a wider public have easy access to the best available evidence.

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> "You can't fake spring coming earlier, or trees growing higher up on mountains, or glaciers retreating for kilometres up valleys, or shrinking ice cover in the Arctic, or birds changing their migration times, or permafrost melting in Alaska, or the tropics expanding, or ice shelves on the Antarctic peninsula breaking up, or peak river flow occurring earlier in summer because of earlier snowmelt, or sea level rising faster and faster, or any of the thousands of similar examples. ... put all the data from around the world together, and you have overwhelming evidence of a long-term warming trend.
>
> **- Michael Le Page**
> *New Scientist*
> 4th December 2009

ABOUT PIRC

PIRC is an independent charity integrating research on climate change, energy & economics - widening its audience and increasing its impact. We sit between research organisations and decision-makers; translating technical research into engaging material which inspires lasting change.

Since the failure of the Copenhagen climate talks in 2009 and the 'Climategate' debacle of early 2010, media interest in climate science has declined, and the public become somewhat more sceptical about its veracity. Yet the evidence base itself has only become more robust in that time. Conveying the certainties and uncertainties of climate science to the public - through a media that has become much more polarised about the subject - is a recurrent challenge for campaigners.

Responding to this, PIRC has put together the following set of factsheets, covering different aspects of climate science. The factsheets look at the evidence for climate change from a range of angles, such as global temperature trends and Arctic ice melt, and traces the fingerprint of climate change in various phenomena, from floods and heatwaves to wildfires and species extinctions. Each briefing contextualises the issue in question, summarises the background science, and addresses common objections raised by sceptics. Drawing on the latest peer-reviewed studies, they are intended to be a solid, reliable and concise guide for campaigners wishing to communicate climate science with accuracy and confidence.

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THANKS

Here we list those who generously donated time and expertise to answer our awkward questions, straighten out our confusions or review our writing. Many kind people helped us with this work in some way or another; far too many to mention individually here. Many, many thanks for all your comments, corrections and conversations.

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Responsibility for any errors, omissions or mistakes lies solely, of course, with PIRC.

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FOREWORD

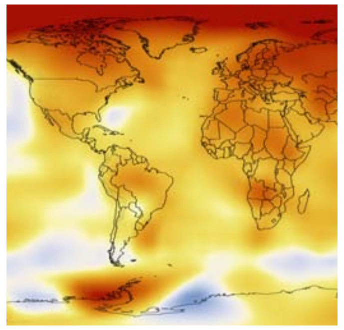
PIRC's Climate Factsheets are a valuable contribution to broader public understanding of the present state of climate science. They clearly and cogently set out the evidence for anthropogenic global warming - from rising global temperatures to melting Arctic sea ice - and its interaction with various climatic events, such as wildfires, droughts and flooding.

In constrained economic times, it is vital that we do not lose focus from tackling what remains the most pressing challenge humanity faces. It falls to policy-makers, journalists and civil society organisations to communicate accurately and without bias the threats we face from a warming planet.

The authors of these Factsheets state clearly what is known, and what isn't, about the contribution that human-induced climate change is making to shifting weather patterns and other observed phenomena. I commend them to anyone wishing to learn more about the science of climate change - and particularly to those communicating climate change to a wider audience, who need the facts at their fingertips now more than ever.

Sir John Houghton

Former Co-Chair of the Intergovernmental Panel on Climate Change (IPCC)
Former Director General of the UK Met Office



TEMPERATURE

The global temperature record is an important indicator of global climate change, and as a result is a major focus of attention for climate sceptics.

Summary

- Average global temperature has increased by around 0.75ºC since the beginning of the 20th century. Most of this is very likely to be due to human greenhouse gas emissions.
- All three main temperature data sets agree on the broad trend, despite slightly different analyses.
- Each of the last three decades was warmer than the last. The 'noughties' was the hottest decade on record.
- Long-term, temperatures are rising, but this doesn't mean that each year will be hotter than the last.

Context

Every January,[1] the global average temperature for the previous year is announced by three independent organisations. Though a single year's ranking ('hottest' or not) attracts media attention, only the long-term trend is evidence of climate change.[2]

Before climate negotiations in Copenhagen (2009) and Durban (2011), private emails from those working on global temperature data were published on the Internet (now referred to as 'Climategate').[3] Since then, nine independent reviews have cleared the scientists involved and their work (for more, see: bit.ly/climateg8).[4]

What's more, the average global temperature is only one piece of evidence of a warming world.[5] Other long-term trends like shrinking Arctic sea ice, advancing spring (see p.10 and p.24 respectively), glacial retreat, melting permafrost and sea level rise are consistent with the warming evident in the temperature record.

Background science

Every day local temperatures are recorded by thousands of weather stations on land, and on buoys and ships at sea.[6] Though the number of weather stations has changed over time, today data from between 4,000 and 6,000 of these weather stations are used to calculate average temperature across the globe.[7]

Three main organisations independently analyse and process data to perform this calculation:

- **GISTEMP** (bit.ly/gistemp) - NASA Goddard Institute of Space Studies (GISS) in the USA.
- **HadCRUT** (bit.ly/hadcrut) - University of East Anglia Climatic Research Unit (UEA CRU) and the Met Office in the UK.
- **NCDC** (bit.ly/ncdc_noaa) - National Oceanographic and Atmospheric Administration (NOAA) in the USA.

All three records show:

- An overall long-term warming trend, showing an increase of roughly 0.75ºC (+/-0.05ºC, so between 0.7ºC and 0.8ºC[8]) since the beginning of the 20th century.[9] (Other research shows most of this is very likely due to human greenhouse gas emissions.[10,11])
- Very similar year-on-year 'ups and downs,' (natural variations).[12] (The El Niño Southern Oscillation (ENSO, p.14), volcanic and solar activity account for most of these. Without them, the long-term trend is much clearer.[13,14])
- That each of the last three decades was warmer than the last (by 0.15-0.2ºC on average).[15]
- That all ten of the hottest years have occurred since 1998.[16]

Independent analyses of the raw data have been conducted by many people, sceptics included. Even the Berkeley Earth Surface Temperature (BEST) project – set up following 'Climategate' to resolve criticism of existing temperature analyses by 'starting from scratch' – show very similar trends (see bit.ly/bestcomparison).[17] All reasonable methods produce almost identical results.[18]

Small differences in results (for example which year is recorded as hottest) stem from differences in analyses - differing ways of dealing with issues in the raw data.[19] Some problems will always remain (hence the +/-0.05ºC uncertainty[20]) whilst others can be ironed out, or reduced for instance:[21]

- **Unreliable or poor quality data.** Data recording is not always good. Bad data sometimes simply cannot be used.[22] Large amounts of bad data can skew results unrealistically, though small bits that slip through won't have much effect.[23]
- **Different surroundings.**[24] The infrastructure in a city makes it slightly warmer than nearby rural areas – the Urban Heat Island (UHI) effect.[25] It is colder up a mountain than down in a valley next to it.[26] Globally, the UHI has contributed only 0.02ºC of warming over the last century.[27] To minimise these differences, the raw data are converted into temperature *anomalies* - a change in temperature from a reference period or baseline. This *change* in temperature is similar both up a mountain and down in the valley next to it; in a city or surrounding rural areas.[28]
- **Short or interrupted records.** Old thermometers are replaced with new ones, or with better technology. Weather stations are closed down, break or are moved to different sites.[29] Interruptions are often identifiable during analysis (for example a sudden 'jump' in temperature), and the record at that station is calibrated to make it continuous; to make sure any increase (or decrease) in temperature is not artificial.[30]
- **Uneven distribution.** There are more weather stations in densely populated areas. The Southern Ocean, Africa, Antarctica and the Arctic have relatively patchy coverage.[31] We can't change history, instantly move, or buy more weather stations to get better coverage. Attempts to deal with this problem vary:[32] GISTEMP assumes the temperature anomaly in an area without many weather stations (most notably the Arctic) is the same as the nearest weather station (within reason[33]).[34,35] HadCRUT and NCDC make no such assumption,[36] effectively assuming that the temperature change in these areas is the same as the average.[37] GISTEMP has slightly higher estimates of average global temperatures as a result, since Arctic regions in particular have been warming faster than the average. For more information, see bit.ly/datadiff.

What the sceptics claim

The temperature data is unreliable.[38,39] The data is not perfect,[40] but many imperfections are ironed out or reduced,[41] and those remaining leave an estimated +/-0.05ºC of uncertainty:[42] much smaller than the observed warming of around 0.75ºC since the beginning of the 20th century.[43]

There's been no global warming since 1998 / this decade / this century.[44,45] Global warming does not mean that each year will be hotter than the last. There is lots of natural variability - daily to decadal 'ups and downs', caused mainly by other factors (ENSO, volcanic and solar activity).[46,47] Short-term flat or cooling periods have happened before (take a look at the graphic below).[48] Long-term, the trend is still on average 0.15-0.2ºC warming per decade;[49,50] each of the last three decades have been warmer than the last (for more info see bit.ly/temperaturetrends).[51]

The observed warming is caused by the Urban Heat Island (UHI) effect[52,53] or 'poorly' located weather stations.[54] Urban, rural, land and ocean temperatures are all rising.[55] The UHI effect has only a minor impact (roughly 0.02ºC of the 0.75ºC temperature rise over the last century[56]), and is corrected for in analyses.[57,58] Both 'poorly-located' and 'well-located' weather stations show warming.[59] (Sceptics help disprove their own argument here: bit.ly/sitelocations)

The weather stations are being cherry-picked.[60] It is true that not all weather stations' data are used. However, most of those dropped actually show more warming than those kept – including them would *increase* the warming trend.[61] Analyses that use more of the data do not show any significant changes in the long term trends.[62,63]

Also, there is a huge amount of other evidence that indicates a warming world (some of which is discussed in other factsheets).[64,65]

What the scientists say

Dr Vicky Pope *(Met Office)*: "The [main 3 temperature] datasets are all independent, and they all show warming."[66]

Prof. Phil Jones *(University of East Anglia Climatic Research Unit)*: "The fact that 2009, like 2008, will not break records does not mean that global warming has gone away. What matters is the underlying rate of warming - the period 2001-2007 ... was 0.21ºC warmer than corresponding values for the period 1991-2000."[67]

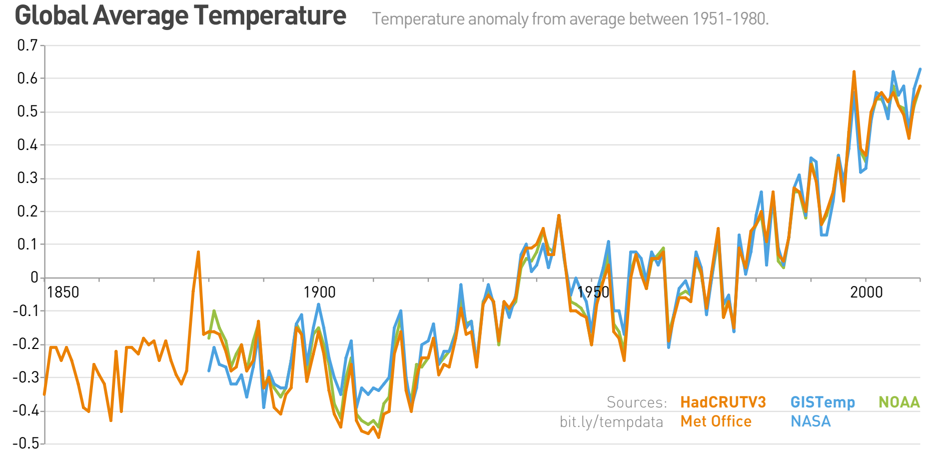
Prof. Myles Allen *(University of Oxford)*: "Even in the 80s [2008] would have felt like a warm year ... For Dickens this would have been an extremely warm year."[68]

Dr Gavin Schmidt *(NASA)*: "for any individual year, the ranking isn't particularly meaningful. The difference between the second warmest and sixth warmest years, for example, is trivial."[69] (The difference is a few hundredths of a degree centigrade.[70])

Dr John R. Christy *(University of Alabama)*, a long-time sceptic, acknowledges: "Long-term climate change is just that, "long term", and 12 months of data are little more than a blip on the screen."[71]

What the data says

Global Average Temperature Temperature anomaly from average between 1951-1980.



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For more info

The latest news on GISTEMP
bit.ly/gistemp

The Met Office: Global warming goes on (2008)
bit.ly/warminggoeson
[PDF; Archive]

Different data analyses show the same trend
bit.ly/temprecord

ARCTIC SEA ICE

The Arctic contains a thin, vulnerable layer of sea ice which reaches a minimum every September, providing a regular opportunity to highlight the impacts of climate change.

Summary

- The Arctic is warming roughly twice as fast as the global average.
- The long-term decline of Arctic sea ice is due to rising temperatures. This long-term decline reinforces natural variability in record low years.
- Even when a record low in sea ice occurs, the long-term trend is still most indicative of climate change.
- The Arctic is changing faster than predicted by the IPCC in 2007. As a result, projections of ice-free Arctic summers have been brought forward.

Context

In 2007, sea ice extent reached a dramatic record minimum, 23% below the previous record.[1] This caused considerable alarm among some Arctic scientists, leading to statements such as: "the Arctic is screaming",[2] "[it's] in its death spiral"[3] and "the canary has died".[4] Others, such as Vicky Pope at the Met Office and science blogger William Connolley, were more cautious.[5,6] They pointed to natural variability (year-to-year changes in weather or ocean currents and cycles) as a possible cause of the record decline.

Since 2007 the minimum moved closer to the long-term trend, as Connolley and Pope suggested it might. A decline in both maximum[7] and minimum extent (the highest and lowest areas covered by sea ice in a particular year, respectively) can be seen in the long-term trend (see graphic below). The minimum has been dropping at a rate of roughly 13% per decade since 1979.[8] 2011 was the second lowest recorded sea ice extent.[9]

Background science

The Arctic is warming around twice as fast as the global average, largely due to an amplifying (or 'positive') feedback.[10,11] Losing bright reflective ice leads to more heat being absorbed by darker ocean surfaces, and more regional warming, which in turn leads to more ice melt. This doesn't necessarily mean it is a 'runaway' process, or that it might reach a 'tipping point'.[12] The extra amount that melts because of the less reflective surface is only a small fraction of the initial melt - it adds up much like interest on a bank account.[13]

Arctic sea ice is affected by a combination of ocean currents and weather patterns (temperature, wind, cloud cover etc.) as well as the increasing influence of climate change.[14] It's not just the area (or extent) of ice that is affected - recurrent melting means that seasonal ice isn't able to build up thickness, a process which takes a number of years.[15] It is therefore more vulnerable to fluctuating weather conditions, since it becomes easier for small changes to melt the reflective ice, supplementing the feedback.[16]

Because of these interactions, there is debate about whether ice extent (a measurement of surface area with greater than 15% ice, most commonly used), area, thickness, volume or age is the best measure or predictor of its future behaviour. However, the overall thickness (and hence volume) of the sea ice is also falling (for more info, see: bit.ly/icemetric).[17] By 2009 only 10% of the Arctic ice was more than two years old, compared to 30% on average between 1981 and 2000.[18]

The 2007 IPCC report said "summer sea ice is projected to disappear almost completely towards the end of the 21st century."[19] In 2009, the Copenhagen Diagnosis, published by 29 leading climate scientists (including several IPCC authors) updated this forecast, noting that:

"The observed summer-time melting of Arctic sea-ice has far exceeded the worst-case projections from climate models of the IPCC AR4... The warming commitment associated with existing atmospheric greenhouse gas levels means it is very likely that in the coming decades the summer Arctic Ocean will become ice-free, although the precise timing of this remains uncertain."[20,21] (to read more: bit.ly/sensitivearctic)

Latest observations show Arctic sea ice is melting at least twice as quickly as computer simulations suggested,[22-24] and is "unprecedented over the last 1450 years."[25] Model runs now predict the Arctic being ice-free (in the summer) around 40 years earlier than scientists predicted before 2007.[26,27]

What the sceptics claim

Arctic sea ice is recovering.[28] Just because there isn't a new record low, this does not mean that the long-term trend has changed. Arctic sea ice is still in decline; there is no evidence of 'recovery'.[29,30] Furthermore, as explained above, the sea ice is melting much faster than expected, which has led to predictions of an ice-free Arctic being brought forward by roughly 40 years.[31]

It's not us: it's natural variability / it's the wind.[32,33] There is a lot of natural variability in the Arctic, but this can't explain the long-term trend. The only explanation for this trend is warming caused by increased atmospheric concentrations of CO_2 - a clear and distinct 'human fingerprint' on long-term Arctic sea ice melt.[34]

It's underwater volcanoes.[35] There are volcanic eruptions under the Arctic, but the heat doesn't reach the surface, and there's nowhere near enough of it to melt all the ice.[36]

There was less ice in the 1930s.[37] Satellite records began in 1979. To know what happened before then scientists have analysed a variety of different shipping records and historic accounts. Analysis of Russian ice charts and other data sets shows Arctic sea ice minima over the last decade are lower than those in the 1930s and 1940s (see bit.ly/arctichistory).[38]

What the scientists say

Dr Vicky Pope *(Met Office, UK)*: "The record-breaking losses in the past couple of years [2006-7] could easily be due to natural fluctuations in the weather, with summer ice increasing again over the next few years."[39]

Dr Gavin Schmidt *(NASA Goddard Institute for Space Studies, USA)*: the Arctic is "a good reminder that uncertainty in model projections cuts both ways."[40]

Dr James Overland *(National Oceanic and Atmospheric Administration)*: "The melting is happening faster in the real world than it has in the models".[41]

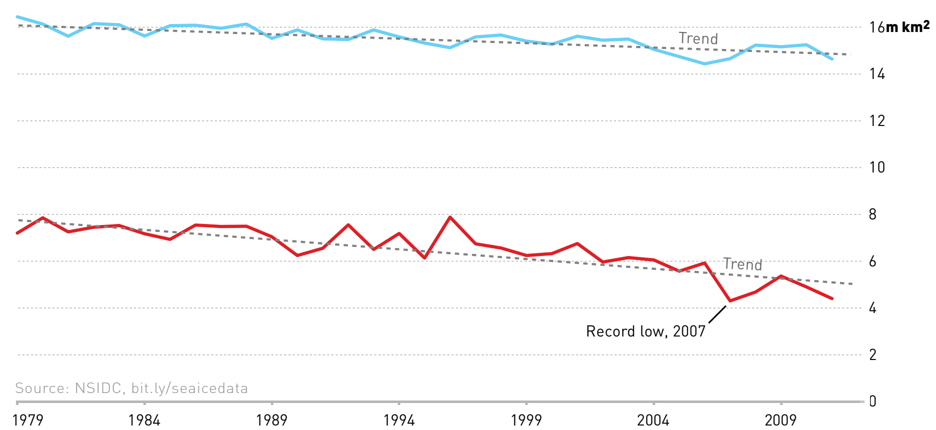
Dr Ted Scambos *(National Snow and Ice Data Centre, USA)*: "The main message is not so much whether or not we set a record, but this year [2011], without any noticeably unusual pattern of weather, we nearly broke a record, which only four years ago took a very unusual weather pattern plus a warming Arctic to achieve".[42]

Dr Christophe Kinnard *(Centro de Estudios Avanzados en Zonas Aridas, Chile)*: "This drastic and continuous decrease [in Arctic sea ice] we've been seeing from the satellites does seem to be anomalous... It does point to a continuation of this trend in the future."[43]

Dr Walt Meier *(National Snow and Ice Data Centre, USA)*: "If we get another warm year, anything like 2007, then the ice is really going to go. And the chances are that at some point in the next few years we are going to get a warm one."[44]

What the data says

Arctic Sea Ice Extent Maximum & Minimum, 1979-2011



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For more info

National Snow and Ice Data Centre (NSIDC) Arctic Sea Ice FAQs
bit.ly/arcticfaq

What caused the dramatic ice loss in 2007
bit.ly/2007causes

UNEP Climate Change Compendium p.17-20
bit.ly/climatecompendium

Latest News (NSIDC)
bit.ly/arcticnews

DROUGHT

Already one of the most widespread and damaging natural disasters, drought is likely to impact more people, more severely, as temperatures increase.

Summary

- Drought happens all around the world, though its impacts can be reduced and are not always severe.
- Severe drought, however, directly affects food and water availability, and can kill.
- Globally, since the 1970s, droughts are getting longer and more widespread, but only perhaps slightly more severe.
- Drought projections are still not very accurate, largely because they rely heavily on uncertain precipitation projections.
- Higher temperatures cause more evaporation from land which will exacerbate drought in the future.

Context

Drought is one of the costliest and most widespread natural disasters.[1] Long droughts reduce reservoir levels, limiting or cutting off water supplies for drinking and agriculture.[2] Drought can cause crop failure, leading to famine locally, and rising food prices globally.[3] Those dependent on local land for food and water are most affected by drought, and usually have the least capacity to adapt.[4] Drought can, and does, kill.[5]

Comparatively, the direct impacts of even severe droughts in the UK (for example 1976, 1995-96[6]) are mild. Drought can diminish water supplies for agriculture and people's health can suffer, especially when there is also a heatwave (as in 2003).[7] However, winter rainfall helps keep reservoirs relatively full during summer droughts,[8] and regulatory measures, like hosepipe bans, save water for more important uses.[9,10] In the UK, droughts are not usually severe or long-lasting.[11]

Background science

Drought describes abnormally dry conditions caused by below-normal precipitation (rain, hail or snow) over months or years.[12,13] It happens even in wet regions because it is defined relative to local conditions.[14] Deserts don't necessarily experience drought because they are always dry.[15] Drought severity depends on how dry it is (intensity), how long it lasts (duration) and how much area it covers (size).[16,17]

The direct impact of climate change on drought is hard to estimate because:

- **Measuring drought is hard.**[18] Groundwater and reservoir levels, river flows and soil moisture all help measure drought.[19] But these records are often short and poorly spread out. Precipitation and temperature data for basic 'water-in, water-out' calculations[20] are more comprehensive, but over-simplify the situation – dryness doesn't always mean drought.[21]
- **Seeing if droughts have changed is difficult.** Droughts change in severity and frequency year-to-year and decade-to-decade.[22] They are regional, and happen relatively infrequently, meaning there may be insufficient data to show any pattern or trend.[23]
- **Many factors contribute to drought.** Some factors may be influenced by climate change and natural variations (El Niño Southern Oscillation (see p.14), or monsoons), such as:[24,25]
  - Local rainfall.
  - Low levels of snowfall (which can cause 'delayed' drought as less spring meltwater flows down rivers).[26]
  - High local temperatures (which increase evaporation, removing water [27,28]).

  Other factors are hardly influenced by climate:
  - Irrigation systems and dams diverting water courses.[29,30]
  - Land use change or erosion (which can cause more water to evaporate or run-off).[31,32]
  - How many people require water and what they need it for (increasing demand can mean supplies fall short.)[33,34]

  Since different combinations of these factors interact to create the particular conditions of a drought, the impact of climate change can be difficult to identify.

However, some changes to drought have been identified:

- Globally, the area affected by serious drought has increased since the 1970s,[35,36] and some evidence suggests that droughts are intensifying, though not by much.[37-39]
- Regionally, since the 1970s, droughts in parts of Africa and East Asia have become more severe, and those in southern Europe and eastern Australia have experienced slightly severer droughts.[40]
- These areas have dried significantly since the 1950s, with the Sahel (south of the Sahara) most severely affected (see graphic below).[41] Evaporation has contributed a small amount to drying since the 1980s.[42,43]

These changes, however, have not been clearly attributed to climate change.

Climate feedbacks

Higher temperatures increase evaporation from land, which in drier areas can increase temperatures further (a reinforcing or 'positive' feedback) – less heat is lost through evaporation because there is less moisture in soils, and more heat comes in because fewer clouds form.[44,45]

Drought also causes vegetation to dry out and die, and can lead to fires.[46] These release CO_2, which can enhance climate change (another reinforcing or 'positive' feedback).[47] Die-back in the Amazon, caused by severe droughts in 2005 and 2010 (both 'once-in-a-hundred-year' droughts [48]) released more CO_2 than the Amazon usually absorbs in a year (see bbc.in/amazondrought).[49,50] In the long-term, if sufficiently sensitive to drought, the Amazon could change from a *sink* to a *source* of CO_2[51] though this may not be permanent.[52]

Projections

In general as global (and local) temperatures increase, drier areas are expected to dry further.[53,54] Some research suggests that droughts will therefore become longer and more widespread, and be more severe.[55,56] Evaporation will likely play a bigger role under higher temperatures, which some research suggests will lead to droughts much more severe than ever recorded.[57] Lower or less frequent precipitation will still be the dominant factor increasing drought in the future.[58]

More specific local (or regional) drought projections are quite uncertain.[59] The precipitation projections on which they rely include natural variations such as ENSO and monsoons, which are currently difficult to predict.[60,61]

What the sceptics claim

Droughts have happened before[62,63] and are (therefore) natural.[64,65] The direct cause of a drought is the particular conditions of the region, which include natural factors.[66] Climate change, however, will likely play a larger part in drought as precipitation patterns change and higher temperatures enhance evaporation.[67]

Flooding and rain mean drought projections are wrong.[68] More severe or frequent droughts do not necessarily mean there will be no rain;[69] and short-term events are different from long-term trends.[70]

There are contradictory projections.[71] Many local (or regional) precipitation projections are still not very certain, and may change as we learn more.[72] Generally, drying regions are likely to continue getting drier, but the specifics are harder to predict.[73]

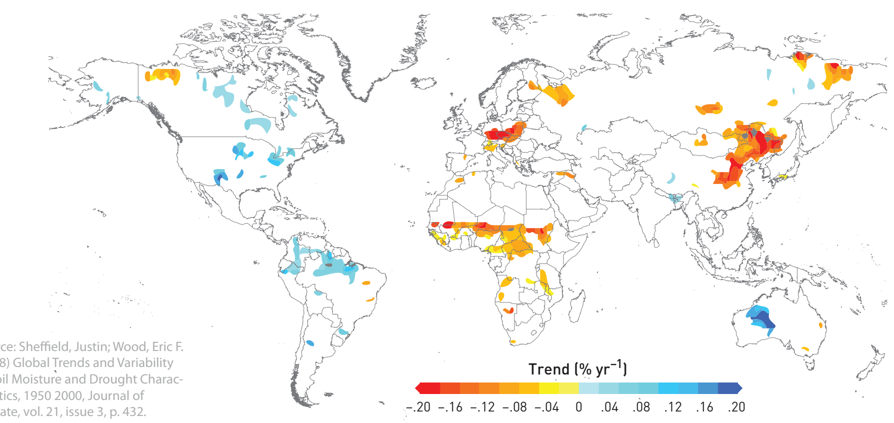
We can adapt agriculture to be more drought resistant so it's not a problem.[74] To an extent, water management and food production can be adapted to be more drought resilient.[75] However, many simply do not have the resources to adapt, and the more frequent and severe drought becomes, the harder it is to maintain such measures.[76]

Droughts are not becoming more frequent, more severe or longer.[77] Droughts are relatively rare and so the quantity of data is small, making identifying trends difficult.[78] Some strong drying trends have been established (for example in the Sahel),[79] and there is evidence that shows drought becoming longer and hence more severe in some areas.[80-82]

The IPCC was wrong about the Amazon.[83] 'Amazongate' was widely reported in the media.[84,85] The IPCC's 2007 report said that "Up to 40% of the Amazonian forests could react drastically to even a slight reduction in precipitation,"[86] referencing a non-peer-reviewed WWF report. However, independent scientific studies concluded the same or worse.[87-89] For more info - bit.ly/amazongate.

What the data says

Annual Volumetric Soil Moisture Statistically significant trends, 1950–2008



Source: Sheffield, Justin; Wood, Eric F. (2008) Global Trends and Variability in Soil Moisture and Drought Characteristics, 1950 2000, Journal of Climate, vol. 21, issue 3, p. 432.

What the scientists say

Dr Simon Lewis *(Leeds University, UK)*: "If events like this (severe drought in 2010) happen more often, the Amazon rainforest would reach a point where it shifts from being a valuable carbon sink slowing climate change, to a major source of greenhouse gases that could speed it up."[90]

Prof. Isaac Held *(National Oceanic and Atmospheric Administration, USA)*: "There is a hint that the current drying may be caused by what the models suggest (climate change), but it's only a hint right now."[91]

Prof. Thomas Reichler *(University of Utah, USA)* "There is a lot of natural variation from year to year (in the drying of the higher latitudes), but we see a slow, gradual change."[92]

Prof. Steven Running *(University of Montana, USA)* "Globally, we're seeing larger and longer droughts."[93]

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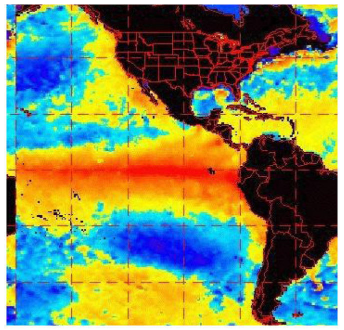
Drought - today and tomorrow
bit.ly/futuredrought

How severe is a drought, and what does it mean
bit.ly/droughtmeasures

Current drought situation in the UK
bit.ly/ukdroughtnow



EL NIÑO

The El Niño Southern Oscillation (ENSO) involves abnormal warming (or cooling) of the central and eastern Pacific Ocean, brought about by interactions between the ocean and the atmosphere. It has impacts around the globe.

Summary

- ENSO is a major part of the natural variability of the Earth's climate.
- Comparatively frequent El Niños (warm phases) likely contributed a small amount to global warming between 1976 and 1998. A possible shift to more frequent La Niñas (cool phases) may have moderated warming since.
- The effects of climate change on ENSO are incredibly difficult to identify because it is such an irregular cycle.
- We don't know yet how climate change might affect ENSO in the future, though it will likely intensify some of the impacts.

Context

ENSO is a natural, irregular cycle that has happened for thousands of years.[1] No link to climate change has been definitively established.[2,3] There are, however, similarities between ENSO and climate change:

- **Prediction**: Though ENSO processes are not entirely understood, its general behaviour and patterns are predictable.[4,5] Specific regional impacts can be difficult to predict.[6,7]
- **Impacts**: ENSO affects temperature and precipitation patterns globally. It changes the likelihood of floods, droughts and tropical storms/hurricanes in different areas.[8]
- **Attribution**: While it is difficult to explicitly label individual extreme events as being caused by El Niño or La Niña, they are strongly linked.[9]

However, the impact of ENSO only lasts for the duration of the cycle (a few months to two years), or with a small delay.[10] Changing somewhat irregularly year-to-year, it is responsible for much of the 'noise' (or natural variation) in various climate indicators.[11]

Background science

ENSO involves an interaction between ocean and atmosphere in the tropical Pacific Ocean.[12] A La Niña (the cool phase of ENSO) is a stronger version of normal (or 'ENSO neutral') conditions: a more intense cooling of the central and eastern Pacific Ocean. El Niño (the warm phase of ENSO) refers to an abnormal warming of these areas of Pacific Ocean.[13] The ocean warming causes a change in the winds, which in turn causes a change in the ocean surface temperatures, reinforcing the initial warming - a 'positive' feedback which builds El Niño.[14,15]

The change between El Niño and La Niña is somewhat erratic: the two phases occur at irregular intervals of two to seven years, lasting between a few months and two years.[16,17] There can be several El Niños or La Niñas in a row, with 'neutral' conditions in between (see graphic below). The strength of an El Niño or La Niña varies significantly.[18]

ENSO forecasting models can predict El Niño or La Niña six-to-nine months in advance by recognising ocean temperature patterns.[19] It is more difficult to predict the strength[20] or specific local impacts of a phase, because ENSO behaves inconsistently.[21,22] It is not entirely understood what initiates or ends the reinforcing feedback.[23]

Global Impacts

ENSO (El Niño and La Niña on average) has likely contributed about 0.06ºC to global warming since 1950.[24] El Niño contributions to individual years can be larger. 1983 and 1998 featured 'super El Niños' far stronger than previously recorded.[25] The super El Niño of 1998 (the hottest year in the Met Office record[26]) likely contributed 0.17ºC of warming to that year.[27] An El Niño causes a temporary increase in global average temperature for two reasons:[28]

1. **Redistribution of heat**: a larger portion of the surface of the Pacific Ocean is warmer than normal, so there is more evaporation. This transfers heat from the ocean to the atmosphere.
2. **Enhanced greenhouse effect**: more evaporation also means more water vapour (also a greenhouse gas), which reinforces this effect - another 'positive' feedback.

With La Niña, a larger portion of the surface of the Pacific Ocean is cooler than normal, so there is less transmission of heat from the ocean into the atmosphere.[29] Despite this, 2011 was the warmest La Niña year ever recorded (for more information see: bit.ly/2011lanina).[30]

ENSO 'focuses' weather in particular areas. Effects are most severe in the equatorial Pacific, tropics and Pacific rim countries:

- **Precipitation**: El Niño is linked to heavy rainfall and flooding along the western coast of South America, and drought in Indonesia, India and Australia.[31,32] La Niña has opposite, though not necessarily equal effects.[33,34]
- **Storms**: La Niña tends to bring more hurricanes, typhoons and tropical cyclones over the Atlantic and Gulf of Mexico. El Niño suppresses them along the eastern coast of North America, and increases storm activity over the Pacific Ocean.[35-37]

ENSO also affects parts of East and South Africa, and parts of Asia;[38] it has only minor impacts in Europe and the UK. It can be difficult to untangle the effects of climate change and ENSO. Because ENSO is irregular, it is difficult to tell if there are changes due to global warming.[39] Some evidence suggests a link to the increasing intensity of the floods and droughts associated with ENSO (see p.12 and 14 respectively).[40] Climate models disagree on the future effects of climate change on ENSO - some predict stronger phases, some weaker and others no change.[41-44] Because ENSO influences global weather patterns so strongly, it is one of the reasons there is uncertainty in regional projections of climate change.[45]

What the sceptics claim

Global warming is due to El Niño.[46-48] El Niño does temporarily enhance the global average temperature. But ENSO cycles are short - a few years maximum.[49] ENSO has likely contributed only 0.06ºC to the 0.55ºC increase seen in global average temperatures since 1950 (note the total warming since 1900 is roughly 0.75ºC[50] - see p.8).[51-53]

Climate models are unreliable because they can't simulate ENSO.[54] Climate models simulate ENSO well on a global scale,[55] but are often less accurate regionally.[56] There is disagreement on how (or if) ENSO might change in the future,[57,58] but greenhouse gases have, and will likely continue to be responsible for most of the warming,[59,60] meaning global projections are still reliable.

Global warming stopped in 1998.[61] The Met Office states that 1998 was the hottest year on record.[62] Some claim wrongly (see p.8) that this means global temperatures have been falling since then.[63] In 1998 there was a super-El Niño, which gave an extra boost to temperatures, *on top* of the long-term warming.[64] Global average temperatures in 2010 and 2005, were very close to 1998 – despite being unaided by any super El Niño.[65,66]

What the scientists say

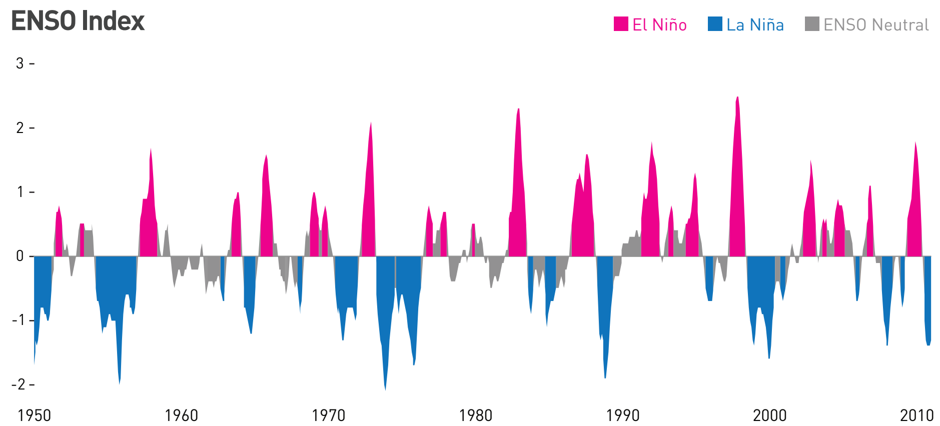
John Cook *(Skepticalscience.com)*: "Data analysis, physical observations and basic arithmetic all show ENSO cannot explain the long-term warming trend over the past few decades."[67]

Dr Wenju Cai *(Commonwealth Scientific and Industrial Research Organisation, Australia)*: "While the possibility of large changes in ENSO cannot be ruled out, research conducted to date does not yet enable us to say precisely whether ENSO variability will be enhanced or moderated, or how the frequency of events will change."[68]

Michel Jarraud *(Secretary-General of the World Meteorological Organisation)*: "La Nina is part of what we call 'variability'. There has always been and there will always be cooler and warmer years, but what is important for climate change is that the trend is up; the climate on average is warming."[69]

What the data says

ENSO Index



Source: NOAA's Oceanic Niña Index , see: 1.usa.gov/ensodata

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For more info

A whole host of ENSO-related info
bit.ly/ensoinfo

Top misconceptions about El Niño explained
bit.ly/topmisconceptions

El Niño and global warming on Real Climate
bit.ly/whatisenso

Non-technical El Niño explanation
bit.ly/nontechy

FLOODING

Climate change is likely to increase flooding, and given physical limits to flood adaptation, emissions reductions are needed to prevent unmanageable flooding in the future.

Summary

- Identifying the influence of climate change in observations is difficult because many factors contribute to flooding.
- However, it is likely that climate change will contribute to flooding from rising sea levels, melting glaciers and by intensifying rainfall.
- In parts of the Northern Hemisphere, climate change has contributed to more intense heavy precipitation since the 1950s.
- Multiple factors likely contributed to a substantial global increase in large floods over the 20th century.

Context

Floods affect roughly 140 million people every year – more than all other natural disasters put together.[1] They contaminate drinking water, ruin harvests and wash out fertilizers and nutrients from soil; water-logged fields rot food and spread crop diseases, prolonging famine.[2] Stagnant water contaminated with sewerage, fertilizers and oil spread water-borne diseases like typhoid, cholera and diarrhoea.[3] Floods interrupt power supplies, communications and transport; they damage homes, property and infrastructure.[4] Floods can also trigger landslides.[5] Many impacts will worsen as temperatures continue to rise.[6]

If flood risk continually increases, adaptive measures become obsolete – there are limits on how high we can build flood defences, for example – we can't play 'catch-up' forever.[7] British people exposed to flooding regard climate change as more concerning and less uncertain, even if the flood cannot be attributed to climate change. They also feel that their actions will have an effect on climate change and are more prepared to act.[8]

Background science

Increasing temperatures affect flooding directly:

- Rising sea levels (from melting land ice, and ocean expansion due to warming), in combination with cyclones and high tidal surges, increase flood risk.[9]
- Melting glaciers put pressure on watercourses downstream which can cause flooding.[10]

and indirectly:

- By encouraging evaporation and reducing condensation, the atmosphere is able to hold more water.[11] This is like fuel for weather systems,[12-15] increasing the chances of more intense precipitation which, given the right conditions, means more flooding.[16] Atmospheric water vapour has increased by 5% over the 20th century, in line with what basic physics expects from the observed temperature rise.[17-19]

But identifying the influence of climate change in observations is difficult, for several reasons:[20]

- **Measuring flooding is hard.** Direct measurements of flooding, and factors that influence flooding (heavy precipitation, continuous wet periods, glacier-melt, sea level rise, river flow, water run-off from land) are often short-term or only cover small areas.[21] Changes in these factors don't necessarily mean more or less floods.[22] Measuring economic damages from flooding can include changes in population, wealth and infrastructure on floodplains and in coastal areas, rather than just changes in flooding.[23,24]
- **Finding a trend is difficult.** Floods are regional and happen relatively infrequently, making trends hard to identify.[25] Long-term trends can be hidden by significant year-to-year and decade-to-decade variation.[26,27] Average precipitation need not change much for more floods to occur – the same amount of rain might fall in more intense but sporadic events, increasing the likelihood of flooding.[28]
- **Many factors contribute to different types of floods.** Local precipitation and water availability can be influenced by climate change but also depend on atmospheric circulations,[29] natural cycles like the El Niño Southern Oscillation (see p14), and monsoons.[30] Human factors like land-use change, water management and irrigation have all affected watercourses; agriculture, deforestation, loss of flood plains, and urbanisation can all affect the likelihood or severity of flooding.[31]
- **Attribution to climate change is hard.**[32,33] The impact of climate change on, or amongst, the multiple factors that create the particular circumstances of a flood (or a trend in flooding) can be difficult to identify.[34,35] It is difficult to say that climate change is *the* cause of a flood, but it can affect the *likelihood* of one – for example one study found that the floods in the UK in 2000 were twice as likely to have happened because of climate change.[36,37]

UK

In the UK, floods have become slightly more frequent over the last 30-40 years,[38-40] as have longer periods of rainfall (a major cause of flooding).[41] Over the 20th century, winter rain has been more 'flashy' (falling in more sporadic, but intense periods), though in summer the opposite is true.[42] All of these changes, however, are small and at present indistinguishable from natural variations.[43]

Very generally, the north of the UK is likely to get wetter in winter, the south drier, though the reliability of such specific regional projections is low (see bit.ly/ukprecip for more info).[44]

World

Globally, large floods have become substantially more frequent over the 20th century,[45] with large inland floods twice as frequent per decade between 1996 and 2005 as between 1950 and 1980.[46] Some of this is likely due to better reporting and changing land use.[47]

The number of heavy precipitation days[48] and sudden downpours[49] has increased over the last half of the 20th century in many areas of the Northern Hemisphere. Though total or average precipitation may not have changed much, evidence suggests climate change is causing it to fall in more intense bursts.[50,51] All these trends are likely to continue.[52]

These observations have been at the upper end of IPCC projections, suggesting that models may be underestimating intense precipitation increases.[53,54] Future projections vary widely and few robust regional projections have been made. Generally, higher latitudes will become wetter, making flooding more likely.[55,56] However, because flooding is very localised, and depends on many factors, it is hard to say where and when floods might be more or less common.

What the sceptics claim

Flooding is not caused by climate change.[57] Climate change affects some of the factors that cause, and can exacerbate flooding - by concentrating or intensifying precipitation; and by melting land ice and warming oceans, contributing to sea-level rise.[58]

There have always been floods.[59-61] Large floods have become substantially more frequent globally over the 20th century, as we'd expect in a warming climate, and they will likely become even more frequent as temperatures increase.[62]

Rainfall hasn't increased, and won't increase.[63] *Average* rainfall doesn't have to change that much for there to be an increase in flooding. If the same amount of rain falls in shorter, heavier events, floods are more likely.[64]

Increased damages from flooding are due to more people living and building on flood plains.[65] As well as these social factors, bigger, more frequent floods increase damages,[66,67] and due to climate change will likely play a bigger role in the future.[68]

You can't blame drought *and* floods on climate change.[69] Observations already show an increase in extreme precipitation and in drought, though in different places (see graphic below).[70] Generally, wet places will get wetter (and make flooding more likely), and dry places will get drier (making droughts more likely).[71]

What the scientists say

Prof. Ian Cluckie *(University of Bristol, UK)*: "Ten per cent of UK housing is on flood plains, but this is quite low compared to some countries – it is 70% in Japan and 100% in the Netherlands."[72]

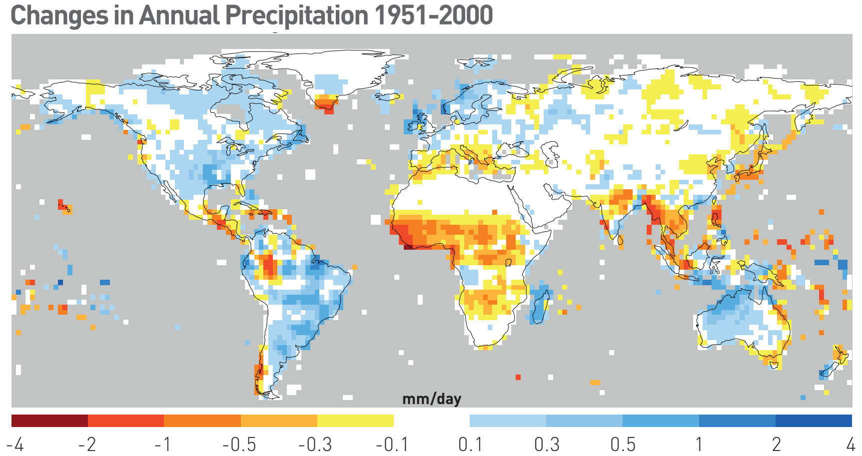
Dr Kevin Trenberth *(National Center for Atmospheric Research, USA)*: "There is a systematic influence on all of these weather events now-a-days because of the fact that there is this extra water vapor [sic] lurking around in the atmosphere ... this is one manifestation of climate change."[73]

Prof. Stefan Rahmstorf *(Potsdam Institute for Climate Impact Research, Germany)*: "Looking only at individual extreme events will not reveal their cause, just like watching a few scenes from a movie does not reveal the plot."[74]

Dr Andrew Weaver *(University of Victoria, Canada)*: "We should continue to expect increased flooding associated with increased extreme precipitation because of increasing atmospheric greenhouse gas."[75]

What the data says

Changes in Annual Precipitation 1951-2000



Change in global annual precipitation when averaged over the whole world between 1951-2000 is only -0.03mm/day.

Source: NASA, 1.usa.gov/precipmap

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For more info

Great satellite pictures of floods (2001-present)
bit.ly/floodimages

A summary of research showing human effects on rainfall
bit.ly/humaneffect

Flood insurance and climate change
bit.ly/flood-insurance

HEATWAVES

As average global temperatures increase, we are likely to see more record highs, and fewer record lows. This would make heatwaves longer, more frequent and more intense.

Summary

- Both natural cycles and climate change can contribute to the local high-temperature periods of a heatwave.
- Local temperatures during the heatwaves in Europe (2003) and in Russia (2010) were much higher than extremes for these places over the last 510 years.
- Globally, heatwaves on average have become slightly hotter and more frequent.
- This trend is likely to continue, with record heatwaves experienced more often in some areas.

Context

Recent heatwaves in Europe (2003) and Russia (2010) were literally off the scale, with temperatures significantly higher than the 'extremes' of the last 510 years,[1] and had less than a one-in-750 chance of occurring naturally in the climate a few decades ago.[2,3] Climate change projections suggest heatwaves like these will become more common in the future if we do little to mitigate climate change:[4] they may be the 'norm' by the 2040s,[5,6] with a possibility that "by the end of the century, 2003 would be a cool year" (Dr Myles Allen, Oxford University, UK).[7]

Historically, the UK has rarely experienced severely high temperatures, but projections suggest we too will have longer, hotter and more frequent heatwaves in the future.[8] Currently, planning to cope with heatwaves is not a major part of central and local government policy, especially outside the healthcare sector.[9] A recent UK survey of those most at risk from heatwaves (the elderly and unwell), found they hugely underestimated the danger of a heatwave.[10]

Background science

Typically, a heatwave is declared once it has been hotter than a particular temperature for a number of days, though there is no universal definition.[11]

Impacts

A heatwave has detrimental effects on human life, regional economies and ecosystems.[12] Anything that is used to near-constant temperatures, or that functions near its temperature limits, is vulnerable to heatwaves.[13]

Heatwaves with hot nights (as well as days) are more dangerous as there is no respite from the heat.[14] Humid heat is more dangerous than dry heat,[15] as it is more difficult to cool down by sweating.[16] Even in dry heat, we rarely survive temperatures that stay higher than 45°C for long.[17] Less severe heatwaves can and do kill – through heat exposure, or by aggravating pre-existing conditions.[18] The very young, elderly and unwell are at most risk.[19,20] Air pollution in cities intensifies the impacts of a heatwave.[21,22] Changes to behaviour (using air conditioning or resting during the hottest hours) and early warning systems can reduce the impact.[23-25]

Knock-on effects such as damage to vegetation from excessive heat, drought or wildfire could act as reinforcing (or 'positive') climate feedbacks,[26-28] and can kill by affecting local food and water sources, or by increasing global food prices, as in Russia in 2010 (see *Drought*, p.12 and *Wildfires*, p.26 for more on these points).[29]

New extremes

Peak temperatures are rising much faster than averages,[30] in line with climate model predictions.[31] Extremely hot days are becoming hotter and more frequent, making heatwaves more likely.[32,33] Globally, there has been an observable increase in the frequency of heatwaves.[34] Since the 1950s, heatwaves have been lengthening in some places (central and eastern Europe,[35,36] Alaska, Canada, Siberia, central Australia [37]); but shortening in others (south-eastern USA, eastern Canada, Iceland and southern China).[38,39]

Local temperatures are influenced not only by climate change, but by cycles such as El Niño (see p.14) and atmosphere and ocean circulations that promote high-pressure systems. This makes attributing any heatwave to climate change difficult, because both climate change and natural factors contribute.[40] New research can, however, tell if climate change has made a heatwave more *likely* – for example, the 2003 European heatwave was at least twice as likely because of warming caused by human greenhouse gas emissions.[41] There is only a 20% chance that the Russian heatwave in 2010 would have happened without climate change, and records like this are now five times as likely.[42]

Europe (2003) and Russia (2010) experienced the hottest heatwaves of the past 510 years, far outside 'normal extremes' (see graphic below). They caused approximately 70,000[43-45] and 55,000[46] deaths respectively.[47] Because almost everything has adapted to, or been made to withstand 'normal' historic extremes, the majority of impacts are harmful outside this range.[48,49] Keep in mind though, that not all recent (and future) heatwaves are outside of what would be expected.[50]

Future projections

Heatwaves are very likely to become generally longer, hotter, and more frequent in places that already experience them.[51-53] In Europe, heatwaves such as 2003's could become five-to-ten times more likely over the next 40 years.[54,55] One study suggests that by 2300, with an eventual global warming of 10°C (possible under business-as-usual scenarios), heat and humidity would make almost half of the world's most populous areas uninhabitable.[56,57]

Little research has focused on future impacts of heatwaves on poorer areas; but with little capacity to adapt,[58] they will likely be severe.[59] Areas less used to heatwaves are likely to be ill-prepared.[60] Cities will be more severely affected than rural areas.[61] The World Health Organisation (WHO) estimates that every 1°C increase in 'apparent' temperature (heat and humidity together), leads to 3% more deaths in European cities.[62] Fewer deaths in generally milder winters will likely be outweighed (up to five times by 2100) by more deaths due to heatwaves.[63,64]

What the sceptics claim

You can't attribute heatwaves to climate change.[65] Excessive heat can be caused by several factors, making heatwaves difficult to attribute directly.[66] However, warming caused by additional greenhouse gases has increased the *likelihood* of some heatwaves.[67]

Heatwaves are natural.[68-70] **/ There have been heatwaves in the past.**[71,72] Recent heatwaves in Europe (2003) and Russia (2010) were by far the hottest of the last five centuries.[73,74] Local temperatures are influenced by high-pressure systems, promoted by natural atmosphere and ocean circulations, or cycles such as ENSO.[75] However, climate change amplifies high temperatures, resulting in hotter, longer and more frequent heat waves.[76,77]

It's the Urban Heat Island (UHI) effect.[78] The UHI effect can push already-high temperatures up further in cities, intensifying heatwave conditions.[79] It is not the cause of heatwaves. Death rates are also higher in cities during a heatwave due to air pollution, making it seem as though the heatwave is worse in urban areas.[80,81]

There are also loads of cold snaps![82,83] No-one is saying there will be no cold periods. But, as average temperatures rise, we are likely to see more record highs and fewer record lows. This trend is already evident in the USA[84,85] and Australia.[86] Peak temperatures are also rising much faster than the averages, making more extreme heatwaves more likely.[87]

It's better when it's warmer because cold winters kill more people than warm summers.[88,89] As heatwaves get longer, hotter and more frequent the number of additional people killed by them will likely outweigh the reduction in deaths due to fewer harsh winters (up to five times by 2100).[90,91]

What the scientists say

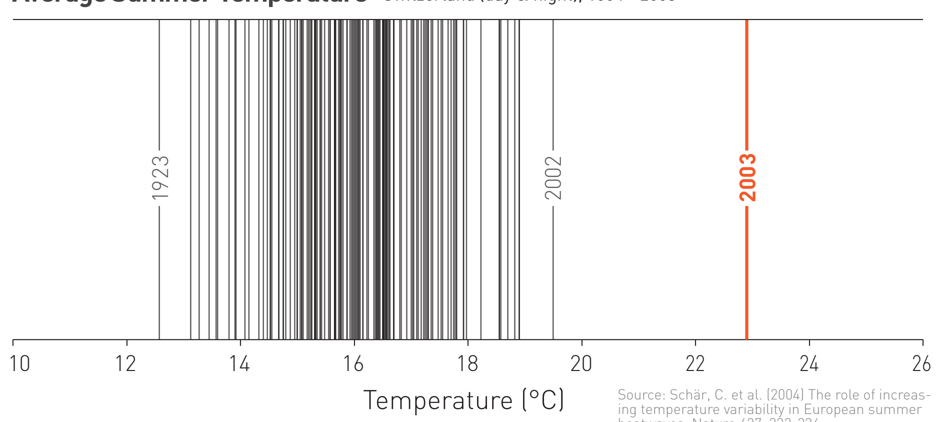
Dr Kevin Trenberth *(National Center for Atmospheric Research, USA)*: "For extreme events, the question isn't, 'Is it global warming or natural variability?' It is always both. The question is just how much each is contributing."[92]

Dr Myles Allen *(Oxford University, UK)*: "... on a middle-of-the-road scenario for emissions - assuming we don't do very much to combat climate change - temperature heatwaves as high as the one in 2003 would be occurring every other year by the middle of this century, ... By the end of the century, 2003 would be a cool year."[93]

Dr Noah Diffenbaugh *(Purdue University, USA)*: "One might expect that an average warming of four degrees would equate to each day warming by 4 degrees, but in fact the hottest days warm quite a bit more."[94]

What the data says

Average Summer Temperature Switzerland (day & night), 1864 - 2003



Source: Schär, C. et al. (2004) The role of increasing temperature variability in European summer heatwaves, Nature 427, 332-336.

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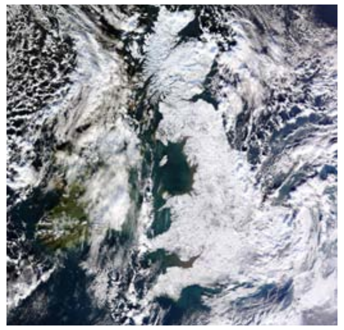
For more info

Crock of the Week videos on heatwaves
bit.ly/heatwavesvideo

Is this extreme down to climate change?
bit.ly/extremeevents

European (2003) and Russian (2010) heatwaves summarised
bit.ly/2003and2010

Is climate change affecting extremes?
bit.ly/extremelyhot



SNOW & COLD

Cold and snowy weather attracts media attention and can have an impact on public opinion and concern about a warming world, but it does not disprove climate change.

Summary

- A warming climate does not mean the end of cold or extreme winters.
- Recent winters in the UK (and parts of the USA) have been cold, but the temperature for the entire Northern Hemisphere was warmer than average.
- In the UK, we could experience more cold winters as the climate changes, though this is still uncertain.
- Globally, however, as temperatures rise, cold winters are likely to be less severe, and less common.
- Snowfall may increase in some places as a result of more evaporation in a warmer climate.

Context

During the past few winters, the UK media ran stories with headlines ranging from 'It's so cold that global warming can't be real',[1-3] to 'cold and snowy weather is caused by climate change'.[4-6] With or without this confusing media influence, it is likely that the cold winter had some impact on public belief in, or concern about, climate change.[7-9]

Historically, the last few UK winters have only been harsh relative to a period of quite mild ones.[10,11] The coldest UK winter[12] of the last century was 1962-63.[13,14] Parts of the sea were frozen, as was the river Cam and parts of the Thames;[15,16] over 400 league football matches were postponed,[17] with some pitches re-opening as ice rinks.[18] The second-coldest (and one of the snowiest) was 1946-47:[19] thousands of people were cut off by snowdrifts up to seven metres deep, and many villages relied on RAF helicopter supplies; between January and March, snow fell somewhere in the UK for 55 days straight.[20]

Background science

Climate gives us an idea of what 'normal' weather might be at a given time of year, what the 'extremes' of weather look like, and how often these extremes might occur. What is 'normal' and 'extreme' depends on the place. A cold and snowy winter here might be relatively common (and more extreme) than you would expect in southern Spain, but less common (and less extreme) than in Siberia - these places have their own climates. The global climate defines what is normal and extreme typically for the world as a whole, taking all these places into account.

Cold and snowy weather will still occur in a warmer climate.[21] This does not stop, cancel out or disprove the long-term warming of the global climate, but neither does it mean that cold or snowy weather is caused by climate change.[22]

There are two main reasons for this:

1. What happens locally in the UK is not representative of what is happening globally (see graphic below). Even though the winter of 2009-10 was the coldest in the UK for over 30 years, in the Northern Hemisphere it was the fifth warmest winter on record.[23,24] At the same time, it was the hottest Southern Hemisphere summer ever recorded.
2. Weather varies so much and so quickly that any one 'extreme' weather event cannot tell us much, if anything, about climate. Roughly 30 years of weather gives us enough information to define what the climate of a region, or the globe, might be. Similarly, we need long periods to see if what is 'normal' or 'extreme' has changed. Changes over a few months (a cold and snowy winter) tell us very little about what is happening to the climate.

Natural cycles have been responsible for cold and snowy winters in the past, and will produce more in the future.[25-27] Research suggests that as the average temperature increases, cold winters should become less severe and less common globally.[28] Local, more immediate impacts on weather in the UK and USA are uncertain.[29]

Cold spells and climate change

Cold spells in the UK are caused mainly by natural atmospheric cycles - the North Atlantic Oscillation (NAO) and Arctic Oscillation (AO), which can be seen as slightly different regional outputs of the same process.[30,31] In the 'negative phase' of both, changes in air pressure around the Arctic (the jet stream) allow more cold air to travel south,[32] resulting in cold weather for parts of Europe, North America and Northern Asia.[33,34]

The sun may also make a minor contribution to cold spells.[35] Low solar activity could either contribute to changes in air pressure directly, or influence the cycles described above, though this is not conclusive.[36,37] Cold winters in parts of the Northern Hemisphere may even become more common [38] - the ongoing reduction of Arctic sea ice could cause additional changes in atmospheric circulation,[39-41] though scientific opinion is far from settled on this point.[42]

Snow and climate change

Perhaps counter-intuitively,[43] a warmer world could lead to more snow in some places.[44,45] More warmth increases evaporation, which leads to more moisture in the air and thus more precipitation.[46] If it is sufficiently cold where or when this precipitation falls, it will fall as snow.[47] A warmer world does not mean that there will be no cold places - if winter temperatures usually reach -6ºC, a warming of 2ºC will not stop it being cold enough to snow.[48]

What the sceptics claim

It's cold/it's snowing, so climate change has stopped/isn't real.[49] Very cold or snowy weather is *short-term* and *local*.[50] It does not disprove climate change. The *long-term* trend in *global* average temperature is upward.[51,52]

It's the sun. The possible contribution of low solar activity to cold winters has re-ignited this common sceptical argument.[53] But, whereas the solar activity cycle lasts roughly 11 years, the warming trend is longer. On average over the last 35 years, the sun has cooled slightly, whilst temperatures have risen (see, for instance, bit.ly/climatesun).[54]

Global warming is due to natural cycles, not human activity.[55] Natural cycles do play a part in short-term weather.[56-58] However, they cannot explain the long-term warming trend observed over the last century.[59,60] Only additional atmospheric CO_2 arising from human activity explains the trend we see (for more: bit.ly/notnaturalcycles, PDF).[61]

What the scientists say

Robert Henson *(University Corporation for Atmospheric Research, USA)*: "People across the northern hemisphere are facing the fact that a warming planet doesn't get rid of winter ... now is a good time to remind ourselves that weather, like death and taxes, will always be with us."[62]

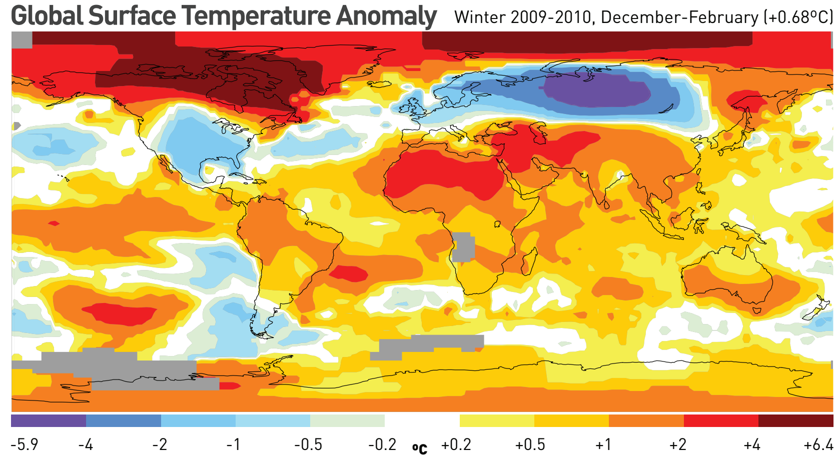
Dr Kevin Trenberth *(National Centre for Atmospheric Research, USA)*: "Too many think global warming means ... relentless warming everywhere year after year. It does not happen that way."[63]

Dr James Hansen *(NASA, USA)*: "The ... 48 states cover only 1.5 percent of the world area, so the U.S. temperature does not affect the global temperature much."[64] (The UK covers only 0.05%.[65])

Dr Peter Stott *(Met Office, UK)*: "The famously cold winter of 1962/63 is now expected to occur about once every 1,000 years or more, compared with approximately every 100 to 200 years before 1850."[66]

What the data says

Global Surface Temperature Anomaly Winter 2009-2010, December-February (+0.68ºC)



The difference between the winter 2009-2010 average temperature and the 1951-1980 average.

Source: NASA GISTEMP 1.usa.gov/wintermap

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For more info

Why a cold winter does not disprove climate change
bit.ly/reallygoodvideo

Winter of 2009-10
bit.ly/winter2009-10 [PDF]

The coexistence of climate change with cold and snowy weather
bit.ly/warmsnow

Why the last couple of winters were so cold
bit.ly/whysocold

SPECIES EXTINCTION

Climate change will likely make a bad situation worse for many species, and could become the main cause of species extinction in the future.

Summary

- The estimated rate of species extinction today is 100-1,000 times higher than historically 'normal'.
- The actual number of recorded extinctions is low; partly because we only know about a small percentage of all species on Earth.
- Climate change is not the main driver of species extinctions either on land or in the oceans at present.
- However, it is exacerbating problems that already threaten species and will likely introduce more threats to species in the future.

Context

In each of the five 'mass extinctions' of the past, between 75-96% of all species became extinct.[1] The last, roughly 65 million years ago, wiped out the dinosaurs.[2] In each, it took up to 10 million years for species numbers to recover.[3,4] All previous 'mass extinctions' are associated with abrupt climate changes (though with different causes).[5]

The climate is changing faster than it was during the last 'mass extinction' – we are releasing CO_2 and acidifying oceans roughly ten times faster.[6,7] Other activities like deforestation and over-fishing already threaten species.[8] Changing land use and more isolated ecosystems have made it harder for species to adapt by moving.[9] Though there is evidence of this happening in many places,[10-14] for some species climate may change too fast for them to adapt. Climate change will likely contribute to a large number of species extinctions in the 21st century,[15,16] possibly becoming the main threat to species.[17]

Background science

Since the year 1500, 869 species have become extinct.[18] This is very likely a significant underestimate because:

- Declaring a species extinct can take decades, and requires monitoring over large areas.[19]
- Scientists don't want to give up on a species too early, prematurely stopping conservation efforts.[20]
- We only know about two million from a possible 30 million species on Earth.[21,22] Many species have likely been lost without us even knowing they existed.
- Only 3% of those species identified have been assessed for risk of extinction.[23,24]
- Small populations of a species can become functionally extinct.[25] Though unlikely to recover, they can take thousands of years to die out completely.[26]
- Local extinctions don't count, even though they can be a 'first step' towards global extinction.[27]

Estimates of extinction are extrapolated to include species we don't know about, making 'rates of extinction' higher, but perhaps more realistic. Currently, species are going extinct 100-1,000 times faster than normal; and the rate is increasing (see graphic below).[28]

Threats

Currently, habitat loss and invasive species are the two main causes of extinction on land. Overfishing is the main cause of local extinctions in the oceans.[29] It is not yet known whether climate change has been the main factor in any species extinction. Often multiple threats act together.[30] The extinction of the Golden Toad, for example, has been linked to climate change, though other threats also played a significant part.[31]

Species are threatened by changes in temperature (land and ocean), precipitation, and extremes in both of these. Acidification (from absorbing atmospheric CO_2), changes in salinity (from more/less precipitation near coastal areas) and anoxia (insufficient oxygen for life) additionally threaten ocean species.[32]

Species most at risk from climate change are likely to be living in:[33]

- Historically stable climates (e.g. the tropics). Species often cannot cope even with small changes in climate.[34]
- Climates projected to change the most (e.g. the Arctic). Species cannot cope with too much change.
- Tight boundaries (up mountains, on islands or in coastal areas). These barriers mean that species don't have anywhere to escape to.[35]

Climate change may have already contributed to some species extinctions in these places.[36]

Projections

The main causes of species extinctions will likely remain the same for some decades. Climate change will likely exacerbate the situation – the *combination* of threats will increase rates of extinction.[37] It is difficult to project the exact threat posed by climate change because:[38-40]

- We don't know anything about many species,[41] so we don't know if they can adapt.[42]
- We don't know the effects of species movement. Displaced species could become invasive species, affecting native species.[43]
- The interactions between species (predator and prey; competition for food and water), are complex. We cannot project how existing or new ('novel') ecosystems might work in the future.[44,45]
- Many different factors can contribute to species extinction – it is difficult to project how they will all change.

Therefore, projected species extinction figures should be used only as a guide. Numbers vary greatly depending on the amount and type of species studied and the methods used – from roughly 5% to almost 80%.[46] All agree, however, that climate change will mean more extinction,[47,48] and could become the main cause of extinctions over the next 100 years.[49]

Species extinction & biodiversity

Biodiversity includes all species, sub-species, populations, genetic differences within sub-species and populations, and the relationships between them.[50] If any *one* of these is lost, biodiversity decreases. Extinction of a species requires *all* its sub-species, populations and individuals to be lost. Biodiversity is lost faster than species are.[51-53] Global biodiversity has declined 30% since the 1970s.[54] Though it is difficult to disentangle the impact of climate change from other causes (as with species extinction),[55] it is likely already a large threat to global biodiversity.[56,57]

What the sceptics claim

It's not climate change.[58-60] Though climate change is not yet a major driver of extinction, it exacerbates other threats and is likely already a large threat to biodiversity.[61,62] Climate change is expected to drive extinction rates up in the future, potentially becoming the main cause.[63]

The numbers are exaggerated[64] **/ wrong**[65-67] **/ too uncertain.**[68] Extinction rates are estimates (see above).[69] It is unlikely that they over-estimate the problem, and more likely that they underestimate it.[70] All research agrees that extinction rates are likely to increase over the next century, in part due to climate change.[71]

Where are all these species supposedly going extinct?[72,73] Recorded extinctions do not take into account the millions of species we do not know about, or haven't assessed.[74,75] The number of recorded species extinctions is very likely a significant underestimate as a result.

Extinction is a natural part of evolution.[76,77] Species have, and always will go extinct. However, the estimated rate of extinction is currently 100 -1,000 times what is 'normal', and will likely increase at least in part due to climate change.[78] Evolution of new species is not balancing these losses.[79]

But [this particular] species is now recovering (or has even reappeared after we thought it was extinct!), so there's no problem.[80] Conservation efforts can change the trajectory of a species, decreasing the likelihood of extinction. But very few species thought extinct reappear, and those close to extinction rarely recover fully.[81] Cherry-picking specific species ignores the big picture – the estimated rate of extinction is currently 100-1,000 times what is 'normal', and is increasing.[82]

What the scientists say

Prof. Alex Rogers *(International Programme on the State of the Ocean)*: "We're seeing a combination of symptoms that have been associated with large, past extinctions."[83]

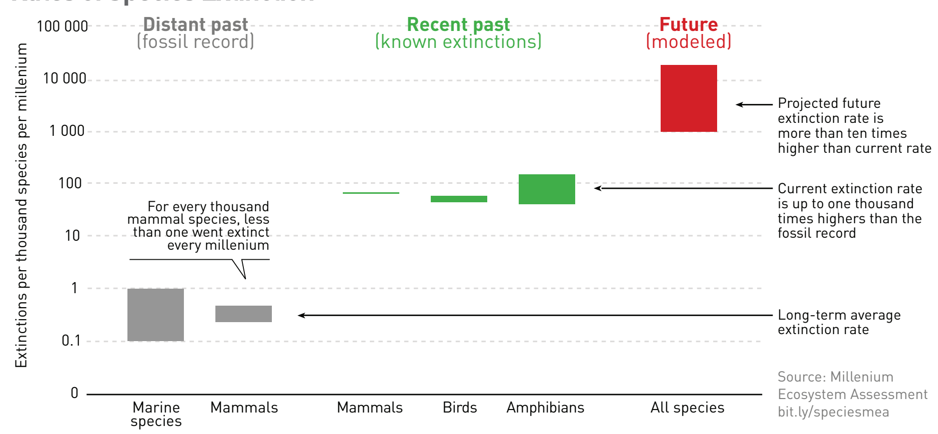
Prof. Simon Stuart *(Species Survival Commission, International Union for the Conservation of Nature)*: "There are uncertainties all the way down; the only thing we're certain about is the extent [of extinction] is way beyond what's natural and it's getting worse."[84]

Prof. Chris Thomas *(University of York, UK)*: "Many of the most severe impacts of climate change are likely to stem from interactions between threats ... rather than from climate acting in isolation."[85]

Dr Klaus Toepfer *(United Nations Environment Programme)*: "If one million species become extinct… it is not just the plant and animal kingdoms and the beauty of the planet that will suffer. ... Billions of people, especially in the developing world, will suffer too as they rely on Nature for such essential goods and services as food, shelter and medicines."[87]

What the data says

Rates of Species Extinction



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For more info

How climate change puts species at risk
bit.ly/speciesatrisk [PDF]

Different species affected by climate change
bit.ly/differentspecies [PDF]

State of the ocean
bit.ly/oceandamage

THE SEASONS

A warming world shifts the seasonal activities of plants and animals, with uncertain consequences.

Summary

- Natural events associated with the start of spring have occurred earlier over the last few decades.
- Natural events associated with the start of autumn are getting later, although this is less pronounced.
- Many independent lines of evidence confirm this: studies on the ground, satellite data, and CO_2 records.
- The changes are not necessarily uniform: events for different species appear to change at different rates. Not all species show significant change.

Context

There is significant popular interest in the UK in the changing seasons. BBC TV programmes focusing on seasonal events in the natural world such as *Springwatch* and *Autumnwatch* are very popular. The first series of *Springwatch* had around four million viewers.[1,2]

Seasonal changes provide opportunities for wider public involvement in, and engagement with, scientific research. Approximately 40,000 people currently record the timings of natural events for *Nature's Calendar*, a survey run by the Woodland Trust since 1998.[3] In the UK, personal involvement in this kind of research goes back to the 18th century.[4] Several individuals have come forward with long-term records. An 81-year-old woman from Surrey was given an OBE in 2009 for her meticulous 62-year record of the leafing dates of trees near her home.[5]

Background science

The study of the seasonal timing of natural events is called phenology. On land, and at higher latitudes, the seasons are most pronounced. Many studies which assess seasonal changes focus on the Northern Hemisphere, as two-thirds of the world's land is there.[6,7] This leaves the Southern Hemisphere less well-studied.[8]

Many studies only look at the phenological response to climate change in one or two specific species or populations of flora and fauna. 'Meta-analyses' review hundreds of scientific papers, encompassing tens of thousands of different species, combining and comparing individual results.[9-12] The conclusions of these studies are that the observed changes present a coherent picture.[13-16]

Spring

Biological events associated with the start of spring include the flowering of many plants, the emergence of hibernating species, the arrival of migrant birds and their egg-laying. Overall, these events have come earlier on average by nearly four days per decade in the UK and around two-to-three days per decade across the Northern Hemisphere.[17,18]

The degree of change varies enormously between species, partly because not all species use temperature to time their seasonal behaviour (some use day length, for example), and others have adapted by moving northward or to higher altitudes.[19] Some species show little or no change. In a major study across Europe, 30% of activities studied were found to be getting significantly earlier and only 3% getting significantly later.[20]

There is a slightly greater advance occurring in more northerly regions of the Northern Hemisphere where there is greater warming. This variation, however, is very small compared to the variation in advancement between species.[21]

Autumn

Biological events associated with autumn, such as fruit ripening and leaf fall,[22] have moved slightly later in the year over the past half a century, by about 0.3–1.6 days per decade over the Northern Hemisphere.[23] Autumn events are, however, less clearly correlated with temperature than spring events, and the factors affecting them are less well understood.[24,25]

As a consequence of the earlier onset of spring and the later coming of autumn, the growing season that stretches between the two has become longer.[26]

Additional evidence

There are two other independent lines of evidence for shifting seasons:

- The 'breathing of the planet': atmospheric CO_2 concentrations rise and fall slightly over the year (most pronounced in the Northern Hemisphere). This shows CO_2 being absorbed by plants as they bloom (spring) and released as they die back (autumn). Since the 1960s, the springtime 'intake of breath' has been coming progressively earlier [27] (though less so since 1990[28]).
- Satellites can measure the greening process that sweeps across the Earth's surface as plants emerge from winter (see graphic below).[29] Although there are difficulties in analysing data,[30] this greening generally appears earlier with plants staying in leaf longer.[31-33]

Impacts

Not all species change the timing of their activities at the same rate, which may cause time gaps to open up in food webs. For example, Dutch populations of one migratory bird (the Pied Flycatcher) have declined by 90% because their behaviour has fallen out of synch with that of the caterpillars that are the main food source for their young.[34] This area of research, however, is still in its infancy.[35]

The consequences for agriculture are expected to be mixed. Regions closer to the poles should benefit from the longer growing season[36] but the overall effect will also depend on whether crops become more or less synchronised with pests and weeds.[37] It is likely that other factors will have a greater impact on agriculture in many areas: land use change, invasive species, and the availability of water and other nutrients.[38]

What the sceptics claim

Where's the advancing spring now? / spring's late this year so climate change isn't happening.[39-41] Spring does not start earlier neatly year on year - there is a lot of natural variation, as there is with annual temperatures.[42] It is necessary to look at longer time frames to establish a trend. Plants and animals are changing their activity as the world warms.[43]

The advance of spring isn't caused by temperature - it's the increase in atmospheric concentration of CO_2 and other substances which act as 'plant food'.[44] Though higher atmospheric levels of CO_2 are likely to have some fertilisation effect in some species, temperature is still the main control of the advancement of spring.[45] Furthermore, CO_2 does not explain why animals are changing the timing of activities, like migration.

Satellites say spring isn't advancing.[46,47] There are different ways of analysing satellite data. It is easier to see change in some places over others; in some places spring is advancing, in others not.[48,49] There is also some debate about whether satellite records reach back long enough to see any meaningful trends.[50] Regardless, there is a large body of ground-based observations that do show an advancing spring.[51,52] Analyses that compare satellite and ground-based work show that the two combine to produce a coherent picture: growing seasons are getting longer.[53]

What the scientists say

Shaun Nixon *(Nature's Calendar)*: "There will be variations year on year, but if we look back over the past 30 years we can see a marked advancement of spring."[54,55]

Dr Tim Sparks *(formerly of the UK Centre for Ecology and Hydrology)*: "Not only do we clearly demonstrate change in the timing of the seasons, but that change is much stronger in countries that have experienced more warming."[56]

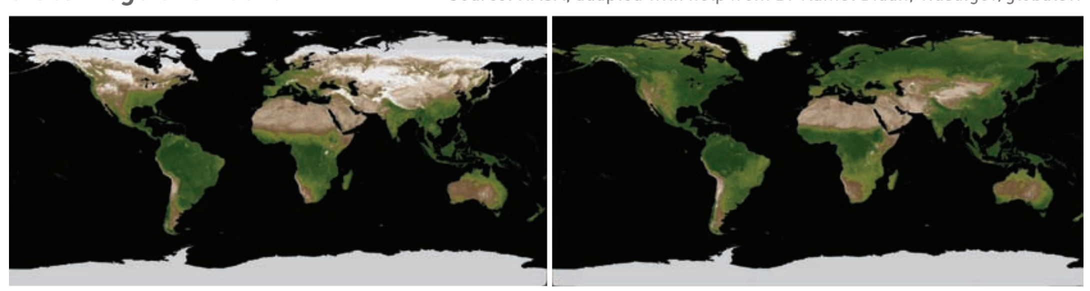
"If you have species that are dependent on each other changing at different rates that could just break down the food web. For example, caterpillars feed on oak trees, and birds feed on the caterpillars. Unless these species remain synchronised, there could be problems for any one or more of those elements of the food web."[57]

Chris Packham *(BBC Springwatch presenter)*: "Without being rude ... let's forget about the scientists and trust nature instead, our unbiased commentator."[58]

What the data says

Global Vegetation Cover

Source: NASA, adapted with help from Dr Kamel Didan, 1.usa.gov/globalevi



January Average **August Average**

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For more info

Summary of phenology and climate change
bit.ly/phenologyandclimate

Nature's Calendar - get involved
bit.ly/NaturesCalendar

Spring changes (not just phenology)
bit.ly/springchanges

WILDFIRES

Wildfire is important to most ecosystems; but higher temperatures can alter natural fire-regimes, changing the ecosystem, permanently releasing greenhouse gases and contributing to climate change.

Summary

- Wildfires are only a net source of greenhouse gases if they change the ecosystem permanently, if they burn where they don't naturally, or in peatlands.
- Climate is the strongest historical control of wildfire, though globally since around 1900, humans have significantly reduced the area burnt by wildfire.
- Increasing temperatures have meant more wildfires in some regions since the 1980s; globally the trend is less clear.
- Higher temperatures are projected to increase wildfire in some places, but other factors may have a mitigating influence in others, making global projections less certain.

Context

Fires are really only a problem for people, causing long-term health problems from inhaling smoke,[1] and destroying crops, homes and lives.[2,3] Most natural ecosystems are used to some type of fire[4,5] - they clear dead vegetation, allowing new growth; heat and smoke from fire is even necessary for some seeds to germinate.[6,7]

Climate change is expected to increase wildfire frequency and intensity in some areas, and also change its location.[8] Regions unaccustomed to wildfire will need to adapt; but even with the knowledge and capacity to adapt, some places may become overwhelmed by more frequent and severe wildfires.[9] In some areas, recent increases in wildfire size and intensity have already been too much for fire-management techniques and fire-fighting systems to cope.[10,11]

Background science

Fire affects almost all types of vegetation around the world (see graphic below). Wildfire is uncontrolled or unplanned fire. Deliberate fires (started by accident or arson, and 'controlled burns') are usually much smaller and less intense.[12]

A 'fire-regime' describes the character of wildfire in a particular area: what kind of fire it is (forest, grass and peatland all burn differently); how often and how intensely they burn; and how fast they spread.[13]

Climate controls fire-regimes by affecting:[14,15]

- **Fuel**: different vegetation grows in different climates. Wet climates have more fuel (more grows), but it can be harder to burn.[16] Drier climates dry vegetation but ultimately limit fuel – plants do not grow without water. Seasonal changes are also important – long warm periods can dry usually wet areas, increasing fire incidence and severity. Climate controls the length of the fire season.[17]
- **Ignition**: hot, humid weather produces more lightning, which starts fires.
- **Weather**: good 'fire weather' is hot and dry; windy conditions help fire spread.[18]

But people also influence:

- **Fuel**: our land use dictates what grows where; whilst our fire-suppression increases the amount of fuel and 'controlled burns' decrease it.[19]
- **Ignition**: lighting fires by accident; arson; for 'controlled burns' or land clearance.[20]

In general, higher temperatures mean more wildfire[21] due to longer fire seasons,[22] drier fuel (more evaporation and not enough precipitation to counter) and more lightning.[23]

Feedbacks

Wildfires release greenhouse gases[24] equivalent to 25-50% of annual fossil fuel emissions.[25,26] Providing vegetation grows back fully afterwards, equal amounts of carbon are taken in by new growth.[27-29] Uncharacteristically severe or frequent fire can permanently change ecosystems, turning forests into grasslands, and grasslands into scrub or desert. Greenhouse gases from these fires stay in the atmosphere causing a reinforcing (or 'positive') feedback, enhancing climate change.[30] This is also true of fires used to clear forests for agriculture, and peatland fires.[31]

Temporary changes to albedo (amount of heat reflected by land) due to soot deposits and vegetation clearing by fires do not affect global climate much, in the long term.[32] Feedbacks to local temperatures (soot absorbing heat), or precipitation (smoke particles affecting clouds),[33] are less well understood and quantified.[34]

Trends

Historically (going back millennia), fire closely correlates with climate, particularly temperature.[35,36] Through land use change, agriculture, forest management and fire-fighting, humans decreased the area burnt by wildfire over the first half of the 20th century – we superseded natural climate controls.[37-39]

But over the last few decades, higher temperatures have caused significant increases in burnt area in the boreal regions of Canada,[40] Alaska[41] and Siberia[42], as well as temperate and western USA[43] (even with advances in fire-fighting and fire-management).[44,45] Large fires have also become more frequent in other areas, likely in part due to temperature increases,[46] but also influenced by humans: fire suppression building up biomass in Australia;[47] decreased fire-management resources in Russia; agricultural policy changes in southern Europe;[48] and land-clearing in Amazonia and Indonesia.[49]

Globally, the trend is less pronounced,[50] as on-going decreases in wildfire in other areas partially offset these increases.[51]

Projections

As temperature increases it is likely to become the main control of wildfire again,[52] continually increasing wildfire frequency and size in the places listed above.[53] In other areas, wildfire may decrease as changes in precipitation or the fuel available limit fire.[54] Directly, humans will still play a large role.[55]

Regional wildfire projections are uncertain: changes to precipitation and soil moisture are complex;[56] knowledge of feedbacks is incomplete;[57] and future fire-management and fire-fighting policy decisions are unknown. Ultimately, there will be limits on our control and management of wildfire;[58] they could become so frequent that ecosystems change from net sinks of carbon to net sources.[59] This may already be true of Canadian forests,[60] where there is some concern that the fire regime is close to a point where fires suddenly get much larger, instead of increasing gradually in size.[61,62]

What the sceptics claim

Fires are natural.[63] Wildfire is part of an ecosystem's natural cycle.[64,65] However, both more frequent and more intense wildfires can mean that ecosystems cannot re-grow – a change of climate alters the natural 'fire-regime'.[66]

Wildfires are caused by natural weather patterns.[67-69] Historically, climate is a strong wildfire control.[70,71] Natural weather patterns do contribute to 'fire weather' (hot, dry, windy conditions; lightning),[72,73] but climate change makes these conditions more intense and frequent over longer periods, increasing the risk of wildfires.[74,75]

The amount of fires today is nothing compared to historical records.[76,77] Humans decreased wildfire over the first half of the 20th century – there is much less fire now than there has been for thousands of years.[78-80] But fire incidence is increasing in some areas (Canada,[81] Alaska,[82] and western USA[83]). Fire-management and fire-fighting techniques may be insufficient to control more frequent and intense wildfire.[84,85]

Wildfires aren't increasing.[86,87] In some areas, wildfire regimes remain unchanged; but in others (western Canada,[88] Alaska,[89] and western USA[90]), there are significant increases in the frequency of large fires.[91,92] Because of the complex effects of people, temperature and precipitation, regional trends will be different. This is also true of future projections.[93]

It's forest management (or mis-management).[94-96] In Russia, less funding of forest management and fire-fighting has contributed to more wildfire,[97] though some argue wildfires were too severe to control regardless. Additionally, increases in burnt area in Canada,[98] and western USA[99] have occurred even with increased investment in fire-fighting and fire-management.[100,101]

What the scientists say

Dr Dan Cayan *(Scripps Institute of Oceanography, USA)*: "[C]limate change ... will probably mean the potential for these large fires is a bit greater ... Nature is shifting towards a more fire-prone environment."[102]

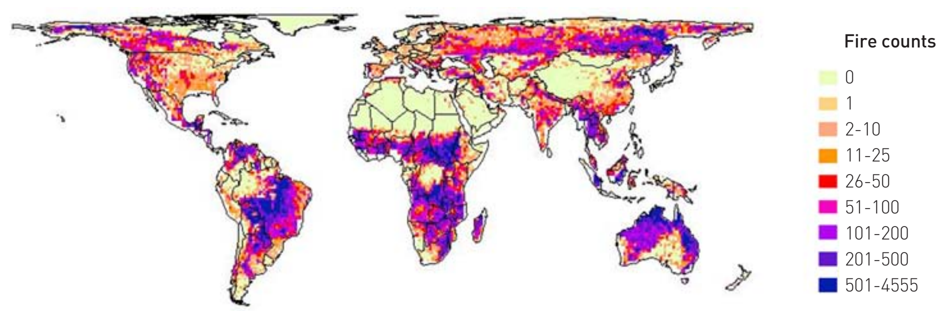
Australian Greenhouse Office *(Department of the Environment and Water Resources)*: "The amount of carbon emitted to the atmosphere during bush fires is, when averaged over time, balanced by the amount taken up in subsequent forest re-growth ... as the fire regime remains unchanged. However, if there is a shift to more frequent and/or more intense fire regimes due to climate change, there could be a discernable [sic] decline in forest carbon stocks"[103]

Matt Wrack *(General secretary, Fire Brigades Union, UK)* "It took last year's floodings to hammer home to policy-makers what we will face as a result of global warming ... But there is a danger the rising number of large grassland and heathland fires will go unnoticed."[105]

What the data says

Global Fire Count 1996-2006

Source: Krawchuk et. al. 2009 (bit.ly/wildfiremap)



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REFERENCES

All URL links last checked 13-16 Jan 2012.

TEMPERATURE

1 The meteorological year runs from December to the end of November. The calendar year (January to December) data is released by all three organisations roughly halfway through January once the data has been analysed and processed - Schmidt, G, Ruedy, R. and Jones, P. (2010) Personal correspondence.

2 NASA GISS (2010) Climatologist Gavin Schmidt Discusses the Surface Temperature Record, NASA website, 21 Jan http://www.giss.nasa.gov/research/news/20100121b/

3 MarkR (2011) 2011 Year in Review (part 1), skepticalscience.com, 31 Dec http://www.skepticalscience.com/2011_review_pt1.html

4 Cook, J. (2010) What do the 'Climategate' hacked CRU emails tell us?, skepticalscience.com, 9 Jul http://www.skepticalscience.com/Climategate-CRU-emails-hacked.htm

5 Le Page, M. (2009) Why there's no sign of a climate conspiracy in hacked emails, New Scientist, 4 Dec http://www.newscientist.com/article/dn18238-why-theres-no-sign-of-a-climate-conspiracy-in-hacked-emails.html?full=true

6 Stott, P. (undated) Global-average temperature records, Met Office [Archive] http://webarchive.nationalarchives.gov.uk/+/http://www.metoffice.gov.uk/climatechange/science/explained/explained5.html

7 Arndt, D.S., M.O. Baringer and M.R. Johnson, (Eds.) (2010) State of the Climate in 2009, Bulletin of the American Meteorological Society , 91 (7), S1–S224., July http://www1.ncdc.noaa.gov/pub/data/cmb/bams-sotc/climate-assessment-2009-lo-rez.pdf [PDF]

8 Hansen, J., R. Ruedy, M. Sato, and K. Lo (2010), Global surface temperature change, Reviews of Geophysics, 48, RG4004, doi:10.1029/2010RG000345. http://pubs.giss.nasa.gov/docs/2010/2010_Hansen_etal.pdf [PDF]

9 Met Office (2008) Global warming goes on, metoffice.gov.uk (Archive) http://webarchive.nationalarchives.gov.uk/+/http://www.metoffice.gov.uk/corporate/pressoffice/2008/pr20080923c.html

10 Solomon, S., et al. (2007a) Summary for Policymakers (Understanding and Attributing Climate Change), in IPCC 2007 Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/spmsspm-understanding-and.html

11 Huber, M. and Knutti, R. (2011) Anthropogenic and natural warming inferred from changes in Earth's energy balance, Nature Geoscience DOI: 10.1038/NGEO132, Published Online: 4 Dec http://www.iac.ethz.ch/people/knuttir/papers/huber11natgeo.pdf [PDF]

12 Arndt, D.S., M.O. Baringer and M.R. Johnson, (Eds.) (2010) Op. Cit.

13 Dana (2011) Foster and Rahmstorf Measure the Global Warming Signal, scepticalscience.com, 20 Dec http://www.skepticalscience.com/news.php?n=1172

14 Foster, G and Rahmstorf, S. (2011) Global temperature evolution 1979–2010, Environmental Research Letters 6 044022 doi:10.1088/1748-9326/6/4/044022 http://iopscience.iop.org/1748-9326/6/4/044022 [Abstract]

15 Vidal, J. (2010) 2010 could be among warmest years recorded by man, guardian.co.uk, 2 June http://www.guardian.co.uk/environment/2010/jun/02/2010-could-be-warmest-year-ever

16 Met Office (2011) 2010 — a near-record year, metoffice.gov.uk, 20 Jan http://www.metoffice.gov.uk/news/releases/archive/2011/2010-global-temperature

17 Muller, R. A. et al. (unpublished, 2011) Decadal Variations in the Global Atmospheric Land Temperatures, Currently submitted to the Journal of Geophysical Research: Atmospheres.

18 'Ned' (2010) Assessing global surface temperature reconstructions, skepticalscience.com, 24 Jul http://www.skepticalscience.com/Assessing-global-surface-temperature-reconstructions.html

19 'Tamino' (2010) Comparing Temperature Data Sets, Open Mind, 16 Dec http://tamino.wordpress.com/2010/12/16/comparing-temperature-data-sets/

20 Hansen, J., R. Ruedy, M. Sato, and K. Lo (2010) Op. Cit.

21 National Oceanic and Atmospheric Administration (undated) Uncertainty of Global Temperature Values: Frequently Asked Questions, National Oceanic and Atmospheric Administration, National Climatic Data Center http://www.ncdc.noaa.gov/cmb-faq/faq-globalprecision.php

22 Brohan, P. et al. (2006), Uncertainty estimates in regional and global observed temperature changes: A new data set from 1850, Journal of Geophysical Research, 111, D12106, doi:10.1029/2005JD006548. http://www.agu.org/journals/ABS/2006/2005JD006548.shtml [Abstract]

23 National Oceanic and Atmospheric Administration (undated) Op. Cit.

24 Ibid.

25 Schmidt, G. (2007) No man is an (Urban Heat) Island, RealClimate.org 2 Jul http://www.realclimate.org/index.php/archives/2007/07/no-man-is-an-urban-heat-island/

26 National Oceanic and Atmospheric Administration (undated) Global Surface Temperature Anomalies Q6. Why use temperature anomalies (departure from average) and not absolute temperature measurements?, National Oceanic and Atmospheric Administration, National Climatic Data Center http://www.ncdc.noaa.gov/cmb-faq/anomalies.html

27 Solomon, S. et al. (2007b) Chapter 3.2.2.2 Urban Heat Islands and Land Use Effects, in IPCC (2007), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p. 996 http://ipcc.ch/publications_and_data/ar4/wg1/en/ch3s3-2-2-2.html

28 Jones, P. and Salmon, M (2011) Temperature: Answers to Frequently-asked Questions, University of East Anglia Climatic Research Unit (Data), Jan http://www.cru.uea.ac.uk/cru/data/temperature/

29 Ibid.

30 Schmidt, G. (2007) Op. Cit.

31 Jones, P. and Salmon, M (2011) Op. Cit.

32 Real Climate (2008) Mind the Gap!, realclimate.org, 18 Nov http://www.realclimate.org/index.php/archives/2008/11/mind-the-gap/

33 Where "within reason" means 1200km - the distance over which temperature anomalies are sufficiently alike to make this approximation http://data.giss.nasa.gov/gistemp/station_data/

34 NASA (undated) GISS Surface Temperature Analysis, NASA website http://data.giss.nasa.gov/gistemp/station_data/

35 Hansen, J.E. et al. (2001) A closer look at United States and global surface temperature change. Journal of Geophysical Research, 106, 23947-23963, doi:10.1029/2001JD000354. http://pubs.giss.nasa.gov/cgi-bin/abstract.cgi?id=ha02300a [Abstract]

36 Schmidt, G. (2011) 2010 updates to model-data comparisons, realclimate.com, 21 Jan http://www.realclimate.org/index.php/archives/2011/01/2010-updates-to-model-data-comparisons/

37 Arndt, D. S., M. O. Baringer, and M. R. Johnson, (Eds.) (2010) Op. Cit. p.27 Table 2.2

38 Watts, A. (2009) Is the U.S. Surface Temperature Record Reliable? The Heartland Institute, Chicago, IL. http://wattsupwiththat.files.wordpress.com/2009/05/surfacestationsreport_spring09.pdf [PDF]

39 World Climate Report (2007) Contaminated Temperature Data, World Climate Report, 22 Dec http://www.worldclimatereport.com/index.php/2007/12/22/contaminated-temperature-data/

40 Beck, C. (2006) 'The temperature record is unreliable'—But temperature trends are clear and widely corroborated, grist.org, 2 Nov http://www.grist.org/article/the-temperature-record-is-simply-unreliable

41 Brohan, P. et al. (2006) Op. Cit.

42 Ibid.

43 Met Office (2008) Op. Cit.

44 Morano, M. (2009) Earth's 'Fever' Breaks! Global temperatures have plunged .74°F since Gore released An Inconvenient Truth, Climate Depot, 5 Jul http://www.climatedepot.com/a/1799/Earths-Fever-Breaks-Global-temperatures-have-plunged-74degF-since-Gore-released-An-Inconvenient-Truth

45 Whitehouse, D. (2009) What you have not been told about Global Warming - the five missing facts, Mail Online, 12 Dec http://www.dailymail.co.uk/sciencetech/article-1235126/What-told-Global-Warming--missing-facts.html

46 Dana (2011) Foster and Rahmstorf Measure the Global Warming Signal, scepticalscience.com, 20 Dec http://www.skepticalscience.com/news.php?n=1172

47 Foster, G and Rahmstorf, S. (2011) Global temperature evolution 1979–2010, Environmental Research Letters 6 044022 doi:10.1088/1748-9326/6/4/044022 http://iopscience.iop.org/1748-9326/6/4/044022 [Abstract]

48 Rahmstorf, S. (2009) A warming pause?, RealClimate.org, 6 Oct http://www.realclimate.org/index.php/archives/2009/10/a-warming-pause/

49 NASA (2010) NASA Research Finds Last Decade was Warmest on Record, 2009 One of Warmest Years, NASA website, Jan. 21 http://www.nasa.gov/home/hqnews/2010/jan/HQ_10-017_Warmest_temps.html

50 NASA (2011) NASA Research Finds 2010 Tied for Warmest Year on Record, NASA website, 12 Jan http://www.giss.nasa.gov/research/news/20110112/

51 Vidal, J. (2010) Op. Cit.

52 Foster, P. (2010) Peter Foster: Climategate Whitewash, Financial Post (re-posted by the Global Warming Policy Foundation), 16 April http://www.thegwpf.org/opinion-pros-a-cons/819-peter-foster-climategate-whitewash.html

53 D'Aleo, J. (undated) Response to Gavin Schmidt on the Integrity of the Global Data Bases, icecap.us http://icecap.us/images/uploads/URBANIZATION_IN_THE_TEMPERATURE_DATA_BASES.pdf [PDF]

54 Watts, A. (2009) Op. Cit.

55 Cook, J. (2010a) Are surface temperature records reliable?, skepticalscience.com, 26 June http://www.skepticalscience.com/surface-temperature-measurements-intermediate.htm

56 Solomon, S. et al. (2007b) Op. Cit.

57 Cook, J. (2010b) Does Urban Heat Island effect exaggerate global warming trends?, skepticalscience.com, 9 July http://skepticalscience.com/urban-heat-island-effect.htm

58 Jones, P. D., D. H. Lister, and Q. Li (2008), Urbanization effects in large-scale temperature records, with an emphasis on China, Journal of Geophysical Research, 113, D16122, doi:10.1029/2008JD009916. http://www.agu.org/pubs/crossref/2008/2008JD009916.shtml [Abstract]

59 Meador, L. and Cook, J. (2010) It's microsite influences, skepticalscience.com http://skepticalscience.com/microsite-influences-on-global-temperature.htm

60 Stewart, W. (2009) Met Office 'manipulated climate change figures' say Russian think tank, The Daily Mail, 17 Dec http://www.dailymail.co.uk/news/article-1236513/Met-Office-manipulated-climate-change-figures-say-Russian-think-tank.html#ixzz11gvpQffC

61 Cook, J (2010c) Why are there fewer weather stations and what's the effect?, skepticalscience.com, 26 June http://www.skepticalscience.com/Dropped-stations-introduce-warming-bias-intermediate.htm

62 'Ned' (2010) Op. Cit.

63 Cook, J (2010c) Op. Cit.

64 Cook, J. (2010d) The many lines of evidence for global warming in a single graphic, skepticalscience.com, 30 Dec http://www.skepticalscience.com/The-many-lines-of-evidence-for-global-warming-in-a-single-graphic.html

65 NASA (undated) Global Climate Change: Evidence, NASA website http://climate.nasa.gov/evidence/

66 Black, R. (2009) This decade 'warmest on record', BBC News (online), 8 Dec http://news.bbc.co.uk/1/hi/8400905.stm

67 Mail Online (2008) Next year set to be one of the warmest on record, The Daily Mail (online), 30 Dec http://www.dailymail.co.uk/news/article-1103094/Next-year-set-warmest-record.html#ixzz11gyihtNX

68 Randerson, J. (2008) 2008 will be coolest year of the decade, guardian.co.uk, 5 Dec http://www.guardian.co.uk/environment/2008/dec/05/climate-change-weather

69 NASA GISS (2010) Op. Cit.

70 Real Climate (2005) 2005 temperatures, RealClimate.org, 15 Dec http://www.realclimate.org/index.php/archives/2005/12/2005-temperatures/

71 Watts, A. (2008) Twelve Months of Cooling Doesn't Make A Climate Trend, WattsUpWithThat.com, 5 March http://wattsupwiththat.com/2008/03/05/twelve-months-of-cooling-doesn%E2%80%99t-make-a-climate-trend/

ARCTIC SEA ICE

1 National Snow and Ice Data Centre Press Room (2007) Arctic Sea Ice Shatters All Previous Record Lows, National Snow and Ice Data Centre website, 1 Oct http://nsidc.org/news/press/2007_seaiceminimum/20071001_pressrelease.html

2 Borenstein, S. (2007) Rate of ice melt shocks warming experts, MSNBC, 12 Nov http://www.msnbc.msn.com/id/22203980/

3 Zabarenko, D. (2008) Arctic ice second-lowest ever; polar bears affected, Reuters, 7 Aug http://www.reuters.com/article/2008/08/27/us-arctic-ice-polarbears-idUSN2745499020080827

4 The Telegraph (2007) Arctic ice be gone in five years, The Telegraph (online), 12 Dec http://www.telegraph.co.uk/earth/earthnews/3318239/Arctic-ice-could-be-gone-in-five-years.html

5 Connolley, W. M. (2007) Betting on sea ice?, Stoat, 16 Sep http://scienceblogs.com/stoat/2007/09/betting_on_sea_ice.php

6 Pope, V. (2009) Scientists must rein in misleading climate change claims, guardian.co.uk, 11 Feb http://www.guardian.co.uk/environment/2009/feb/11/climate-change-science-pope

7 The Carbon Brief (2011) Arctic sea ice decline continues, carbonbrief.org, 3 Mar http://www.carbonbrief.org/blog/2011/03/arctic-sea-ice-decline-continues

8 Comiso, J. (2010) Characteristics and Variability of the Sea Ice Cover, Atmospheric and Oceanographic Sciences Library, Volume 41, 295-363, DOI: 10.1007/978-0-387-68300-3_7 http://www.springerlink.com/content/k8725667q3155252/

9 'MarkR' (2011) 2011 Year in Review (part 1), skepticalscience.com, 31 Dec http://www.skepticalscience.com/2011_review_pt1.html

10 Flanner, M. G. et al. (2011) Radiative forcing and albedo feedback from the Northern Hemisphere cryosphere between 1979 and 2008, Nature Geoscience 4, 151–155, doi:10.1038/ngeo1062 http://www.nature.com/ngeo/journal/v4/n3/full/ngeo1062.html [Abstract]

11 Lemos, M. C. and Clausen, T. J. (2009) Synthesis Report from Climate Change: Global Risks, Challenges & Decisions (Second Edition), University of Copenhagen, Copenhagen, 10-12 March http://climatecongress.ku.dk/pdf/synthesisreport [PDF]

12 Serreze, M. C. (2011) Climate change: Rethinking the sea-ice tipping point, Nature 471, 47–48 doi:10.1038/471047a, 2 Mar http://www.nature.com/nature/journal/v471/n7336/full/471047a.html [Preview]

13 Screen and Simmonds (2010) The central role of diminishing sea ice in recent Arctic temperature amplification. Nature, 464, 1334-1337. http://www.nature.com/nature/journal/v464/n7293/full/nature09051.html [Preview]

14 NASA Earth Observatory (undated) Arctic Sea Ice, NASA Earth Observatory http://earthobservatory.nasa.gov/Features/SeaIce/page3.php

15 Serreze, M. C. (2011) Op. Cit.

16 Ibid.

17 Allison, I. et al. (2009) The Copenhagen Diagnosis 2009: Updating the world on the Latest Climate Science, The University of New South Wales Climate Change Research Centre (CCRC), Nov http://www.copenhagendiagnosis.com/

18 National Snow and Ice Data Centre (2009) Arctic sea ice younger, thinner as melt season begins, National Snow and Ice Data Centre: Arctic Sea Ice News & Analysis, 6 Apr http://nsidc.org/arcticseaicenews/2009/040609.html

19 Solomon, S. D. et al. (2007) Technical Summary, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p.73 http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ts.html

20 Allison, I. et al. (2009) Op. Cit.

21 Ballantyne et al. (2010) Significantly warmer Arctic surface temperatures during the Pliocene indicated by multiple independent proxies. Geology 38: 603-606. http://geology.gsapubs.org/content/38/7/603.abstract [Abstract]

22 Flanner, M. G. et al. (2011) Op. Cit.

23 'MarkR' (2011) A Flanner in the Works for Snow and Ice, skepticalscience.com, 23 Jan http://www.skepticalscience.com/Flanner2011.html

24 Payne, V. (2011a) IPCC models underestimate future sea ice loss - new scientific paper, The Carbon Brief, 6 Oct http://www.carbonbrief.org/blog/2011/10/ipcc-models-underestimate-future-sea-ice-loss-new-scientific-paper

25 Payne, V. (2011b) New scientific study - Arctic sea ice decline 'unprecedented', The Carbon Brief, 24 Nov http://www.carbonbrief.org/blog/2011/11/new-scientific-study-arctic-sea-ice-decline-is-unprecedented

26 Guardian Data Blog (2010) Arctic sea ice: the data behind the climate change fightback, guardian.co.uk, 5 Mar http://www.guardian.co.uk/news/datablog/2010/mar/05/arctic-sea-ice-climate-change-visualisation

27 Met Office (2009) The decline in Arctic summer sea ice, metoffice.gov.uk (Archive), 15 Oct http://webarchive.nationalarchives.gov.uk/+/ http://www.metoffice.gov.uk/corporate/pressoffice/2009/pr20091015b.html

28 Morano, M. (2009) Arctic Fact Sheet, Climate Depot, 30 Jul http://www.climatedepot.com/a/2226/Now-Debuting-Climate-Depot-Arctic-Fact-Sheet--Get-the-latest-peerreviewed-studies-and-analysis

29 Guardian Data Blog (2010) Op. Cit.

30 Cook, J. (2011) Arcticgate: perpetuating the myth that Arctic sea ice has recovered, skepticalscience.com, 7 Feb http://www.skepticalscience.com/Articgate-perpetuating-myth-Arctic-sea-ice-recovered.html

31 Met Office (2009) Op. Cit.

32 Goddard, S. (2010) Sea Ice News #12, WattsUpWithThat.com, 4 Jul http://wattsupwiththat.com/2010/07/04/sea-ice-news-12/

33 Whitehouse, D. (2010) Arctic Sea-Ice Recovery, Global Warming Policy Foundation, 23 Jun http://www.thegwpf.org/the-observatory/1139-arctic-sea-ice-recovery.html

34 Cook, J. (2010) Arctic icemelt is a natural cycle, skepticalscience.com, 26 Jun http://www.skepticalscience.com/Arctic-sea-ice-melt-natural-or-man-made-intermediate.htm

35 Bryner, J. (2008) Huge Volcanoes May Be Erupting Under Arctic Ice, Fox News, 2 Jul http://www.foxnews.com/story/0,2933,374542,00.html

36 National Snow and Ice Data Centre (2008) Have undersea volcanoes caused the Arctic sea ice decline?, National Snow and Ice Data Centre: Arctic Sea Ice News & Analysis, Jun http://nsidc.org/arcticseaicenews/faq.html#volcanoes

37 Watts, A. (2008) You ask, I provide. November 2nd, 1922. Arctic Ocean Getting Warm; Seals Vanish and Icebergs Melt., WattsUpWithThat.com, 16 Mar http://wattsupwiththat.com/2008/03/16/you-ask-i-provide-november-2nd-1922-arctic-ocean-getting-warm-seals-vanish-and-icebergs-melt/

38 National Snow and Ice Data Centre (2008) What was the sea ice like before the satellite era?, National Snow and Ice Data Centre: Arctic Sea Ice News & Analysis, Jun http://nsidc.org/arcticseaicenews/faq.html#presatellite

39 Pope, V. (2009) Op. Cit.

40 Associated Press (2007) Arctic sea ice melting three times faster than projected, USA Today, 1 May http://www.usatoday.com/tech/science/environment/2007-04-30-arctic-ice-melt_N.htm

41 Walsh, B. (2011) Farewell to the Arctic — as We Know It, Time Science (online), 27 Sep http://www.time.com/time/health/article/0,8599,2095114,00.html#ixzz1ihVdv8hW

42 Holmes, T. (2011) Disentangling media coverage about Arctic sea ice, The Carbon Brief, 13 Sep http://www.carbonbrief.org/blog/2011/09/arctic-sea-ice-extent,-volume-and-media-coverage

43 Payne, V. (2011b) Op. Cit.

44 Black, R. (2009) Pause in Arctic's melting trend, BBC News (online), 17 Sep http://news.bbc.co.uk/1/hi/8261953.stm

DROUGHT

1 Sheffield, J. and Wood, E. F. (2007) Global Trends and Variability in Soil Moisture and Drought Characteristics, 1950–2000, from Observation-Driven Simulations of the Terrestrial Hydrologic Cycle, Journal of Climate Vol. 21, 423, 13 Jun http://journals.ametsoc.org/doi/pdf/10.1175/2007JCLI1822.1 [Fulltext,PDF]

2 Romm, J. (2010) New study puts the 'hell' in Hell and High Water, ClimateProgress.org, 20 Oct http://climateprogress.org/2010/10/20/ncar-daidrought-under-global-warming-a-review/

3 Romm, J. (2011a) China's droughts nears worst in 200 years, adding pressure to world food prices, ClimateProgress.org, 24 Feb http://climateprogress.org/2011/02/24/china-drought-worst-in-200-years-food-prices/

4 Laurance, W. (2010) Climate shock: One heatwave from oblivion, New Scientist, 8 Dec http://www.newscientist.com/article/mg20827891.100-climate-shock-one-heatwave-from-oblivion.html?full=true [Preview]

5 Dai, A. (2011) Drought under global warming: a review, Wiley Interdisciplinary Reviews: Climate Change, 2: 45–65. doi: 10.1002/wcc.81 http://onlinelibrary.wiley.com/doi/10.1002/wcc.81/full [Fulltext]

6 Marsh, T. (2004) The UK drought of 2003 - an overview, An extended version of a paper published in 'Weather', Vol. 59, No. 8, Aug http://www.nwl.ac.uk/ih/nrfa/yb/yb2003/drought2003/index.html [Fulltext]

7 Hopkin, M. (2005) Heatwaves spell bad news for carbon sinks, Nature News doi:10.1038/news050919-5, 21 Sep http://www.nature.com/news/2005/050921/full/news050919-5.html

8 Gaffney, O. (2007) Droughts, floods and what is in store for the UK, NERC Planet Earth Online, 20 Aug http://planetearth.nerc.ac.uk/features/story.aspx?id=119

9 Marsh, T. (2004) Op. Cit.

10 Gaffney, O. (2007) Op. Cit.

11 Ibid.

12 Marsh, T. (2004) Op. Cit.

13 Dai, A. (2011) Op. Cit.

14 Ibid.

15 Ibid.

16 Marsh, T. (2004) Op. Cit.

17 Dai, A. (2011) Op. Cit.

18 Sheffield, J. and Wood, E. F. (2007) Op. Cit.

19 Marsh, T. (2004) Op. Cit.

20 Where 'water-in' is calculated using precipitation data, and 'water-out' is approximated using temperatures. A higher temperature means more evaporation - more 'water-out'. - Dai, A. (2011) Op. Cit.

21 Sheffield, J. and Wood, E. F. (2007) Op. Cit.

22 Ibid.

23 Australian Government Bureau of Meteorology (undated) The Greenhouse Effect and Climate Change http://www.bom.gov.au/info/GreenhouseEffectAndClimateChange.pdf [PDF]

24 Romm, J. (2010) Op. Cit.

25 Dai, A. (2011) Op. Cit.

26 Giles, J. (2008) US drought 'man-made' says study, New Scientist, 31 Jan http://www.newscientist.com/article/dn13262-us-drought-manmade-says-study.html

27 Marsh, T. (2004) Op. Cit.

28 Dai, A. (2011) Op. Cit.

29 Marsh, T. (2004) Op. Cit.

30 Dai, A. (2011) Op. Cit.

31 Ibid.

32 Sheffield, J. and Wood, E. F. (2007) Op. Cit.

33 Daily Mail Reporter (2011) Water demand will 'outstrip supply by 40% within 20 years' due to climate change and population growth, The Mail Online, 1 Mar http://www.dailymail.co.uk/sciencetech/article-1361374/Water-demand-outstrip-supply-40-20-years-climate-change-population-growth.html

34 The Environment Agency (2011) Questions and answers about drought, environment-tagency.gov.uk, http://www.environment-agency.gov.uk/homeandleisure/drought/31791.aspx

35 Sheffield, J. and Wood, E. F. (2007) Op. Cit.

36 Dai, A. (2011) Op. Cit.

37 Allison, I. et al. (2009) The Copenhagen Diagnosis, 2009: Updating the World on the Latest Climate Science., The University of New South Wales Climate Change Research Centre (CCRC), Sydney, Australia, p.60 http://www.ccrc.unsw.edu.au/Copenhagen/Copenhagen_Diagnosis_LOW.pdf [PDF]

38 Trenberth, K. E. et al. (2007) Chapter 3: Observations: Surface and Atmospheric Climate Change, in Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Chapter 3.3 Changes in Surface Climate: Precipitation, Drought and Surface Hydrology http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch3s3-3.html

39 Sheffield, J. and Wood, E. F. (2007) Op. Cit.

40 Dai, A. (2011) Op. Cit.

41 Ibid.

42 Dai, A. (2011) Op. Cit.

43 Romm, J. (2010) Op. Cit.

44 Alexander, L. (2010) Climate science: Extreme heat rooted in dry soils, Nature Geoscience 4,12–13 News and Views, 12 Dec http://www.nature.com/ngeo/journal/v4/n1/full/ngeo1045.html

45 Hirschi, M. et al (2010) Observational evidence for soil-moisture impact on hot extremes in southeastern Europe, Nature Geoscience 4,17–21, doi:10.1038/ngeo1032,12 Dec http://www.nature.com/ngeo/journal/v4/n1/full/ngeo1032.html [Full text]

46 Romm, J. (2011b) Science: Second '100-year' Amazon drought in 5 years caused huge CO_2 emissions. If this pattern continues, the forest would become a warming source., ClimateProgress.org, 8 Feb http://climateprogress.org/2011/02/08/science-amazon-drought-co2-emissions-source-sink-simon-lewis/

47 Ibid.

48 'Andy S' (2011) The 2010 Amazon Drought, skepticalscience.com, 6 Feb http://www.skepticalscience.com/The-2010-Amazon-Drought.html

49 University of Leeds (2009) Amazon carbon sink threatened by drought, 5 Mar http://www.leeds.ac.uk/news/article/36/amazon_carbon_sink_threatened_by_drought

50 Lewis, S. L. (2011) The 2010 Amazon Drought, Science Vol. 331 no. 6017 p. 554 DOI: 10.1126/science.1200807, 4 Feb http://www.sciencemag.org/content/331/6017/554.abstract?sid=2b48efd6-3837-45a4-8210-94cc9c7498f7 [Abstract]

51 Allison, I. et al. (2009) Op. Cit.

52 Schmidt, G. (2006) Amazonian drought, RealClimate.org, 4 Aug http://www.realclimate.org/index.php/archives/2006/08/amazonian-drought/

53 McMullen, C. P. (Ed.) (2009) Chapter 4: Earth's Ecosystems, In: Climate Change Science Compendium 2009, United Nations Environment Programme http://www.unep.org/pdf/ccScienceCompendium2009/cc_ScienceCompendium2009_ch4_en.pdf

54 Romm, J. (2010) Op. Cit.

55 IPCC (2011) Summary for Policymakers. In: Intergovernmental Panel on Climate Change Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C. B., Barros, V., Stocker, T.F., Qin, D., Dokken, D., Ebi, K.L., Mastrandrea, M. D., Mach, K. J., Plattner, G.-K., Allen, S., Tignor, M. and P. M. Midgley (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA http://www.ipcc.ch/pdf/special-reports/srex/SREX_FD_SPM_final.pdf [PDF]

56 Sample, I. (2006) Extreme droughts will spread, warn forecasters, guardian.co.uk, 4 Oct http://www.guardian.co.uk/environment/2006/oct/04/water.climatechange

57 Dai, A. (2011) Op. Cit.

58 Sheffield, J. and Wood, E. F. (2007) Op. Cit.

59 Romm, J. (2010) Op. Cit.

60 IPCC (2011) Op. Cit.

61 Dai, A. (2011), Op. Cit.

62 Goddard, S. (2011) Stable Climate In 1959 Brought The Worst Drought In 70 Years, Climate Depot,16 Feb http://www.climatedepot.com/r/9812/Stable-Climate-In-1959-Brought-The-Worst-Drought-In-70-Years

63 Maue, R. (2011) After the Noachian floods in 1861, California experienced a punishing drought, WattsUpWithThat.com, 17 Jan http://wattsupwiththat.com/2011/01/17/after-the-noachian-floods-in-1861-california-experienced-a-punishing-drought/

64 World Climate Report (2010) Update on Global Drought Patterns (IPCC Take Note), World Climate Report, 24 Feb http://www.worldclimatereport.com/index.php/2010/02/24/update-on-global-drought-patterns-ipcc-take-note/

65 Watts, A. (2011) CSIRO – climate variability caused drought, not climate change, WattsUpWithThat.com, 21 Jan http://wattsupwiththat.com/2011/01/21/csiro-climate-variability-caused-drought-not-climate-change/

66 Dai, A. (2011) Op. Cit.

67 Romm, J. (2010) Op. Cit.

68 Haunting the Library (2011) More Nonsense About Queensland Droughts & Floods, Haunting the Library (re-posted by The Global Warming Policy Foundation), 15 Jan http://www.thegwpf.org/the-climate-record/2231-more-nonsense-about-queensland-droughts-a-floods.html

69 Dai, A. (2011) Op. Cit.

70 Ibid.

71 Watts, A. (2011) USGS on their mission to explore African drought, WattsUpWithThat.com, 28 Jan http://wattsupwiththat.com/2011/01/28/usgs-on-their-mission-to-explore-african-drought/

72 Laurance, W. (2010) Op. Cit.

73 Dai, A. (2011) Op. Cit.

74 Watts, A. (2020) Worse than we thought: "unpredictability of the weather" and crops, WattsUpWithThat.com, 7 Oct http://wattsupwiththat.com/2010/10/07/worse-than-we-thought-unpredictability-of-the-weather-and-crops/

75 Marsh, T. (2004) Op. Cit.

76 Black, R. (2009) West Africa faces 'megadroughts', BBC News Online, 16 Apr http://news.bbc.co.uk/1/hi/sci/tech/8003060.stm

77 World Climate Report (2010) Op. Cit.

78 Australian Government Bureau of Meteorology (undated) Op. Cit.

79 Sheffield, J. and Wood, E. F. (2007) Op. Cit.

80 Allison, I. et al. (2009) Op. Cit.

81 Trenberth, K. E. et al. (2007) Op. Cit.

82 Sheffield, J. and Wood, E. F. (2007) Op. Cit.

83 Eschenbach, W. (2010) Out of the Ama-zone, Wattsupwiththat.com, 27 Jun http://wattsupwiththat.com/2010/06/27/out-in-the-ama-zone/

84 Booker, C. (2010) Amazongate: new evidence of the IPCC's failures, The Telegraph Online, 30 Jan http://www.telegraph.co.uk/comment/columnists/christopherbooker/7113582/Amazongate-new-evidence-of-the-IPCCs-failures.html

85 Monbiot, G. (2010) Sunday Times admits 'Amazongate' story was rubbish. But who's to blame?, guardian.co.uk, 24 Jun http://www.guardian.co.uk/environment/georgemonbiot/2010/jun/24/sunday-times-amazongate-ipcc

86 Magrin, G. et al. (2007) Chapter 13: Latin America. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, (Eds.), Cambridge University Press, Cambridge, UK, 581-615. Section 13.4 Summary of expected key future impacts and vulnerabilities http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch13s13-4.html

87 Tollefson, J. (2010) Amazon drought raises research doubts, Nature 466, 423 doi:10.1038/466423a, 20 Jul http://www.nature.com/news/2010/100720/full/466423a.html

88 Allison, I. et al. (2009) Op. Cit.

89 McMullen, C. P. (Ed.) (2009) Op. Cit.

90 Connor, S. (2011) Special report: Catastrophic drought in the Amazon, The Independent (online), 4 Feb http://www.independent.co.uk/news/science/special-report-catastrophic-drought-in-the-amazon-2203892.html

91 Reilly, M. (2007) Serious drought may strike western US, New Scientist, 5 Apr http://www.newscientist.com/article/dn11552-serious-drought-may-strike-western-us.html

92 Brahic, C. (2009) Drought warning as the tropics expand, New Scientist, 1 Feb http://www.newscientist.com/article/dn16516-drought-warning-as-the-tropics-expand.html

93 Marshall, M. (2010) Water cycle goes bust as the world gets warmer, New Scientist, 13 Oct http://www.newscientist.com/article/mg20827825.300-water-cycle-goes-bust-as-the-world-gets-warmer.html [Preview]

EL NIÑO

1 McPhaden, M. J. and Soreide, N. (undated) Frequently Asked Questions about El Niño and La Niña, National Oceanic and Atmospheric Administration http://www.elnino.noaa.gov/lanina_new_faq.html

2 Cane, M. (2005) The evolution of El Niño, past and future, Earth and Planetary Science Letters 230 (2005) 227–240, 15 Feb http://www.sciencedirect.com/science/article/pii/S0012821X04007083 [Abstract]

3 Hegerl, G. C. et al. (2007) Chapter 9: Understanding and Attributing Climate Change, In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Section 9.5.3 Atmospheric Circulation Changes http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch9s9-5-3.html

4 Kessler, W. (undated) Frequently-(well, at least once)-asked-questions about El Niño, National Oceanic and Atmospheric Administration, Q5. Some words of caution on El Niño forecasts. http://faculty.washington.edu/kessler/occasionally-asked-questions.html

5 Ibid. Q7. Why don't you see much publicity about the causes of El Niño?

6 Ibid. Q5. Some words of caution on El Niño forecasts.

7 Ibid. Q7. Why don't you see much publicity about the causes of El Niño?

8 Centre for Climate and Energy Solutions (C2ES) (undated) Hurricanes and Global Warming FAQs: How does El Niño influence hurricane activity? http://www.pewclimate.org/hurricanes.cfm#elnino

9 World Meteorological Organisation (undated) La Niña and current extreme weather: Questions and Answers http://www.wmo.int/pages/mediacentre/factsheet/LaNinaQA.html

10 Trenberth, K. (1999) The Extreme Weather Events of 1997 and 1998, U.S. Global Change Research Information Office, Consequences Vol. 5, No. 1, pp. 3-15 http://www.gcrio.org/CONSEQUENCES/vol5no1/extreme.html

11 National Oceanic and Atmospheric Administration (2006) El Niño, La Niña, and ENSO: Public Fact Sheet, NOAA National Weather Service, Aug http://www.nws.noaa.gov/om/brochures/climate/El_NiñoPublic.pdf [PDF]

12 Trenberth, K. E. et al. (2007) Chapter 3: Observations: Surface and Atmospheric Climate Change. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Section 3.6.2 El Niño-Southern Oscillation and Tropical/Extratropical Interactions http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch3s3-6-2.html

13 Wang, H.-J. et al. (1999) El Niño and the related phenomenon Southern Oscillation (ENSO): The largest signal in interannual climate variation, Proceedings of the National Academy of Sciences of the United States of America vol. 96 no. 20 11071-11072 doi:10.1073/pnas.96.20.11071, 28 Sep http://www.pnas.org/content/96/20/11071.full [Full text]

14 National Weather Service, Climate Prediction Center (2005) Frequently Asked Questions about El Niño and La Niña, National Oceanic and Atmospheric Administration, Dec 19 http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensofaq.shtml

15 Pearce, D. W. (1997) So What is an El Niño, Anyway? Scripps Institution of Oceanography, Jun 25 http://meteora.ucsd.edu/~pierce/elnino/whatis.html

16 World Meteorological Organisation (undated) Op. Cit.

17 McPhaden, M. J. and Soreide, N. (undated) Op. Cit.

18 Henson, B. and Trenberth, K. (2001) Children of the Tropics: El Niño and La Niña, University Corporation for Atmospheric Research (NCAR), Oct http://www.ucar.edu/communications/factsheets/elnino/

19 Kessler, W. (undated) Op. Cit. Q7. Why don't you see much publicity about the causes of El Niño?

20 Ibid. Q28. What initiates El Niños?

21 Ibid. Q5. Some words of caution on El Niño forecasts.

22 Ibid. Q7. Why don't you see much publicity about the causes of El Niño?

23 Henson, B. and Trenberth, K. (2001) Op. Cit.

24 Trenberth, K. E., J. M. Caron, D. P. Stepaniak, and S. Worley (2002) Evolution of El Niño–Southern Oscillation and global atmospheric surface temperatures, Journal of Geophysical Research, 107(D8), 4065, doi:10.1029/2000JD000298.http://www.agu.org/journals/ABS/2002/2000JD000298.shtml [Abstract]; http://www.cgd.ucar.edu/cas/papers/jgr2001b/jgr2.html [Full text]

25 Hansen, J., R. Ruedy, M. Sato, and K. Lo (2005) GISS Surface Temperature Analysis: Global Temperature Trends: 2005 Summation, NASA GISS website, 15 Dec http://data.giss.nasa.gov/gistemp/2005/

26 Met Office (2011) 2010 - A near-record year, metoffice.gov.uk (Archive), 20 Jan http://www.metoffice.gov.uk/news/releases/archive/2011/2010-global-temperature

27 Trenberth, K. E., J. M. Caron, D. P. Stepaniak, and S. Worley (2002) Op. Cit.

28 Ibid.

29 Ibid.

30 'MarkR' (2011) 2011 Year in Review (part 1), skepticalscience.com, 31 Dec http://www.skepticalscience.com/2011_review_pt1.html

31 National Oceanic and Atmospheric Administration (undated) El Niño theme page: What is an El Niño? Pacific Marine Environmental Laboratory, Tropical Atmosphere Ocean Project National Oceanic and Atmospheric Administration http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html

32 Glantz, M. H. (2001) Currents of Change: Impacts of El Niño and La Niña on climate and society, Cambridge University Press 2001, ISBN 0 521 78672 X (pbk.)

33 Trenberth, K. (1999) Op. Cit.

34 National Oceanic and Atmospheric Administration (NOAA) Public Affairs (undated) Answers to La Niña Frequently Asked Questions, National Oceanic and Atmospheric Administration, http://www.elnino.noaa.gov/lanina_new_faq.html

35 Trenberth, K. (1999) Op. Cit.

36 Glantz, M. H. (2001) Op. Cit.

37 Centre for Climate and Energy Solutions (C2ES) (undated) Op. Cit.

38 Henson, B. and Trenberth, K. (2001) Op. Cit.

39 Cane, M. (2005) Op. Cit.

40 Trenberth, K. E. (2011) Changes in precipitation with climate change. Climate Research, 47, 123-138, doi:10.3354/cr00953. http://www.int-res.com/articles/cr_oa/c047p123.pdf [PDF]

41 IPCC (2011) Summary for Policymakers. In: Intergovernmental Panel on Climate Change Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C. B., Barros, V., Stocker, T.F., Qin, D., Dokken, D., Ebi, K.L., Mastrandrea, M. D., Mach, K. J., Plattner, G.-K., Allen, S., Tignor, M. and P. M. Midgley (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA http://www.ipcc.ch/pdf/special-reports/srex/SREX_FD_SPM_final.pdf

42 Stevenson, S. et al. (2011) "Will there be a Significant Change to El Niño in the 21st Century?," Journal of Climate, DOI: 10.1175/JCLI-D-11-00252.1http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-11-00252.1?prevSearch=%5BAllField%3A+Baylor+Fox-Kemper%5D&searchHistoryKey= [Abstract]

43 Kessler, W. (undated) Op. Cit. Q16. Why can't I find any information about links between El Niño and global warming?

44 Latif, M. and N. S. Keenlyside (2009) El Niño/Southern Oscillation Response to Global Warming. Proceedings of the National Academy of Sciences, doi:10.1073/pnas.0710860105, http://www.pnas.org/content/early/2008/12/05/0710860105.abstract [Abstract]

45 Wratt, D. and Mullan, B. (undated) Global Climate Models, National Institute of Water and Atmospheric Research http://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/models#interaction

46 Watts, A. (2010) Flashback – Bob Tisdale's November prediction on GISS exploiting the "warmest decade on record", WattsUpWithThat.com, 22 Jan http://wattsupwiththat.com/2010/01/22/flashback-bob-tisdales-november-prediction-on-giss-exploiting-the-warmest-decade-on-record/

47 Morano, M. (2009) Peer-Reviewed Study Rocks Climate Debate! 'Nature not man responsible for recent global warming... little or none of late 20th century warming and cooling can be attributed to humans', Climate Depot, 23 July http://www.climatedepot.com/a/2117/PeerReviewed-Study-Rocks-Climate-Debate-Nature-not-man-responsible-for-recent-global-warminglittle-or-none-of-late-20th-century-warming-and-cooling-can-be-attributed-to-humans

48 Booker, C. (2011) What happens when the great fantasies, like wind power or European Union, collide with reality?, The Telegraph (online), 13 Apr http://www.telegraph.co.uk/comment/columnists/christopherbooker/8440423/What-happens-when-the-great-fantasies-like-wind-power-or-European-Union-collide-with-reality.html

49 McPhaden, M. J. and Soreide, N. (undated) Op. Cit.

50 Met Office (2008) Global warming goes on, metoffice.gov.uk [Archive] http://webarchive.nationalarchives.gov.uk/+/http://www.metoffice.gov.uk/corporate/pressoffice/2008/pr20080923c.html

51 Trenberth, K. E., J. M. Caron, D. P. Stepaniak, and S. Worley (2002) Op. Cit.

52 Dana (2011) Foster and Rahmstorf Measure the Global Warming Signal, scepticalscience.com, 20 Dec http://www.skepticalscience.com/news.php?n=1172

53 Foster, G and Rahmstorf, S. (2011) Global temperature evolution 1979–2010, Environmental Research Letters 6 044022 doi:10.1088/1748-9326/6/4/044022 http://iopscience.iop.org/1748-9326/6/4/044022 [Abstract]

54 Watts, A. (2010) Op. Cit.

55 Randall, D.A. et al. (2007) Chapter 8: Climate Models and Their Evaluation, In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Section 8.4.7 El Niño-Southern Oscillation, http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch8s8-4-7.html

56 Wratt, D. and Mullan, B. (undated) Op. Cit.

57 Kessler, W. (undated) Op. Cit. Q16. Why can't I find any information about links between El Niño and global warming?

58 Latif, M. and N. S. Keenlyside (2009) Op. Cit.

59 Dana (2011) Op. Cit.

60 Foster, G and Rahmstorf, S. (2011) Op. cit.

61 Carter, B. (2006) There IS a problem with global warming... it stopped in 1998, The Telegraph (online), 9 Apr http://www.telegraph.co.uk/comment/personal-view/3624242/There-IS-a-problem-with-global-warming...-it-stopped-in-1998.html

62 Met Office (2011) Op. Cit.

63 Cook, J. (2010) Did global warming stop in 1998?, skepticalscience.com, 26 Jun http://www.skepticalscience.com/global-warming-stopped-in-1998-intermediate.htm

64 Trenberth, K. E. et al. (2002) The evolution of ENSO and global atmospheric temperatures. Journal of Geophysical Research, 107, 4065, doi:10.1029/2000JD000298 http://www.cgd.ucar.edu/cas/papers/jgr2001b/jgr2.html [Full text]

65 Met Office (2010) Near record temperatures in 2010 to be followed by cooler 2011, metoffice.gov.uk (Archive), 2 Dec http://webarchive.nationalarchives.gov.uk/+/http://www.metoffice.gov.uk/corporate/pressoffice/2010/pr20101202b.html

66 Hansen, J., R. Ruedy, M. Sato, and K. Lo (2005) Op. Cit.

67 Cook, J. (2010) Global warming and the El Niño Southern Oscillation, SkepticalScience.com, 3 Sep http://www.skepticalscience.com/el-nino-southern-oscillation.htm

68 Science Centric (2010) Global warming's influence on El Niño still unknown, 24 May http://www.sciencecentric.com/news/10052408-global-warming-influence-on-el-nino-still-unknown.html

69 Harrabin, R. (2008) Global temperatures 'to decrease', BBC News (online), 4 Apr http://news.bbc.co.uk/1/hi/7329799.stm

FLOODING

1 Ganeshan, S. and Diamond, W. (2009) Forecasting the numbers of people affected annually by natural disasters up to 2015, Oxfam, Apr http://www.oxfam.org.uk/resources/policy/climate_change/downloads/forecasting_disasters_2015.pdf [PDF]

2 New Scientist Environment and Reuters (2007) Extreme weather brings flood chaos round the world, New Scientist (online), 30 Jul http://www.newscientist.com/article/dn12385-extreme-weather-brings-flood-chaos-round-the-world.html?full=true

3 Ibid.

4 Houses of Parliament (2010) POSTNOTE Number 362 Resilience of UK Infrastructure, The Parliamentary Office of Science and Technology, Oct http://www.parliament.uk/documents/post/postpn362-resilience-of-UK-infrastructure.pdf [PDF]

5 New Scientist Environment and Reuters (2007) Op. Cit.

6 Lemos, M. C. and Clausen, T. J. (2009) Synthesis Report from Climate Change Global Risks, Challenges & Decisions (Second Edition): Water Resources and Climate Change: Building Resilience Towards a Sustainable Future, University of Copenhagen, Copenhagen, p. 13, 10-12 March http://climatecongress.ku.dk/pdf/synthesisreport [PDF]

7 Press Association (2010) UK must help homes adapt to climate change, MPs say, guardian.co.uk, 25 Mar http://www.guardian.co.uk/environment/2010/mar/25/uk-homes-climate-change-adaptation

8 Spence, A., Poortinga, W., Butler, C., and Pidgeon, N. F. (2011), Perceptions of climate change and willingness to save energy related to flood experience, Nature Climate Change 1,46–49, doi:10.1038/nclimate1059, 20 Mar http://www.nature.com/nclimate/journal/v1/n1/full/nclimate1059.html?WT.ec_id=NCLIMATE-201104 (Full Text)

9 Lemos, M. C. and Clausen, T. J. (2009) Op. Cit.

10 McMullen, C. P. (Ed.) (2009) Chapter 2: Earth's Ice, In: Climate Change Science Compendium 2009, United Nations Environment Programme http://www.unep.org/pdf/ccScienceCompendium2009/cc_ScienceCompendium2009_ch2_en.pdf [PDF]

11 Cook, J. (2011a) OK global warming, this time it's personal!, ABC Environment, 17 Jan http://www.abc.net.au/environment/articles/2011/01/17/3114597.htm

12 Ibid.

13 New Scientist Environment and Reuters (2007) Op. Cit.

14 Mail Online (2008) Better get used to being weather-beaten... there's another 25 years of floods and storms to come, 1 Feb http://www.dailymail.co.uk/news/article-511603/Better-used-weather-beaten--theres-25-years-floods-storms-come.html#ixzz1Dx3JcPCN

15 Romm, J. (2011) Masters on Brazilian floods: Brazil's deadliest natural disaster in history: The role of near-record sea surface temperatures, climateprogress.org, 16 Jan http://climateprogress.org/2011/01/16/brazilian-floods-brazil-deadliest-natural-disaster-in-history/

16 Meehl, G.A. et al. (2007) Chapter 10: Global Climate Projections, in: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. p. 783 Frequently Asked Question 10.1 Are Extreme Events, Like Heat Waves, Droughts or Floods, Expected to Change as the Earth's Climate Changes? http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-10-1.html

17 Dessler, A. E. and Davis, S. M. (2010) Trends in tropospheric humidity from reanalysis systems, Journal of Geophysical Research, Vol. 115, D19127, doi:10.1029/2010JD014192, http://geotest.tamu.edu/userfiles/216/Dessler10.pdf [Full text, PDF]

18 Rahmstorf, S. (2010) Will this summer of extremes be a wake-up call? guardian.co.uk, 16 Aug http://www.guardian.co.uk/environment/2010/aug/16/summer-extremes-wake-up-call

19 Trenberth, K. E. et al. (2007) Chapter 3: Observations: Surface and Atmospheric Climate Change. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., FAQ 3.2: How is Precipitation Changing? http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-3-2.html

20 Schmidt, G. (2011) Going to extremes, realclimate.org, 17 Feb http://www.realclimate.org/index.php/archives/2011/02/going-to-extremes/

21 European Environment Agency, World Health Organisation and Joint Research Centre (2008a) Chapter 8: Data gaps, uncertainties and future needs, in Impacts of Europe's changing climate - 2008 indicator-based assessment, European Environment Agency, European Commission, EEA Report No 4/2008; JRC Reference Report No JRC47756, 29 Sep http://www.eea.europa.eu/publications/eea_report_2008_4/pp193-207CC2008_ch8_Data_gaps.pdf [PDF]

22 Tryhorn, L. and Shaw, S. (2010) Does more extreme rainfall mean more flooding? Answer: Not always, skepticalscience.com, 15 Sep http://www.skepticalscience.com/Does-more-extreme-rainfall-mean-more-flooding-Answer-Not-always.html

23 Kundzewicz, Z. W.et al. (2007) Chapter 3: Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, pp. 173-210. http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch3.html

24 Ibid.

25 European Environment Agency, World Health Organisation and Joint Research Centre (2008b), Chapter 5, Section 5: Water quantity, river floods and droughts: In, Impacts of Europe's changing climate - 2008 indicator-based assessment, European Environment Agency, European Commission, EEA Report No 4/2008; JRC Reference Report No. JRC47756, 29 Sep http://www.eea.europa.eu/publications/eea_report_2008_4/pp76-110CC2008_ch5-4to6_Water_quantity_and_quality.pdf [PDF]

26 Ibid.

27 Milly, P. C. D. et al. (2002) Increasing risk of great floods in a changing climate, Nature 415, 514-517 doi:10.1038/415514a, 31 Jan http://www.nature.com/nature/journal/v415/n6871/full/415514a.html [Abstract]

28 Trenberth, K. E. et al. (2007) Op. Cit. Section 3.8.2.2, Precipitation, http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch3s3-8-2-2.html

29 Solomon, S. et al. (2007) Technical Summary. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ts.html

30 Khandekar, M. L. (2010) 2010 Pakistan Floods: Climate Change or Natural Variability?, Canadian Meteorological and Oceanographic Society Bulletin Vol.38, No.5, Oct http://pielkeclimatesci.files.wordpress.com/2010/09/mlk-2010-pakistan-floods.pdf [PDF]

31 European Environment Agency, World Health Organisation and Joint Research Centre (2008b) Op. Cit.

32 IPCC (2011) Summary for Policymakers. In: Intergovernmental Panel on Climate Change Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C. B., Barros, V., Stocker, T.F., Qin, D., Dokken, D., Ebi, K.L., Mastrandrea, M. D., Mach, K. J., Plattner, G.-K., Allen, S., Tignor, M. and P. M. Midgley (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA http://www.ipcc.ch/publications_and_data/ar4/wg1/en/spm.html

33 Schmidt, G. (2011) Op. Cit.

34 Chivers, T (2010) Climate change, Pakistani floods, and causality, The Telegraph Online, 11 Aug http://blogs.telegraph.co.uk/culture/tomchivers/100045912/climate-change-pakistani-floods-and-causality/

35 Cook, J. (2011b) The Queensland floods, skepticalscience.com, 12 Jan http://www.skepticalscience.com/The-Queensland-floods.html

36 Pall, P. et al.(2011) Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000, Nature 470, 382–385 doi:10.1038/nature09762, 17 Feb http://www.nature.com/nature/journal/v470/n7334/full/nature09762.html [Preview]

37 Borenstein, S. (2011) Scientists connect global warming to extreme rain, Associated Press (CBS News), 16 Feb http://www.cbsnews.com/stories/2011/02/16/scitech/main20032304.shtml

38 Wigmore, B (2008) Britain faces spring floods and summer droughts as climate change accelerates, warns report, Mail Online, 30 Sep http://www.dailymail.co.uk/sciencetech/article-1064189/Britain-faces-spring-floods-summer-droughts-climate-change-accelerates-warns-report.html#ixzz1DxDjRp3p

39 Ibid.

40 Marsh, T. J. and Hannaford, J. (2007) The summer 2007 floods in England and Wales – a hydrological appraisal. Centre for Ecology & Hydrology. p.32. ISBN: 978-0-9557672-4–1 http://www.ceh.ac.uk/documents/CEH_FloodingAppraisal.pdf [PDF]

41 Fowler, H. J. and Kilsby, C. G. (2003) A Regional Frequency Analysis of United Kingdom Extreme Rainfall from 1961 to 2000, International Journal of Climatology A Regional Frequency Analysis of United Kingdom Extreme Rainfall from 1961 to 2000, International journal of Climatology 23: 1313–1334 DOI: 10.1002/joc.943 http://www.staff.ncl.ac.uk/h.j.fowler/2003IJC_regfreqanalysis.pdf [Full text, PDF]

42 Osborn, T. J., Hulme, M., Jones, P. D. and Basnett, T. A. (2000), Observed trends in the daily intensity of United Kingdom precipitation. International Journal of Climatology, 20: 347–364. doi: 10.1002/(SICI)1097-0088(20000330)20:4←347::AID-JOC475→3.0.CO;2-C http://onlinelibrary.wiley.com/doi/10.1002/(SICI)1097-0088(20000330)20:4%3C347::AID-JOC475%3E3.0.CO;2-C/abstract [Abstract]

43 European Environment Agency, World Health Organisation and Joint Research Centre (2008b) Op. Cit.

44 Heffernan, O. (2009) UK climate effects revealed in finest detail yet, Nature News, 19 Jun http://www.nature.com/news/2009/090619/full/news.2009.586.html

45 Milly, P. C. D. et al. (2002) Op. Cit.

46 Kundzewicz, Z. W. et al. (2007) Op Cit.

47 European Environment Agency, World Health Organisation and Joint Research Centre (2008b) Op. Cit.

48 Cook, J. (2011c) The Climate Show #5: Green roofs and Brisbane floods, skepticalscience.com, 21 Jan http://www.skepticalscience.com/Climate-Show-5-Green-roofs-Brisbane-floods.html

49 McMullen, C. P. (Ed.) (2009), Chapter 4: Earth's Ecosystems, In: Climate Change Science Compendium 2009, United Nations Environment Programme http://www.unep.org/pdf/ccScienceCompendium2009/cc_ScienceCompendium2009_ch4_en.pdf

50 IPCC (2011) Op. Cit.

51 Min, S-K. et al. (2011) Human contribution to more-intense precipitation extremes, Nature 470, 378–381 doi:10.1038/nature09763, 17 Feb http://www.nature.com/nature/journal/v470/n7334/full/nature09763.html [Preview]

52 IPCC (2011) Op. Cit.

53 Daily Mail Reporter (2009) Global warming could lead to increased flooding and rising food prices in UK, claim leading scientists, Mail Online, 24 Nov http://www.dailymail.co.uk/sciencetech/article-1230453/Global-warming-threat-lead-increased-flooding-rising-food-prices-claim-leading-UK-scientists.html#ixzz1Dwo7CQdH

54 Schiermeier, Q. (2010) The real holes in climate science, Nature 463, 284-287 (News Feature) doi:10.1038/463284a, 20 Jan http://www.nature.com/news/2010/100120/full/463284a.html

55 Ibid.

56 Groisman, Pavel Ya, Richard W. Knight, David R. Easterling, Thomas R. Karl, Gabriele C. Hegerl, Vyacheslav N. Razuvaev, 2005: Trends in Intense Precipitation in the Climate Record. Journal of Climate, 18, 1326–1350.http://journals.ametsoc.org/doi/full/10.1175/JCLI3339.1

57 Watts, A (2011) New UW peer reviewed paper on the 2010 Pakistan floods – nothing to do with "climate change", WattsUpWithThat.com, 25 Jan http://wattsupwiththat.com/2011/01/25/new-uw-peer-reviewed-paper-on-the-2010-pakistan-floods-nothing-to-do-with-climate-change/

58 Cook, J. (2011a) Op. Cit.

59 Watts, A. (2011) Is the Brazilian flooding catastrophe evidence of another global warming era extreme?, WattsUpWithThat.com, 15 Jan http://wattsupwiththat.com/2011/01/15/is-the-is-the-brazilian-flooding-catastrophe-evidence-of-another-global-warming-era-extreme/

60 Watts, A. (2010) Climate Central confuses weather and climate – you help write the rebuttal, WattsUpWithThat.com, 17 Dec http://wattsupwiththat.com/2010/12/17/climate-central-confuses-weather-and-climate-you-help-write-the-rebuttal/

61 Maue, R. (2011) After the Noachian floods in 1861, California experienced a punishing drought, WattsUpWithThat.com, 17 Jan http://wattsupwiththat.com/2011/01/17/after-the-noachian-floods-in-1861-california-experienced-a-punishing-drought/

62 Milly, P. C. D. et al. (2002) Op. Cit.

63 Hoffman, D. L. (2011) Precipitation, Convection & Climate Change, The Resilient Earth (re-posted by the Global Warming Policy Foundation, with additional intro paragraph), Jan 25 http://www.thegwpf.org/the-observatory/2303-precipitation-convection-a-climate-change.html

64 Trenberth, K. E. et al. (2007) Op. Cit. Section 3.8.2.2: Precipitation http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch3s3-8-2-2.html

65 Hoffman, D. L. (2011) That Wicked Weather, The Resilient Earth (re-posted by The Global Warming Policy Foundation), 28 Jan http://thegwpf.org/the-observatory/2325-that-wicked-weather.html

66 Romm, J. (2010) The year of living dangerously. Masters: "The stunning extremes we witnessed gives me concern that our climate is showing the early signs of instability", climateprogress.com, 23 Dec http://climateprogress.org/2010/12/23/the-year-of-living-dangerously-masters-weather-extremes-climate-change/

67 Kundzewicz, Z. W. et al. (2007) Op. Cit.

68 Ibid.

69 Haunting The Library (2011) Queensland Floods. Climate Scientists 2010: Less Moisture Over Australia. Climate Scientists 2011: More Moisture Over Australia, Haunting The Library (reposted by The Global Warming Policy Foundation), 15 Jan http://hauntingthelibrary.wordpress.com/2011/01/15/queensland-floods-climate-scientists-2010-less-moisture-over-australia-climate-scientists-2011-more-moisture-over-australia/ and http://thegwpf.org/the-climate-record/2231-more-nonsense-about-queensland-droughts-a-floods.html

70 Cook, J. (2011a) Op. Cit.

71 Sun, Y. et al. (2007) How Often Will It Rain? Journal of Climate, Vol. 20, 1 Oct http://www.cgd.ucar.edu/cas/adai/papers/Sun_etal_JC07.pdf [Full text, PDF]

72 Carrington, D. (2007) Flooding in England: What can be done?, New Scientist Blogs: Environment Blog, 24 Jul http://www.newscientist.com/blog/environment/2007/07/flooding-in-england-whats-to-be-done.html

73 Romm, J. (2011) Terrific ABC News story: "Raging Waters In Australia and Brazil Product of Global Warming" Scientists: Climate Change No Longer a Theory, It's Happening", climateprogress.org, 14 Jan http://climateprogress.org/2011/01/14/abc-news-australia-floods-extreme-weather-global-warming-climate-change/

74 Rahmstorf, S. (2010) Op. Cit.

75 Borenstein, S. (2011) Op. Cit.

HEATWAVES

1 Shearer, C. and Rood, R. B. (2011) Changing the Media Discussion on Climate and Extreme Weather, earthzine.org, 17 Apr http://www.earthzine.org/2011/04/17/changing-the-media-discussion-on-climate-and-extreme-weather/

2 'MarkR' (2011) 2011 Year in Review (part 1), skepticalscience.com, 31 Dec http://www.skepticalscience.com/2011_review_pt1.html

3 Hansen, J., Sato, M. and Ruedy, R. (in press, 2011) Climate Variability and Climate Change: The New Climate Dice, NASA, 10 Nov http://www.columbia.edu/~jeh1/mailings/2011/20111110_NewClimateDice.pdf [PDF]

4 Benzie, M. (2011) Vulnerability to heatwaves and drought: adaptation to climate change, Joseph Rowntree Foundation, 20 Feb http://www.jrf.org.uk/publications/vulnerability-heatwaves-and-drought-adaptation-climate-change

5 Department for Environment, Food and Rural Affairs (2009) UK Climate Projections: Adapting to Climate Change, DEFRA, Jun http://www.defra.gov.uk/publications/files/pb13274-uk-climate-projections-090617.pdf [PDF]

6 Stott, P. et al (2004) Human contribution to the European heatwave of 2003, Nature 432, 610-614 doi:10.1038/nature03089, 2 Dec http://www.nature.com/nature/journal/v432/n7017/full/nature03089.html [Abstract] http://climateprediction.net/science/pubs/nature03089.pdf [Full text, PDF]

7 Black, R. (2005) Heatwave makes plants warm planet, BBC News Online, 21 Sep http://news.bbc.co.uk/1/hi/sci/tech/4269066.stm

8 Benzie, M. (2011) Op. Cit.

9 Ibid.

10 Abrahamson, V. et al. (2009) Perceptions of heatwave risks to health: interview-based study of older people in London and Norwich, UK, Journal of Public Health 31 (1): 119-126.doi: 10.1093/pubmed/fdn102 http://jpubhealth.oxfordjournals.org/content/31/1/119.full

11 Meehl, G. A. and Tebaldi, C. (2004) More Intense, More Frequent, and Longer Lasting Heat Waves in the 21st Century, Science Vol. 305 no. 5686 pp. 994-997 DOI: 10.1126/science.1098704, 13 Aug http://www.sciencemag.org/content/305/5686/994.full

12 Ibid.

13 Laurence, W. (2010) Climate shock: One heatwave from oblivion, New Scientist, 8 Dec http://www.newscientist.com/article/mg20827891.100-climate-shock-one-heatwave-from-oblivion.html?full=true

14 Schiermeier, Q. (2010) Mediterranean most at risk from European heatwaves, Nature News doi:10.1038/news.2010.238, 17 May http://www.nature.com/news/2010/100517/full/news.2010.238.html

15 Karl, T. R. et al. (2008) Weather and Climate Extremes in a Changing Climate, Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands U.S. Climate Change Science Program Synthesis and Assessment Product 3.3, Jun http://www.climatescience.gov/Library/sap/sap3-3/final-report/sap3-3-final-all.pdf (PDF)

16 Muir, H. (2010) Thermogeddon: When the Earth gets too hot for humans, New Scientist, 26 Oct http://www.newscientist.com/article/mg20827835.600-thermogeddon-when-the-earth-gets-too-hot-for-humans.html?full=true

17 Ibid.

18 McMichael, A. J. et al. (Eds.) (2003) Climate change and human health: Risks and responses, World Health Organisation (WHO) http://www.who.int/globalchange/publications/climchange.pdf [PDF]

19 Ibid.

20 Muir, H. (2010) Op. Cit.

21 McMichael, A. J. et al. (Eds.) (2003) Op. Cit.

22 Patz, J. A. et al. (2005) Impact of regional climate change on human health, Nature 438, 310-317 doi:10.1038/nature04188, 17 Nov http://www.nature.com/nature/journal/v438/n7066/full/nature04188.html

23 Ibid.

24 Committee on Stabilization Targets for Atmospheric Greenhouse Gas Concentrations; National Research Council (2011) Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia. Washington, DC: National Academies Press. http://www.nap.edu/catalog.php?record_id=12877

25 Smith, T. (2011) 'Mega-heatwaves' to become more common. We must adapt, say scientists, Climate Action Programme, 23 Mar http://www.climateactionprogramme.org/news/mega_heatwaves_to_become_more_common._we_must_adapt_say_scientists/

26 Hopkin, M. (2005) Heatwaves spell bad news for carbon sinks, Nature News doi:10.1038/news050919-5, 21 Sep http://www.nature.com/news/2005/050921/full/news050919-5.html

27 Alexander, L. (2010) Climate science: Extreme heat rooted in dry soils, Nature Geoscience 4,12–13 News and Views, 12 Dec http://www.nature.com/ngeo/journal/v4/n1/full/ngeo1045.html

28 Hirschi, M. et al (2010) Observational evidence for soil-moisture impact on hot extremes in southeastern Europe, Nature Geoscience 4,17–21, doi:10.1038/ngeo1032,12 Dec http://www.nature.com/ngeo/journal/v4/n1/full/ngeo1032.html

29 Petherick, A. (2011) Food and the future, Nature Climate Change 1, 20–21 doi:10.1038/nclimate1052, 29 Mar http://www.nature.com/nclimate/journal/v1/n1/full/nclimate1052.html#/correction1

30 Clark, R.T., Brown, S. J. and Murphy, M. J. (2006) Modeling Northern Hemisphere Summer Heat Extreme Changes and Their Uncertainties Using a Physics Ensemble of Climate Sensitivity Experiments. Journal of Climate, 19, 4418–4435 http://journals.ametsoc.org/doi/full/10.1175/JCLI3877.1

31 Marshall, M. and Hamzelou, J. (2010) Is climate change burning Russia?, New Scientist, 12 Aug http://www.newscientist.com/article/dn19304-is-climate-change-burning-russia.html?full=true

32 Trenberth, K. E. et al. (2007) Chapter 3: Observations: Surface and Atmospheric Climate Change. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., FAQ 3.3 Has there been a Change in Extreme Events like Heat Waves, Droughts, Floods and Hurricanes? http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-3-3.html

33 Meehl, G.A. et al. (2007) Chapter 10: Global Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., 10.3.6.2 Temperature Extremes http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch10s10-3-6-2.html

34 Trenberth, K. E. et al. (2007) Op. Cit.

35 Brahic, C. (2007) Europe's recent heatwaves aren't a mirage, New Scientist, 3 Aug http://www.newscientist.com/article/dn12419-europes-recent-heatwaves-arent-a-mirage.html

36 Della-Marta, P. M. et al. (2007) Doubled length of Western European summer heat waves since 1880. Journal of Geophysical Research 112. doi:10.1029/2007JD008510 http://www.agu.org/pubs/crossref/2007/2007JD008510.shtml

37 Frich, P. et al. (2002) Observed coherent changes in climatic extremes during the second half of the twentieth century, Climate Research Vol. 19: 193–212, 16 Jan http://www.int-res.com/articles/cr2002/19/c019p193.pdf [PDF]

38 Ibid.

39 Alexander, L. et al. (2006) Global observed changes in daily climate extremes of temperature and precipitation. Journal of Geophysical Research 111 https://bora.uib.no/bitstream/1956/1477/1/Stephenson.pdf [PDF]

40 Shearer, C. and Rood, R. B. (2011) Op. Cit.

41 Stott, P. et al (2004) Op. Cit.

42 Rahmstorf, S. (2011) Increase of extreme events in a warming world, Proceedings of the National Academy of Sciences of the United States of America (PNAS , doi: 10.1073/pnas.1101766108, 24 Oct http://www.pnas.org/content/early/2011/10/18/1101766108.abstract [Abstract]

43 Schiermeier, Q. (2010) Op. Cit.

44 Robine, J. et al. (2008), Death toll exceeded 70,000 in Europe during the summer of 2003, Comptes rendus biologies, 331(2), 171-178. http://www.ncbi.nlm.nih.gov/pubmed/18241810

45 Smith, T. (2011) Op. Cit.

46 Ibid.

47 Shearer, C. and Rood, R. B. (2011) Op. Cit.

48 Karl, T. R. et al. (2008) Op. Cit.

49 Trenberth, K. E. et al. (2007) Op. Cit.

50 McMichael, A. J. et al. [Eds.] (2003) Op. Cit.

51 Meehl, G. A. and Tebaldi, C. (2004) Op. Cit.

52 Karl, T. R. et al. (2008) Op. Cit.

53 Fischer, E. M., and C. Schär (2010), Consistent geographical patterns of changes in high-impact European heatwaves, Nature Geoscience, 3, 398-403. https://www.uni-hohenheim.de/file-admin/einrichtungen/klimawandel/Literatur/Fischer-Schaer-NatureGeo2010.pdf [PDF]

54 Carrington, D. (2011) Deadly heatwaves will be more frequent in coming decades, say scientists, guardian.co.uk, 17 Mar http://www.guardian.co.uk/environment/2011/mar/17/deadly-heat-waves-europe?INTCMP=SRCH

55 Barriopedro, D. et al. (2011) The Hot Summer of 2010: Redrawing the Temperature Record Map of Europe, Science, 332 (6026), 220-224. http://www.sciencemag.org/content/early/2011/03/16/science.1201224.abstract [Abstract]

56 Sherwood, S. C. and Huber, M. (2010) An adaptability limit to climate change due to heat stress, Proceedings of the National Academy of Sciences vol. 107 no. 21 9552-9555 doi:10.1073/pnas.0913352107PNAS, 25 May http://www.pnas.org/content/107/21/9552

57 Muir, H. (2010) Op. Cit.

58 Meehl, G. A. and Tebaldi, C. (2004) Op. Cit.

59 McMichael, A. J. et al. [Eds.] (2003) Op. Cit.

60 Meehl, G. A. and Tebaldi, C. (2004) Op. Cit.

61 Benzie, M. (2011) Op. Cit.

62 Schiermeier, Q. (2010) Op. Cit.

63 Wayne, G. (2010) The Good, The Bad and The Ugly Effects of Climate Change, Skepticalscience.com, 17 Aug http://www.skepticalscience.com/The-Good-The-Bad-and-The-Ugly-Effects-of-Climate-Change.html

64 Committee on Stabilization Targets for Atmospheric Greenhouse Gas Concentrations; National Research Council (2011) Op. Cit.

65 Harvey, F. (2010) When Extreme Weather Becomes Climate Change, Financial Times (re-posted by the Global Warming Policy Foundation), 30 Aug http://www.thegwpf.org/science-news/1454-when-extreme-weather-becomes-climate-change.html

66 Shearer, C. and Rood, R. B. (2011) Op. Cit.

67 Stott, P. et al (2004) Op. Cit.

68 Watts, A. (2011) Final words on the 2010 Russian heat wave from AGU: weather, predictable, wattsupwiththat.com, 13 Apr http://wattsupwiththat.com/2011/04/13/final-words-on-the-russian-heat-wave-from-agu-weather-predictable/

69 Watts, A. (2011) NOAA finds "climate change" blameless in 2010 Russian heat wave, wattsupwiththat.com, 9 Mar http://wattsupwiththat.com/2011/03/09/noaa-findsclimate-change-blameless-in-2010-russian-heat-wave/

70 Watts, A. (2009) Reporter down under: "Don't blame climate change" for "hottest August on record", wattsupwiththat.com, 1 Sep http://wattsupwiththat.com/2009/09/01/reporter-down-under-dont-blame-climate-change-for-hottest-august-on-record/

71 Watts, A. (2010) World's Worst Heatwave – The Marble Bar heatwave, 1923-24, wattsupwiththat.com, 21 Aug http://wattsupwiththat.com/2010/08/21/worlds-worst-heatwave-the-marble-bar-heatwave-1923-24/

72 Watts, A. (2011) 100 years ago today, "climate disruption" traveled back in time to kill 652 people, wattsupwiththat.com, 10 Jul http://wattsupwiththat.com/2011/07/10/100-years-ago-to-day-climate-disruption-traveled-back-in-time-to-kill-652-people/

73 Shearer, C. and Rood, R. B. (2011) Op. Cit.

74 Barriopedro, D. et al. (2011) Op. Cit.

75 Trenberth, K. E. et al. (2002) The evolution of ENSO and global atmospheric surface temperatures Journal of Geophysical Research, 107, D8, 10.1029/2000JD000298. http://www.cgd.ucar.edu/cas/papers/2000JD000298.pdf [PDF]

76 Trenberth, K. E. et al. (2007) Op. Cit.

77 Meehl, G.A. et al. (2007) Op. Cit.

78 Watts, A. (2008) NASA JPL on Heatwaves: "it's the asphalt, not the atmosphere", wattsupwiththat.com, 26 Sep http://wattsupwiththat.com/2008/09/26/nasa-jpl-heatwaves-its-the-asphalt-not-the-atmosphere/

79 Patz, J. A. et al. (2005) Op. Cit.

80 McMichael, A. J. et al. [Eds.] (2003) Op. Cit.

81 Patz, J. A. et al. (2005) Op. Cit.

82 Goddard, S. (2011) Moscow Heatwave Update : Yet Another Coldest Winter Ever (Every Five Years), ClimateDepot.com, 21 Feb http://www.climatedepot.com/r/9893/Heatwave-Con-Game-Moscow-Heatwave-Update-Yet-Another-Coldest-Winter-Ever-Every-Five-Years

83 Watts, A. (2011) Monckton skewers Steketee, WattsUpWithThat.com, Jan 9 http://wattsupwiththat.com/2011/01/09/monckton-skewers-steketee/

84 Cook, J. (2011) Monckton Myth #9: Monckton vs Monckton on heat waves, skepticalscience.com, 8 Feb http://www.skepticalscience.com/Monckton-Myth-9-Monckton-vs-Monckton-on-heat-waves.html/

85 Meehl, J. et al. (2009) Relative increase of record high maximum temperatures compared to record low minimum temperatures in the U. S, Geophysical Research Letters, *36*, L23701, doi:10.1029/2009GL040736. http://europa.agu.org/?uri=/journals/gl/gl0923/2009GL040736/2009GL040736.xml&view=article

86 Trewin, B. and Vermont, H. (2010) Changes in the frequency of record temperatures in Australia`, 1957-2009, Australian Meteorological and Oceanographic Journal 60, 113-11 http://www.bom.gov.au/amm/docs/2010/trewin.pdf [PDF]

87 Clark, R.T., Brown, S. J. and Murphy, M. J. (2006) Op. Cit.

88 The Mail Online (2006) Is this week's heatwave proof of global warming? 19 Jul http://www.dailymail.co.uk/news/article-396581/Is-weeks-heatwave-proof-global-warming.html#ixzz1NTiNso7r

89 Clark, R. (2010) Ross Clark: Why The Met Office Can No Longer Be Trusted, Daily Express (re-posted by the Global Warming Policy Foundation), 30 Dec http://www.thegwpf.org/opinion-pros-a-cons/2122-ross-clark-why-the-met-office-can-no-longer-be-trusted.html

90 Wayne, G. (2010) Op. Cit.

91 Committee on Stabilization Targets for Atmospheric Greenhouse Gas Concentrations; National Research Council (2011) Op. Cit.

92 Kenward, A. (2011) What's With the Weather? Is Climate Change to Blame?, Yale Environment 360, 21 Apr http://e360.yale.edu/feature/whats_with_the_weather_is_climate_change_to_blame/2388/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+YaleEnvironment360+%28Yale+Environment+360%29

93 Black, R. (2005) Op. Cit.

94 Brahic, C. (2007) Med to get five times as many dangerously hot days, New Scientist, 18 Jun http://www.newscientist.com/article/dn12086-med-to-get-five-times-as-many-dangerously-hot-days.html

SNOW & COLD WEATHER

1 Mail Online (2010) Could we be in for 30 years of global COOLING?, dailymail.co.uk, 11 Jan http://www.dailymail.co.uk/news/article-1242202/Could-30-years-global-COOLING.html

2 Rose, D. (2010) The mini ice age starts here, The Daily Mail (online), 10 Jan http://www.dailymail.co.uk/sciencetech/article-1242011/DAVID-ROSE-The-mini-ice-age-starts-here.html

3 Brown, M. (2010) SNOW CHAOS: AND THEY STILL CLAIM IT'S GLOBAL WARMING, The Daily Express (online), 6 Jan http://www.dailyexpress.co.uk/posts/view/149966

4 Cohen, J. (2010) Bundle Up, It's Global Warming, The New York Times (online), 25 Dec http://www.nytimes.com/2010/12/26/opinion/26cohen.html?_r=1&ref=opinion

5 Monbiot, G. (2010) That snow outside is what global warming looks like, guardian.co.uk, 20 Dec http://www.guardian.co.uk/commentisfree/2010/dec/20/uk-snow-global-warming

6 Connor, S. (2010) Expect more extreme winters thanks to global warming, say scientists, The Independent (online), 24 Dec http://www.independent.co.uk/news/science/expect-more-extreme-winters-thanks-to-global-warming-say-scientists-2168418.html

7 BBC News (2010) Climate scepticism 'on the rise', BBC poll shows, BBC News (online) 7 Feb http://news.bbc.co.uk/1/hi/sci/tech/8500443.stm

8 Carrington, D. (2011) Public belief in climate change weathers storm, poll shows, guardian.co.uk, 31 Jan http://www.guardian.co.uk/environment/2011/jan/31/public-belief-climate-change

9 Doughty, S. (2011) Britons going cold on global warming: Number of climate change sceptics doubles in four years, Mail Online, 28 Jan http://www.dailymail.co.uk/sciencetech/article-1351217/Climate-change-sceptics-double-4-years-Britain-goes-cold-global-warming.html

10 Fauvell, D. and Simpson, I. (undated) The history of British winters, netweather.tv http://www.netweather.tv/index.cgi?action=other;type=winthist;sess=

11 Met Office News (2009) Coldest winter for a decade, metoffice.gov.uk (Archive), 25 Feb http://webarchive.nationalarchives.gov.uk/+/http://www.metoffice.gov.uk/corporate/pressoffice/2009/pr20090225.html

12 'Coldest' in the UK is defined as the lowest average Central England Temperature from December through to February.

13 MeteoGroup (2009) The winter season 2008-2009 - how does it compare with past cold winters?, meteogroup.co.uk, 16 Feb http://www.meteogroup.co.uk/uk/home/services_for_business/climate_change/blog/archive/2009/february/ch/799807f9c0/article/the_winter_season_2008_2009_how_does_it_compare_with_past_cold_winters.html

14 Jones, S. (2010) The coldest winters in the UK, guardian.co.uk, 5 Jan http://www.guardian.co.uk/uk/2010/jan/05/coldest-winters-britain-snow

15 Ibid.

16 Fauvell, D. (undated) Famous British Winters, netweather.tv http://www.netweather.tv/index.cgi?action=other;type=famwint;sess=

17 Williamson, M. (2010) Rewind: The big freeze of 1962-63, ESPN Soccernet,12 Jan http://soccernet.espn.go.com/feature?id=724225&cc=5739

18 Jones, S. (2010) Op. Cit.

19 Ibid.

20 Met Office (undated) Severe Winters, Met Office Education website http://www.metoffice.gov.uk/education/teens/case-studies/severe-winters

21 Kodra, E., Steinhaeuser, K. and Ganguly, A. R. (2011) Persisting cold extremes under 21st century warming scenarios, Geophysical Research Letters, Vol 38., L08705, doi:10.1029/2011GL047103 http://www-users.cs.umn.edu/~ksteinha/papers/GRL11.pdf (PDF)

22 Connolley, W. M. (2010) Explaining too much, Stoat blog, 29 Dec http://scienceblogs.com/stoat/2010/12/explaining_too_much.php

23 The meteorological definition of winter is December to February inclusive.

24 Met Office (2010) Coldest UK winter for over 30 years, metoffice.gov.uk (Archive), 1 Mar http://webarchive.nationalarchives.gov.uk/+/http://www.metoffice.gov.uk/corporate/pressoffice/2010/pr20100301.html

25 Hoerling, M., Human, K. and Deluisi, B. (2010) Forensic Meteorology Solves the Mystery of Record Snows, National Oceanic and Atmospheric Administration (NOAA) Climate Services, March 26 http://www.climatewatch.noaa.gov/2010/articles/forensic-meteorology-solves-the-mystery-of-record-snows

26 Adam, D. (2010) Leading climate scientist challenges Mail on Sunday's use of his research, guardian.co.uk, 11 Jan, http://www.guardian.co.uk/environment/2010/jan/11/climate-change-global-warming-mojib-latif

27 Keenlyside, N. S. et al. (2008) Advancing decadal-scale climate prediction in the North Atlantic sector, Nature 453, 84-88, 1 May, http://www.nature.com/nature/journal/v453/n7191/abs/nature06921.html [Abstract]

28 Met Office (2009a) Coldest winter for a decade, metoffice.gov.uk (Archive), 25 Feb http://webarchive.nationalarchives.gov.uk/+/http://www.metoffice.gov.uk/corporate/pressoffice/2009/pr20090225.html

29 Real Climate (2010) Cold winter in a world of warming? realclimate.org, 14 Dec http://www.realclimate.org/index.php/archives/2010/12/cold-winter-in-a-world-of-warming/

30 National Snow and Ice Data Centre (undated), Glossary: Arctic Oscillation, NSIDC Education http://nsidc.org/arcticmet/glossary/arctic_oscillation.html

31 Ambaum, M. H. P., Hoskins, B. J. and Stephenson, D. B. (2001) Arctic Oscillation or North Atlantic Oscillation? American Meteorological Society, 2 Jan http://journals.ametsoc.org/doi/pdf/10.1175/1520-0442(2001)014%3C3495:AOONAO%3E2.0.CO;2 [Full text; PDF]

32 Black, R. (2010) Arctic roots of 'upside-down' weather, BBC News (online), 5 Jan http://www.bbc.co.uk/blogs/thereporters/richardblack/2010/01/arctic_conditions_arctic_cause.html

33 Bissolli, P. et al. (2010) Assessment of the observed extreme conditions during the 2009/2010 boreal winter, World Meteorological Organization, WMO/TD-No. 1550 http://www.wmo.int/pages/prog/wcp/wcdmp/wcdmp_series/documents/winter2009-2010_TD1550_EN_web.pdf [PDF]

34 Wang, C., Liu, H. and Lee,S. (2010) The record-breaking cold temperatures during the winter of 2009/2010 in the Northern Hemisphere, Atmospheric Science Letters, Atmospheric Science. Letters 11: 161–168, 8 Jul http://www.aoml.noaa.gov/phod/docs/Wang_etal_ASL_2010.pdf [Full text, PDF]

35 Clark, S. (2010) Quiet sun puts Europe on ice, New Scientist, 4 May http://www.newscientist.com/article/mg20627564.800-quiet-sun-puts-europe-on-ice.html?full=true [Preview]

36 Lockwood, M. et al. (2010) Are cold winters in Europe associated with low solar activity?, Environmental Research Letters. 5, 024001 doi: 10.1088/1748-9326/5/2/024001, 14 April http://iopscience.iop.org/1748-9326/5/2/024001/ (Abstract); http://iopscience.iop.org/1748-9326/5/2/024001/pdf/1748-9326_5_2_024001.pdf [Full text, PDF]

37 Clark, S. (2010) Op. Cit.

38 Monbiot, G. (2010) Op. Cit.

39 Potsdam Institute for Climate Impact Research (2010) Global Warming could cool down temperatures in winter, Potsdam Institute Press Release, 16 Nov http://www.pik-potsdam.de/news/press-releases/global-warming-could-cool-down-temperatures-in-winter

40 Petoukhov, V., and V. A. Semenov (2010), A link between reduced Barents-Kara sea ice and cold winter extremes over northern continents, Journal of Geophysical Research, 115, D21111 doi:10.1029/2009JD013568 http://www.agu.org/pubs/crossref/2010/2009JD013568.shtml [Abstract]

41 Michael Bishop (2012) Cold winters caused by warmer summers, research suggests, EurekAlert (Institute of Physics),12 Jan http://www.eurekalert.org/pub_releases/2012-01/iop-cwc011112.php

42 Real Climate (2010) Op. Cit.

43 Mooney, C. (2011) Global Warming and Snowstorms: Communication Nightmare, or Opportunity?, desmogblog.com, 2 Mar http://www.desmogblog.com/global-warming-and-snowstorms-communication-opportunity-or-nightmare

44 Cook, J. (2010) Does record snowfall disprove global warming? skepticalscience.com, 9 Jul http://www.skepticalscience.com/Record-snowfall-disproves-global-warming.htm

45 Changnon, S. A., Changnon, D. and Karl, T. R. (2006) Temporal and Spatial Characteristics of Snowstorms in the Contiguous United States. Journal of Applied Meteorology and Climatology, 45, 1141–1155. doi: 10.1175/JAM2395.1 http://journals.ametsoc.org/doi/full/10.1175/JAM2395.1 [Abstract]; http://journals.ametsoc.org/doi/pdf/10.1175/JAM2395.1 [Full text, PDF]

46 Real Climate (2007) El Niño, Global Warming, and Anomalous U.S. Winter Warmth, RealClimate.org, 8 Jan http://www.realclimate.org/index.php/archives/2007/01/el-nino-global-warming-and-anomalous-winter-warmth/

47 Masters, J. (2010) Heavy snowfall in a warmer world, Dr Jeff Masters' Wunder Blog, 8 Feb http://www.wunderground.com/blog/JeffMasters/archive.html?year=2010&month=02

48 Ibid.

49 Brown, M. (2010) Op. Cit.

50 Lean, G (2010) UK snow: It's the weather, sceptics, The Telegraph (online), 8 Jan http://www.telegraph.co.uk/earth/earthcomment/geoffrey-lean/6952943/UK-snow-Its-the-weather-sceptics.html

51 Met Office (2008) Global warming goes on: Global average temperature anomaly 1975-2007, metoffice.gov.uk (Archive), 23 Sep http://webarchive.nationalarchives.gov.uk/+/http://www.metoffice.gov.uk/corporate/pressoffice/2008/pr20080923c.html

52 Hansen, J. (2010) 2009 temperatures: If It's That Warm, How Come It's So Damned Cold? realclimate.org, 17 Jan http://www.realclimate.org/index.php/archives/2010/01/2009-temperatures-by-jim-hansen/

53 Goddard, S. (2010), Lockwood demonstrates link between low sun and low temps, WattsUpWithThat.com, 14 April http://www.wattsupwiththat.com/2010/04/14/lockwood-demonstrates-link-between-low-sun-and-low-temps/

54 Lockwood, M. and Fröhlich, C. (2007) Recent oppositely directed trends in solar climate forcings and the global mean surface air temperature. Proceedings of the Royal Society A, 463, (2086), 2447-2460. doi:10.1098/rspa.2007.1880 http://www.atmos.washington.edu/2009Q1/111/Readings/Lockwood2007_Recent_oppositely_directed_trends.pdf [Full text; PDF]

55 Mail Online (2010), Op. Cit

56 Adam, D. (2010) Op. Cit.

57 Henson, R. (2010) Snow, ice and the bigger picture, guardian.co.uk, 6 Jan http://www.guardian.co.uk/commentisfree/cif-green/2010/jan/06/snow-ice-climate-change-arctic-oscillation

58 Rutherford, P. (2010) Huge snowfall caused by rare clash of weather events, BBC News (online), 2 Sep http://www.bbc.co.uk/news/science-environment-11152077

59 Met Office (2009b) Warming. Climate Change: The Facts p.10, metoffice.gov.uk, http://webarchive.nationalarchives.gov.uk/%2B/http://www.metoffice.gov.uk/climatechange/guide/downloads/quick_guide.pdf [PDF]

60 Skeptical Science (2011) It's a natural cycle, skepticalscience.com,11 Jan http://www.skepticalscience.com/global-warming-natural-cycle.htm

61 Lacis, A. (2010) CO_2: The Thermostat that Controls Earth's Temperature, NASA website, Oct http://www.giss.nasa.gov/research/briefs/lacis_01/

62 Henson, R. (2010) Op. Cit.

63 Myers, K. (2010) Recent global cool-down challenges validity of climate change models, Examiner, 1 Jan, http://www.examiner.com/seminole-county-environmental-news-in-orlando/recent-global-cool-down-challenges-validity-of-climate-change-models

64 Voiland, A. (2010) 2009: Second Warmest Year on Record; End of Warmest Decade, NASA website, 21 Jan http://www.nasa.gov/topics/earth/features/temp-analysis-2009.html

65 % of global surface area covered by UK = (UK surface area (in km2) / global surface area (in km2)) x 100 = (243,610 / 510,072,000) x 100 = (approx.) 0.05%

66 Met Office (2009a) Op. Cit.

SPECIES EXTINCTION

1 Barnosky, A. et al. (2011) Has the Earth's sixth mass extinction already arrived? Nature 471, 51-57, doi:10.1038/nature09678, 3 Mar http://www.biologia.ufrj.br/labs/labpoly/Barnosky2011.pdf [Full text, PDF]

2 Cook, J. (2010) Earth's five mass extinction events, skepticalscience.com, 15 Apr http://www.skepticalscience.com/Earths-five-mass-extinction-events.html

3 McCarthy, M. (2007) Animal Extinction - the greatest threat to mankind, The Independent, 30 Apr http://www.independent.co.uk/environment/animal-extinction--the-greatest-threat-to-mankind-397939.html

4 Kirchner, J. W. and Weil, A. (2000) Delayed biological recovery from extinctions throughout the fossil record, Nature 404, 177-180 doi:10.1038/35004564; 9 Mar http://www.nature.com/nature/journal/v404/n6774/abs/404177a0.html [Abstract]

5 Barnosky, A. et al. (2011) Op. Cit.

6 Marshall, M. (2011) Earth's oceans on course for mass extinction, New Scientist, 21 Jun http://www.newscientist.com/article/dn20595-earths-oceans-on-course-for-mass-extinction.html

7 Zimmer, C. (2010) An Ominous Warning on the Effects of Ocean Acidification, Yale Environment 360, 15 Feb http://e360.yale.edu/content/feature.msp?id=2241

8 Dulvy, N. K. et al, (2003) Extinction Vulnerability in marine populations, Fish and Fisheries 4, 25-64 http://www.botany.hawaii.edu/faculty/cunningham/CunninghamCourse/Dulvy_et_al_FF_03.pdf [Full text, PDF]

9 Walther, G.-R. et al. (2002) Ecological responses to recent climate change, Nature Vol 416, 390-395, 28 Mar http://eebweb.arizona.edu/courses/Ecol206/Walther%20et%20al%20Nature%202002.pdf [Full text, PDF]

10 'MarkR' (2012) 2011 Year in Review (part 2), skepticalscience.com, 10 Jan http://www.skepticalscience.com/news.php?n=1193

11 Nicolas, D. et al. (2011) Impact of global warming on European tidal estuaries: some evidence of northward migration of estuarine fish species, Regional Environmental Change, Vol. 11,No. 3, pp. 639- 649, Doi: 10.1007/s10113-010-0196-3 http://dx.doi.org/10.1007/s10113-010-0196-3 [Abstract]

12 Yamano, H., K. Sugihara, and K. Nomura (2011), Rapid poleward range expansion of tropical reef corals in response to rising sea surface temperatures, *Geophys. Res. Lett.*, *38*, L04601, doi:10.1029/2010GL046474.http://www.agu.org/pubs/crossref/2011/2010GL046474.shtml [Abstract]

13 Chen, I.C. et al. (2011) Rapid Range Shifts of Species Associated with High Levels of Climate Warming, Science, Vol. 333 no. 6045 pp. 1024-1026 DOI: 10.1126/science.1206432, 19 Aughttp://www.sciencemag.org/content/333/6045/1024.abstract [Abstract]

14 Natural Environmental Research Council (2011) Climate shifts could leave some species homeless, new research shows, NERC Press Release, 4 Nov http://www.nerc.ac.uk/press/releases/2011/27-climate-shifts.asp

15 Anisimov, O. et al. (2002) IPCC Technical Paper V: Climate Change and Biodiversity, [Eds. Gitay, H., Suarez, A. Watson, R. and Dokken, D. J.], WMO Intergovernmental Panel on Climate Change http://www.ipcc.ch/pdf/technical-papers/climate-changes-biodiversity-en.pdf [PDF]

16 Pereira, H. M. et al. (2010) Scenarios for Global Biodiversity in the 21st Century, Science 330, 1496; DOI: 10.1126/science.1196624, 10 Dec http://www.sciencemag.org/content/early/2010/10/26/science.1196624 [Abstract]http://www.ipicyt.edu.mx/storage-sipicyt/materialposgrado/Pereira%20et%20al_2010_Scenarios%20for%20Global%20Biodiversity%20in%20the%2021th%20Century.pdf [Full Text, PDF]

17 Fischlin, A. et al. (2007) Chapter 4: Ecosystems, their properties, goods, and services. In Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, [M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds.], Cambridge University Press, Cambridge, UK, 211-272. http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch4.html

18 Vié, J.C., Hilton-Taylor, C. and Stuart, S. N. [Eds.] (2008) Wildlife in a Changing World: An analysis of the 2008 IUCN Red List of Threatened Species, IUCN, Gland, Switzerland http://data.iucn.org/dbtw-wpd/edocs/RL-2009-001.pdf [PDF]

19 Pereira, H. M. et al. (2010) Op. Cit.

20 Butchart, S. H. M., A. J. Stattersfield and T. M. Brooks (2006) Going or gone: defining 'Possibly Extinct' species to give a truer picture of recent extinctions, Bulletin of the British Ornithologists' Club 126A http://www.birdlife.org/news/news/2006/06/possibly_extinct_paper.pdf [Full Text, PDF]

21 Jowit, J. (2010) Humans driving extinction faster than species can evolve, say experts, guardian.co.uk, 7 Mar http://www.guardian.co.uk/environment/2010/mar/07/extinction-species-evolve

22 Vié, J.C., Hilton-Taylor, C. and Stuart, S. N. [Eds.] (2008) Op. Cit.

23 Jowit, J. (2010) Op. Cit.

24 Vié, J.C., Hilton-Taylor, C. and Stuart, S. N. [Eds.] (2008) Op. Cit.

25 Dulvy, N. K. et al, (2003) Op. Cit.

26 Gilpin, M. E., and M. E. Soulé (1986) Minimum viable populations: processes of species extinction. In M. E. Soule, (Ed.]. Conservation biology: The science of scarcity and diversity. Sinauer, Sunderland, MA., p.19-34 http://md1.csa.com/partners/viewrecord.php?requester=gs&collection=ENV&recid=1450544&q=Minimum+viable+populations%3A+processes+of+species+extinction&uid=791132052&setcookie=yes

27 Pereira, H. M. et al. (2010) Op. Cit.

28 Pimm, S. L., G. J. Russell, J. L. Gittleman and T. M. Brooks (1995) The future of biodiversity. Science 269:347–350 http://www.sciencemag.org/content/269/5222/347 [Abstract]

29 Dulvy, N. K. et al, (2003) Op. Cit.

30 Ibid.

31 Pounds, J. A., Fogden, M. L. P. and Campbell, J. H. (1999) Biological response to climate change on a tropical mountain. Nature 398, 611–615 http://www.cct.or.cr/publicaciones/Pounds-Fogden-Campbell-Nature-398-1999.pdf [Full Text, PDF]

32 Dulvy, N. K. and Forrest, R. E. (2010) Chapter 17: Life Histories, Population Dynamics, and Extinction Risks in Chondrichthyans. In Sharks and Their Relatives II: Biodiversity, Adaptive Physiology, and Conservation, Carrier, J. C., Musick, J. A. and Heithaus, M. R. [Eds.], CRC Press, 9 Mar http://www.crcpress.com/product/isbn/9781420080476 [Summary]

33 Foden, W. et al. (2008) Species susceptibility to climate change impacts. In: The 2008 Review of The IUCN Red List of Threatened Species, J.-C. Vié, C. Hilton-Taylor and S.N. Stuart (Eds).. IUCN Gland, Switzerland http://cmsdata.iucn.org/downloads/species_susceptibility_to_climate_change_impacts_1.pdf [PDF]

34 Malcolm, J. R. et al. (2006), Global Warming and Extinctions of Endemic Species from Biodiversity Hotspots. Conservation Biology, 20: 538–548. doi: 10.1111/j.1523-1739.2006.00364.x http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2006.00364.x/full http://ddr.nal.usda.gov/bitstream/10113/28647/1/IND44194501.pdf [Full Text, PDF]

35 Anisimov, O. et al. (2002) Op. Cit.

36 Pounds, J. A. et al. (2005) Widespread amphibian extinctions from epidemic disease driven by global warming, Nature 439, 161-167 doi:10.1038/nature04246, 21 Sep http://www.nature.com/nature/journal/v439/n7073/full/nature04246.html [Preview]

37 Anisimov, O. et al. (2002) Op. Cit.

38 Thuiller, W. et al. (2004) Biodiversity Conservation: Uncertainty in predictions of extinction risk, Nature (Brief Communications), 430, doi:10.1038/nature02716 , 1 Jul http://www.nature.com/nature/journal/v430/n6995/full/nature02716.html [Preview]

39 Foden, W. et al. (2008) Op. Cit.

40 Buckley, L. B. and Roughgarden, J. (2004) Biodiversity Conservation: Effects of changes in climate and land use, Nature (Brief Communication), 430, doi:10.1038/nature02717, 1 Jul http://www.nature.com/nature/journal/v430/n6995/full/nature02717.html [Preview]

41 Williams S. E. et al. (2008) Towards an integrated framework for assessing the vulnerability of species to climate change. Public Library of Science, Biology 6(12): e325. doi:10.1371/journal.pbio.0060325 http://www.plosbiology.org/article/info%3Adoi%2F10.1371%2Fjournal.pbio.0060325 [Full text]

42 International Union for the Conservation of Nature Species Survival Commission (undated) Climate Change and Species, IUCN http://www.iucn.org/about/work/programmes/species/our_work/climate_change_and_species/

43 Foden, W. et al. (2008) Op. Cit.

44 Williams S. E. et al. (2008) Op. Cit.

45 Thomas, C. D. et al. (2004) Extinction risk from climate change, Nature Vol. 427 p.145 , 8 Jan http://eprints.whiterose.ac.uk/83/1/thomascd1.pdf [Full Text, PDF]

46 Thuiller, W. et al. (2004) Op. Cit.

47 Sinervo, B. et al. (2010) Erosion of lizard diversity by climate change and altered thermal niches. Science;328(5980):894-899. http://www.sciencemag.org/content/328/5980/894.abstract [Abstract]

48 Anisimov, O. et al. (2002) Op. Cit.

49 Malcolm, J. R. et al. (2006) Op. Cit.

50 McCarthy, M. (2007) Op. Cit.

51 Anisimov, O. et al. (2002) Op. Cit.

52 Jetz, W., Wilcove, D. S. and Dobson, A.P. (2007) Projected impacts of climate and land-use change on the global diversity of birds. Public Library of Science, Biology 5(6): e157. doi:10.1371/journal.pbio.0050157 http://www.plosbiology.org/article/info:doi/10.1371/journal.pbio.0050157 [Full text]

53 Pereira, H. M. et al. (2010) Op. Cit.

54 Editorial (2011) Biodiversity on the brink, Nature Climate Change 1, 275 doi:10.1038/nclimate1223, 26 Aug http://www.nature.com/nclimate/journal/v1/n6/full/nclimate1223.html

55 Ibid.

56 Maclean, I. M. D. and Wilson, R. J. (2011) Recent ecological responses to climate change support predictions of high extinction risk. Proceedings of the National Academy of Sciences, DOI: 10.1073/pnas.1017352108 http://www.pnas.org/content/108/30/12337 [Abstract]

57 Thomas, C. D. et al. (2004) Op. Cit.

58 Watts, A. (2011) Amphibian decline – climate change not the single culprit, wattsupwiththat.com, 25 Apr http://wattsupwiththat.com/2011/04/25/amphibian-decline-climate-change-not-the-single-culprit/

59 Watts, A. (2011) Climate change hype – it's turtles all the way down under, wattsupwiththat.com, 3 Jul http://wattsupwiththat.com/2011/07/03/climate-change-its-turtles-all-the-way-down-under/

60 Watts, A. (2010) What frog science can teach us about global warming, wattsupwiththat.com, 13 Dec http://wattsupwiththat.com/2010/12/13/what-frogs-can-teach-us-about-global-warming/

61 Maclean, I. M. D. and Wilson, R. J. (2011) Recent ecological responses to climate change support predictions of high extinction risk. Proceedings of the National Academy of Sciences, DOI: 10.1073/pnas.1017352108 http://www.pnas.org/content/108/30/12337 [Abstract]

62 Thomas, C. D. et al. (2004) Op. Cit.

63 Anisimov, O. et al. (2002) Op. Cit.

64 Foster, P. (2011) Peter Foster: Norman Myers' Sinking Ark, The Financial Post (re-posted by the Global Warming Policy Foundation), 15 Jun http://thegwpf.org/opinion-pros-a-cons/3212-peter-fosternorman-myers-sinking-ark.html

65 Watts, A. (2011) IPCC's species extinction hype "fundamentally flawed", wattsupwiththat.com, 19 May http://wattsupwiththat.com/2011/05/19/species-extinction-hype-fundamentally-flawed/

66 Eschenbach, W. (2011) Common Sense Added to Endangered Species List, wattsupwiththat.com, 1 Jun http://wattsupwiththat.com/2011/06/01/common-sense-added-to-endangered-species-list/

67 AFP (2011) IPCC Wrong Again: Species Loss Far Less Severe Than Feared, The Global Warming Policy Foundation (thegwpf.org), 18 May http://thegwpf.org/the-observatory/3035-ipcc-debunked-species-loss-far-less-severe-than-feared.html

68 Jowit, J. (2010) Op. Cit.

69 Baillie, J. E. M., Hilton-Taylor, C. and Stuart, S. N. [Eds.] (2004) 2004 IUCN Red List of Threatened Species. A Global Species Assessment. IUCN, Gland, Switzerland and Cambridge, UK. xxiv p.191, International Union for the Conservation of Nature http://data.iucn.org/dbtw-wpd/edocs/RL-2004-001.pdf [PDF]

70 Romm, J. (2011) Global Warming May Cause Far Higher Extinction of Biodiversity, ClimateProgress.org, 20 Sep http://thinkprogress.org/romm/2011/09/20/323639/global-warming-extinction-of-biodiversity/

71 Anisimov, O. et al. (2002) Op. Cit.

72 Eschenbach, W. (2011) Op. Cit.

73 Morano, M. (2011) Greenpeace Co-Founder Slams Species Extinction Scare Study as proof of how 'peer-review process has become corrupted' – Study 'greatly underestimate the rate new species can evolve', Climate Depot, 4 Mar http://climatedepot.com/a/9996/Greenpeace-CoFounder-Slams-Species-Extinction-Scare-Study-as-proof-of-how-peerreview-process-has-become-corrupted-ndash-Study-greatly-underestimate-the-rate-new-species-can-evolve

74 Jowit, J. (2010) Op. Cit.

75 Vié, J.C., Hilton-Taylor, C. and Stuart, S. N. [Eds.] (2008) Op. Cit.

76 World Climate Report (2004) Disappearing Act, 24 May http://www.worldclimatereport.com/index.php/2004/05/24/disappearing-act/

77 Van Loon, A. J. (2003) The dubious role of man in a questionable mass extinction. Earth Science Reviews, 62, 177-176. http://geoinfo.amu.edu.pl/wngig/ig/UAM_Ing/VanLoon/EarthSci-Rev_62(2003).pdf [Full Text, PDF]

78 Pimm, S. L., G. J. Russell, J. L. Gittleman and T. M. Brooks (1995) Op. Cit.

79 Parmesan, C. (2006) Ecological and Evolutionary Responses to Recent Climate Change, Annual Review of Ecology, Evolution, and Systematics Vol. 37: 637-669 DOI: 10.1146/annurev.ecolsys.37.091305.110100, Dec http://www.annualreviews.org/doi/abs/10.1146/annurev.ecolsys.37.091305.110100 [Abstract]

80 Watts, A. (2010) Op. Cit.

81 McCarthy, M. (2007) Op. Cit.

82 Pimm, S. L., G. J. Russell, J. L. Gittleman and T. M. Brooks (1995) Op. Cit.

83 Marshall, M. (2011) Op. Cit.

84 Jowit, J. (2010) Op. Cit.

85 Kirby, A. (2004) Climate risk 'to million species', BBC News Online, 7 Jan http://news.bbc.co.uk/1/hi/sci/tech/3375447.stm

86 Brahic, C. (2008) Map reveals species most at risk from climate change, New Scientist, 8 Oct http://www.newscientist.com/article/dn14899-map-reveals-species-most-at-risk-from-climate-change.html?full=true

87 Kirby, A. (2004) Op. Cit.

THE SEASONS

1 The Guardian (2005) Wild at Heart, guardian.co.uk, 16 Jun http://www.guardian.co.uk/media/2005/jun/16/realitytv.environment

2 Dowell, B. (2009) TV ratings: Springwatch return watched by 3.9m, guardian.co.uk, 26 May http://www.guardian.co.uk/media/2009/may/26/springwatch-tv-ratings

3 Amano, T. Smithers, R. J. Sparks, T.H. and Sutherland, W.J. (2010) A 250-year index of first flowering dates and its response to temperature changes, Proceedings of the Royal Society B 277, 2451–2457 doi:10.1098/rspb.2010.0291 http://rspb.royalsocietypublishing.org/content/early/2010/04/01/rspb.2010.0291.short?rss=1&ssource=mfc

4 Sparks, T. H. and Carey, P. D. (1995) The responses of species to climate over two centuries: an analysis of the Marsham phenological record, 1736-1947, Journal of Ecology 83 (2): 321–329. doi:10.2307/2261570 http://www.jstor.org/pss/2261570 (Abstract/Preview)

5 Woodland Trust (undated) For the love of trees. Recording nature's calendar for 62 YEARS!, Woodland Trust Website http://www.woodlandtrust.org.uk/en/take-part/measure-climate-change/Pages/for-the-love-of-trees.aspx

6 Yahoo Answers (undated) What percentage of the Earth's land is above the equator?, yahoo.co.uk http://au.answers.yahoo.com/question/index?qid=20100627214258AAFSdoj

7 kgb answers (undated) What percentage of the world's land mass is in the northern hemisphere? http://www.kgbanswers.co.uk/what-percentage-of-the-worlds-land-mass-is-in-the-northern-hemisphere/3280201

8 Chambers, L. E (2009) Evidence of climate related shifts in Australian phenology 18th, paper presented at World IMACS / MODSIM Congress, Cairns, Australia, 13-17 Jul http://www.mssanz.org.au/modsim09/G2/chambers.pdf [Full text, PDF]

9 Rosenzweig, C. et al. (2007) Chapter 1: Assessment of observed changes and responses in natural and managed systems. In Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 79-131. Section 1.3.5.1 Changes in phenology http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch1s1-3-5-1.html

10 Thackeray, S. J. et al. (2010) Trophic level asynchrony in rates of phenological change for marine, freshwater and terrestrial environments, Global Change Biology, doi: 10.1111/j.1365-2486.2010.02165.x http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2010.02165.x/full [Full text]

11 Parmesan, C. and Yohe, G. (2002) A globally coherent fingerprint of climate change impacts across natural systems, Nature 421, 37-42 doi:10.1038/nature01286; 2 Jan http://www.nature.com/nature/journal/v421/n6918/abs/nature01286.html [Abstract]

12 Root, T. L. et al. (2003) Fingerprints of global warming on wild animals and plants. Nature 421(6918):57-60., 2 Jan http://www.ncbi.nlm.nih.gov/pubmed/12511952 [Abstract]

13 Menzel, A. et al. (2006) European Phenological Response To Climate Change Matches The Warming Pattern, Global Change Biology 12, 1969–1976, Doi: 10.1111/J.1365-2486.2006.01193.X http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2006.01193.x/abstract [Abstract]

14 Rosenzweig, C. et al. (2007) Op. Cit.

15 Parmesan, C. (2007) Influences of species, latitudes and methodologies on estimates of phenological response to global warming, Global Change Biology 13, 1860–1872, doi: 10.1111/j.1365-2486.2007.01404.x http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2007.01404.x/abstract [Abstract]

16 Thackeray, S. J. et al. (2010) Op. Cit.

17 Parmesan, C. (2007) Op. Cit.

18 Thackeray, S. J. et al. (2010) Op. Cit.

19 Centre for Ecology and Hydrology (2011) Wildlife responds increasingly rapidly to climate change, 18 Aug http://www.ceh.ac.uk/news/news_archive/SpeciesshiftpaperScienceChen-etal_2011_51.html

20 Menzel A. et al. (2006) Op. Cit.

21 Parmesan, C. (2007) Op. Cit.

22 Parmesan, C. and Yohe, G. (2002) Op. Cit.

23 Sherry R. A. et al. (2007) Divergence of reproductive phenology under climate warming, Proceedings of the National Academy of Science USA.; 104(1): 198–202. doi: 10.1073/pnas.0605642104., 2 Jan http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1713188/ [Full text]

24 Linderholm, H. W. (2006) Growing season changes in the last century, Agricultural and Forest Meteorology 137 1–14 http://research.eeescience.utoledo.edu/lees/papers_PDF/Linderholm_2006_AFM.pdf [Full text, PDF]

25 Rosenzweig, C. et al. (2007) Op. Cit.

26 Ibid.

27 Keeling, C. D., J. F. S. Chin and T. P. Whorf, (1996) Increased activity of northern vegetation inferred from atmospheric CO_2 measurements. Nature, 382, 146-149 http://www.nature.com/nature/journal/v382/n6587/abs/382146a0.html [Abstract]

28 "The phasing of the cycle … hasn't changed much since 1990" - Keeling, R. (2011) Personal correspondence, May 5

29 NASA (undated), Feeling the Sting of Climate Change, youtube.com http://www.youtube.com/watch?v=r1LXrfnZmgE [Video]

30 Zimmer, C. (2007) Greenup of the Planet Is Not Black-and-White, wired.com 11 Sep http://www.wired.com/science/planetearth/news/2007/11/dissectionanddissent_1109

31 Lucht, W. et al. (2002) Climatic control of the high-latitude vegetation greening trend and Pinatubo effect. Science, 296, 1687-1689 http://www.sciencemag.org/content/296/5573/1687.abstract [Abstract]

32 Zhou, L. et al. (2001) Variations in northern vegetation activity inferred from satellite data of vegetation index during 1981 to 1999, Journal of Geophysical Research, 106, 20,069–20,083, doi:10.1029/2000JD000115. http://www.agu.org/journals/ABS/2001/2000JD000115.shtml [Abstract]

33 Miller, J. B. (2008) Carbon Cycle: Sources, sinks and seasons, Nature News and Views Vol 451, 26-27 doi:10.1038/451026a, 3 Jan http://www.nature.com/nature/journal/v451/n7174/full/451026a.html [Preview]

34 Both, C. et al. (2006) Climate change and population declines in a long-distance migratory bird. Nature 441: 81–83 http://www.nature.com/nature/journal/v441/n7089/abs/nature04539.html [Abstract]

35 Sparks, T. (2010) Personal communication, 4 Oct

36 Linderholm, H. W. (2006) Op. Cit.

37 Rosenzweig, C. et al. (2007) Op. Cit.

38 Ibid.

39 Booker, C. (2010) Springwatch finds the BBC in cloud cuckoo land, The Telegraph (Online), 22 May http://www.telegraph.co.uk/comment/columnists/christopherbooker/7754128/Springwatch-finds-the-BBC-in-cloud-cuckoo-land.html

40 Worstall, T. (2010) Saving the Earth need not cost us the Earth, express.co.uk, 4 Feb http://www.express.co.uk/posts/view/160147/Saving-the-earth-need-not-cost-us-the-earth

41 Goddard, S. (2010) Global Warming and "The Early Spring" Part II. WattsUpWithThat.com, 6 April. http://wattsupwiththat.com/2010/04/06/global-warming-and-%E2%80%9Cthe-early-spring%E2%80%9D-part-ii/

42 Schmidt, G and Rahmstorf, S. (2008) Uncertainty, noise and the art of model-data comparison, RealClimate.org, 11 Jan http://www.realclimate.org/index.php/archives/2008/01/uncertainty-noise-and-the-art-of-model-data-comparison/

43 Rosenzweig, C. et al. (2007) Op. Cit.

44 Goklany, I.M. (2010) Caveats Regarding Dr Phil Jones' Phenological Arguments for Global Warming, WattsUpWithThat.com, 18 Feb http://wattsupwiththat.com/2010/02/18/caveats-regarding-dr-phil-jones%E2%80%99-phenological-arguments-for-global-warming/

45 Idso, D. C. et al. (2000) Ultra-enhanced spring branch growth in CO_2-enriched trees: can it alter the phase of the atmosphere's seasonal CO_2 cycle?, Environmental and Experimental Botany, Volume 43, Issue 2, pp. 91-100, ISSN 0098-8472, DOI: 10.1016/S0098-8472(99)00054-4. April 2000 http://www.sciencedirect.com/science/article/B6T66-3YJYCS7-1/2/bf4de5fe141770f6015bd5821a7e38e1 [Abstract]

46 Goklany, I.M. (2010) Op. Cit.

47 Pielke, R. Sr. (2009) New Paper In Press "Intercomparison, Interpretation, and Assessment Of Spring Phenology In North America Estimated From Remote Sensing For 1982 To 2006" By White et al.2009, Climate Science: Roger Pielke Sr., 30 Mar http://pielkeclimatesci.wordpress.com/2009/03/30/new-paper-in-press-intercomparison-interpretation-and-assessment-of-spring-phenology-in-north-america-estimated-from-remote-sensing-for-1982-to-2006-by-white-et-al2009/

48 Zhou, L. at al. (2001) Op. Cit.

49 White et al. (2009) Intercomparison, interpretation, and assessment of spring phenology in North America estimated from remote sensing for 1982–2006, Global Change Biology Doi: 10.1111/J.1365-2486.2009.01910.X http://tenaya.ucsd.edu/~dettinge/gcb_white_2009.pdf [Full text, PDF]

50 Ibid.

51 Cook, J. (2010) How is climate change affecting the advance of spring?, skepticalscience.com, 9 Jul http://www.skepticalscience.com/advancing-spring-global-warming.htm

52 Amano, T. Smithers, R. J. Sparks, T. H. Sutherland, W. J. (2010) Op. Cit.

53 Studer, S et al. (2007) A comparative study of satellite and ground-based phenology, International Journal of Biometeorlology 51:405–414 DOI 10.1007/s00484-006-0080-5 http://www.ncbi.nlm.nih.gov/pubmed/17235537 [Abstract]

54 Derbyshire, D. (2009) Back in season: Freezing winter means spring is on schedule - for the first time in a decade, Mail Online, 13 Mar http://www.dailymail.co.uk/news/article-1161828/Back-season-Freezing-winter-means-spring-schedule--time-decade.html

55 Stokes, P. (2009) Spring to emerge earlier than ever, The Telegraph (online), 14 Mar http://www.telegraph.co.uk/topics/weather/4987197/Spring-to-emerge-earlier-than-ever.html

56 Brown, J. (2006) Animals and plants 'prove' that spring arrives earlier every year, The Independent (online), 26 Aug http://www.independent.co.uk/environment/animals-and-plants-prove-that-spring-arrives-earlier-every-year-413374.html

57 BBC (2006) Climate changes shift springtime, BBC News Online, 25 Aug http://news.bbc.co.uk/1/hi/sci/tech/5279390.stm

58 Hollingshead, I. (2010) Chris Packham on the return of Springwatch, The Telegraph (online), 14 May http://www.telegraph.co.uk/culture/tvandradio/bbc/7724722/Chris-Packham-on-the-return-of-Springwatch.html

WILDFIRES

1 Flannigan, M. D. et al. (2009) Implications of changing climate for global wildland fire. International Journal of Wildland Fire,18, 483-507 http://cfs.nrcan.gc.ca/publications/?id=29889

2 Gilbert, G. (2010) Russia counts environmental cost of wildfires, Nature News doi:10.1038/news.2010.404, 12 Aug http://www.nature.com/news/2010/100812/full/news.2010.404.html

3 Romm, J. (2009) Global warming, California, and wildfires, grist.org, 1 Sep http://www.grist.org/article/2009-09-01-global-warming-california-and-wildfires

4 Black, R. (2007) Fires: Counting the eco-cost, BBC News Online, 28 Aug http://news.bbc.co.uk/1/hi/sci/tech/6966822.stm

5 Flannigan, M.D. et al. (2009) Op. Cit.

6 McKenzie, S. (2011) Wildfires 'a threat' to ecology and soil quality, BBC News (Highlands and Islands), 3 May http://www.bbc.co.uk/news/uk-scotland-highlands-islands-13265776

7 Atwell, B. J., Kriedemann, P. E. and Turnbull, C. G. N. (Eds.) (1999) Plants in Action: 19.2.1 Plant responses to fire and smoke, Australian Society of Plant Scientists, New Zealand Society of Plant Biologists, and New Zealand Institute of Agricultural and Horticultural Science, http://sci-wikibook.bacs.uq.edu.au/?q=content/19-2-1-plant-responses-re-and-smoke

8 Krawchuk, M.A. et al. (2009) Global Pyrogeography: the Current and Future Distribution of Wildfire. Public Library of Science ONE 4(4): e5102. doi:10.1371/journal.pone.0005102, Apr http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/29421.pdf [Full text, PDF]

9 Nikiforuk, A. (2011) More and More, the Boreal Will Burn, TheTyee.ca, May 20 http://thetyee.ca/News/2011/05/20/Boreal-WillBurn/

10 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Changing Climates, Earth Systems and Society, International Year of Planet Earth, Chapter 21: Fire in the Earth System, Springer Science+Business Media B.V., DOI 10.1007/978-90-481-8716-4_3 https://springerlink3.metapress.com/content/t13341464245456u/resource-secured/?target=fulltext.pdf&sid=ahyol445deqh5gzagsdhko45&sh=www.springerlink.com

11 Bowman, M. J. S. et al. (2009) Fire in the Earth System, Science Vol. 324 , 24 Apr http://www.sciencemag.org/content/324/5926/481.abstract [Abstract]

12 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

13 Bowman, M. J. S. et al. (2009) Op. Cit.

14 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

15 Committee on Stabilization Targets for Atmospheric Greenhouse Gas Concentrations; National Research Council (2011) Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia. Washington, DC: National Academies Press. http://www.nap.edu/catalog.php?record_id=12877 [Full text]

16 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

17 Committee on Stabilization Targets for Atmospheric Greenhouse Gas Concentrations; National Research Council (2011) Op. Cit.

18 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

19 Flannigan, M. D. et al. (2009) Op. Cit.

20 Bowman, M. J. S. et al. (2009) Op. Cit.

21 Flannigan, M. D. et al. (2009) Op. Cit.

22 Westerling, A. L., Hidalgo, H. G., Cayan, D. R. and Swetnam, T. W. (2006) Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity, Science Vol. 313 no. 5789 pp. 940-943 DOI: 10.1126/science.1128834, 18 Aug http://www.sciencemag.org/content/313/5789/940.full [Full text]

23 Flannigan, M. D. et al. (2009) Op. Cit.

24 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

25 Flannigan, M. D. et al. (2009) Op. Cit.

26 Bowman, M. J. S. et al. (2009) Op. Cit.

27 Ibid.

28 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

29 Arndt, D.S., Baringer, M.O. and Johnson, M.R. (Eds.) (2010) State of the Climate in 2009 Bulletin of the American Meteorological Society Vol. 91, No. 7, July http://www1.ncdc.noaa.gov/pub/data/cmb/bams-sotc/climate-assessment-2009-lo-rez.pdf [PDF]

30 Lavorel, S., Flannigan, M. D., Lambin, E. F. and Scholes, M. C. (2007) Vulnerability of land systems to fire: Interactions among humans, climate, the atmosphere, and ecosystems, Mitigation and Adaptation Strategies for Global Change (2007) 12:33–53 DOI 10.1007/s11027-006-9046-5, Jan http://www.firelab.utoronto.ca/pubs/2007%20Lavorel%20et%20al.%20Miti%20and%20Adap%20-%20Vulnerability%20of%20land%20systems.pdf [PDF]

31 Bowman, M. J. S. et al. (2009) Op. Cit.

32 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

33 Bowman, M. J. S. et al. (2009) Op. Cit.

34 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

35 Ibid.

36 Williams, R. J. and Bradstock, R. A. (2008) Large fires and their ecological consequences: introduction to the special issue, International Journal of Wildland Fire 17(6) 685–687 doi:10.1071/WF07155, 12 Dec http://www.publish.csiro.au/view/journals/dsp_journal_fulltext.cfm?nid=114&f=WF07155

37 Flannigan, M. D. et al. (2009) Op. Cit.

38 Heffernan, O. (2010) Forestry: Fuelling the fire, Nature Climate Change doi:10.1038/nclimate1007, 9 Nov http://www.nature.com/nclimate/2010/101109/full/nclimate1007.html [Preview]

39 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

40 Gillett, N. P., A. J. Weaver, F. W. Zwiers, and M. D. Flannigan (2004) Detecting the effect of climate change on Canadian forest fires, Geophysical Research Letters, 31, L18211, doi:10.1029/2004GL020876., 29 Jun http://firelab.forestry.utoronto.ca/pubs/2004%20Gillett%20et%20al.%20Geophys%20Res%20Letters%20-%20Detecting%20the%20effect.pdf [PDF]

41 Kasischke, E.S. and M.R. Turetsky (2006) Recent changes in the fire regime across the North American boreal region. Geophysical Research Letters 33, 10.1029/2006GL025677 http://www.agu.org/pubs/crossref/2006/2006GL025677.shtml [Abstract]

42 Soja, A. J. et al. (2007) Climate-induced boreal forest change: Predictions versus current observations. Global and Planetary Change, Special NEESPI Issue, 56: 274–296, doi:10.1016/j.gloplacha.2006.07.028. http://www.agci.org/dB/PDFs/07S2_ASoja_presessiondoc.pdf [PDF]

43 Running, S. W. (2006) Is Global Warming Causing More, Larger Wildfires?, Science Vol. 313 no. 5789 pp. 927-928 DOI: 10.1126/science.1130370, 18 Aug http://secure.ntsg.umt.edu/publications/2006/Run06/SRunningScienceAug18.pdf [PDF]

44 Westerling, A. L., Hidalgo, H. G., Cayan, D. R. and Swetnam, T. W. (2006) Op. Cit.

45 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

46 Ibid.

47 Bowman, David M. J. S. et al. (2009) Op. Cit.

48 Flannigan, M.D. et al. (2009) Op. Cit.

49 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

50 Ibid.

51 Flannigan, M.D. et al. (2009) Op. Cit.

52 Ibid.

53 Stocks, B. J. et al. (1998) Climate change and forest fire potential in Russian and Canadian boreal forests. Climatic Change, 38: 1-13 http://www.springerlink.com/content/wu3172g220vu6j26/ [Abstract]

54 Committee on Stabilization Targets for Atmospheric Greenhouse Gas Concentrations; National Research Council (2011) Op. Cit.

55 Williams, R. J. and Bradstock, R. A. (2008) Op. Cit.

56 Committee on Stabilization Targets for Atmospheric Greenhouse Gas Concentrations; National Research Council (2011) Op. Cit.

57 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

58 Nikiforuk, A. (2011) Op. Cit.

59 Allison, I. et al. (2009) The Copenhagen Diagnosis, 2009: Updating the World on the Latest Climate Science., The University of New South Wales Climate Change Research Centre (CCRC), Sydney, Australia, p.60 http://www.ccrc.unsw.edu.au/Copenhagen/Copenhagen_Diagnosis_LOW.pdf [PDF]

60 Lavorel, S., Flannigan, M. D., Lambin, E. F. and Scholes, M. C. (2007) Op. Cit.

61 Zinck, R. D., Pascual, M. and Grimm, V. (2011) Understanding Shifts in Wildfire Regimes as Emergent Threshold Phenomena., The American Naturalist , Vol. 178, No. 6, pp. E149-E161,The University of Chicago Press for The American Society of Naturalists, DOI: 10.1086/662675 http://www.jstor.org/stable/10.1086/662675 [Full text]

62 Hartz, J. (2011) Climate change threshold nears for rapid increase in wildfires in Canada, skepticalscience.com, 26 Dec http://www.skepticalscience.com/news.php?n=1176

63 Watts, A. (2009a) More rubbish from 60 Minutes tonight. "The Age of Megafires", wattsupwiththat.com, 6 Sep http://wattsupwiththat.com/2009/09/06/more-rubbish-from-60-minutes-tonight-the-age-of-megafires/

64 Black, R. (2007) Op. Cit.

65 Flannigan, M.D. et al. (2009) Op. Cit.

66 Lavorel, S., Flannigan, M. D., Lambin, E. F. and Scholes, M. C. (2007) Op. Cit

67 Delingpole, J. (2010) Big, hot, shiny orb in sky caused by 'climate change' says UK Met Office, Telegraph Online, 10 Aug http://blogs.telegraph.co.uk/news/jamesdelingpole/100050200/big-hot-shiny-orb-in-sky-caused-by-climate-change-says-uk-met-office/

68 World Climate Report (2007) Wildfires: The Results of Cyclic Oceanic Variations or Global Warming?, 27 Mar http://www.worldclimatereport.com/index.php/2007/03/27/wildfires-the-results-of-cyclic-oceanic-variations-or-global-warming/

69 Watts, A. (2009b) California Wildfires caused by cooler Pacific, La Niña, wattsupwiththat.com, 3 Sep http://wattsupwiththat.com/2009/09/03/california-wildfires-caused-by-cooler-pacific-la-nina/

70 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

71 Williams, R. J. and Bradstock, R. A. (2008) Op. Cit.

72 Flannigan, M.D. et al. (2009) Op. Cit.

73 Committee on Stabilization Targets for Atmospheric Greenhouse Gas Concentrations; National Research Council (2011) Op. Cit.

74 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

75 Williams, R. J. and Bradstock, R. A. (2008) Op. Cit.

76 World Climate Report (2007) Torching the Forest Fire Myth, 25 Apr http://www.worldclimatereport.com/index.php/2007/04/25/torching-the-forest-fire-myth/

77 Watts, A. (2008) California Wildfires: not global warming, but "business as usual" for nature, wattsupwiththat.com, 8 Jul http://wattsupwiththat.com/2008/07/08/california-wildfires-not-global-warming-but-business-as-usual-for-nature/

78 Flannigan, M.D. et al. (2009) Op. Cit.

79 Heffernan, O. (2010) Op. Cit.

80 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

81 Gillett, N. P., A. J. Weaver, F. W. Zwiers, and M. D. Flannigan (2004) Op. Cit.

82 Kasischke, E.S., and M.R. Turetsky (2006) Op. Cit.

83 Running, S. W. (2006) Op. Cit.

84 Heffernan, O. (2010) Op. Cit.

85 Flannigan, M.D. et al. (2009) Op. Cit.

86 World Climate Report (2010) Raining On Boreal Forest Fires, Global Warming Policy Foundation, 15 Jun http://thegwpf.org/the-observatory/1101-raining-on-boreal-forest-fires.html

87 World Climate Report (2007) Global View of Wildfires, 2 May http://www.worldclimatereport.com/index.php/2007/05/02/global-view-of-wildfires/

88 Gillett, N. P., A. J. Weaver, F. W. Zwiers, and M. D. Flannigan (2004) Op. Cit.

89 Kasischke, E.S. and M.R. Turetsky (2006) Op. Cit.

90 Running, S. W. (2006) Op. Cit.

91 Westerling, A. L., Hidalgo, H. G., Cayan, D. R. and Swetnam, T. W. (2006) Op. Cit.

92 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

93 Committee on Stabilization Targets for Atmospheric Greenhouse Gas Concentrations; National Research Council (2011) Op. Cit.

94 Lacey, M. (2011) As Arizona Fire Rages, Officials Seek Its Cause, New York Times, 11 Jun http://www.nytimes.com/2011/06/12/us/12wildfire.html?_r=2&ref=us

95 Watts, A. (2009a) Op. Cit.

96 Watts, A. (2009b) Op. Cit.

97 Flannigan, M.D. et al. (2009) Op. Cit.

98 Gillett, N. P., A. J. Weaver, F. W. Zwiers, and M. D. Flannigan (2004) Op. Cit.

99 Running, S. W. (2006) Op. Cit.

100 Westerling, A. L., Hidalgo, H. G., Cayan, D. R. and Swetnam, T. W. (2006) Op. Cit.

101 Harrison, S. P., Marlon, J. R. and Bartlein, P. J. (2010) Op. Cit.

102 Huck, P. (2008) Changing Californian climate 'will make wildfires worse', guardian.co.uk, 19 Nov http://www.guardian.co.uk/environment/2008/nov/19/climatechange-usa?INTCMP=SRCH

103 Holtum, D. (2007) Fires, forests and climate, New Scientist, 24 Feb http://www.newscientist.com/article/mg19325921.300-fires-forests-and-climate.html [Preview]

104 O'hanlon, L. (1995) Fighting fire with fire, New Scientist, 15 Jul http://www.newscientist.com/article/mg14719864.000-fighting-fire-with-fire.html?full=true [Preview]

105 Doward, J. (2008) Wildfire risk to tinder-dry rural Britain, guardian.co.uk, 10 Aug http://www.guardian.co.uk/environment/2008/aug/10/endangeredhabitats.climatechange?INTCMP=SRCH

All URL links last checked 13-16 Jan 2012.

PHOTO CREDITS

Temperature: NASA.

Arctic Sea Ice: NASA.

Drought: Photo taken on June 20, 2010 in Merthyr Tydfil, Wales by Stuart Herbert.

El Niño: NASA/JPL-NOAA.

Flooding: Photo taken on July 21, 2007 in Witney, England by user 'dachalan'.

Heatwaves: Image captured on July 18, 2006 by the European Space Agency's Advanced Along-Track Scanning Radiometer.

Snow & Cold: NASA, MODIS Rapid Response Team

Species Extinction: Photo taken on December 19, 2009 in Southland, NZ by Martin Sharman.

The Seasons: Photo taken on July 23, 2011 in Lake Forest, USA by user 'JanetandPhil'.

Wildfires: Photo taken on August 29, 2009 in the Mojave Desert, USA by Rennett Stowe.

With many thanks.

NOTES

MORE ON PIRC

PIRC is an independent charity working towards a more sustainable society. We recognise that big problems cannot be tackled in isolation - a more sustainable society is also a more equal and democratic one. Through research and advocacy, we press for the structural changes necessary to bring this about.

Other PIRC projects therefore include

COMMON CAUSE

The world currently faces some big, serious and growing problems - from global poverty, to human rights violations, to child abuse, to environmental destruction. Yet so far, we have been able to make only small steps towards solving them. Why? One major, connected and largely overlooked factor is the values that motivate people and underpin our culture.

In 2010, a coalition of NGOs published Common Cause: The Case for Working With Our Cultural Values, drawing on decades of social psychology research to show the importance of values to the way charities campaign. Inspired by this, and working closely with the same group of NGOs, PIRC produced The Common Cause Handbook, distilling the evidence into a clear and accessible format for people and organisations to apply in their work, and developed a popular workshop and training programme. The aim of the Common Cause project going forward is to build alliances between diverse groups of people and organisations to rebalance our cultural values.

››› *valuesandframes.org*

TALKING CLIMATE

At Talking Climate, the best research on climate change communication is translated into practical guides on a wide range of topics, ensuring academics and practitioners get the most from the available evidence base. With a comprehensive and frequently updated database of academic papers, a regular newsletter, and a blog featuring comment and analysis from climate change communication experts, Talking Climate is the gateway to research on climate change communication.

Talking Climate is a partnership between PIRC, the Climate Outreach and Information Network (COIN), and the 'Climate change as complex social issue' research group at the School of Sociology and Social Policy, Nottingham University.

››› *talkingclimate.org*

CARBON OMISSIONS

The UK's emissions are still rising: official figures exclude the carbon we outsource overseas. With the Government reluctant to even acknowledge this problem, our consumption of high-carbon imports continues to grow unchecked. PIRC's investigation into the matter has seen the Government forced into releasing documents revealing how much it knows yet has failed to act, and has helped trigger an inquiry by the Energy and Climate Change Committee. In 2012, PIRC is working to produce an engaging animation to further raise awareness of the UK's carbon omissions - and demand action from the Government.

››› *pirc.info/omissions*

TOWARDS A SUSTAINABLE SOCIETY

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