Green Alliance briefing
July 2011

green alliance...

Climate science explained

A Climate Leadership Programme briefing

in association with

Grantham Institute for Climate Change
An institute of Imperial College London

This explanation of the science of climate change has been produced under the Climate Leadership Programme by Green Alliance, in partnership with the Grantham Institute at Imperial College London. It is based on information compiled in a more extended form by the Royal Society, the Committee on Climate Change and the Met Office. It is not intended as a comprehensive guide, but as an aid to communicating the issue. All scientific evidence is referenced and sources of further information are given.

Climate science explained

The natural greenhouse effect and climate variability

Solar radiation warms the planet and provides the energy that drives the climate system. It has been known since the nineteenth century that some gases in the atmosphere let in sunlight but trap heat - infrared radiation - in the atmosphere, raising the surface temperature above what it would otherwise be until the outgoing energy again balances the incoming solar energy.[1] Without this natural greenhouse effect, average temperatures on Earth would be 33˚C cooler, or about -18˚C.[2] The main greenhouse gases (GHGs) are water vapour and carbon dioxide (CO_2), but methane, nitrous oxide and others also have an effect.[3]

There is considerable natural variability within the climate system.[4] The Earth was some six to seven degrees warmer around 50 million years ago, after which both global temperatures and atmospheric CO_2 levels slowly declined, until recently.[5]

In the last 800,000 years there have been a series of ice ages and warmer periods.[6] The trigger for these is thought to be changes in the Earth's orbit that affect the amount of solar radiation falling on high latitudes in summer.

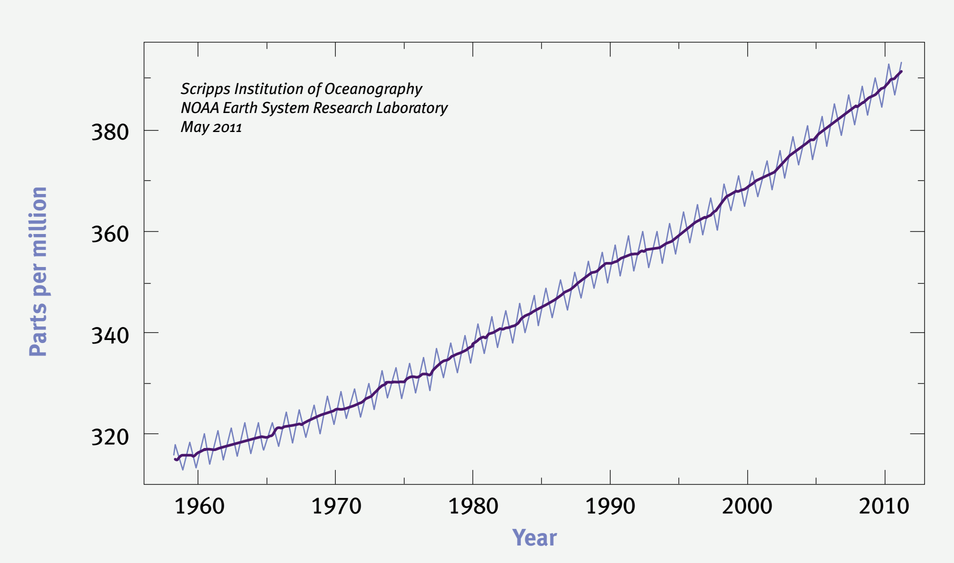
The limited extent of climate change in the past ten thousand years has allowed the development of agriculture, settlements, modern societies and economies. On shorter timescales, interactions between the land surface, the oceans and the atmosphere can give rise to complex variations in climate.[7]

The human contribution

In pre-industrial times, the proportion of the volume of the atmosphere made up by CO_2 was about 0.0280 per cent (280 parts per million or 280 ppm). It has risen to about 0.0390 per cent today.[8]

CO_2 has been measured in the past from Antarctic ice cores and then from direct atmospheric sampling at Mauna Loa, Hawaii. It is now measured using a globally distributed network of sites.[9] Results from these different measuring methods are very similar during their period of overlap.[11]

Figure 1: Annual mean CO2 growth rates for Mauna Loa Observatory, Hawaii.[10]



Present day levels of atmospheric CO_2 are higher than observed in the previous 800,000 years,[12] when CO_2 varied between about 180 and 300 ppm as the climate moved into and out of ice ages, and where CO_2 acted as an amplifying factor rather than a trigger of change.[13] The recent sharp increase is mainly due to human activity, as shown for example by the balance of different carbon atom isotopes in the atmosphere.[14] The different isotopes act as atomic 'markers' showing where the carbon has come from.

The primary human activities that increase CO_2 levels include burning fossil fuels (coal, oil and gas), land use changes such as deforestation and cement manufacture.[15] Emissions of methane and nitrous oxide have also increased due to agriculture and other activity.[16]

Around half of the CO_2 due to human activity has remained in the atmosphere, with the rest taken up by the oceans, soils and plants.[17] The impact is potentially long-term; even if human CO_2 emissions were to stop immediately, it would take thousands of years for concentrations to get back to pre-industrial levels, all other things being equal.[18]

Increases in atmospheric GHGs have enhanced the natural greenhouse effect.[19] There is unequivocal evidence that warming is occurring.[20] The Earth's global mean temperature has increased by 0.8˚C, with an uncertainty of plus or minus 0.2˚C and considerable year-to-year variability, since 1850.[21]

This evidence has led scientists to conclude with a high level of certainty that human activities are having a significant effect on the Earth's climate.[22] It is noteworthy that the 2010 review of the Intergovernmental Panel on Climate Change (IPCC) by the InterAcademy Council made no criticism of the most recent and comprehensive assessment of the physical science basis of climate change provided by the IPCC Working Group I (see more on this below).

Other factors influencing the climate

In addition to GHGs, many other factors also influence the Earth's climate in different ways and on different timescales. Some of the most important include: the total amount of solar radiation and its very short wavelength component hitting the earth, which may be due to solar variability or changes to

> "There is already clear evidence of warming from a range of physical indicators such as direct measurements of surface temperatures, sea level rise and the extent of Arctic sea ice."

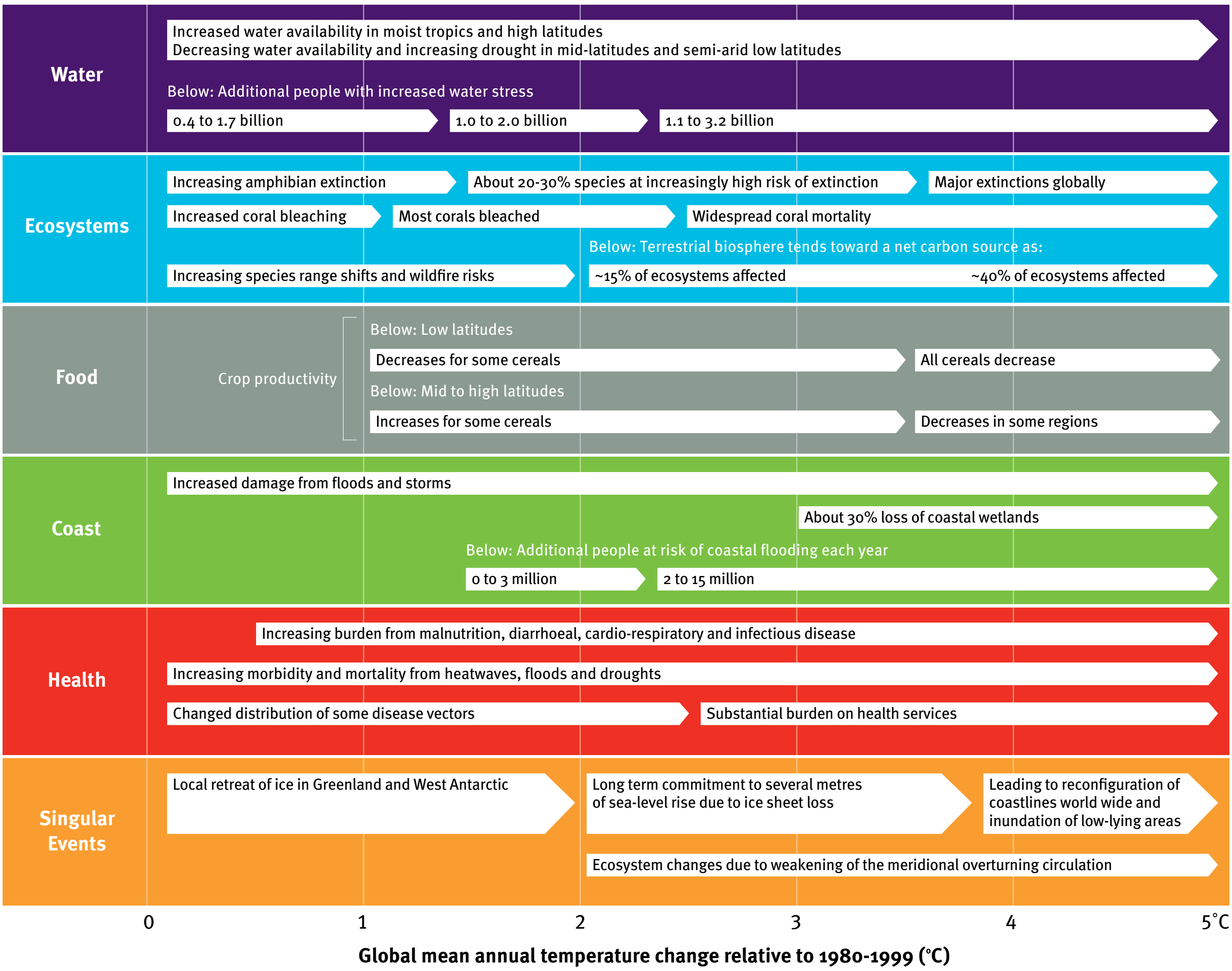
the Earth's orbit around the Sun; the reflectivity of the Earth's surface – its albedo – affected by land surface changes and clouds; the presence of atmospheric aerosols; stratospheric ozone levels; and others.[23]

These factors may amplify or moderate the impact of GHG increases and the precise effect of some, for example clouds, is not well understood.[24] Such uncertainties mean that projections of future global temperature increases due to climate change span a significant range, with the equilibrium climate response to a hypothetical doubling of atmospheric CO_2 levels thought likely to be in the range 2-4.5°C.[25]

Effects of climate change

There is already clear evidence of warming from a range of physical indicators such as direct measurements of surface temperatures, sea level rise and the extent of Arctic sea ice.[26] Future projections depend on modelling of the climate and how this interacts with other natural and human systems. Given the complexity of the climate system on its own, it is difficult to predict future impacts with precision.[27] However, a combination of modelling and effects already observed can help to predict some of the very likely future effects of climate change:

Figure 2: Estimates of possible impacts of a changing climate due to increased GHGs, shown using a globally averaged temperature rise as an index of the extent of that change[28] (Source: IPCC)



Note: the temperature in 1980 was already more than half a degree warmer than the pre-industrial temperature.

“There is very little uncertainty that climate change due to increased GHGs is happening, and that in future it is very likely to have significant impacts upon human and other life.”

- There will be significant regional differences in the patterns of climatic change, with climate change overlaid on natural variability. Greater warming will occur on land than at sea, particularly on the northern continents in winter.[29] Some regions could even cool for a decade or more.
- Climate change is likely to amplify precipitation patterns, with increased rainfall in areas with already high amounts of rainfall, and decreased rainfall in drier areas.[30] Intense rainfall events will be even more intense, leading to more flood damage.
- Loss of glaciers due to warming may cause water availability to vary more in some regions, as it will depend on seasonal snow and rainfall, rather than the steady release of stored water from the glacier.[31]
- Sea levels are very likely to continue to rise by at least as much as 20 cm per century, as observed over the past century[32] due to the thermal expansion of the oceans. Further rises may be caused by the melting of land ice. Significantly more and faster sea level rise would affect major coastal population centres, such as the US Eastern seaboard, Bangladesh and Eastern China.[33]
- The frequency of extreme weather events is very likely to increase. While it is not possible to establish a causal link between climate change and individual events, recent extreme weather, such as the 2003 and 2010 European heat waves, two of the most extreme over the last 500 years,[34] and the recent Pakistan floods,[35] are consistent with predictions for climate change.
- Climate change will affect agriculture significantly, but effects will differ by region and by crop,[36] with some benefits in high latitudes for moderate local warming but with negative effects likely at lower latitudes such as the tropics, where dependence on agriculture is high.
- There could be serious impacts on ecosystems and biodiversity, which are already facing pressures due to other aspects of human activity. However, robust predictions are difficult to formulate. The response of species and communities to climate change is likely to be highly variable and science in this area is still developing.[37]

Remaining uncertainties

There is very little uncertainty that climate change due to increased GHGs is happening and that, in future, it is very likely to have significant impacts upon human and other life, as described above.

Many uncertainties remain over the magnitude and details of likely future changes, especially on a regional and local scale. These uncertainties include those due to the effects of clouds, the potential for sea level rise caused by the ice sheets of Greenland and West Antarctica, and changes to the circulation of the oceans.[38]

One important area of uncertainty is the ability of the land and oceans to store carbon, either as CO_2 or as methane.[39] It is likely that warming will lead to less carbon being stored in this way which, in turn, will increase GHG emissions and amplify climate change as it did in the past in the fluctuation between ice ages and warmer periods. However, the future strength of these mechanisms is very poorly understood.[40]

Recent climate science controversies and reviews

In 2009 there were two widely-publicised controversies about climate science; the first about leaked emails from the Climatic Research Unit (CRU) at the University of East Anglia (UEA), and the second about errors in reports published by the Intergovernmental Panel on Climate Change (IPCC). These controversies were the subject of a number of reviews, as follows:

- The **House of Commons Science and Technology Committee** carried out an inquiry into the CRU email controversy, and found that there was no deliberate attempt to mislead. Scientists were criticised for not sharing data adequately.[41]
- The **Independent Climate Change Email Review**, established by UEA, and chaired by Sir Muir Russell, looked at the work of the CRU scientists. It concluded that their rigour and honesty as scientists was not in doubt, and that their behaviour had not prejudiced the advice given to policy-makers, but that the scientists had failed to display a proper degree of openness.[42]
- The **Science Assessment Panel**, also established by UEA, and chaired by Lord Oxburgh, reviewed research papers published by the CRU and concluded that they saw no evidence of any deliberate scientific malpractice.[43]
- The **InterAcademy Council (IAC)**, an umbrella body of scientific academies, undertook a review of the processes and procedures of the IPCC, prompted in part by the few errors discovered in the latest IPCC Working Group II (Impacts) report. The IAC found that the IPCC assessment process had been successful overall. It made a series of recommendations to enhance the governance and management of the IPCC, in particular its review process and how it characterises and communicates uncertainty.[44] The IPCC gave a final response to the review in May 2011,[45] and the IAC issued a statement saying that it was “pleased that so many of our report’s recommendations were adopted” and that it hoped its report “will continue to inform management of the IPCC”.[46]

Further information

Climate change: a summary of the science (Royal Society, 2010) summarises the current scientific evidence on climate change.
The fourth carbon budget – reducing emissions through the 2020s (Committee on Climate Change, December 2010) has a chapter which does the same in greater depth.
www.metoffice.gov.uk provides an interactive guide to climate science.

Endnotes

1 *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p49

2 *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p49; Professor Sir Brian Hoskins' presentation to MPs, 1 March 2010

3 *Climate change: a summary of the science*, Royal Society, September 2010, p2

4 *Climate change: a summary of the science*, Royal Society, September 2010, p2-3

5 *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p50

6 *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p50

7 *Climate change: a summary of the science*, Royal Society, September 2010, p2-3

8 *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p52; *Climate change: a summary of the science*, Royal Society, September 2010, p6

9 *Trends in atmospheric carbon dioxide*, Earth System Research Laboratory, National Oceanic and Atmospheric Administration, www.esrl.noaa.gov/gmd/ccgg/trends/global.html#global_data, accessed on 7 June 2011

10 Dr Pieter Tans, NOAA/ESRL and Dr Ralph Keeling, Scripps Institution of Oceanography (scrippsco2.ucsd.edu/), www.esrl.noaa.gov/gmd/ccgg/trends/

11 *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p52

12 *Climate change: a summary of the science*, Royal Society, September 2010, p6

13 *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p50-1

14 *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p52; *Climate change: a summary of the science*, Royal Society, September 2010, p6

15 *Climate change: a summary of the science*, Royal Society, September 2010, p6

16 *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p53

17 *Climate change: a summary of the science*, Royal Society, September 2010, p6

18 *Climate change: a summary of the science*, Royal Society, September 2010, p8

19 *Climate change: a summary of the science*, Royal Society, September 2010, p6

20 *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p54-5

21 *Climate change: a summary of the science*, Royal Society, September 2010, p5; *The fourth carbon budget – reducing emissions through the 2020s*, p54-56

22 *The physical science basis*, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007, 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.

23 *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p51 & p54

24 *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p54; *Climate Change: A summary of the science*, Royal Society, September 2010, p11

25 *Climate change: a summary of the science*, Royal Society, September 2010, p9

26 *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p55

27 *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p60

28 Contribution of *Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, 2007, chapter 20, p828

29 *Climate change: a summary of the science*, Royal Society, September 2010, p10

[30] *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p61; *Climate change: a summary of the science*, Royal Society, September 2010, p10

[31] www.metoffice.gov.uk/climate-change

[32] *Climate change: a summary of the science*, Royal Society, September 2010, p10

[33] *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p62

[34] *The hot summer of 2010: redrawing the temperature record map of Europe*, D. Barriopedro, E. M. Fischer, J. Luterbacher, R. M. Trigo, R. Garcia-Herrera, Science, 2011; DOI: 10.1126/science.1201224

[35] www.metoffice.gov.uk/climate-change

[36] *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p62

[37] *Beyond predictions: biodiversity conservation in a changing climate*, TP Dawson, ST Jackson, JI House, IC Prentice, GM Mace, Science 332 no. 6025 pp. 53-58, DOI: 10.1126/science.1200303, 1 April 2011

[38] *Climate change: a summary of the science*, Royal Society, September 2010, p11

[39] *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p72

[40] *Climate change: a summary of the science*, Royal Society, September 2010, p11; *The fourth carbon budget – reducing emissions through the 2020s*, Committee on Climate Change, December 2010, p72

[41] *The disclosure of climate data from the Climatic Research Unit at the University of East Anglia*, House of Commons Science and Technology Committee, March 2010

[42] *The independent climate change emails review*, Chaired by Sir Muir Russell for UEA, July 2010

[43] Report of the International Panel set up by the University of East Anglia to examine the research of the Climatic Research Unit, April 2010

[44] *Climate change assessments: review of the processes and procedures of the IPCC*, InterAcademy Council, October 2010

[45] Eleventh Session of IPCC Working Group III and Thirty-third Session of the IPCC, Abu Dhabi, United Arab Emirates, 5-8 and 10-13 May 2011, www.ipcc.ch/scripts/_session_template.php?page=_33ipcc.htm, accessed on 8 June 2011

[46] Statement by the InterAcademy Council, reviewipcc.interacademycouncil.net/IACAbuDhabiMay2011.html, 14 May 2011, accessed on 8 June 2011.

Green Alliance
36 Buckingham Palace Road,
London SW1W 0RE
Tel 020 7233 7433
Fax 020 7233 9033

ga@green-alliance.org.uk
www.green-alliance.org.uk

Green Alliance is a registered charity 1045395 and a company limited by guarantee 3037633

Climate science explained
A Climate Leadership Programme briefing

ISBN 978-1-905869-42-8

The Climate Leadership Programme, run by Green Alliance with the Ashridge Business School, aims to give MPs knowledge and skills to lead a proactive and ambitious agenda on climate change.

The Climate Leadership Programme is supported by the Tellus Mater Foundation.

This is a **Green Alliance briefing** produced under the Political Leadership theme, in association with the Grantham Institute for Climate Change. For more information, visit www.green-alliance.org.uk/politicalleadership and www3.imperial.ac.uk/climatechange

Author: Rebecca Willis, Green Alliance associate; with input from Brian Hoskins and Simon Buckle, Grantham Institute for Climate Change, and Joanna Haigh, Imperial College London.

Green Alliance
Green Alliance is a charity and independent think tank focused on effective leadership for the environment. We have a track record of over 30 years working with the most influential leaders from the political, NGO and business communities. Our work generates new thinking and dialogue, and has increased political support and action for ambitious environmental solutions in the UK.