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Probabilistic Drought Forecasts Based on the Northern American Multi-Model Ensemble (NMME)

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1. Introduction

In this study, we investigated a framework to predict drought probabilistically based on the precipitation forecast from Northern American Multi-model Ensemble (NMME). The total sixty ensemble members are selected from six NMME participated models for the study of meteorological drought forecast. The NMME precipitation forecasts are downscaled to the 0.5 degree CONUS grid and bias corrected with the Bias Corrected Spatial Disaggregation (BCSD) method. Then, the meteorological drought forecast based on the standardized precipitation index SPI6 (six months accumulation) are computed and converted to the corresponding drought categories. The grand mean (GM) index is tested to summarize the mean state of drought from the all NMME members. The probabilistic information for each drought category is measured by the concurrence at each ensemble member. The accumulated probabilities for drought categories are evaluated against observed drought events during 1982-2010 period. The results show the meteorological drought forecasts based on the NMME display robust skills over the climatological forecast at lead one to three months, indicated by both the Spearman rank correlation (Rho) and Rank Probability Skill Score (RPSS).

2. Challenges

Frequent occurrences of drought in US had major societal, economical, and environmental impacts. Large differences exist in current operational drought forecasts by dynamical models, such as seen in NMME forecasts (Kirtman *et al.* 2014). The different forecasts may be able to identify a drought event, but the uncertainties are too large to classify the drought into a particular drought categroy Dx (x=0-4) (Mo 2008). And also, current forecast does not estimate the uncertainty thus not giving risk managers or decision makers the best or worst scenario information.

3. Data and methods

We selected six representive models, i.e. CanCM3 model, CanCM4 model, GFDL_FLOR model, NASA GEOS5 model, NOAA CFSv2 model and NCAR CCSM4 model, from the NMME historical archives. For each model we selected only 10 ensemble members which are closest to the forecast initial time (day 01 at each month). The hindcasts were run for every month from 1982 to 2010 (total 29 years), and the real-time forecasts from 2011 till recently.

The precipitation (P) forecast for lead 1-6 months are firstly downscaled to 0.5 degree CONUS grid. The downscaled P forecasts are then bias corrected by the BCSD method (Yoon *et al.* 2012) with leave-one-out cross-validation, which guarantees the target year is removed from the training pool to avoid the overfitting problem.

Six month accumulated standardized precipitation index (SPI6), as the forecast for meteorological drought with lead 1-6 months, are computed, using the corrected P forecast and the CPC unified P observations. The SPI6 forecasts from 60 ensemble members are then transferred from the normal distribution to the uniform distribution (percentile). Based on Table 1, the percentiles could be converted to the drought category Dx (x=0 to 4) defined by U.S. Drought Monitor.

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Table 1 The table used to convert drought conditions to corresponding drought categories.

Category	Drought cond.	SPI (SRI)	Percentile
D0	Anomaly Dry	-0.5 to -0.8	30% tile
D1	Moderate	-0.8 to -1.2	20% tile
D2	Severe	-1.3 to -1.5	10% tile
D3	Extreme	-1.6 to -1.9	5% tile
D4	Exceptional	-2 or less	2% tile

The sixty drought forecasts based on the percentile (uniform distribution) are averaged to the grand mean (GM) for the drought category Dx forecast. This percentile-mean method will reduce the "mean error" due to uneven distribution of SPI at "the long tail of normal distribution", in particular for the extreme events, such as droughts. However, due to the offset effect (cancel out) of the arithmetic mean, the GM index will serious underestimated the drought intensity (Mo and Lettenmaier 2014). We remapped the grand mean index again

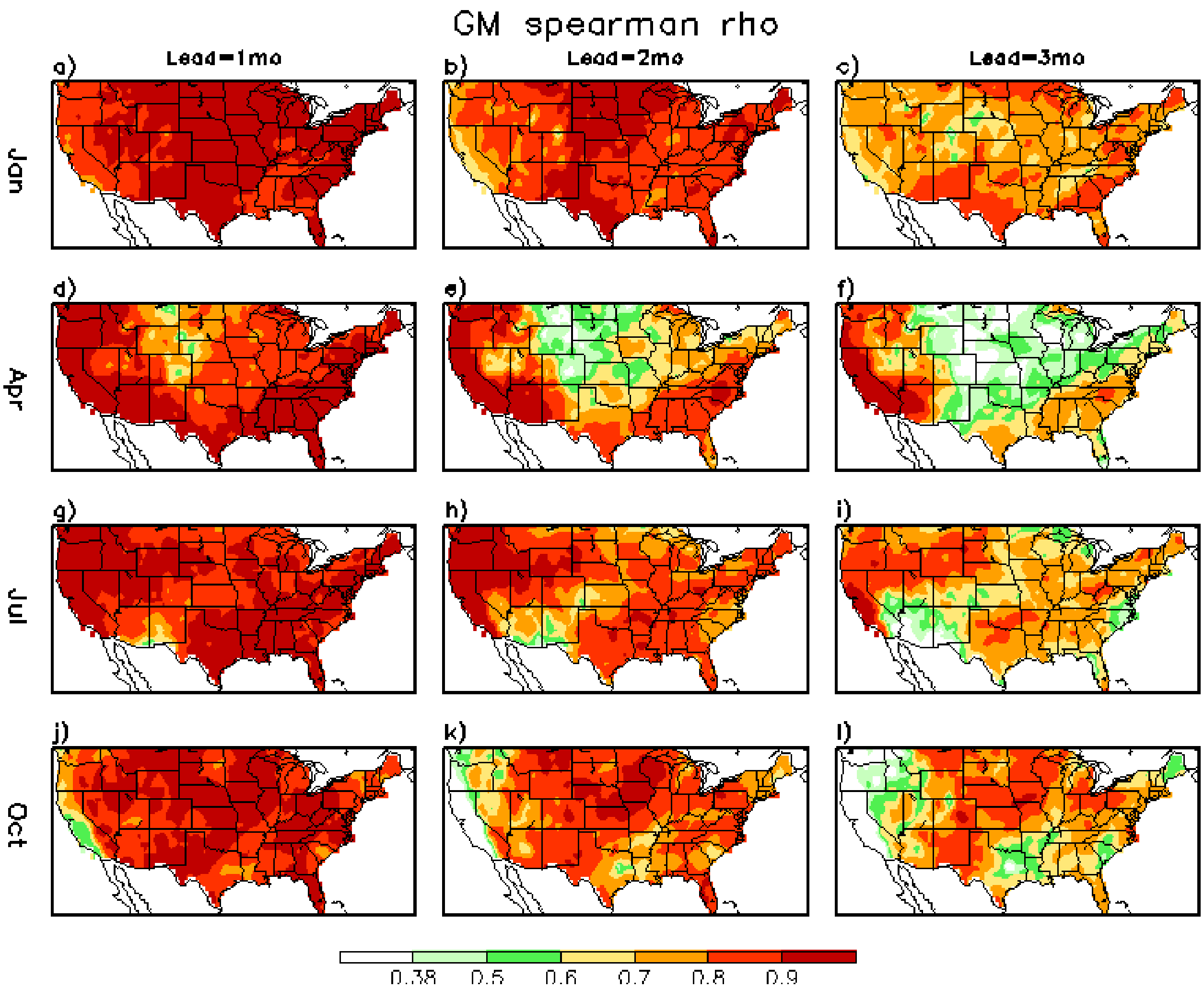

Fig. 1 The Spearman rank correlation (rho) for the Grand Mean (GM) of drought index forecast with observation for January 01, April 01, July 01 and October 01 initial time (from top to bottom) during 1982-2010. The left, central and right columns are for the lead one, two and three months forecast, respectively.

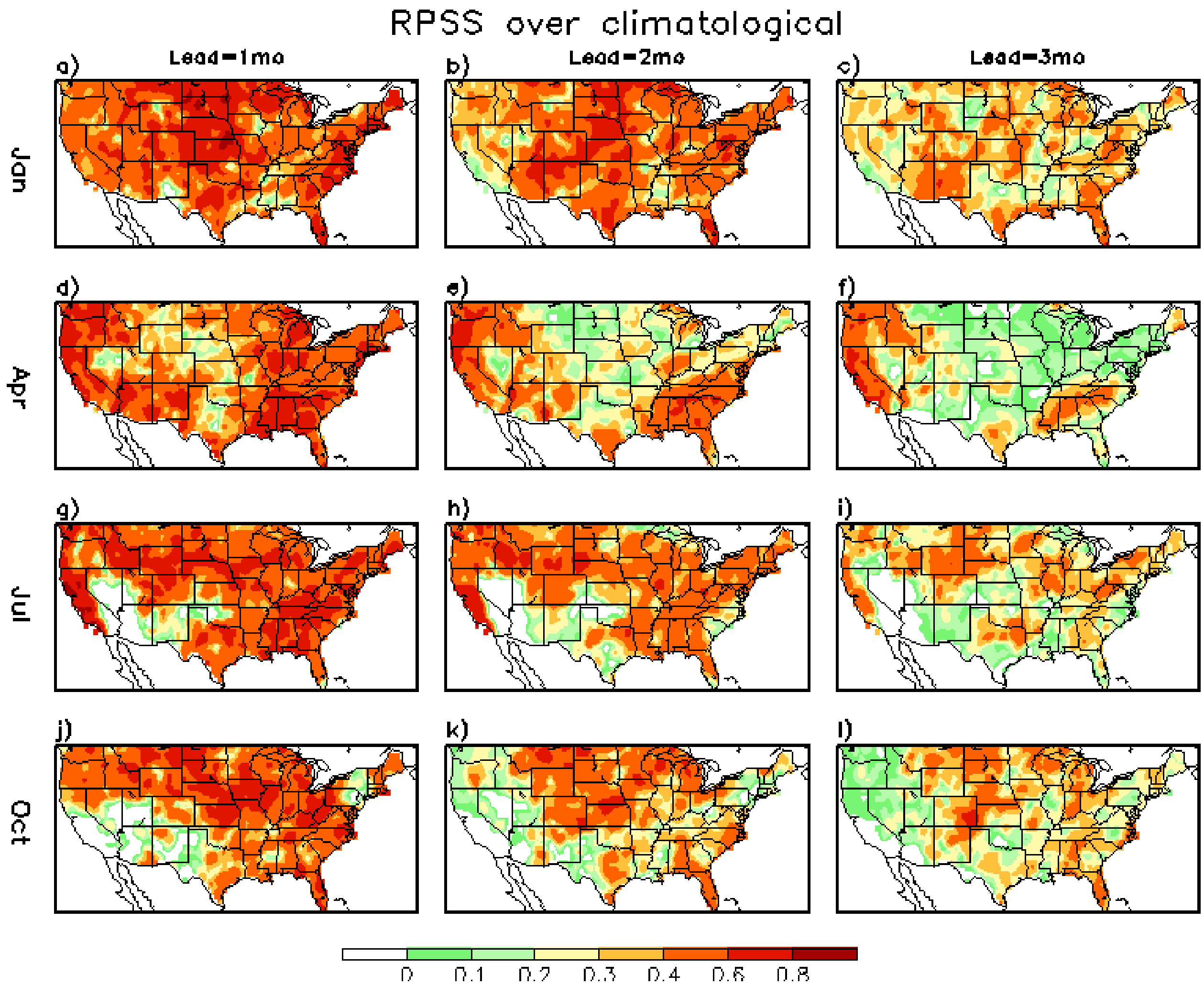

Fig. 2 The same as Fig. 1 but for the RPSS over the climatological forecast.

to the uniform distribution based on the 29 year historical values.

The probabilistic information for each drought category Dx is measured by counting the concurrence of all sixty ensemble member. The accumulated probabilities for drought categories Dx are then evaluated against observed drought events during 1982-2010.

4. Results

Observed drought events are defined by the SPI6 based on the observed rainfall from CPC unified Precipitation analyses. The rank correlation (Spearman Rho) is used to assess the GM index and Rank Probability Skill Score (RPSS) for the probabilistic forecast.

In general, the grand mean index has higher skill than individual member (figure not show). The skill of drought forecast is regional and seasonal dependent (Fig. 1). For the most regions, the rank correlation coefficients are high at lead 1-3 month, and gradually become insignificant after four months lead. The forecasts are skillful in the regimes where the initial condition dominates. Compared to the climatological forecast, the probabilistic forecasts display robust skills (Fig. 2). The skills could persist to the lead three months forecast at most US regions, but fading quickly after lead four months. The forecast skills are relative lower in spring and summer, compared with winter and fall seasons. The NMME tends to over-forecast droughts with large false alarm rate (figure not show).

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