Risks of dangerous climate change

Climate research has a firm basis in physical science and is supported by a wealth of evidence from real-world observations. Like any other scientific discipline, climate science develops through vigorous debate between experts. But there is overwhelming agreement on the fundamentals — that our climate is changing and this represents a real and urgent global problem.

In 2007, the IPCC[1] Fourth Assessment Report (AR4) presented an authoritative overview of the science, effects and mitigation of climate change. Recently, Met Office Hadley Centre and AVOID[2] programme scientists have conducted new research to better understand potentially 'dangerous' climate change and inform the global debate on what needs to be done to avoid it.

The work of the AVOID programme provides scientific evidence to underpin many aspects of domestic policies on mitigation options and adaptation strategies, as well as international negotiations on reducing carbon dioxide (CO_2) emissions.

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The table overleaf is our summary of post-IPCC AR4 work on those aspects of the climate that are most at risk. We also show some of the potential consequences expected by the end of the 21st century from the climate changes associated with a 'business as usual' emissions scenario. This scenario assumes that no policies are put in place to limit CO_2 emissions. As part of this research, we have consulted with recognised experts in a number of areas to ensure that the following table presents the very latest view.

Whilst there is still a high degree of uncertainty in how many components of the climate system will respond out to 2100, our new work highlights where progress in understanding has been made. We use a traffic light system to highlight how our understanding of impact severity has changed since IPCC AR4. These are impacts that we expect to see by the end of the century, under a medium to high emissions scenario.

Red shows where the impact is worse.

Green shows where the impact is better.

Amber shows where the impact is the same.

AVOID is a UK research programme funded by DECC/Defra and led by the Met Office in a consortium with the Walker Institute, Tyndall Centre and Grantham Institute.

1 Intergovernmental Panel on Climate Change.
2 Avoiding Dangerous Climate Change.

Summary of post-IPCC AR4 work

Climate sector	Change in our understanding of impact severity	Median projections for 2100 under 'business as usual' scenario
Arctic sea-ice	New analyses that combine models and observations suggest that the Arctic may become largely ice free during most summers earlier in the century than predicted by many (but not all) AR4 models. The record low in 2007 raised concerns about rapid loss of Arctic sea-ice within a few decades. Since then, the ice has remained thin but the September extent has not subsequently dropped below the 2007 value. However, there is emerging statistical evidence that the rate of decline of ice extent has increased slightly over the long-term loss rate. It is too early to tell whether this will be sustained, as short-term increases in rate are also seen in model projections.	Summer and winter sea-ice extent significantly reduced. Models able to reproduce observations (including the Met Office model) indicate frequent ice-free summers by the end of the century. Mean thickness reduced at the end of the winter, leading to an increase in interannual variability of ice extent.
Ice-sheets	Increased loss from Greenland and Antarctic ice-sheets observed, but we now know more about the various processes responsible. Possible stages in the melting of Greenland identified in one model simulation, suggesting it may not be able to recover once certain limits are reached.	**Greenland ice-sheet:** considered at risk of significant mass loss through surface melting, though over timescales much longer than a century. An additional contribution may come from glaciers flowing more quickly into the sea, but the contribution from this source is still very uncertain. **West Antarctic ice-sheet:** mechanisms for rapid collapse are possible, relating to movements of the boundary between floating ice shelves and ice on the land. However, the threshold for such a change and its contribution to the rate of sea-level rise are currently difficult to estimate.
Sea-level rise	The relationship between temperature and sea-level rise is non-linear and the range for 21st century sea-level rise remains uncertain. Some evidence that sea-level rise by 2100 may exceed the 95th percentile AR4 model-based projection of 59 cm. Evidence that a rise significantly above 2 m by 2100 is very unlikely.	AR4 model range of sea-level rise for this scenario was 0.21–0.59 cm. However, some of the newer evidence suggests that a sea-level rise of 2 m cannot be ruled out, but an increase of more than 1 m is currently viewed as unlikely.
Atlantic Ocean conveyor belt	Ocean circulation is highly variable and improved observations cast doubt on previously reported evidence of recent slowdown. Improved understanding of the ocean processes that affect the potential collapse of the Atlantic Ocean conveyor belt and irreversibility. These processes are not all well represented in models.	A published survey of experts put the chance of collapse at 10% for moderate to high warming, but computer modelling results are inconclusive.

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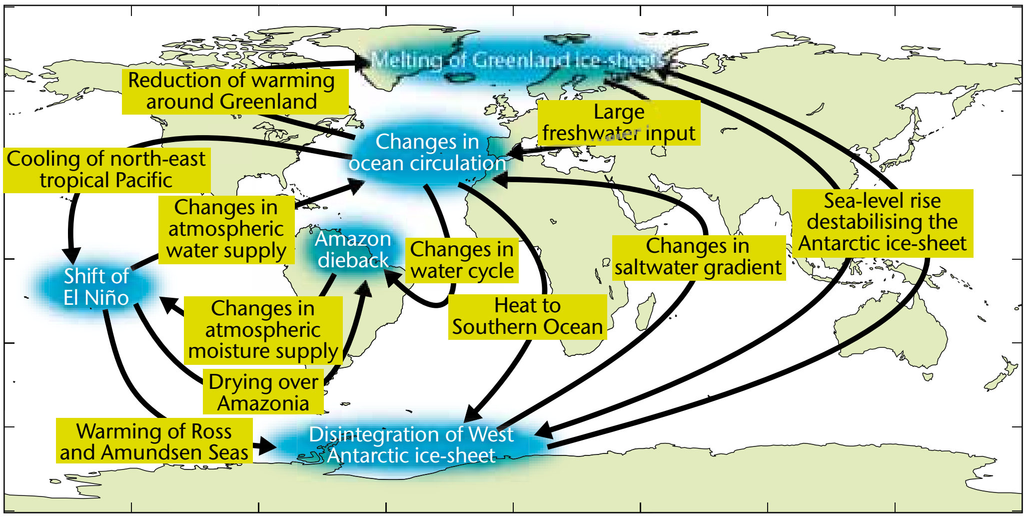
Climate sector	Change in our understanding of impact severity	Median projections for 2100 under 'business as usual' scenario
Tropical forests	New evidence of susceptibility to drought. A growing number of model studies show susceptibility of vegetation to non-CO_2 gases such as nitrous oxide (N_2O) and ozone, and particulates. Old forest was thought to be carbon neutral but, in fact, still absorbs CO_2. It therefore has the benefit of helping to slow climate change, but also has the potential to accelerate climate change if deforestation of pristine old growth forest is not controlled. Improved observations and understanding of mechanisms, but large uncertainty remains.	Current studies suggest a wide range from little or no loss, to 80% reduction in Amazon vegetation carbon. This reflects the large uncertainty in both the present day simulated climate over the Amazon region and simulated changes in climate. Large differences in the way vegetation is represented in some computer models is another factor.
Methane emissions from wetlands	More model evidence for a future increase in global wetlands emissions, which may increase man-made warming by several percent.	Methane emissions from wetlands are likely to increase by somewhere between 10 and 35% globally per degree of global temperature increase, even though some regional wetlands may dry out. It is not possible to produce a robust estimate of the risk at this time.
Carbon emissions from terrestrial permafrost	Some evidence of thawing permafrost has been observed. Improved understanding of processes, but large uncertainties remain in the size of the carbon store along with the possible timescale and temperature threshold of any potential release.	Significant uncertainty in this developing area precludes an estimate of the potential thresholds or risk at this time.
Ocean methane hydrates	It is unclear where methane hydrates are beneath the ocean bed, or in what volumes. They have the potential to cause significant climate change if destabilised, but the size, likelihood and timescale of release are very uncertain.	Significant uncertainty in this developing area precludes an estimate of the potential thresholds or risk at this time.
Extremes	Physical understanding and computer model studies both suggest there will be significant future changes in a range of climate extremes, such as intense rainfall events. At present, we have poor skill in quantifying the local changes in extremes. It remains unclear whether there have been changes in the frequency of tropical storms outside natural variability.	Tropical storm intensity is projected to increase.
Interactions between potentially abrupt changes	Expert consultation has highlighted concern on this issue. New work with Earth system models has focused on understanding possible interactions.	Incomplete understanding of individual elements makes assessment of interactions difficult, particularly the determination of particular thresholds.



Sketch of the main interactions (in green) between potential thresholds (in blue)[3].

INTERACTIONS

Climate scientists now understand that many potentially dangerous climate changes are linked (see schematic).

These links, which can act over very large distances, have the potential to greatly increase the impacts resulting from just one type of dangerous event. However, the strength of the links cannot yet be reliably quantified.

Two examples of such large-scale interactions are:

Greenland ice-sheet

- Freshwater from the melting ice could increase the risk of a shutdown of the Atlantic Ocean conveyor belt.
- Sea-level rise caused by melting of Greenland ice could increase the risk of destabilising the Antarctic ice-sheet.
- In the long-term, the melting of Greenland ice might also lead to further warming (as the exposed land surface becomes darker) increasing the risk across the globe of other temperature-dependent abrupt changes being triggered.

Tropical Pacific

- El Niño[4] in the Tropical Pacific has a profound effect on the climate of the surrounding region and widespread impacts around the world.
- El Niño affects rainfall patterns in the Tropics. Changes in El Niño could change the supply of moisture to the Amazon, reducing rainfall, and making the rainforest more vulnerable to dieback. This could further reduce rainfall and affect moisture supply back to the Pacific.
- El Niño could also affect, and be affected by, the ocean circulation, changing the heating around Antarctica and at high northern latitudes.

New observations and emerging work with Earth system models — like the new model from the Met Office Hadley Centre — is focused on better understanding the different components of the climate system and the interactions between potentially abrupt climate changes.

3 Adapted from expert consultation study: Kriegler E, Hall JW, Held H, Dawson R and Schellnhuber HJ. 2009: Imprecise probability assessment of tipping points in the climate system. PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA. Volume: 106, Issue: 13, Pages: 5041-5046.

4 During El Niño warm water spreads from the West Pacific and Indian Ocean to the East Pacific.

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