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Towards More Accurate Particulate Matter Forecasting via Data Assimilation in RACM-MADE/VBS

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In this study, WRF-Chem version 3.9.1 was applied with a newly developed interface between WRF-Chem and the Gridpoint Statistical Interpolation (GSI) system to support the Regional Atmospheric Chemistry Mechanism (RACM) coupled with the Modal Aerosol Dynamics Model for Europe (MADE) and the Volatility Basis Set (VBS) aerosol schemes. This interface enables assimilation of ground-based $PM_{2.5}$ and PM_{10} observations.

Two nested domains were employed: East Asia with 27 km grid spacing and South Korea with 9 km grid spacing. The simulation period covered 1–5 January 2024, and the three-dimensional variational (3DVAR) data assimilation method was implemented. Results show that background error covariance (BEC) strongly influences assimilation outcomes. Using one month of model simulation to generate BEC produced weaker corrections (correlation = 0.91, RMSE = 6.63) compared with BEC from a 5-day simulation (correlation = 0.97, RMSE = 5.61). Additionally, sensitivity analysis demonstrated that the parameter LAT_BINS_IN_DEG is a critical factor in BEC estimation.

These results highlight the importance of BEC configuration and parameterization when applying data assimilation to particulate matter simulations in WRF-Chem with RACM-MADE/VBS, and provide guidance for improving air quality forecasting in regional modeling applications.

Keywords: WRF-Chem, RACM-MADE/VBS, GSI, Data Assimilation, $PM_{2.5}$, PM_{10}, Background Error Covariance