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NMME Year 2: Verification of Real-time Monthly-mean Forecasts

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1. Introduction

The North American Multi-Model Ensemble (NMME) is a forecasting system consisting of coupled global circulation models from U.S. and Canadian modeling centers (Kirtman *et al.*, 2013). August, 2013, marked two years of real-time NMME forecasting, with forecast data delivered on-time by all modeling centers and posted by the 9th of each month. Real-time and archived forecast graphics from Aug. 2011 – present are available at www.cpc.ncep.noaa.gov/products/NMME. Hindcast and forecast data is archived at the International Research Institute for Climate and Society (IRI), accessible at iridl.ldeo.columbia.edu/SOURCES/Models/NMME/.

NMME forecasts during the first two years focused on monthly-mean 2m surface temperature (T2m), precipitation rate (prate), and sea-surface temperature. Additional environmental variables were added in Year 2, and further additions, as well as intra-seasonal forecasts, are in development. NMME forecast fields are global, and produced at a 1°-longitude by 1°-latitude resolution. Forecast leads and number of ensemble members vary by model; during Year 2 of NMME real-time forecasting, the multi-model ensemble included 79 members. Table 1 contains the models involved in NMME Phase I, and more details on the models and forecasting structure can be found in Kirtman *et al.* 2013. Monthly mean and 3-month average seasonal forecast graphics are published by the CPC in deterministic and probabilistic formats: anomalies for each model's forecast are departures from that model's climatology, and the multi-model ensemble was created with equal weighting for all models.

TABLE 1 Models included in the NMME. The first part of each model's name is the center where it was produced.

Model	Hindcast	Ensemble Size	Lead Times	Forecast
NCEP-CFSv1	1981-2009	15	0-8 Months	Aug 2011 – Oct 2012
NCEP-CFSv2	1982-2010	24 (28)	0-9 Months	Aug 2011 – present
GFDL-CM2.2	1982-2010	10	0-11 Months	Aug 2011 – present
IRI-ECHAM4-a	1982-2010	12	0-7 Months	Aug 2011 – Jul 2012
IRI-ECHAM4-f	1982-2010	12	0-7 Months	Aug 2011 – Jul 2012
CMC1-CanCM3	1981-2010	10	0-11 Months	Aug 2012 – present
CMC2-CanCM4	1981-2010	10	0-11 Months	Aug 2012 – present
NCAR-CCSM3.0	1982-2010	6	0-11 Months	Aug 2011 – present
NASA-GEOS5	1981-2010	10	0-9 Months	Aug 2011 – present

Hindcast ensembles were run for all NMME models from all initial months for approximately 30 years. The hindcast database allows for both calibration of the forecasts and an assessment of average skill. For example, Fig. 1 shows the anomaly correlation (AC) of the prate multi-model ensemble for the July-August-

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September (JAS) period, from June initial conditions. Over the hindcast period, some skill is found over the western half of the United States, including portions of the region affected by the North American Monsoon. As prate is a notoriously difficult field to forecast, even limited skill is welcome.

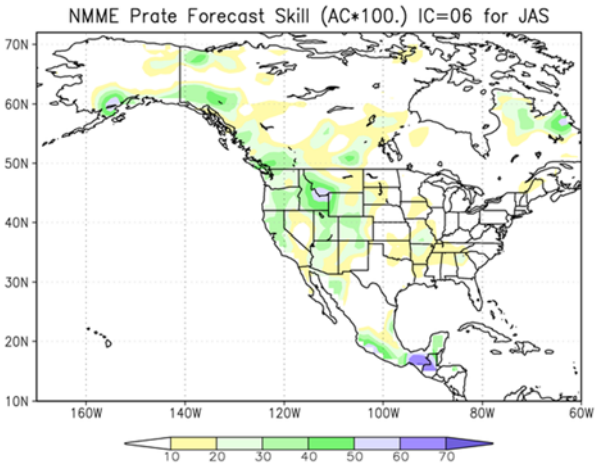

Fig. 1 Anomaly correlation for the NMME multi-model ensemble prediction of precipitation rate for the July-August-September period, from June initial conditions, based on hindcast data. ACs are multiplied by 100.

2. Assessment

With two years of operation under our belts, we can look back to see how well the NMME forecasts have performed. Figure 2 depicts the anomaly correlations for bias-corrected seasonal T2m and prate forecasts, area-averaged over North America, all land north of 15°N (Greenland is not included), averaged for each of the first two years of the project. T2m forecasts were verified against the station observation-based GHCN+CAMS (Fan and van den Dool, 2008), and prate forecasts against the CPC global daily Unified Rainguage Database (URD, Xie *et al.*, 2010). ACs are the average of the "leads 1 – 3" seasons from all the initial conditions in the year. For example, the leads 1 – 3 seasons from January initial conditions are FMA, MAM, and AMJ. The averages over the 5 available seasonal leads (not shown) are similar to the ACs in Figure 2. This is a sample of the real-time verification analysis, which covers both monthly and seasonal forecasts from August, 2011, available at www.cpc.ncep.noaa.gov/products/NMME/verif/.

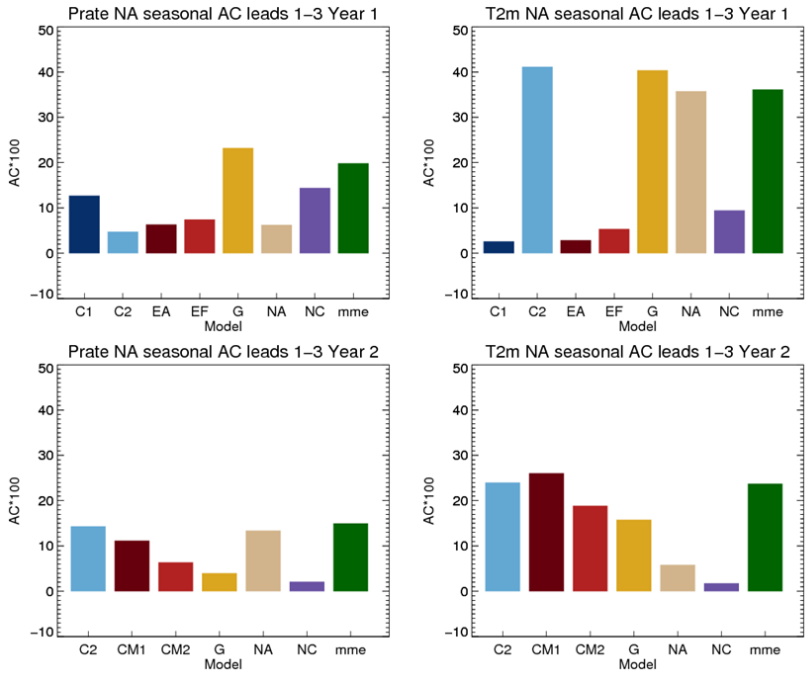

Fig. 2 Area-average North American prate (left) and T2m (right) anomaly correlations for NMME operational Year 1 (top row) and Year 2 (bottom row). Label key: C1=CFSv1, C2=CFSv2, EA=ECHAMa, EF=ECHAMf, G=GFDL, NA=NASA, NC=NCAR, CM1=CMC1, CM2=CMC2. The green bar, "mme", indicates AC for the 7-model (Year 1) or 6-model (Year 2) ensemble mean.

Year 1, August 2011 – July 2012 (top row), includes seven models and the multi-model ensemble mean (mme). The ACs shown are for the ensemble mean of each model and the mme. The models show a wide range of success in forecasting during Year 1, especially in the T2m field. While the mme score is not always the highest among the models, it is consistently among the highest; this held true when other regions were examined (not shown.)

The Year 1 period featured some remarkable climate extremes, including the record heat and "flash drought" of July, 2012, in the central North American continent. The NMME monthly-mean ensemble forecast for July indicated a likelihood of hot and dry conditions as far out as five months in advance, contributing to the relatively high pattern correlations found in Year 1. The record high temperatures over much of the United States and southern Canada in March, 2012,

were suggested by the NMME some months in advance, as well, although the spatial extent of this event was underestimated.

Year 2, August 2012 – July 2013, was a more challenging year for the NMME forecasting system in North America. ACs for Year 2 forecasts, SON 2012 – JJA 2013, are shown in Fig. 2, lower row. CFSv1 is not included in these results, although it did contribute to the mme until October, 2012. In June, 2013, the NMME indicated an increased probability of above-average precipitation during July-August-September in the southwestern United States (Fig. 3). While the verification period for this forecast was not complete at the time of writing, through late September much of this region was showing 90-day average precipitation rates of 150-200% of normal.

Obviously, two years of forecasts and a handful of specific events cannot be generalized to an overall statement of skill, and this assessment lacks an attribution component that could help diagnose why the models captured some events and not others. However, it is still worthwhile to take stock of our results, to understand how the NMME is contributing to long-lead climate forecasting. With some encouraging results thus far, we can look forward to further refinements to the system as it develops over the next few years.

This work has been published in CLIVAR Exchanges / VAMOS! Newsletter in 2013.

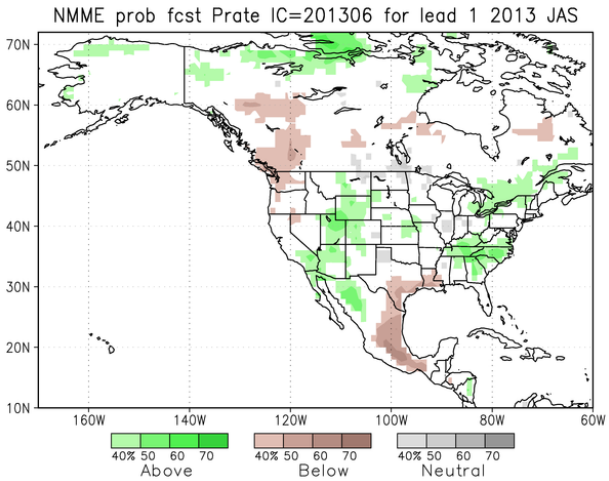

Fig. 3 NMME tercile-based prate probability forecast for July-August-September 2013, made in June 2013, using 79 ensemble members from six models. Above and Below contours show when one class has >38% of ensemble members, and the opposite class is below 33%. In the case that Above is >38% and Near-neutral is >33%, Above will be shown. This is the same for Below. Gray contours show when >38% of ensemble members fall in the "Neutral" tercile, and both A and B are below 33%. White areas show where no one class is dominant: either all terciles are under 38%, or both Above and Below are over 38%.

References

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