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Why are we uncertain about how extremely wet conditions will change in Australia in the future?

ARC Centre Of Excellence for Climate Extremes Briefing Note 3

The computer models used by scientists to simulate the global climate system agree that the climate will warm in response to increasing amounts of greenhouse gases in the atmosphere. However, a recent paper by Bador et al. (2018)[1] includes results that highlight our uncertainty about exactly how extremely wet conditions will change in Australia. Further development of Australia's national climate model, the Australian Community Climate and Earth-System Simulator (ACCESS)[a], may help to reduce this uncertainty.

Although global climate models have limitations, they are a key source of information underpinning projections of future climate conditions in Australia. All global climate models agree on future warming of the Australian climate. Data from simulations of over 50 models developed by over 20 research institutions around the world have been collated by the international Coupled Model Intercomparison Project phase 5 (CMIP5). However, gaps in our understanding of how the climate system works and limited computer power mean that the models are not perfect, and they simulate different future climate conditions when given the same assumptions about how the greenhouse effect may strengthen in the future. Nonetheless, all models agree that the Australian climate will warm in response to increasing amounts of greenhouse gases in the atmosphere, with the temperature inland increasing more than near the coast.

It is more difficult to use global climate models to give clear messages about how extremely wet conditions may change in Australia in the future. This is because the models are unable to simulate the behaviour of some of the key measures of extreme rainfall and there is disagreement between models on aspects of future changes in these measures. One such measure is the amount of rain falling on the wettest day of the year, typically abbreviated to "Rx1day"[b]. Overall, the CMIP5 models simulate future increases in the amount of rain falling on the wettest day of the year across most of the country[2]. However, individual models disagree on both exactly how Rx1day will respond to the strengthening greenhouse effect and on whether this response will be larger than changes on decade-to-decade and longer timescales due to natural variations in the climate[c]. The result is, although most of the models show future increases in Rx1day across large parts of Australia in response to the strengthening greenhouse effect, others show decreases, and some show changes smaller than those associated with natural climate

variability for most of the country.

Recent research has shed some light on this disagreement by beginning to unpick what drives changes in daily rainfall extremes over Australia. Like other studies[3], the Bador et al. (2018) paper shows the CMIP5 models agreeing on future increases in daily rainfall extremes across most land regions of the globe, especially in regions outside the tropics, such as most of Europe and North America. This agreement has been attributed to the atmosphere being able to contain more moisture as it warms[4,5]. However, in some regions, including Australia, future changes in rainfall extremes may also be strongly influenced by changes in the circulation of the atmosphere. These circulation changes are difficult to model and the CMIP5 models disagree on how they affect daily rainfall extremes over Australia. In addition, differences between the models in the computer programs that simulate convection in the atmosphere are also important. Atmospheric convection, the upward movement of moist air to form clouds and thunderstorms, is a key process responsible for heavy rain. There are different ways of representing convection in a climate model. Bador et al. (2018) show that there is some similarity in future changes in Rx1day over Australia between climate models with similar convection codes, while models with different convection codes tend to simulate different Rx1day changes.

To provide Australian decision makers with clearer messages about future changes in extremely wet conditions, we need a deeper understanding of the differences in the behaviour of the climate models over Australia, including the roles of the circulation of the atmosphere and atmospheric convection. This will require greater capability to model Australia's unique climate. The ARC Centre of Excellence for Climate Extremes is continuing to investigate the extent to which observations of the real climate can be used to establish which climate models produce the most reliable simulations of future changes in extreme rainfall. It is important that this effort be complemented by continuing development of ACCESS.

Explainers

a. The Australian Community Climate and Earth-System Simulator (ACCESS) has been developed by the Australian Bureau of Meteorology, CSIRO and a network of Australian universities. It is used by the Bureau of Meteorology to create weather forecasts for Australia. It can also be set up as a world-class global climate model, and is one of Australia's CMIP5 models. The model is undergoing continuous improvement and a more advanced version will be Australia's major contribution to the next phase of the Coupled Model Intercomparison Project (CMIP6). Developing ACCESS to improve the simulation of climate extremes is a priority for the ARC Centre of Excellence for Climate Extremes.

b. Although it is often short intense rainfall events that impact society (e.g. through flooding), to overcome limitations of both climate models and rainfall measurements, climate scientists have traditionally analysed the amount of rain falling in a day (i.e. 24-hour rainfall accumulations) to get a global picture of how rainfall extremes are changing. Our confidence in the ability of climate models to simulate sub-daily rainfall extremes may increase in the future as our understanding of the atmospheric processes that lead to intense rainfall improves and as increasingly powerful computers enable more detailed simulations to be run. However, the global coverage of sufficiently long records of measurements of rainfall accumulated over periods of less than one day is likely to remain limited.

c. There are large natural variations in Rx1day in Australia from year-to-year, decade-to-decade and on longer timescales. These can contribute to differences between climate model simulations and can be confused with changes due to the strengthening greenhouse effect. In their analysis of the CMIP5 models, Bador et al. (2018) have identified changes that are too large to be due to natural climate variability. They have determined the size of the natural variability in Rx1day in the models by examining long simulations where the amount of greenhouse gas in the atmosphere has been fixed at the level that existed in 1850, before the rapid increase over the last 100 years.

References

1. Bador, Donat, Geoffroy and Alexander (2018) Assessing the robustness of future extreme precipitation intensification in the CMIP5 ensemble. Journal of Climate. https://doi.org/10.1175/JCLI-D-17-0683.1

2. Alexander and Arblaster (2017) Historical and projected trends in temperature and precipitation extremes in Australia in observations and CMIP5. Weather and Climate Extremes. https://doi.org/10.1016/j.wace.2017.02.001

3. Fischer, Sedláček, Hawkins and Knutti (2014) Models agree on forced response pattern of precipitation and temperature extremes. Geophysical Research Letters. https://doi.org/10.1002/2014GL062018

4. Emori and Brown (2005) Dynamic and thermodynamic changes in mean and extreme precipitation under changed climate. Geophysical Research Letters. https://doi.org/10.1029/2005GL023272

5. Pfahl, O'Gorman and Fischer (2017) Understanding the regional pattern of projected future changes in extreme precipitation. Nature Climate Change. https://doi.org/10.1038/nclimate3287

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