Assimilating MODIS AOD with WRF/Chem and GSI

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Outline

- Scientific background
- Results for a dust storm over East Asia
- Future work

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AOD DA: previous work

- Collins et al. (2001), Adhikary et al. (2008), Zhang et al. (2008, NAAPS)
  - Two-step procedure:
    - first use 2D-OI or 2D-VAR to analyze 2D AOD field
    - then adjust 3D aerosol concentration profiles from updated AOD fields.
  - Usually do a scaling in the second step by assuming constant weight of each species to total aerosol mass concentration.
  - May not be straightforward to integrate AOD DA with meteorological DA

- Benedetti et al. (2009, ECMWF): 4DVAR, but use total aerosol mass as analysis variable

Our approach for AOD DA: 3DVAR

- Directly analyze 3D aerosol mass concentration with a one-step procedure of variational minimization within the GSI
  - Do NOT apply any assumption about vertical shape and relative weight of individual species.

$$J(x) = \frac{1}{2}(x - x_b)^T B^{-1}(x - x_b) + \frac{1}{2}[y - H(x)]^T R^{-1}[y - H(x)]$$

- 14 WRF/Chem-GOCART 3D aerosol mass concentration as analysis variables
  - need background error covariance statistics for each aerosol species

- Use CRTM as AOD observation operator, including both forward and Jacobian models
  - Dr. Quanhua (Mark) Liu at the JCSDA developed the CRTM-AOD operator.
  - We (NCAR) made CRTM-AOD operator interface to GSI.

Advantages of our 3DVAR approach

- Straightforward to add more AOD data from multi-sensor/angle products and also other aerosol related observations (e.g., PM10/PM2.5).

- Allow simultaneous assimilation of aerosol and meteor. observations.
  - though NOT for the results shown here

Liu Z. et al. (2011), submitted to JGR.

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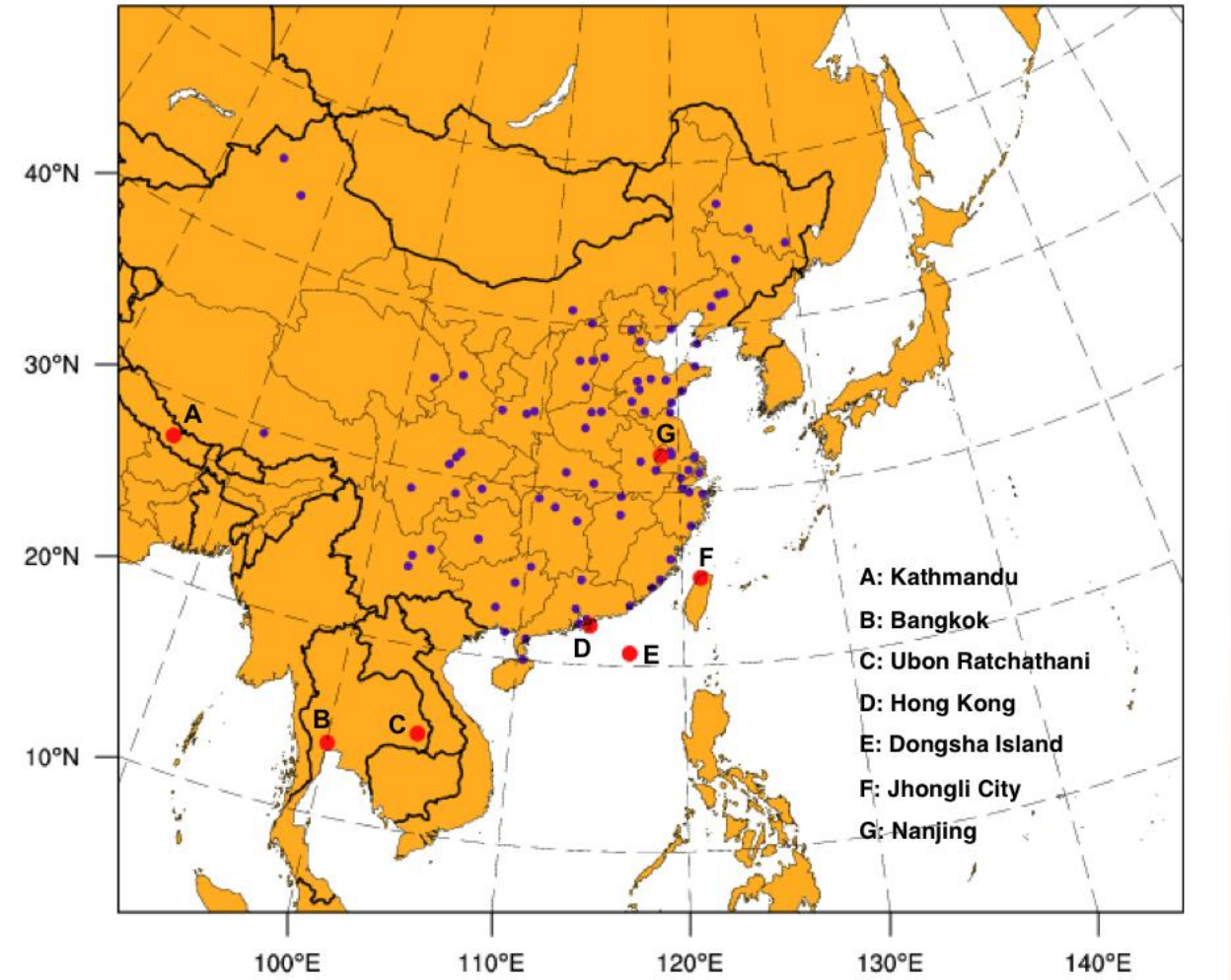
East Asia domain



261x222 @27 km
45L with top @50 hPa

Validation observations:
7 AERONET sites
83 PM10 sites

chem_opt=301:
GOCART+RACM

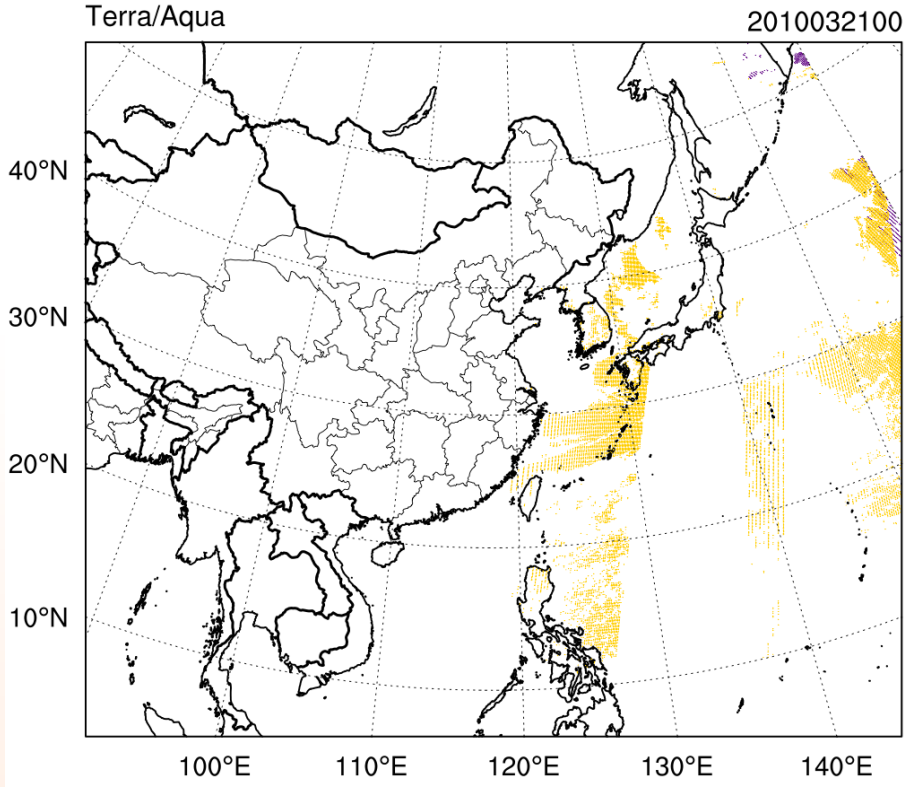
Emissions:
Online biogenic
RETRO+"Streets" anthropogenic

LBC: NCAR CAM-Chem

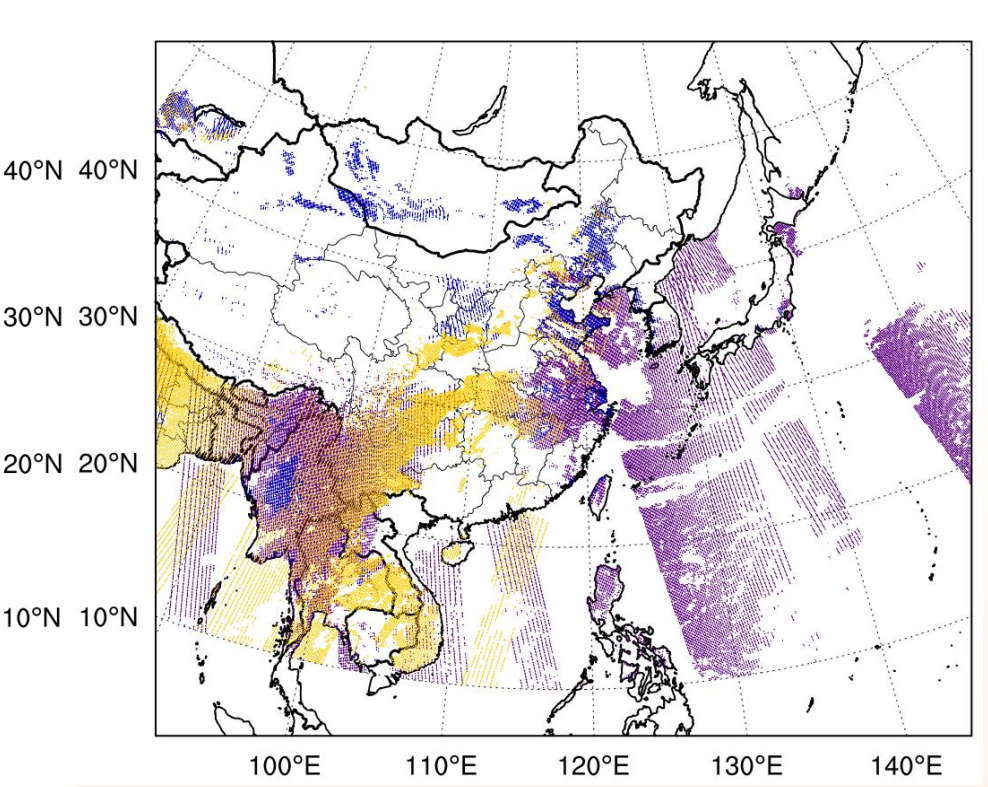
6-hr cycling DA/FC experiment:
17~24 March, 2010.
MET fields updated from GFS.
Aerosol fields updated from AOD DA.

L2 MODIS AOD@0.55µm coverage

0000 UTC, 21 March 2010



0600 UTC, 21 March 2010



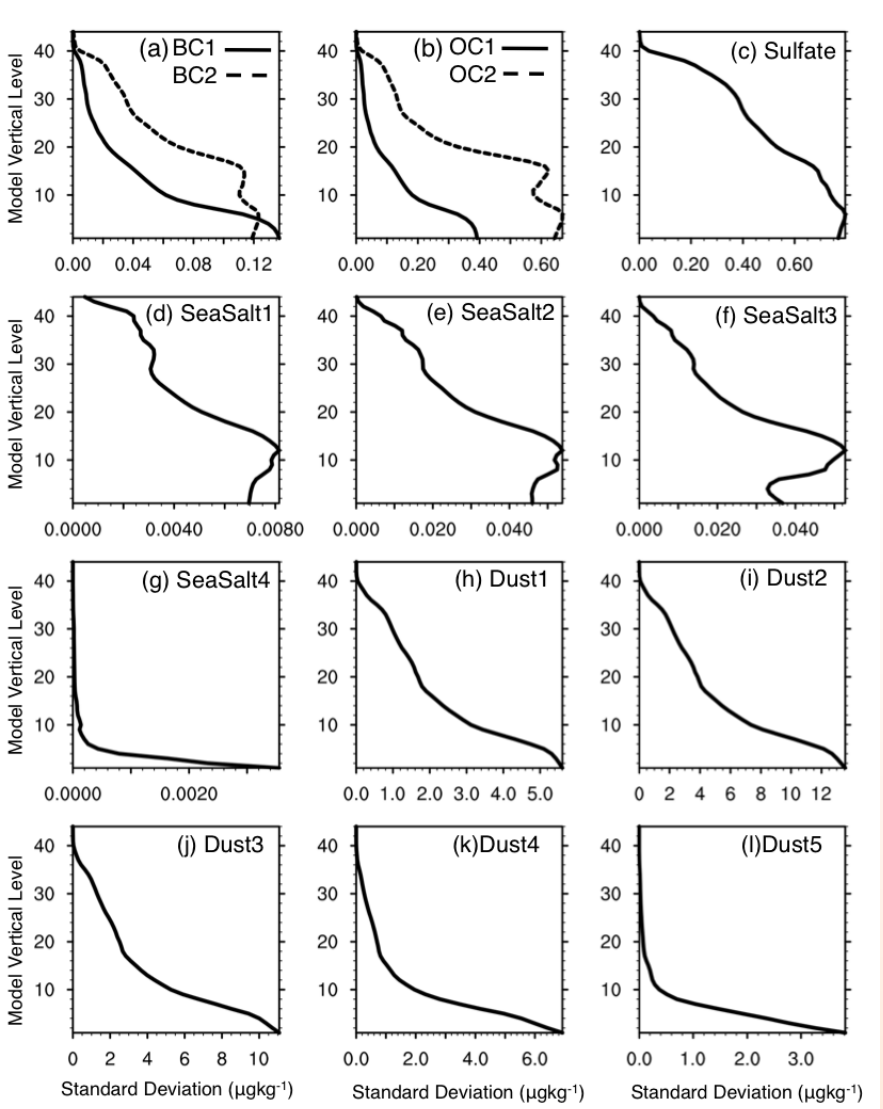
Data only available at day time (00Z and 06Z), visible band.

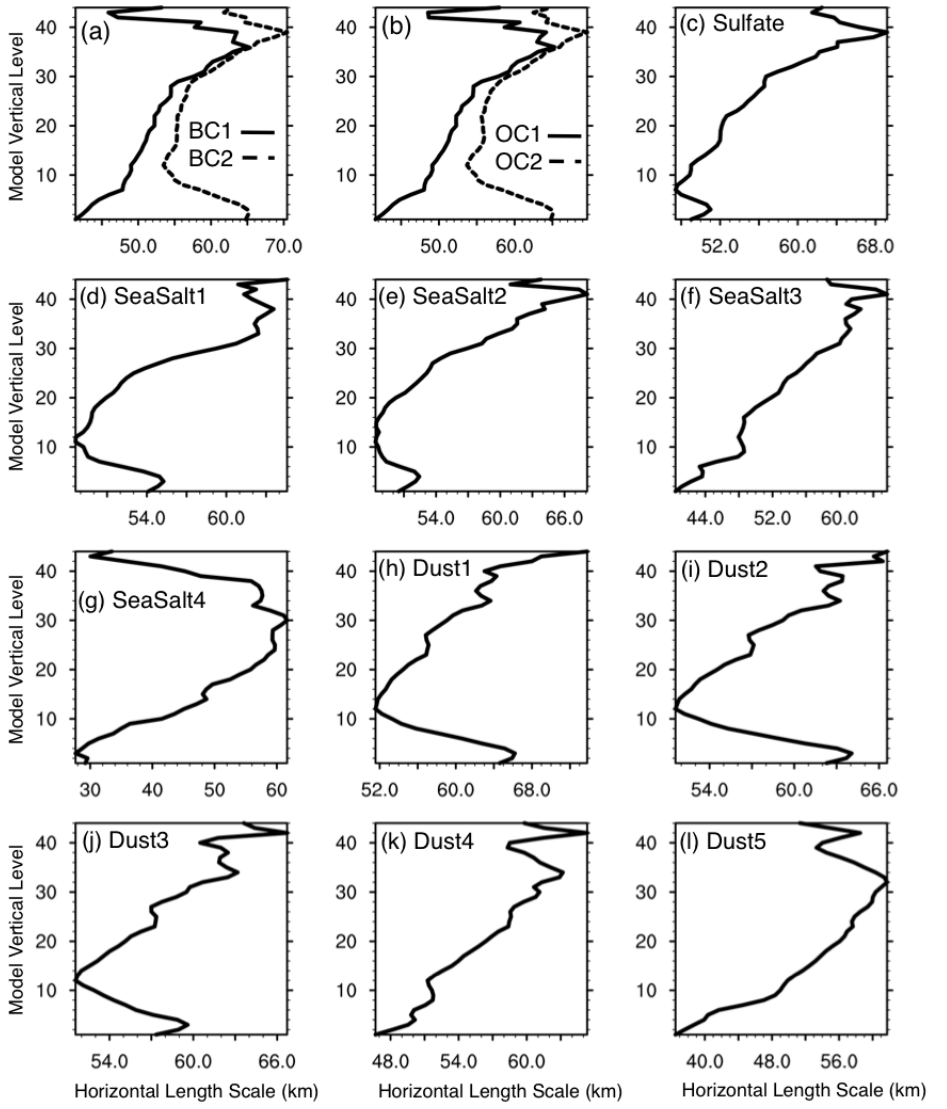
purple: dark-surface retrievals from Aqua;
gold: dark surface from Terra;
blue: deep-blue produced from Aqua.

Estimate B for Aerosol Species

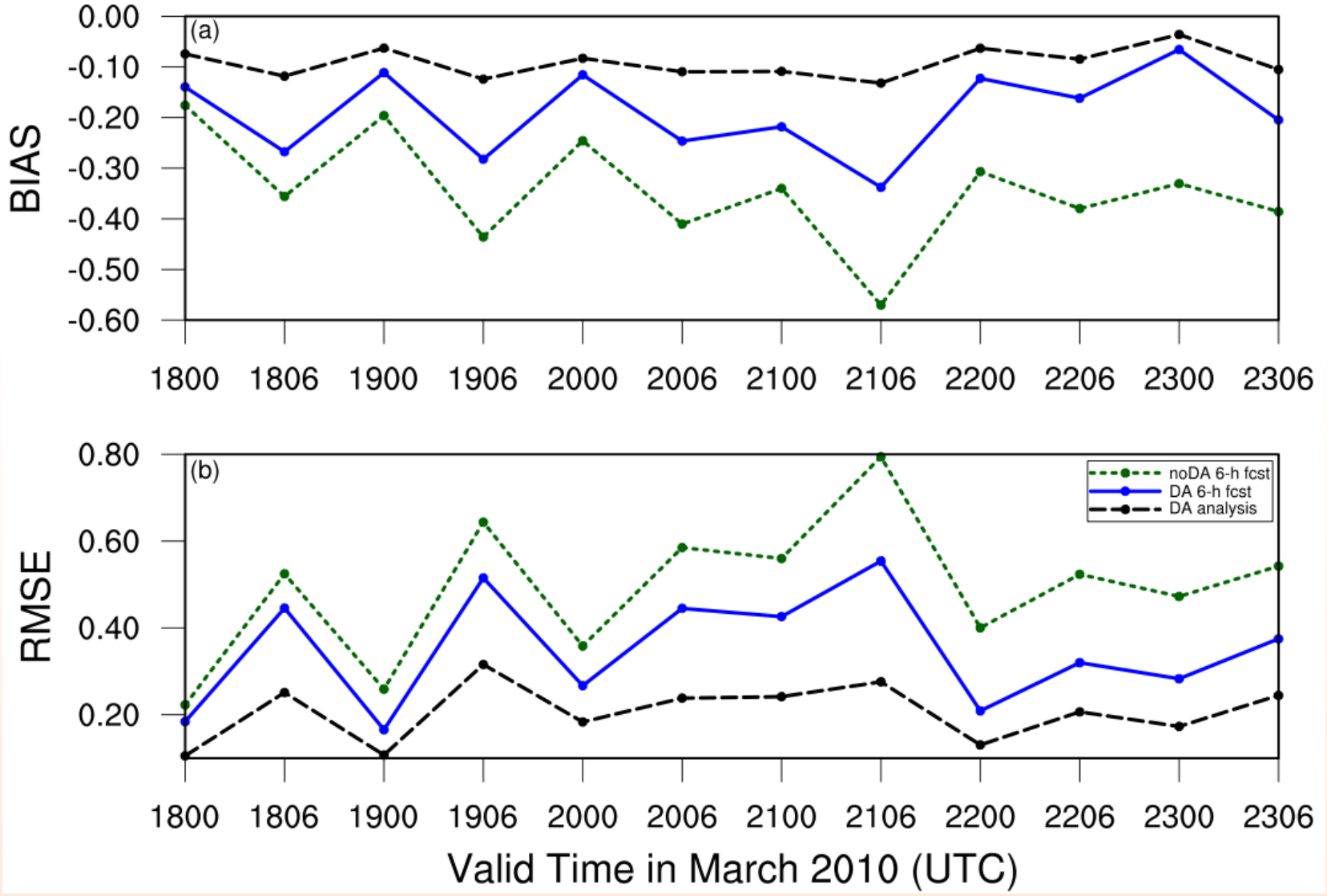
- NMC method was used to compute aerosol background error covariance (B) statistics using WRF-Chem model forecasts (at 00Z and 12Z) in March.
  - Uses differences between 24- and 12-hr forecasts valid at the same time
  - Compute standard deviation, vertical and horizontal length-scale for 14 GOCART aerosol variables
  - No multivariate correlation

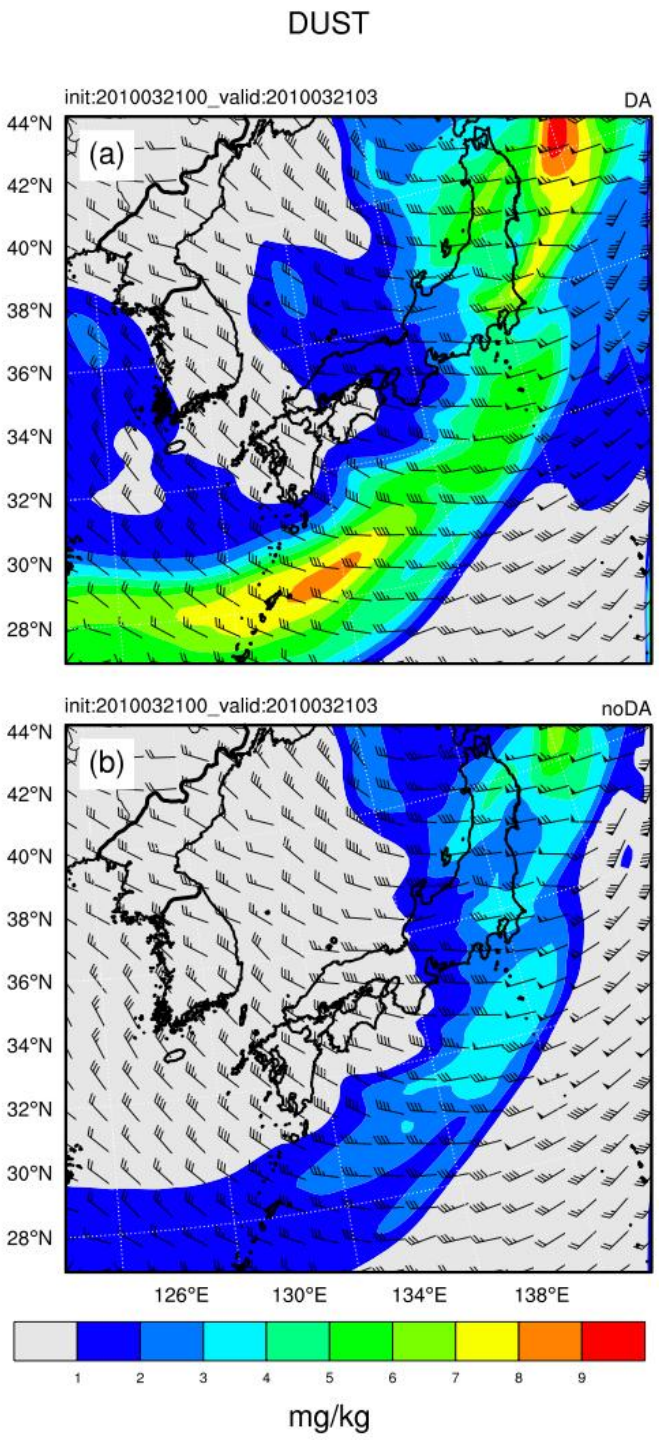
Matrix B: Standard deviation & horizontal length-scale



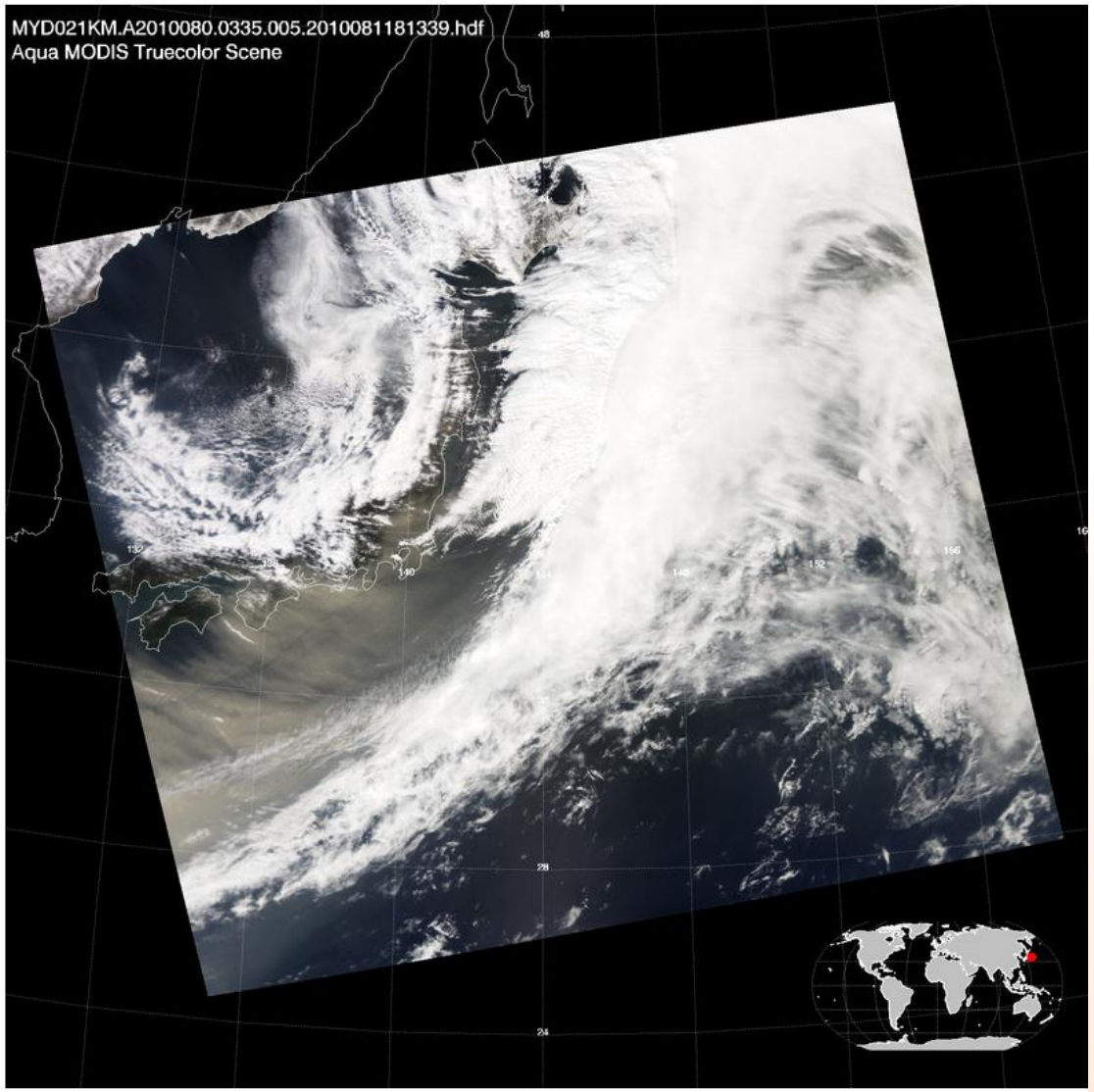


OMB/OMA of MODIS AOD

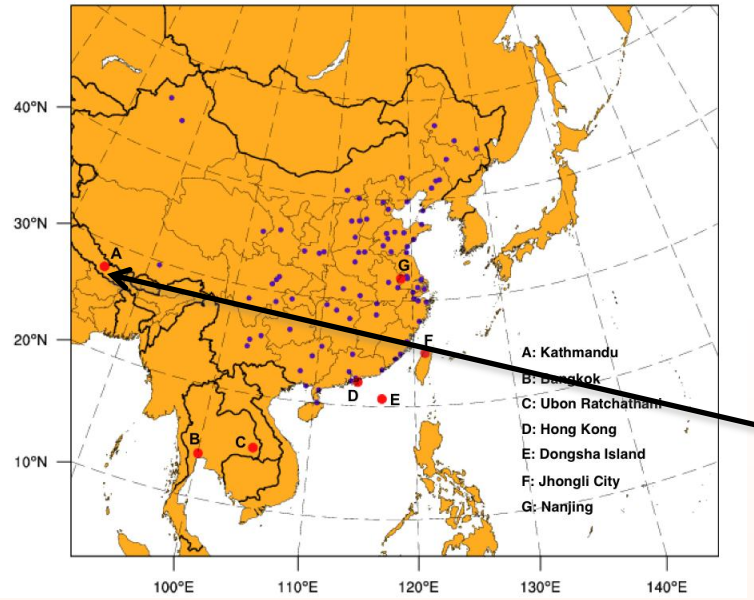




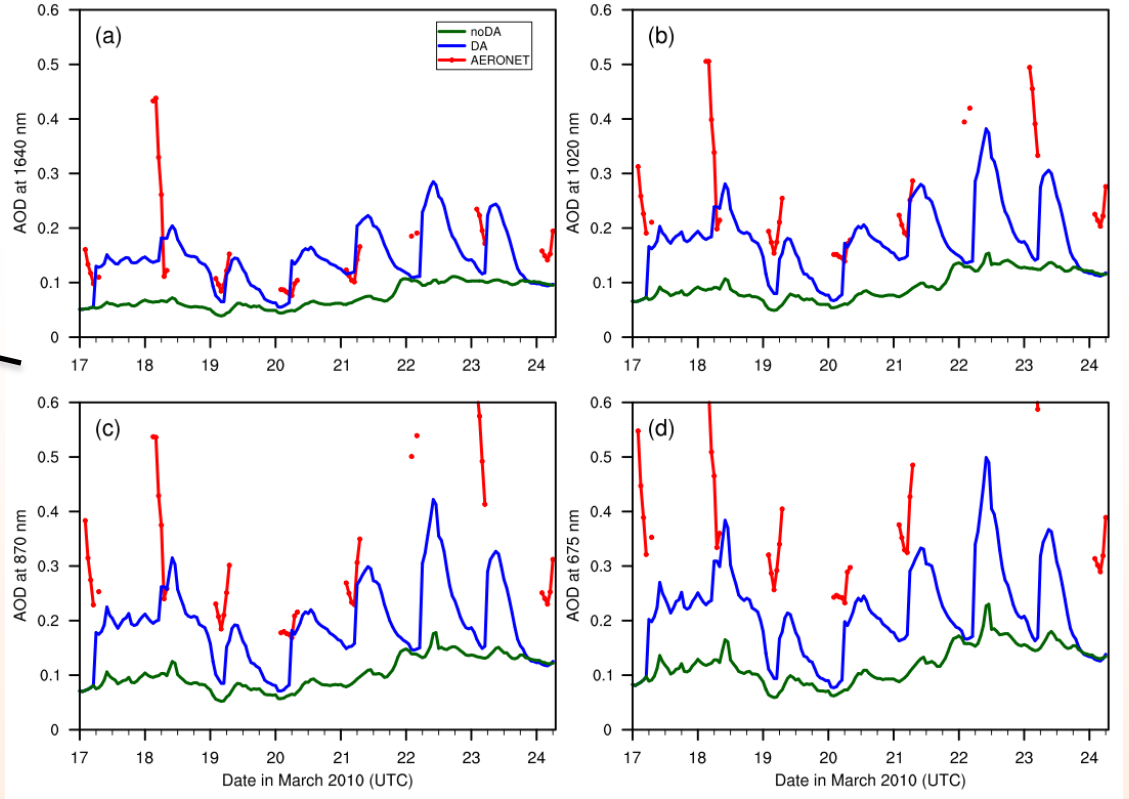
Column dust vs. MODIS true color image. 2010032103



Verify vs. AERONET AOD @1640, 1020, 870, 675 nm

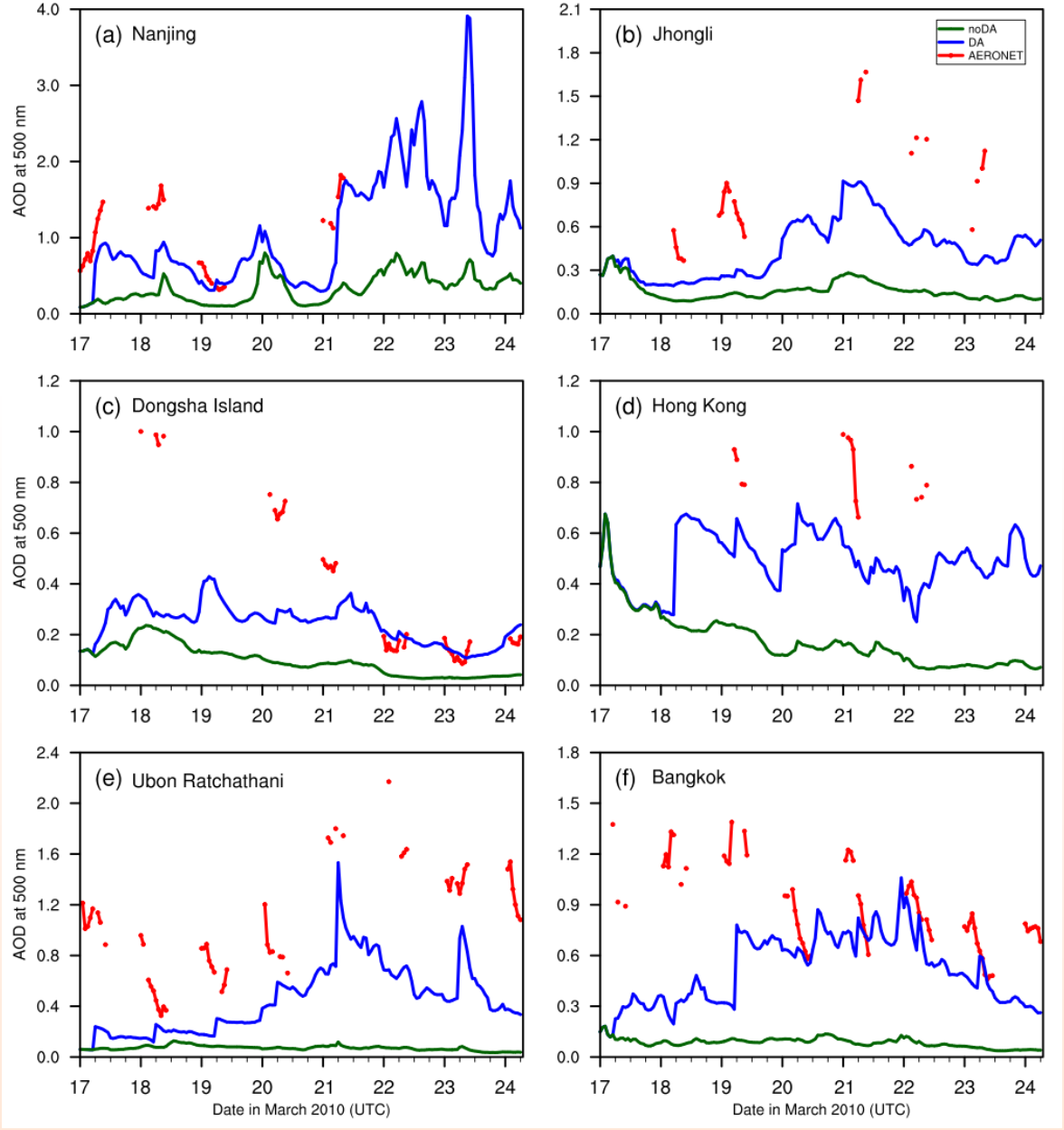


Kathmandu of Nepal



AERONET obs and DA likely reflect air-pollution variation due to the traffic.

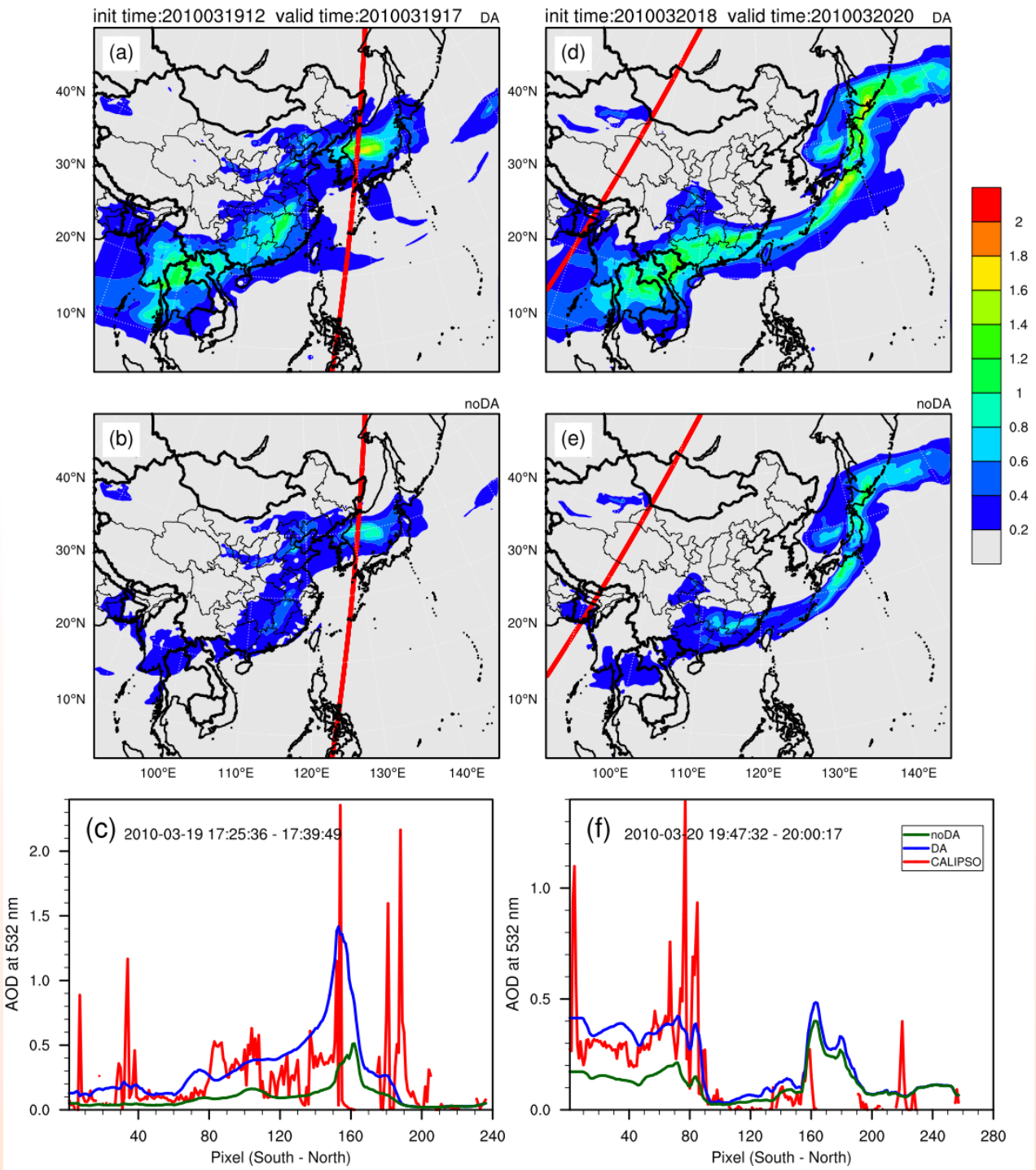
Verify @550nm at other 6 AERONET sites



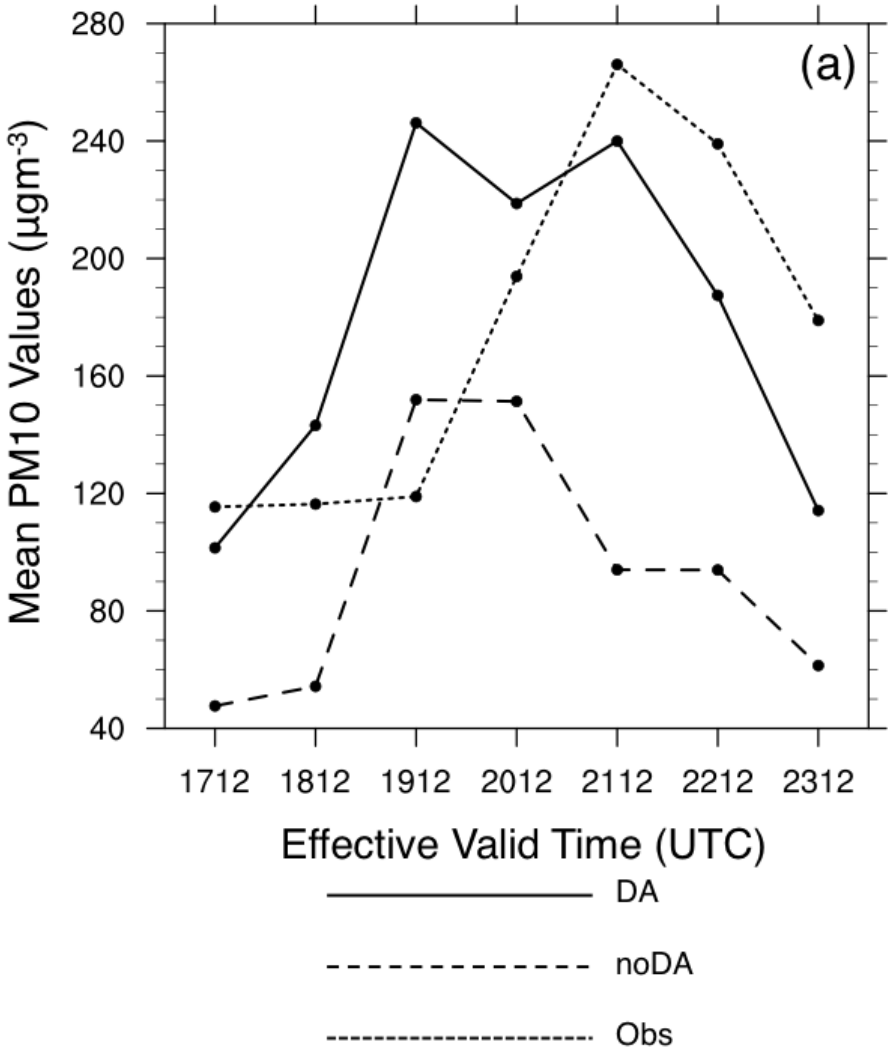
Dust storm affected Nanjing on Mar. 21, 2010

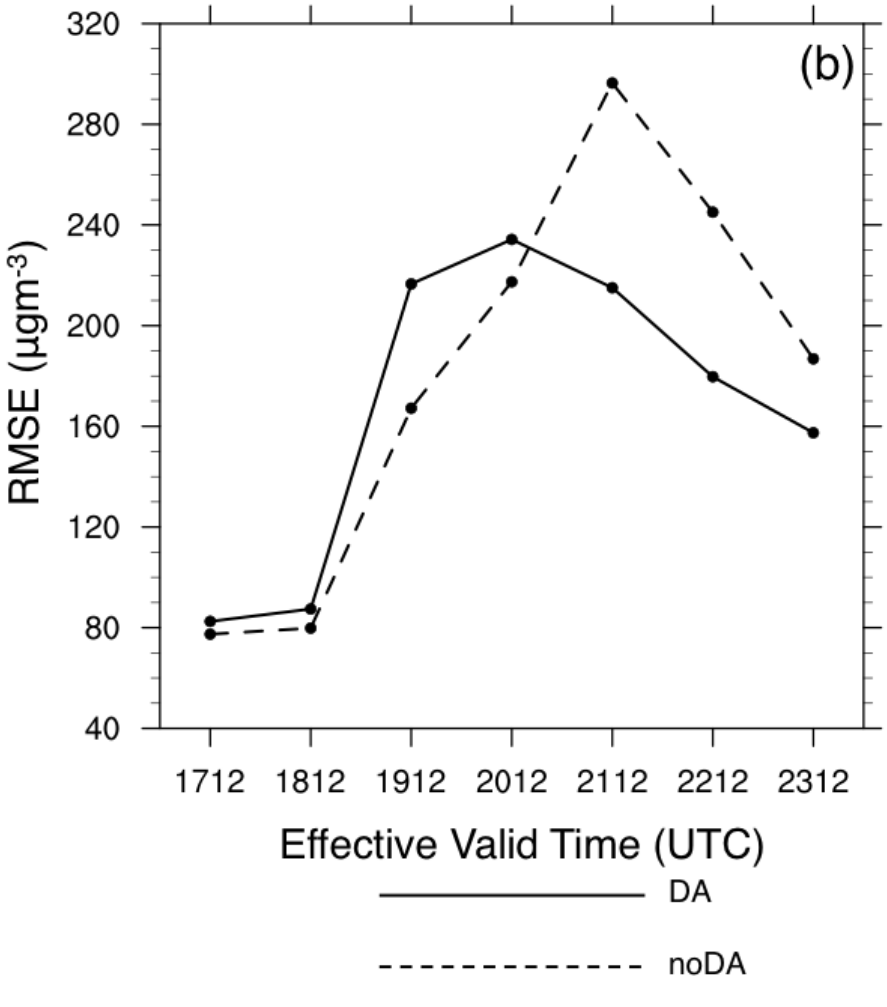
昨天北方沙尘来到南京，使南京蒙上灰蒙蒙的"沙帐"。张鸽 摄

Verify vs. CALIPSO AOD



Verify vs. Surface PM10 (83 sites)





Future work

- Assimilate multi-channel MODIS AOD
  - Improve QC and observation error modeling
- Assimilate multi-sensor & multi-angle AOD products
  - GOES, AVHRR, SeaWiFS, MISR, future GOES-R/VIIRS …
- Assimilate other aerosol related observations
  - e.g., PM2.5/PM10, Lidar ext. coeffs. profiles (both ground- and satellite-based)
- Explore direct radiance DA for aerosol analysis
- Develop 4DVAR and EnDA approach for aerosol analysis

Questions?

The NESL Mission is:
To advance understanding of weather, climate, atmospheric composition and processes;
To provide facility support to the wider community; and,
To apply the results to benefit society.

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