El Niño, La Niña and Australia's Climate

Photograph by Wayne Hawkins

Australia's climate is highly variable from year to year. For example, 1998 to 2001 were all very wet years across northern and central Australia, with some parts receiving more than double their average rainfall over the four-year period. In contrast, 2002 and early 2003 saw one of the worst droughts in Australia's history. In eastern Victoria alone, the drought led to approximately 1.2 million hectares of land, including 41 houses and 9000 livestock, being burnt over a span of 59 days starting in January 2003. This was the largest fire event in Victoria since 1939.

Much of the variability in Australia's climate is connected with the atmospheric phenomenon called the Southern Oscillation, a major see-saw of air pressure and rainfall patterns between the Australian/Indonesian region and the eastern Pacific. The Southern Oscillation is measured by a simple index, the Southern Oscillation Index (SOI), which can also be related to specific changes in the temperature of the underlying ocean, commonly referred to as El Niño and La Niña events.

Rural productivity, especially in Queensland and New South Wales, responds significantly to the behaviour of the Southern Oscillation. Figure 1 shows how Australia's wheat yield has fluctuated with variations in the SOI. Negative phases in the oscillation, associated with drier periods, usually lead to reduced wheat crops.

What is El Niño?

The term El Niño refers to the situation when sea surface temperatures in the central to eastern Pacific Ocean are significantly warmer than normal. This recurs every three to eight years and is generally associated with a strong negative phase in the Southern Oscillation pendulum.

Parliament House shrouded by smoke from the bushfires on Friday 17 January 2003, during the 2002–03 El Niño. Photograph by Jacky Ghossein, Fairfax Photos.

The Pacific Ocean influences climate over a very wide area of the globe. The equatorial expanse of the Pacific, far larger than the Indian and Atlantic Oceans, is critical to the development of El Niño and the Southern Oscillation.

In most years, the Humboldt Current brings relatively cold water northward along the west coast of South America, an effect enhanced by deep cold water 'upwelling' along the Peruvian Coast.

Under the influence of the equatorial trade winds, this cold water flows westwards along the equator where it is slowly heated by the tropical sun.

These 'normal' conditions mean the western Pacific is 8 to 10°C warmer than the eastern Pacific. That is, while the ocean surface north and northeast of Australia is typically 28 to 30°C or warmer, near South America the Pacific Ocean is close to 20°C. However, in El Niño years, the normal cold water flow along the South American coast and in the eastern Pacific weakens or may even vanish completely, and the central and eastern Pacific may become almost as warm as the western Pacific.

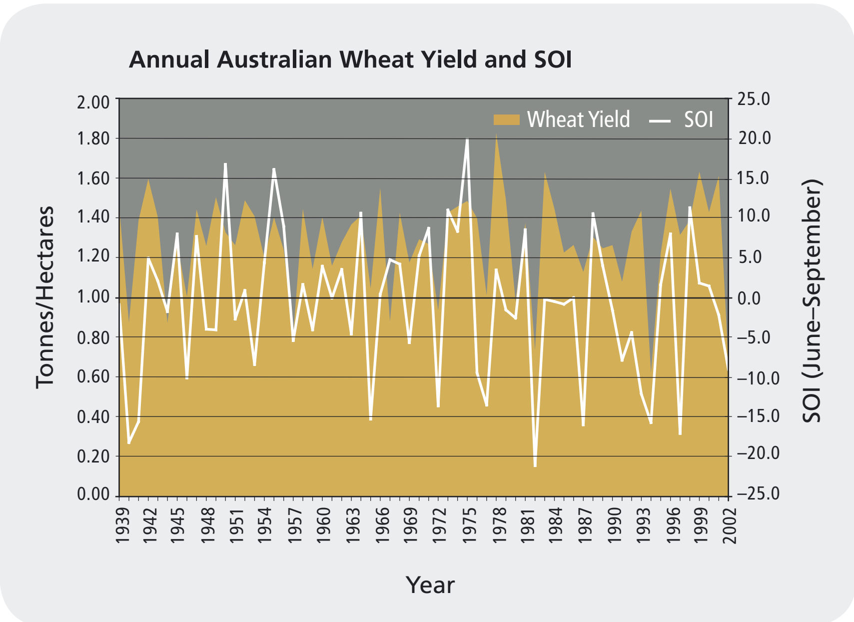

Figure 1 Low wheat yield years often coincide with El Niño (low values of the Southern Oscillation Index).

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The Walker Circulation

The Walker Circulation refers to an east-west circulation of the atmosphere in the vertical plane above the tropical Pacific, with air rising above warmer ocean regions (normally in the west), and descending over the cooler ocean areas (normally in the east). Its strength fluctuates with the Southern Oscillation.

This circulation was named after Sir Gilbert Walker, a Director-General of British observatories in India who, early last century, described a number of apparent relationships between seasonal climate variations in Asia and the Pacific region.

The easterly trade winds are the low-level component of the Walker Circulation. Typically, the trades bring warm moist air towards the Indonesian region. Here, over the normally warm seas, moist air rises to high levels in the atmosphere causing abundant rainfall over the maritime continent and providing a source of moisture for rainfall over Australia.

The air then travels eastward before sinking over the much colder eastern Pacific Ocean (see top panel of Figure 2). The rising air in the west is associated with a region of low surface air pressure, towering cumulonimbus clouds and heavy rainfall. In the east, high pressure and dry conditions accompany the sinking air.

During El Niño events the Walker Circulation weakens and may even reverse in the more intense episodes. In this instance westerly winds are observed (see bottom panel of Figure 2) over parts of the equatorial western and central Pacific where normally easterly (trade) winds would be expected. Oceans around Australia cool, and less moisture is fed into the region.

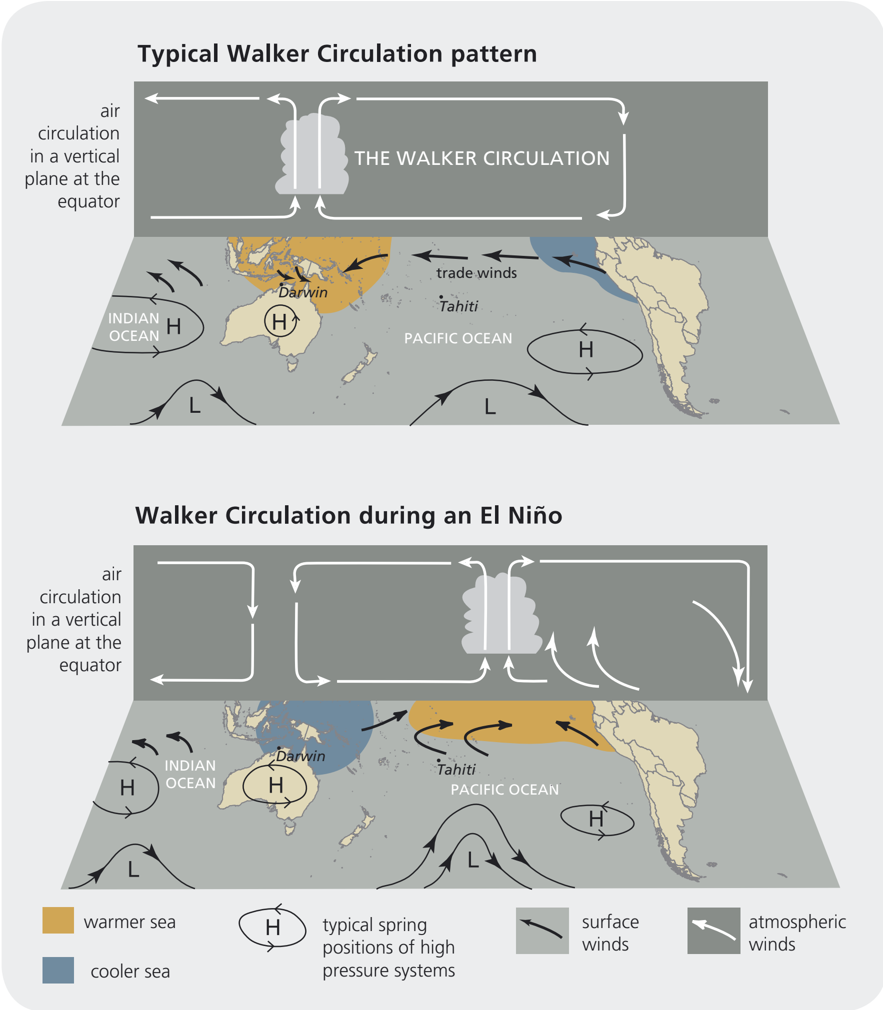

Figure 2 The Walker Circulation in neutral (top) and El Niño (bottom) conditions.

The Southern Oscillation Index (SOI)

The SOI provides a simple measure of the strength and phase of the Southern Oscillation and Walker Circulation. The SOI is calculated from the monthly mean air pressure difference between Tahiti and Darwin. The 'typical' Walker Circulation pattern shown in the top panel of Figure 2 has an SOI close to zero (Southern Oscillation close to the long-term average state).

During El Niño episodes the SOI becomes persistently negative (say below –7). Air pressure is higher over Australia and lower over the central Pacific in line with the shift of the Walker Circulation.

The SOI reflects changes in atmospheric circulation patterns over a wide area and can fluctuate from month to month. A single month with a strongly negative SOI does not of itself mean an El Niño is taking place. Sustained negative values over a period of several months are more usual when an El Niño is developing in the Pacific. Equally, the SOI may occasionally rise close to zero for a month or two during an El Niño event (see Figure 9).

El Niño events usually emerge in the March to June period. It is at this time of year that we can first expect to see falling SOI values and a weakening of the Walker Circulation heralding the onset of an event. An event usually reaches its peak late in the year before decaying during the following year.

Figure 3 The average pattern of winter/spring rainfall during El Niño events. Darker areas indicate moderately consistent shifts towards dry conditions in El Niño years.

El Niño and the Australian climate

El Niño events are associated with an increased risk of dry conditions across large areas of Australia. The period of strongest influence is the six months of winter/spring (i.e., June to November) and Figure 3 shows where the average rainfall impact (taken over the 12 El Niño events 1905, 1914, 1940, 1941, 1946, 1965, 1972, 1977, 1982, 1991, 1994, 1997) is most consistent.

Although most major Australian droughts are associated with El Niño events, widespread drought is not guaranteed just because an El Niño is present.

The effects of El Niño events are not uniform. The greatest impacts are usually over inland eastern Australia; in some other regions, such as south-west Western Australia and coastal New South Wales, the effects of El Niño on rainfall are variable, and in western Tasmania the effects are generally weak.

Some El Niño events are referred to as 'weak' or 'strong', based on the extent to which ocean temperatures in the tropical eastern Pacific increase above their normal levels. In that sense 1982–83 and 1997–98 were very strong events, whilst 1991–92, 1994 and 2002–03 were weaker. While, on the average, a strong event in the ocean tends to have a larger impact over Australia, not all follow this pattern. For example, the weak El Niño of 1994 had a far greater rainfall impact over most of eastern Australia than the very strong event of 1997–98.

All events, even major ones, have different outcomes – ranging from 2002–03, which brought severe drought over most of Australia, to the so-called 'event of the century' in 1997–98, when only relatively small parts of Victoria, New South Wales and Queensland were significantly affected by the time the event had run its course (see Figure 4).

In addition to its effect on rainfall, the El Niño phenomenon also has a strong influence on temperatures over Australia. During winter/spring, El Niño events tend to be associated with warmer than normal daytime temperatures, which serve to worsen the effect of below normal rainfall by increasing evaporation. Conversely, reduced cloudiness and rainfall means that temperatures tend to cool very rapidly at night, often leading to widespread and severe frosts. Indeed, Australia's coldest recorded temperature of –23.0˚C was recorded at Charlotte Pass on June 29, during the 1994 El Niño event.

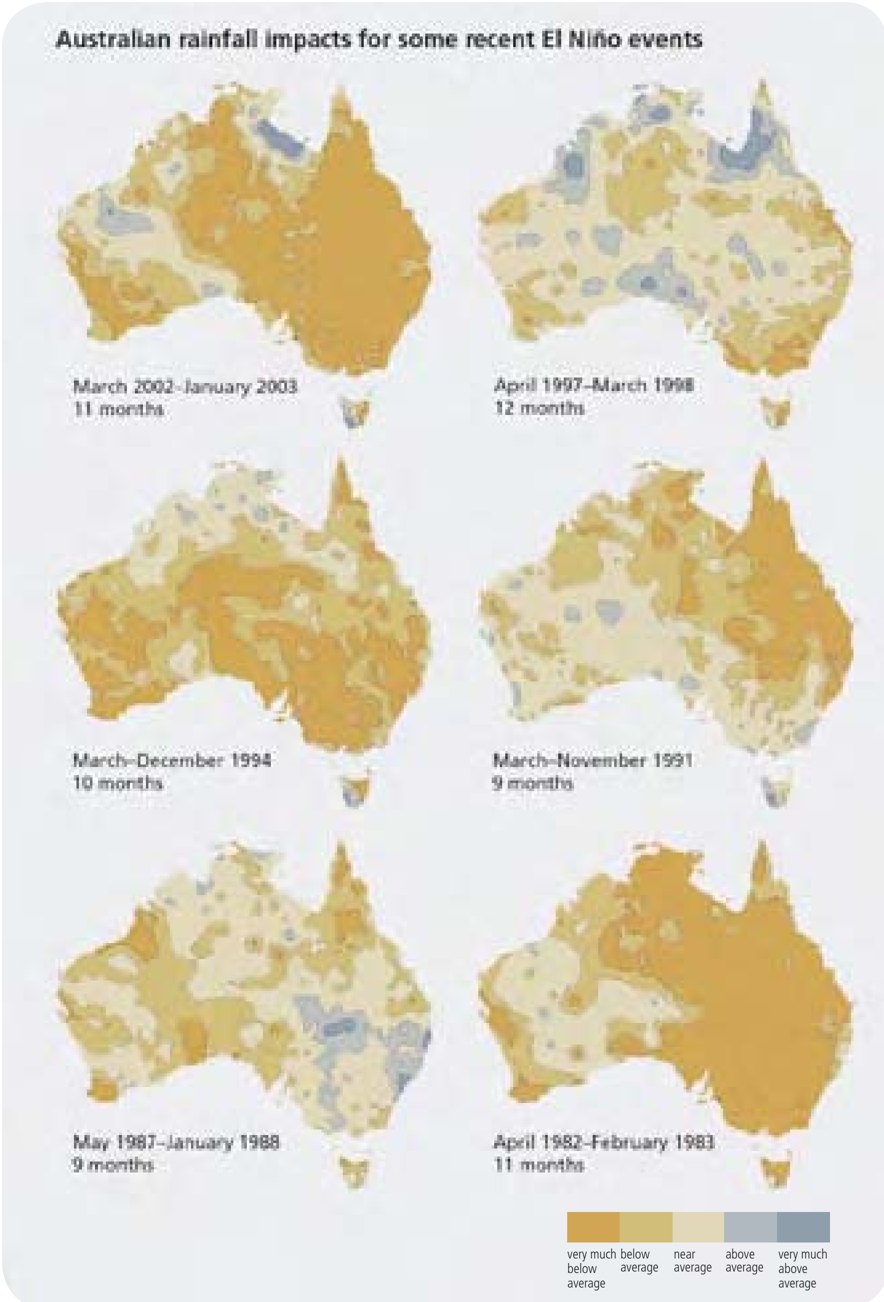

Figure 4 Australian rainfall impacts for some recent El Niño events.

Figure 5 The average pattern of winter/spring rainfall during La Niña events. Darker areas indicate moderately consistent shifts towards wet conditions in La Niña years.

El Niño's Opposite Phase – La Niña

When the eastern Pacific Ocean is much cooler than normal, the SOI is usually persistently positive (say about +7) and the Walker Circulation (upper panel of Figure 2) is stronger than average. These changes often bring widespread rain and flooding to Australia – this phase is called La Niña.

Figure 5 shows that the average La Niña outcome for winter/spring rainfall is not the exact opposite of the corresponding El Niño outcome. This averaged rainfall pattern is drawn from 12 events (1910, 1916, 1917, 1938, 1950, 1955, 1956, 1971, 1973, 1975, 1988 and 1998). The effect of La Niña on Australian rainfall patterns is more widespread than that of El Niño. Parts of northern and central Australia tend to feel the impacts of La Niña (i.e., wetter than normal) more than they feel the impacts of El Niño.

Recent La Niña years include 1973–74 (Brisbane's worst flooding of the 20th century), 1988–89 (vast areas of inland Australia had record rainfall in March 1989) and 1998–2000 (see Figure 6). The 1998–2000 period was wet across most of northern and eastern Australia, with the year 2000 being Australia's second wettest year on record in terms of a national average.

During La Niña phases, temperatures tend to be below normal, particularly over northern and eastern parts of Australia. The cooling is relatively strongest during the October to March period.

La Niña phases tend to have a stronger effect on temperatures than El Niño phases; that is, temperatures are much cooler than average during La Niña events than they are warmer than average during El Niño events.

Monitoring El Niño and La Niña

Meteorologists watch for changes in the atmosphere and ocean, which help them detect the onset of an El Niño or a La Niña, and forecast its life cycle.

Indicators for an El Niño include:

- The Walker Circulation and trade winds weaken, and the latter may even be replaced by westerlies.
- The area of warmest water, usually over the western tropical Pacific, cools and the warmest water is located further east in the central and eastern tropical Pacific.
- An increase in sub-surface temperatures in the central to eastern tropical Pacific to approximately 3˚C above average.
- The SOI remains negative for several consecutive months.
- Increased convection or cloudiness in the central tropical Pacific Ocean – the focus of convection migrates from the Australian/Indonesian region eastward towards the central Pacific Ocean.

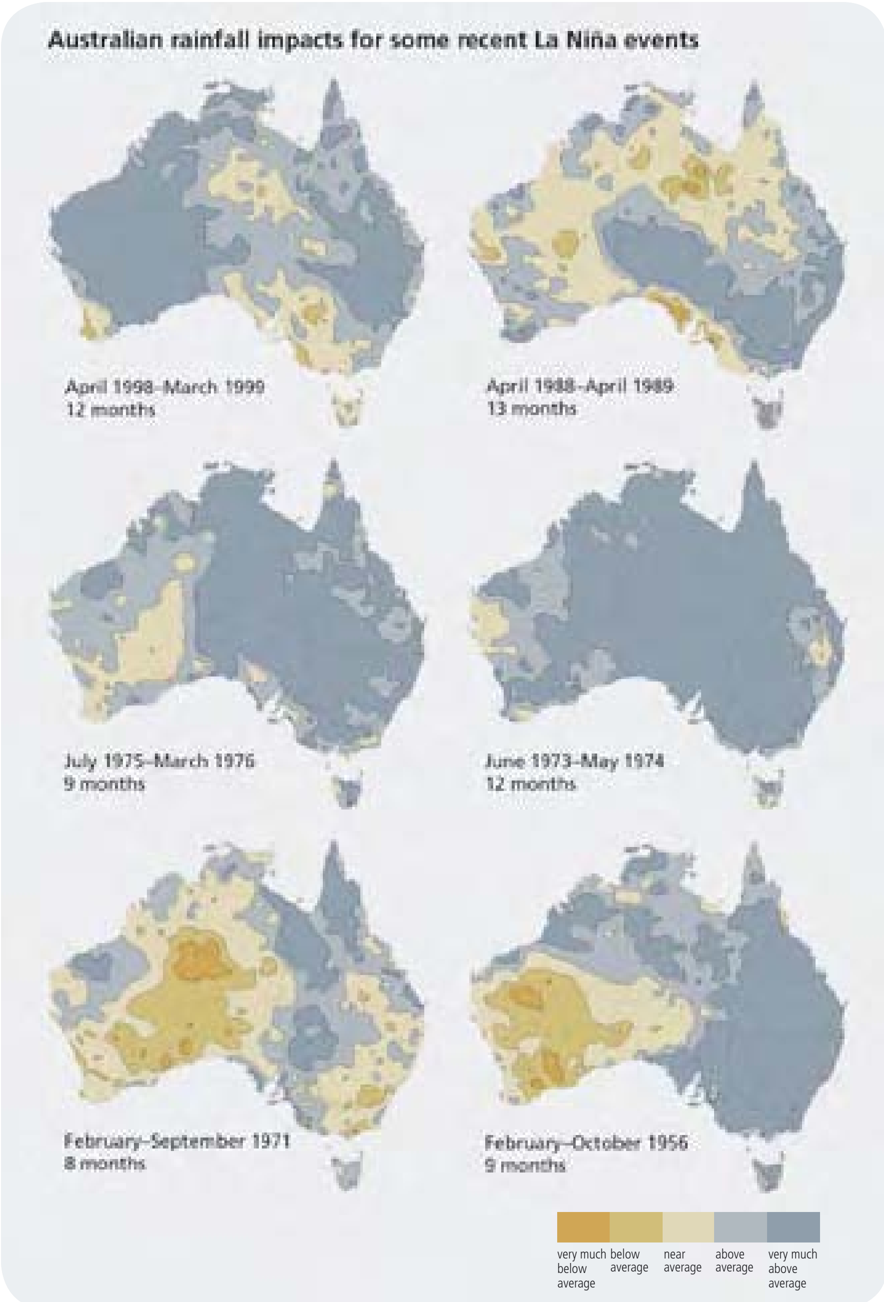

Figure 6 Australian rainfall impacts for some recent La Niña events.

Rising flood waters at Agnes Creek in South Australia, during the 1988–89 La Niña event. Photograph by Ern Mainka.

Indicators for a La Niña include:

- The Walker Circulation strengthens leading to stronger than normal (easterly) trade winds across the Pacific Ocean.
- Cooler than normal ocean temperatures across the central and eastern tropical Pacific Ocean.
- Cooler than average sub-surface waters in the eastern tropical Pacific.
- Consistently positive values of the SOI.
- Increased convection or cloudiness over tropical Australia, Papua New-Guinea and Indonesia.

Forecasting El Niño and La Niña

Scientists have made important advances in understanding the El Niño/La Niña phenomenon in recent decades as a result of research undertaken at the Bureau of Meteorology and other organisations world-wide. This has led to the development of computer models which can be used to forecast the behaviour of El Niño and La Niña some months in advance.

Using this knowledge, the Bureau of Meteorology's National Climate Centre has been producing seasonal climate outlooks for Australia since 1989. The service offers three-monthly outlooks of rainfall and temperature on a regional basis, together with longer term projections of the behaviour of the El Niño-Southern Oscillation.

The monitoring and forecasting of El Niño and La Niña requires a sound understanding of the global climate. The Global Climate Observing System (GCOS) was designed specifically to provide the basic set of observations required for monitoring the global climate, detecting climate change, and predicting climate variations. Part of GCOS is the Global Ocean Observing System (GOOS) which gathers and allows for the processing and analysis of oceanographic observations on a consistent basis. Under the Tropical Atmosphere Ocean (TAO)/TRITON project, over 70 moored buoys across the tropical Pacific send daily information on the Pacific Ocean surface and atmospheric temperatures and winds. Another project within GOOS is the Argo network of temperature-salinity floats. These instruments oscillate over time between the surface and depths of approximately 2000 metres, recording the temperature and salinity to produce profiles of prevailing conditions in the upper ocean. The data is transmitted through satellites as a way of monitoring the ocean and climate fluctuations. The data will provide important information for ocean and ocean-atmosphere computer models. A primary focus of Argo is to document seasonal to decadal climate variability and predictability.

The Argo data, as well as data collected from a wide variety of sources (satellites, ground stations, ships, *etc*.), are

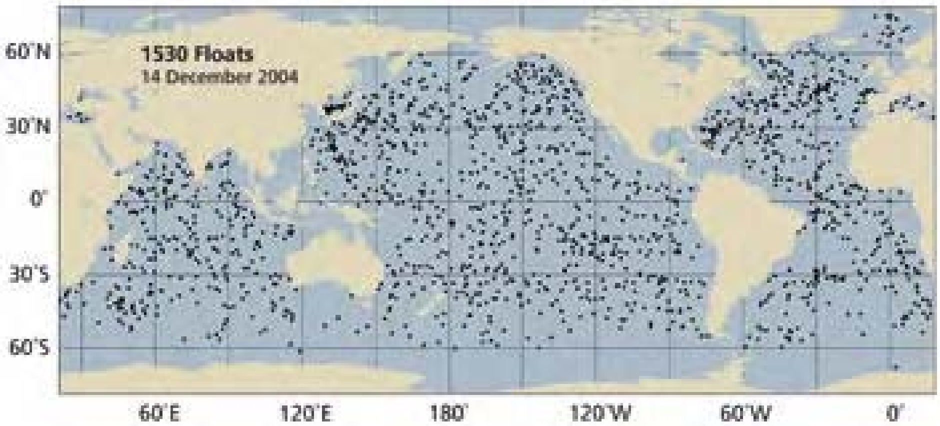

Figure 7 There are currently over 1500 Argo floats spread throughout the world's oceans. The target is to reach 3000 by 2006. Eighteen countries (including Australia) have contributed floats, the USA contributing more than half. Image courtesy of Argo.

assimilated into computer models (at the Bureau of Meteorology and at other meteorological institutes throughout the world), where Pacific Ocean variability several months ahead is monitored and forecast. These models have performed with promising skill in forecasting recent El Niño events.

The Future

The most complex prediction models are the coupled ocean-atmosphere models. These models assimilate data from the atmosphere, ocean and land and use mathematical interpretations of dynamical and physical processes within and between all three earth domains, to generate seasonal forecasts of ocean and atmospheric conditions.

The Bureau of Meteorology is testing a coupled model for suitability in producing seasonal forecasts. The current model, abbreviated to POAMA, has been developed from a joint project between the Bureau of Meteorology Research Centre and CSIRO Marine Research, and its skill is being analysed by the National Climate Centre (see Figure 8).

A major advantage with coupled models is that they are not limited by historical relationships, and have the potential to predict new sets of climate conditions that might not be evident in past records. This means, for example, that they should be capable of incorporating the effects of climate change on El Niño, or distinguishing between the effects of weak or strong El Niño and La Niña events.

POAMA forecasts and analysis

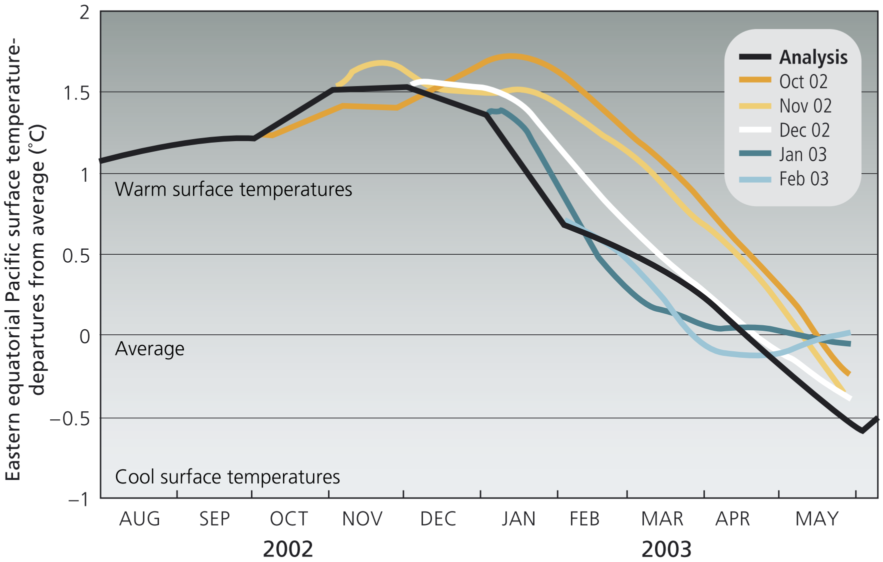

Figure 8 Forecasting the end of the 2002–03 El Niño. Five forecasts run in consecutive months (coloured lines) are compared with the observed values (black line).

Southern Oscillation Index (SOI) 1994–2004

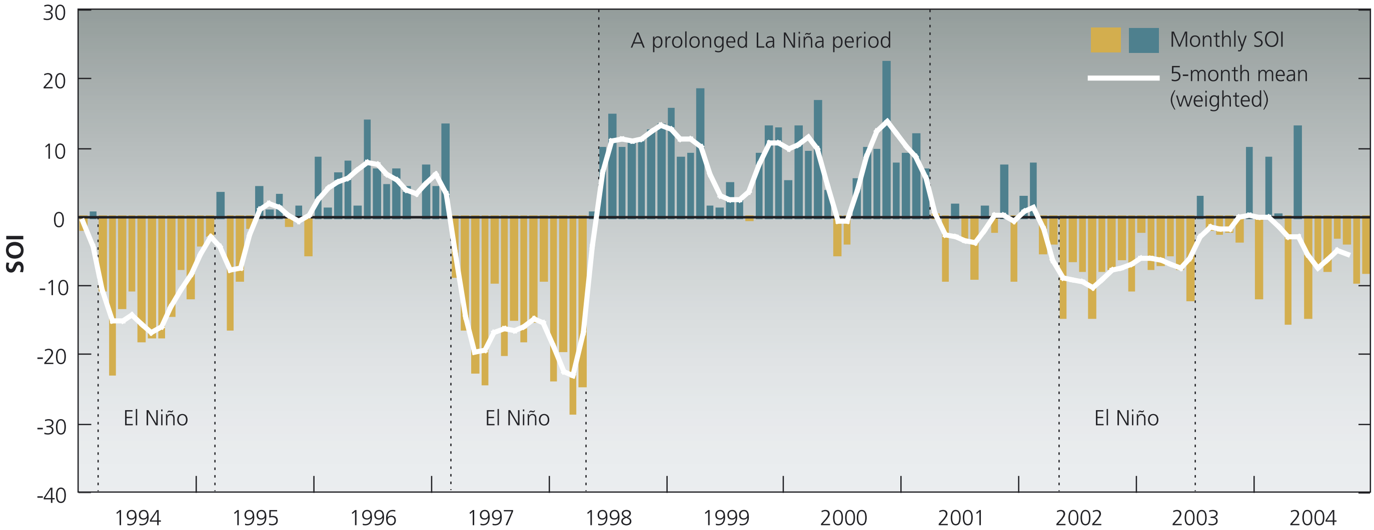

Figure 9 An eleven-year period showing typical fluctuations in the SOI. Positive SOI values are shown in blue, with negative in orange. Sustained positive values are indicative of La Niña conditions, with sustained negative values indicative of El Niño conditions.

Further Information

Visit the Bureau's web site.

www.bom.gov.au

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