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Realizing the impacts of a 1.5°C warmer world

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The academic community could make rapid progress on quantifying the impacts of limiting global warming to 1.5 degrees, but a refocusing of research priorities is needed in order to provide reliable advice.

The decision on whether to increase the ambition of climate change mitigation efforts to stabilise temperatures at 1.5°C rather than 2°C above pre-industrial is arguably one of the most momentous to be made in the coming decade, and should be informed by sound scientific analysis. In its Paris Agreement of 2015 the Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC) invited the Intergovernmental Panel on Climate Change (IPCC) to prepare a special report in 2018 "on the impacts of global warming of 1.5°C above pre-industrial levels and related greenhouse gas emission pathways." The IPCC have now accepted this, however, there is currently a paucity of scientific analysis of the relative risks associated with this outcome, particularly regarding the role of extreme weather. To inform the proposed IPCC assessment, research will therefore need to be undertaken immediately, over the period 2016 to 2017.

A two-year review of the adequacy of the 2°C goal has just been completed.[1] While this included a comparison to 1.5°C, the lack of research to inform that comparison was repeatedly highlighted during the UNFCCC expert dialogue[2]. Specific research into the impacts of 2°C has increased in recent years, as well as studies into 4°C and beyond[3,4], but there has been very little attention to 1.5°C (notable exceptions include refs 5 and 6). The widely held assumption that 2°C represents the lowest feasible outcome has undoubtedly led to a lack of research into the impacts of lower stabilisation trajectories. The Paris Agreement has directly prompted an overview of the science questions around 1.5°C[7], and a specific discussion on the mitigation needed to achieve 1.5°C[8]. Here, we focus on the analysis needed to understand the *impacts* of a 1.5°C warmer world.

Much research on climate change projections and impacts considers changes for specific time periods, such as 2080-2100, under a particular emission scenario or Representative Concentration Pathway (RCP). But the UNFCCC has chosen not to frame the climate mitigation problem as a choice between emission scenarios, or even target CO_2 concentrations, but as an adaptive process based on global temperature goals. The scenario-driven design is not ideal for this purpose, particularly for ambitious mitigation scenarios: globally averaged surface air temperatures under the lowest scenario considered in CMIP5 (RCP2.6) stabilise over a 5-95% range of 0.9-2.3 degrees above preindustrial[9], where the response range on these timescales arises primarily from the model uncertainty rather than internal variability[10]. Responses to a more ambitious scenario, as is planned for CMIP6, with a 0.5°C lower median outcome would overlap this range heavily. This does not mean there is no significant difference between a 1.5°C and a 2°C world, just that uncertainty in the global temperature response to a specific emission scenario is larger than 0.5°C. The UNFCCC did not ask for an assessment of the relative risks associated with scenarios that give a median response of 1.5 or 2°C, they asked for the risks associated with these two outcomes, accepting uncertainties in what it will take to achieve them[11].

Hulme[12] argues that that the academic community should be cautious in "undertaking new cycles of studies in the expectation they will make a difference to the world of politics." However, we also add that it is our job as scientists, first and foremost, to inform. Whether or not the information we provide "makes a difference" is ultimately up to others.

Policy-makers generally understand that no one knows what it will take to achieve a 2°C or 1.5°C goal, and that they will only find out after many years of mitigation experience: hence the call for specific research into the relative impacts of different temperature outcomes before updating their decision on the overall goal in 2020. This seems to us to be precisely the kind of "pragmatic and decision-centred" research Hulme is calling for. But can such research be carried out in time with a high enough level of reliability to properly inform such a momentous policy decision?

The adequacy of our current climate experiments

Hulme warns that research attempting to compare the impacts of 2°C and 1.5°C may not be scientifically robust. This is a risk, especially for regional-scale assessments and particularly for extreme weather, if such studies are not appropriately designed. The impact community often utilize climate experiments that have not explicitly been designed for the problem at hand. This makes sense if the experiments are fit for purpose, as they often are, but for some issues, new specifically targeted experiments may be needed.

At present, the most commonly-used tool in the IPCC Working Group 1 (WG1), Coupled Model Inter-comparison Project (CMIP) scenario driven experiments, are somewhat limited in being able to address impacts at 1.5 degrees. Whilst it is possible to extract anomalies from CMIP scenario experiments at 1.5°C and 2°C, it is difficult to assess whether the resulting differences are due to the enhanced global warming or some other factor.

Precipitation, for example, does not only respond solely to rising temperatures[13]. The global mean precipitation response to a 1.5-degree warming is very different under RCP2.6 and RCP8.5 (see Fig. 1a or Figure 12.6 of ref 9). The distribution of global precipitation change (and, by implication, the overall intensification of the hydrological cycle) is very different between the two scenarios (Fig. 1b). This is in part driven by non-CO_2 forcings, which play a larger role in the middle of the 21st century than towards the end, but also because the sensitivity of precipitation is known to be emission-scenario dependent[14,15]. Since the hydrological cycle does not response uniformly, any assessment of impacts at 1.5 degrees based on transient simulations could not simply be scaled to agree with a more realistic, equilibrated 1.5-degree scenario without a considerable amount of guesswork. This is especially true when considering localised extremes or events that have been amplified through feedback mechanisms such as soil moisture[15]. Dedicated experiments should be assessed to understand the relative impacts of climate equilibrated at 1.5 and 2 degrees for the 2018 special report. Why rely on a scaling pattern when we have spent the last several decades developing GCMs to give us a physically coherent response?

New experiments needed

Impacts of a global warming of 1.5°C, and the impacts avoided by stabilising temperatures at 1.5 instead of 2°C, will be dominated, in many regions, by changing risks of extreme weather events exceeding critical thresholds (e.g. for human health[17]). Relatively small ensembles of coupled model integrations, as requested by CMIP, are primarily suited to the assessment of expected changes in mean climate, not weather extremes. To quantify these changes, both high atmospheric resolution and large initial-condition ensembles are required.

The attribution community has been using large ensembles to deal with low signal-to-noise problems for over a decade, and their methodology[18] could be directly applied to this climate projection problem. To directly address impact differences between a 1.5 and 2-degree world, climate modellers could run large ensembles (>50 members) of 10-year periods for recent observed and 1.5°C and 2°C warmer worlds, using projected changes in sea surface temperatures drawn from existing coupled model simulations. The use of 10-year time slices would allow for the assessment of long-lived extreme events, such as droughts, while still allowing for large ensembles. The use of >50 ensemble members of a 10-year analysis period should allow for statements to be made regarding policy-relevant return-times such as 50-100 years. The resultant probabilistic assessment of climate would allow for any clear and tangible differences to be detected between small changes in global temperature.

If additional research is not undertaken as a matter of urgency, there is a danger, under the UNFCCC/IPCC timetable, that the 2018 special report will present all the negative economic constraints of achieving 1.5 degrees[19] but with insufficient evidence to distinguish between impacts at 1.5°C and 2°C of warming, even if very different levels of risk are associated with these two outcomes in reality. The resources required for targeted “attribution-style” ensembles addressing this question are small relative to the investment planned in CMIP6. The climate research community prides itself on its policy relevance[20]. For once, we have been asked a very specific question, so we need a very good reason indeed not to step up and answer it.

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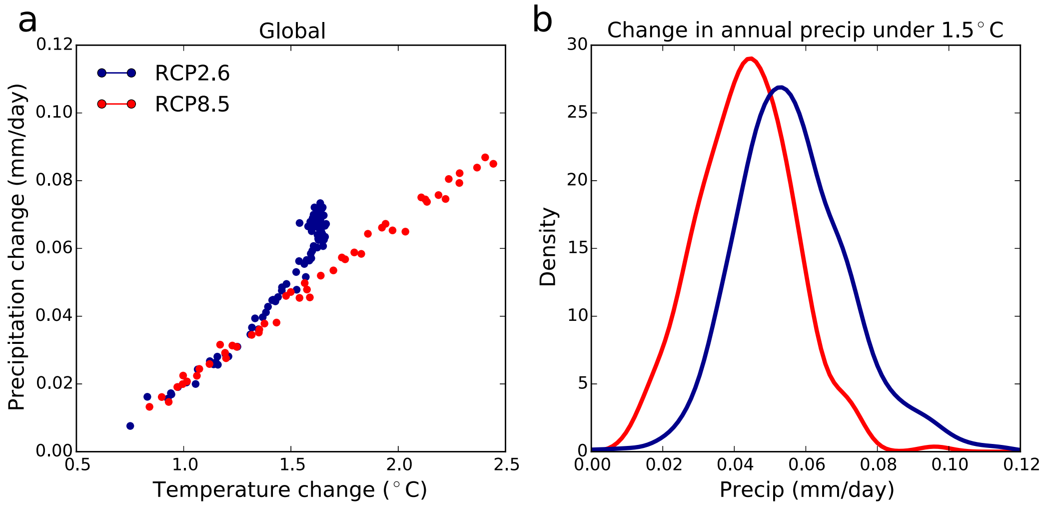

Figure 1: **Precipitation response to different Representative Concentration Pathways (RCPs).** (a) Changes in global mean precipitation (mm/day) verses changes in global mean surface temperature (°C) for annual-mean multi-model-mean data from CMIP-5. Data cover the period 2006-2100 for (blue) RCP2.6 and (red) RCP8.5. (b) Smoothed PDFs of precipitation change for all CMIP-5 models that have a global temperature response of between 1.35-1.65°C. All anomalies are relative to 1850-1900. Only the first ensemble member of each model is used.

References

1. UNFCCC. Report on the structured expert dialogue on the 2013-2015 review. 2015.
2. Tschakert, P.. "1.5 C or 2 C: a conduit's view from the science-policy interface at COP20 in Lima, Peru." *Climate Change Responses* 2.1 (2015): 1.
3. James, R *et al*. What difference does half a degree make? Progress in modeling regional climate responses to global warming targets. *WIRES.* In revision.
4. New, M. Four degrees and beyond: the potential for a global temperature increase of four degrees and its implications. Phil Trans R Soc 369 (2011).
5. Fischer, E., and Knutti, R. Anthropogenic contributions to global occurrence of heavy-precipitation and high-temperature extremes. *Nature Climate Change* 5.6 (2015): 560-564.
6. Schleussner, CF, *et al.* Differential climate impacts for policy relevant limits to global warming: The case of 1.5 and 2C. *Earth System Dynamics Discussions* 6.2 (2015).
7. Rogelj, J. and Knutti, R. *Geoscience after Paris.* (2016). 187-189.
8. Peters, G. *The best available science to inform 1.5C policy choices.* (2016)
9. Collins, M. *et al*. IPCC AR5, Chapter 12. (2013).
10. Hawkins, E., and Sutton, R. "The potential to narrow uncertainty in regional climate predictions." *Bulletin of the American Meteorological Society* 90.8 (2009): 1095-1107.
11. Otto, F. E., Frame, D. J., Otto, A., & Allen, M. R. (2015). Embracing uncertainty in climate change policy. *Nature Climate Change*.
12. Hulme, M. 1.5C and climate change after the Paris Agreement. *Nature Climate Change, 6, 222-234.* (2016).
13. Pendergrass, AG., et al. "Does extreme precipitation intensity depend on the emissions scenario?." *Geophysical Research Letters* 42.20 (2015): 8767-8774.
14. Ishizaki, Y., *et al.* Dependence of precipitation scaling patterns on emissions scenarios for representative concentration pathways. *J. Clim.* (2013).
15. Shiogama, H., *et al.* Emission scenario dependencies in climate change assessments of the hydrological cycle. *Climatic Change.* (2010).
16. Tebaldi, C. and Arblaster, J. Pattern scaling: Its strengths and limitations, and an update on the latest model simulations. *Climatic Change.* (2014). 459-471.
17. Pal, JS. and Eltahir, E. "Future temperature in southwest Asia projected to exceed a threshold for human adaptability." *Nature Climate Change* (2015).
18. Allen, M. "Liability for climate change." *Nature* 421.6926 (2003): 891-892.
19. Gasser, T., et al. "Negative emissions physically needed to keep global warming below 2 [thinsp][deg] C." *Nature communications* 6 (2015).

20. James, R, et al. "Characterizing loss and damage from climate change." *Nature Climate Change* 4.11 (2014): 938-939.