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Multi-year La Niña events

ARC Centre of Excellence for Climate Extremes Briefing Note 20

- La Niña is an important cause of rainfall variability over Australia
- La Niña promotes increased winter-spring rainfall in eastern Australia and increased late summer-autumn rainfall along the east coast, often resulting in widespread flooding
- La Niña contributed to the recent heavy rainfall and widespread flooding across New South Wales and Queensland in 2021 and 2022
- About half of La Niña events occur in two consecutive years, which could increase the risk of flooding in the second year due to saturated catchments
- Some climate models are indicating that La Niña may continue for a third year through spring and summer 2022-23, increasing the chances of more rain and flooding

What is La Niña?

La Niña is one part of a naturally occurring coupled ocean-atmosphere phenomenon called the El Niño-Southern Oscillation (ENSO)[1]. During La Niña (Figure 1), the Pacific trade winds strengthen. These stronger winds cause warm ocean water to pile up around northern Australia and colder water to rise from depth to the surface in the central and eastern Pacific off South America. This leads to ocean circulation changes, reinforcing the east-west sea surface temperature difference along the equatorial Pacific. This situation intensifies an atmospheric circulation across the equatorial Pacific known as the Walker Circulation. Consequently, warm rising air and rainfall increase in the western Pacific. El Niño is the counterpart to La Niña[2]. It is characterised by warming in the central and eastern Pacific Ocean and a weaker Walker Circulation. The changes in the tropics during La Niña and El Niño trigger a ripple effect in the global atmospheric circulation, with impacts affecting Australia.

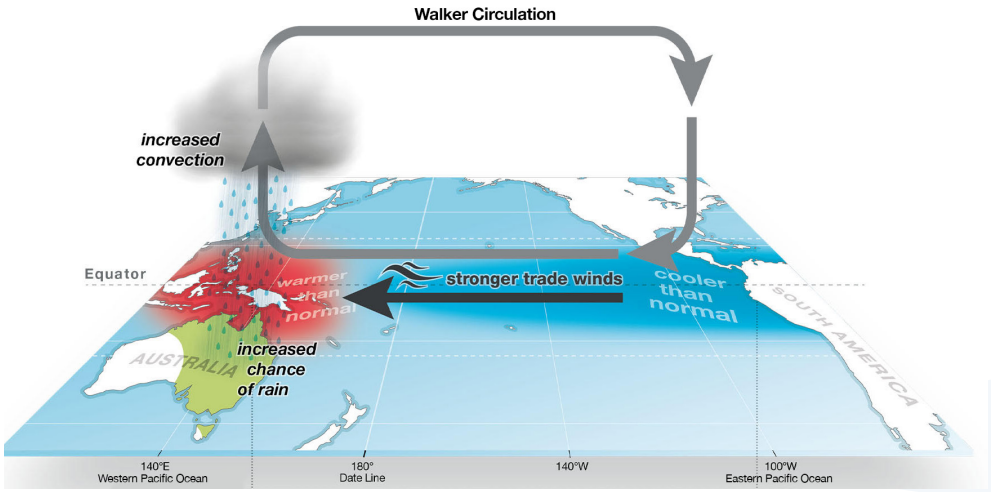

Figure 1. Schematic diagram of La Niña conditions (adapted from the Bureau of Meteorology[1]). During La Niña, the trade winds (black arrow) strengthen, the central and eastern Pacific Ocean cools and the western Pacific warms. The Walker Circulation (grey arrows) intensifies, favouring more clouds in the western Pacific and increasing the chances of rain for Australia.

How does La Niña affect Australia's climate?

La Niña promotes increased moisture, cloud development and rainfall over much of the Australian continent due to the strengthened Walker Circulation and warmer ocean waters to the north of Australia[1,3] (Figure 1). La Niña exerts its strongest influence on eastern Australian rainfall during winter and spring[4], and is usually associated with increased rain and cooler daytime temperatures. It also increases the likelihood of tropical cyclones in the Australian region[5]. For the east coast, the increased rainfall persists into late summer and autumn[4,6]. This increased rainfall leads to a much higher frequency of flooding during La Niña years than during El Niño years[7]. La Niña is therefore often associated with drought-breaking rains[8].

Every La Niña event is different and does not guarantee that eastern Australia will be unusually wet. Australia's rainfall is influenced by several regional weather systems and global modes of climate variability[9], which may amplify or dampen the effects of La Niña[3]. For instance, wet conditions across southeast Australia during winter and spring typically intensify when La Niña and the negative phase of the Indian Ocean Dipole (IOD)[10,11] co-occur. Similarly, when La Niña coincides with the positive phase of the Southern Annular Mode (SAM), rainfall tends to intensify across eastern Australia during spring and summer[12]. When La Niña co-occurs with the opposite phases (positive IOD and negative

SAM), its effects are dampened. Although La Niña increases the likelihood of increased rain, this does not always occur. For example, south-eastern Queensland and north-eastern New South Wales experienced significantly below-average rainfall in spring 2020 despite La Niña[13]. Thus, the existence of La Niña does not mean it *will* be wet, but it does increase the likelihood of wetter conditions.

Strong past La Niña events include 1973-74 and 2010-11, both of which were part of multi-year La Niña events and were associated with widespread flooding in many parts of Australia[14]. 1974 is still Australia's wettest year on record, and 2010 and 2011 is Australia's wettest 24-month period on record[14]. The record-breaking rainfall during these two events occurred in association with two of the strongest La Niña events on record and strong negative IOD and positive SAM[15]. Multi-year persistence of La Niña events and the combination of La Niña, negative IOD and positive SAM can exacerbate the impacts of rainfall in Australia.

When do La Niña events occur?

One of the metrics used to measure ENSO is based on the sea surface temperature variations in the Niño 3.4 region, the area between 170°W and 120°W in the equatorial Pacific. A La Niña event is typically defined when there is a sustained period of negative Niño 3.4 values below a certain threshold[16]. La Niña events usually develop during Southern Hemisphere winter to early spring, mature in late spring to early summer and decay by autumn in the following year. They recur every two to seven years, and 25 La Niña events have been recorded in summer from 1950 to the present (Figure 2).

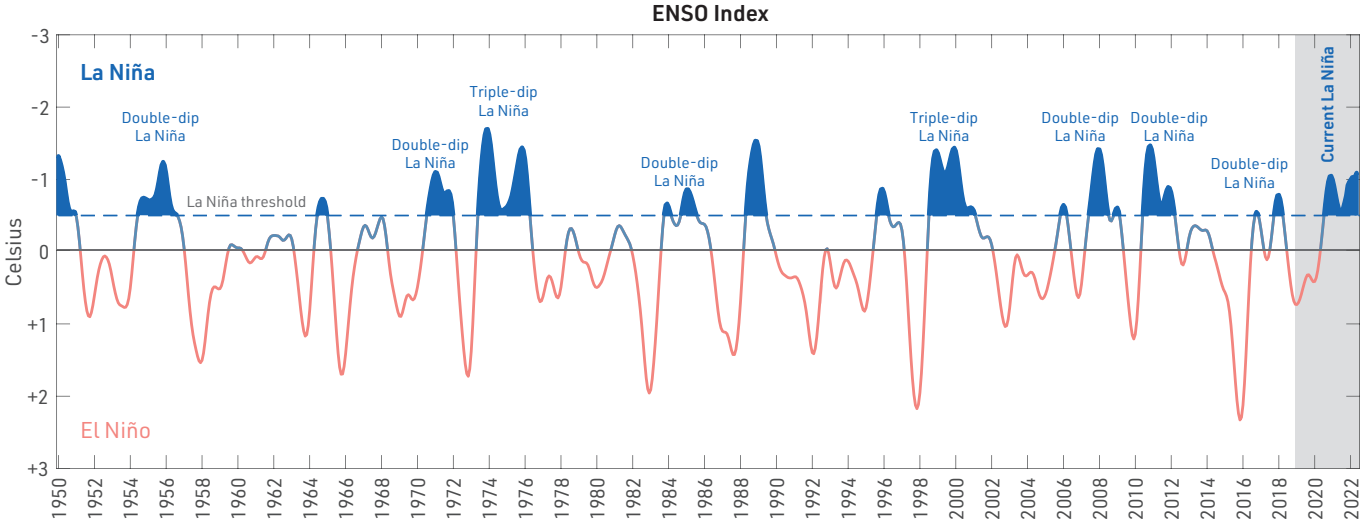

Figure 2. The ENSO index from NOAA is based on the sea surface temperature variations in the Niño 3.4 region (170°W-120°W, 5°S-5°N). The blue line shows the La Niña phase of ENSO, and the red line shows the El Niño phase (note reversed y-axis for easier visualisation of La Niña). The dashed blue line indicates the threshold used to define La Niña events (shaded blue). NOAA uses a threshold of -0.5°C. Note: other agencies use different thresholds and ENSO index definitions. Double-dip and triple-dip La Niña events are labelled. The ENSO index over the grey shaded area is zoomed in Figure 3.

It is not uncommon for multi-year La Niña events to happen. Double-dip La Niña events, i.e., a La Niña occurring in two consecutive summers, usually with a transition to weak La Niña or ENSO neutral conditions in between, have occurred in about 50% of La Niña events since 1950 (in 1954-56, 1970-72, 1983-85, 2007-09, 2010-12 and 2016-18) (Figure 2). Triple-dip La Niña events, i.e., La Niña conditions in three consecutive summers, are rare and have only happened twice since 1950 (in 1973-76 and 1998-2001).

A multi-year La Niña event can be particularly important for some climate risks. For example, above-average rainfall in the first event could lead to saturation of some catchments, increasing the risk of flooding during the second event.

What causes a multi-year La Niña and can we predict it?

Based on our historical record from 1950 to the present, when a La Niña occurs, there is about a 50% chance that La Niña will occur again in the following year. The reason why La Niña can reappear the year after the previous La Niña has ended is due to ENSO asymmetry, meaning that El Niño and La Niña are not exactly the mirror of each other. The spatial pattern, strength, and wind stress changes in the tropical Pacific during ENSO favour a stronger coupling between the ocean and the atmosphere during El Niño than La Niña. This causes El Niño to terminate rapidly and often trigger a La Niña in the following year. However, the weaker ocean-atmosphere coupling during La Niña does not necessarily lead to an El Niño after a La Niña.

Previous studies suggest that the multi-year occurrence of La Niña can be linked to the strength of a preceding El Niño[17,18]. El Niño releases ocean heat away from the equatorial Pacific, while La Niña restores ocean heat to the equatorial Pacific. The discharge of ocean heat during a strong El Niño event can be too large to be restored by a single La Niña event. So, another La Niña appears in the following year. Therefore, multi-year La Niña events might be predictable more than a year in advance based on the strength of a preceding El Niño event[19]. For example, the two triple-dip La Niña events (1973-76 and 1998-2001) were preceded by an extreme El Niño.

However, sometimes a La Niña can develop without a previous strong El Niño, as is the case for the current La Niña event. Other factors such as unpredictable winds in the tropical Pacific and sea surface temperature variability of the neighbouring ocean basins add to the complexity in predicting when a La Niña will occur[20]. Monitoring the tropical Pacific conditions is crucial for predicting El Niño and La Niña events. Key measurements include ocean heat content in the equatorial Pacific, wind conditions, sea surface temperatures and sea level pressure.

The 2020-22 multi-year La Niña

A La Niña was declared at the end of September 2020[21] and by early autumn 2021, the tropical Pacific returned to neutral ENSO conditions (Figure 3). Eastern and central Australia experienced extreme rainfall and flooding in March 2021 towards the end of this event[22]. In the downtime after this first La Niña event, a weak negative IOD developed during winter 2021 and contributed to a wet cool season across southern and eastern Australia[23]. Pacific Ocean temperatures started to cool again from mid-2021. A second La Niña was declared in late spring to early summer[24] and persisted through early winter 2022. November 2021 was the wettest November in 122 years for New South Wales, South Australia, and Australia as a whole[25]. The positive phase of the SAM also acted to increase rainfall in eastern Australia during November. Widespread flooding returned in early 2022, affecting south-eastern Queensland and eastern New South Wales from late February to early March[26].

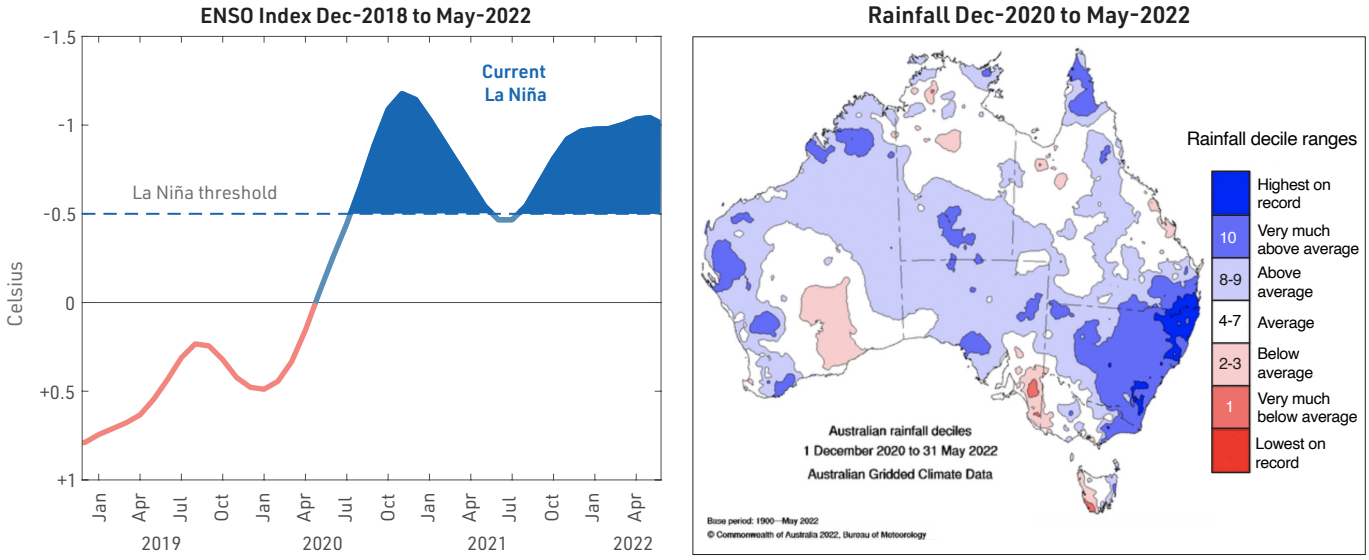

Figure 3: A zoomed-in view of the current La Niña event from Figure 2 is shown in the left panel. The associated impacts of the current La Niña event measured as Dec-2020 to May-2022 rainfall deciles are shown in the right panel (source: Bureau of Meteorology).

How might La Niña and its influence on Australia's climate change in the future?

Climate models are a useful tool for understanding the processes behind climate variability and climate change. Despite the challenges in representing different types of ENSO[27], most models project that extreme La Niña events will occur almost twice as often in the twenty-first century as they did in the twentieth century[28]. This increase is partly linked to a projected increase in extreme El Niño events[28], which provides favourable conditions for an extreme La Niña to develop. Importantly for Australia, this suggests frequent swings from extreme El Niño impacts to extreme La Niña impacts, i.e., from droughts to flooding rains. Warming of the oceans north of Australia can also increase the likelihood of extreme rainfall during La Niña[29].

However, these projections from climate models need to be interpreted with care. While the new generation of climate models are showing more consistency in simulating ENSO, they still exhibit biases. In addition, the way the Pacific Ocean temperatures connect to the atmosphere and further translate to rainfall over Australia is complex. Crucially, extreme rainfall over Australia tends to be linked with moisture flows established by La Niña, interacting with processes that originate in the Southern Ocean and connected via smaller scale features such as East Coast Lows and atmospheric rivers[30]. The ability of climate models to capture these processes acting to create extreme rainfall is a topic of research in the ARC Centre of Excellence for Climate Extremes (CLEX).

La Niña usually temporarily causes temperatures to cool globally[31] and in Australia[6]; however, temperature records are still being broken during La Niña events. For example, spring 2020 and November 2020 are Australia's hottest on record[32] despite La Niña and 2021 was Australia's warmest La Niña year on record. These record temperatures would have been almost impossible without human-induced climate change.

As of June 2022, La Niña has weakened in the tropical Pacific, but some climate models indicate that a third consecutive La Niña could form during spring or summer 2022. A triple-dip La Niña has only occurred twice since 1950.

Created by:

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