Australian Government
Bureau of Meteorology

Record-breaking La Niña events

An analysis of the La Niña life cycle and the impacts and significance of the 2010–11 and 2011–12 La Niña events in Australia

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A heavy rain shower crosses Cleveland Bay, off Townsville, Queensland, as the first storms of the Wet Season brew (Bureau of Meteorology Weather Calendar, April 2011)

About this publication

La Niña events greatly influence Australia's climate. The 2010–12 La Niñas were two of the most significant events in Australia's recorded meteorological history. This publication explores these extraordinary events and their effect on the weather and climate of Australia during 2010–12.

It provides an overview of how La Niña events occur and the extreme impacts that these events can have on Australia's climate.

The publication is structured according to two interrelated, parallel streams to assist the reader – 'background' and 'story'. The 'background' stream explains some of the major factors that drive La Niña events and how they influence Australia's climate. The 'story' stream illustrates the significance and widespread impacts of the 2010–11 and 2011–12 La Niña events.

Unless otherwise indicated, all temperature and rainfall anomalies (i.e. departures from average) in this publication are calculated with respect to the 1961–1990 average, as recommended by the United Nations World Meteorological Organization.

At a glance: the impact of these La Niña events in Australia

The successive La Niña events spanning 2010–12 were associated with record rainfall over much of Australia and some of the biggest floods in living memory. This followed years of severe drought in many parts of the country, and while it brought relief to many Australians, it also brought devastation to others.

Some facts about the 2010–11 and 2011–12 La Niña events

2010–11 La Niña

The 2010–11 La Niña event was one of the strongest on record, comparable in strength with the La Niña events of 1917–18, 1955–56 and 1975–76

In October and December 2010, and February and March 2011, the Southern Oscillation Index values (a measure of a La Niña's strength) were the highest recorded for each month since records commenced in 1876

2011 was Australia's coolest year in a decade (2001–2011)

2010 was Australia's third-wettest calendar year on record

The Murray–Darling Basin experienced its wettest calendar year on record in 2010 and Western Australia experienced its wettest year on record in 2011

2011 was Australia's second-wettest calendar year (with the wettest year since national rainfall records began in 1900 being 1974 – also a La Niña year)

Ocean temperatures to the north of Australia were highest on record in 2010

April 2010 to March 2012 was Australia's wettest two-year period on record

Widespread flooding occured in many parts of Australia associated with the record rainfalls

See pages 20–23 for a full timeline of the La Niña events

What are El Niño and La Niña events?

The El Niño–Southern Oscillation (ENSO) is described in more detail on pages 6–7.

Coupled

Because ENSO involves interaction between the ocean and the atmosphere – both of which play a role in reinforcing changes in each other – it is known as a **coupled** ocean–atmosphere phenomenon.

Thermocline

Thermocline comes from the Greek for 'heat slope' and is the name for the region separating warm, well-mixed surface water from cool, deep ocean water. Typically water temperatures above the thermocline are more than 25°C while those below the thermocline are 15°C or less.

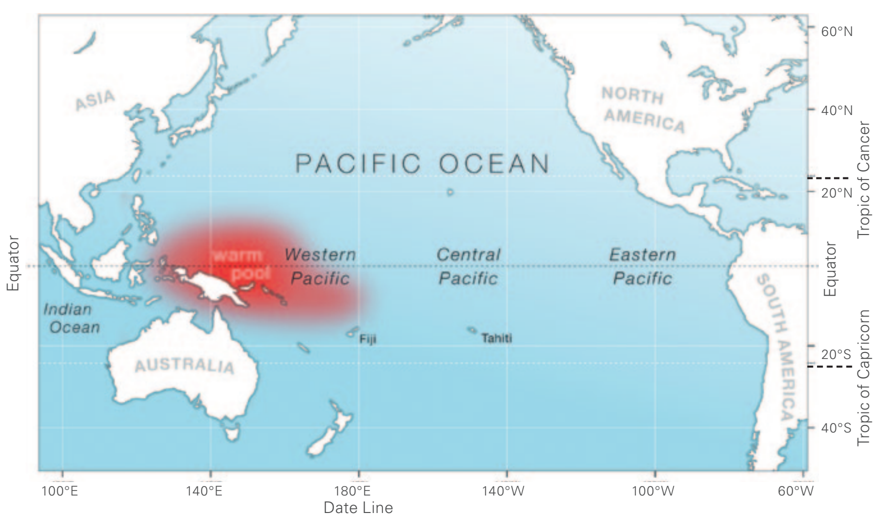
Central and Eastern Pacific Ocean

Warmer water	El Niño
Cooler water	La Niña
Neither warm nor cool	Neutral

El Niño and La Niña events are a natural part of the global climate system. They occur when the Pacific Ocean and the atmosphere above it change from their neutral ('normal') state for several seasons. El Niño events are associated with a warming of the central and eastern tropical Pacific, while La Niña events are the reverse, with a sustained cooling of these same areas.

These changes in the Pacific Ocean and its overlying atmosphere occur in a cycle known as the **El Niño–Southern Oscillation (ENSO)**. The atmosphere and ocean interact, reinforcing each other and creating a 'feedback loop' which amplifies small changes in the state of the ocean into an ENSO event. When it is clear that the ocean and atmosphere are fully **coupled** an ENSO event is considered established.

Even in a neutral state, temperatures in the Pacific Ocean vary from east to west – for example, the western Pacific 'warm pool' in the tropical Pacific has some of the warmest large-scale ocean temperatures in the world. During an ENSO event, ocean temperatures become warmer than usual or cooler than usual at different locations, which are reflected in ocean temperature gradients. The most important driver of ENSO is these temperature gradients across the Pacific, both at the surface and below the surface, particularly at the **thermocline**.



Pacific Ocean – even in neutral state the Western Pacific is warm

Why are they called El Niño and La Niña?

The term El Niño translates from Spanish as 'the boy-child'. Peruvian fishermen originally used the term to describe the appearance, around Christmas, of a warm ocean current off the South American coast. It is now the commonly accepted term to describe the warming of the central and eastern tropical Pacific Ocean. La Niña translates as 'girl-child' and is the opposite ENSO phase to El Niño.

From El Niño to La Niña

The 2009–10 El Niño commenced in May 2009, reaching its peak in late December 2009 before breaking down in the first quarter of 2010. The Pacific Ocean returned to neutral by late April 2010, but continued to cool rapidly during autumn.

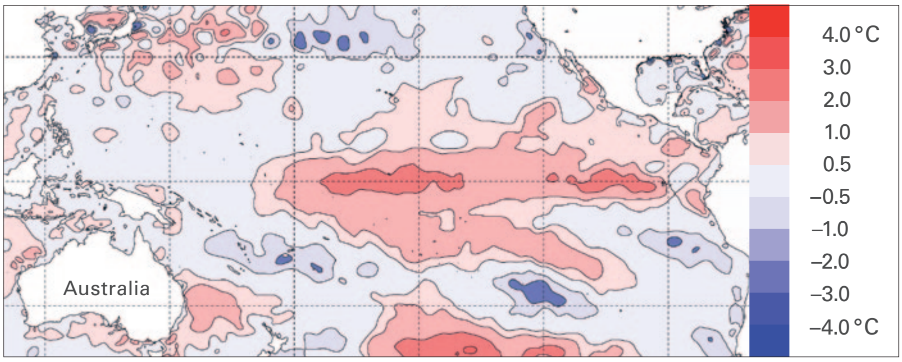
As early as April 2010, a number of climate models from meteorological agencies around the world suggested a La Niña event could commence later in 2010. Subsequently, the first observed signals of a potential La Niña became apparent in the tropical Pacific Ocean during the following month.

As sea surface temperatures approached values (or 'thresholds') associated with a La Niña in July 2010, and as long-range outlooks became more consistent, the Bureau of Meteorology announced that a La Niña event was more likely than not to persist for the rest of the year.

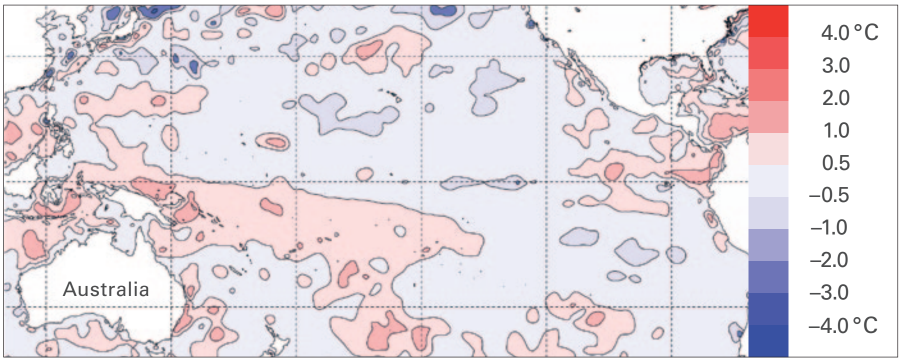
By October 2010, and with the event showing parallels to the La Niña events of the early 1970s, seasonal outlooks were increasingly suggesting wet conditions for northern and eastern Australia. As a result, the Bureau began briefing key federal and state government agencies of increased flood and tropical cyclone risk, and decreased bushfire potential, over the summer period.

The La Niña strengthened further during spring and into summer, peaking around January 2011, before weakening during autumn 2011. The 2010–11 La Niña drew to a close in May 2011, with both Pacific Ocean and atmospheric indicators returning to neutral levels by mid-year.

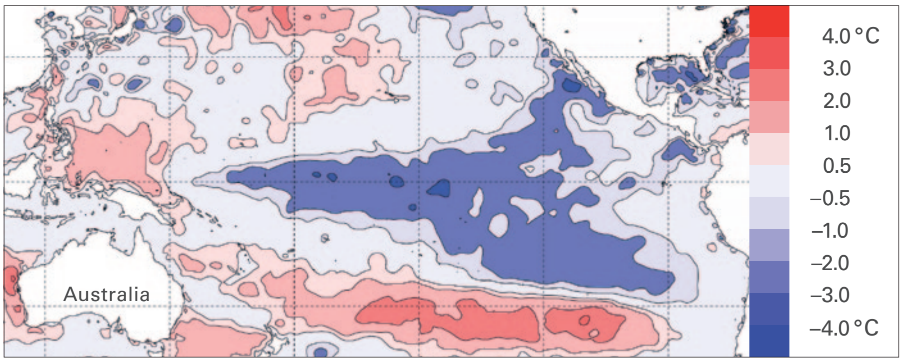
Monthly sea surface temperature anomalies (differences from normal) in the Pacific Ocean indicate where the ocean is warmer than usual (red) and cooler than usual (blue).



December 2009 – peak of the 2009–10 El Niño; warmer than normal sea surface temperatures in the central and eastern Pacific



May 2010 – between the end of El Niño and the start of the 2010–11 La Niña; relatively neutral state of the ocean



January 2011 – peak of the 2010–11 La Niña; cooler than normal sea surface temperatures in the central and eastern Pacific

When do El Niño and La Niña events occur?

Climate models

Climate models come in two forms:

1. Statistical climate models are based on what has happened in the past – that is, they use historical patterns to estimate what is likely to happen in the future.
2. Dynamical climate models are based on physics – that is, they model the physical processes driving the current climate situation forward in time to predict what is likely to happen.

Data are collected from a wide variety of sources – including satellites, buoys (moored, drifting and expendable), sea level analysis and meteorological surface observations – all drawn from a network of national and international observing systems.

The Southern Oscillation Index (SOI) is described in more detail on page 8.

The tropical Pacific Ocean and atmosphere swings, or oscillates, between warm, cool and neutral phases on a timescale of a few years.

A typical El Niño or La Niña event may show its first signs of development during the southern hemisphere autumn and strengthen over winter and spring. It will normally start to decay in the mid to late southern summer, and finally dissipate in the subsequent autumn. ENSO events typically decay during autumn, as this is the time of year when the tropical Pacific Ocean naturally evens out the temperature difference between the east and west. This annual weakening of the temperature gradient across the Pacific also means the weather patterns which help reinforce a La Niña or El Niño ease, allowing ENSO to return to neutral.

In general, El Niño events tend to only last for a single cycle (i.e. one year from autumn to autumn), but it is not uncommon for multi-year La Niña events to occur. For example, the 1998–2001 La Niña affected three consecutive years from autumn 1998 to autumn 2001.

Watching out for events

The first signs of an emerging El Niño or La Niña event are often observed in the ocean. The Bureau of Meteorology monitors and reports on a range of ENSO indicators, including:

- short-term bursts of tropical rainfall activity
- water temperatures at the sea surface and at depth
- ocean heat content – measuring the amount of energy stored in the ocean
- the Southern Oscillation Index (see page 8)
- atmospheric air pressure
- cloudiness – measuring the amount of cloud in tropical regions
- the strength of the trade winds and winds higher in the atmosphere
- ocean currents.

These climate indicators provide information about current ENSO conditions, and are inputs into climate models that are used to predict conditions for the months ahead.

From one La Niña to the next

The central Pacific began to cool again during winter 2011, and from September 2011 models and observations indicated a re-emergence of the La Niña during spring was likely.

The 2011–12 La Niña was relatively late forming, with most indicators only reaching La Niña thresholds by mid-October 2011. This event was not forecast to be as strong as the 2010–11 La Niña, as reflected in seasonal climate outlooks issued at the time. Outlooks indicated a wetter than average spring and early summer for much of northern and eastern Australia, but were not as dramatic as they were during the previous year.

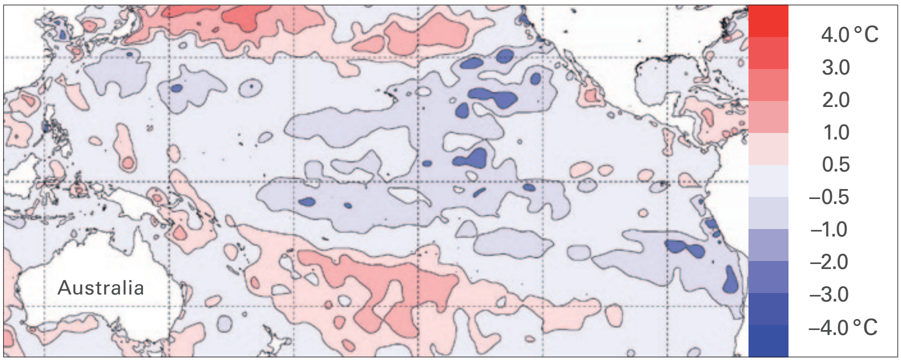
The La Niña consolidated over spring 2011, with many indicators only strengthening slightly during October and early November. The event reached its peak during December 2011 when climate models forecast a return to a neutral ENSO phase during autumn 2012. The 2011–12 La Niña gradually declined over late summer, with some atmospheric indicators continuing to show a La Niña signal during March 2012, while oceanic indicators were generally faster to return to neutral levels. The 2011–12 La Niña concluded in late March 2012.

Want more?

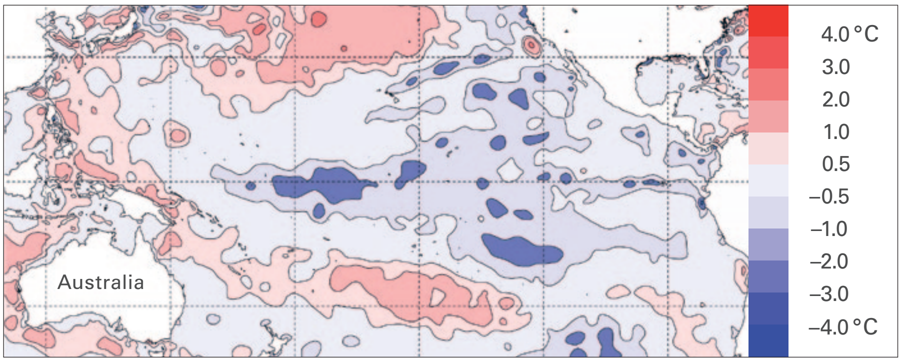
The Bureau publishes a regular ENSO Wrap-Up and Model Summary on its website **http://www.bom.gov.au/climate/enso/**

These reports contain information about current conditions across the tropical Pacific Ocean, as well as a summary of predictions for ENSO conditions several months ahead from a number of international dynamical climate models, including the Bureau's own model, POAMA (Predictive Ocean Atmosphere Model for Australia).

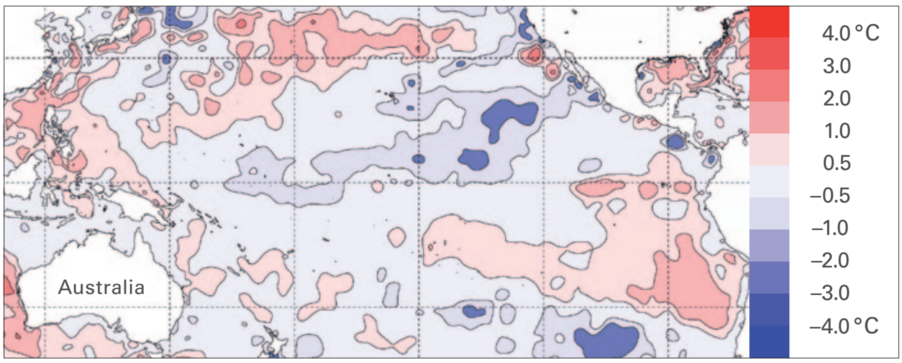
Monthly sea surface temperature anomalies (difference from normal) in the Pacific Ocean indicate where the ocean is warmer than usual (red) and cooler than usual (blue).



September 2011 – cooling in the central Pacific as the La Niña re-forms



December 2011 – peak of the 2011–12 La Niña; cooler than normal central and eastern Pacific, but not as cool as at the 2010–11 La Niña peak



March 2012 – 2011–12 La Nina has declined; ocean temperatures in the Pacific approach neutral

The three phases of El Niño–Southern Oscillation

Convection

Convection is the process generally associated with warm rising air and the formation of cloud.

Walker Circulation

The **Walker Circulation** is named after Sir Gilbert Walker, the scientist who first recognised a semi-regular pattern of high and low rainfall (and hence feast and famine) over India.

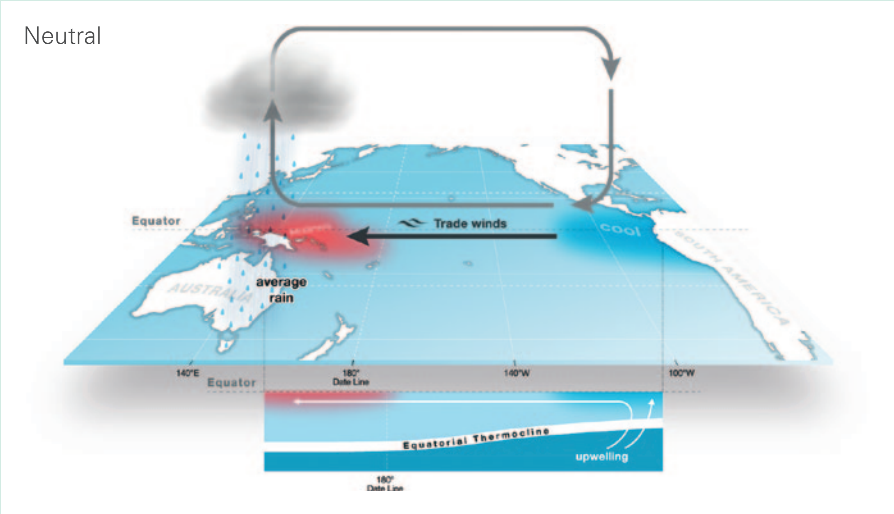
Upwelling

Upwelling is a vertical motion of water. When wind or currents displace water at the surface of the ocean, water from deeper in the ocean is drawn up to replace the displaced water. Deep water is generally cooler and richer in nutrients than surface water so upwelling is important in supporting productivity in the oceans of the world.

The neutral phase

In the neutral state (neither El Niño nor La Niña) trade winds blow east to west across the surface of the tropical Pacific Ocean, bringing warm moist air and warmer surface waters towards the western Pacific and keeping the central Pacific Ocean relatively cool. The thermocline is deeper in the west than the east.

Warm sea surface temperatures in the western Pacific pump heat and moisture into the atmosphere above. In a process known as atmospheric convection, this warm air rises high into the atmosphere and, if the air is moist enough, causes towering cumulonimbus clouds and rain. This now-drier air then travels east before descending over the cooler eastern tropical Pacific. The pattern of air rising in the west and falling in the east with westward moving air at the surface is referred to as the Walker Circulation.



El Niño

During an El Niño event, trade winds weaken or may even reverse, allowing the area of warmer than normal water to move into the central and eastern tropical Pacific Ocean.

These warmer than normal ocean temperatures are associated with a deepening of the thermocline in the central to eastern Pacific. A weaker upwelling of cooler ocean waters from below also contributes to warmer sea surface temperatures.

Sea surface temperatures around northern Australia are cooler than normal and the focus of convection migrates away from Australia eastward towards the central tropical Pacific Ocean. This results in increased rainfall for nations such as Kiribati and Peru, but less rainfall over Australia. The greatest impacts are usually felt over inland eastern Australia, while effects for regions such as southwest Western Australia and coastal New South Wales can vary from event to event, and in western Tasmania the effects are generally weak.

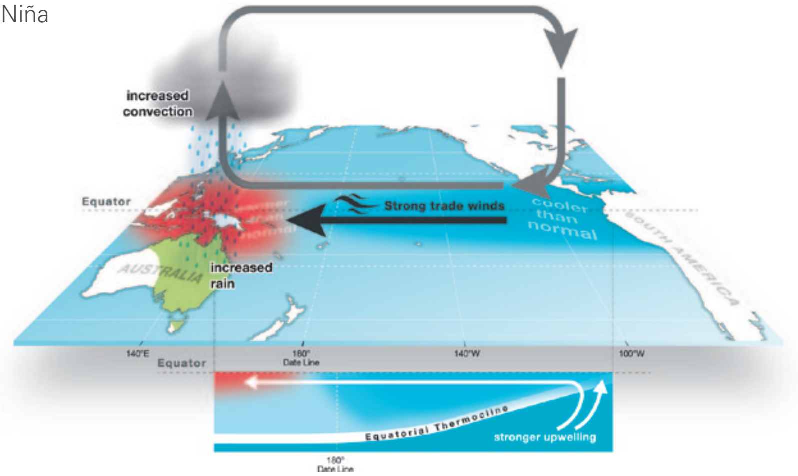
La Niña

During a La Niña event, the Walker Circulation intensifies with greater convection over the western Pacific and stronger trade winds.

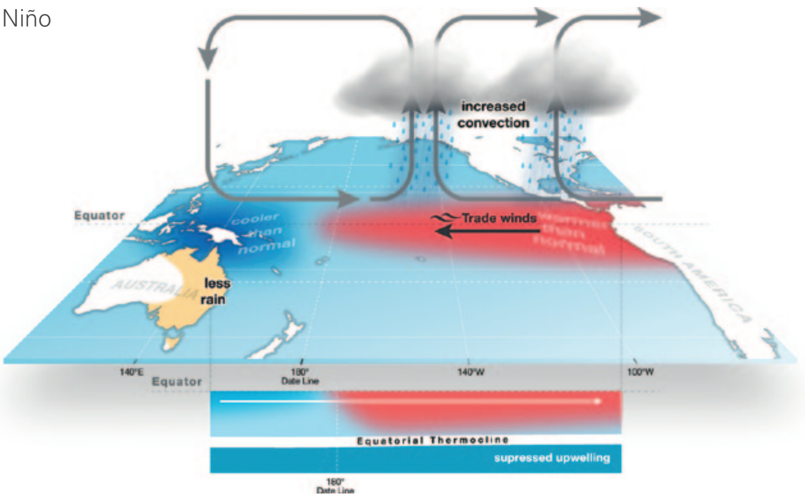
As the trade winds strengthen, the pool of warmer water is confined to the far western tropical Pacific, resulting in warmer than usual sea surface temperatures in the region north of Australia. Sea surface temperatures across the central and eastern tropical Pacific Ocean become cooler than usual and the thermocline moves closer to the surface – cool waters from the deep ocean are drawn to the surface as upwelling strengthens.

Convection and hence cloudiness over the region north of Australia increases as stronger winds provide more moisture to the overlying atmosphere and the Walker Circulation intensifies. This strengthens the Australian monsoon and, if the conditions are right, directs increased humidity and rainfall inland over Australia. La Niña events are associated with increased rainfall over much of northern and eastern Australia. Parts of northern and central Australia tend to feel the impacts of La Niña more than they feel the impacts of El Niño.

La Niña



El Niño



Below the surface

ENSO events are typically led and sustained by changes in the amount of heat held in the waters below the surface of the tropical Pacific Ocean.

The deeper ocean is important in gauging the strength, and hence potential longevity, of an event. These large stores of heat (El Niño) or lack of heat (La Niña) act like a flywheel and ensure that an event will not dissipate rapidly. For example, during the 1997–98 El Niño event – which many consider the El Niño of the century – surface temperatures were around 3.5 °C warmer than normal in the eastern tropical Pacific, but temperatures at 150 m below the surface were up to 8 °C above average. Conversely, during the 2010–11 La Niña, eastern Pacific Ocean surface temperatures were up to 2 °C cooler than normal, but the subsurface temperatures were almost 7 °C below average.

Such large changes in the deeper ocean ensure that the surface waters stay warm or cool even when the atmosphere above might try to push the system back towards neutral, and so can sustain or lead an ENSO event.

The Southern Oscillation Index

The Southern Oscillation Index (SOI) is a measure of the intensity or strength of the Walker Circulation. It is one of the key atmospheric indices for gauging the strength of El Niño and La Niña events and their potential impacts on the Australian region.

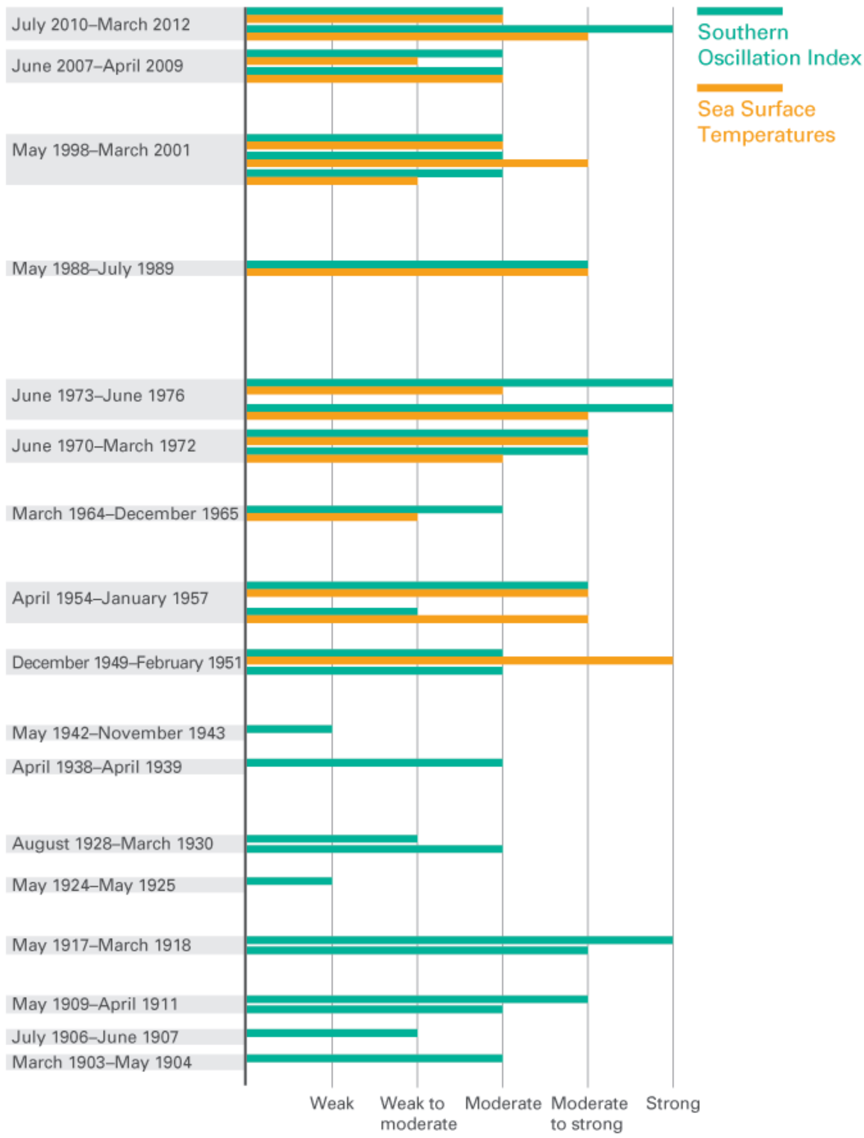
The SOI measures the difference in surface air pressure between Tahiti and Darwin. The index is best represented by monthly (or longer) averages as daily or weekly SOI values can fluctuate markedly due to short-lived, day-to-day weather patterns, particularly if a tropical cyclone is present.

Sustained positive SOI values above about +8 indicate a La Niña event while sustained negative values below about –8 indicate an El Niño.

La Niña events over time

As La Niña events recur on a two to seven-year cycle, there have been many over the last century, varying in strength and impacts. The SOI and sea surface temperatures can be used to compare the intensity of La Niña events. (See graph below for more details.)

Atmospheric and oceanic intensity of La Niña events since 1900. Intensity ranked by SOI values for atmosphere, while oceanic intensity is ranked by sea surface temperature indicators (only available reliably since mid-century). Some multi-year events have two or three La Niña peaks.

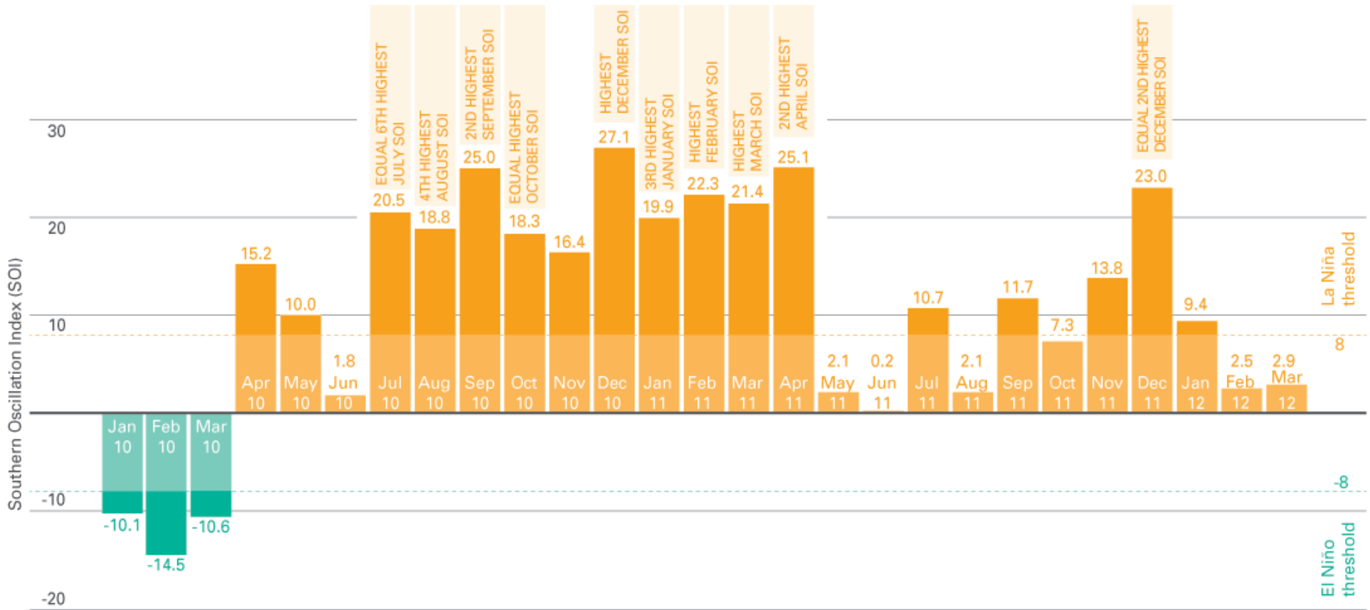


Record high Southern Oscillation Index values

During the 2010–12 La Niña events, record and near-record high Southern Oscillation Index values occurred in many individual months and multi-month periods.

The surface air pressures near Tahiti were consistently high throughout both the 2010–11 and 2011–12 La Niña events, and they were particularly high during the first event. These high SOI values reflect large changes in the typical weather patterns over the South Pacific, which relate to the strong trade winds experienced over the same period and an enhanced Walker Circulation.

The El Niño–Southern Oscillation (ENSO) is described in more detail on pages 6–7.



Monthly SOI values for the 2010–11 and 2011–12 La Niña events – numerous record and near-record values for that particular month are indicated

Comparison to past La Niña events

The 2010–11 La Niña was one of the strongest on record, comparable in strength to the events of 1917–18, 1955–56 and 1975–76. Widespread impacts were experienced across a large part of Australia, including record rainfall and severe flooding.

While the intensity of atmospheric indicators during the event was exceptional, tropical Pacific Ocean indicators did not reach record cool levels. This may have been partly due to the general warming trend in the Pacific Ocean, which has warmed around 0.5 °C since 1950.

The 2011–12 La Niña was a weaker event, but still of moderate strength by both atmospheric and oceanic measures. Despite flooding in a number of areas during summer, the impact of this second event upon Australia's climate was generally less significant than during the previous event.

The previous two La Niña episodes were also multi-year events, lasting from September 2007 to March 2009 and from May 1998 to March 2001, respectively.

The 2007–08 and 2008–09 La Niña events were weak to moderate, with relatively minor impacts across Australia. Although the 2007–08 event brought the typical heavy rainfall to most of northern Australia and the eastern tropics, the southern half of the Murray–Darling Basin did not receive the above-average rainfall and cool temperatures typical of past La Niña events. The 2008–09 La Niña was a short event, bringing significantly above-average rainfall across the north of Australia, although most parts of southeastern Australia received below-average rainfall, consistent with persistent drought conditions in place for the region since at least 2000.

The 1998–2001 La Niña persisted for three years with three distinct peaks over the summers of 1998–99, 1999–2000, and 2000–01. The event was generally moderate in strength, with widespread above-average rainfall and flooding, particularly in New South Wales and Queensland. While much of the north received record high falls, parts of the southeast and Tasmania missed out on the heavy rainfall, and hence did not get the relief from the dry conditions that had started around late 1996.

El Niño–Southern Oscillation impacts – rainfall

The complex interactions between the ocean, atmosphere and adjacent landmasses across the Pacific mean that ENSO events have impacts on weather in areas outside the tropical Pacific region. El Niño and La Niña events are associated with distinct climatic conditions around the Pacific.

La Niña events are associated with greater convection over the warmer ocean to Australia's north. Typically this leads to higher than average rainfall across much of Australia, particularly inland eastern and northern regions, sometimes causing floods.

During El Niño events, the ocean near Australia is cooler than usual, bringing lower than average winter–spring rainfall over eastern and northern Australia. Although most major Australian droughts have been associated with El Niño events, widespread drought is certainly not guaranteed when an El Niño is present.

Deciles ?

Deciles are calculated by (1) taking all available data (say, annual Australian rainfall from 1901 to 2000), (2) ordering them from lowest to highest, and (3) dividing them into 10 separate groups of equal size. Each group is called a decile – the lowest 10 per cent of historical values is decile 1, the next lowest 10 per cent will be decile 2, and so on, up to the highest 10 per cent of historical values which lie in decile 10. This creates a scale against which we can rank the amount or intensity of a measurement or event.

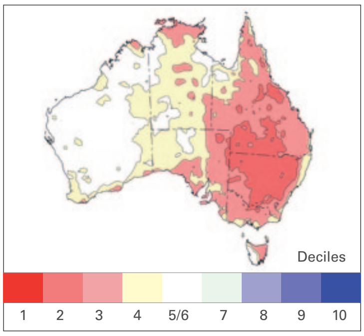
Rainfall patterns during La Niña and El Niño events

Australian rainfall data for 13 of the strongest 'classic' or 'canonical' events (having the typical autumn to autumn pattern of evolution and decay) since 1900 have been combined to form a composite of average impacts of La Niña and El Niño events upon rainfall across Australia.

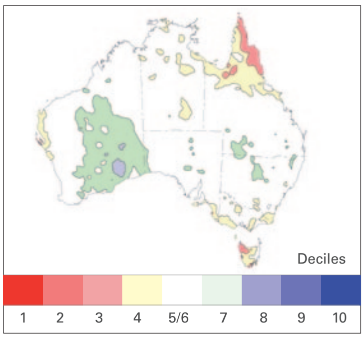
Each map shows mean rainfall deciles, where green to blue tones indicate above-average to very much above-average rainfall totals and yellow to red tones indicate below-average to very much below-average rainfall. Note that the rainfall patterns can vary significantly from one event to the next.

El Niño

El Niño is typically associated with reduced rainfall in northern and eastern Australia



Winter/spring rainfall – below average across eastern Australia

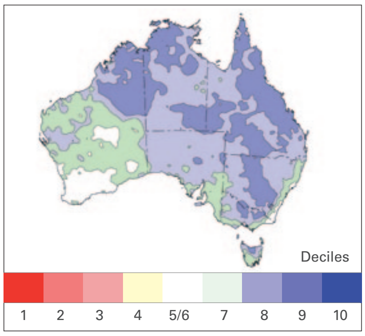


Summer rainfall – mostly near average

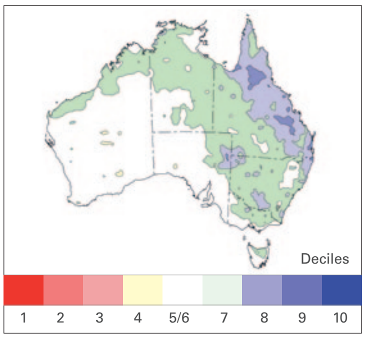
The onset years for the 13 strongest 'classic' El Niño events used are 1905, 1914, 1940, 1941, 1946, 1965, 1972, 1977, 1982, 1991, 1994, 1997 and 2002.

La Niña

La Niña is typically associated with increased rainfall in northern and eastern Australia



Winter/spring rainfall – above average across most of eastern and northern Australia



Summer rainfall – above average in eastern and northern Australia

The onset years for the 13 strongest 'classic' La Niña events used are 1906, 1910, 1916, 1917, 1950, 1955, 1956, 1971, 1973, 1975, 1988, 1998 and 2010.

Record rainfall and widespread flooding across Australia

In 2010, Australia experienced its third-wettest year since national rainfall records began in 1900, with second place taken by 2011. Averaged across Australia, both years experienced rainfall well above the long-term average of 465 mm – 703 mm in 2010 and 708 mm in 2011.

Only 1974, dominated by one of the strongest La Niña events on record, was wetter with 760 mm. 2010 was also the wettest year on record for the Murray–Darling Basin and Queensland, while 2011 was the wettest year on record for Western Australia.

During the 2010–11 La Niña, most of mainland Australia experienced significantly higher than average rainfall over the nine months from July 2010 to March 2011. Parts of Tasmania also received heavy rainfall while southwest Western Australia missed out, experiencing its driest year on record. A number of new Australian rainfall records were set: wettest September, December and March on record and second-wettest October and February. May to October 2010 was the wettest 'dry' season on record in northern Australia, and July to December 2010 was the wettest second half of the year on record for Australia as a whole.

Several seasonal records were also set: wettest spring on record for Australia, and all States except Victoria and Tasmania; wettest summer on record for Victoria; and second-wettest summer on record for Western Australia and Australia as a whole.

While the 2010–11 La Niña event was costly in an economic and social sense, it relieved one of the longest and most severe droughts across the Murray–Darling Basin in recorded history. Heavy rain provided a significant boost to water storages in Queensland, New South Wales and South Australia. Nationally, water held in major publicly owned storages rose by more than 20 per cent between May 2010 and May 2011.

During the 2011–12 La Niña, rainfall was above average for most of mainland Australia for the six months from October 2011 to March 2012, but not as much above average as for the 2010–11 event. Nevertheless, several rainfall records were set: second-wettest November and spring on record for Western Australia, and second-wettest March for New South Wales.

Combined, the two events yielded Australia's wettest 24-month period on record (April 2010 to March 2012), and wettest two-calendar-year period (2010–2012). The record rainfall of 1411 mm in 2010–2011 beat the previous

Widespread flooding

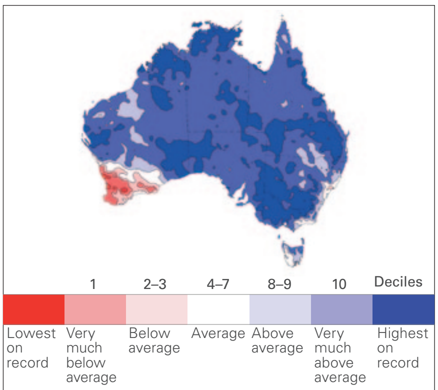
The record-breaking rainfall during the 2010–11 La Niña led to widespread flooding in many regions between September 2010 and March 2011. As well as the severe flooding in southeast Queensland, large areas of northern and western Victoria, New South Wales, northwestern Western Australia and eastern Tasmania were subject to significant flooding. There were also some highly unseasonable rain events in the tropics during what is typically its dry season.

Flooding was also widespread during the 2011–12 La Niña. Much of inland southern and far northern Queensland, most of New South Wales, northern Victoria, and central Australia experienced flooding at least once between late November 2011 and March 2012.

See the timeline on pages 20–23 for more details on the widespread flooding across Australia.

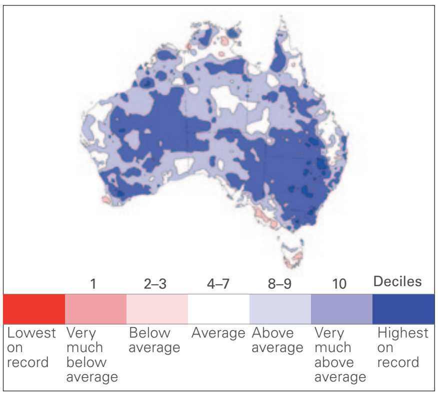
Heavy rainfall during both La Niña events

2010–11 La Niña event
Extreme rainfall



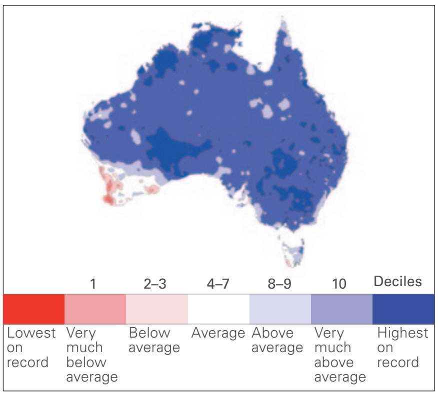
July 2010 to March 2011 rainfall deciles (based on climatology of gridded monthly rainfall analyses from 1900)

2011–12 La Niña
Well above-average rainfall



October 2011 to March 2012 rainfall deciles (based on climatology of gridded monthly rainfall analyses from 1900)

The two events combined
Record-breaking rainfall



July 2010 to March 2012 rainfall deciles (based on climatology of gridded monthly rainfall analyses from 1900)

El Niño–Southern Oscillation impacts – temperature

Evaporative cooling ?

Evaporation of surface water, such as lakes, or moisture in the soil, cools the environment surrounding it. This happens because changing a substance from a liquid phase to a gaseous phase (evaporation) requires energy. The energy required for a phase change is known as latent heat, and can be provided by absorption of solar radiation or by drawing heat energy from the air or other substances in contact with the liquid.

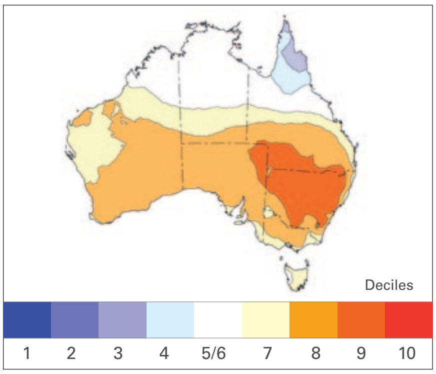
The increased cloudiness and rainfall associated with La Niña periods typically reduces daytime temperatures and keeps nights warmer, particularly over northern and eastern Australia. In the north of Australia, the monsoon is typically enhanced, which can lead to both cooler days and nights during the summer monsoon season as the higher rainfall allows for increased **evaporative cooling**, and increased onshore winds provide additional cooling in the same way a sea-breeze brings relief from a hot summer day.

Temperature patterns during ENSO events

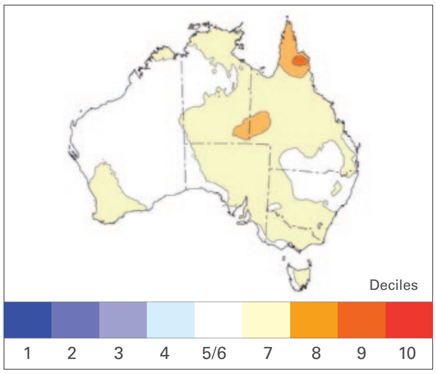
Average impacts of La Niña and El Niño events on maximum (daytime) and minimum (night-time) temperatures across Australia are shown below in composite maps combining temperature data from 12 of the strongest 'classic' events.

The maps show mean maximum and minimum temperature deciles, where blue tones indicate below-average temperatures and orange to red tones indicate above-average temperatures. Note that the temperature patterns can vary significantly from one event to the next.

El Niño

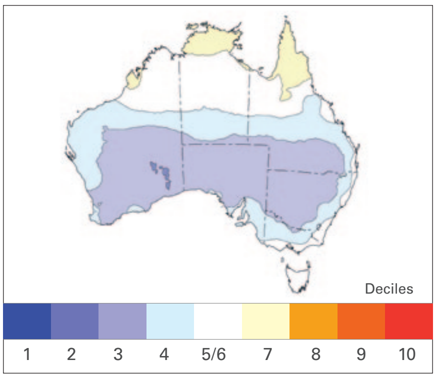


Winter/spring daytime temperatures – above average across southern Australia

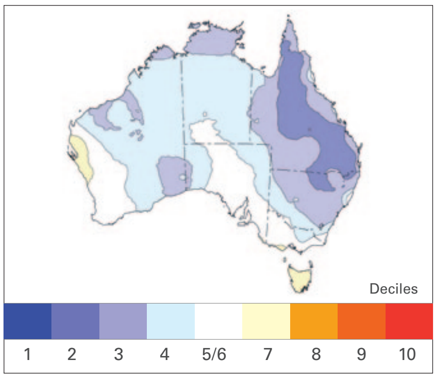


Summer daytime temperatures – slightly above average for most of eastern and northern Australia

La Niña



Winter/spring daytime temperatures – below average across southern Australia



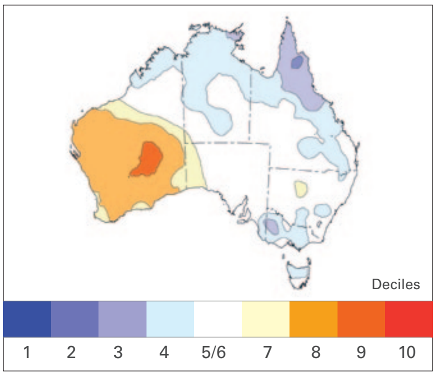
Summer daytime temperatures – below average across most of northern and eastern Australia

In contrast, during El Niño events, reduced cloudiness means daytime temperatures are typically warmer than normal, exacerbating the effect of lower than normal rainfall by increasing evaporation. Reduced cloudiness also means that nights can be cool, sometimes leading to widespread and severe frosts; Australia's lowest recorded temperature, –23.0 °C, was observed at Charlotte Pass on 29 June 1994, during the 1994–95 El Niño event.

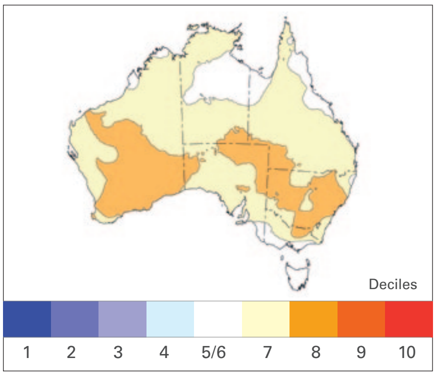
The temperature effect of El Niño events are felt most strongly during winter and spring, while the effects of La Niña events tend to have the greatest impact between October and March. The effect of La Niña events also tends to be stronger than that for El Niño; temperatures are generally further below average during La Niña events than they are above average during El Niño events.

During La Niña
increased cloudiness and rainfall can lead to cooler days.

During El Niño
reduced cloudiness can lead to warmer days.

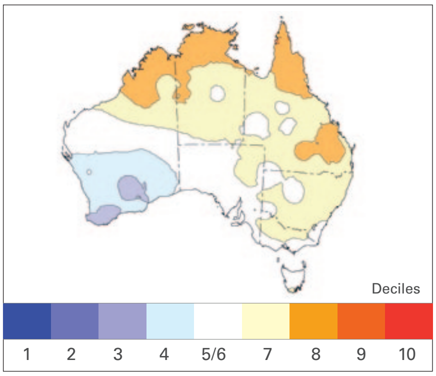


Winter/spring minimum temperatures –
above average for the southwest, below average for the northeast and parts of the east

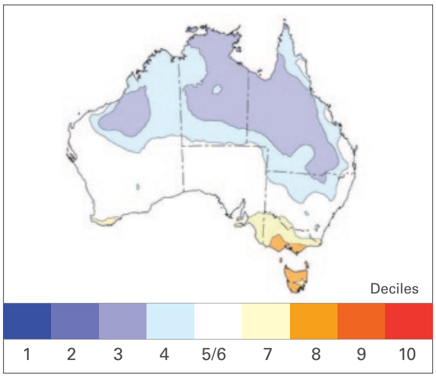


Summer minimum temperatures –
above average across southern Australia

The onset years for the 12 strongest 'classic' El Niño events used are 1914, 1940, 1941, 1946, 1965, 1972, 1977, 1982, 1991, 1994, 1997 and 2002.



Winter/spring minimum temperatures –
above average for much of northern Australia, below average for most of the southwest



Summer minimum temperatures –
below average for northern Australia, above average for parts of the southeast

The onset years for the 12 strongest 'classic' La Niña events used are 1910, 1916, 1917, 1950, 1955, 1956, 1971, 1973, 1975, 1988, 1998 and 2010.

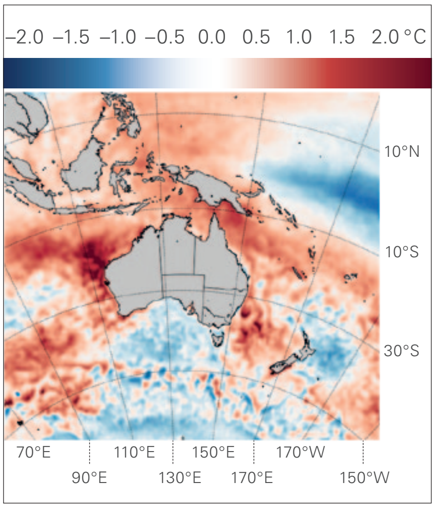
Record sea surface temperatures

Following the 2009–10 El Niño, 2010 was globally (both land and ocean) the warmest year on record, marginally warmer than 1998 (which immediately followed the strongest El Niño event of that century).

Sea surface temperatures north of Australia were also at record-breaking highs – October, November and December 2010 tropical sea surface temperatures north of Australia broke previous records by large margins and, in contrast to temperatures over land, ocean temperatures around Australia were the highest on record during 2010.

This contributed to the strength of the 2010–11 La Niña and its impacts on Australia. The very high sea surface temperatures contributed to an increase in evaporation and high (and at times record) humidity levels over Australia. The increase in humidity was associated with the Australian monsoon arriving earlier and being stronger than normal during the 2010–11 northern wet season. Ultimately, the increase in monsoonal activity and evaporated water added to the potential for high rainfall over northern and eastern Australia.

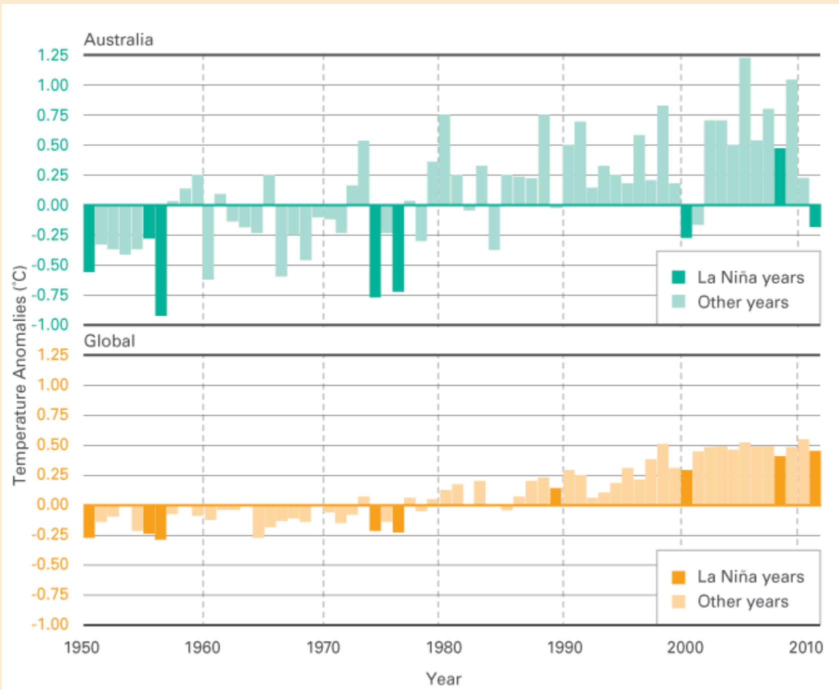
Sea surface temperatures around the northern coasts of Australia were also above average during the 2011–2012 La Niña event, particularly between December 2011 and February 2012, though were not at the record-breaking levels seen in 2010. This would suggest a weaker influence on Australian rainfall.



Sea surface temperature anomalies (°C) in the Australian region, for the period May 2010 to April 2011

Cool down under, warm globally

2011 was Australia's coolest year in a decade (2001–2011). Eight of the last nine years with sustained La Niña conditions recorded a cooler than normal Australian average temperature, except 2008, which was Australia's warmest year on record commencing with a La Niña.



Global temperatures are also influenced by La Niña and El Niño events due to the exchange of heat between the atmosphere and oceans. The end of an El Niño is typically associated with higher than average global air temperatures. However, years commencing with a La Niña in place are cooler than average.

The World Meteorological Organization ranked 2011 as the equal-tenth-warmest year on record. 2011 was the warmest La Niña year on record globally, considerably warmer than the most recent moderate-to-strong La Niña years (2008, 2000, and 1989).

The ten-year average for 2002–2011 was the equal-warmest ten-year period on record both for Australia and globally.

Australian (top) and global (bottom) annual mean temperature anomalies (difference from normal) – in this instance La Niña years are defined as those where central Pacific sea surface temperature anomalies were below –1 °C for a sustained period leading into the start of the year

Warmer nights and cooler days

Record high sea surface temperatures in the tropics from June to December 2010 also contributed to high minimum temperatures in this region, as sea surface temperatures moderate minimum air temperatures over coastal and island regions.

For instance, at Horn and Coconut islands in the Torres Strait, the previous Queensland August record high minimum temperature of 25.4 °C was surpassed on 24 separate occasions during 2010, peaking at 26.8 °C at Horn Island on 19 August. Similarly, record warm ocean waters off Western Australia's west coast led to the hottest year on record for southwest Australia.

High rainfall and associated cloud cover generally kept Australian maximum temperatures below average during both La Niña events. Conversely, increased cloud cover and damp soils meant less heat was lost during the nights, resulting in above-average minimum temperatures for most of Australia during the 2010–11 event, and for southern Australia during the 2011–12 event.

2010–11 La Niña

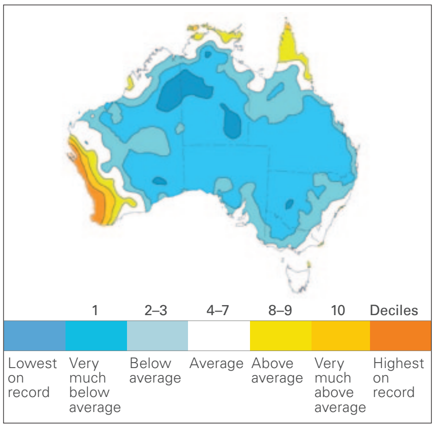
The 2010–11 La Niña was associated with much cooler than average daytime temperatures and much warmer than average night-time temperatures.

2011–12 La Niña

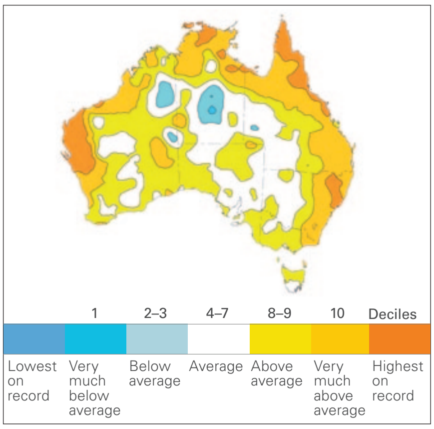
The 2011–12 La Niña was associated with cooler than average daytime temperatures in some areas, but the deviation from normal was not as marked.

The maps below show mean maximum (daytime) and minimum (night-time) temperature deciles, where blue tones indicate below-average temperatures and orange tones indicate above-average temperatures.

2010–11 La Niña

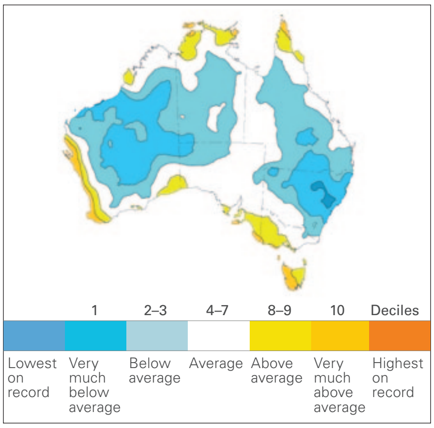


Daytime temperatures (July 2010 to March 2011) – below to very much below average across most of inland Australia

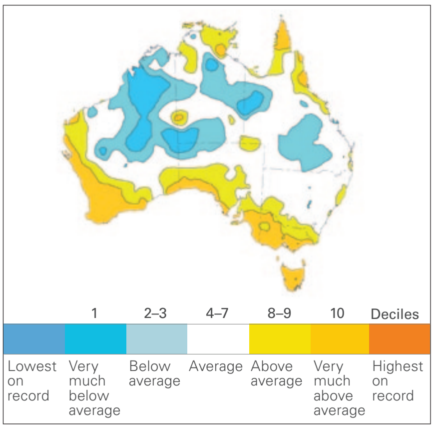


Night-time temperatures (July 2010 to March 2011) – above average to highest on record for large parts of the country

2011–12 La Niña



Daytime temperatures (October 2011 to March 2012) – below average in some parts of inland Australia, above average in some coastal regions



Night-time temperatures (October 2011 to March 2012) – above average across parts of southern Australia and the north, below average inland

2010

Record warm ocean waters off the west coast of Western Australia was associated with the hottest year on record for southwest Australia.

Other El Niño–Southern Oscillation impacts

Other La Niña impacts

- stronger easterly trade winds
- increased risk of tropical cyclones around Australia
- increased cloudiness over Australia.

Other El Niño impacts

- weakened easterly trade winds
- reduced risk of tropical cyclones around Australia
- reduced cloudiness over Australia.

Winds and cyclones

Measurements of winds, both from tracking weather balloons and from satellite observations, also tell us about ENSO. When trade winds blowing from the east increase at the surface, and winds around 10 km above the ground strengthen in the opposite direction, it is clear that the Walker Circulation has strengthened – typical of La Niña. If the Walker Circulation shifts into an El Niño phase, the surface easterlies weaken, or even reverse, and the westerly winds aloft do likewise.

With a stronger Walker Circulation comes a shift westward in the typical area of the Pacific affected by tropical cyclones. Hence the only wet seasons in which Queensland has experienced multiple tropical cyclones crossing its coast have been during La Niña periods.

Cloudiness

Changes in the location of convection over the Pacific mean that the location and level of cloudiness can be used to track the intensity and phase of the Walker Circulation, much as the SOI tracks changes in atmospheric pressure. Radiation ('heat') released into space acts as a good proxy (an indirect measure) for cloudiness as cloud tops are generally far cooler than the earth's surface, and hence more long-wave radiation is released from cloud-free regions, and less in cloudy regions. This radiation can be easily and accurately detected by satellites. Cloudiness along the equator – particularly near the Date Line – typically increases during an El Niño and decreases during a La Niña. Likewise, rainfall for equatorial countries near the Date Line, such as Kiribati, is lower during La Niña and higher during El Niño – the opposite of Australian impacts.

Tropical depression ?

A **tropical depression** is a low pressure system of clouds and thunderstorms with a defined circulation but does not usually have an eye or the spiral shape associated with cyclones or more powerful storms.

The Indian Ocean Dipole (IOD) and the Southern Annular Mode (SAM) are described in more detail on pages 18–19.

No two events are the same

Each El Niño and La Niña event is different from region to region, and event to event. Variations in the timing, location and magnitude of ocean temperature anomalies and wind patterns cause differences both in the strength and extent of climate impacts.

In addition, a chaotic 'weather' factor is involved in any event. For instance, flooding in western Victoria during the 2010–11 La Niña event originated from two tropical cyclones (*Anthony* and *Yasi*) which decayed over central Australia before moving south. While both were 'random' weather events, more cyclones and **tropical depressions** occur in the Australian region and more cross the eastern coast during La Niña events. ENSO also interacts with other drivers of climate variability, such as the Indian Ocean Dipole (IOD) and the Southern Annular Mode (SAM), which increases the likelihood of each event differing from the last.

Tropical cyclone activity during 2010–11 and 2011–12

Tropical cyclone activity in the 2010–11 season was, overall, near normal, with 10 tropical cyclones in the Australian region, while the 2011–12 season was below average, with 7 tropical cyclones. Usually, during La Niña events, tropical cyclone numbers around Australia's north are higher than the long-term average (11) over the November to April tropical cyclone season.

However, five of the tropical cyclones during 2010–11 were in the severe category, which is above average. At least 29 systems developed into tropical depressions, which is one level below a tropical cyclone. This is well above the number of tropical depressions observed in any tropical cyclone season in the Australian region since at least the mid-1990s (20 tropical depressions developed in 2011–12, also above average). In addition, three tropical cyclones (*Tasha, Yasi,* and *Anthony*) crossed the Queensland coast in the 2010–11 season, and two ex-tropical cyclones (*Grant* and *Jasmine*) in 2011–12. Historically, multiple landfalls of severe tropical cyclones between Port Douglas and Ballina on the Queensland coast have only occurred in a single season during La Niña years. It remains unclear why both seasons saw numerous tropical depressions but an unusually small number of these eventually formed into tropical cyclones.

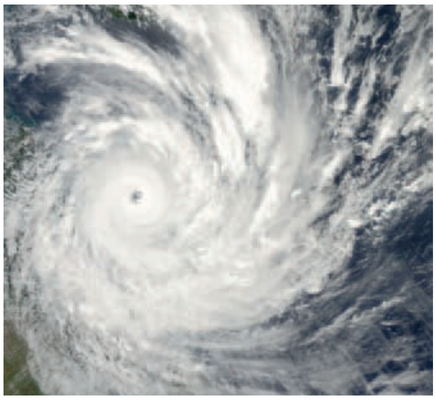
Severe tropical cyclone *Yasi*, possibly the most powerful cyclone to make landfall in Queensland since 1918 (when two powerful tropical cyclones hit Innisfail and Mackay, also at the tail end of a La Niña), crossed the coast between Cairns and Townsville on 3 February 2011.

Tropical cyclone *Carlos* brought very heavy rainfall to the greater Darwin area between 15 and 17 February 2011, breaking numerous records, including record high daily rainfall at Darwin Airport with 367.6 mm on 16 February and a record three-day total of 684.8 mm. The average February monthly rainfall at Darwin Airport is 376.1 mm.

Tropical cyclone *Grant* brought very heavy falls to the Top End over 25 and 26 December 2011, resulting in flooding north of Katherine, which caused significant infrastructure damage, cutting roads and rail links, as well as derailing a freight train.

Tropical cyclone *Lua* made landfall on the Pilbara coast as a severe tropical cyclone on 17 March 2012. It was the strongest cyclone to cross the Western Australian coast since *Laurence* in 2009, and brought significant rainfall to a broad area of western and central Western Australia.

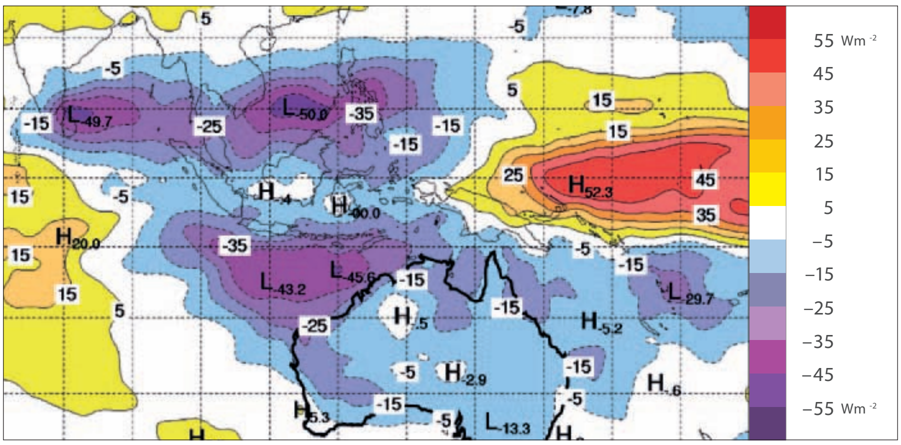
A tropical depression made landfall in the Gascoyne region of Western Australia, and while it never reached official tropical cyclone status it resulted in 207.8 mm of rainfall at Carnarvon on 17 December 2010 and 255 mm for the event. Carnarvon's average December rainfall is 5.6 mm and its annual average total rainfall is 231 mm.



Tropical cyclone Yasi *as it approached the Queensland coast just south of Cairns, captured by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite, 2 February 2011*

Cloud cover

During the peak of the 2010–11 La Niña event, cloudiness over Australia increased. This increase in cloud can be correlated with the increased rainfall (as seen on page 10), reduced daytime temperatures and increased night-time temperatures (pages 12–13) observed during the La Niña event.



Outgoing long-wave radiation (OLR) anomalies over the greater Australasian region for summer 2010–11. Negative anomalies (blue and purple colours) indicate increased cloudiness and less heat lost to space, while positive anomalies (yellow and red colours) indicate reduced cloudiness. The widespread cloud over the Australia–Indonesia region during the summer is clearly shown.

The Indian Ocean Dipole

The Indian Ocean Dipole

Positive event

- Warmer sea surface temperatures in the western Indian Ocean relative to the east
- Easterly wind anomalies across the Indian Ocean and less cloudiness to Australia's northwest
- Less rainfall over southern Australia and the Top End.

Negative event

- Cooler sea surface temperatures in the western Indian Ocean relative to the east
- Winds become more westerly, bringing increased cloudiness to Australia's northwest
- More rainfall in the Top End and southern Australia.

The Indian Ocean Dipole (IOD) is defined by the difference in sea surface temperature between two areas (or poles, hence a dipole) – a western pole in the Arabian Sea (western Indian Ocean) and an eastern pole in the eastern Indian Ocean south of Indonesia. The IOD affects the climate of Australia and other countries that surround the Indian Ocean Basin, and is a significant contributor to rainfall variability in this region.

Like ENSO, the change in temperature gradients across the Indian Ocean results in changes in the preferred regions of rising and descending moisture and air.

In scientific terms, the IOD is a coupled ocean and atmosphere phenomenon, similar to ENSO but in the equatorial Indian Ocean. It is thought that the IOD has a link with ENSO events through an extension of the Walker Circulation to the west and associated Indonesian throughflow (the flow of warm tropical ocean water from the Pacific into the Indian Ocean). Hence, positive IOD events are often associated with El Niño and negative events with La Niña. When the IOD and ENSO are in phase the impacts of El Niño and La Niña events are often most extreme over Australia, while when they are out of phase the impacts of El Niño and La Niña events can be diminished.

The Southern Annular Mode

Southern Annular Mode

Positive phase

- Band of westerly winds contracts toward Antarctica
- Higher pressures over southern Australia
- Can relate to stable, dry conditions.

Negative phase

- Band of westerly winds expands towards the equator
- More (or stronger) low pressure systems over southern Australia
- Can mean increased storms and rain.

The Southern Annular Mode (SAM), also known as the Antarctic Oscillation, describes the north–south movement of the westerly wind belt that circles Antarctica, dominating the middle to higher latitudes of the southern hemisphere.

The changing position of the westerly wind belt influences the strength and position of cold fronts and mid-latitude storm systems, and is an important driver of rainfall variability in southern Australia.

In a positive SAM event, the belt of strong westerly winds contracts towards Antarctica. This results in weaker than normal westerly winds and higher pressures over southern Australia, restricting the penetration of cold fronts inland.

Conversely, a negative SAM event reflects an expansion of the belt of strong westerly winds towards the equator. This shift in the westerly winds results in more (or stronger) storms and low pressure systems over southern Australia.

During autumn and winter, a positive SAM value can mean cold fronts and storms are farther south, and hence southern Australia generally misses out on rainfall. However, in spring and summer, a strong positive SAM can mean that southern Australia is influenced by the northern half of high pressure systems, and hence there are more easterly winds bringing moist air from the Tasman Sea. This increased moisture can turn to rain as the winds hit the coast and the Great Dividing Range.

In recent years, a high positive SAM has dominated during autumn–winter, and has been a significant contributor to the 'big dry' observed in southern Australia from 1997 to 2010.

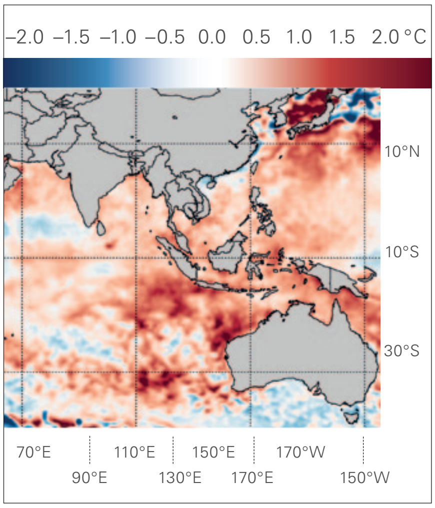
Negative Indian Ocean Dipole increases rain

The IOD was negative from late August to late November 2010 encouraging clouds to form over the eastern Indian Ocean and enhancing the flow of moisture over Australia from the northwest.

The 2010 IOD event was characterised by much warmer than normal ocean surface temperatures in the eastern Indian Ocean, and slightly above-average ocean surface temperatures in the west. This differed from the classical pattern for a negative IOD, which has warmer than usual water in the east and cooler than usual water in the west. At least part of the unusual behaviour of the IOD can be linked to global warming which is leading to a rapid warming of the Indian Ocean both in the east and west.

The combination of a negative IOD and La Niña conditions has historically increased the likelihood of heavy rainfall across Australia which may partially explain the strong rainfall response. However, during the 2010–11 La Niña a strong positive Southern Annular Mode (SAM) partly offset at least some of the effect of the negative IOD across southern, and particularly southwestern, Australia (see SAM below).

There was a weakly positive IOD event during spring 2011, coinciding with the 2011–12 La Niña. The positive IOD may have partially moderated the effect of the La Niña in southeastern Australia during these months, reducing rainfall from what might otherwise have been observed.



October 2010 monthly sea surface temperature anomalies (°C) in the Indian Ocean show much warmer than usual waters in the eastern end of the dipole near Australia. (Anomalies are calculated with respect to the Reynolds climatology for 1971–2000 from the National Climatic Data Center.)

Positive Southern Annular Mode and why Western Australia missed out on rain

The SAM was positive from March 2010 until February 2011. Record-high positive monthly values were observed in 2010 for June, July and November, while August and October were the second-highest on record. The SAM appears to have a weak but discernible relationship with La Niña and El Niño in summer. Hence the positive SAM values in late 2010 may well have been enhanced by the La Niña event.

For southwest Western Australia, 2010 was the driest year on record, continuing and worsening the long drying trend that has affected the southwest since the late 1960s. At least partly as a result of climate change, there has been a change in the dominant weather systems over the region, including a weakening of storms and southwards movement of storm tracks and cold fronts, leading to a reduction in rainfall.

The persistently strong SAM during 2010 meant that high-pressure anomalies dominated parts of southern Australia for most of the southern hemisphere winter–spring. The dominance of the SAM over southern Australia is likely to have contributed to dry conditions in southwest Western Australia during winter and spring.

SAM event

The strong positive SAM event during 2010 is likely to have contributed to the dry conditions in southwest Western Australia.

A timeline of events

Impacts

2010 Australia's third-wettest calendar year, wettest on record for the Murray–Darling Basin and Queensland

Australia's wettest two-calendar year period (2010–2011)

Southwest Australia's driest year on record

JAN '10–DEC '11

El Niño breaking down

Australia's wettest 24-month period on record (April 2010–March 2012)

Australia's third-wettest 12-month period (April 2010–March 2011)

APR '10–MAR'11

Wettest 'dry' season on record for northern and central Australia

2009

2010

December

2009–10 El Niño reaches its peak around late December

January

February

March

APR '10–FEB'11

Pacific Ocean cools rapidly during autumn

Positive SAM (March 2010 –February 2011) – record high values June, July, and November, second highest for August and October

April

ENSO indicators neutral by late April

Climate models suggest increased chance of La Niña

May

First signs of La Niña apparent

June

Sea surface temperatures approach La Niña thresholds

July

Bureau announces La Niña about to become established

Climate models predict La Niña likely to persist through the remainder of 2010

First indication of falling IOD index

Indicators

Represents time duration

Above-average monthly rainfall for most of Australia (July 2010–March 2011)

Wettest second half of the year on record for Australia

JUL '10–MAR'11

Floods and landslips in northeast Tasmania (10–11 August)

Wettest September on record for Australia

Wettest spring on record for Australia, and all States except for Tasmania and Victoria

Major flooding in northern Victoria

Second-wettest October on record for Australia

Floods in southeast Queensland (10–12 October) – Wivenhoe Dam spills for the first time since 2001

Floods in Riverina and southwest slopes New South Wales (13–16 October)

Record high sea surface temperatures around the northern coasts of Australia (October–December)

OCT–DEC '11

Wet season second wettest on record for northern Australia, Queensland, and Western Australia (November 2010–April 2011)

Australian monsoon arrived earlier and was stronger than normal

NOV '10–APR '11

Wettest December on record for Australia and Victoria

Wettest summer on record for Victoria, second-wettest for Western Australia and Australia as a whole

Widespread flooding on inland rivers, especially in New South Wales (early December)

Severe floods in Gascoyne associated with a tropical depression (16–18 December)

Floods in southern and central Queensland (mid-December–January)

August

AUG–NOV '10

Negative Indian Ocean Dipole event (late August–late November)

September

SEP–NOV '10

Monthly SOI second highest on record (+25.0), also the highest monthly value for any month since November 1973

Indian Ocean Dipole strongly negative (September–November)

October

OCT '10–MAR '11

Monthly SOI equal highest on record (+18.3) for October

Bureau seasonal outlooks indicate very high probabilities of above-average spring–summer rainfall for parts of Queensland and New South Wales

Climate models predict La Niña conditions into first quarter 2011

November

Negative Indian Ocean Dipole event decays

December

Monthly SOI highest on record (+27.1) for December

A timeline of events (continued)

Impacts

2011 Australia's second-wettest calendar year, wettest on record for Western Australia

Wettest January on record for Queensland and Victoria

Flooding in western and central Victoria and northern Tasmania (12–15 January)

Flooding in northeastern and western New South Wales and southeast Queensland, notably in Brisbane River catchment and severe flash floods in Toowoomba/ Lockyer Valley

Tropical cyclone *Bianca* brings rain and strong winds to the Kimberley and Pilbara (25–30 January)

Second-wettest February on record for Australia

Tropical cyclone *Yasi* strongest to hit Queensland coast since at least 1918 (3 February)

Severe thunderstorms associated with ex-tropical cyclone *Anthony* cause flash flooding in Victoria (4 February)

Tropical cyclone *Carlos* inundates Darwin (15–17 February)

Wettest March on record for northern Australia

Monsoonal burst causes flooding in eastern Kimberley (week ending 14 March)

Prolonged flooding across western Queensland

Flooding in northeastern Tasmania, southeast New South Wales and Gippsland (20–24 March)

Flash flooding and river flooding in eastern Tasmania (10–13 April)

Increased vegetation following high rainfall in 2010 and 2011 fuels widespread grassfires in central Australia (August–November)

AUG–NOV '11

2011

January

Monthly SOI third highest on record (+19.9) for January

2010–11 La Niña reaches its peak

Unusually warm sea surface temperatures in the western Pacific Ocean

February

Monthly SOI highest on record (+22.3) for February

Climate models predict La Niña to decline to neutral by winter

March

Monthly SOI highest on record (+21.4)

Oceanic ENSO indicators decline but atmospheric indicators continue to indicate strong La Niña conditions (late March)

Climate models forecast neutral ENSO conditions by winter

April

Monthly SOI second highest on record (+25.1) for April

May

Sharp drop in SOI

2010–11 La Niña ends

August

September

Model outlooks indicate re-emergence of La Niña likely

Brief, weakly positive IOD event during spring

Indicators

Represents time duration

Rainfall above average for most of mainland Australia (October 2011 –March 2012)

Australia's record highest October rainfall total: 1494 mm at Bellenden Ker

Second-wettest November and spring on record for Western Australia

Extensive flooding through northeastern New South Wales west of the Great Divide (late November)

Sea surface temperatures around northern Australia above average (December 2011–February 2012)

Tropical cyclone *Grant* brings very heavy rain to the Top End (25 and 26 December)

Extended flooding in northern New South Wales (late January)

Severe flooding in inland southern Queensland and northeast New South Wales (early February to March)

Torrential rain in central and northeast Victoria cause flash flooding (late February)

Flooding in southern New South Wales and northern Victoria (record seven-day falls, 27 February –4 March)

Second-wettest March on record for New South Wales

Heavy rain exacerbates flooding from northern Victoria through southeast and western Queensland

Tropical cyclone *Lua* strongest to cross the Western Australian coast since Laurence in 2009 (17 March)

Australia's rainfall 41 per cent below average

Rainfall across the Murray–Darling Basin is 63 per cent below average

DEC '11–FEB '12

2012

October

2011–12 La Niña declared mid-October, forecast not to be as strong as the 2010–11 La Niña

November

December

Monthly SOI equal second highest on record (+23.0) for December

2011–12 La Niña reaches its peak

January

February

Most oceanic ENSO indicators returned to neutral

March

2011–12 La Niña ends late-March

April

Some climate models indicate that an El Niño may emerge later in 2012

The Bureau regularly issues up-to-date statements and information about the past, current and forecast state of the climate.

ENSO wrap-up

www.bom.gov.au/climate/enso/

Climate model forecast summary

www.bom.gov.au/climate/ahead/ENSO-summary.shtml

Seasonal climate outlooks

www.bom.gov.au/climate/ahead/

United Nations World Meteorological Organization El Niño and La Niña Updates

www.wmo.int/pages/prog/wcp/wcasp/enso_update_latest.html

Watch the Climate Dogs video

The Victorian Department of Primary Industries has produced short videos that depict some of Australia's climate influences in a fun and engaging way.

www.dpi.vic.gov.au/agriculture/farming-management/weather-climate/understanding-weather-and-climate/climatedogs

In collaboration, the New South Wales Department of Primary Industries have also created short videos about how these climate dogs influence New South Wales.

www.dpi.nsw.gov.au/agriculture/resources/climate-and-weather/variability/climatedogs

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Learn more about the science – the Bureau's website and other meteorological organisations provide extensive information aboutclimate drivers and influences.

2010–11 La Niña feature page

www.bom.gov.au/climate/enso/feature/ENSO-feature.shtml

Water and the Land 'Australian Climate Influences'

www.bom.gov.au/watl/about-weather-and-climate/australian-climate-influences.shtml

About the Indian Ocean Dipole

www.bom.gov.au/climate/IOD/about_IOD.shtml

Effects of ENSO in the Pacific: National Oceanic and Atmospheric Administration (NOAA)

www.srh.noaa.gov/jetstream/tropics/enso_patterns.htm

NOAA La Niña Page

www.elnino.noaa.gov/lanina.html

From Arctic Oscillation to Pineapple Express: A Weather-Maker Patterns Glossary

www2.ucar.edu/news/backgrounders/arctic-oscillation-pineapple-express-weather-maker-glossary

Patterns of Atmospheric Circulation Variability – ENSO and Tropical/Extratropical Interactions IPCC Fourth Assessment Report

www.ipcc.ch/publications_and_data/ar4/wg1/en/ch3s3-6-2.html

www.bom.gov.au

Australian Government
Bureau of Meteorology

The 2010–12 La Niñas were two of the most significant events in Australia's recorded meteorological history. This publication explores these extraordinary events and their effect on the weather and climate of Australia during 2010–12. Structured in two parallel streams, the 'background' stream explains some of the major factors that drive La Niña events and how they influence Australia's climate and the 'story' stream illustrates the significance and widespread impacts of the two events.