Modellers keep an eye on the future

Graeme O'Neill

FOR more than 30 years researchers have tried to simulate the world's climate by means of computer models that link oceanic and atmospheric processes. In another five years, these models may be sophisticated enough to predict, 12 months in advance, climate variability induced by better known climatic phases such as El Niño (see page 13).

A believer in this possibility is Barrie Hunt, a climate modeller at CSIRO's Division of Atmospheric Research. In 1991 and 1992 he made global climate predictions, a year in advance, that were 'reasonably successful' in describing the actual rainfall over eastern Australia.

Hunt's forecasts were based on predictions of sea-surface temperature made by a United States research team at New York's Columbia University. Variations in sea-surface temperatures are the main driving force of long-term climate variation. The ability to predict these temperatures a year in advance is therefore vital to making long-term climate predictions.

Scientists know the underlying processes, and hence can predict, with varying accuracy, the sea-surface temperatures that characterise a Pacific El Niño. As a result, they are becoming increasingly confident of making useful predictions, up to a year in advance, of the climatic changes likely to surround such an event.

To predict sea-surface temperatures during an extended sequence of El Niños, however, such as occurred in 1993 and 1994, is more difficult. This is because not enough is known about the underlying causes. Fortunately these events are much rarer, occurring only once every few decades.

The difficulty in predicting sea-surface temperatures is one of many constraints that climate modellers are working to overcome. They also face complications such as the influence of 'chaos'; the need for enormous computing power; variations in geographical scale; the difficulty of representing convection; and factors beyond the Pacific Basin that affect the climate system.

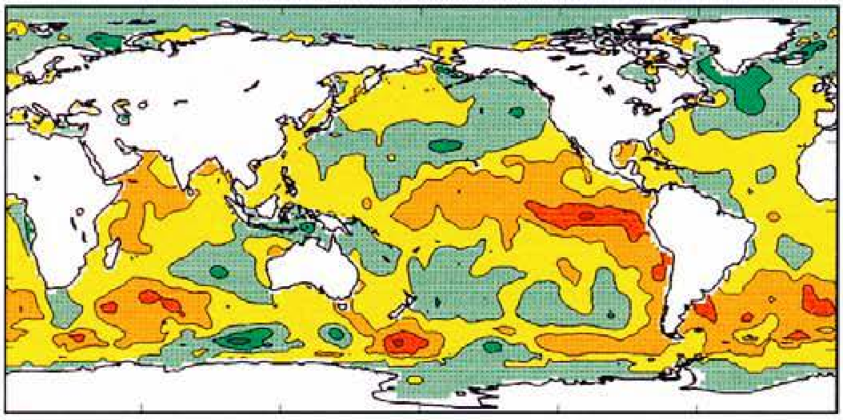
Some of these constraints, such as the poor knowledge of climate influences outside the Pacific, are also being addressed in CSIRO's Climate Variability Program. Others are tackled through a cycle that involves running existing models, comparing the outcomes with real-world records, making refinements where needed, and then repeating the process.

A chaotic response

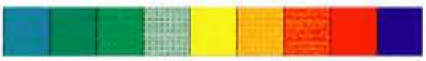
Hunt says a major problem facing all prediction schemes is the presence of 'chaos' in the climatic system. Chaos is ubiquitous in natural systems and means that in any model run, even slight changes in the initial conditions of the experiment can result in a wide spread of responses at the regional level.

Since it is impossible to obtain a 'perfect' set of initial conditions, experiments are designed to encompass the uncertainties of chaos. This means doing

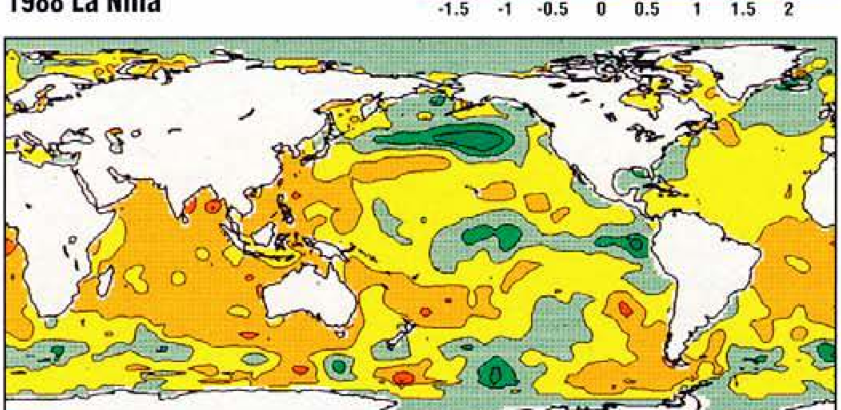
1982 El Niño



Sea-surface temperature anomalies



1988 La Niña



A computer output of observed sea-surface temperature anomalies (differences from the long-term average) for 1982 (an El Niño year) and 1988 (a La Niña year).
The major difference is the behaviour of the low-latitude Pacific Ocean. In 1982 there was a warming over most of this region, particularly in the eastern Pacific, and a cooling around northern Australia. It is this sea-surface temperature pattern which produces drought over eastern Australia. In 1988 the pattern was reversed and wet conditions prevailed over eastern Australia.
Because annual mean conditions are used in these figures, the magnitude of the sea-surface temperature anomalies is reduced compared with the extreme values occurring in individual months.

multiple (at least 10) experiments with slightly different initial conditions and then averaging the results.

'Computer manufacturers love chaos', Hunt says. 'It means we need much more computer power and computer time to get our results'.

In other computer experiments, Hunt and his colleagues have shown that the more pronounced the sea-surface temperature changes are from year to year, the more predictable are the outcomes. Marked temperature variations apparently constrain the influence of chaos. They have also found that the influence of chaos is minimal at low latitudes, particularly over the Pacific Ocean, and increases steadily at higher latitudes. This suggests the chances of making reliable climate predictions decrease as one moves further from the equator.

Economies of scale

As part of an international study of climatic variability, Hunt and his colleagues are using a 122-year record of monthly sea-surface temperatures collected by the United Kingdom Meteorology Office for 1871 to 1993.

The temperatures are being used to determine the year-to-year climatic variability in a relatively fine-scale climatic model (200 x 200 kilometre 'boxes' at the equator). It is expected that at least five repeated experiments will be needed to reveal the range of chaotic influences on the model's outcomes.

The experiment is huge: running full-time on the equivalent of a Cray YMP supercomputer, it takes a week of computer time to process just four years' worth of data. At this rate, it will take almost three years of computer time to complete the five planned runs.

An early assessment of this model run indicates that it is reproducing most of the major rainfall events that occurred over Australia during this period.

Four extended El Niño events have occurred since 1873. Hunt says it should be possible through this exercise to study the differences between these events. This could help determine their predictability, either through statistical or model methods.

In another experiment, Hunt's team plans to use data from the model to drive an oceanic model of the Pacific Ocean for extended El Niño events, and then to compare the results with a more typical, shorter-lived one. Their aim will be to better understand such events.

A local perspective

These experiments are helping to characterise climatic processes on a global scale, but how does this relate to predicting regional droughts and storms, for the benefit of farmers, foresters, fishers and even city dwellers?

To get the local picture, information about global climate patterns affecting a particular geographic area is taken from broad-scale models and used as the basis of finer-scale models for particular regions. Details of local rainfall, atmospheric pressure patterns, topography, soil moisture, convection and winds factors that cannot be represented at a global scale are then added.

Tracing colonial clues

DETAILED instrumental records exist of European weather and climate dating to the 17th century, in some cases even earlier, yet data from most other parts of the world – especially the Indo-Pacific region – are sparse.

Dr Rob Allan at the Division of Atmospheric Research has traced these old records. He has delved into barometric pressure measurements kept by colonial officials in Turkey, by British observers in Capetown during the 1840s, and by the British East India Company's Observatory in Madras dating from 1796.

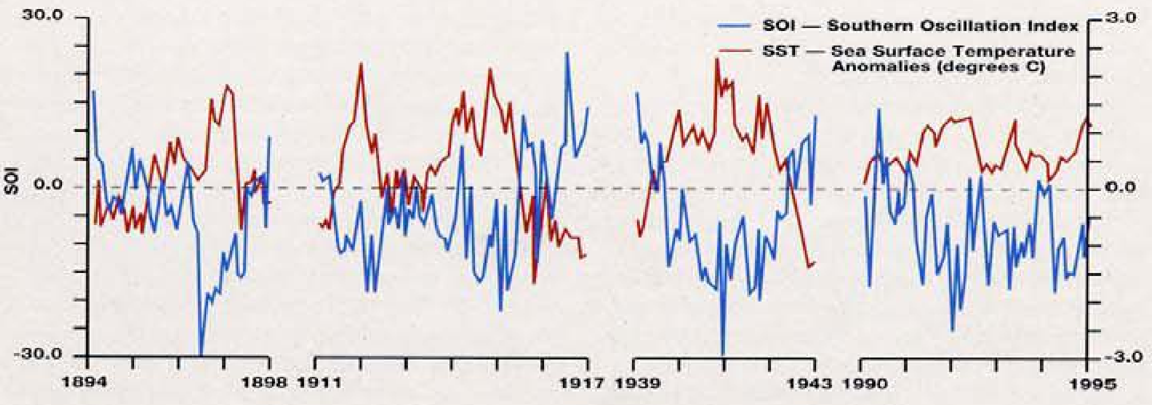
Allan is using the Indian records to extend knowledge of El Niño-Southern Oscillation (ENSO) episodes, given that El Niño and La Niña are known to influence the timing and intensity of the Indian Monsoon.

As part of an international project to document global climate variation, Allan is working with Dr Janette Lindesay of the Australian National University's Department of Geography and Dr David Parker of the UK Hadley Centre for Climate Prediction and Research on the first global atlas of ENSO and climate variability.

The atlas will offer monthly and seasonal descriptions of patterns of both barometric pressure and sea-surface temperatures around the world between 1871 and 1993. It is due to be published this year and will be available as a two-part package consisting of a CD-ROM and a full-colour, hard-copy version.

'The atlas will enable scientists to look globally at long-term climatic fluctuations as well as individual El Niño and La Niña phases, and to examine their evolution, intensity, duration and nature,' Allan says.

'It will also focus on particularly important El Niño or La Niña events and display their impacts around the world, such as their effects on destructive phenomena such as tropical cyclones, drought and flooding.'



This graph of persistent El Niño sequences – defined from raw Southern Oscillation index values since 1876 – illustrates the close relationship between sea-surface temperature and atmospheric pressure. Persistent La Niña episodes have also occurred in this period.

What is a climate model?

A CLIMATE model is a simplified mathematical representation of a part or parts of the climatic system (atmosphere, oceans or sea-ice) that allows scientists to perform simulated climate experiments.

The models are needed because scientists can't test their theories by manipulating climatic variables under controlled conditions, nor can they describe the movement of every air or water molecule through the climate system.

Instead they try to describe in mathematical terms the major dynamic and physical processes determining the average behaviour of the climatic system, and then to simulate those processes in a numerical form on a high-speed computer.

This work is being undertaken by Dr Ian Smith, also from the Division of Atmospheric Research. He says the regional models will be tested by seeing how well they can replicate real-world climatic patterns.

'Our long-term aim is to obtain reliable predictions out to three seasons ahead, and to use the climate model to produce rainfall predictions for an area the size of south-east Queensland,' Smith says.

One of the main factors affecting the prediction of regional rainfall patterns is the ability to accurately represent convection. Convection is integral to the evaporation/precipitation cycle as it determines how much moisture is lofted into the atmosphere to fall later as rain. But it is one of the most difficult climatic variables to represent in global-scale models.

The position of a region of intense convection north-east of New Guinea determines rainfall patterns over northern Australia. Models must be able to represent this region and simulate its behaviour accurately if they are to predict rainfall patterns in northern Australia, which in turn influence patterns in south-eastern Australia.

'The other area we are interested in is the Indian Ocean, because of the recent finding of a link between regional sea-surface temperatures there and rainfall fluctuations that occur in Australia independently of what might be happening in the Pacific,' Smith says.

He says long model runs with real-world data may provide insights into these relationships, and perhaps even answers to the following questions.

Could events in the Indian Ocean explain why El Niño events vary in intensity? Before the 1930s, rainfall in Western Australia correlated with El Niño events; why is this no longer the case? Hunt says the models being developed in Australia and overseas are approaching a level where these questions can be addressed.

More about climate modelling

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