Climate Forecasting Status and

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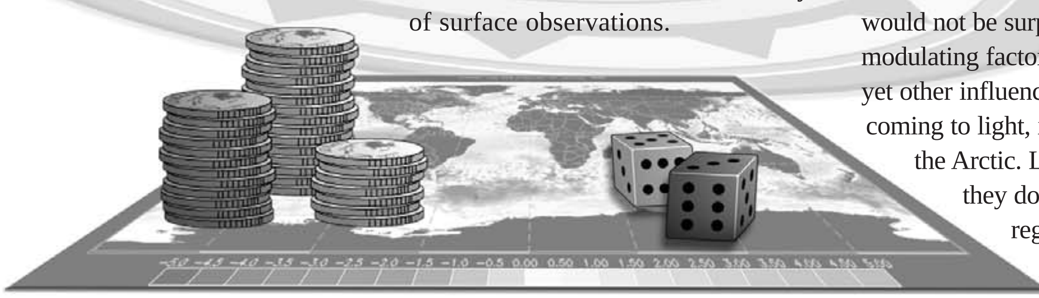
Beginning in late 1994, the Climate Prediction Center (part of the National Weather Service) began to issue seasonal outlooks extending to the next twelve months for temperature and precipitation. An impressive body of research on how the climate engine works had led to the realization that the general character of upcoming climate is at least partly predictable in certain circumstances. By the same token, it is probably unrealistic to expect that climate can be forecast equally well under all circumstances.

Climate varies for multiple reasons, all operating at once, many of which we do not understand well, some of which we may only suspect, and others that we simply don't know. We do not have the luxury of watching how each cause alone affects climate; it has to be disentangled all at once from a relatively short record of 50 years of good three-dimensional observations and a little over a century of surface observations.



Predicting The Odds

Climate forecasts are generally presented in probability terms. This approach explicitly acknowledges the gaps and limitations in our understanding, and provides needed information on forecaster confidence in the prediction. Most people can relate to gambling analogies (especially here in Reno), and we can think of climate outlooks as tilting the odds, or loading the climate dice, toward or away from various outcomes. This far better reflects the real situation in the mind of a forecaster than a deterministic forecast (e.g., "December will be wetter"). Maps that present forecasts often have blank spots: not enough is known to tilt the odds one way or the other. Sometimes these "spots" occupy nearly the whole map. Depending on optimism, this reflects that we are either still very much in the dark or that we still have many opportunities for learning.

Because the causative factors that drive climate vary with time, and because the ways that the climate system responds to those drivers vary with season, geographical location, and elevation, our ability to predict climate varies as well. When El Niño or La Niña are present, we see certain recurring patterns in U.S. climate. However, we are discovering that there appear to be factors in the North Pacific that strengthen or weaken such El Niño / La Niña connections. These factors remain in the same phases for two to three decades at a time and then switch. We would not be surprised to discover that such modulating factors are themselves subject to yet other influences. Other influences are coming to light, in the North Atlantic and in the Arctic. Labeled as "oscillations," they do not exhibit the clockwork regularity the term implies, often switching erratically and, unfortunately, unpredictably, between two main states generally opposite from each other.

Furthermore, some of the causes of climate variation are internal to the system (able to be changed by the climate itself), and others are more external (volcanic eruptions, solar variations, atmospheric composition, land surface alterations) with different predictability.

Prospects

What We Do Know

So, where are we now? In general we can predict winter climate better than summer climate. With some exceptions, we can predict temperature better than precipitation. We can predict better during El Niño or La Niña than when neither phase is present (about half the time). In fact, much of the skill to date derives from this, and forecasters become more nervous when the equatorial Pacific is neutral. The most predictable patterns are in winter, for precipitation, for the southern tier of states stretching from the Desert Southwest across toward Texas, the Gulf Coast, and Florida. Arizona in particular seems to have the most predictable response in the country to El Niño and La Niña, especially the latter and especially during winter. For both El Niño and La Niña, two of the West's great rivers, the Columbia and the Colorado, typically have precipitation departures for winter that are opposite from each other. La Niña seems to produce the most consistent response in Southwest winter (always dry or average, never wet), whereas El Niño winters are usually wet, sometimes extremely so but sometimes average, and sometimes dry. El Niño shows far more personalities than does La Niña, and there are physical reasons why this should be so, but that's a topic for another day. The predictability of the summer monsoon is very marginal; however, the North American Monsoon Experiment (NAME) is gearing up to help change this (see page 30).

In the past, forecast methodologies were nearly entirely statistical, but we are witnessing a slow evolution to dynamic models or simulations. Statistical approaches rely on the repeatability of past relationships, where a pattern of one thing (such as ocean temperature distribution) is often followed by a later pattern of another thing (North American precipitation). Also, recent climate trends are incorporated this way. These approaches are simple, extremely cheap, and show good skill. They look for associations and do not ask why, just what. They do not do as well when presented with new combinations of driving causes, because they haven't the requisite experience base. Until recent years, mathematical models have not adequately simulated observed climate behavior as well as statistical models, but now the two approaches are more comparable. Like toddlers "getting their legs," they will grow into their major inherent strengths: physical underpinnings and the ability to deal with new situations. The modeling approach involves a kind of double prediction: first predict what the ocean will do, then predict how the atmosphere will react to the predicted oceanic conditions. Increasingly, these two processes will be coupled from the start.

In order to predict, we must first understand. Paradoxically, to understand the driest climates in North America, we must look to the depths of the wettest portion of the planet. In fact, we cannot fully understand the climate of the Southwest, and how and why it varies, unless we understand the climate of the entire world. We thus need to observe, much better than now, the world's oceans, and the atmosphere above them.

Furthermore, there are small-scale effects in the Southwest having to do with the differences between the mountains and the adjoining valleys. These differences are extremely important, because they govern the origin of most streamflow. To understand this better, we must have a more dense network of systematic observations meeting climate standards in the complex topography of the mountainous West. A better observation system is a prerequisite to better climate forecasts.

The rough consensus is that climate forecasts are at the stage where weather forecasts were about 35-40 years ago. The pace of advance will be controlled by our understanding of why the climate system varies, by our knowledge of ocean behavior at all depths, by significant improvements in observational capability at mountain-valley scales and at the global scale, by the ability to characterize and explain the variations seen during past centuries, and by our ability to include human effects such as atmospheric composition and land use change, and finally by computer capacity. One climate prediction with high confidence, however, is that climate forecasts will improve steadily and significantly!

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