The Long View of Weather

Learning how to read the climate several seasons in advance

By RICHARD MONASTERSKY

Chaos in the atmosphere bedevils weather forecasters. Their primary tool, complex computer models, can look only a few days into the future before countless winds and eddies sweep away any chance of making a skillful prediction. Even if meteorologists had access to an infinitely powerful supercomputer, they could not hope to forecast rain or shine a month ahead of time. The atmosphere is simply too turbulent.

But if they surrender the idea of making specific predictions, meteorologists may succeed in buying some time in the forecasting game. With that possibility in mind, several research groups are now testing experimental approaches designed to anticipate general climatic conditions as much as a year in advance. If such a strategy works, it could warn farmers to expect a withering drought or the kind of persistent rains that flooded the midwestern United States last summer.

"I think this is going to revolutionize the way we think about forecasting. The concept of long-lead forecasting for a region is something that people haven't really worked with before," says David Rodenhuis, chief of the National Weather Service's Climate Analysis Center (CAC). From its home in Camp Springs, Md., the CAC makes the monthly and seasonal outlooks issued by the weather service.

The experimental schemes for long-range forecasting have evolved out of recent advances in understanding the behavior of Earth's climate, particularly that beast known as El Niño — an occasional warming in the tropical Pacific that develops every four to seven years. Scientists have learned that El Niño and its cool counterpart, La Niña, exert influences far beyond their local neighborhood. Like a rock dropped into a pond, the Pacific's hot and cold spells send ripples spreading through the world's atmosphere, altering weather around much of the globe. For instance, the El Niño that simmered earlier this year inundated southern California with unusually heavy winter rains but dried out northeastern Brazil. The warming even contributed to the summer floods in the Midwest.

In strength, this El Niño pales in comparison to the biggest of the century, which struck in 1982 and 1983. The record warmth in the equatorial Pacific those years redirected normal jet stream patterns, generating floods and droughts that left thousands dead worldwide and caused more than $13 billion in damages.

Spurred by that event, 18 countries invested in a decade of research aimed at understanding how the Pacific waters and atmosphere conspire to bring about El Niños and La Niñas. As part of this project, called the Tropical Ocean Global Atmosphere (TOGA) Study, scientists have developed computer models for predicting when the tropical Pacific will swing toward warm or cool temperatures. Nature still has the upper hand, however, having fooled almost all of them last year and perhaps again this year with a subtle El Niño that was difficult to anticipate (see box). But major warmings and coolings advertise themselves much more openly, and the models have started to exhibit skill at detecting such events as many as 12 to 18 months ahead of their actual arrival.

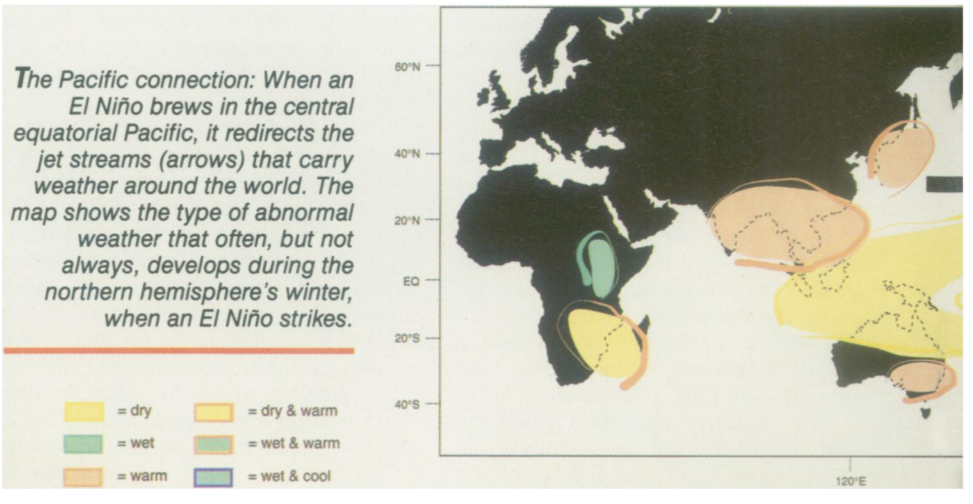
Piggybacking on that success, researchers are now looking beyond simple El Niño predictions to forecasts of how these disturbances in the Pacific will actually disrupt weather in the United States and other parts of the globe.

Just down the hall from Rodenhuis' office, Ants Leetmaa is developing a long-range forecasting strategy for the U.S. weather service. Leetmaa uses a tool called a coupled global circulation model (GCM), which simulates how streams in the oceans and atmosphere shuttle heat and moisture around the planet. The model starts with a portrait of the current weather and then projects how temperature, wind speed, precipitation, and other factors will vary with time.

To make a nine-month forecast for the United States, Leetmaa would ideally feed the necessary meteorological measurements into the computer, let the model spin through 270 simulated days, then examine the picture that developed. But the coupled model is not yet up to the task; inherent biases make its Pacific Ocean run consistently hot or cold during different seasons.

To minimize such problems, Leetmaa uses a hopscotch approach, jumping from the coupled GCM to a smaller one. After running the first model, he corrects the known biases in the Pacific Ocean forecasts, then feeds the projected ocean temperatures into the second GCM, which simulates the atmosphere only. Much faster and cheaper to run, this model forecasts how the global atmosphere will respond over the next six months to the predicted sea surface temperatures of the Pacific.

This hopscotch method relies on the theory that the tropical Pacific Ocean plays the central role in fashioning weather around much of the planet. So by predicting what will happen in this remote ocean region over the next few seasons, forecasters can gain some insight into what conditions will develop over the United States and other populated parts of the globe. "It is really the



The Pacific connection: When an El Niño brews in the central equatorial Pacific, it redirects the jet streams (arrows) that carry weather around the world. The map shows the type of abnormal weather that often, but not always, develops during the northern hemisphere's winter, when an El Niño strikes.

hub of the climate system," says oceanographer Timothy P. Barnett of the Scripps Institution of Oceanography in La Jolla, Calif.

Barnett and his colleagues have developed a long-range forecasting technique that exploits the tropical ocean's importance in climatic affairs. They contend that since conditions in the Pacific are critical, long-range forecasts need not start off with a model that includes a sophisticated atmosphere. The Scripps group therefore works with a hybrid consisting of a relatively simple atmospheric model wedded to an ocean GCM that simulates only the tropical Pacific. This hybrid model has the advantage of running much more quickly than the everything-but-the-kitchen-sink GCM that Leetmaa uses.

Barnett's group starts by running a four-month forecast on the hybrid model to predict tropical Pacific temperatures. Once they get a picture of how the ocean will act, the researchers insert the predicted Pacific temperatures into a sophisticated atmospheric GCM developed by the Max Planck Institute for Meteorology in Hamburg, Germany.

Can this technique actually say anything useful about the weather three or six months hence? As a test, the Scripps-Max Planck team chose seven periods during the last 23 years and tried to "hindcast" conditions for each one. They selected periods when a major El Niño or La Niña gripped the tropical Pacific, because these events should have exerted the clearest effects on weather in the middle latitudes. To make a hindcast, Barnett and his colleagues fed the models meteorological data gathered before each event and watched to see how the weather evolved over several seasons.

In general, the test showed that the two-tiered modeling approach could offer some insight into upcoming conditions in certain regions, the team reported in the Aug. 20 SCIENCE. For the 1982-1983 El Niño, the hindcast accurately depicted the major pressure patterns over the Pacific and northwestern United States with lead times of six to eight months. The hindcast did moderately well in the middle latitudes of the southern hemisphere and over much of North America and central Asia. But it showed little skill in predicting conditions over Europe, eastern North America, and Southeast Asia.

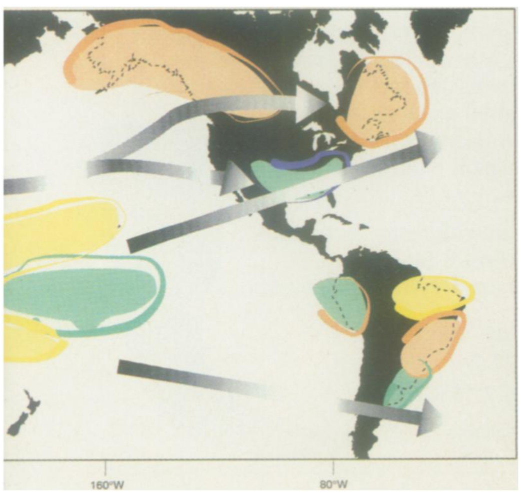
The technique clearly does not work for all areas of the world, particularly those located far from the action in the central Pacific. Moreover, say the researchers, the forecasting scheme can't help every year. "It's really only going to work when there's a large event in the tropics, and that might be only once every three or four years. On the other hand, those are generally the extreme events that cause the most problems for folks," says Barnett.

Leetmaa has higher hopes for long-range forecasting. "I think Tim is talking about the tip of the iceberg. I think we'll be able to exploit this almost every year, for every season," he contends.

That's a bold assertion, especially since the conventional wisdom holds that El Niños significantly warp North American weather only during wintertime. But Leetmaa, who began his career as an oceanographer, believes that the tropical Pacific exerts influence in all seasons, even during years with a mild warming or cooling. Models should eventually be able to pick up these subtle forecasting hints from the ocean at any time of year.

One shouldn't expect such remarkable sensitivity anytime soon, however. In its most recent strategic plan, the National Oceanic and Atmospheric Administration set a target date of 2005 for developing the ability to forecast general climatic conditions up to a year in advance with a success rate of 70 percent. While that percentage may sound low, it represents the same degree of accuracy achieved now in forecasting temperatures two days in advance. "This is pretty hard to achieve," says Leetmaa. "Whether we ever get there is a separate issue. But that's what we're shooting for."

Before they can run the equivalent of a marathon, long-range forecasters have to demonstrate that they can crawl the first few yards. Leetmaa's group only last summer started using the coupled model



International Research Institute for Climate Prediction

A confusing time for El Niño forecasters

The lingering El Niño in the Pacific has taught frustrated climate forecasters yet another lesson in humility by refusing to leave as expected.

El Niños typically follow a 12- to 18-month cycle that starts when westward-blowing winds slacken along the equator, allowing warm water to pile up in the central and eastern tropical belt. The warming there pulls atmospheric moisture eastward and jostles the jet streams out of their typical positions. Eventually, the El Niño fades away when the westward winds regain strength, pulling up cold water that spreads across the central and eastern Pacific.

The present warming developed in 1991, and almost all models of the Pacific forecast that it would die by the end of 1992. The El Niño hung on, however, and unexpectedly redeveloped last December (SN: 1/23/93, p.53; 5/8/93, p.292). Of the major experimental forecasting models in use now, only the coupled global circulation model at the National Meteorological Center (NMC) in Camp Springs, Md., predicted the restrengthening last year.

The NMC model won't score as well this year. Along with most of its counterparts, the model called for the warmth to dissipate in the Pacific by the latter part of 1993. This summer, the Pacific seemed headed in that direction (SN: 9/11/93, p.172). But the cooling trend halted and reversed itself in September and October, causing gun-shy forecasters at NMC to issue an advisory noting the possible reestablishment of the El Niño during the winter.

"It sure looks like we're getting a redevelopment," says the center's Vernon Kousky.

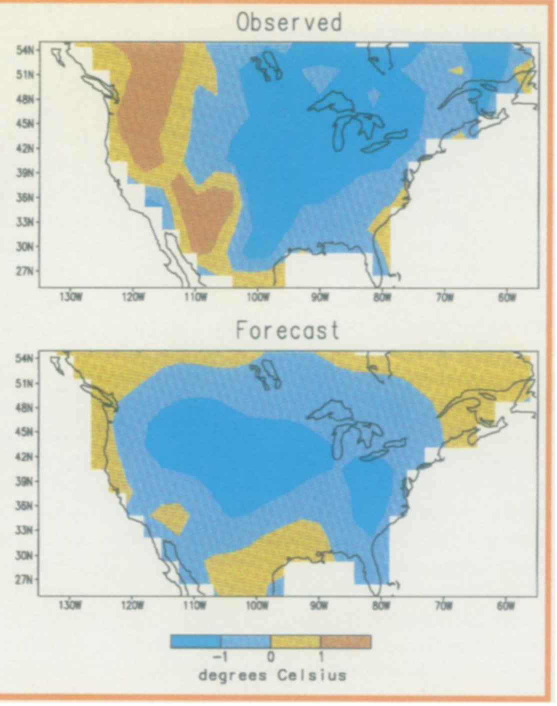
Oceanographers say the Pacific has used up its supply of warm surface water, a situation that should — in theory — cause the El Niño to peter out. But while the ocean appears ready to cool, the atmosphere has not received the message and has yet to break out of its El Niño state.

Since conditions in the Pacific have defied expectations, Kousky and others have no idea whether the warming will continue or how strong it will get. If it does last through winter, the current El Niño will become the longest on record, beating out two other noteworthy episodes in 1911-1913 and 1939-1942.

Even if the warming remains a mild one, it could dramatically affect weather around the world this winter, Kousky warns. Having already endured a lasting El Niño, the atmosphere is conditioned to the Pacific warmth, with enhanced jet streams that flow closer than normal to the equator. Such an arrangement tends to strengthen storm systems, shifting the typical precipitation patterns in many spots.

That could mean bad news for many regions, such as northeastern Brazil and southeastern Africa, that have already endured two years of El Niño-inspired droughts.

— R. Monastersky



A cold heart: A two-month forecast by the coupled model at the National Meteorological Center accurately predicted that temperatures would average below normal in the center of the United States during September and October. The model failed, however, to anticipate the western warmth. The forecast combines a suite of individual computer simulations driven by information about Pacific Ocean temperatures during June, July, and August.

Leetmaa

to make experimental forecasts for North America. In the next year, he hopes to show that this technique has some predictive ability at least one season in advance. Then the operational side of the weather service could regularly incorporate these results into its seasonal predictions.

The move toward GCM models would mark a major shift in philosophy. Currently, meteorologists put together their seasonal forecasts mostly on the basis of statistics on past weather, analogies with previous situations, and judgment gained from years of watching weather, says CAC's Rodenhuis. In general, such techniques have a poor track record, and Rodenhuis says that forecasters can make only incremental improvements in this empirical approach. To really boost accuracy and extend the range of forecasts beyond three months, meteorologists need to start incorporating the physics-based GCM model that Leetmaa is developing, he says.

"While the human is going to be in this business for quite some time, the expectation is that the coupled model is going to radically change the way we do these forecasts," says Rodenhuis.

As the first step in that direction, Leetmaa's group will soon start assessing the coupled model's accuracy by making hindcasts for the last 10 years. Although the researchers are ready to test the model by forecasting weather, nature has refused to cooperate with them this year. The model has the greatest chance of success when it predicts the appearance of a strong El Niño or La Niña. But present conditions in the tropical Pacific have remained stuck in a slightly warmer-than-normal pattern, and the model is not calling for any major oceanic temperature swing this winter.

"It's going to be tough to do the U.S. forecasts this winter because the temperature anomalies in the Pacific are going to be so small," says Leetmaa. "It will be a harder demonstration test than if it had gone really warm or really cold. But that's the hand that nature deals you." □