Fog Prediction from a Multimodel Mesoscale Ensemble Prediction System

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A new diagnostic fog-detection scheme

Liquid Water Content (LWC) at the model's lowest level was commonly used to represent fog in previous studies. However, the LWC-only approach doesn't work well in an operational NWP model for the following two reasons: too coarse spatial resolution to properly resolve important physics in fog near the surface, and physics schemes or parameterizations not tailored for near-ground fog but for precipitation or clouds at higher levels. As a result, the LWC from NWP models is usually not reliable enough to represent fog and tends to seriously under-forecast fog in many cases. To better detect fog, other variables besides LWC should be considered. Considering that fog has different types with different formation mechanisms, e.g., some build from stratus-subsidence, some from advection, and some from radiation cooling near the ground, a new multi-variable based diagnostic fog-detection scheme is proposed as follows:

LWC at model lowest level ≥ 0.015 g/kg, OR
Cloud Top ≤ 400 m AND Cloud Base ≤ 50 m, OR
10-Wind Speed ≤ 2 m AND 2m-RH ≥ 90 %

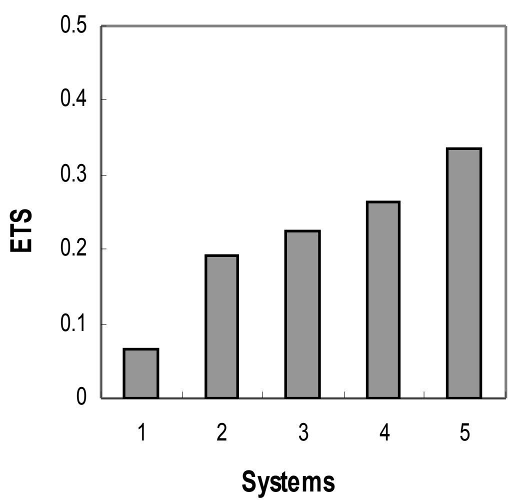
Results

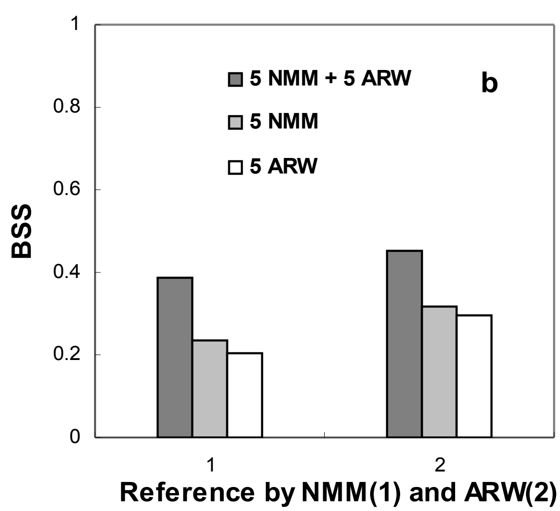
Using a 10-member 15km multimodel mesoscale ensemble prediction system (Zhou and Du, 2010), various verifications of fog forecasts were performed including deterministic (left figure), probabilistic (right figure) scoring measures as well as individual cases (not shown) over Eastern China from February to August 2008. Left Figure shows how the deterministic fog forecast skill improves with various approaches, while Right Figure shows how multimodel ensemble outperforms single-model ensembles in probabilistic forecasts.

Summary of the study

A new multivariable based diagnostic fog-forecasting method has been developed at NCEP. Since all the five base variables used for the diagnosis are direct outputs from a model, this fog diagnostic algorithm can be included as part of the model post-processor and, therefore, the fog forecast can now be provided conveniently and centrally as a direct NWP model guidance.

Applying the various approaches including the new fog detection scheme, ensemble technique, multi-model approach and the increase in ensemble size, the improvement in fog forecast accuracy was steady in each of the approaches and dramatic: from a basically no-skill-at-all (Equitable Threat Score=0.063) to a skill level equivalent to that of warm-season precipitation forecasts of the current state-of-the-art NWP models (0.334). In specific, (1) The multivariable based fog diagnostic method has a much higher detection capability than LWC-only based approach (a commonly used method in current practice). The latter has a very low detection rate and tends to miss almost 90% of fog events; the former can greatly improve the fog detection rate; (2) The ensemble-based forecasts are, in general, superior to a single forecast measured both deterministically and probabilistically. The case study also demonstrates that ensemble approach could provide more societal value than a single forecast to end-users especially for low-probability significant events like fog. Deterministically, a forecast close to the ensemble median (50% probability) is particularly helpful; (3) The reliability of probabilistic forecasts can be effectively improved by using a multi-model ensemble instead of a single-model ensemble. For small-size ensemble such as the one in this study, the increase in ensemble size is also important in improving probabilistic forecasts although such an importance is expected to decrease with the increase in ensemble size (Du et. al, 1997). For the detail of this study, readers are referred to Zhou and Du (2010).





Left Figure. Equitable Threat Scores (ETSes, averaged of the two models, NMM and ARW, over the 7-month period at 12- and 36-h forecast lengths) from the various forecast systems: 1) the single control runs based on the LWC-only approach (ETS=0.063), 2) the single control runs but based on the new multivariable fog diagnosis (0.192; a 205% improvement over the previous step), 3) the 40% probability forecasts based on the 5-member single model ensembles (0.225; 17.2%),

4) the 40% probability forecast based on the 5-member multimodel NMM-ARW ensemble (0.264;17.3%), and 5) the 40% probability forecast based on the 10-member multimodel NMM-ARW ensemble (0.334;26.5%).

Right Figure. Seven-month averaged (Feb. – Aug. 2008) Brier Skill Scores (BSS) of probabilistic forecasts based on 5-member NMM, 5-member ARW, and 10-member multimodel ensemble, using both NMM (1) and ARW (2) control as references.

References:

Du, J., S. L. Mullen, and F. Sanders, 1997: Short-range ensemble forecasting of quantitative precipitation. *Mon. Wea. Rev.*, **125**, 2427-2459.

Zhou, B., and J. Du, 2010: Fog prediction from a multimodel mesoscale ensemble prediction system, *Weather and Forecasting*, **25**, 303-322.