Forecast Consolidation for Seasonal Climate Outlooks

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As the science of seasonal forecasting has evolved, new tools have been created to produce the operational monthly and seasonal products issued by the NOAA Climate Prediction Center. This article describes a new tool that has led to the greatest single long-term skill improvement achieved since these forecasts were introduced

Introduction

A new technique developed at the Climate Prediction Center (CPC) is bringing more objectivity and uniformity to climate forecasting. Known as the "Consolidation Forecast," the new method combines forecasts from four climate models into a single forecast tool that can be used for seasonal climate outlooks. The Consolidation Forecast method has been available to CPC forecasters since 2006. Performance statistics indicate that the Consolidation Forecast has significantly improved the skill of ½ month lead seasonal (3-month) forecasts over random (climatology) outlooks. Therefore, the creation and incorporation of this new tool is helping to create more accurate seasonal forecasts that benefit various user communities.

Ensemble Forecasting

The Consolidation Forecast, also known as the CON, is an example of a multi-model ensemble technique that combines "ensembles" from several models. A forecaster examines many different ensemble-based models to create many of today's climate forecasts. An "ensemble" is created by running a single model multiple times in order to give an idea of the wide variety of potential climate outcomes for the seasons ahead. The different forecasts from a single model are created by adjusting the "initial conditions" slightly from run to run. These initial conditions are based on the most recent atmospheric and oceanic observations. The average of the ensembles is a single "ensemble mean" forecast, which is more reliable than just one single forecast from just one initial condition. Then to create a climate forecast, the forecaster considers the ensemble mean from many different climate models. However, in order to create an official climate outlook, the forecaster still has to use his/her best subjective judgment to combine ensemble forecasts from the multiple statistical and dynamical models. The Consolidation Forecast technique improves upon the subjective method by using the independent skill of each ensemble forecast to combine the forecasts from multiple models. This new technique results in a single objective climate forecast for many seasons into the future and generally exceeds the predictive skill of a single climate forecast model.

Consolidation of Multiple Forecast Tools

The consolidation method uses ensembles from four different climate forecasting tools to make a single climate forecast. Each forecast tool uses different equations to model relationships between climate conditions and outcome variables (e.g. temperature and precipitation). The four climate forecasting tools used by the CPC in the CON are the Climate Forecast System, Canonical Correlation Analysis, Screening Multiple Linear Regression, and Optimal Climate Normals.

The Climate Forecast System (CFS) is the only dynamical model out of the four climate forecasting tools. It is a state-of-the-art global climate model (GCM) run at the NOAA National Centers for Environmental Prediction. A dynamical model predicts the atmospheric and oceanic responses to elements that are known to affect climate, such as sea surface temperatures (SSTs), soil moisture, snow cover, and ocean/atmosphere interactions. The CFS model is run many times during the course of a given month to produce an ensemble forecast for the coming seasons, out to about nine months.

The other three climate forecasting tools are statistical models, which means they leverage a statistical relationship among multiple variables (i.e. SSTs, temperature, precipitation) in order to make a forecast several seasons into the future. The Canonical Correlation Analysis (CCA) technique relates patterns in SSTs and upper level atmospheric circulations from a point in the past to the patterns of observed temperature and precipitation observed over the U.S. in the following months. The Screening Multiple Linear Regression (SMLR) tool uses some of the same variables as the CCA, but it also includes local soil moisture conditions. The SMLR has the added advantage of being more tailored to individual locations than the CCA, which is more global in scale and can miss local climate signals. Finally, the Optimal Climate Normals (OCN) tool measures temperature and precipitation trends to determine when past trends can be used to make meaningful climate predictions. The climate often exhibits decadal changes and trends that can be used to help predict the likely seasonal temperatures or precipitation in the upcoming seasons.

The new Consolidation Forecast provides an objective method for forecasters to combine ensembles from the four tools (described technique that produces a probability density for each variable

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(i.e. seasonal temperature and precipitation). The consolidation technique weights each tool's ensemble forecast based on how well the tool performed at each forecast location over all the past cases for which forecasts are available. The final step of the consolidation forecast is to add the trend based on the OCN tool. An example of how the Consolidation Forecast combines the information from several tools into a single forecast is shown in Figure 14 a-c of the June 2008 Intermountain West Climate Summary. Even though the CON is an objective tool, the forecaster is still permitted to alter the forecast based on his or her knowledge of the climate system. For example, a forecaster can choose to emphasize a forecast tool that may have a better skill at predicting the climate effects of La Nina when La Nina conditions are anticipated. This was the case in November 2007, when CPC forecasters improved the winter Consolidation Forecast by adjusting temperatures over the northern Great Plains and Pacific Northwest to account for the expected moderate to strong La Niña.

The CON can have some drawbacks. For example, this tool may produce an area of unrealistic spatial patterns where there are weak predictive signals (i.e. areas that are harder to predict) and the forecaster can either ignore or alter them to improve spatial consistency. In creating the outlooks made in June 2008 for July 2008 and subsequent 3 month seasons, the forecaster left out weak signals for below normal temperatures in western Texas and the Southeast because of conflicting signals nearby. Other times, the CON predicts anomalies where the cause is unclear. The forecaster chose to ignore forecasts for above median rainfall in the northeastern U.S. for lack of a clear physical cause (Figure 14c). In the end, the official seasonal climate outlook may not always look exactly like the CON because of these subjective decisions made by the forecaster, but the addition of this new forecast tool results in a more skillful seasonal outlook overall.

Skill Improvement

Forecasters at CPC have documented the improvement in skill of the official forecasts when they take advantage of the CON forecast. Heidke skill scores are often used to assess how forecasting techniques compare to one another. 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 (e.g. climatology A recent study compared the skill of the CON with real-time official 0.5 month lead 3- month temp forecasts (like Figure 10b) from 1995 to 2005 and found a significant improvement compared to climatology and the official forecasts (O'Lenic et al. 2008). The skill for the official forecasts in use during that period (without consolidation) was 22, i.e., a 22% improvement compared to random or climatology, but the skill of the CON-based forecasts is 26, or a 26% improvement over climatology. For precipitation forecasts at the same 0.5 month lead, the skill score for the official forecasts is 4, but the skill score of the CON-based forecasts is a 12, or 12% improvement over climatology. This comparison reveals that the forecasts produced using this tool outperformed the official forecast during this period. When used as a tool in creating outlooks, the CON has thus lead to improvements in the skill of the official forecast. Consolidation Forecasts are expected to improve with time as more tools are included in the consolidation and as forecasters find more accurate methods to weight the input tools.

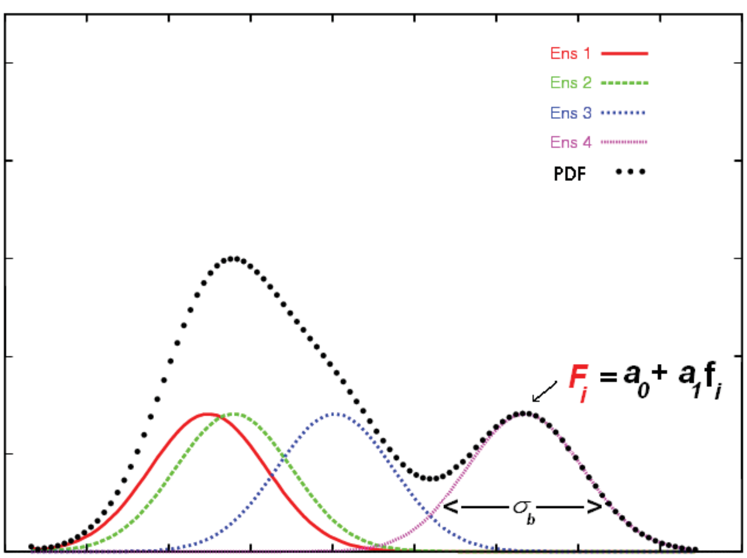

Figure 14a. Schematic illustrating how different forecast tools contribute to the Consolidation forecast. In this case there are 4 tools each with equal skills (as illustrated by the small error distributions associated with each tool - σ_b, which are all the same size) but with different forecasts (determined by the different locations on the x axis). The consolidation method determines the appropriate contribution from each tool and combines the information into a single forecast (dark line).

Key

Consolidation Forecast
Numbers are the estimated probabilities of the observation falling into one of three equally probable categories: above, near, or below normal. Elevated chances of above normal temperatures (below median precipitation amounts) are shown in yellow/red colors, and below normal temperatures (above median precipitation amounts) in green/blue. White areas are approximately equal chances.

Official Forecast
Shaded areas represent the percent chance of temperature or precipitation being in the above or below average tercile. For a detailed description see pages 14 and 15.

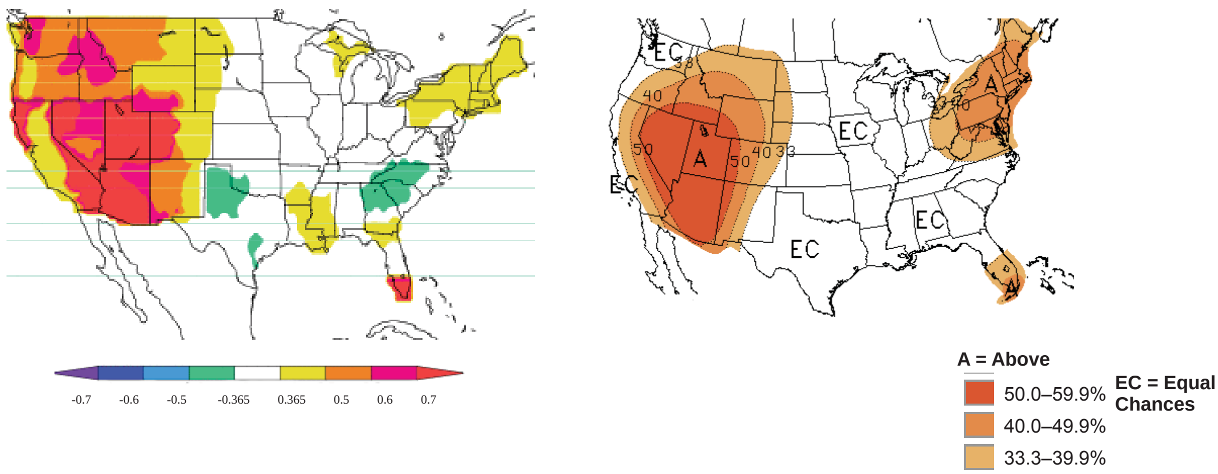

Figure 14b. The latest CPC consolidation forecast (left) and official forecast (right) for seasonal mean temperature over the continental U.S. for June through August, issued in April 2008.

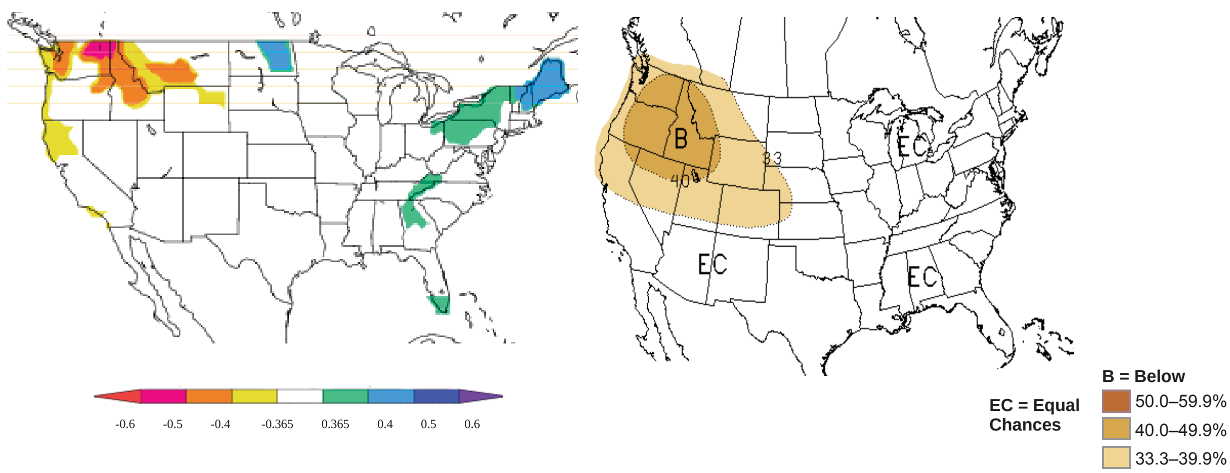

Figure 14c: The latest CPC consolidation forecast (left) and official forecast (right) for seasonal precipitation amount over the continental U.S. for June through August, issued in April 2008.

References

O'Lenic, E. A., Unger, D. A., Halpert, M. S., and Pelman, K. S. (2008, in press) "Developments in Operational Long-Range Climate Prediction at CPC." Weather and Forecasting.

On the Web

- The consolidation forecast for the both the seasonal forecasts and Niño 3.4 SSTs are currently available on CPC's seasonal forecast briefing page: http: // www.cpc.ncep.noaa.gov/products/predictions/90day/tools/briefing/; under "Cons Fcst" and "Nino 3.4: CPC" headings on the left hand frame.
- For more on seasonal forecasting in the Intermountain West, see "Seasonal Forecasting: Skill in the Intermountain West?," in the May 2005 Intermountain West Climate Summary and "How to use the climate Forecast Evaluation Tool," in the January 2006 Summary, both at http://wwa.colorado.edu