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Forecasting Temperature Extremes with the North American Multi-Model Ensemble (NMME)

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This study examines the forecast skill of 2 m temperature extremes in the monthly mean (T2m), maximum (Tmax), and minimum (Tmin) using the North American Multi-Model Ensemble (NMME; Kirtman *et al.* 2014), an ensemble of state-of-the-art coupled global climate models. Extremes are where the real impact of weather and climate are felt, yet there are currently very few forecasts for short-term climate extremes (STCE). Aggregate skill (as assessed using the anomaly correlation) for forecasts of STCE only has previously been found to be higher than the aggregate skill of all forecasts (Becker *et al.* 2013), providing confidence that a useful forecast for STCE might be possible.

The NMME currently provides real-time guidance for NOAA's operational short-term climate forecasts, and includes a database of retrospective forecasts (1982-2010), used for bias correction, calibration, and skill studies. Seven models from the NMME contribute to this study: NCEP-CFSv2, Environment Canada's CanCM3 and CanCM4, GFDL's CM2.1 and FLOR, NASA-GEOS5, and NCAR-CCSM4. A new maximum and minimum temperature dataset was recently created at CPC, and is interpolated to the NMME grid and timescale to allow for an initial assessment of these fields. The aggregate skill of deterministic forecasts of Tmax and Tmin in general is found to be slightly lower in magnitude to that of 2 m temperature, with some differences in geography.

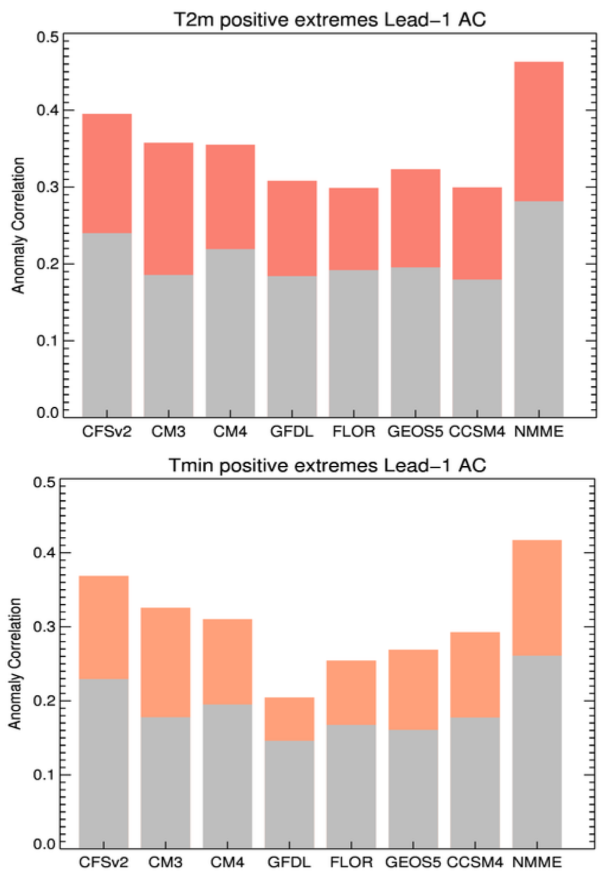

Fig. 1 Anomaly correlation for monthly-mean 2 m temperature (top) and minimum temperature (bottom), area-aggregated over North America, for the seven individual NMME models' ensemble means and the NMME grand ensemble mean, averaged over all 12 initial conditions. Gray bars show anomaly correlation for all forecasts, and orange indicates the upper decile, *i.e.* positive extremes.

Temperature extremes are herein defined as the top and bottom decile (10%) of the historical record at each gridpoint, using the 1982-2010 hindcasts, with cross-validation. A Gaussian distribution is assumed, but may not be the most accurate fit; this is a point that requires further examination. This study assesses forecast verification, that is, the question of "did the forecast come true?" using deterministic forecasts, at a one-month lead for the monthly mean, over all initial conditions. Area-average skill is assessed using the anomaly correlation. When assessing the skill at individual gridpoints, the Symmetric Extremal Dependence Index

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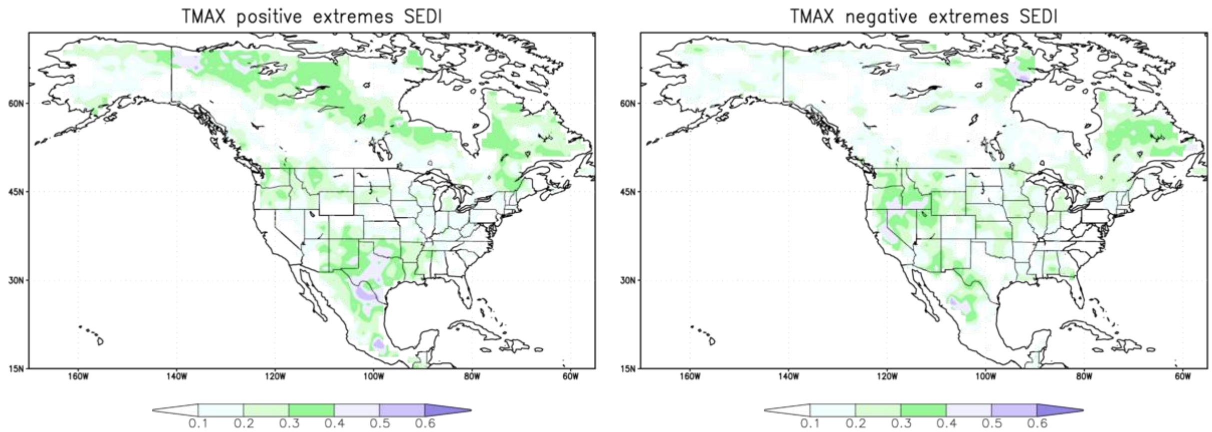

Fig. 2 Symmetric Extremal Dependence Index (SEDI) for upper-decile (left) and lower-decile (right) forecasts of monthly-mean maximum temperature, averaged over all 12 initial months.

(SEDI; Ferro and Stevenson 2011) which is non-degenerate for rare events, is employed. The decile definition of extremes results in approximately 35 "extreme" events per gridpoint over all 12 initial months for 29 years of retrospective forecasts.

The previous finding of higher anomaly correlation for forecasts of extremes is confirmed (Fig. 1). Skill for forecasts of extremes of mean 2 m temperature (both negative and positive extremes) is slightly higher than extremes in Tmax and Tmin. Overall, Tmin is predicted slightly more skillfully than Tmax, especially when positive extremes are examined. Tmin has been more affected by the warming trend over the past several decades, which may in part explain this difference. Forecasts for positive extremes of all three temperatures are highest over the northern tier of North America, where they are generally >30% better than a climatological forecast (Fig. 2).

This is a preliminary study that demonstrates that there is some potential for skillful forecasting of extremes. Further experimentation will examine the definition of "extreme", including possible use of absolute temperature thresholds and consideration of warm-season positive Tmax extremes and cold-season negative Tmin extremes. A large ensemble such as the NMME is valuable in constructing probabilistic forecasts, and further analysis will be necessary to discover valid thresholds for triggering an extreme forecast.

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