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# El Niño's Impact on Australia's Weather and Climate





## Key Messages

1

The El Niño-Southern Oscillation is a major influence on Australia's weather and climate.

2

El Niño increases the risk of heatwaves, droughts and bushfires in Australia.

3

The impacts of El Niño may become more severe with climate change.

El Niño and La Niña events have a huge influence on Australia's climate. La Niña promotes above average rainfall and cooler temperatures in eastern Australia, while El Niño increases the chance of hot and dry conditions in Australia. Here we look at El Niño and its impacts on Australia's weather and climate.

## What is El Niño?

El Niño is a naturally occurring ocean-atmosphere phenomenon which has major influences on weather and climate in Australia and the globe. During El Niño, there is warming of the sea surface temperatures in the central and eastern Pacific Ocean and cooling to the north of Australia (Figure 1). The warming in the east and cooling in the west is accompanied by a weakening of the easterly trade winds and an atmospheric circulation across the equatorial Pacific Ocean known as the Walker Circulation. This is due to increased air rising in the east and air sinking in the west. These changes in the ocean and atmosphere interact with each other, forming a coupled ocean-atmosphere interaction known as the El Niño-Southern Oscillation (ENSO).

The opposite state of El Niño is called La Niña<sup>1</sup>, which is associated with a cooling of the central Pacific Ocean and warmer temperatures to the north of Australia. Both El Niño and La Niña have a large impact on global weather patterns.

## El Niño generally promotes hotter temperatures across Australia, and reduced rainfall in the east and north of Australia.

El Niño events heighten the risk of heatwaves<sup>2</sup>, drought and bushfires. While El Niño increases the chance of hotter temperatures and reduced rainfall over the east and north of Australia, an El Niño does not guarantee it will be hotter and drier.

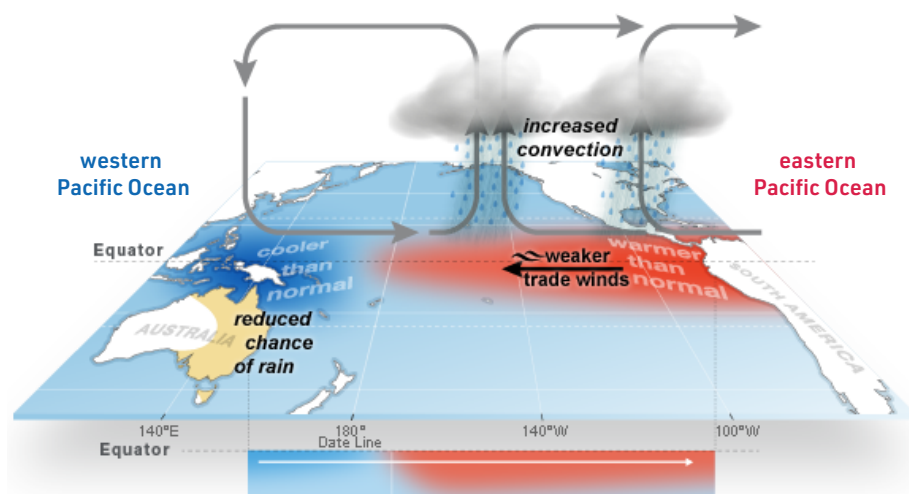


Figure 1: Schematic diagram of El Niño in the tropical Pacific Ocean. During El Niño the easterly trade winds weaken, the western Pacific Ocean cools and the central and eastern Pacific Ocean warms. There is increased convection and rainfall over the warm waters in the central and eastern Pacific Ocean, and reduced rainfall over Australia. Source: adapted from Bureau of Meteorology.

El Niño - Southern Oscillation (ENSO): El Niño

## When does El Niño occur?

El Niño events occur every 3-7 years and can last anywhere from 6 months to 2 years. An El Niño usually starts to develop in the Southern Hemisphere autumn and winter, matures in late spring to early summer and then weakens in autumn of the following year. There are several indicators we can look out for when determining if an El Niño is developing:

- warming temperatures in the tropical Pacific Ocean
- build-up of ocean heat content in the western Pacific Ocean
- higher surface air pressure over the western Pacific Ocean and lower pressure in the east
- weakening of the easterly trade winds
- westerly wind bursts in the western Pacific Ocean
- increases in cloud cover over the International Date Line

Forecasting agencies, such as the Australian Bureau of Meteorology, consider many of these indicators in seasonal prediction models to determine if an El Niño is underway<sup>3</sup>.

However, forecasting El Niño is challenging, particularly from March to May when uncertainties are largest due to the autumn predictability barrier<sup>4</sup> (see 'What is the autumn predictability barrier?'), a phenomenon well-known by the agriculture sector.

We can look at a timeline of past El Niño (and La Niña) events by using an ENSO index (Figure 2), a metric based on sea surface temperatures in the central Pacific Ocean which is commonly used to define ENSO events. An El Niño event is defined when the index is sustained above a determined temperature threshold for a certain number of months, however the temperature threshold used varies between agencies. The National Oceanic and Atmospheric Administration (NOAA) uses a threshold of +0.5°C, as shown in the red shaded regions in Figure 2. In Australia, the Bureau of Meteorology uses a threshold of +0.8°C when classifying El Niño events.

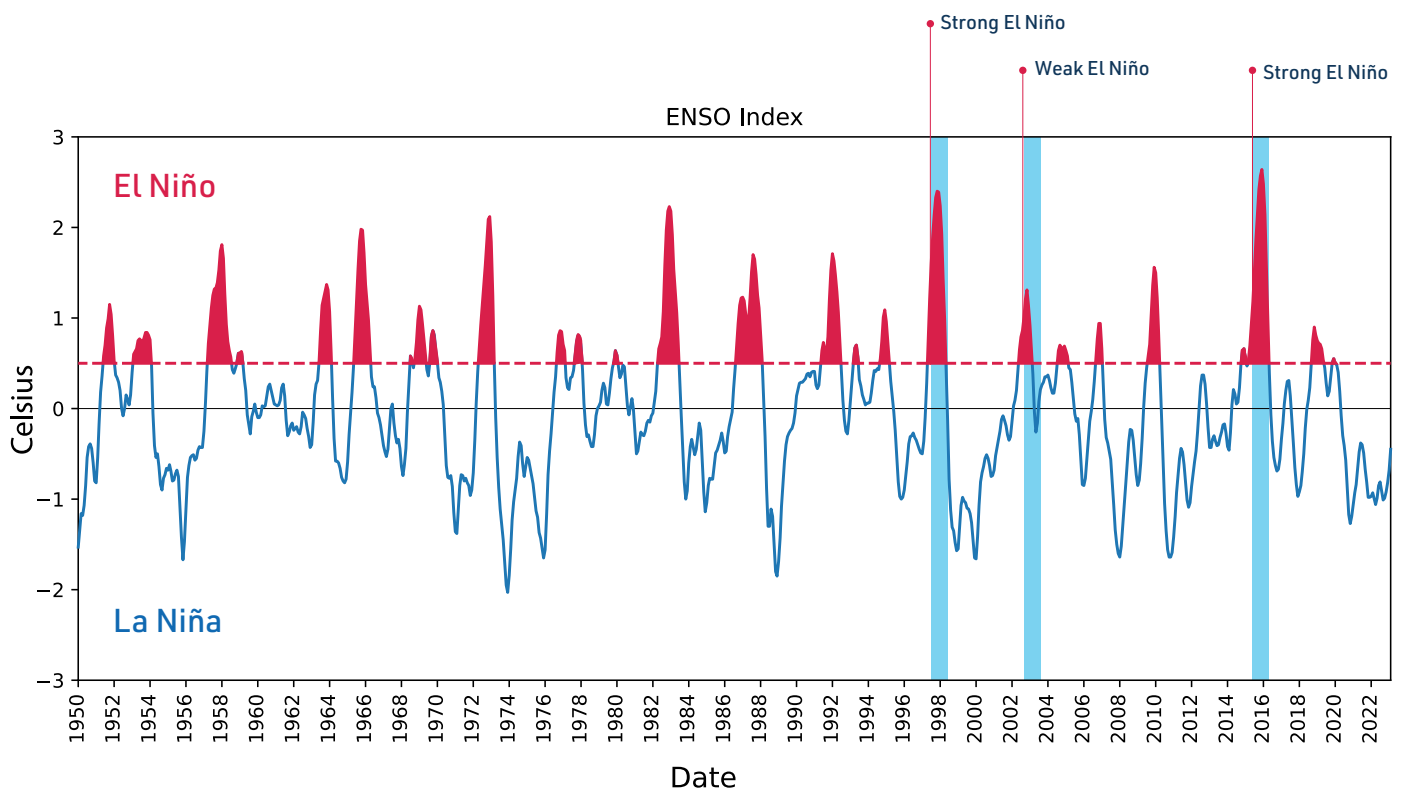
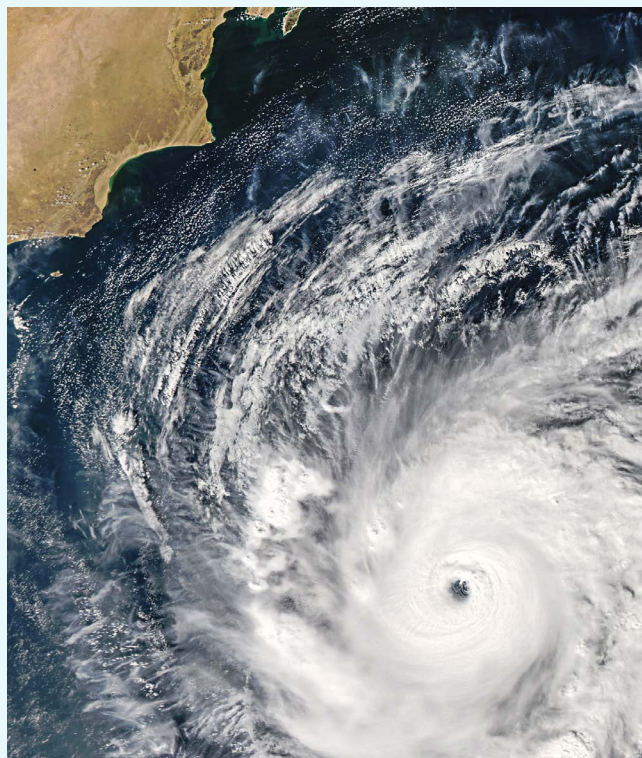


Figure 2: Time series of the ENSO index from NOAA for 1950 to Feb 2023<sup>5</sup>. The index is calculated using the sea surface temperatures in the Niño 3.4 region (area between 170°W-120°W and 5°S-5°N). Dashed red line shows the temperature threshold (NOAA uses +0.5 Celsius) and El Niño events are shaded in red. The strongest events occurred in 1997/98 and 2015/16 and are shaded in blue. The 2002/03 weak El Niño shaded in blue caused widespread impacts on Australia. Source: ARC Centre of Excellence for Climate Extremes.

### What is the autumn predictability barrier?

Southern Hemisphere autumn is normally the season when ENSO tends to transition. El Niño or La Niña events that peaked in the spring and summer tend to weaken in autumn and sea surface temperature variability reduces. El Niño or La Niña events may then begin to emerge in late autumn and winter but until then, forecasts of ENSO are less skilful than at other times of year. This is because atmospheric processes, that are not predictable beyond about 10 days, become too large compared to the more predictable signal from the ocean, making seasonal predictions of ENSO extremely tricky.

By the time we move into winter, ENSO events are typically advanced enough in their formation that disruption from less predictable elements of the climate system may not greatly influence the progression of ENSO events.



### How does El Niño impact Australia's climate?

Every El Niño event is different. When an El Niño is declared, it is uncertain exactly how the climate system will react. However, there are some general responses that we can expect. El Niño usually promotes higher temperatures over Australia, especially in the southern half of the country (dark red in Figure 3a), and reduced rainfall in the east and north<sup>6</sup> (dark brown in Figure 3b).

Nine of the ten driest winter-spring periods in southeast Australia occurred during El Niño events. These warmer and drier conditions can increase the risk of drought and bushfire<sup>7</sup>.

Most of the major Australian droughts, such as the severe droughts of 1982, 1994, 2002, 2006, and 2015, coincided with El Niño. Recent research at the ARC Centre of Excellence for Climate Extremes (the Centre) found that the drier conditions during El Niño result, in part, from local conditions that prevent the conversion of moisture into rainfall<sup>8</sup>.

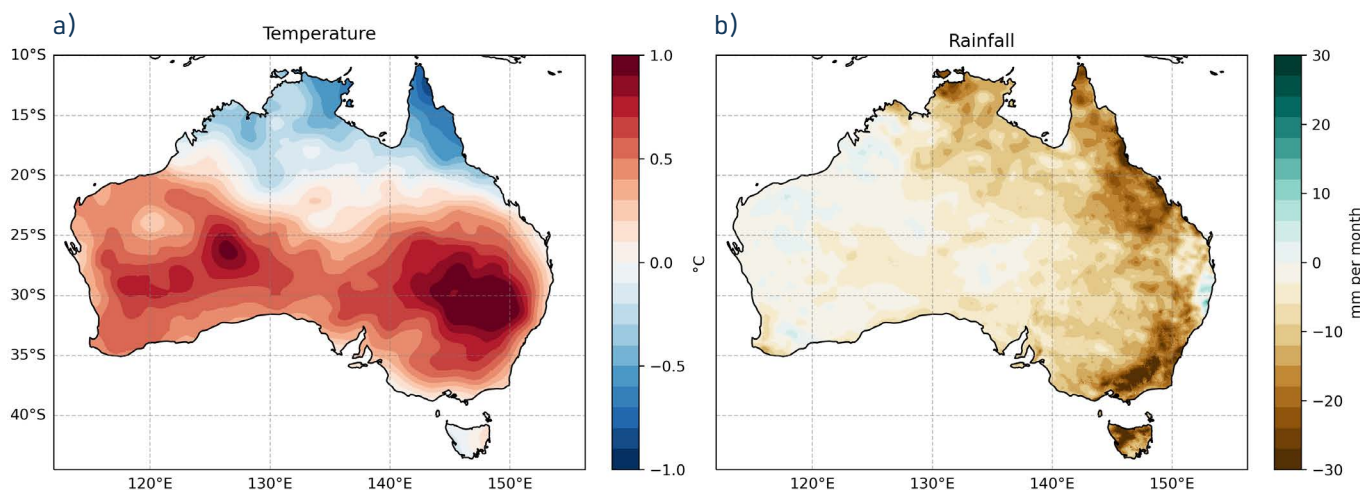


Figure 3: a) Average temperature anomaly in °C and b) precipitation anomaly in mm per month for spring averaged over nine El Niño events (1965, 1972, 1977, 1982, 1991, 1994, 1997, 2002, 2015) using monthly data from AGCD<sup>9</sup>. Source: Ruby Lieber.

El Niño events can evolve differently over time and exhibit different temperature patterns and strengths. Depending on whether the warming is located closer to South America or in the central Pacific Ocean near the International Date Line, the event can be classified as either an Eastern Pacific El Niño or a Central Pacific El Niño<sup>10</sup>. Eastern Pacific and Central Pacific El Niño events can have different impacts on Australian climate<sup>11</sup>. Despite Eastern Pacific El Niño events generally having warmer ocean temperatures than Central Pacific El Niño events, Central Pacific events appear to have a greater influence on Australian rainfall. This is in part due to the closer proximity of the warm surface ocean waters to Australia<sup>12</sup>.

For example, the 1997/98 Eastern Pacific El Niño is one of the strongest events in the historical record (Figure 2), but the overall impacts on Australia's rainfall were weak, with decreases in rainfall mostly confined to southeast Australia and the East Coast (Figure 4a). In contrast, the weak 2002/03 Central Pacific El Niño (Figure 2) was associated with extreme rainfall decreases and widespread drought across much of Australia (Figure 4b), causing a significant impact on the economy and the loss of over 100,000 jobs in the agricultural industry<sup>13</sup>.

**This demonstrates that the strength of an El Niño event does not necessarily influence the amount of rainfall and is therefore not a good predictor of the rainfall response.**

This contrasts with La Niña, where the strength of the rainfall response is closely linked to the magnitude of the event<sup>14</sup>. Although the type of El Niño influences temperature and rainfall, recent research by the Centre found that the type does not seem to have a significant effect on the Australian land carbon balance.<sup>15</sup>

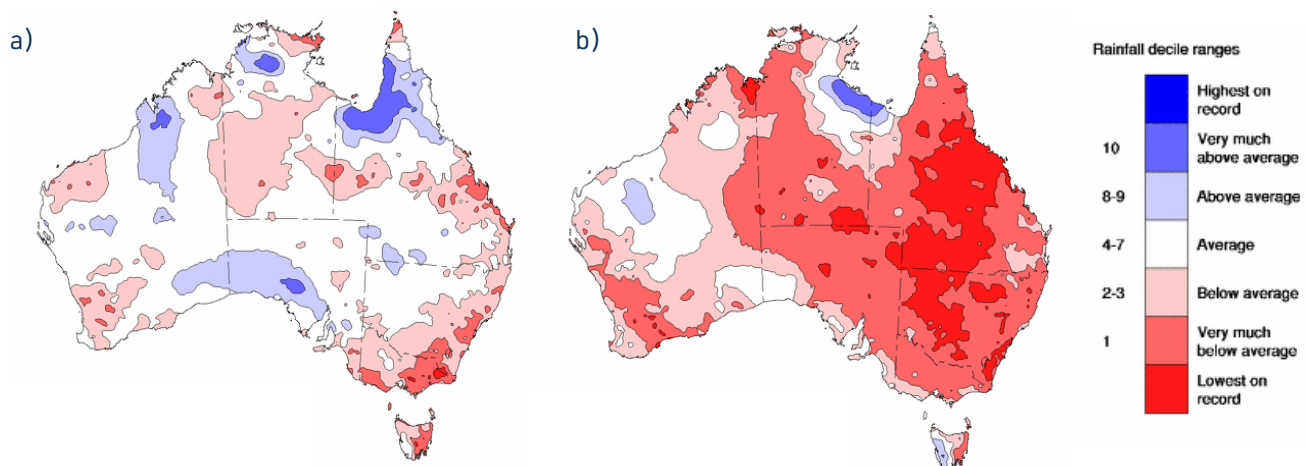


Figure 4: a) Rainfall deciles during 1997/98 El Niño. Average to below average rainfall across much of the country. b) Rainfall deciles during the 2002/03 El Niño. Very much below average to lowest on record rainfall for much of the country. Source: Bureau of Meteorology.

Due to reduced cloud cover during El Niño, there are often cooler overnight temperatures and increases in frost risk<sup>3</sup>. This has implications for agriculture as frost can result in severe losses in stone fruit yield, for example. Reduced winter-spring rainfall can also lead to crop losses, and so El Niño generally results in lower crop yields<sup>16</sup> and an average decline in farm gross domestic product of approximately 13%<sup>17</sup>. Wheat yield during the El Niño of 2002/03 dropped from 24 million tonnes to 13.5 million tonnes and total winter crop production fell by 40%, which is estimated to have impacted the Australian economy by billions of dollars<sup>18</sup>.

El Niño events can also contribute to coral bleaching on the Great Barrier Reef. The major El Niño events of 1997/98 and 2015/16 (Figure 2) combined with global warming of the oceans have corresponded with significant coral bleaching in the Great Barrier Reef region<sup>19</sup>. The extreme El Niño of 2015/16 resulted in the worst coral bleaching event on record<sup>20</sup>, with almost every species of coral in the northernmost 1000km of the reef experiencing severe bleaching.



## How does El Niño interact with other climate modes?

Although it is the most dominant phenomenon in the tropics and on Earth, ENSO is not the only driver that influences Australia's weather and climate. ENSO's Indian Ocean cousin, the Indian Ocean Dipole (IOD), and the Southern Annular Mode (SAM) also play a part<sup>21</sup>. Southeast Australia usually experiences even drier conditions when El Niño coincides with the positive IOD<sup>22</sup> and negative SAM<sup>23</sup>. ENSO also interacts with the Madden Julian Oscillation (MJO), an eastward moving 'pulse' of alternating dry and rainy conditions that impacts tropical Australia. The rainfall response to the MJO appears to be greater during El Niño, with greater rainfall decreases during the dry MJO phases<sup>24</sup>.

## How might El Niño and its influence on Australian climate change in the future?

We can use global climate models to simulate how El Niño (and La Niña) might change in the future. However, it is important to note that exploring future changes to El Niño is extremely challenging and many uncertainties remain<sup>25</sup>.

**What we do know at present is: most climate models tell us that the influence of El Niño on Australia's climate is likely to become stronger as the world continues to warm.**

Climate models suggest that the rainfall decrease and temperature increase during El Niño will likely intensify in the future<sup>26</sup>. Many of the hottest years on record have occurred during El Niño years<sup>27</sup>, and so combined with background warming, we can expect future El Niño events to increase the chance of record-breaking temperatures. Researchers from the Centre found that in recent decades there has been an increasing trend in the frequency of Central Pacific El Niño events, and so there is a possibility that the impact of future El Niño events may be more like the ones seen during these types of events<sup>28</sup>.

In addition, under increasing global warming, climate models project an increase in the frequency of extreme El Niño and La Niña events<sup>25</sup>, resulting in more extreme swings in Australia's climate from heatwaves and drought to flooding rains. If we can slow global warming by rapidly transitioning to net-zero emissions, we may expect reduced amplitudes of El Niño and La Niña in the longer term, although further research is needed<sup>29</sup>.

Building our understanding of this major climate phenomenon and how it impacts Australian weather and climate is vital for understanding our current and future climate. Efforts to reduce these uncertainties are on-going and one major strategy is to dramatically increase the spatial detail used in the ocean models used for climate projections. This is led by the Australian Community Climate and Earth System Simulator (ACCESS) [National Research Infrastructure](#) which is supported by the federal National Collaborative Research Infrastructure Strategy, Consortium for Ocean-Sea Ice Modelling in Australia ([COSIMA](#)) and by researchers in the ARC Centre of Excellence for Climate Extremes.



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## Written by



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### Dr Zoe Gillett

is a Research Associate at the ARC Centre of Excellence for Climate Extremes. She has a PhD in Atmospheric Science from Monash University. Zoe's research uses large climate model simulations to understand interactions between the tropical oceans and Southern Hemisphere climate, focusing on the drivers of multi-year drought in Australia. This research can help improve drought forecasting, with implications for industry sectors dependent on accurate drought predictions, such as agricultural and water management sectors.

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