



Queensland rainfall—past, present and future



Historically, Queensland has had a variable climate, and recent weather has reminded us of that fact. After experiencing the longest drought in recorded history, Queensland is now emerging from one of the wettest years on record.

Heavy rains over the 2010–11 summer period resulted in almost the entire state being activated under joint State

and Commonwealth government natural disaster relief and recovery arrangements.

Two of the strongest cyclones to have crossed the Queensland coast—Yasi and Larry—have also hit in the past five years.

Failure to adapt to climate change has the potential to severely impact on the lives of Queenslanders.

Statistics on Queensland

- Queensland’s rainfall varies substantially from year to year and decade to decade. El Niño and La Niña events explain about 25 per cent of these variations. Tropical cyclones and variations in coastal wind direction are also important drivers of rainfall.
- There is no clear long-term trend in annual or seasonal-mean rainfall in Queensland over the last 100 years—the period for which we have reliable rainfall records.
- The total annual rainfall in Queensland depends primarily on the number of days with heavy rain (more than 25 mm). The number of intense events varies significantly from year to year.
- This dependence on heavy rainfall explains why Queensland experiences such intense floods and droughts: the state is highly sensitive to relatively rare, variable and intense rainfall.
- As greenhouse gases continue to increase in the atmosphere, Queensland could experience a markedly shorter rainfall season and considerably more intense rainfall events.

Managing the risks from climate— a partnership approach

Queensland's economy relies heavily on sectors such as tourism, livestock and other agriculture, which are vulnerable to both natural variations in rainfall and shifts in rainfall due to climate change.

To design adequate strategies for managing climate impacts and reducing the risk of harmful climate change, it is essential that we first understand the causes of natural rainfall variations and the potential effects of climate change.

Scientists from the Department of Environment and Resource Management's Queensland Climate Change Centre of Excellence (QCCCE) have been working in partnership with the Walker Institute for Climate System Research at the University of Reading,

United Kingdom (UK) to improve understanding of Queensland's rainfall, how and why it has varied and how rainfall may in change in future decades.

From 2009 to 2012, Dr Nicholas Klingaman, a research scientist with the UK's National Centre for Atmospheric Science-Climate and the Walker Institute, has worked with scientists from QCCCE to investigate rainfall in the state.

The Walker Institute is a world leading climate research centre established by the University of Reading in the UK.

These research findings will be used to help inform state government and business about the risks posed by climate variability and climate change.



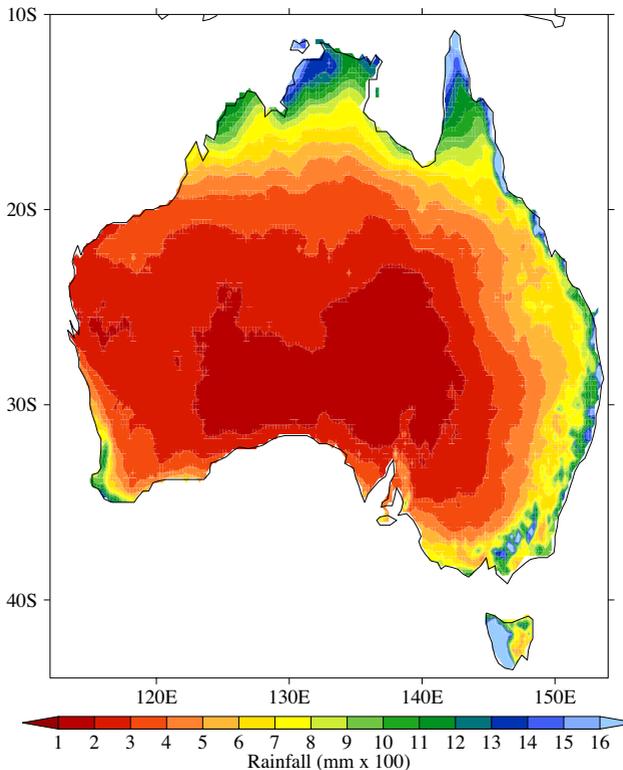
Dr Nicholas Klingaman



About Queensland's climate

The majority of Queensland's rainfall occurs in summer (December-February). Far North Queensland receives 800-1200 mm during this season, most of which comes from the monsoon winds bringing tropical moisture from ocean to land. Summer rainfall totals are lower in southern Queensland, as this region lies on the edge of the monsoon circulation, but still often exceed 500 mm.

In spring and autumn, extra-tropical coastal low pressure systems from the south can bring rainfall to central and southern Queensland. Winter and spring are very dry seasons in the north, where the monsoonal circulation reverses and warm, dry southerly winds blow from the interior of Australia. The Pacific south-easterly trade winds produce rainfall along the eastern coast throughout the year.

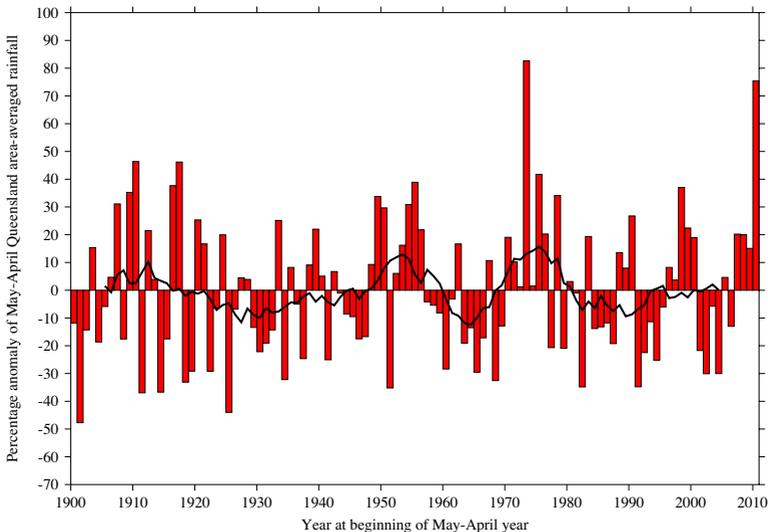


Annual-total rainfall in mm, derived from the Specialised Information for Land Holders (SILO) gridded gauge dataset.

How and why has Queensland rainfall varied in the past?

There are no clear trends in annual-total Queensland rainfall over the 20th century. Most striking in the rainfall record is the considerable natural variability from year to year and from decade to decade.

The late 1990s and early 2000s were generally a dry period in Queensland, particularly in summer. Comparable dry periods can be seen in the record in the 1930s and 1960s. It is likely that none of these 20th and 21st century dry periods were as severe as the Federation Drought of 1896-1902.



The red bars show the percentage deviation of each year's rainfall from the long-term (1900-2010) average. The black line (11 year moving average) demonstrates decade-to-decade changes in rainfall.

The influence of the El Niño Southern Oscillation

About 25 per cent of the year-to-year and decade-to-decade variability in Queensland rainfall is driven by the El Niño Southern Oscillation (ENSO). El Niño and La Niña describe variations in equatorial Pacific Ocean temperatures. During El Niño the tropical Pacific is abnormally warm, during La Niña it is abnormally cold. El Niño events in Queensland tend to experience drier conditions, conversely, La Niña events are associated with wetter than normal conditions.

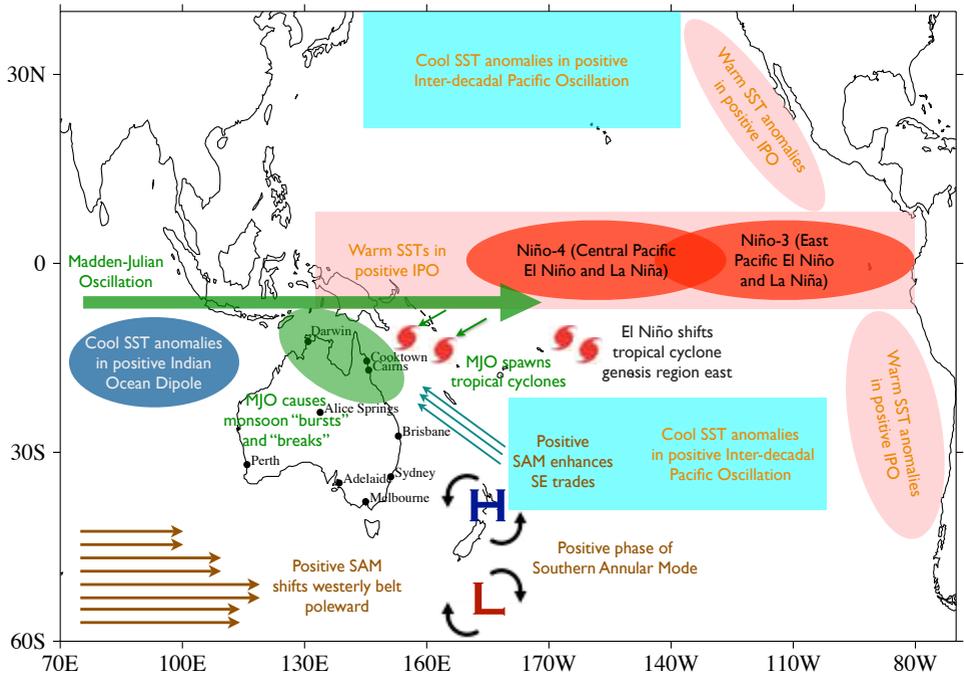
Queensland's rainfall is sensitive, not only to the magnitude of El Niño and La Niña events, but also to their position in the Pacific.

Events that are focused in the central Pacific have a much stronger impact on Queensland than events that are focused in the eastern Pacific, near the west coast of South America.

The effect that El Niño and La Niña events have on summer rainfall in Queensland has varied from one decade to the next. As well as El Niño/La Niña events, the Pacific Ocean experiences slower temperature variations over one or more decades, which is called the Inter-decadal Pacific Oscillation (IPO). The IPO has a period of about 20-30 years. Its positive (warm) phase resembles El Niño, while its negative (cool) phase resembles La Niña. El Niño and La Niña events can occur 'on top' of either phase of the IPO.

During the 1920-1950 IPO warm phase, there was hardly any connection between ENSO and rainfall in Queensland. Cool phases of the IPO have been associated with an abnormally strong link between ENSO and Queensland rainfall.

Warm phases of the IPO are also associated with weak ENSO variations; relatively stable, normal levels of rainfall in Queensland; fewer tropical cyclones in the Coral Sea; and a northward and eastward migration of the South Pacific Convergence Zone (SPCZ), the band of heavy rainfall that parallels the east coast of Queensland. The SPCZ normally lies off-shore, but during La Niña events it moves closer to Queensland's coast, bringing heavy rainfall to the state.



Key climate drivers of rainfall in Queensland.

- SST - Sea Surface Temperature
- SAM - Southern Annular Mode
- SE - South East
- MJO - Madden Julian Oscillation

Other influences on Queensland rainfall

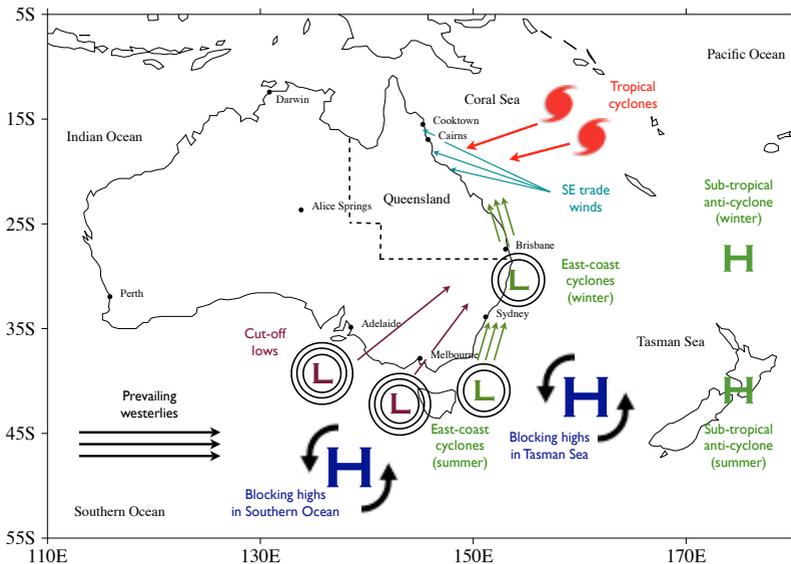
Autumn rainfall in Queensland depends on the behaviour of the end of the monsoon season. Ocean temperatures tend to be warm around eastern Australia when autumns are wet, and cool when autumns are dry. It may be possible to use ocean temperatures to predict autumn rainfall.

Cape York summer rainfall is tied to the frequency and intensity of land-falling tropical cyclones, most of which form in the Coral Sea. El Niño is associated with fewer tropical cyclones striking Queensland, while La Niña is associated with more tropical cyclones. Changes in the frequency, intensity or tracks of these cyclones under climate change could have substantial consequences for total rainfall in this region, as well as for risks to human life and infrastructure.

In South East Queensland, rainfall is driven by the strength and moisture content of onshore easterly winds, which are often connected to blocking anti-cyclones (high pressure systems) in the Tasman Sea.

Coastal rainfall in South East Queensland has declined since in the 1950s, associated with a reduction in the number of coastal cyclones and weaker onshore easterly winds. This decline is particularly evident in summer rainfall.

Rainfall over South East Queensland shows substantial decade-to-decade variations that, unlike state-wide rainfall, are not associated with large-scale climate drivers such as Pacific Ocean temperatures. The source of this variability and whether the variations are predictable remain open questions.



The main weather systems that bring rain to Queensland.

Daily rainfall and extreme events

On average, roughly half of Queensland's rainfall comes from days with relatively intense precipitation (accumulations greater than 25 mm). This dependence is highest in the heavily-populated coastal regions, with 40-60 per cent of the total annual rainfall falling on these heavy rain days. Coastal Queensland experiences an average of around 20 heavy rain days per year; in the dry south-west, there are on average only 1 or 2 days heavy rain days each year.

The number of heavy rain days varies considerably from year to year; this explains much of the year to year variability in rainfall. La Niña is also associated with more heavy rainfall events, while El Niño years experience fewer.

This dependence on heavy rain days likely explains why Queensland experiences such intense floods and droughts: the state is highly sensitive to relatively rare, variable and intense rainfall.

Previous studies have identified that over Queensland as a whole, the contribution of extreme events to the annual rainfall total has grown over the 20th century. If this trend continues in the 21st century, it will have profound hydrological implications for the region in terms of surface runoff, river flows and flooding frequency. Similar upward trends in the contribution of daily extreme events to total rainfall have been found in other regions of the world during the second half of the 20th century.

How might Queensland rainfall change in the future?

Computer based models of the climate system are used by scientists to investigate rainfall and other aspects of climate and how they might change in the future. The UK state-of-the-art high-resolution climate model HiGEM is able to simulate many of the critical aspects of Queensland rainfall and its year-to-year variability and can be used to project future climates as greenhouse gases increase.

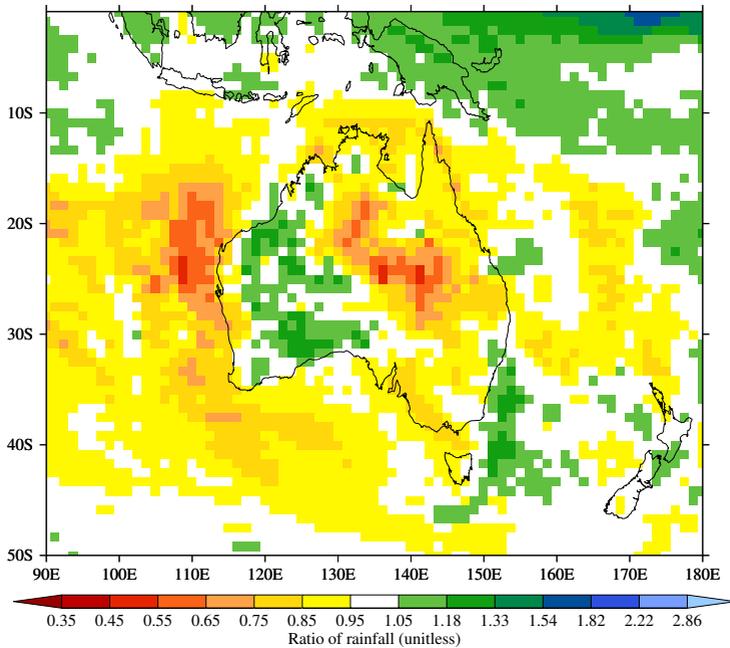
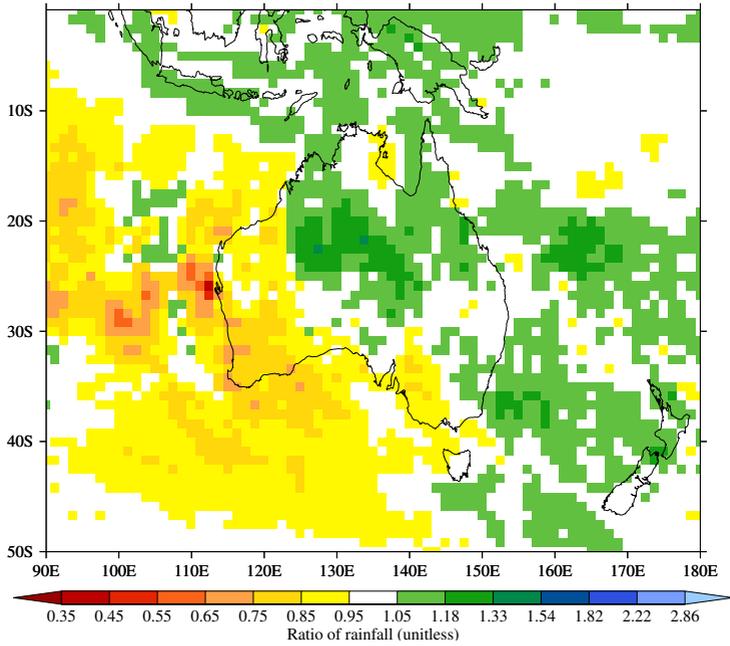
To date, research studies have given a wide range of rainfall projections for the Australian region by the end of the 21st century: some studies suggest a drying of up to 40 per cent; some suggest conditions may be up to 40 per cent wetter.

The HiGEM model was used to examine how Queensland's climate might change in the future. With carbon-dioxide levels increased to predicted 2090 levels, there was little change in total annual Queensland rainfall, but marked changes in when and how the rain falls during the year. The wet season is projected to start slightly later and end significantly earlier, due to an earlier retreat of the monsoon. Although the wet season becomes shorter, it also becomes considerably more intense, so that overall rainfall does not change.

A shorter but stronger rainfall season would make Queensland more reliant on rainfalls during January and February. Because the monsoon retreats earlier, autumns in southern Queensland become much drier. The number of rainy days in Queensland decreases slightly, but the amount of rain that falls on each wet day increases by up to 20 per cent.

Extreme rainfall events become significantly more frequent with a 40 per cent increase in the number of days with more than 100 mm of rainfall, with the greatest increases in summer during the intensified monsoon.

It is important to emphasise that these results come from a single climate model and that other climate models are likely to give different projections. These results should not be considered as a definite prediction of changes in Queensland's climate, but as a possible future climate projected by a model that has been shown to robustly simulate Queensland's present-day climate.



Projected changes in (top) summer and (bottom) autumn rainfall from HiGEM with atmospheric carbon-dioxide concentrations twice the 1980 value (approximately 2090 with moderate future emissions).

The QCCCE and Walker Institute partnership has produced four research reports including:

- Part 1: Key drivers of rainfall variability and change in Queensland rainfall: a literature survey.
- Part 2: Is the inter-annual variability in Queensland's rainfall due to variations in frequency, intensity or both?
- Part 3: Empirical Orthogonal Teleconnection analysis of inter-annual variability in Queensland rainfall.
- Part 4: The ability of HiGEM to simulate Queensland's rainfall variability and its drivers.

All of the reports can be accessed from the Climate Change website at www.climatechange.qld.gov.au.

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