

The loneliness of the long - range weather forecaster

by Andrew Bell

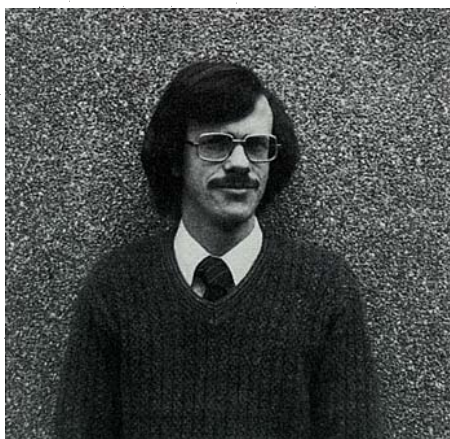
A meteorologist getting himself involved in long-range forecasting is frequently regarded in the same light as an astronomer dabbling in astrology. Both individuals are considered as practitioners of black arts that are beyond the scientific pale. Perhaps this is because most meteorologists have shied away from the problem, perceiving that they have enough problems predicting tomorrow's weather, let alone next month's, or next year's.

A long-range forecast will generally attempt to specify one of three possibilities — for example whether the weather will be wetter than average, drier, or just average. A random, unskilled forecast will therefore have an accuracy of 33%. However, the atmosphere displays a characteristic meteorologists call 'persistence'.

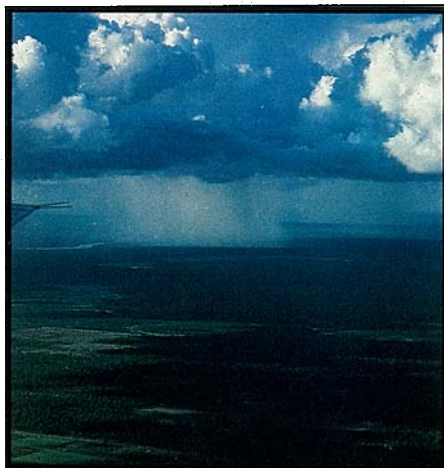
Looking for cyclic behaviour in the atmosphere is the most time-honoured technique.

What this means is that if you say that tomorrow's weather is going to be the same as today's, you have about an 80% chance (in Melbourne) of being right. Similarly, with next month's weather, you may have a 40% chance of it being similar to this month's.

Thus we see that the degree of accuracy above these levels of persistence reflects the true skill of a meteorologist's forecast. Viewed in this light, present-day long-range forecasts are pretty poor. For instance, the accuracy of British Meteorological Office monthly rainfall forecasts can be variously assessed at between 31 and 43%. Forecasts of seasonal temperatures that have been for the United States have averaged 42% correct in recent years.



Mr Neville Nicholls.



Mr Nicholls' model allows spring rainfall to be predicted from the observed air pressure over northern Australia the previous winter.

Mr Neville Nicholls, of the Australian Numerical Meteorology Research Centre, is one of the few professional meteorologists in the world devoted to the study of long-range forecasting. He concludes that 40% is a reasonable estimate of the accuracy of presently available long-range forecasts. That means that, despite concentrated efforts, there has been virtually no progress in the last 10 years. Yet forecasts will need to improve to about 50% accuracy before they have much value, according to Mr Nicholls.

Perhaps there is some as-yet-undiscovered factor, or 'key', that is needed to unlock the mysteries of long-range forecasting.

A closer look

What are the chances of reaching this figure? Let us look in more detail at what has been achieved to date, and how the different approaches have worked out.

In the Soviet Union, for instance, seasonal forecasts of temperature and rainfall have been prepared since 1968 by that country's Hydrometeorological Service. The temperature forecasts have shown very little 'skill', or improvement over chance. In general, persistence calculation has been much more skilful than the forecasts — only in 1974 did the forecasts outperform it, and no trend towards improvement has been demonstrated.

Precipitation forecasts have fared somewhat better. In most years, they have outperformed persistence calculations, but only by a few per cent. There is a hint of a trend towards improvement in skill.

The United States National Weather Service routinely produces 30-day forecasts of how temperature and rainfall are expected to vary from average. In a verification study, the skill of the temperature forecasts at some 100 American cities has been found to be 11% greater than chance, while rainfall forecasts have been found to be 2% better. But taking persistence into account, the forecasts were only 2–3% better than you would expect. And furthermore, these forecasts haven't improved over the past 30 years.



Darwin after Cyclone Tracy. Mr Nicholls thinks he may have found a way of predicting cyclone activity in the forthcoming season.

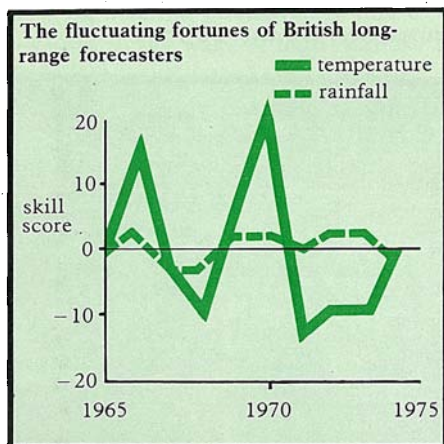


Satellite observations help to improve the accuracy of numerical models of the atmosphere. Even so, models are limited to forecasts of only a few days ahead.

The British have also tried their hand at long-range forecasting. Since 1963, the Meteorological Office has issued 30-day forecasts of temperature and rainfall. Have they fared any better?

Unfortunately, no. Analysing the outcome of the predictions, one researcher in 1974 was led to conclude: 'it is doubtful whether one can honestly say that they are even marginally better than chance'. Similar conclusions have been reached by other workers, who found that, on a skill score ranging from 0 (no skill) to 16 (perfect predictions), the Meteorological Office would win 1.5 for their temperature predictions and, for rainfall, minus 0.2. Another recent paper showed that the temperature forecasts were bettering persistence calculation by 0.6%.

It is probably no wonder that, in the land of the fervent knocker, the Australian Bureau of Meteorology has resisted the temptation to issue long-range forecasts and opted for preserving its credibility instead.



The skill of British 30-day forecasts of temperature and rainfall for London fluctuates above and below a score of zero. This demonstrates that they don't do any better than chance.

Predicting long-range weather is not simply a case of better and more extended weather forecasting.

Two different approaches

What methods have long-range forecasters been using to land themselves in this situation? Remember that we are talking about serious meteorologists, dedicated to the scientific method and with a faith in the orderliness of the atmosphere's behaviour.

Primarily, two basic methods have been brought to bear. One is to look for cycles in the weather; the other is to find past 'analogues' (close resemblances) to the existing weather and to expect the course of the present weather to progress identically to that in the past.

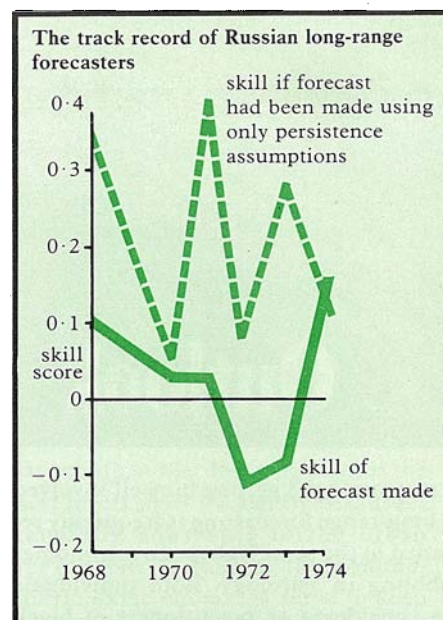
Looking for cyclic behaviour in the atmosphere is the most time-honoured technique. After all, the effect of the sun, in its daily and yearly cycle, is well known; why not then look for the influence of other cycles such as the 11- and 22-year periods of sunspots and the 18.6-year periodicity of the inclination of the moon's orbit to the equator?

Vast numbers of scientific papers have been published purporting to have found correlations between sunspot cycles and climate. Dr Barry Pittock of the CSIRO Division of Atmospheric Physics recently examined more than 140 relevant papers on the subject. He concluded that 'despite a massive literature on the subject, there is at present little or no convincing evidence of statistically significant or practically useful correlations between sunspot cycles and the weather or climate'.

A Russian review of the subject in 1973 reached a similar conclusion: 'the literature on the question convinces us of little, but it familiarizes us with a set of contradictions, uncertainties, interpretations, unproved propositions and even breaks with elements of scientific meteorology and also with the (*sic*) sad deficiency of self-criticism'.

Statistical rhythms

A harder idea to dismiss is the notion that the atmosphere does behave cyclically, but not necessarily in rhythm with sun, moon, or planets. Rather, the cycles are 'quasi-periodic', being simply discovered through statistical analysis of past weather records. Rapidly expanding data



Seasonal forecasts of temperature for a number of years have been rated for skill. No skill rates 0 and a perfect prediction rates 1; a negative score is worse than chance. Even forecasts made using persistence are better.

bases and the use of computers have made this empirical method extremely popular in recent times.

Dr Taffy Bowen (former Chief of the CSIRO Division of Radiophysics, now working in America) and his colleagues found six dominant cycles, ranging from 3 years to 70 years in length, in July rainfall recorded at Amarillo, Texas, between 1895 and 1964. June rainfall at the same station showed cyclic behaviour at intervals from 2.3 to 36 years. June rainfall at two other nearby stations showed 11 statistically significant periodicities.

Dr Bowen then calculated what rainfall would be expected from 1965 to 1974 if the cycles were real. He concluded that 'general agreement' was found between the actual and projected rainfall figures.

However, other workers have had less successful outcomes with their predictions. For example, a series of long-range forecasts were made nearly 20 years ago for various locations in the United States. Forecasts of monthly precipitation, up to 10 years in advance, were made by a complicated method based on 16 cycles from 91 years to 8 months in length. Similarly, monthly temperatures were predicted. In the pursuit of scientific knowledge, the National Research Council resurrected the forecasts and compared them with what came to pass. The conclusion was that the forecasts were no better than random.

One forecaster analysed the precipitation record from Fortaleza, Brazil, and

concluded that the data showed cycles of 13 and 26 years. However, when the data were reanalysed independently, it was shown that the apparent periodicities could simply be due to random variability.

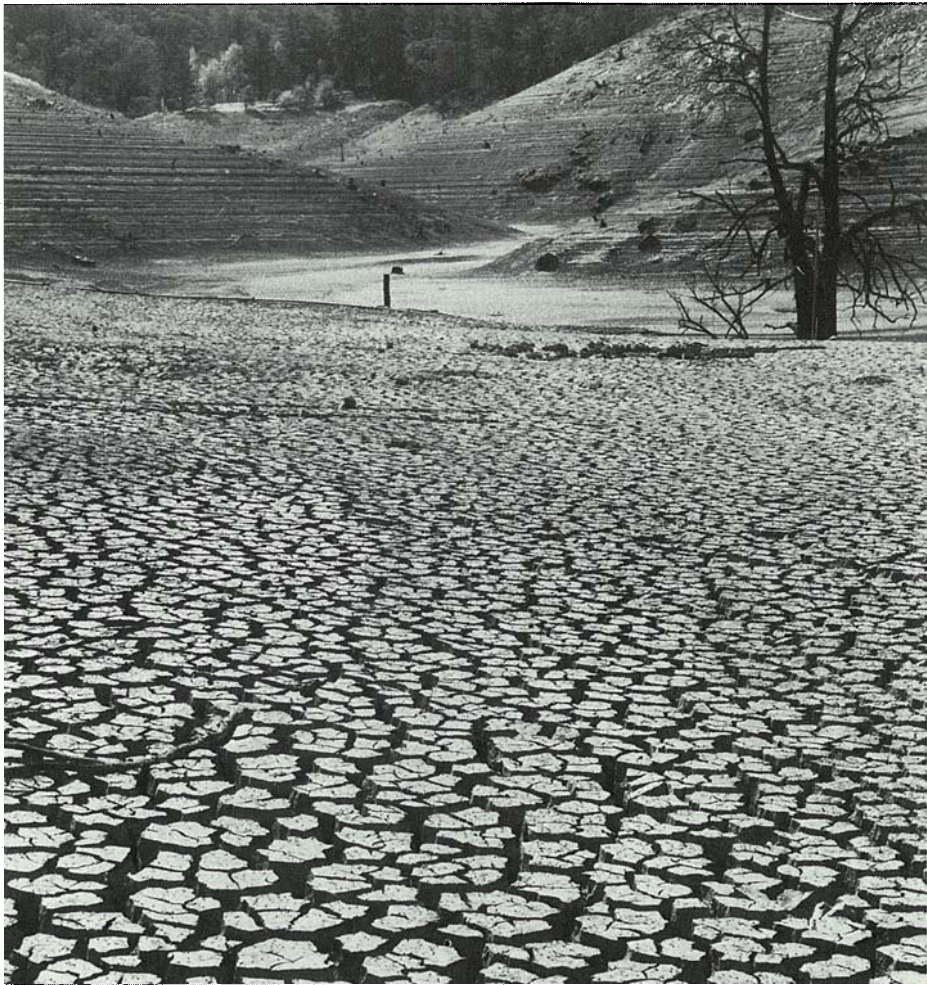
In fact, Mr Nicholls cites evidence that most, if not all, proposed atmospheric cycles greater than a year are simply due to sampling variations. A statistician recently carefully analysed seasonal rainfall figures at 98 Northern Hemisphere stations using data for 64 years. The number of stations showing 'statistically significant' cycles was similar to that expected from 98 random series of numbers.

In 1946, Sir Gilbert Walker, a noted British meteorologist, was moved to say: 'I think it likely that after long ages of belief in the control of our affairs by the heavenly bodies men are born with instinctive faith in the existence of periods in weather. I lost mine when the imperative need of reliability in seasonal forecasts drove me to replace instinct by valid quantitative criteria applied to the results given by standard methods.'

Thirty years later, the results of Man's search for cycles in atmospheric behaviour were summarized by the National Academy of Sciences in a less poetic, but just as damning, statement: 'it has become clear that almost all the alleged climatic cycles are either (1) artifacts of statistical sampling, (2) associated with such small fractions of the total variance that they are virtually useless for prediction purposes, or (3) a combination of both'.

Close resemblances

If the method of discovering cycles in the weather has been discredited, that still leaves the method of finding past analogues to current weather conditions. The idea is to examine past weather records and find months or seasons that resemble the month or season just past and



Next summer could be dry, like the one in 1968 that caused Burrinjuck Dam to dry up.

predict that the ensuing weather will be similar to that which transpired last time. The technique can vary from simply examining, for instance, the likelihood of a hot summer following a hot spring, to examination of atmospheric and oceanic data over a very large region.

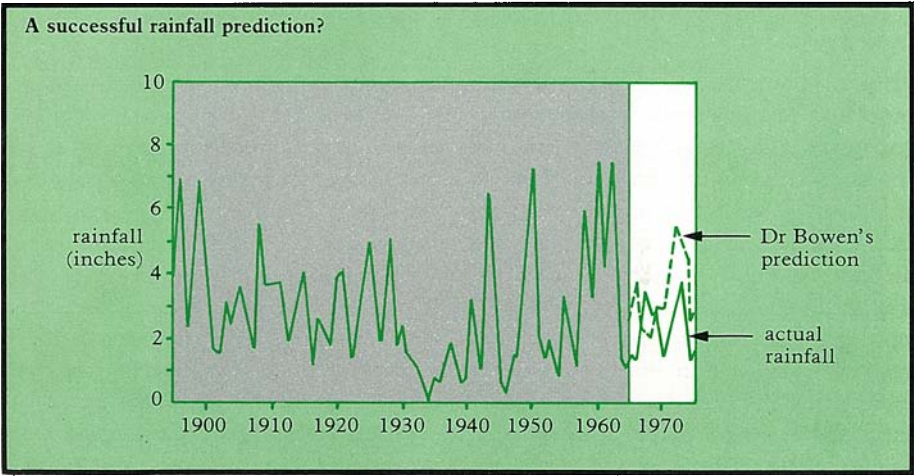
Considerable study of analogues for long-range forecasting has been carried out in the past decade, particularly in the British Isles. Many studies have used the simplest type of analogue selection, which is really a search for persistence.

Many researchers have found small but

statistically significant correlations between temperature 'anomalies' in successive months throughout most of the year. This indicates what we probably knew already — that persistence assumptions can show some skill in monthly temperature forecasts. However, the method can uncover negative correlations ('anti-persistence') as well, such as the finding that an anomaly in February temperature in north-western Europe is usually followed in June by a temperature anomaly in the opposite direction.

Generally, persistence is too small to be of much practical significance, but at least in some regions persistence appears to be very strong and may allow a somewhat larger improvement over chance than is usually observed through such methods. For instance, some Mexican peasant communities hold a belief that the amount of rain falling in the early part of the year indicates how much will fall in the second half (the growing season).

The white area shows where Dr Bowen claimed 'general agreement' between predicted and actual rainfall at Amarillo, Texas. He used cycles found in the rainfall pattern for the previous 70 years to make his predictions.



Weather men often have trouble forecasting tomorrow's weather, let alone next month's or next year's.



When meteorological data were examined, this belief received strong support and showed how valuable this understanding must have been to early cultivators.

More sophisticated analogue techniques have attempted to improve on the basic method. The analysis has included such factors as atmospheric pressure, sea-surface temperature, circulation indices, the degree of ice and snow cover, and other variables. Some such studies have produced very promising results; others are best forgotten. Compared with other methods, it is one that can bear further examination.

Remote connections

Indeed, a refinement of the method has produced some worth-while forecasts (of

an experimental nature, mind you, not routine official ones). Broadly called 'teleconnection', the method involves finding a relation between the variable to be forecast and some other variable from a different region. Why this should result in better forecasts than those obtained through examining persistence in the same region is unclear. Whatever the cause, there is no doubt that in certain special circumstances such teleconnections do occur. For example, Hawaii winter rainfall is well correlated with autumn pressure over the south-western North Pacific.

An impasse?

All in all, then, we can see that, despite computers and elaborate mathematical procedures, and despite considerable efforts, long-range forecasting hasn't made much progress. Whereas short-range forecasting (1 or 2 days) has reaped considerable benefit from such approaches, monthly forecasts do not appear to have improved at all and show, at best, only a very slight increase in skill over persistence. Some seasonal forecasts, for particular seasons for particular places, may have improved slightly, but they are gen-

erally of limited usefulness. Mr Nicholls has found no evidence of any skill in forecasting for periods longer than a year ahead.

The question naturally arises — why has so little progress been made in a field of such considerable widespread importance?

One proffered explanation is that the atmosphere is inherently unpredictable over long time scales. That is, the atmosphere is so incredibly complicated that predicting its motions is more difficult than predicting which Tattsлото numbers will appear from a barrel.

Mr Nicholls thinks that things aren't quite as bad as that. The best seasonal forecasts manage to take into account 30–40% of the total variability of the meteorological condition to be forecast. That degree of prediction is probably of some use, since it's as good as some shorter-range forecasts presently available (such as special 5-day forecasts in the Northern Hemisphere).

Well then, perhaps the answer to the question is that we have reached the limit of predictability at long time scales — no matter how hard we try, it is impossible for us to do better. Or perhaps there is some

Does this mean that successful long-range forecasting has receded into the realm of the impossible?

as-yet-undiscovered factor, or 'key', that is needed to unlock the mysteries of long-range forecasting. Both these theories would explain our current impasse, but the first is decidedly more gloomy than the second.

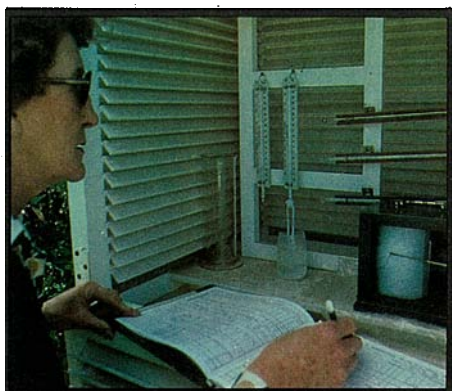
Mr Nicholls prefers to think that the explanation, or at least part of it, is something a little easier to come to grips with — that the methods so far used are somehow deficient.

The weather as a stream

To understand what this means, let us look at an analogy first elaborated by Dr Garth Paltridge of the Division of Atmospheric Physics. Consider a river flowing under a bridge from which we view the whirls and eddies in the water. We can measure these motions directly under the bridge, but how would we go about predicting the nature of the flow further downstream?

There are two inherently different regimes, each using different sorts of physics to give a prediction.

First, consider the short region of river immediately downstream of the bridge; there, if you were handy with dynamical equations of motion, you could calculate the specific form of whirls and eddies on the basis of your measurements back at the bridge. But, since errors multiply quickly, and because of mid-stream snags



Collecting weather data, the starting point for constructing a model of the atmosphere.

and an irregular river-bed, you are limited to only a few metres of river.

Second, consider the regime from that point to the first bend. There, you have no hope of predicting each whirl or eddy, but you could at least say something about the statistical properties of the general flow. If nothing else, you could with reasonable certainty predict that on average the water would continue downstream, and with a lot less certainty you could say that the observed statistical properties upstream of the bridge would be re-established downstream. The uncertainty arises because you cannot be sure that the river bottom and snags are the same upstream as down.

The point of the analogy is probably

obvious enough — the observer on the bridge is like the weather forecaster.

Different regimes

In region one, the problem is mainly one of fluid dynamics, just like short-term weather prediction. It is a process concerned with specific prediction of whirls and eddies for up to a week or so ahead. An accurate knowledge of the present weather is required so that the detailed interaction of many individual parcels of air can be calculated. It is a classic medium for application of number-crunching computers.

48-hour forecasts are now better than the 24-hour forecasts of a decade ago.

The vast general circulation models of today are tools that have evolved to take the problem in hand. They are remarkably successful in forecasting weather details up to 4 days or so ahead — beyond that, errors multiply too rapidly to give accurate answers.

In other words, predicting long-range weather is not simply a case of better and more extended weather forecasting. We must enter the second regime, where we encounter a complex non-linear system in which physics and statistics are inextricably interwoven.

This is what Mr Nicholls means when he asks whether the methods used in long-range forecasting are somehow deficient. It is not even known if classical techniques can lead to a solution, or if any methods whatsoever can do so. Basic mechanistic physics is inadequate to cope with the problem, and as for statistics, an examination of past records shows that climate is forever changing on all time scales. This means in effect that the statistics of one period are not necessarily (and are not even likely to be) the same as those of another.

Perhaps this is the reason why those long-range forecasting methods we have looked at here that used statistical approaches (almost all) have rarely met with success. And it may also be why mechanistic approaches (such as those looking for cosmic influences or the effect of quasi-biennial oscillations) have failed as well.

Brisbane, 1974. Knowledge that next summer would be wet could be useful in protecting against floods.





The weather forecaster is like an observer on a bridge who, by measuring the flow under the bridge, tries to predict the flow further downstream.

Physics and statistics

Does this mean that the prospect of successful long-range forecasting has receded into the realm of the impossible? Well, there is still a glimmer of hope, and that is what has spurred Mr Nicholls on. He believes that a judicious blending of physics and statistics offers promise if not a prescription.

Already, hopeful signs have emerged. People have taken numerical weather-forecasting models and run them beyond their normal limit of accuracy — say, for a month. Such a model may bear little resemblance to what would in reality occur, but if the model is run many times over using different initial data, we can use a statistical averaging technique to allow us to look at the general trend of cause and effect.

By this means we can elucidate the effect of anomalous sea-surface temperatures, for example, by comparing runs made with and without the anomaly. To date, no notable skill has emerged, but it was the knowledge that statistical relations occur between sea-surface temperature anomalies and later atmospheric behaviour that has encouraged further study.

Perhaps the pack-ice has begun to budge, because Dr Peter Webster of the Division of Atmospheric Physics has seen confirmation of his predictions for the specific behaviour of monsoons (his special field of study). Dr Webster's simplified numerical model of the Indian

monsoon, which includes an air-sea interaction, showed up 'breaks' (or respites) in the intensity of the monsoon rainfall. These breaks are a known phenomenon, and the predicted period of 2 weeks is close to that observed.

Shaping up models

To cap his thinking that a hybrid technique of statistics and physical models is the way to go, Mr Nicholls has recently had considerable success in modelling aspects of the atmosphere's behaviour in northern Australia. Based on his feeling that everything in long-range forecasting comes back to the ocean, he has devised a very simple physical model of how sea-surface temperature north of Australia may interact with the atmosphere.

When the model was run in a manner similar to more complex numerical models, it produced a number of interesting results, some of which were significant for long-range forecasting. The model correctly simulated aspects of the observed statistical behaviour of the ocean and atmosphere, including the seasonal variation in persistence of pressure anomalies, a biennial oscillation in the atmosphere and ocean, and certain correlations between pressure, temperature, and rainfall.

For example, Mr Nicholls' model, verified statistically, suggested that observed winter pressure over northern Australia should provide a means of forecasting Australian spring rainfall. Furthermore, a significant correlation was found between winter pressure at Darwin and the number of tropical cyclones observed in the following season. The correlations

are large enough to suggest that useful seasonal forecasts of tropical cyclone activity may be possible. Looking at data from the 16 years 1959–74, Mr Nicholls' forecasts would have failed only twice.

The big advantage of Mr Nicholls' approach is that it allows the important variables to be tracked down through statistical methods, from which point their influence is calculated through a numerical model. It's like sifting a pile of photographs of the river for whirlpools that seem to persist, and from there determining the ongoing effect of that whirlpool. In this way many variables of little effect on gross behaviour can be discarded, simplifying the model enormously and making it manageable with even modest computers.

Towards reliable forecasts

This still leaves us a long way off a general long-range forecasting scheme, but it will, Mr Nicholls hopes, give forecasts with a measure of confidence for some seasons in some parts of Australia. He points out that decades ago people put blind faith in numerical models for short-term forecasting; only recently have they been proved right in that they can now produce better forecasts than can the intuition of the experienced forecaster. Similarly, 48-hour forecasts are now better than the 24-hour forecasts of a decade ago.

Achievements in short-term weather forecasting should make us hopeful that the same may occur with long-range forecasting. But, of course, there is no guarantee of success.

More about the topic

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