THE FORECAST FOR 2018 IS CLOUDY WITH RECORD HEAT

EFFORTS TO PREDICT THE NEAR-TERM CLIMATE ARE TAKING OFF, BUT THEIR RECORD SO FAR HAS BEEN PATCHY.

BY JEFF TOLLEFSON

In August 2007, Doug Smith took the biggest gamble of his career. After more than ten years of work with fellow modellers at the Met Office's Hadley Centre in Exeter, UK, Smith published a detailed prediction of how the climate would change over the better part of a decade[1]. His team forecasted that global warming would stall briefly and then pick up speed, sending the planet into record-breaking territory within a few years.

The Hadley prediction has not fared particularly well. Six years on, global temperatures have yet to shoot up as it projected. Despite this underwhelming result, such near-term forecasts have caught on among many climate modellers, who are now trying to predict how global conditions will evolve over the next several years and beyond. Eventually, they hope to offer forecasts that will enable humanity to prepare for the decade ahead just as meteorologists help people to choose their clothes each morning.

These near-term forecasts stand in sharp contrast to the generic projections that climate modellers typically produce, which look many decades ahead and don't represent the actual climate at any given time. "This is very new to climate science," says Francisco Doblas-Reyes, a modeller at the Catalan Institute of Climate Sciences in Barcelona, Spain, and a lead author of a chapter that covers climate prediction for a forthcoming report by the Intergovernmental Panel on Climate Change (IPCC). "We're developing an additional tool that can tell us a lot more about the near-term future."

In preparation for the IPCC report, the first part of which is due out in September, some 16 teams ran an intensive series of decadal forecasting experiments with climate models. Over the past two years, a number of papers based on these exercises have been published, and they generally predict less warming than standard models over the near term. For these researchers, decadal forecasting has come of age. But many prominent scientists question both the results and the utility of what is, by all accounts, an expensive and time-consuming exercise.

"Although I have nothing against this endeavour as a research opportunity, the papers so far have mostly served as a 'disproof of concept'," says Gavin Schmidt, a climate modeller at NASA's Goddard Institute for Space Studies in New York, which declined to participate in the IPCC's decadal-predictions experiment.

INITIAL IDEAS

To make its climate prediction, Smith's team used its standard climate model, but broke the mould by borrowing ideas from the way meteorologists forecast the weekly weather. Typical climate projections start some way back in the past, often well before the industrial era, in a bid to capture the average climate well enough to forecast broad patterns over the long term. Weekly weather forecasts, however, begin with the present. They make multiple simulations with slightly different initial meteorological conditions to give an array of outcomes that has some statistical validity despite the weather's inherent chaos.

Smith and his team applied this same approach. They collected a slew of climate measurements — air temperature, wind speed and direction, atmospheric pressure, ocean temperature and salinity — for 20 days during 2005. For each prediction, they 'initialized' the Hadley Centre's main climate model by plugging in a single day's data. Then they ran the model forward for a decade under the influence of various factors such as rising greenhouse-gas concentrations.

By starting in the present with actual conditions, Smith's group hoped to improve the model's accuracy at forecasting the near-term climate. The results looked promising at first. The model initially predicted temperatures that were cooler than those seen in conventional climate projections — a forecast that basically held true into 2008. But then the prediction's accuracy faded sharply: the dramatic warming expected after 2008 has yet to arrive (see 'Hazy view'). "It's fair to say that the real world warmed even less than our forecast suggested," Smith says. "We don't really understand at the moment why that is."

The answer may lie in the oceans. Although the atmosphere largely controls day-to-day weather, the slow-moving oceans hold so much more energy and heat that they dominate how the climate changes from year to year. Researchers suspect that much of this variability is tied to widespread cycles, such as the El Niño warming and La Niña cooling system in the eastern tropical Pacific. In theory, the fact that salt water circulates more slowly than air should also make the oceans a little easier to model.

In 2008, a group of climate modellers led by Noel Keenlyside, now at the University of Bergen in Norway, made a prediction through to 2030 that incorporated the effects of sea surface temperatures in the Atlantic[2]. They focused on one of the Atlantic's dominant current patterns, the meridional overturning circulation. This carries sun-baked waters from the tropics to the north Atlantic, where it releases heat into the atmosphere, before sinking into the deep ocean and travelling south again. The model predicted that this circulation would weaken, helping to stabilize or even cool global temperatures over the next several years.

The prediction sparked a furore: some researchers questioned the Keenlyside team's analysis as well as the way the model was initialized. The highly publicized study also became wrapped up in a broader debate in the media about whether global warming had paused. Shortly after the study came out, a group of scientists led by Stefan Rahmstorf, an oceanographer at the Potsdam Institute for Climate Impact Research in Germany, publicly refuted the paper and challenged Keenlyside's group to a pair of bets together worth €5,000 (US$6,525) if the predictions bore fruit.

"We felt a need to make it publicly known that this was not climate science as such that was predicting a cooling period," Rahmstorf says. Keenlyside and his team did not take the bets, which turned out to be a smart choice. The circulation did not flag and the temperatures were higher than predicted, says Rahmstorf.

Keenlyside acknowledges the model's shortcomings, but says that it captured at least the initial trends in global temperatures, which did not rise in the first few years of the prediction period. "Our system was very crude, but we were able to show that initializing the oceans is very important in these models," he says.

Despite their faults, such efforts helped spark a wave of research among modellers who are hungry for ways to test and improve their calculations. The global climate-modelling groups that took part in the IPCC's experiments invested a substantial portion of their

LOST HEAT

Why has the warming slowed?

It is one of the biggest mysteries in climate science: humans are pumping more greenhouse gases into the atmosphere today than ever before, yet global temperatures have not risen much in more than a decade. That trend does not undermine the idea that greenhouse gases will eventually push global temperatures into uncharted territory, but it does have scientists puzzled.

One partial explanation is natural variation: temperatures are expected to plateau occasionally even during a warming climate. And the world remains a very warm place. The ten hottest years on record have all occurred since 1998.

Yet with the stalled warming now approaching its 15th year, researchers are seeking some deeper explanation. "The heat must be going somewhere," says Ed Hawkins, a climate scientist at the University of Reading, UK. "The question is where."

One likely culprit is the oceans, which already absorb most of the heat. The latest research suggests that more heat than expected could be going into the deep oceans, below 700 metres[7]. Another possibility that scientists have investigated is whether volcanic ash from minor eruptions and pollution from the industrialization of China and other countries are reflecting more of the Sun's energy back into space[8]. Still another is the prolonged lull in solar activity early in the millennium, which might decrease the amount of energy hitting Earth.

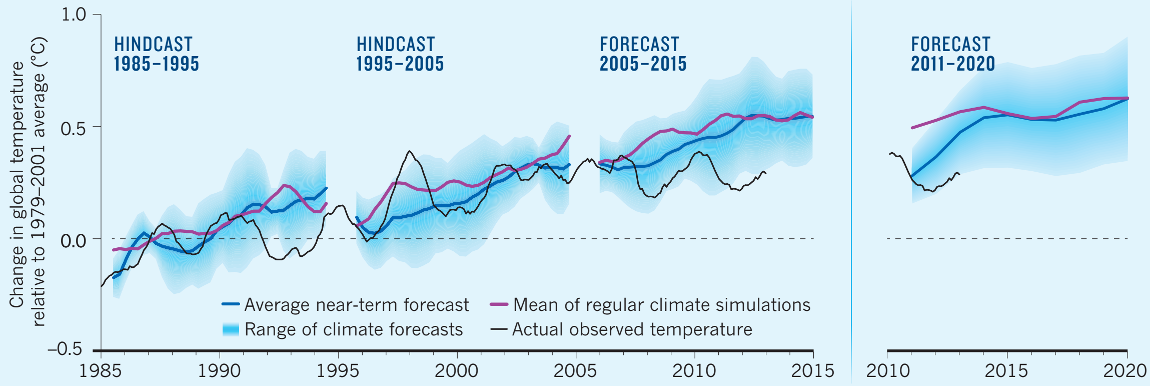
But scientists cannot yet fully explain the recent trends, and the larger question is whether the lack of warming today portends less warming in the future.

Michael Ring and his colleagues at the University of Illinois at Urbana-Champaign argue that Earth might in fact be less sensitive to greenhouse gases than previously believed[9]. Whereas the Intergovernmental Panel on Climate Change estimates that doubling atmospheric carbon dioxide levels would ultimately increase global temperatures by 2–4.5 °C, with a best estimate of 3 °C, the Illinois group says that the rise is more likely to be between 1.5 °C and 2 °C.

Other researchers argue the opposite[10], and the issue remains unsettled. Besides, the continuing climb in global emissions means that a lower climate sensitivity would cause only a slight delay in global warming, says Alexander Otto, a climate policy researcher at the University of Oxford, UK. "The impacts we were expecting in 2050 would happen a decade later," he says. "There is certainly no reason for complacency." **J.T.**

HAZY VIEW

Researchers at the Hadley Centre, UK, developed a method to predict the near-term climate. After making test hindcasts for two prior decades, they produced a forecast to 2015 that showed less warming than seen in regular simulations; but observed temperatures were even lower. New forecasts for 2011–20 give cooler temperatures initially, followed by sharp warming.



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modelling time to produce the first systematic predictions of how the global climate will evolve in the coming years. These models predict cooler temperatures: on average 15% less warming over the next few decades compared with standard climate projections[3].

To determine whether these projections are likely to hold, the groups ran the usual test of seeing how well their models performed when hindcasting, or predicting the past. The teams plugged in all of the observational data and ran decadal climate predictions at least every five years beginning in 1960, comparing the resulting hindcasts to the actual climate as well as standard climate models. In one such analysis[4], Doblas-Reyes and his colleagues say that their model anticipated the slowdown in global warming up to five years in advance. Their paper also bolstered the theory that the deep oceans, notably the Atlantic and tropical Pacific, had stalled atmospheric warming by absorbing much of the heat being trapped by rising concentrations of greenhouse-gas concentrations in the air (see 'Lost heat').

ERROR CORRECTION

These results have yet to win over sceptics such as Rahmstorf, who questions whether the models are accurately anticipating variations in Earth's climate, but many others say that the newer simulations are showing some skill at a regional level, particularly within the oceans.

"We do see that there are some improvements," says Lisa Goddard, a climate scientist at Columbia University in New York who is heading a systematic analysis and comparison of the predictions from the IPCC models[5]. Many models, for instance, captured a sudden warming of sea surface temperatures in the North Atlantic that began around 1995. "They all predict the shift beautifully," Goddard says. "Unfortunately, from what I hear, different models are doing it for different reasons."

If so, the models' success could be deceptive: whatever accuracy they show for the first year or two of their predictions might stem in part from the fact that the simulations start off with a snapshot of the current climate. Because the climate does not usually change drastically from one year to the next, the model is bound to start off predicting conditions that are close to reality. But that effect quickly wears off as the real climate evolves. If this is the source of the models' accuracy, that advantage fades quickly after a few years.

Although the prediction experiments show limited forecasting skill at the moment, modellers are trying to use these exercises to improve their creations. One key challenge is the way in which the models are initialized. To start a simulation, modellers plug as many values as possible into a three-dimensional grid of the oceans and atmosphere. But modellers must make assumptions for areas without data, including the deep oceans.

Another challenge stems from the fact that each model has its own equilibrium state — the climate that it generates naturally if left on its own. By plugging in actual values for the ocean and atmosphere, researchers pull the model away from its natural state. When the model starts to run forward in time, it immediately begins to drift back to its preferred climate, which can introduce additional complications.

"What are the causes of that drift?" asks Doblas-Reyes. By comparing prediction simulations with conventional climate projections, scientists hope to correct for that drift and detect problems in the models that would otherwise remain hidden. "If these models can help scientists identify systematic errors, it will benefit the entire climate-modelling community," says Doblas-Reyes.

Schmidt says that these efforts are "a little misguided". He argues that it is difficult to attribute success or failure to any particular parameter because the inherent unpredictability of weather and climate is built into both the Earth system and the models. "It doesn't suggest any solutions," he says.

Even advocates have no illusions about the challenges ahead. Kevin Trenberth, a climate scientist at the National Center for Atmospheric Research in Boulder, Colorado, says that it could be a decade or more before this research really begins to pay off in terms of predictive power, and even then climate scientists will be limited in what they can say about the future. But many people might welcome hints about what's to come. "For a farmer in Illinois," Trenberth says, "any indications about what to expect could turn out rather valuable."

Smith says that his group at the Hadley Centre has doubled the resolution of its model, which now breaks the planet into a grid with cells 150 kilometres on each side. Within a few years, he hopes to move to a 60-kilometre grid, which will make it easier to capture the connections between ocean activities and the weather that society is interested in. With improved models, more data and better statistics, he foresees a day when their models will offer up a probabilistic assessment of temperatures and perhaps even precipitation for the coming decade.

In preparation for that day, he has set up a 'decadal exchange' to collect, analyse and publish annual forecasts. Nine groups used the latest climate models to produce ten-year forecasts beginning in 2011. An analysis of the ensemble[6] shows much the same pattern as Smith's 2007 prediction: temperatures start out cool and then rise sharply, and within the next few years, barring something like a volcanic eruption, record temperatures seem all but inevitable.

"I wouldn't be keen to bet on that at the moment," Smith says, "but I do think we're going to make some good progress within a few years." ■

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