Drought and the El Nino phenomenon

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Because we live on the world's most drought-prone continent and the Australian economy depends so heavily upon reliable harvests from dryland crops and pastures, understanding — and possibly predicting — droughts is a major concern of all. While much remains to be learnt, research has begun to throw light on the causes of Australia's devastating droughts.

Back in 1964, Dr C.H.B. Priestley of the former CSIRO Division of Meteorological Physics noted a relation between sea surface temperatures (SST) off the New South Wales coast and the rainfall in the State. More recently, Dr Neil Streten, of the Australian Numerical Meteorology Research Centre (ANMRC), using SST recordings made by ships plying the trade routes around Australian waters, has extended these observations to the whole continent.

Sea surface temperature graphs and rainfall maps prepared by Dr Streten show that anomalously low SSTs are associated with dry years, and higher temperatures with wet years, the changes usually being quite small — of the order of $1-2^{\circ}$ C. Higher SSTs increase regional precipitation not so much through enhanced evaporation from the sea surface as through the warming of the atmosphere; such warming influences the winds and this, in turn, affects the rainfall pattern.

On the larger scale

So the question arises: why do sea surface temperatures around Australia vary from year to year? To fit the Australian observations into a broader picture, Dr Streten extended his analysis of SST to cover as much of the Indian and Pacific Oceans as the limited amount of observations made possible. He found that SST in the eastern Pacific waters off South America, despite being thousands of kilometres away, could be linked to Australian rainfall.



Two scenes from the recent drought.



When these eastern Pacific waters were colder than normal, wet years reigned over Australia. For the dry years - 1957, 1961, and 1965 — that appeared in his 20-year analysis of SST and rainfall, examination of Pacific SST in the years before and after showed that the onset of the dry period usually followed a sudden warming of the eastern Pacific during the summer. The rise was significantly less dramatic in 1961 than in the other two years - showing that a drought can start without being signalled by a big rise in SSTs off South America. However, the link was strong in 1957 and 1965 when a rise in SSTs occurred in the eastern Pacific - associated with the El Nino phenomenon about which much has been written recently.

Since the war, Australia has suffered from droughts of varying severity in 1951, 1957, 1961, 1965–67, 1972, and, most recently for large parts of eastern Australia, 1982–83. El Nino events of varying



The proportion of Australia receiving above-average rainfall was much lower in 1951 than in 1950. The change coincided with a reduction in the proportion of the ocean surrounding Australia that was warmer than normal.

intensity happened around these periods - excepting the drought of 1961 - in 1951, 1953, 1957, 1963, 1965, 1969, 1972, 1976, and 1982.

El Nino

The El Nino is essentially a large-scale warming of the tropical Pacific Ocean off the western coast of South America. It is associated with the trade winds that blow from the south-eastern Pacific towards the area just north of Australia.

These winds generally keep SSTs in the tropical eastern Pacific and along the South American coast lower than those elsewhere in the tropics, by causing cool waters from the deeper ocean to reach the surface. The cold Humboldt Current along the South American coast also helps to keep the SST low in this area.

An El Nino (or 'little child' — because it usually happens around Christmas) event occurs when the trade winds slow, or sometimes even turn back on themselves, and the cool, nutrient-rich subsurface waters can't reach the surface. As a result, local fisheries suffer — but the climatic effects of El Nino are more farreaching, being associated with flooding in South America, droughts across southeastern Asia and Australia, and, occasionally, severe winters in North America.

Combining all the measurements for recent El Nino events shows that, compared with the normal seasonal fluctuation, the average variation is only about 2°C. However, this increase has world-wide repercussions. Observational records suggest that a number of changes to the atmosphere's circulation over the South Pacific precipitate an El Nino event. Around October-November, in the year preceding El Nino, surface pressure at Darwin increases and trade winds west of the International Dateline weaken, while ocean waters near the Dateline warm slightly.

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In the early months of the El Nino year, the inter-tropical convergence zone where the south-east and north-east trade winds meet - moves further south than usual.

These very subtle changes often fall within the expected seasonal variation and are not always reliable signs of an im-



pending El Nino event. However, once an El Nino event begins, the slight change in the normal seasonal cycle is rapidly amplified and a recognizable pattern of changes occurs across the Pacific.

Because of the diminution of the trade winds, warm water builds up in the eastern Pacific, and the East Australia Current, which branches off the South Equatorial Current and runs down the coast of Australia into the Tasman Sea, is not as warm as usual. So the sea surface temperatures off the tropical and eastern coasts of Australia drop and drought sets in; in a more complex fashion, the El Nino event, through its association with higher atmospheric pressure over south-eastern Asia, also affects circulation and SST in the Indian Ocean.

The most recent El Nino event, which occurred last year, slightly differed from earlier ones; its pool of warm water developed in the central Pacific before spreading eastwards, and it began earlier — in May 1982. Because of the associated phenomena, SSTs off the eastern coast of Australia in winter were $1^{\circ}-2^{\circ}C$ lower than usual and these low temperatures persisted into spring and summer.

Only when the trade winds started up again in February 1983, and stirred up the underlying cooler ocean waters, did the pool of warm water (a pool that was up to 5° C warmer than surrounding waters) start to disperse and the seasons start to revert to normal. The warm water spread through most of the central Pacific and down the eastern coast of Australia, presumably bringing with it the autumn 1983 rains that arrived soon afterwards.

Predicting drought

If we could predict El Nino events, it would clearly be a great aid to droughtforecasting. But obviously a complex array of influences determines whether the changes preceding an El Nino are amplified to the stage where a full-scale event occurs.

In ocean temperatures and the extent of the Antarctic ice cap, the earth retains a 'memory' of the weather of recent years; this tends to act as a buffer preventing too great an oscillation in the seasonal cycles, and sometimes what could become a fullblown El Nino event is aborted by as-yetunknown factors.

Dr Streten's analysis shows that SSTs around Australia were low in the 1961 drought year, even though El Nino didn't appear. Similarly, in 1979 and 1980 changes in the wind, sea level, and rainfall west of the Dateline resembled those



El Nino events are associated with some of Australia's severest droughts, but there are anomalies — most notably the absence of El Nino in the 1961 drought and the good rainfall in 1963. Some of these differences can be explained by the varying intensity of El Nino events. For example, in the 1965 event SSTs off South America were 4°C above the long-term average, while in 1963 the increase was less than 1°C. However, much more needs to be known about the dynamics of the Pacific circulation before a full explanation will be possible.

occurring during the development of the El Nino phenomenon. While no El Nino occurred in those years, dry spells set in over eastern Australia, their effects being exacerbated by the 1982 El Nino event. This 1982 event also shows the sort of anomalies that can appear — instead of beginning in summer and being an amplification of the normal seasonal cycle, the 1982 El Nino began in autumn.

Understanding the array of climatic in-

fluences on our weather is the aim of the Climate Research Group within ANMRC. According to the group's leader, Mr Barrie Hunt, they hope to be able to use the knowledge they gain to predict drought.

One of their most important tools is a computer model – described in *Rural* Research 117. This model is being used

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to study the effect of lower and higher SSTs on global rainfall patterns and to determine whether other factors are also involved in initiating drought. So far the model, in manipulating southern Pacific SST, has reproduced many of the weather anomalies discussed earlier, confirming that there is a genuine cause and effect



relation between SST and rainfall variation.

Mr Hunt is particularly interested in understanding how atmospheric patterns during drought conditions can force changes in the behaviour of the oceans, a common example being the stationary highs centred over south-eastern Australia that block the entry of rain-bearing low pressure systems.

To investigate this, the group has developed another model, which has a much simpler representation of the atmosphere, to facilitate experiments dealing with events over many years. At the moment a 10-year simulation, involving changing ocean temperatures, is under way. Plans are afoot to couple this model with an ocean circulation model that will be able to follow the changes in a combined ocean-atmosphere system.

While we now know the general nature of the link between SST and local rainfall, many gaps in our knowledge still need to be filled. Most importantly, we don't know what initiates the changes in the trade winds that lead to the development of the first pool of warm water in an El Nino event; equally, when the warm pool does appear we don't know what sometimes aborts its amplification into a fullscale El Nino event. If we can uncover the factors involved, we will be well on the way to being able to predict droughts. *Wayne Ralph*

More about the topic

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In a normal year the south-east trade winds bring warm water and rain to northern Australia. When El Nino appears, the air flow slows or sometimes even reverses.

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