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Performance comparisons of the three data assimilation methods for improved predictability of $PM_{2.5}$: EnKF, EnSRF, and 3D-Var

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To improve the predictability of concentrations of atmospheric particulate matter, a data assimilation (DA) system using ensemble square root filter (EnSRF) has been developed for the Community Multiscale Air Quality (CMAQ) model. The EnSRF DA method is a deterministic variant of the ensemble Kalman filter (EnKF) method, which means that unlike the EnKF method, it does not add random noise to the observations. To compare the performances of the EnSRF with those of other DA methods, such as EnKF and 3DVAR (three-dimensional variational), these three methods were applied to the same CMAQ model simulations with identical experimental settings. This is the first attempt in the field of chemical DA to compare the EnKF and EnSRF methods. An identical set of surface fine particulate matter ($PM_{2.5}$) were assimilated every 6 h by all the DA methods over a CMAQ domain of East Asia, during the period from 01 May to 11 June 2016. In parallel with 'reanalysis ex-periments', we also carried out '48 h prediction experiments' using the optimized initial conditions produced by the three DA methods. Detailed analyses among the three DA methods were then carried out by comparing both the reanalysis and the prediction outputs with the observed surface $PM_{2.5}$ over four regions (i.e., South Korea, the Beijing–Tianjin–Hebei (BTH) region, Shandong province, and Liaoning province). The comparison results revealed that the EnSRF produced the best reanalysis and prediction fields in terms of several statistical metrics. For example, when the 3DVAR, EnKF, and EnSRF methods were used, averaged normalized mean biases (NMBs) decreased by (57.6, 85.6, and 91.8) % in reanalyses and (39.7, 87.6, and 91.5) % in first-day predictions, compared to the CMAQ control experiment (i.e., without DA) over South Korea, respectively. Also, over the three Chinese regions, the EnSRF method outperformed the EnKF and 3DVAR methods.