Seasonal Forecasting: Skill in the Intermountain West?

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People have long been interested in outlooks of climate, as shown by the popularity of the Farmer's Almanac for over two centuries. More recently, climate scientists have been producing official climate forecasts on a regular basis. This article describes what seasonal forecasts are, the scientific basis for making forecasts, and the skill of these forecasts over the U.S. West.

A seasonal climate forecast is about the average conditions over a future period of time, rather than a prediction for a particular day. (The latter is commonly called a weather forecast.) In addition, a seasonal climate forecast is a prediction of the departure from the normal march of the seasons. So, saying that summer comes after winter is hardly a seasonal forecast! What we really wish to know is whether this summer will be abnormally hot and whether a drought will leave our crops stunted where typical summer rains normally nourish the soil.

Therein lies a most curious situation. While the daily weather much beyond two weeks is nearly impossible to predict accurately, the seasonal climate is, at times, quite predictable. The reason is that the climate system has a modest degree of memory, which is mostly imperceptible on a daily basis, but detectable in the average of seasons. Long-term temperature trends also provide valuable clues to the future.

The memory of climate conditions can influence the future seasonal state of the atmosphere, and leave a definable and predictable signal. Climate memory is most prevalent in the world oceans, where cool or warm anomalies in the sea surface can take months, and sometimes years, to revert to normal. Unusual land surface conditions, such as excess spring soil moisture accumulated from heavy rains or deep early winter snow cover, may also provide memory. Climatologists have only recently fully understood the "granddaddy" of these signals, an irregular prolonged warming (or cooling) of the tropical Pacific Ocean, known as El Niño (or La Niña) or collectively as the El Nino/Southern Oscillation (ENSO). In the late 20th century, climate scientists were able to unravel the global mystery linking tropical Pacific Ocean conditions to the subsequent seasonal climate of many far-away places, including the United States. ENSO is the phenomenon that has formed the backbone of seasonal forecasting since its official inception.

Who produces these "official" seasonal climate forecasts? In 1995, the Climate Prediction Center (CPC), a part of NOAA's National Weather Service, began issuing seasonal climate forecasts for precipitation and temperature each month based on dynamical and statistical forecasting techniques. CPC issues forecasts for three-month periods with lead times ranging from 0.5 to 12.5 months. For example, in mid-May, CPC will issue temperature and precipitation forecasts for June-July-August (0.5 month lead), July-August-September (1.5 month lead) and all subsequent forecasts up to June-July-August of 2006 (12.5 month lead). These forecasts rely primarily upon two critical climate processes: (1) the status of ENSO and (2) long-term upward temperature trends, which climatologists have been observing for the past several decades. In the Western U.S. especially, this trend is pronounced (see Figure 1a).

How do we assess these forecasts? There are two standard measures to assess the performance of forecasts, accuracy and skill. Accuracy is a measure of how close the prediction is to the observed climate variable, such as temperature or precipitation. Skill, on the other hand, measures how well one forecast performs compared to a reference or baseline forecast. Climatology is used as a typical baseline forecast, referring to the expected values of temperature, precipitation or other climate variables for a given location and time of year. Climatology is the simplest way to predict future climate, and suggests that the average temperature or precipitation is the most likely outcome, but a range of conditions that have occurred in the historical record are also possible. Skill measures the ability of a forecast method to predict conditions.

What is the skill of CPC forecasts? In late 2004, NOAA's Climate Services Division (CSD) evaluated the forecast skill of the ten years of CPC forecasts. NOAA CSD chief Bob Livezey and University Corporation for Atmospheric Research scientist Marina Timofeyeva performed the study, evaluating forecasts

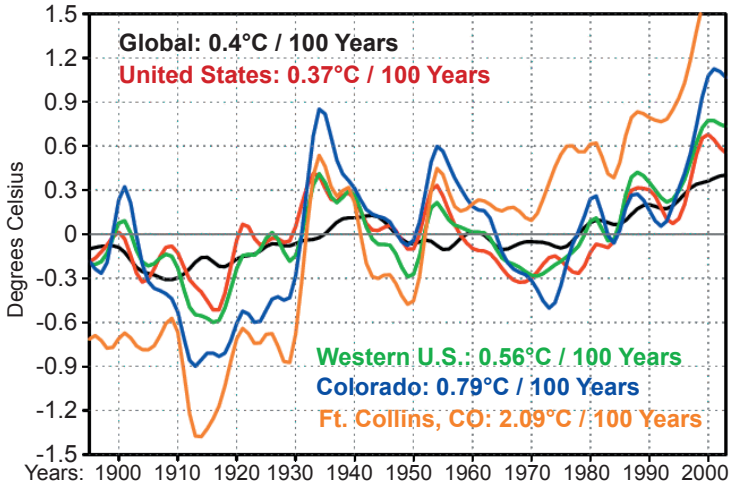

Figure 1a: Temperature trends for different regions of the globe since 1900. The Western U.S. has warmed about 1°F, Colorado 1.5 °F and Fort Collins about 4°F during the last 100 years. (1°C is approximately 2°F.)

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on a regional basis using climatology as the baseline forecast. During 1995-2004, CPC official forecasts show skill in three distinct ways, depending on climate variable, time of year and ENSO status. First, in ENSO years, CPC forecasts are skillful at predicting *temperature* for the winter and early spring throughout the U.S. (except California). Second, in ENSO years, CPC forecasts are skillful at predicting *precipitation* for the winter and early spring in the southwestern, southeastern and northwestern U.S. (Figure 1b). Third, in non-ENSO years, CPC forecasts are skillful at predicting *temperature* for the spring, summer, and early fall in the western U.S. (Figure 1c).

Along with demonstrating where and when CPC seasonal climate forecasts have skill, the CSD assessment also examined the times and places for which the CPC forecasts lack skill. In general, they have no skill for summer precipitation and very low skill for temperature during non-ENSO years in areas outside of the western U.S. More specifically, skill in the Intermountain West region includes temperature skill in spring and summer attributed principally to trends, and some modest precipitation skill in the southernmost part of the region (central and southwestern Colorado and southern Utah), likely connected to the ENSO signal in the Southwest. This area has quite complex physical geography, which is difficult to represent in climate models.

What's the future of climate predictions? As they say in the mutual fund industry, past performance is no guarantee for future success. The CPC forecasts evaluated have only been issued for 10 years, not enough to compile meaningful statistics, and the forecast methodologies used at CPC have evolved and will continue to evolve. In an effort to improve seasonal predictions, climatologists have been searching the globe for new climate drivers since the significance of ENSO was discovered. Researchers are combing through sea surface temperature records of the North Pacific, the South Pacific, the Atlantic, and all other oceans and seeking to understand their predictive value. Scientists are also engaged in "great archeological digs", in which climate records are being reconstructed for the entire past 1000 years using "proxies" for temperature and precipitation, such as the growth patterns of trees. However, given the current state of forecasting, not all CPC forecasts have the same skill, and users should consider these skill scores when valuing these forecasts. WWA is involved with NOAA in improving the basis for, and usability of, seasonal forecasting in the West and will continue to report on the skill of seasonal forecasting.

The diagrams below show the modified *Heidke skill score* of CPC forecasts relative to a seasonal average baseline forecast. Heidke skill scores range from negative infinity to 100 with 100 indicating perfect forecasts, zero being no improvement over the baseline forecast, and negative infinity indicating the worst possible score. A simplistic way to consider skill scores is to consider the score as a percent improvement (or decline in the case of negative skill) over the baseline forecast. Thus, a score of 20 would indicate a 20% improvement over the baseline forecast.

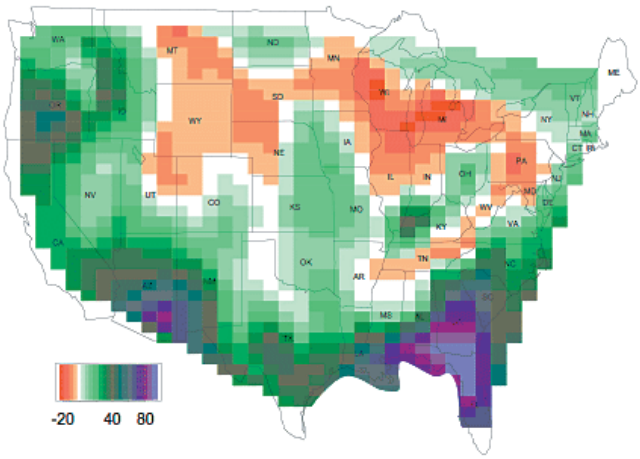

Figure 1b: Skill scores for December to April precipitation during El Niño and La Niña events, predicted at 0.5 to 6.5 months in advance. Note the strong skill in the southwest, southeast, and northwest; areas where ENSO most directly affects precipitation.

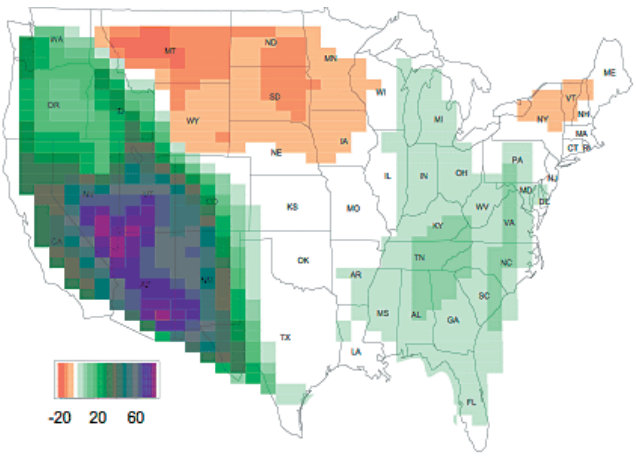

Figure 1c: Skill scores for February to June temperature during non-ENSO events, predicted at 0.5 to 12.5 months in advance. Note the strong skill in the western United States.

On the Web

- Climate Prediction Center Forecasts: http://www.cpc.ncep.noaa.gov/products/predictions/90day/
- Skill Study on CPC Forecast by Scientists Robert Livezey and Marina Tamofeyeva: http://www.cpc.ncep.noaa.gov/products/outreach/proceedings/cdw29_proceedings/livezey.ppt
- Australian Bureau of Meteorology website discussion about 'forecast verification' measures such as skill and accuracy: http://www.bom.gov.au/bmrc/wefor/staff/eee/verif/verif_web_page.html