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Variational data assimilation for the optimized ozone initial state and the short-time forecasting

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In this study, we apply the four-dimensional variational (4D-Var) data assimilation to optimize initial ozone state and to improve the predictability of air quality. The numerical modeling systems used for simulations of atmospheric condition and chemical formation are the Weather Research and Forecasting (WRF) model and the Community Multiscale Air Quality (CMAQ) model . The study area covers the capital region of South Korea, where the surface measurement sites are relatively evenly distributed.

The 4D-Var code previously developed for the CMAQ model is modified to consider background error in matrix form, and various numerical tests are conducted. The results are evaluated with an idealized covariance function for the appropriateness of the modified codes. The background error is then constructed using the NMC method with long-term modeling results, and the characteristics of the spatial correlation scale related to local circulation is analyzed. The background error is applied in the 4D-Var research, and a surface observational assimilation is conducted to optimize the initial concentration of ozone. The statistical results for the 12-hour assimilation periods and the 120 observatory sites show a 49.4% decrease in the root mean squred error (RMSE), and a 59.9% increase in the index of agreement (IOA). The temporal variation of spatial distribution of the analysis increments indicates that the optimized initial state of ozone concentration is transported to inland areas by the clockwise-rotating local circulation during the assimilation windows.

To investigate the predictability of ozone concentration after the assimilation window, a short-time forecasting is carried out. The ratios of the RMSE with assimilation versus that without assimilation are 8% and 13% for the +24 and +12 hours, respectively. Such a significant improvement in the forecast accuracy is obtained solely by using the optimized initial state. The potential improvement in ozone prediction for both the daytime and nighttime with application of data assimilation is also presented.