Evaluation of Aerosol Data Assimilation and Forecasts in the NASA GEOS Model during the ASIA-AQ Campaign

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Introduction

- Fine particulate matter ($PM_{2.5}$) poses significant risks to health and the environment, causing respiratory and cardiovascular diseases.
- The Goddard Earth Observing System (GEOS) Forward Processing (FP) model, operated by the GMAO at NASA's GSFC, provides real-time weather and aerosol forecasts by assimilating Moderate Resolution Imaging Spectroradiometer (MODIS) and Aerosol Robotic Network (AERONET) aerosol Optical Depth (AOD) data.
- ASIA-AQ is international joint project with Asian partners (South Korea, Philippines, Taiwan and Thailand) to enhance understanding of local air quality issues and address common challenges in satellite data interpretation and air quality modeling.

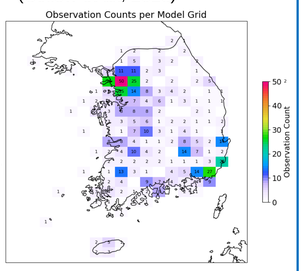
Data

❖ GEOS-FP Model

- Run: ASSIM, FCAST (00UTC 10day forecast)
- Data: inst3_3d_aer_Nv, 3hourly
- Resolution: 0.312°x0.25° lon-lat grid (12km), 72 model grid layers
- Aerosol Module: GOCART (Chin et al., 2002)
- Emissions: EDGAR HTAPv2.2, biomass burning - QFED
- Aerosol Data Assimilation: bias-corrected MODIS AOD at 550nm, AERONET AOD
- Study Period: Feb. 15 – Mar. 13, 2024 (ASIA-AQ campaign in South Korea)
- $PM_{2.5}$ = (0.9614 * DU001 + frh_ss1 * SS001 + frh_ss2 * SS002 + frh_ss3 * 0.4752 * SS003 + frh_bc * BCPHILIC + BCPHOBIC + frh_oc * OCPHILIC + OCPHOBIC + NH4A + frh_ni * NO3AN1 + frh_su * SO4) * AIRDENS * 1e^9 (Collow et al., 2023)

❖ $PM_{2.5}$ In-situ Observation

- $PM_{2.5}$ surface concentration in South Korea
- 659 stations from NIER AirKorea (available at https://www.airkorea.or.kr/)
- Data precision is rounded to the nearest integer
- $PM_{2.5}$ measure method: the Beta-Ray Absorption Method (BAM1020 machine)



Obs. Quality Control - Buddy check (BC)

1) Background Check:
- Analyze differences between observed and modeled daily means.
- Identify suspect observations based on a specified tolerance.

2) Iterative Buddy-Check:
- Perform a refined acceptance test on each suspect observation.
- Use reliable "buddies" within a defined radius for comparison.

3) Adaptive Tolerance:
- Tolerance is adjusted based on current observation minus model differences.
- Local modulation of innovation variances is applied during the threshold test. (Dee et al., 2001; Burchard et al., 2014)

GEOS-FP Assimilation and Forecast evaluation

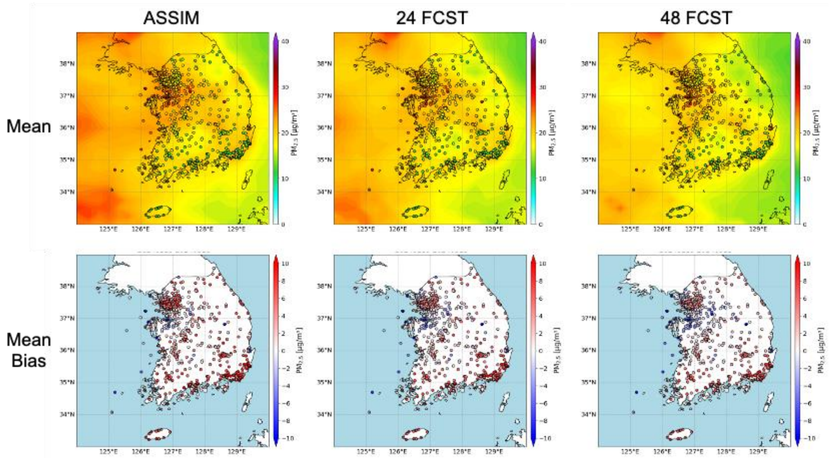


Fig 1: Spatial distribution of $PM_{2.5}$ concentrations over South Korea for assimilation (ASSIM), 24-hour forecast (24 FCST), and 48-hour forecast (48 FCST) (top panels). Bottom panels show the differences between observed and modeled $PM_{2.5}$ concentrations.

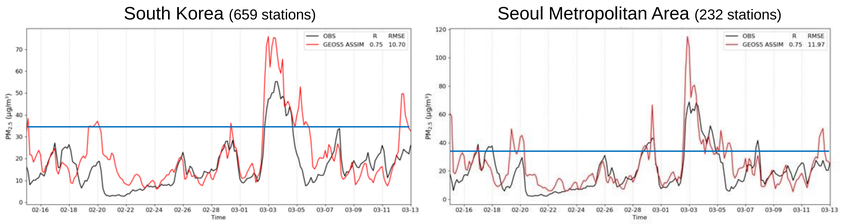


Fig 2: 3 hourly time-series of $PM_{2.5}$ concentration from observation (black line) and GEOS-FP assimilation run(red line) in South Korea (right) and the Seoul Metropolitan Area (right). The four yellow boxes indicate local pollution events and three pink box indicate transport pollution events. The horizontal blue line represents the threshold of 35 μg/m³, which is the "unhealthy" standard in South Korea.

Revised result after the buddy check

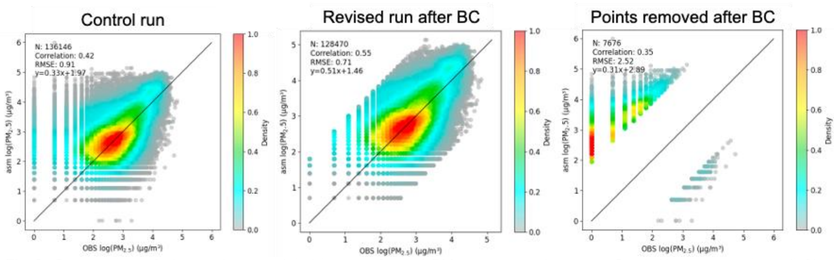


Fig 3: Scatter plots of observed vs. modeled log-transformed $PM_{2.5}$ concentrations over South Korea: control run (left), revised run after buddy check (BC, middle), and removed points (right). Model data are rounded to match observational precision.

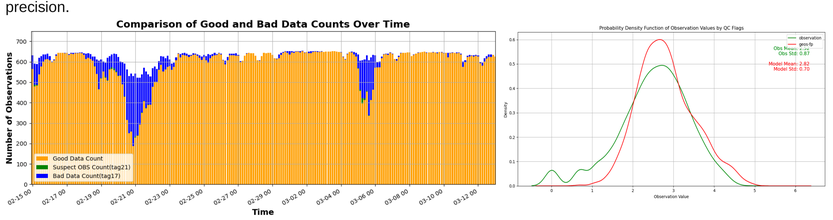


Fig 4: Time series of good (orange), suspect (blue), and bad (green) data counts, showing the number of observations over time (left). Probability density functions of log-transformed observation (green) and model (red) values (right).

Case study

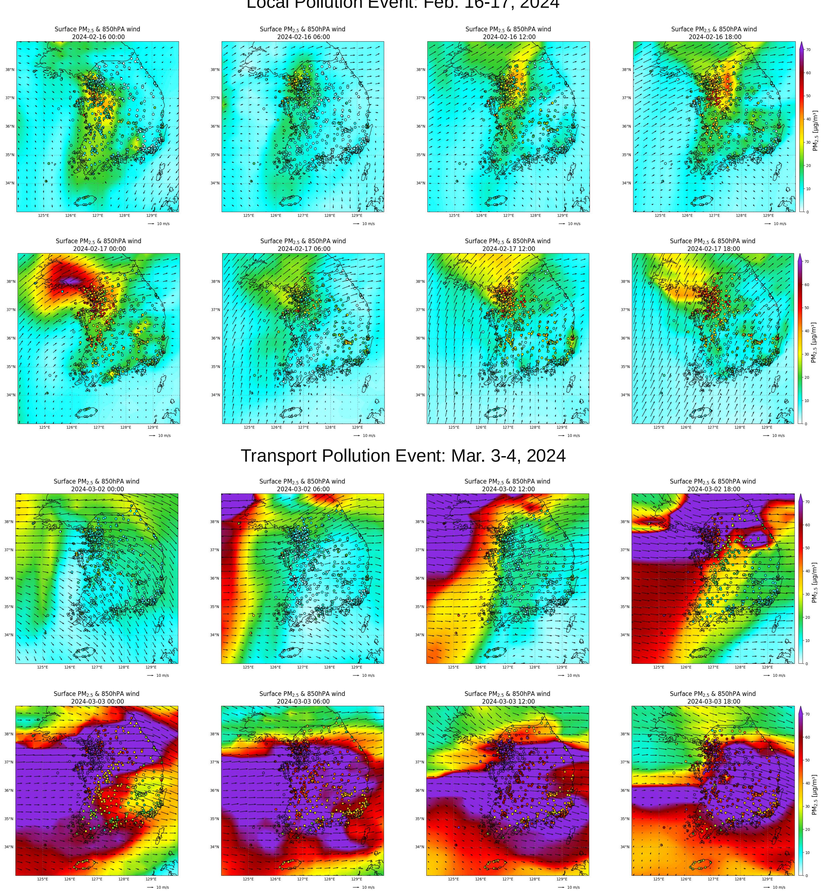


Fig 5: 6-hourly temporal evolution of surface $PM_{2.5}$ concentrations and 850hPa wind vectors during the local (top panels) and transport (bottom panels) pollution events.

Summary

- This study evaluates the data assimilation and forecasting performance of $PM_{2.5}$ concentrations in the NASA GEOS-FP model over South Korea.
- While GEOS-FP generally captured $PM_{2.5}$ concentrations well, some limitations were identified.
- It overestimated $PM_{2.5}$ levels during precipitation-drive low-concentration periods (Feb. 19–20) and showed a tendency to overestimate high-concentration long-range transport events (Mar. 3–4).

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