Sensitivity of Earth Systems

Lessons from the 1.5 Degrees Conference: how sensitive are earth systems to 1.5°C?

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Introduction

Why is this an important issue?

Discussion of 1.5°C often focuses on how difficult it would be to achieve. This can be seen in the headlines following the conference, including "Scientists made clear…that the challenges will be enormous" (Scientific American), "Experts see few paths to planet-saving climate goal" (phys.org), and "Paris climate goal will be 'difficult if not impossible to hit'" (The Guardian).

Yet it's the potential impacts of going beyond 1.5°C which motivated vulnerable countries to call for this goal. Understanding potential impacts of global warming is important to help establish whether it's worth pursuing a 1.5°C pathway. The sensitivity of the earth system is a key component of these impacts. So what can we learn from the 1.5 Degrees conference about the sensitivity of earth systems to 1.5°C?

Relevance to the IPCC Special Report

Currently one chapter on impacts has been proposed for the IPCC Special Report, including impacts on natural as well as human systems (IPCC 2016). Here we consider lessons from the conference about the current state of the science, and future work which might be needed to inform the Special Report, in relation to the following key questions: How sensitive are earth systems to anthropogenic global warming? What changes in the atmosphere, oceans, cryosphere, and biosphere might be expected at 1.5°C? How do these compare to potential changes at 2°C and higher levels of warming?

The 1.5 Degrees Conference

We draw in particular on the first day of the conference, which focused on impacts, including plenary talks by Valérie Masson-Delmotte, Richard Betts, Sonia Seneviratne and Andreas Merkl. Day 1 also featured a parallel session on the Sensitivity of Earth Systems, and relevant research was presented in the poster session.

Key messages

1. A 1.5°C warmer world is not a safe one: the earth is already experiencing anthropogenic climate change

Several of the speakers started their talks with an assessment of "where we are at now", highlighting that human-induced change in the earth system has already occurred. We cannot assume that an even warmer world will be safe: 1.5°C implies even larger changes in earth systems. Whilst scientists may not be able to predict exactly what might happen at 1.5°C or beyond, there is strong evidence of changes which have occurred in recent history.

One such change is the existing rise in global temperature. Valérie Masson-Delmotte drew attention to this, presenting evidence that the global mean surface temperature has already exceeded 1°C above the preindustrial (2015 was >1°C warmer than 1720-1800); or, as Jim Hall put it, "we are already two-thirds of the way there" (quoted in The Guardian).

Glacier loss was also highlighted as an important recent change in the earth system, demonstrating that even a small change in global temperature can be a big concern. Richard Betts showed IPCC figures illustrating retreating glaciers in many locations globally, whilst Emily Shuckburgh drew attention to glacier loss in polar regions.

Coral reefs are also an example of a highly sensitive system which is already experiencing impacts from anthropogenic greenhouse gases. Carl-Friedrich Schleussner reminded the conference how topical this is given the recent mass bleaching of the Great Barrier Reef.

2. There has been limited scientific research which specifically examines 1.5°C

Understanding the exact impacts of 1.5°C, and the difference between 1.5°C and 2°C, is challenging in part due to limited previous research. Whilst 1.5°C has been in international policy discussions for at least five years, many scientists were surprised when the IPCC was invited to produce a special report on this topic in Paris. This "1.5°C surprise" was referred to several times during the conference. Myles Allen described it as "rather embarrassing" that the scientific community had done so little research, and Joeri Rogelj said it was "rather awkward". Richard Betts began his talk about regional impacts by joking that he was "delighted to speak on a topic with almost no material".

During the conference many of the presentations relating to earth systems used existing literature to draw out messages about 1.5°C; however the parallel session on Sensitivity of Earth Systems also included new research specifically targeting the impacts of 1.5°C (Schleussner et al. 2015; Mitchell et al. 2016).

One challenge in generating new findings about 1.5°C, and comparing earth system responses at 1.5°C and 2°C, is the lack of existing climate model experiments which simulate these warming levels. Valérie Masson-Delmotte showed a figure illustrating global temperature responses from the most commonly used climate model experiments (from the Coupled Model Intercomparison Project), demonstrating the limited evidence base available to examine 1.5°C (Figure 1). Most greenhouse gas scenarios represent higher levels of anthropogenic forcing. There was some discussion of a new, lower emission, scenario planned under CMIP6, but this will not be run in time to provide evidence for the IPCC Special Report. The challenges of using existing model experiments to examine climate signals at 1.5°C and 2°C were also discussed in a poster by Rachel James (James et al. 2016).

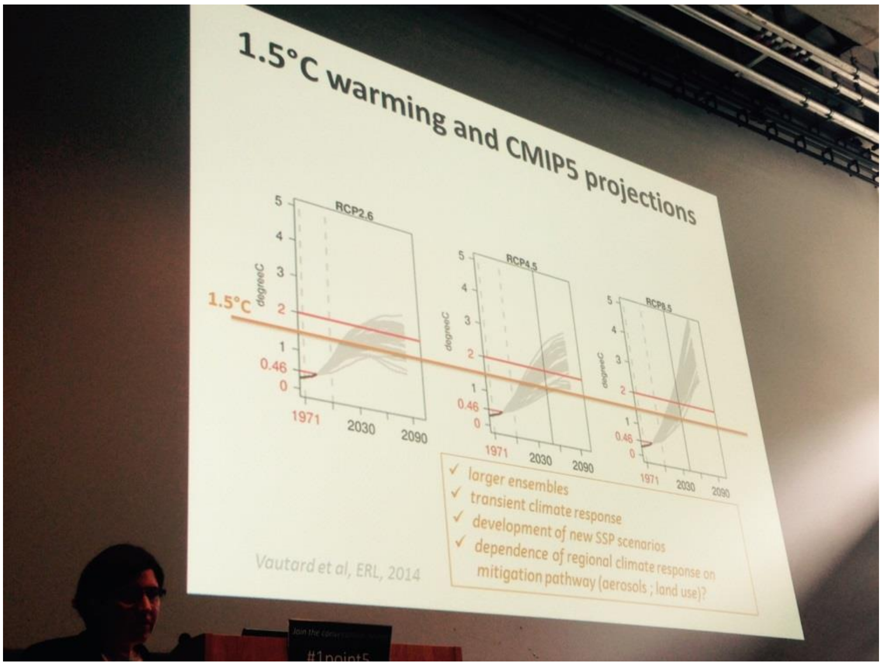

Figure 1: Valérie Masson-Delmotte presents global temperature responses from CMIP5

Further scientific research to investigate impacts at 1.5°C also faces a challenge in terms of uncertainty, in particular to extract meaningful information about relatively small global temperature signals (0.5°C) against the background noise of natural variability in the earth system. In this context there was discussion about whether research into 1.5°C impacts is worth the effort. Some questioned whether it was possible to make meaningful statements about 0.5°C differences, whilst others, like Jan Fuglesvelt, highlighted that uncertainty is "endemic but not crippling". The potential for new uncertainty analysis was discussed, including using a new set of large climate model ensembles from the HAPPI project (happimip.org). Several researchers, including Karim Bergaoui and Michael Wehner, presented initial findings from HAPPI, and there was also a side meeting about HAPPI prior to the conference.

3. **Those studies which do examine 1.5°C suggest that limiting to 1.5°C would avoid some dangerous climate change impacts**

Existing research which has compared 1.5°C with 2°C or higher degrees of warming suggests some important impacts might be avoided by limiting to 1.5°C. Whilst the mean differences between 1.5°C and 2°C may not be that large, there could be important differences in the probability of extreme weather events, as explained by [Joeri Rogelj](). Sonia Seneviratne highlighted that there is relatively high confidence in particular about the influence of anthropogenic warming on hot and cold extremes and extreme precipitation events (see also Fischer and Knutti 2015).

Carl-Friedrich Schleussner presented the first paper to compare 1.5°C with 2°C impacts across regions and systems (Schleussner et al. 2016, also summarised by carbon brief, Figure 2), which suggests that for some places the difference between 1.5°C and 2°C matters a lot. The Mediterranean is projected to experience a much higher probability of dry events under 2°C than 1.5°C. Earth systems where there is strong evidence for an important difference include coral reefs. Under 2°C virtually all coral reefs are threatened: only limiting to 1.5°C may allow some ecosystem adaptation.

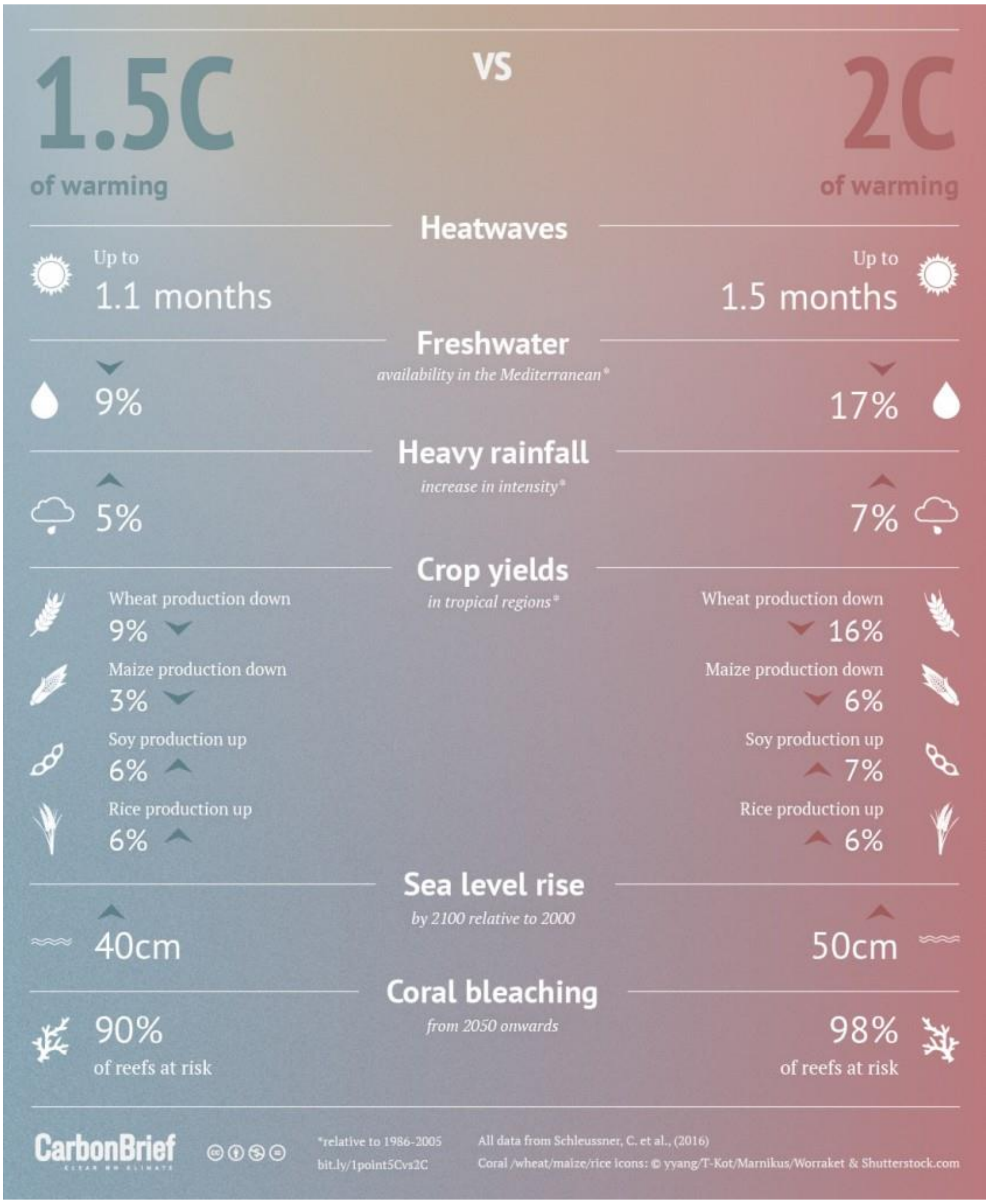

Figure 2. Summary of Schleussner et al. 2016 by the Carbon Brief

Paul Bowyer also presented an analysis comparing 1.5°C and 2°C, suggesting that for some impacts in Europe there is not a very important difference between 1.5°C and 2°C. However, he highlighted that the more important differences were likely to be seen in vulnerable regions. It was noted several times during the conference that more evidence was needed for vulnerable regions, specifically small island states.

4. Physical understanding of earth systems suggests potential for nonlinear responses to global warming: A 1.5°C world is not just "a bit less warm" than 2°C

Several experts stressed that the response of earth systems to 1.5°C would unlikely be as simple as 75% of a 2°C response. 2°C is not just "the same but worse". Many studies of regional climate change in climate models do show an approximately linear response to global warming (including Sonia Seneviratne's recent work, presented during her talk, Seneviratne et al. 2015). However, physical understanding of earth systems suggests that there are important feedbacks in earth systems. Feedbacks and nonlinearities might be associated with accelerated change, trend reversals, or tipping points, meaning the impacts of 2°C could be qualitatively different from impacts of 1.5°C.

Valérie Masson-Delmotte highlighted the potential for abrupt changes as a key question which should be considered in the light of the 1.5°C goal, presenting evidence from Djifhout et al. (2015) that abrupt changes in ocean circulation, sea, and land ice have been modelled in response to approximately 2°C. The importance of nonlinear change was also emphasised with reference to oceans, by Andreas Merkl, who described oceans as "an intensely feedback-y" system; and polar regions, by Emily Shuckburgh, who explained how nonlinearities are expected due to ozone recovery, sea ice feedbacks on atmosphere-ocean dynamics, and internal ocean dynamics.

5. The sensitivity of earth systems at 1.5°C will also depend on mitigation technologies

Richard Betts made an important point that the impacts *at* 1.5°C might be different from the impacts *of* 1.5°C. If we want to know how earth systems might be different in a 1.5°C world, we should not only examine the influence of rising greenhouse gases and temperature, but also consider how natural systems might respond to mitigation technologies and mitigation pathways towards 1.5°C. Jeff Price, presenting on the difference 0.5°C might make for terrestrial biodiversity, emphasised potential negative impacts from mitigation. He argued that the net effect on biodiversity is uncertain: for some species and ecosystems, the ecological damage caused by mitigation projects may exceed the benefits of limiting global warming.

There are thus genuine questions about whether 1.5°C or 2°C would be preferable for natural systems. Researching the sensitivity of earth systems to 1.5°C is not as simple as gathering evidence about how much worse 2°C is than 1.5°C. There are important potential trade-offs associated with mitigation which should be considered with reference to impacts. Sonia Seneviratne called for joint adaptation-mitigation scenarios to explore this interaction. BECCS is particularly relevant here: if 1.5°C is achieved by growing additional crops for BECCS, what is the impact of this change in land use on the biosphere? Are there influences on oceans and feedbacks to the atmosphere? And how do these interact with the influence of global warming?

6. The impacts associated with a 1.5°C goal depend on how the goal is defined

There are remaining questions about how to define a 1.5°C goal, including: which baseline is 1.5°C measured against? When would 1.5°C be reached: at the first year of exceedance, or only after the average temperature is 1.5°C? And temperature averaged over how many years? Could a 1.5°C goal include the possibility of overshooting that temperature for several years before stabilising at 1.5°C? And should there be a limit on this overshoot? Would a 1.5°C pathway include some probability of stabilising at a higher global temperature? Many of these questions were raised during the conference and they will likely be important issues to address in the framing and context chapter currently proposed for the IPCC Special Report.

Some of these definitional issues have important relevance for assessment of earth system response to 1.5°C. For example, overshoot could have specific implications, particularly for ecosystems. Jason Lowe highlighted the need to understand the temporary resilience of systems to a short period of higher temperatures.

If a 1.5°C pathway includes the probability of exceeding 1.5°C this should also be considered. The 2°C goal has been interpreted as a 'likely' or greater than 66% chance of staying below 2°C. This suggests that there would still be a 1/3 probability of exceeding 2°C. In comparing 1.5°C and 2°C goals, it might also be worth thinking about those impacts that are avoided if the limit is missed.

Outlook

Summary

In summary, there was a clear message from the conference that our current 1°C world is not safe, and neither would a 1.5°C world be. 1.5°C would probably be safer than 2°C, especially for glaciers, coral reefs, and in terms of changes in extreme weather events. And, due to feedbacks and nonlinearities in earth systems, 1.5°C might actually be *much* safer than 2°C. However, this also depends on how 1.5°C would be achieved, as some mitigation technologies could have their own impacts on earth systems.

There are many remaining questions, and perhaps even more questions than answers. How should 1.5°C be measured? What is the potential for abrupt change between 1.5°C and 2°C? What might be the impact of a temperature overshoot? During the impacts plenary each speaker raised a different important issue which further complicated the analysis of responses to 1.5°C. The questions and gaps in our understanding are particularly large with reference to the most vulnerable countries.

So what are the implications for the IPCC Special Report? Is there potential to provide a better understanding of earth system response to 1.5°C? And how?

Although there was some discussion about whether scientists should focus on 1.5°C, the emerging consensus was that increased research attention has the potential to provide important information. Analysing the impacts of 1.5°C and 2°C is important: without this the Special Report could conclude that mitigating to 1.5°C is extremely difficult, without enough evidence to assess whether it is worth the effort.

Identifying scientific messages about 1.5°C and 2°C impacts is also possible: “uncertainty is endemic but not crippling” (Jan Fuglesvelt). The best approach to deal with this uncertainty was debated. Some highlighted the importance of quantitative evidence and running new model experiments to obtain probability estimates of impacts at 1.5°C and 2°C, whereas others questioned whether a more fruitful approach might be to focus on process-based studies to improve the qualitative understanding of the potential for difference between 1.5°C and 2°C.

Clearly there is a lot of work to do, and the challenge of addressing all of the questions and issues within one chapter of the Special Report was highlighted. It was also recognised that research in this area would be valuable beyond the Special Report, contributing to the IPCC AR6.