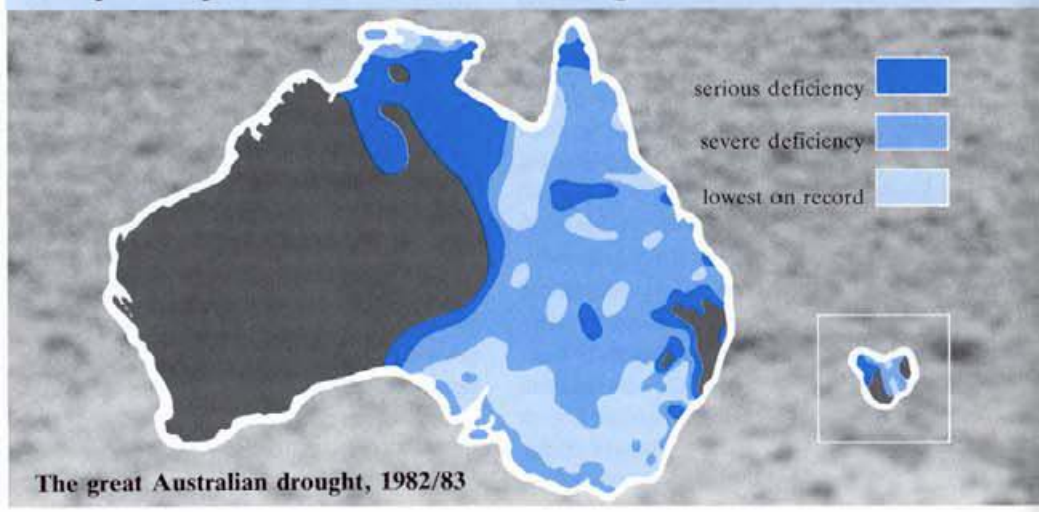
El Niño, and prospects for drought prediction

Australia's 1982/83 drought — the most severe in nearly 100 years, and a major national disaster — will be long remembered. Among atmospheric scientists it is memorable for having been heralded by a huge perturbation, affecting both atmosphere and ocean, known as ENSO (El Niño/Southern Oscillation). This has encouraged meteorologists in one of their fondest hopes: perhaps it will prove possible to forecast droughts.



The great Australian drought, 1982/83

Drought, according to one succinct definition, is the unfulfilment of expected rainfall. But it means very different things to different people. An Australian will conjure up a brown parched landscape, while for an English farmer drought means 14 days without rain.

Rainfall is so infrequent in some semi-arid areas of our 'land of droughts and flooding rain' that monthly rainfall totals are 'below average' more than 70% of the time. And statistics point to seriously low rainfall occurring for 40% of the time in some rainfall district or other.

In economic terms, the 1982/83 drought, which affected about half the continent, reduced the net value of national rural production from more than $4000 million to $2300 million. Wheat production in New South Wales was 29%, and in Victoria 16%, of the averages for the previous 5 years.

The 1982/83 drought was the worst on record for large areas of the country.

Reduced harvests, livestock losses, and general economic hardship in the rural community are regular features of Australian droughts. City-dwellers experience flow-on economic effects and, occasionally, dramatic events like dust storms and all-consuming bushfires.

Far more tragic results can occur in third-world countries when the expected rains fail to appear. Across Africa in 1982/83, intense drought amplified the malnutrition and starvation already present. The effects of the drought in Ethiopia were starkly brought to our notice, but less well-reported was the impact on countries to the south. The entire east of that continent was affected, with Tanzania, Uganda, and Zimbabwe most severely afflicted. At the height of the drought, 150

children starved to death every day in Tanzania alone. Many farmers in southern Africa lost up to 90% of their cattle.

Clearly, understanding the causes of drought, and being able to predict its occurrence, would be valuable. Probably we'll never be able to control climate, but prediction of the time and place of forthcoming droughts would allow us to make preparations — moves that might mitigate the worst consequences.

In the last two decades scientists have made progress in understanding cause and effect in the globe's weather patterns. Computers have been an important tool, and so have weather satellites. When the 1982/83 ENSO came along, it became the most widely studied climate anomaly ever and revealed far-reaching interactions in the world's climate system.

A 10-year international scientific project was launched in January 1985 to study these interactions. The aims of this Tropical Ocean and Global Atmosphere (TOGA) study are described in the box on page 17. The Australian scientists involved expect the study will throw light on the causes of drought and other climate anomalies here and in other parts of the world.

Late last year Mr Barrie Hunt of the CSIRO Division of Atmospheric Research convened a meeting of Australian scientists working on an understanding of drought processes. The general view among those attending was that, for some areas at some times, prediction of drought should become possible, even if the prediction was a probability of occurrence rather than a definite statement.

Rain — where and why

Earth's atmosphere contains 'circulation cells' that distribute heat from the sun — accumulated most strongly in the tropics — towards the poles. The one nearest the equator, the Hadley cell, is driven by warm moist air rising from the equatorial surface to a height of 10–15 km, and descending again at a latitude of 20–30° North or South. Its descending arm causes a subtropical high-pressure belt to encircle the globe.

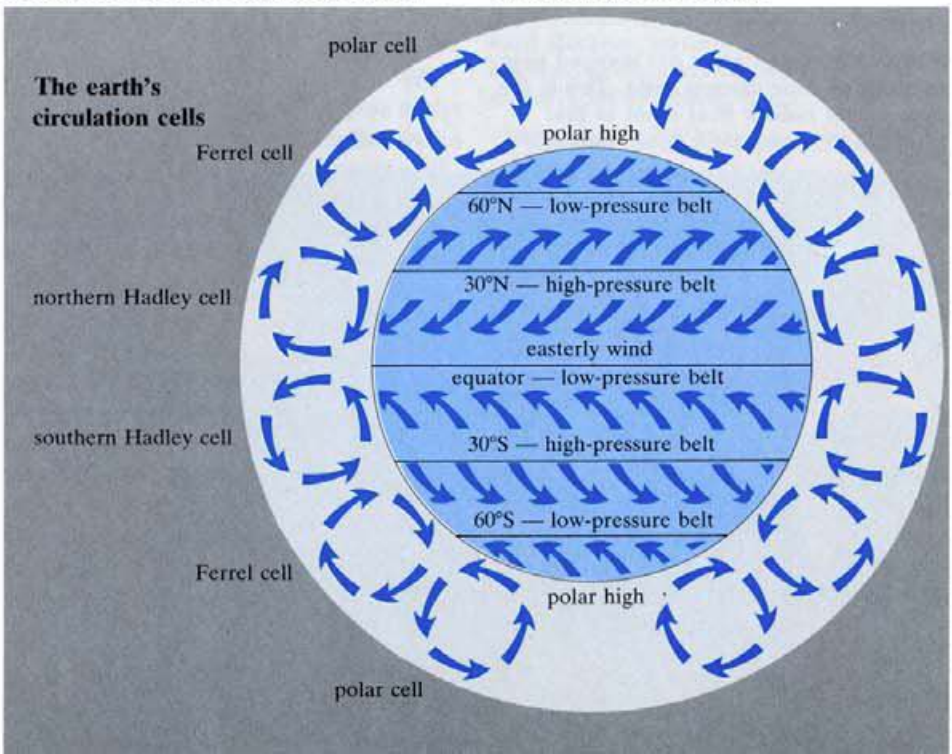
Far-flung correlations have tantalised researchers with the possibility of forecasting drought.

Other main features of the atmosphere's 'general circulation' are the depression-laden westerlies of temperate latitudes, the trade winds of the subtropics, the polar easterlies, and the great monsoons.

When we recall that regions of high pressure on a weather map generally point to absence of rain, it comes as no surprise to recognise that the world's great deserts (see the map on the next page) occupy the region beneath the subtropical high-pressure belt. Adjacent areas experience drought when any anomaly moves the belt from its normal position.

Among such anomalies, the most significant and clearly identifiable are those of sea surface temperature (either cold zones or hot spots). Because of their very large heat-holding capacity, the oceans play a major role in driving the atmosphere. A persistent temperature anomaly in the oceans of only 1° or 2°C can cause appreciable disruptions in the atmospheric circulation.

Heat flows from the equator to the poles through a series of circulation cells. Winds created by atmospheric circulation are deflected by the Coriolis force of the earth's rotation. In the equatorial region this provides the easterly winds that are vital in controlling ENSO events.



The best-known anomaly of sea surface temperatures is El Niño. The term, meaning 'The Christ Child' because the phenomenon appears near Christmas, was used by Peruvian fishermen in the 19th century to describe the abnormally warm water that occasionally appears in Peru's coastal regions in late December. The warm water temporarily displaces the nutrient-rich upwelling cool water, with consequent bad effects on the anchovy fishery.

In early studies, El Niño was seen as primarily an oceanic event of only local importance, with an atmospheric link to increased rainfall over northern Peru and the coast of Ecuador. As a result of the intensive data-gathering of the 1957 International Geophysical Year, however, scientists recognised that El Niño formed part of a large-scale atmospheric phenomenon. This recognition has been one of the major advances in comprehending how the global climate system works.

The link is through the so-called Walker circulation. In the same way that circulation cells appear between the tropics and the poles, air circulates east–west along the equator in cells centred over the great oceans.

The strongest east–west circulation takes place above the Pacific. Warm moist air rises over the Indonesian region, resulting in cloud and rain. The air rises to the upper troposphere (12 km or so) and travels eastwards, to sink towards the cold waters off Peru. The descending air creates an oceanic dry zone off South America.

Air rises over the Indonesian region rather than off Peru because the easterly trade winds drive the ocean circulation and create a thicker and warmer surface layer in the west. The diagram on page 15 shows how this also brings about a cold upwelling off South America.

Under normal easterly trade wind conditions, the sea level is actually about 40 cm higher in the west than in the east. It's when these winds slacken that interesting things start to occur.

Birth of El Niño

Suddenly, the drag on the ocean surface diminishes, and the pile of warm water runs back to the east and stops the upwelling of cold water off Peru: an El Niño is born. The 1982/83 El Niño will go down in the records as one of the strongest this century. From a human and economic standpoint, it might also have been one of the most costly, affecting the lives of nearly half the earth's population.

Reconstructing events, the first signs came during the middle of 1982, when the equatorial easterly trade winds slackened. The easterlies continued to be weaker than usual for nearly a year before abruptly returning to normal.

Late in September 1982 (unusually early as El Niños go), the sea surface temperature off Peru rose 4°C in 24 hours. The fisheries of Ecuador and Peru suffered a drastic reduction, estimated at more than $US 200 million. The rains started in October and persisted until July 1983. Along the coast of Ecuador monthly rainfall reached up to 30 times normal, and in northern Peru it reached a high of 340 times the average.

Further south, severe drought plagued southern Peru and Bolivia. Drought also hit southern India, Indonesia, and the Philippines, and spread over much of Australia.

Our immense dust storms, tragic bushfires, and $2000 million loss in agriculture and livestock production can all be attributed to El Niño. So too can violent storms along the western coast of the United States, which left considerable wind, wave, and rain damage.

The convective region of maximum cloudiness and rain, which normally resides north of Australia, shifted eastwards with the flow of Pacific surface water. Sea surface temperatures reached record values — more than 5° greater than normal in the eastern equatorial Pacific.

These altered conditions led to shifts in the tracks of tropical cyclones. French Polynesia had escaped their fury for the previous 75 years, but was hit six times during the 1982/83 event.

The Southern Oscillation

Just as quickly as it begins, El Niño ends. Ocean temperatures revert to normal, and the Walker circulation changes around to its usual direction. Long sets of meteorological data show that we seem to have a coupled ocean–atmosphere system that irregularly switches to the El Niño state every 2 to 7 years.

The alteration can be seen in records of sea surface temperature, sea level heights, and wind, but the most prominent characteristic is one that was identified (by Sir Gilbert Walker) in the 1920s. It is called the Southern Oscillation, and involves the see-sawing of the atmospheric pressure level between points in the western and eastern Pacific.

Normally, the pressure in the west (Darwin has been picked as the representative station) is lower than that in the east (Tahiti). But during the El Niño events the opposite condition prevails. Scientists now talk of El Niño and the Southern Oscillation in the same breath, and call it ENSO. Both aspects are different manifestations of the same thing.

Although ENSO effects are mainly seen in countries bordering the Pacific, the repercussions are truly global. For example, a significant link exists between Darwin pressure and those in Africa and North America. Recently, Dr Don Adamson of Macquarie University and Mr Jim Baxter and Professor Martin Williams, of Monash University, have found that major droughts and floods over the past 100 years have almost invariably appeared simultaneously over the Nile and Darling basins. These events in turn connect with the state of the Southern Oscillation.

Mr E.T. Quayle reported in 1929 that Victorian rainfall appeared to relate to Darwin air pressure. Dr Robert Allan of Flinders University has reported a link between Australian monsoon behaviour and ENSO, and more recently he has documented relations between the flooding and filling of Lake Eyre and the ENSO cycle.

The intriguing discovery by a colleague, Mr John Pariwono, that sea levels along the western and southern coasts of Australia rise a year before an ENSO event and then fall during it set off a new line of research. Dr Allan and Mr Pariwono are now collaborating in a study of ENSO and ocean–atmosphere interactions in Australasia involving sea levels, sea surface temperatures, and wind-induced oceanic flow from the Pacific through to the Indian Ocean via the Indonesian archipelago.

Correlations

It is such far-flung correlations (or 'teleconnections') that have tantalised researchers with the possibility of forecasting drought.

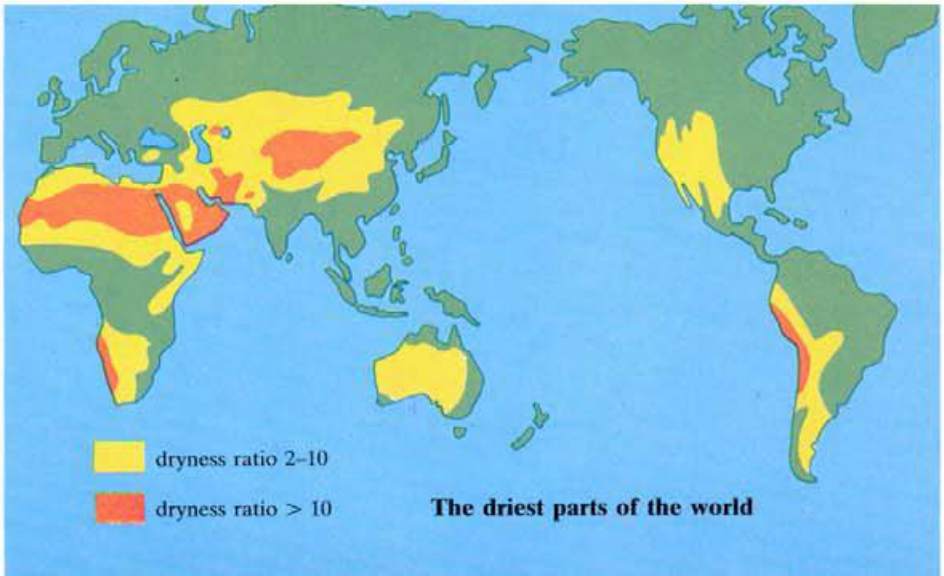
In the mid seventies, Dr Barrie Pittock of the CSIRO Division of Atmospheric Research identified a correlation between Australian rainfall and an index (the pressure difference between Tahiti and Darwin) of the state of the Southern Oscillation. He found that index values showing a greater-than-average pressure difference, indicating strong Walker circulation, are related to increases in eastern Australian rainfall the same year.

Several years later, Dr Michael Coughlan and, subsequently, Dr John McBride and Dr Neville Nicholls, all now at the Bureau of Meteorology, found further interrelations along these lines. In particular, Dr Nicholls demonstrated an ability to predict rainfall a few months in advance, although not very accurately. Dr Neil Streten, also with the Bureau, followed up with a link between sea surface temperatures around Australia and ensuing rainfall. Articles in *Ecos* 9, 22, and 38 describe these findings.

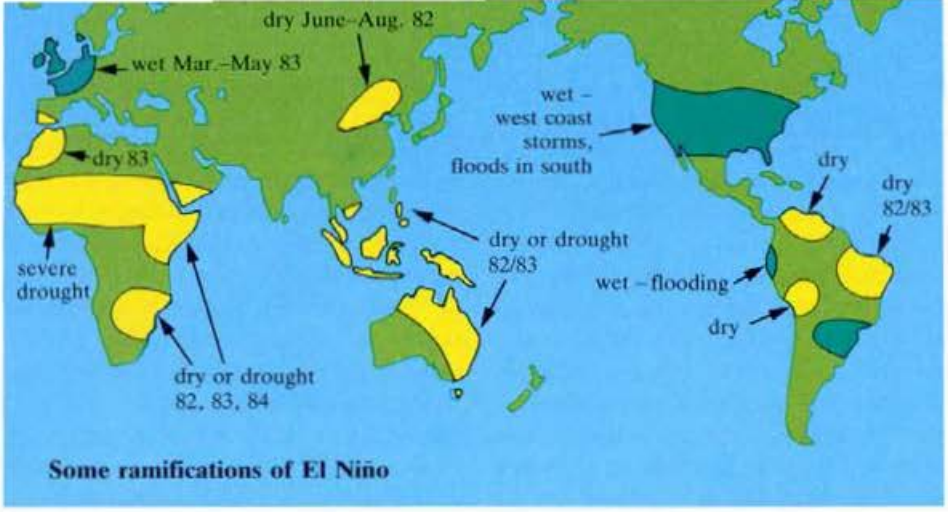
Professor Bill Budd of the Meteorology Department of Melbourne University has also found links between ENSO events and Victorian rainfall.

More recently, Dr Pittock has undertaken an analysis of a larger data set and concluded that other circulation patterns,

The world's driest areas are mapped here in terms of their dryness ratio. This is the ratio of net radiant heat input to that required to evaporate 1 year's rainfall.

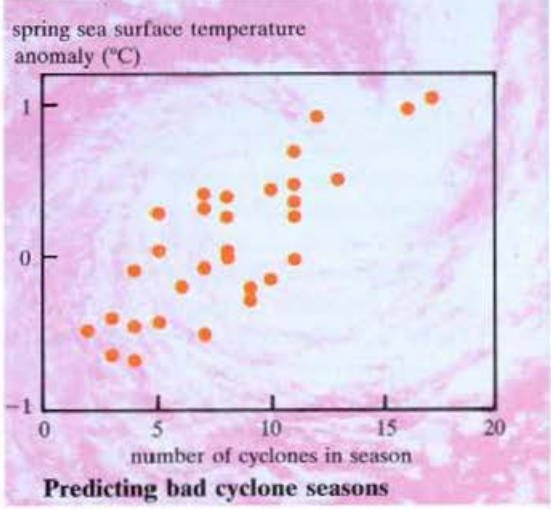


The driest parts of the world



Some ramifications of El Niño

These extremes of precipitation were associated with the 1982/83 ENSO event.



Predicting bad cyclone seasons

When the spring sea surface temperature north of Australia is 1° higher than usual, many cyclones are imminent. Each dot represents one cyclone season; 31 years of data are represented here.

apart from ENSO, must play major roles in determining Australian rainfall. While statistically significant relations between ENSO and Australian rainfall stand, the correlation coefficients hardly ever exceed 0·6, meaning that, at best, these relations can account for only about one-third of the controlling variables.

In addition, some of the patterns and sequences of correlations don't appear to remain constant over time. The correlations wax and wane from decade to decade, casting doubt on the reliability of any forecasting scheme.

Drought precursors

Undeterred, Dr Nicholls has studied links between the Southern Oscillation and major drought in Australia. After drawing up a drought index for the whole of Australia, he has had success in relating it to the Southern Oscillation. Using 50 years' data, he found a correlation coefficient of 0·76 — accounting for more than half the controlling variables.

The drought index is a statistical measure of the extent to which rainfall readings from Australia's 107 rainfall districts vary in unison. When the index is low, large areas of Australia are experiencing drought, and when it's high, widespread rain is falling.

Dr Nicholls found that the areas contributing most to the size of the index were the north of Victoria and the western half of New South Wales, where much of Australia's agricultural production occurs. This shows that rainfall patterns within the rainfall districts of these areas follow each other closely. Dr Nicholls confined his analysis to winter and spring rainfall.

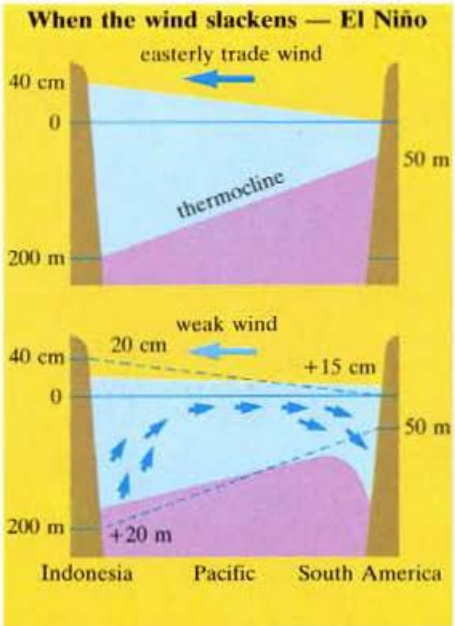
While the drought index formulated this way correlated very well with the Southern Oscillation index, this brings us no closer to being able to predict drought because the correlation is between changes that occur more or less simultaneously. So Dr Nicholls began searching for correlations of the drought index with variables known to change early in the Southern Oscillation cycle.

Sea surface temperature north of Australia is one of these, but unfortunately good data don't extend back very far. Instead Dr Nicholls used the 3-monthly average of the minimum air temperature at Willis Island, off northern Queensland, as a substitute, since data for that go back 44 years.

He found that the trend in the Willis Island temperature from summer to autumn gave a good correlation (of 0·64) with the drought index in the following winter and spring. If the temperature fell 1°C, there was a good chance that much of Australia's agricultural land would experience drought.

Dr Nicholls has uncovered further correlations. For example, an indication of the number of tropical cyclones during a season can be gained from the state of the Southern Oscillation (measured by Darwin air pressure) several months earlier. And variations in the gross crop value, and the yield per hectare, of wheat, oats, barley, and sugar-cane generally follow changes in the sea surface temperature north of Australia. Similar variations with mean sea level pressure at Darwin can be seen. Correlations of up to 0·75 turn up.

Under normal conditions, the easterly trade winds cause a bank up of water on the western boundary of the Pacific. If the wind slackens, warm water runs back towards South America, smothering the normal cold upwelling there.



More recently, Dr Nicholls has come up with a strong correlation (0·7–0·8) between Australia's sorghum yield and the state of the Southern Oscillation even before the crop has been planted!

The Bureau of Meteorology has commenced monthly analyses of meteorological data — such as northern Australian sea surface temperature — that are considered to be important for monitoring the state of the ENSO phenomenon. When characteristic ENSO signals are detected, longer-term outlooks are prepared.

At present, the monthly outlooks are incorporated within the Bureau's Drought Watch System, which has run for more than 20 years now. 'Drought statements' are made whenever any of the more than 100 drought-watch rainfall stations return rainfall figures of less than 10% of the long-term average over a period of 3 months or longer. Since 'drought' is a subjective term, the Bureau prefers to speak of 'rainfall deficiencies'.

Dr Coughlan, now with the Bureau's recently established National Climate Centre, is keen to see as much pertinent information as possible used in preparing the monthly outlooks. For example, estimates of the probability of a drought breaking within given periods, based on historical statistics, may be given. If these estimates can be refined by using trends in sea surface temperatures, then this will be done.

Computer models

Probably it will never be possible to predict all droughts. Indeed the results of experiments with a computer model of the earth's

atmosphere run at the Division of Atmospheric Research by Dr Hal Gordon and Mr Hunt support the idea that some droughts are inherently unpredictable.

The scientists simulated the global atmosphere's activity for 10 years, calculating its characteristics at 30-minute intervals. The model contained nothing out of the ordinary — no anomalies that might induce exceptional behaviour. And its general results mirrored the world's actual regional climate patterns.

Nevertheless, the model showed that rainfall varied substantially from year to year and place to place, and a number of locations experienced droughts lasting a year or two. This suggests that a degree of drought is inherent in the climate system. Nothing untoward preceded these 'natural' droughts; so if they occur by the same sort of mechanism in the real world, they are effectively unpredictable.

However, the cause of drought forecasting is not lost. The droughts uncovered by this modelling exercise are the local sort — they appear at one location but not simultaneously at neighbouring ones. Wide-ranging droughts are clearly of a different order, and Mr Hunt believes we have a good chance of predicting these.

Scientists are now satisfied that the large-scale perturbations associated with El Niño do indeed give rise to widespread drought. Other phenomena, not associated with El Niño, must also be responsible for causing some big droughts, but researchers cannot yet agree what they are.

Some scientists contend that sunspot cycles trigger drought episodes, but this is highly controversial. Others, including Professor Budd, suggest that extensions of the Antarctic sea ice and changes in the Antarctic circumpolar flow may do so. Many maintain that drought begets drought.

This last scenario proposes that the amount of rain falling in a region depends greatly on the pre-existing moisture content of the soil. In inland regions, much atmospheric moisture, and hence rainfall, is believed to derive from local evaporation; hence drying out of the soil — and clearing of the vegetation from land — can promote further drought. This may help explain the protracted drought in the Sahel region of Africa where below-average rains have persisted for more than 10 years.

Numerical models have the potential to answer some of the questions about what causes drought. By running a model with a standard set of conditions, and then with particular changes in those conditions, scientists can isolate cause and effect, and gauge whether the impacts are significantly above those due to random fluctuations.

Mr Hunt believes that, if we had good enough numerical models, we could identify the main drought precursors. He thinks that an International Drought Research Centre, preferably based in Australia, is needed to tackle this problem. Since drought is not just a regional affair, Mr Hunt sees such a Centre contributing both to Australia's welfare and to that of the world at large.

Looking for patterns

Numerical model experiments by Mr Hunt and Ms Mary Voice of the Bureau of Meteorology have provided confirmation that sea surface temperature anomalies are indeed factors leading up to drought conditions in Australia.

In one experiment, the researchers placed a large cold anomaly north of Australia, and drought conditions resulted over parts of Australia, Africa, and the Americas. In another, they looked at the impact of the same cold anomaly plus a warm anomaly in the tropical eastern Pacific. This time, the drought was accompanied by extremely heavy rain over Peru and Ecuador. The similarity to the real-world manifestations of El Niño is striking.

Mr Hunt wants to use numerical models to study possible links between soil and vegetation changes and drought. He hopes to refine his existing model with an improved soil moisture simulation that Dr John Garratt of the Division is currently working on. He also plans to study the circumstances that induce droughts to break.

One phenomenon clearly connected with drought is atmospheric 'blocking', which occurs when an expanded high-pressure cell (or high–low pair) holds its position and prevents the normal west-to-east progression of weather patterns. During the winter of 1982, persistent blocking removed the major source of winter rainfall by displacing winter cyclone tracks southwards.

Two of Mr Hunt's CSIRO colleagues, Dr Jorgen Frederiksen and Dr Alan Plumb, are using mathematical models to uncover the physical processes involved. Some of Dr Frederiksen's research was outlined in *Ecos* 43. Dr Plumb is working with simplified models of the coupled ocean and atmosphere in an endeavour to find the basic mechanism responsible for initiating an El Niño. One interesting possibility suggested overseas and under examination here is that El Niño is a self-contained 'chaotic' system; in other words, it is like a cat chasing its tail, and no external triggering is needed to bring it about.

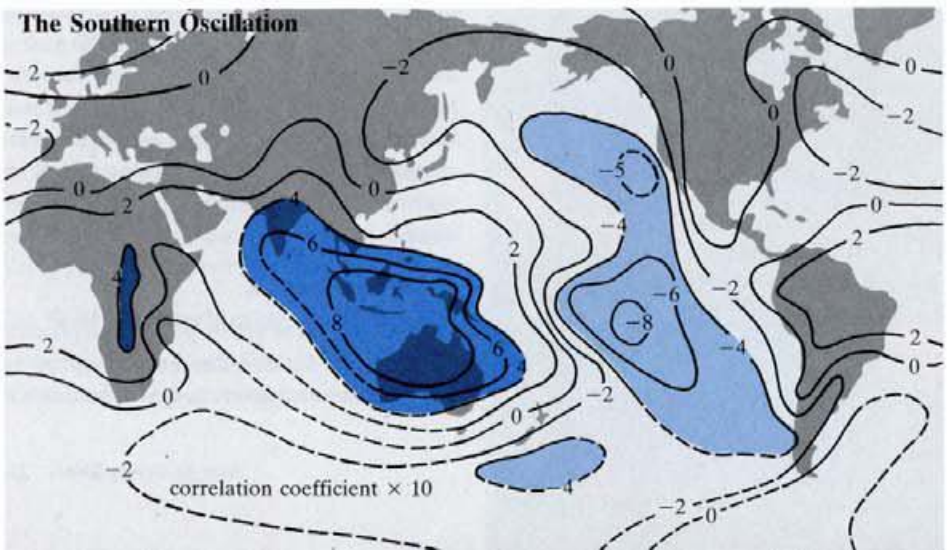
Dr David Karoly of the Mathematics Department of Monash University is studying pressure patterns over the Southern Hemisphere during ENSO events, particularly in the atmosphere at a height of 10–15 km. He finds that 'wave trains' of high–low pairs spread out from the major temperature anomaly and extend over most of the Southern Hemisphere. A similar phenomenon has been observed in the Northern Hemisphere.

The role of the oceans

Most scientists agree that the processes that lead from an initial ENSO trend to a full-blown event involve interactions between ocean and atmosphere. However, existing numerical models that include such interactions leave a lot to be desired, and Mr Hunt is working with Dr Gordon, a meteorologist, and another Divisional colleague Dr Roger Hughes, an oceanographer, to develop a more accurate one.

Dr Hughes believes it will be necessary to simulate the ocean's behaviour at three

When the barometer reading is high in Darwin, it tends to be low at Tahiti, and *vice versa*; this see-sawing of pressure is called the Southern Oscillation. The contours show the correlation coefficient, over many years, between the annual mean sea-level pressure at Darwin and that at other stations throughout the globe. Positive numbers indicate movements in unison; negative ones indicate shifts in opposite directions.



Tropical convection and release of latent heat are the main driving forces for the atmospheric circulation. To understand global climate, we need to study the tropical atmosphere and oceans.

The Tropical Ocean and Global Atmosphere (TOGA) study, begun in January 1985, is doing this in a big way. A 10-year effort, TOGA is part of the World Climate Research Programme (WCRP), initiated by the World Meteorological Organization (WMO) and the International Council of Scientific Unions. The main aims of the WCRP are to determine to what extent climate change can be predicted, and to assess the extent of man's influence on climate.

Building on existing meteorological and oceanographic systems, particularly WMO's World Weather Watch network, TOGA aims at assembling a full range of information on the tropical oceans from about 20°N to 20°S. The research will involve:

- ▷ systematic monitoring of the ocean and atmosphere during large-scale climatic variations such as El Niño, monsoons, and droughts
- ▷ studies of the variability of the oceans and atmosphere over the 10 years, with the aim of understanding the mechanisms that may make climate predictions possible
- ▷ modelling studies — ranging from the use of simple models, to detect incipient climate changes, to the development of the use of very complex ones to explore the coupling between ocean and atmosphere

The thermal properties of the top 500 m of the oceans are important, and an enlarged XBT (expendable bathythermograph) network will be required. The CSIRO Division of Oceanography is involved in expanding its sector of the network to the Indian Ocean.

The Division has also recently installed an additional 10 sea-level gauges to provide additional measurements for the western Pacific Ocean and the eastern Indian Ocean. The gauges register the sea level every 15 minutes.

A major expedition by the new ocean research vessel *Franklin* was devoted to directly measuring equatorial currents and their capacity to alter sea surface temperature patterns.

A new batch of ocean-sensing satellites, planned for launch in the 1990s, will boost TOGA's data input. Sea surface temperature, winds, wave heights, and currents can be sensed by satellite. Dr Ian Barton of the Division of Atmospheric Research has helped design the radiometer to be launched on one of these — the European Space Agency's ERS-1 remote-sensing satellite.

This radiometer will view the sea surface at three infra-red wavelengths and at two different angles, enabling tropical sea surface temperatures to be measured with an accuracy of nearly 0·3°, twice as good as that possible with existing satellite systems and close to the study's ideal requirements. (A significant sea surface anomaly is 1°C.)

Calibration of the satellite sensor is obviously vital. Yet existing 'ground truth' data are less accurate than the information the satellite will supply, and 'skin effect' at the ocean surface and other potential errors need to be allowed for.

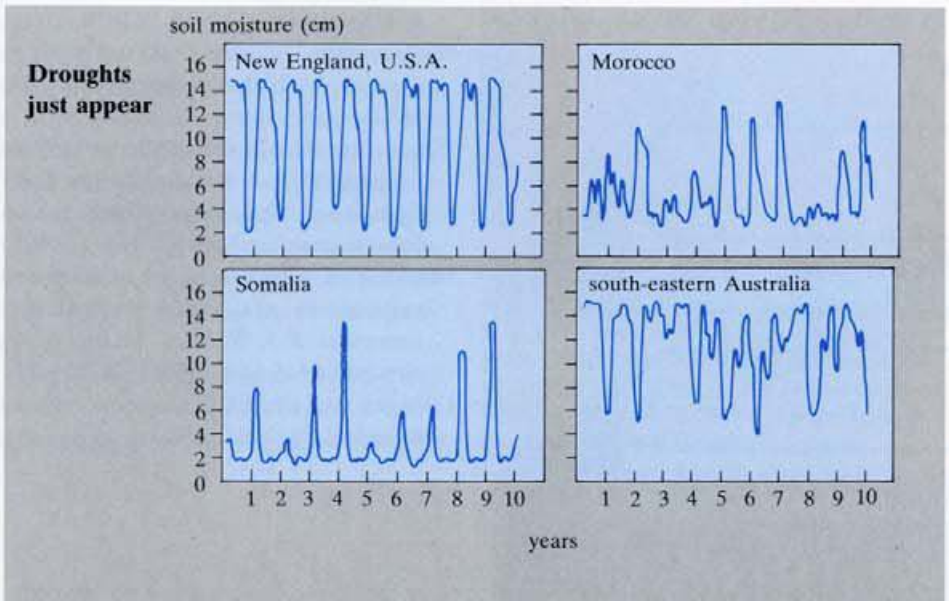
For these reasons Dr Barton is organising a satellite validation experiment for 1990 in waters between Queensland and the equator. Many Australian meteorological and oceanographic institutions will be involved, and a number of international ones too.

This experiment will help ensure that the capabilities of ERS-1, and others that will follow such as N-ROSS, RADARSAT, and JERS-1, will be fully utilised.

In 1986/87, another major observational and research program, the Australian Monsoon Experiment (AMEX), will aim at improving our understanding of the tropics — in particular the monsoon circulation, which dominates tropical weather and climate. AMEX will be co-ordinated by the Bureau of Meteorology Research Centre and it coincides with two major aircraft-based experiments: the Stratosphere-Troposphere Exchange Project (STEP), undertaken by NASA, and the Equatorial Mesoscale Experiment (EMEX), which involves American universities, the United States National Oceanic and Atmospheric Administration (NOAA), and CSIRO.

For a 1-month period during AMEX, the Bureau's observation network will be upgraded so that enough data can be collected to resolve, for the first time, monsoon storm systems. These important systems interact in a complex way with the monsoon circulation, and researchers are keen to improve their understanding of what actually goes on in the Australian tropics.

depths to produce realistic results. He is convinced that changes in ocean temperature provide the driving force for the atmospheric changes associated with El Niño, and he suspects they produce other major atmospheric anomalies not yet recognised. But why does the sea surface temperature vary?



Scientists think the answer may lie not far north of Australia. This region is special for at least two reasons.

Firstly, the world's warmest ocean waters (up to 30°C) and most intense convection occur here. The region can be identified on satellite pictures as predominantly cloudy. As El Niño progresses and the heat centre moves eastwards, the clouds can be seen to move with it.

The second reason is the exceptionally sensitive dynamics of both the atmosphere and the ocean in the equatorial zone. The

Over the 10 'years' that the computer model of Dr Gordon and Mr Hunt ran, it monitored the rainfall, evaporation, and soil moisture at many locations. Some experienced regular seasons, others were subject, apparently at random, to drought years.

One of the side-effects of drought — bushfires.

Coriolis acceleration due to earth's rotation is nearly zero here and prevailing winds are weak. Computer models have indicated that these factors allow small temperature and motion anomalies to be greatly amplified. In 1981, separate mathematical analyses by Dr Peter Webster, then with CSIRO, and by Dr Karoly, then at Reading University, confirmed that this should be the case.

It is extremely tricky pointing to any one anomaly as the trigger for an ENSO event; it is very much a chicken-and-egg affair. Climate is an interactive system, with all manner of movements in the atmosphere and oceans affecting each other. Conceivably, essentially random events are capable of triggering the development of an El Niño.

Sounding the deeps

Dr Gary Meyers of the CSIRO Division of Oceanography is among those looking for clues to the origin of ENSOs. His approach is to look for anomalous patterns in ocean temperature, and try to understand why they develop. Since 1979, in a collaborative project involving Australia, France, and the United States, he has arranged for 20 merchant vessels to be equipped with temperature-sounding equipment known as XBTs (expendable bathythermographs). These are now taking more than 7000 temperature soundings a year in the Pacific and Indian Oceans, mostly between 30°N and 30°S, down to a depth of about 400 m.

The XBT network allows, for the first time, accurate measurement of the amount of heat stored in the surface layers. The data can be used to study the processes controlling surface temperature. Ocean currents can also be calculated.

Dr Meyers used the XBT network to observe the redistribution of oceanic heat during the 1982/83 ENSO, and this allowed him to draw up a model of what happened. He calculated that a current of 10–20 million cu. m per second drained the heat pool in the western Pacific, re-establishing the pool in the central Pacific a few months later. The diagram below illustrates this, and shows the effect the movement had on the atmospheric circulation, which is arranged so that convection and rainfall are located above the warmest ocean waters.

Looking at possible causes of changes in surface temperature, Dr Meyers examined the correlations between surface temperatures and winds. He found that, at the same time as the heat pool was moving east, an anomalous wind from southern latitudes was removing heat from the western Pacific by evaporation. Is it this wind that sets the ENSO process in motion? And if so, what causes the wind?

Dr Meyers is convinced that an understanding of the processes controlling sea surface temperature, and the use of this knowledge in the numerical models discussed earlier, can allow useful predictions of climate anomalies to be made.

Until next time

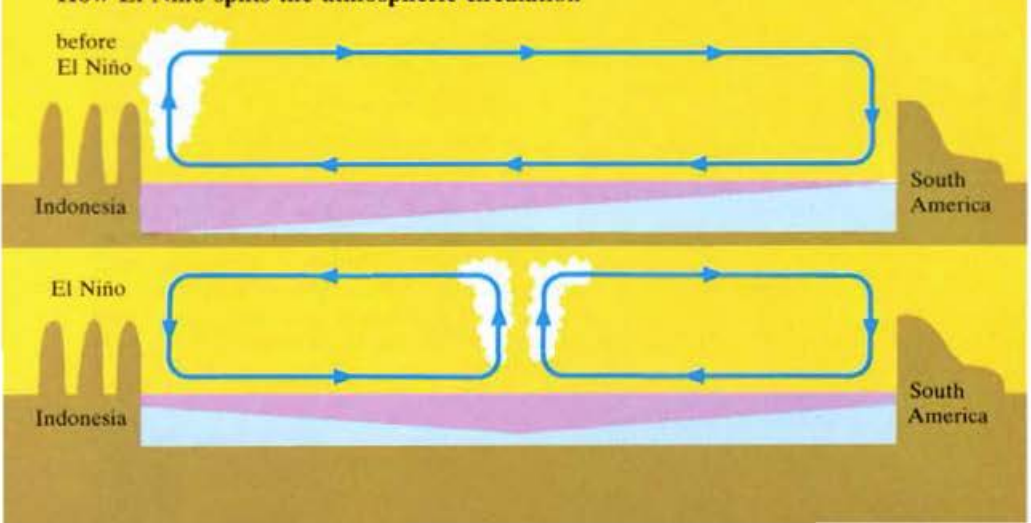
Because of the importance of ENSO, the Pacific is a key area for increasing our understanding of global weather and, perhaps, developing a capacity to predict drought. The TOGA program will advance our understanding of what affects what during ENSO. At the moment there are plenty of theories but, as Dr Hughes comments, 'it will take another ENSO to sort them all out'.

The next ENSO event will certainly be the most closely monitored ever — the instruments are poised and waiting.

Andrew Bell

Dr Meyers presents this model of how shifting ocean heat masses affect the atmospheric circulation over the Pacific. He believes that winter winds from higher latitudes cool the western Pacific while currents shift the Indonesian heat pool to the eastern side of the date-line.

How El Niño splits the atmospheric circulation



More about the topic

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