US National Oceanic and Atmospheric Administration
Climate Test Bed Joint Seminar Series
NASA Goddard Space Flight Center, Greenbelt, Maryland, 14 April 2010

Recent Analyses of Drought Character and Prediction

Randal Koster
Global Modeling and Assimilation Office, NASA/GSFC
Greenbelt, MD 20771

Three recent studies at the GMAO related to drought were discussed at the seminar. The first, relatively well-developed study examines streamflow prediction (quite relevant to "hydrological drought") at seasonal lead times associated with snow and soil moisture initialization. This study reveals that soil moisture initialization and snow initialization on a forecast start date contribute independently to streamflow forecast skill at seasonal leads. The paper has been submitted for publication.

A second, more preliminary study focuses on skill in the seasonal forecast of soil moisture anomalies, relevant to "agricultural drought". For this purely synthetic study, observations-based meteorological data are used to drive a 0.5ºx0.5º grid of land surface model elements covering CONUS, resulting in an 84-year offline control simulation regarded as "truth". Then, an extensive series of 5-month warm season forecasts are performed, during which the land surface is driven with the (geographically varying) climatological seasonal cycles of meteorological forcing extracted from the control simulation. Skill levels (r^2, the square of correlation of forecast vs. synthetic truth) are shown in Figure 1 for soil moisture one month into the forecast and five months into the forecast. Soil moisture memory by itself provides substantial skill at one month and even some skill at five months – soil moisture can be predicted even without information on meteorological anomalies during the forecast period. Of course, soil moisture memory is a highly model-dependent quantity. The results here are therefore not provided as a representation of nature but as a demonstration of the type of analysis that should be performed with any modeling system to isolate the contributions of model-dependent soil moisture

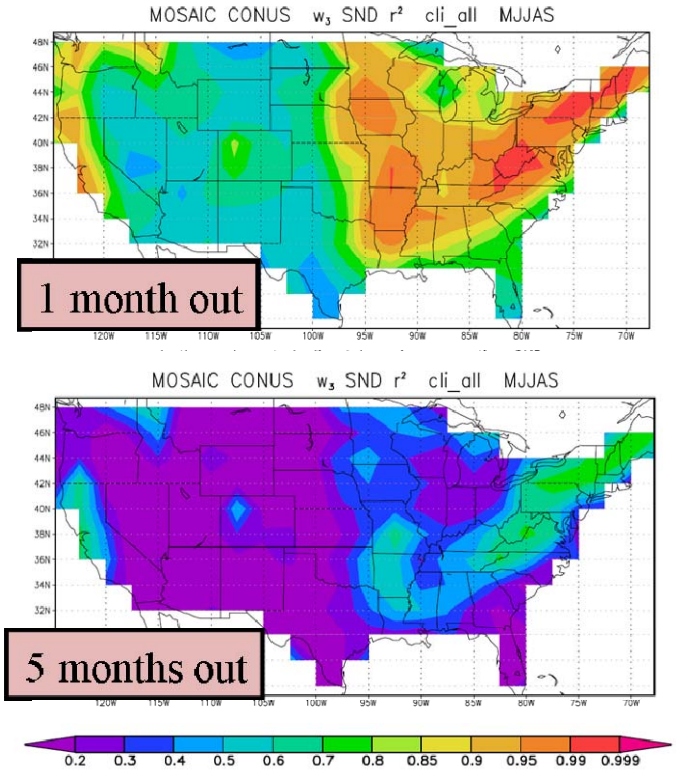

Fig. 1 Skill levels (r^2) of forecasted soil moisture versus synthetic truth, for warm season forecast starts.

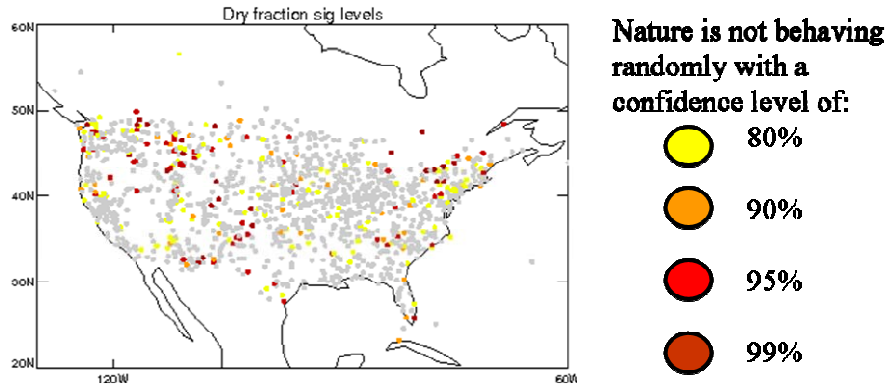

Fig. 2 Indication of the degree to which the observed occurrences of multi-year drought may be attributable to some external mechanism (see text).

Correspondence to: Randal Koster, Global Modeling and Assimilation Office, NASA/GSFC, Greenbelt, MD 20771;
E-mail: randal.d.koster@nasa.gov

memory and forecasted meteorology to forecasted soil moisture – key to understanding any soil moisture forecast. Additional analysis shows that of all the forecasted meteorological fields, precipitation is by far the most important; the others (air temperature, radiation, *etc.*) can be replaced with climatology with little impact on forecasted soil moisture.

The third (also preliminary) study examines the "attributability" of multi-year meteorological drought. Figure 2 shows a sample result. At each dot in the figure, the observational time series of annual rainfall was ranked, and a given year's rainfall was determined to be in the lower, middle, or upper tercile of all realized values. The number of times that a dry year (in the lowest tercile) followed another dry year was established, and the occurrences of such a "multi-year drought" were compared to occurrences obtained for thousands of random shufflings of the yearly historical data. At the orange dots, the actual occurrences of multi-year drought exceeded those obtained in 90% of the shufflings, indicating that the null hypothesis of "no multi-year attribution" can be rejected at the 90% confidence level. However, even with no attribution, 10% of the dots in the figure should show up orange (or darker), and in fact, roughly 10% do. The upshot of this (perhaps overly simple) analysis is that while it's natural to want to attribute multi-year drought to a physical mechanism that acts on multi-year time scales, the observational record is not inconsistent with the idea that multi-year drought is a consequence of the random clumping of independent dry years. Perhaps an external multi-year mechanism exists, but the "random juxtaposition of dry years" argument is not disproven by the data.