climate extremes
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The Intergovernmental Panel on Climate Change 6th Assessment Report

A special briefing by the ARC Centre of Excellence for Climate Extremes

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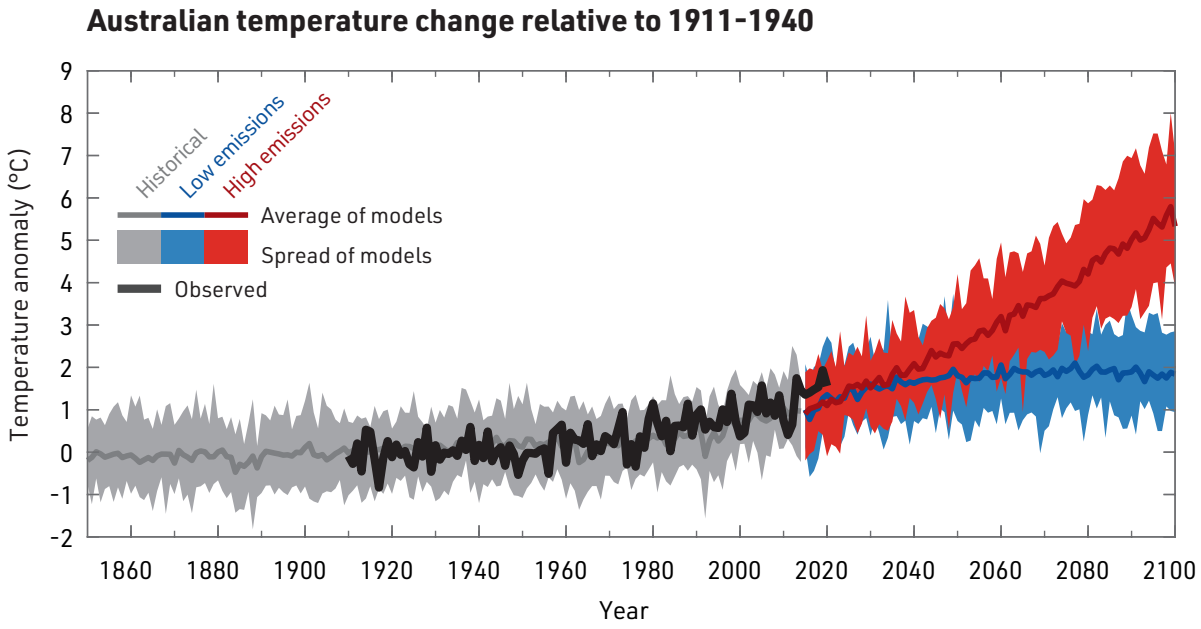
The 2021 report by Working Group 1 of the Intergovernmental Panel on Climate Change (IPCC), the 6th Assessment report (AR6), is a comprehensive assessment of the physical science associated with climate change. Australian researchers in the ARC Centre of Excellence for Climate Extremes have made major contributions to this report, through authorship of the report, review of the report and via the many scientific papers cited in the report. AR6 provides an assessment of thousands of scientific papers, each independently reviewed, and builds on earlier IPCC assessments in 1990, 1995, 2001, 2007, 2013, and three special reports released in 2018–2019. Scientific advances have enabled many statements on the causes and effects of climate change to be made with increased confidence in AR6 compared with previous reports.

The current state of our climate

- Global surface temperatures are now about 1.1°C higher than in 1850-1900 with human activities explaining the observed warming. Climate change is already affecting people across the world, particularly through worsening weather and climate extremes.
- Extreme heat and heatwaves have become more frequent and intense over both land[1,2] and the oceans[3,4]. For Australia, warming over land has exceeded 1.4°C and consequently heat extremes have increased[5].
- Globally averaged rainfall has increased since 1950, and the frequency and intensity of heavy rainfall has increased over most land areas where we have good observations[6], including Northern Australia[7].
- Human-induced climate change has increased droughts in some regions, including southern Australia.
- The risk of extreme events acting simultaneously (compound events, e.g. drought and extreme heat, conditions associated with extreme fire weather[8]) has increased in many regions, including Australia.
- Based on multiple lines of evidence, new science has improved our confidence that equilibrium climate sensitivity is between 2.5°C-4.0°C, with a best estimate of 3°C[9,10].
- The recent speed of global surface temperature increases and sea level rise are unprecedented over many thousands of years. Temperatures in the last decade are now warmer than at any time during the last 100,000 years.

Climate models

Global climate models are research tools based at their core on the laws of physics. To explore future climate, global climate models are run under a range of greenhouse gas emission scenarios. The global climate models are rigorously evaluated and have generally improved since the last IPCC assessment, including in their simulation of many elements of the Australian climate[11,12,13]. Some of the models assessed in AR6 simulate warming due to increases in greenhouse gases that are lower than expected based on multiple lines of evidence, while some simulate more warming than evidence suggests[14,15]. This has been widely reported in the scientific literature, and the causes of some models simulating too much warming has been traced to a cloud feedback that is too strong. Issues of this kind are taken into account when assessing future climate change. Moreover, the science community's concerns over global warming are not based on climate models alone; they are also based on observations, paleoclimate reconstructions and supported by scientific understanding. The basic recognition that the Earth's climate warms as greenhouse gases increase can be traced back to Fourier in the 1820s, Foote in the 1850s, Tyndall in the 1860s, Arrhenius in 1895 and Callendar in the 1930s. Robust projections for a given level of global warming allow assessments to be made independent of when that warming level is reached.



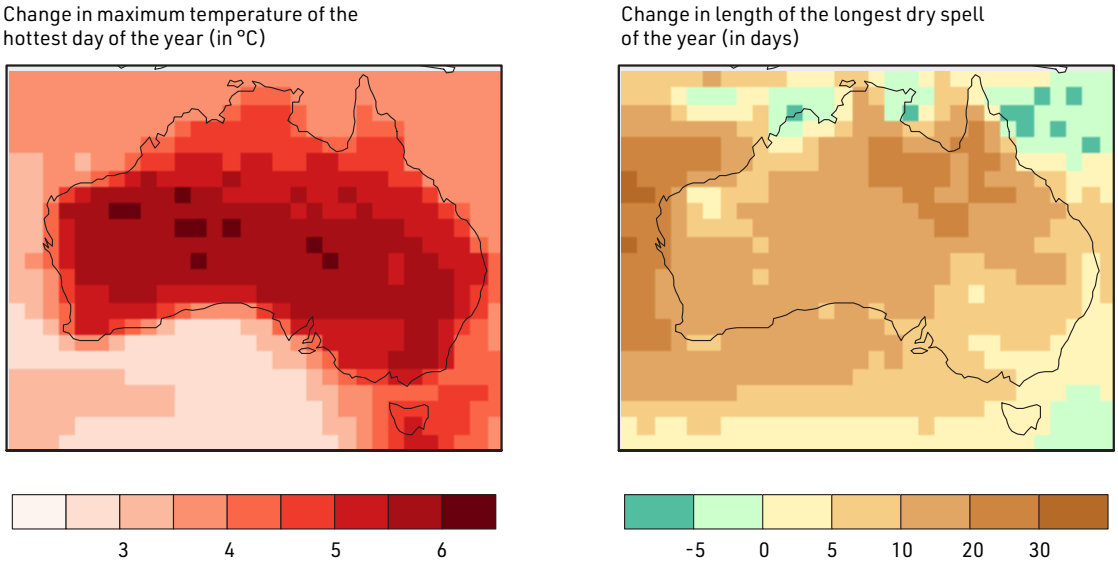
Adapted from article in *The Conversation* written by the ARC Centre of Excellence for Climate Extremes:
https://theconversation.com/yes-a-few-climate-models-give-unexpected-predictions-but-the-technology-remains-a-powerful-tool-165611

Figure 1 – Australian mean annual temperature changes 1850-2100 from climate model simulations (models that are thought to simulate warming above or below that expected based on multiple lines of evidence have been removed – see "Climate models" box). The observations are sourced from the Australian Bureau of Meteorology (ACORN-SAT v2).

Our future climate and consequences for Australia

- All regions, including Australia, will experience further increases in climate change impacts, and the frequency and intensity of these impacts increases with each increment of additional warming.
- Global surface temperatures will continue to rise until at least 2050 under all emission scenarios. The amount of warming globally depends on the amount of future global greenhouse gas emissions and the ability to deploy large-scale greenhouse gas removal from the atmosphere. The same is true for warming of Australia (Figure 1).
- Even under a very low emissions scenario (assuming global reductions in emissions from the 2020s reaching net zero emissions by 2050, and negative emissions thereafter) there is now less than a 50% chance of limiting warming to 1.5°C. If a very low emission future were achieved, temperatures could drop back to below 1.5°C by the end of the century (i.e. the warming is reversible).
- Under medium and high emission scenarios, the 2.0°C ceiling for warming under the Paris Agreement will be exceeded by around 2050.
- The effectiveness of natural carbon sinks into the ocean and land is expected to decrease in the second half of the century. Any reduced effectiveness of natural sinks would necessitate deeper cuts in human emissions to stabilise global temperatures.
- The positive effects of a low emission future as distinct from a high emission future (e.g. reduced warming and smaller changes in many extremes) would become clearly evident within around 20 years, and are large by the end of this century.
- Further increases in climate extremes, relative to those already observed[16], are inevitable. The intensity and frequency of most extremes get worse at higher levels of warming[17],[18]. The increased intensity of heatwaves is larger than the associated increase in global average temperature, and increasing numbers of extreme events that are unprecedented in the observational record can be expected even if warming is limited to 1.5°C.
- For Australia these changes imply increases in many climate extremes[19] including increased risk of ecological and agricultural drought[20], more intense short-duration rainfall[21], less frequent but more intense tropical cyclones, intensifying land[22] and marine heatwaves[23,24], and an increase in the intensity, frequency and duration of fire weather[25]
- For Australia, under a high emissions scenario, an increased vulnerability associated with sea level rise is projected, with the potential loss of 50-200 metres of shoreline along sandy coasts.
- Figure 2 shows climate model estimates of changes in climate indices related to extreme heat and drought by the end of the century under a high emissions future.

Climate model estimates of changes in Australian climate extremes by 2080-2099 for a high emissions scenario



Adapted from Grose et al. (2020). Insights from CMIP6 for Australia's Future Climate. Earth's Future. https://doi.org/10.1029/2019EF001469

Figure 2 – Projections of changes in Australian climate extremes by the end of the century for a high emissions scenario, generated using a large number of climate models[26].

- A key risk to Australia is that rainfall variability associated with the El Niño-Southern Oscillation is very likely to increase in the second half of the century[27,28], leading to more very wet and very dry years. This risk is mitigated under very low emission scenarios.
- A further risk to Australia is a continued southward (poleward) shift of the storm tracks[29] which would lead to continued wintertime drying in southern Australia[30]. This risk is minimised in summer due to the offsetting effects of ozone recovery and reduced under very low emission scenarios.
- Sea level rise will continue, but the speed of change is dependent on the emission scenario. While likely limited to 1 metre this century, an increase of 5 metres by 2150 cannot be excluded if very high greenhouse gas emissions continue.
- Sea level rise is now irreversible even if warming is limited to 1.5°C, and will continue for centuries to millennia due to committed changes in the deep ocean and ice sheets.
- Risks to Australia's climate and coasts associated with ice sheet collapse and abrupt changes in ocean circulation, which would have catastrophic consequences, cannot be discounted and their chances of occurring increase under higher emission scenarios.
- Ocean acidification and ocean deoxygenation will continue to worsen and are probably irreversible on timescales of centuries to millennium.

Actions required to achieve Paris targets

There is a near-linear relationship between the cumulative emissions of CO_2 by humans and global warming. This allows a carbon budget to be defined for a given warming target, with the proviso that this budget depends on assumptions including climate system feedbacks.

- To limit warming to 1.5°C with a high probability (80%), there is about 300 billion tonnes of CO_2 left in the global carbon budget. This would be fully spent in 7–8 years at current rates of emissions.
- Limiting warming to 2°C with a high probability (80%), there is about 900 billion tonnes of CO_2 left in the global carbon budget (22 years at current rates of emission).
- Large-scale deployment of carbon removal methods, if feasible, could extend these timelines, but have the potential to have wide-ranging effects on water availability and food production and will be partly compensated by changes in natural sinks.
- Low and very low emission pathways that give a good chance of meeting the Paris Agreement temperature targets also assume negative emissions from the middle of this century, with more CO_2 being drawn out of the atmosphere than is emitted.

Overall, the AR6 report is an important step in further solidifying our understanding of climate risk. The conclusions of the report echo strongly previous reports that near immediate and very deep cuts to greenhouse gas emissions are now overdue and any further delay commits us to an escalating risk of climate extremes. At a global scale, current commitments to reductions in emissions remain too small, and the reduction in emissions too slow, to avoid in excess of 2°C warming and multiple consequences to the climate of Australia[31].

References

The ARC Centre of Excellence for Climate Extremes has contributed to a large number of scientific papers that support the conclusions of the report, a selection of which are listed below. Further details of some relevant issues can also be found in the Centre briefing notes also listed below.

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