Climate Systems

National Environmental Science Program

What makes flash droughts different: understanding how Australian droughts develop

Challenging traditional understanding of how long it takes for droughts to develop

- The time agricultural droughts take to develop can vary – in Australia flash droughts typically take around 2–3 weeks to onset while conventional droughts take around 4–5 weeks.
- Flash droughts are more likely to develop when unusually low rainfall and humidity combine with intense solar radiation and a higher atmospheric demand to draw out moisture from soils.
- Australia's flash droughts tend to typically last for about 2 months, and often run longer than in many other parts of the world.
- A warmer future will lead to more evaporation. This calls for appropriate consideration of the risk of flash droughts in future planning and preparedness activities.

Generally, drought occurs when there's not enough rain. Known as meteorological droughts, if sustained, these kinds of droughts can have cascading impacts on the environment leading to a lack of water in rivers and soils. In cases where meteorological drought conditions translate to an abnormal reduction in the availability of water in the soil, the result may be known as an agricultural drought, also called a soil moisture drought.

Droughts can impact agriculture, ecosystems, industry, water resources and communities. Traditionally, droughts are viewed as slow-developing phenomena, described as taking months or longer of below average rainfall to onset, and with drought conditions remaining anywhere from months to years (referred to as conventional droughts here). Recent research by the Climate Systems Hub has identified that droughts can often develop more quickly than previously thought. Instead of taking months to reach and sustain drought conditions in soil, it takes just weeks. Soil moisture droughts that develop over a relatively short period of time compared to what is typically expected of a conventional drought are known as `flash droughts.' These flash droughts are different from a typical short period of unusually low rainfall, in that they last relatively longer, resulting in significant on-ground impacts.

Like conventional soil moisture droughts, these rapid-onset flash droughts, through sudden soil moisture depletion, can lead to vegetation stress, crop losses, higher food prices, and even compounding risks of dust storms, bushfires and heatwaves.

Current hub research has looked at how quickly we transition into droughts in Australia and under what conditions droughts, including flash droughts, develop. This is becoming increasingly important as drought conditions in Australia change under a warming climate.

Building on previous hub research which investigated flash drought likelihood across Australia and its links to evaporation, our current hub project looked at how quickly flash droughts develop across different parts of Australia and what makes flash droughts different from the more slowly developing, conventional droughts.

How quickly can we transition into droughts in Australia?

Global studies describe flash droughts as having an onset period of 2 to 12 weeks (Pendergrass et al., 2020, Ford et al., 2017, Neelam et al., 2024). We wanted to test whether this applied to regions in Australia by understanding the typical rate at which soils transition into drought conditions.

To address this, we analysed soil moisture data from across the country over a 29-year period, from 1990 to 2018, to understand the rate at which the soil moisture declines from near normal conditions to abnormally dry conditions, with abnormally dry being defined relative to a location's climatology.

Our findings showed that the rate of drought onset varies across the country but is much quicker than our traditional perception.

Most locations transition from near-normal (above the 40th percentile) to sustained drought conditions (at or below the 20th percentile) in just three to four weeks, with some regions in as little as two weeks (Figure 1a).
In parts of southwest, south, southeast, and northern Australia, soil moisture drought conditions typically develop within 15–20 days, while central Australia and the east coast have slightly longer onset times of around 20–30 days. In some instances, those drought conditions are sustained for several months. Some of the fastest onset droughts take as little as two to three weeks at most locations (Figure 1b). Again, the most rapid drought onset times were in parts of the southwest, south, southeast, and northern Australia, at approximately 10–15 days (as illustrated by the brown and dark orange shades on the map); while the rate of rapid onset in central Australia and parts of the east coast were around 20 days.

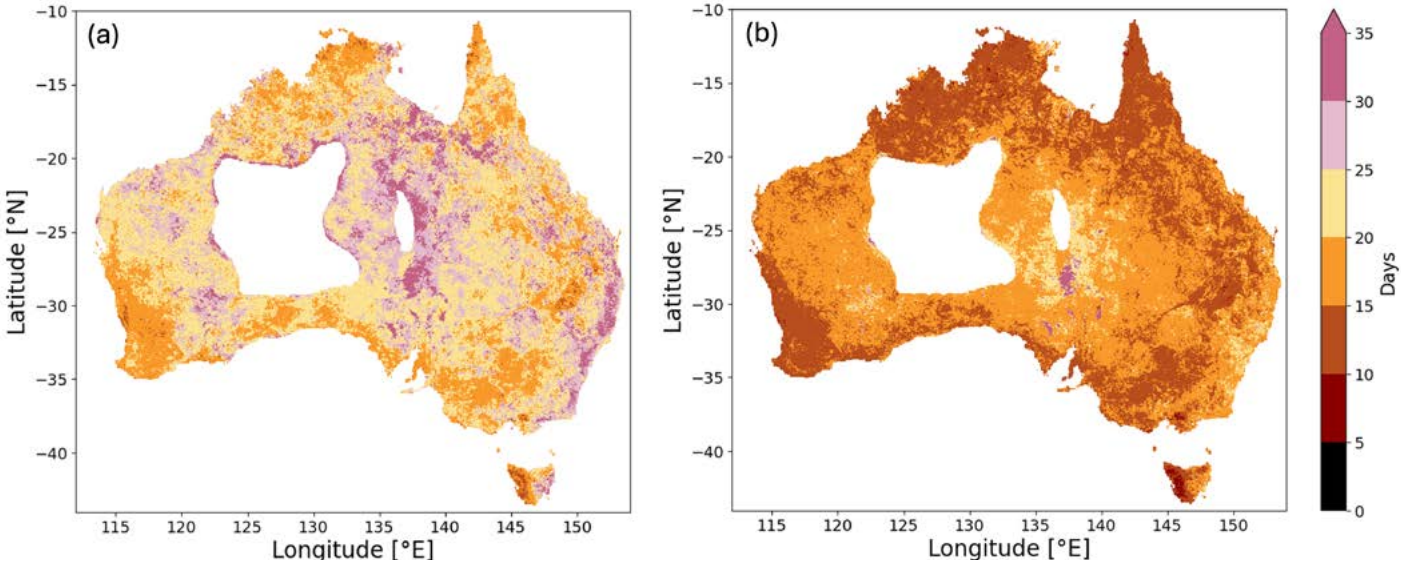


Figure 1: Spatial patterns of the (a) median and (b) the top 10% (i.e. most rapid) of the time to drought onset over Australia using root zone soil moisture data from the Australian Water Resource Assessment Landscape model (AWRA-L), Bureau of Meteorology (Frost et al, 2018). Drought onset is defined as the period in which root zone soil moisture changes from being near-normal (i.e. above the 40th percentile) to well below normal (i.e. at or below the 20th percentile). Areas in white represent regions with insufficient observations and were excluded from the analysis.

These results demonstrate that Australia's soil moisture typically dries quickly, faster than those rates of flash droughts that are reported from studies carried out in other parts of the world. This can also be because such studies often assume that a drought event that takes less than 15 days to onset does not have the potential to persist for a sufficiently long period to cause detrimental impacts. However, our study shows that is not the case. That is, drought events of shorter onset periods can also last sufficiently longer and can have severe impacts.

Are flash droughts a 'flash in the pan'?

Generally, soil moisture takes less time to recover to near-normal levels during flash droughts compared to conventional droughts. Our research shows that flash droughts tend to typically last for about 60 days, whereas conventional droughts tend to last around 100 days. The duration of flash droughts in Australia is notably longer than in other parts of the world, where flash droughts may often end around 10 days after they start (Liu et al., 2023).

Which regions in Australia are most susceptible to flash droughts?

The area of Australia impacted under a conventional drought (Figure 2a – green bars) is larger than the area typically impacted by flash drought when they occur (Figure 2b – blue bars). Zooming in on five notable instances of flash drought, corresponding to the vertical lines in Figure 2b, we see that the spatial extent impacted by flash droughts can still be substantial.

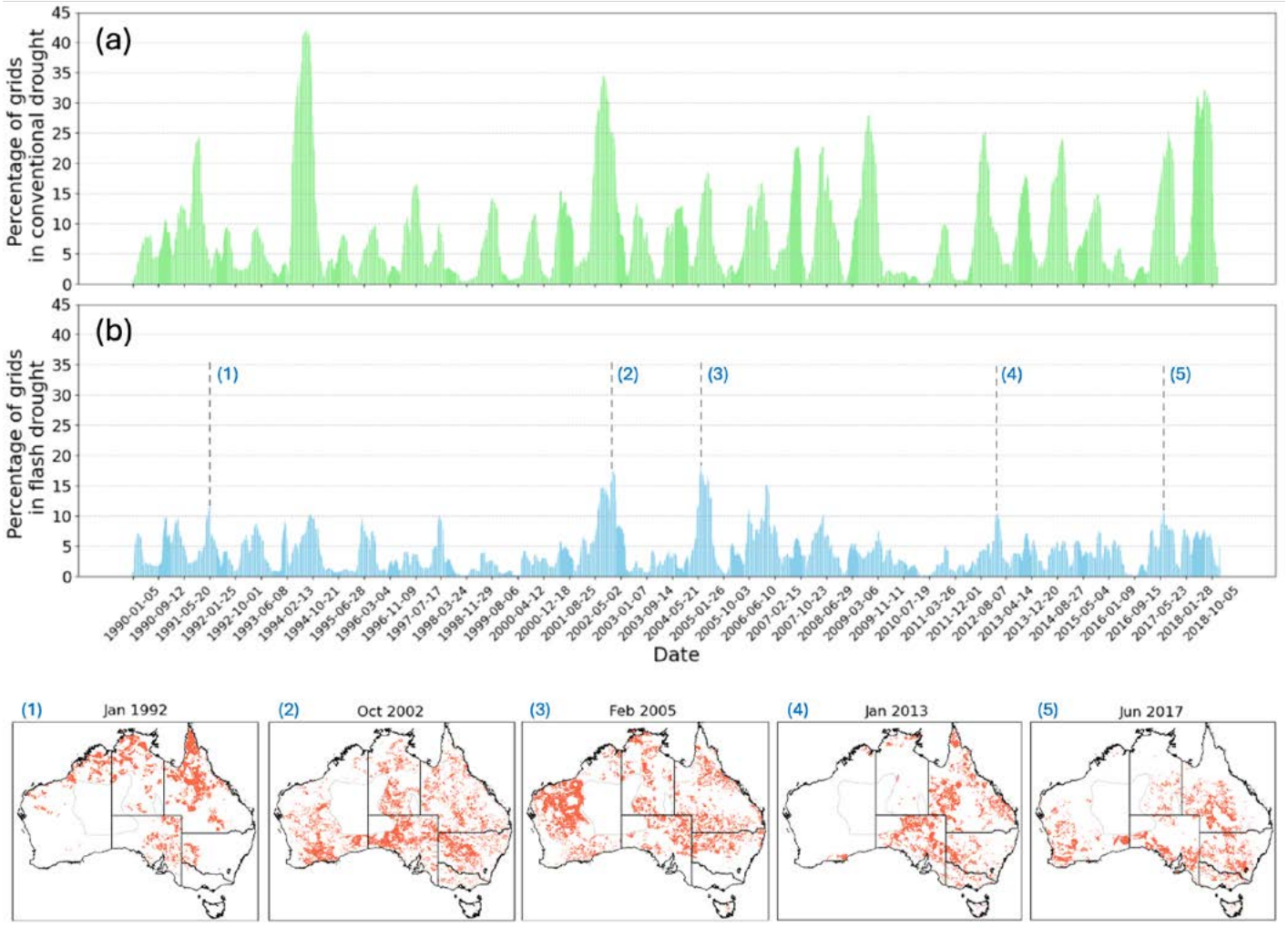


Figure 2: The top two horizontal panels show the percentage of Australia experiencing a conventional drought (panel (a) – in green) and a flash drought (panel (b) – in blue) during the period 1990 to 2018. The bottom panel (c) shows the regions within Australia that were in flash droughts at five sample points in time that correspond to the dotted vertical lines, numbered 1 to 5 in panel (b) above the maps.

Certain regions in Australia proved more prone to flash droughts than others, and for different durations. Along the east coast, flash droughts have an onset period of around 15 days but typically last more than 2 months from the start of the drought to the time the soil recovers (i.e. soil moisture levels return to normal).

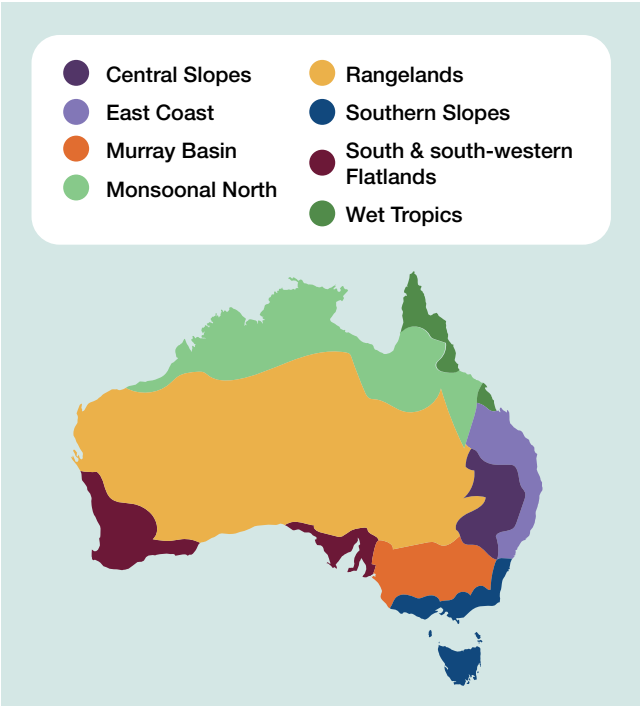
In contrast, northern tropical regions experience faster onsets, around 10 days, and quicker recoveries, with the overall time spent in the drought often less than 2 months.

The southwest of Australia is a significant hotspot for both conventional and flash droughts. Hub research showed that in this area, droughts develop rapidly, are more frequent, and have extended recovery times (Table 1).

These results highlight the importance of location-specific information of drought characteristics for decision makers to help prepare for these events.

Table 1: The differences between characteristics of flash drought and conventional drought for 8 Natural Resource Management (NRM) regions across the country, highlighting the typical duration of onset (i.e. how fast soil moisture changes from near-normal to drought conditions), the total duration (i.e. how long soil moisture deficits are maintained) and the dominant season in which each type of event begins. The location of the 8 NRM regions are shown in the image below the table.

NRM region	Median onset duration (days)		Total event duration (days)		Dominant season	
	Conventional drought	Flash drought	Conventional drought	Flash drought	Conventional drought	Flash drought
Central Slopes	30	15	100	50	autumn, winter	summer
East Coast	30	15	110	65	autumn, winter	summer
Murray Basin	30	10	85	55	winter	autumn
Monsoonal North	30	10	125	50	autumn	summer
Rangelands	30	15	85	50	autumn, winter	summer
Southern Slopes	30	15	100	75	autumn, winter	summer, autumn
South and south-western Flatlands	25	10	75	50	summer, winter	autumn
Wet Tropics	30	10	100	45	autumn	summer, autumn
Australia (all regions)	30	15	85	50	-	-



Through this research, engagement with the Bureau of Meteorology's Hydrological Services experts also raised questions about droughts in hydrological systems. Ongoing, aligned engagement has led to research into the existence of rapid declines in streamflow levels leading to hydrological droughts. This new research is investigating streamflow records from undisturbed perennial catchments across Australia to establish how rapidly streamflow can change.

Preliminary findings show that rapid transitions from near normal to low streamflow states can occur in as little as 2 weeks, with typical reductions (as measured by the median reduction) of nearly 60% when these rapid transitions occur.

What causes some droughts to develop more rapidly?

Drought onset is often characterised by complex combinations of departures from regular atmospheric or weather conditions. This includes unusually low rainfall, low humidity, and reduced cloud cover, which can combine to make a 'thirsty' atmosphere.

Faster transitions to soil moisture drought, as in the case of flash droughts, are notable for greater extremes of these atmospheric irregularities during the onset period compared to conventional droughts. For example, very low rainfall, very low humidity and low cloud cover conditions led to flash droughts in the years 2000 and 2006 in parts of southwest Western Australia. Our research shows that, more often than not, during the onset of a flash drought, there is a heightened atmospheric demand for moisture which is drawn out from the soil. This is primarily driven by low humidity and intense solar radiation.

These types of conditions accelerate soil moisture depletion, intensify vegetation stress, and provide little opportunity for warning land managers. The two main types of mechanisms that can lead to a flash drought onset are: 1) precipitation deficit, where abnormally low precipitation is the main driver, and 2) evaporation, where precipitation deficits accompanied by abnormally high evaporation are the main drivers (Figure 4). What this also suggests is that some land and water managers might not be able to realise a flash drought is underway if they only rely on monitoring rainfall. This is particularly applicable if a flash drought happens in that part of the year when it is not expected to rain a lot, where the rapid loss in soil moisture is primarily due to enhanced evaporation-driven loss of soil water.

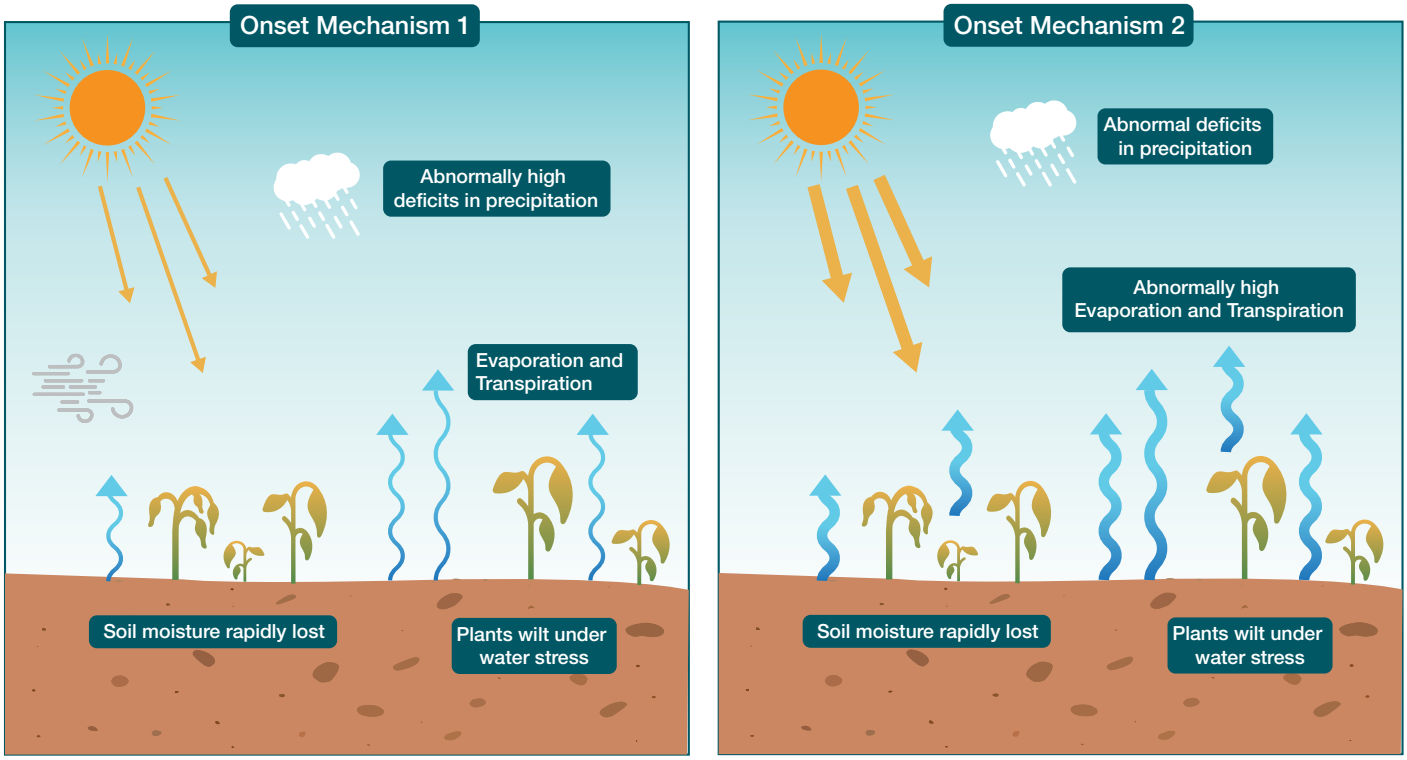


Figure 4: Illustration of the two main mechanisms that can cause a flash drought to onset. The left panel illustrates the precipitation deficit mechanism, while the right panel illustrates the high evaporation mechanism (see text for details).

How does this research help manage drought risks?

Understanding drought onset timescales, characteristics, and the physical drivers of flash and conventional droughts are important to inform the sort of reliable early warning systems needed. For Australia, a typical onset period of 30 days for conventional droughts means there is often limited time for land and water managers, to prepare. This time is even shorter for flash droughts, increasing the importance of timely and accurate information.

Traditional definitions and metrics for drought warnings use monthly scale data, which our research shows may be less reliable in capturing the faster–onsetting drought conditions. Knowing more about the time frames over which a region may dry, and what contributes to the drying, may help improve the indices used to identify drought onset in regions that may dry quickly, or where conventional drying may be speeding up with climate change. This is important to ensure land and water management approaches are more resilient to future droughts and are better equipped for handling the knock-on effects of these events.

Future considerations

Following on from this research, a number of future areas to investigate have been identified, including to:

- Make improvements to enable better predictability of droughts, particularly ones with rapid onset.
- Improve drought metrics so they can more reliably capture the onset of Australian droughts.
- Develop a more detailed understanding of the dominant mechanisms leading to droughts.
- Quantify the differences in the impacts caused by flash droughts compared to conventional droughts, to understand how impacts amplify when droughts happen more quickly.
- Understand the causes of rapid soil moisture depletion in croplands, when there is an increased uptake of soil water in the growing season combined with lack of precipitation.

Further studies could assess a greater number of longer datasets, preferably 50 years or more, to not only corroborate the results discussed above but also investigate trends in the occurrences of flash drought events. Additionally, validating trends through ground-truthing—such as using local soil moisture probe data from the Agriculture Victoria Soil Moisture Probe Network or other examples—would enhance and complement the findings.

The findings discussed here are based on soil moisture analysis from the Bureau of Meteorology's AWRA-L model, which has its own limitations. For example, AWRA-L is suggested to perform much better for perennial pastures than for some cropping regions. The reliability of the model to simulate soil moisture accurately at a local spatial scale (for example at the farm level) is also not likely to be as high.

Overall, improving soil moisture modelling and observations will significantly enhance the characterisation of flash droughts.

For more information:

www.nesp2climate.com.au | info@nesp2climate.com.au

Cite this article as:

Goswami, P., Gallant, A. J. E., Chung, C., Bloustein, H., Dalla Pozza, R., & Evans, H. (2025). What makes flash droughts different: understanding how Australian droughts develop. National Environmental Science Program Climate Systems Hub, Govt. of Australia.

References

Ford, T. W., & Labosier, C. F. (2017). Meteorological conditions associated with the onset of flash drought in the eastern United States. Agricultural and forest meteorology, 247, 414–423.

Frost, A., Ramchurn, A., & Smith, A. (2018). The Australian landscape water balance model 654 (AWRA-L v6). Technical description of the Australian water resources assessment 655 landscape model version, 6.

Liu, Y., Zhu, Y., Ren, L., Singh, V. P., & Yuan, S. (2023). Flash drought fades away under the effect of accumulated water deficits: the persistence and transition to conventional drought. Environmental Research Letters, 18(11), 114035.

Goswami, P., & Gallant, A. J. E. (2025). Understanding drought onset: what makes flash droughts different from conventional droughts? Weather and Climate Extremes (https://doi.org/10.1016/j.wace.2025.100782).

Neelam, M., & Hain, C. (2024). Global flash droughts characteristics: Onset, duration, and extent at watershed scales. Geophysical Research Letters, 51(10), e2024GL109657.

Mo, K. C. (2011). Drought onset and recovery over the United States. Journal of Geophysical Research: Atmospheres, 116(D20).

Pendergrass, A. G., Meehl, G. A., Pulwarty, R., Hobbins, M., Hoell, A., AghaKouchak, A., . . . others (2020). Flash droughts present a new challenge for subseasonal-to-seasonal prediction. Nature Climate Change, 10 (3), 191–199.

The Climate Systems Hub is funded by the Australian Government under the National Environmental Science Program, with co-investment from the following partners: