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Seasonal climate forecasts: reading tea-leaves in a digital age

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Tea-leaves, entrails, cockatoos: we all want to forecast the future. Weather forecasts have become so commonplace we rarely think about the technology, research, computing power and millions of observations behind those couple of words: 'mostly sunny'.

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It's not just the family BBQ that is at stake here. Farmers make decisions about planting, fertilising and harvesting worth many hundreds of thousands of dollars based on weather forecasts. Emergency services rally resources on high flood or fire risk days. Energy companies crank up the power if the forecast is hot or cold.

But that's not enough. They all need to see further into the future than a weather forecast allows, and that's where a seasonal climate forecast comes in.

Lewis Fry Richardson came up with the idea of numerical weather forecasting in 1922. Back then, his computers were real people in a large room scribbling parts of the calculation on notepads and passing them to messengers and an overall coordinator. A weather forecast starts with Newton's laws of motion as they apply to gases (the atmosphere) and throws in some basic thermodynamics and the 'ideal gas' law. These days, digital computers synthesise millions of observations with Richardson's mathematical equations on a fine grid covering the entire planet to produce 10-day weather forecasts before morning tea.

But are they any good? In short, yes, and improving all the time. The skill of a seven-day forecast today is equal to the skill of a three-day weather forecast 30 years ago. Put that down to faster computers, more observations, and better techniques for using the observations to start the forecast.

However, beyond ten days, there is a problem. The ability to forecast individual weather systems rapidly decreases due to chaos. What this means is that very small errors in the starting conditions for the model (a butterfly flapping its wings in Brazil) can amplify over time and cause large errors. That's where the ocean comes in.

Water has a much higher heat capacity than air, so the ocean changes its temperature slowly relative to the overlying atmosphere.

Once a large patch of ocean becomes warm, it stays warm for many months, influencing weather systems all the while.

A recent example is the 2010-2011 La Niña, where warmer-than-normal ocean temperatures north of Australia contributed to increased rainfall, particularly in Queensland. More generally, ocean surface temperatures in the Pacific and Indian oceans can be linked to rainfall in different parts of the country. The link is made by analysing data going back to 1950 to determine how ocean temperature changes affect rainfall for the following season. This has been the basis of statistical seasonal forecast models such as the Bureau of Meteorology's Seasonal Climate Outlook.

However, there is an emerging problem. The observations make it clear that the climate is changing and the oceans are warming. The Indian Ocean has warmed by more than half a degree since 1970, and it's likely that this is affecting its relationship with Australian rainfall.

The past is becoming less of a guide to the future. Statistical models based on these past relationships are gradually losing accuracy and need to be replaced.

The ingredients for a better seasonal forecast are simple: take one weather model, add global models of the ocean, land-surface and sea-ice, add a healthy dash of observations to start it all off and blend at high speed in a supercomputer.

The weather model cannot accurately predict individual weather systems beyond about ten days, but the ocean model ensures that the average behaviour of the individual weather systems is about right for many months into the future. These individual weather systems in turn change the slow-to-respond ocean in a realistic way. The result is a useful forecast of average temperature, rainfall and winds for the next few seasons.

These so-called 'coupled ocean-atmosphere global models' are the future of seasonal forecasting. They do not depend on a long history of observations, but instead start from present-day conditions and use physics to divine the future.

As the climate changes, these models adapt because they start from recent observations. Even without the effect of climate change, global coupled models now outperform their simpler statistical counterparts. The seasonal climate outlook has entered the digital age.

Seasonal climate forecasts will never be perfect; there are just too many butterflies out there. But they don't have to be perfect. In the same way that you can make money betting on dice that you know are loaded, a seasonal forecast can shift the odds in a farmer's favour. The new breed of seasonal climate forecast will give farmers and others who depend on seasonal climate outlooks the best chance to cope with an uncertain future. And maybe some time to simply sit back and enjoy that cuppa.

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