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Probabilistic ozone and PM2.5 forecast skill using an ensemble of air quality models including bias correction methods

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Surface ozone data from 119 AIRNOW observation sites and PM2.5 data from 38 observation sites collected during the TEXAQS August 01-October 15, 2006 field program are used to evaluate 7 different air quality models (AURAMS, BAMS-15km, CHRONOS, NMM-CMAQ, WRF-12km, WRF-36km and STEM) and their ensemble mean. Following national regulatory standards, the metric of evaluation for ozone is the daily 8-hour maximum concentration, while for PM2.5 it is the daily 24-hour average concentration. For ozone the ensemble is found to have better forecast skill (lower RMSE and higher correlation coefficient) than each of the individual 7 models, while for PM2.5 the ensemble has lower RMSE than all of the individual models and a higher correlation coefficient than all but one model.

Because of the significant ozone and PM2.5 biases that occur in each of the models and their ensemble, three different bias correction techniques are evaluated: a simple running-mean bias correction, a Kalman Filter approach, and a dynamical weighting method using the Singular Value Decomposition (SVD) technique. The running mean and Kalman filter methods generate bias corrections for each model that are specific for each observational site and each hour of the day. In contrast, the SVD method

calculates a single weight for each of the seven models that are only used in calculating the weighted ensemble mean. The weights of the models are chosen so as to minimize the RMSE of the weighted ensemble mean. For all three methods, observations and model forecasts over the previous 7 days are used to calculate the bias corrections.

A comparison of the running-mean and Kalman filter methods shows that although both techniques improve the ozone and PM2.5 forecast statistics, the Kalman filter method is significantly superior. Application of the Kalman filter improves the RMSE and correlation coefficients not only for the ensemble, but also for each of the individual models for both ozone and PM2.5.

The SVD method is applied to the raw ozone and PM2.5 forecasts, as well as to the running-mean and Kalman filter corrected forecasts. The SVD weighting of the raw ozone and PM2.5 forecasts results in improved skill compared to the non-bias corrected ensemble, but has lower skill than the Kalman filter corrected ensemble forecasts. However, a modest improvement over the Kalman filter bias-corrected ensemble mean is found by applying the SVD method to the previously Kalman filter bias corrected forecasts. This leads to the best overall ensemble skill, with improvements over the raw ensemble mean of 29% for ozone RMSE, 13% for ozone correlation coefficient, 45% for PM2.5 RMSE, and 40% for PM2.5 correlation coefficient. Compared to persistence forecasts, the raw model forecasts of PM2.5 have much less skill than the ozone forecasts. In fact, of all the PM2.5 models and ensembles, only the Kalman filter and the SVD Kalman filter bias corrected ensembles do better than persistence for both RMSE and correlation coefficient.

Skill from the individual models at forecasting surface ozone and PM2.5 concentrations is also evaluated using categorical forecast statistics (frequency bias, false alarm ratio, probability of detection, percent correct, and critical success index) as a function of ozone concentration. A comparison of the raw ozone ensemble with the SVD Kalman filter bias corrected ensemble shows that the later ensemble has improved skill using each of these metrics for virtually all ozone threshold limits from 25 to 105 ppb.