Earth Systems and Climate Change Hub

National Environmental Science Programme

Thunderstorms and climate change in Australia

Thunderstorm over city

> There is no clear trend in thunderstorm occurrence in Australia over the past decades based on the available observations.

> Extreme rainfall caused by thunderstorms is likely to increase in intensity resulting in increased flood risk factors in some cases.

> Climate models indicate a potential increase in future thunderstorm frequency for parts of eastern Australia, with uncertain changes for other regions of Australia.

Thunderstorms are relatively small-scale weather systems, characterised by strong updrafts of relatively warm, moist air. They can cause hazards such as lightning, hail and tornadoes as well as extreme winds, rainfall and flash flooding.

Thunderstorm hazards can result in severe impacts for Australia, including loss of life, damage to property and disruption to power networks. Lightning during thunderstorms can ignite bushfires and directly cause human injury and death. Severe hailstorms, such as the Sydney hailstorm of 1999, rank among the most expensive weather events for Australia in terms of insurance losses. Consideration of thunderstorm hazards is therefore important for sectors such as emergency services, health, energy, finance and insurance.

The costs associated with extreme weather hazards and disasters, including those caused by thunderstorms, are likely to change in the future due to increasing greenhouse gas emissions. Understanding extreme weather hazards and how they may change as the climate continues to warm is valuable for increasing Australia's preparedness and resilience to such events.

Researchers in the Earth Systems and Climate Change Hub are developing improved resources on thunderstorms and how they may change in the future to help us plan for and deal with climate change with greater confidence.

Characteristics of thunderstorms in the current climate

Thunderstorms occur predominantly during the warmer months of the year, with more activity towards the north and east of the continent.

There are some exceptions to this, including a localised region of enhanced thunderstorm activity that occurs during the cooler months near the central east coast of Australia. East coast lows (a type of cyclone that occurs around the east coast region) can also occur together with strong thunderstorms during winter, often leading to more extreme weather conditions.

Observations of thunderstorms and associated hazards (including hail and tornadoes) are generally not consistent throughout different regions of Australia. However, satellite observations of lightning activity can be used to provide a consistent climatology of thunderstorm conditions for Australia.

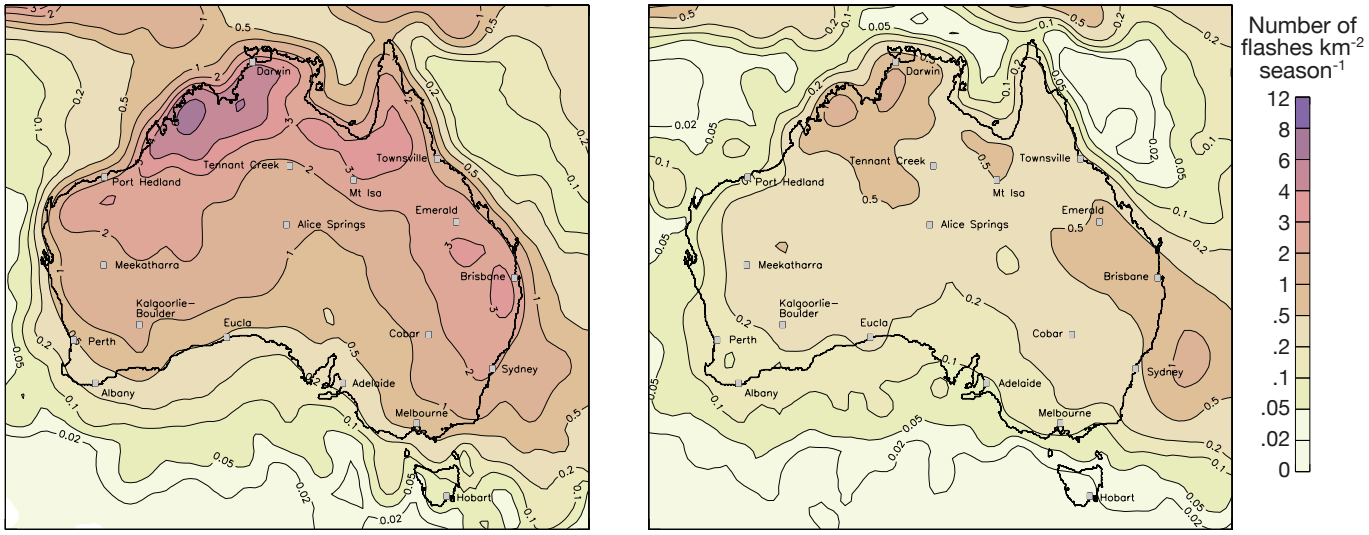
Thunderstorms can sometimes occur together with other weather systems such as cyclones or cold fronts. These 'compound events' can lead to a higher risk of extreme weather occurring (e.g. extreme rainfall and damaging winds). This is particularly important in the mid-latitude regions of the world, including Australia.

Thunderstorms are a leading cause of extreme rainfall in many parts of Australia, especially when they occur simultaneously with other weather systems. For example, a 'triple storm', which includes a thunderstorm, cyclone and front occurring together, is one of the most frequent causes of extreme rainfall around eastern Australia.

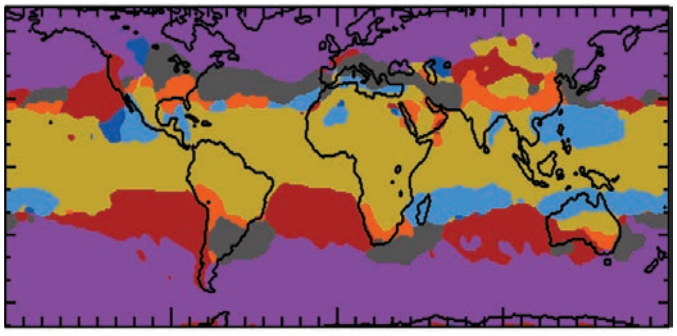
Radar observations around Australia indicate that there is more hail activity during the warmer months of the year than the cooler months, with a peak in hail activity around the start of summer (from about October to February). Subtropical northern regions and eastern regions of Australia generally have more hail events than southern and western regions. These results, based on radar observations around Australia, provide general guidance on broad-scale climatological patterns of hail variability. Additional observations in coming years will also help further improve confidence in these results.

Average warm season lightning density

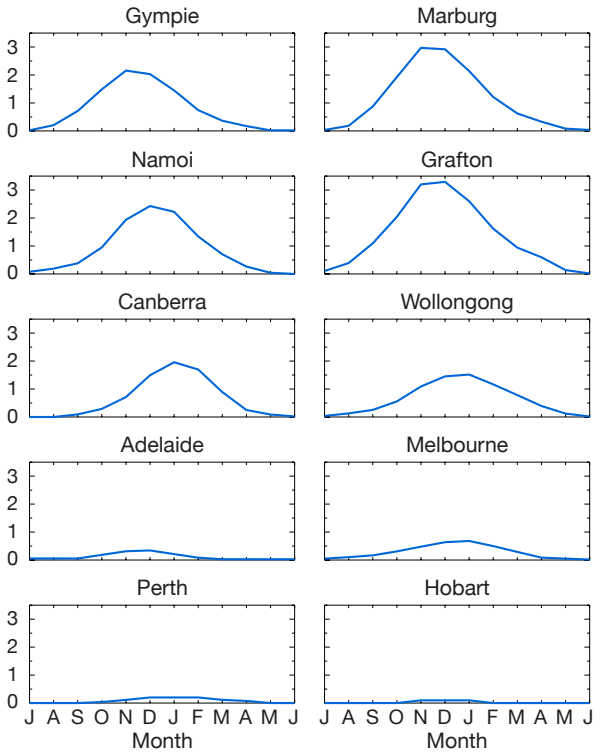
Average cool season lightning density



ABOVE: **Thunderstorm climatology for Australia, as indicated by satellite observations of lightning.** Cloud-to-ground lightning flashes (average number per square kilometre) are shown based on satellite observations over the years 1995–2012. This is shown individually for warm (left panel: November–April) and cool (right panel: May–October) periods of the year.



ABOVE: **The most frequent causes of extreme precipitation.** Types of weather events that most often cause extreme rainfall in a given location, representing combinations of thunderstorms, cyclones, and fronts occurring simultaneously with each other. The compound events, which comprise more than one type of weather system, do not occur very frequently but they account for a high number of extreme weather events.



ABOVE: **The average number of days with hail activity as indicated by radar data.** This is shown for each month, using observations within the period from 1997 to 2018 (with the available period ranging from about 7 to 22 years at these locations).

Long-term trends in thunderstorms and their associated hazards in Australia (such as hailstorms and extreme winds from downbursts or tornado events) are difficult to determine based on observations, primarily due to a lack of suitable data that is consistent over time for different regions of Australia. However, lightning observations based on long-term station records show some indication of a recent decrease in frequency of thunderstorms for southern Australia during the winter months. Uncertainty remains around whether these changes in lightning characteristics are associated with human-caused or natural influences on the climate.

Thunderstorm activity in a changing climate

Currently available modelling techniques are not able to directly simulate thunderstorm activity due to the small spatial and temporal scales required to model thunderstorm processes. Future projections have been produced in some studies based on assessing changes in larger-scale indicators of atmospheric conditions favourable to thunderstorm occurrence. Some projections indicate an increase in the frequency of severe thunderstorm environments for parts of eastern Australia. Due to the wide range of factors influencing convective processes as well as the limitations of available observations and modelling capabilities, these large-scale projections methods could be explored further to determine if they produce robust results in relation to various thunderstorm hazards.

Lightning that is accompanied by relatively little rainfall, known as 'dry-lightning', is a major cause of bushfires that can burn large areas of land in Australia. Although some methods have been developed to enable dry-lightning risk to be examined based on climate model output, the confidence in future projections of dry-lightning risk remains relatively low. This continues to be an active area of research.

There is some evidence based on observations that climate change has increased the intensity of extreme rainfall events in Australia. Global warming can influence the occurrence of extreme rainfall, as the capacity of the atmosphere to contain water vapour increases by about 7% per degree of warming. Short-duration (e.g. hourly) extreme rainfall events produced by thunderstorms could potentially increase in intensity by more than this rate of 7% per degree of warming, as the additional moisture in the atmosphere may also cause more intense convection for thunderstorms. Short duration rainfall intensity could increase by about 15% per degree of warming, noting that there are a range of plausible values both above and below this rate. An increase in flash flooding risk is therefore also possible, particularly for urban environments where soil moisture may have less influence on flood risk factors.

Tools, data and further information

- Climatology data for lightning ground flashes available from: **http://www.bom.gov.au/jsp/ncc/climate_averages/thunder-lightning/index.jsp?maptype=otdg#maps**
- Information on trends in lightning activity in Australia: **https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/2014JD023011**
- The influence of El Niño, and other large-scale conditions, on lightning and thunderstorm seasonal variations and predictability: **https://www.nature.com/articles/srep20874.pdf**
- Information on compound storms types (thunderstorm, cyclones and fronts) and the extreme rainfall and winds they cause: **https://www.nature.com/articles/srep40359.pdf**
- Extreme weather research under Project 2.8 of the Earth Systems and Climate Change Hub – including links to a variety of research publications on this topic: **http://nespclimate.com.au/extreme-weather-projections/**
- Bates BC, Dowdy AJ, Chandler RE. 2017. Lightning prediction for Australia using multivariate analyses of large-scale atmospheric variables. *Journal of Applied Meteorology and Climatology*, doi: 10.1175/jamc-d-17-0214.1
- Terrasson A, McCarthy N, Dowdy AJ, Richter H, McGowan H, Guyot A. 2019. Weather radar insights into the turbulent dynamics of a wildfire-triggered supercell thunderstorm. *Journal of Geophysical Research – Atmospheres*, https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2018JD029986

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