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Ensemble forecast verification adversely affected by model bias

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Abstract
This study demonstrates how model bias can adversely affect the assessment of the quality of an ensemble prediction system (EPS) by ensemble verification metrics. A 15-member regional EPS (GRAPES-EPS) was verified over a period of one month over China. Three variables (500 hPa and 2-m temperatures and 250 hPa wind) are selected to represent "strong bias" (upper air and surface) and "weak bias" situations, respectively. Ensemble spread and probabilistic forecasts are assessed and compared before and after a bias correction. The results show that the conclusions drawn from ensemble verification about the EPS quality are completely misleading if forecasts possess a strong bias. This is true for both ensemble spread and probabilistic forecasts. For example, the GRAPES-EPS is severely under-dispersive before the bias correction but becomes calibrated afterwards, although the improvement in spread's spatial structure is much less; the spread-skill relation is also improved. The probabilistic forecasts become much sharper and almost perfectly reliable after the bias is removed. Therefore, it is necessary to remove forecast biases before one can accurately evaluate an EPS since an EPS deals only with random error but not systematic error. Only when an EPS has no or little forecast bias, can ensemble verification metrics reliably reveal the true quality of an EPS without removing forecast bias first. An implication of this study is that EPS developers should not be expected to introduce methods to dramatically increase ensemble spread to achieve reliability. Instead, the preferred solution is to reduce model bias through prediction system developments and to focus on the quality of spread (not the quantity of spread).