Assimilating MODIS AOD using WRF/Chem and GSI: Application to a Chinese dust storm

Zhiquan Liu (liuz@ucar.edu)
NCAR/NESL/MMM

Quanhua (Mark) Liu (JCSDA), Hui-Chuan Lin (NCAR),
Craig Schwartz (NCAR) and Yen-Huei Lee (NCAR)

Outline

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

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AOD DA: 3DVAR

- Directly analyze 3D aerosol mass concentration with variational minimization procedure 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

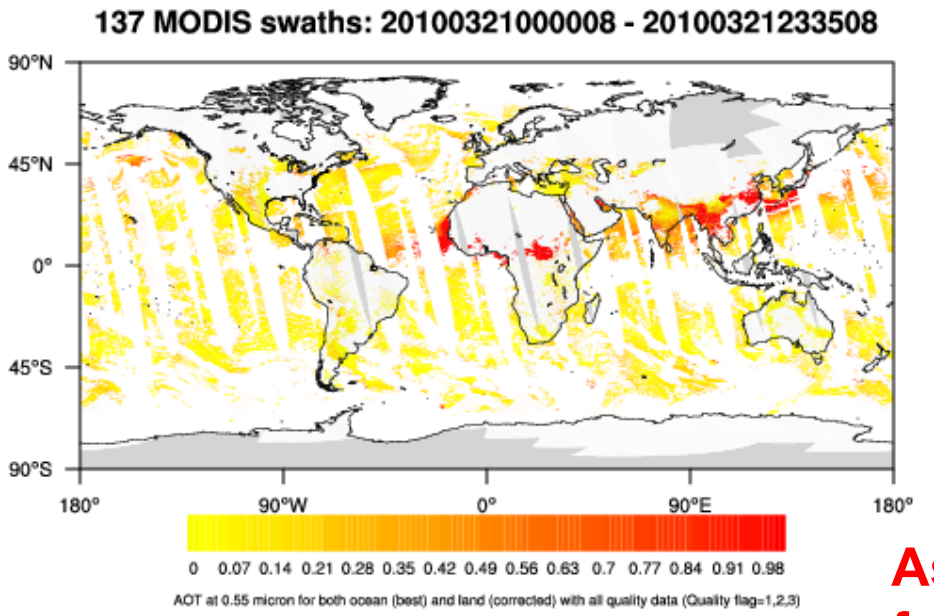
- Use CRTM as the AOD observation operator, including both forward and Jacobian models

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, Lidar profile).

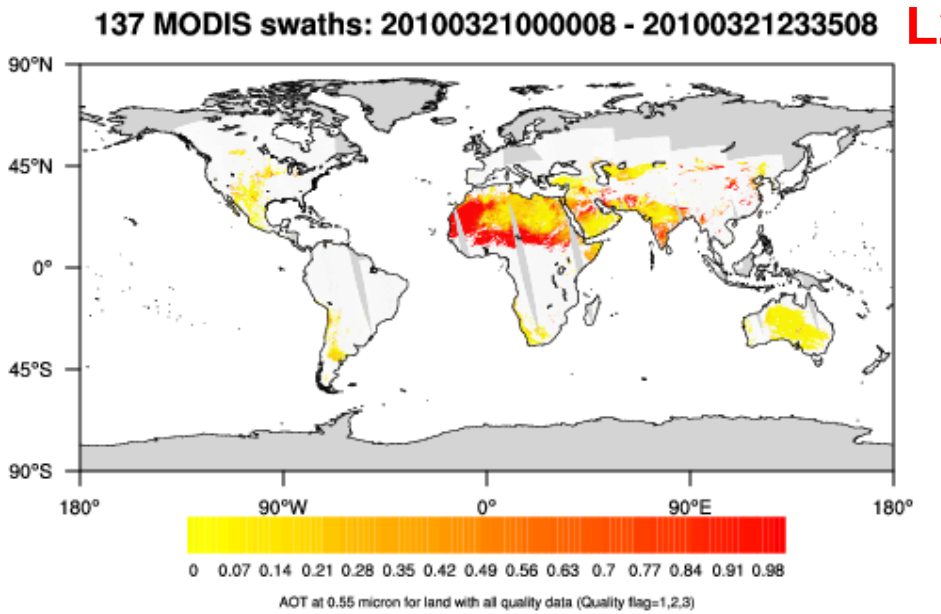
- Allow simultaneous assimilation of aerosol and meteor. observations.
  - though NOT for the results shown here

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



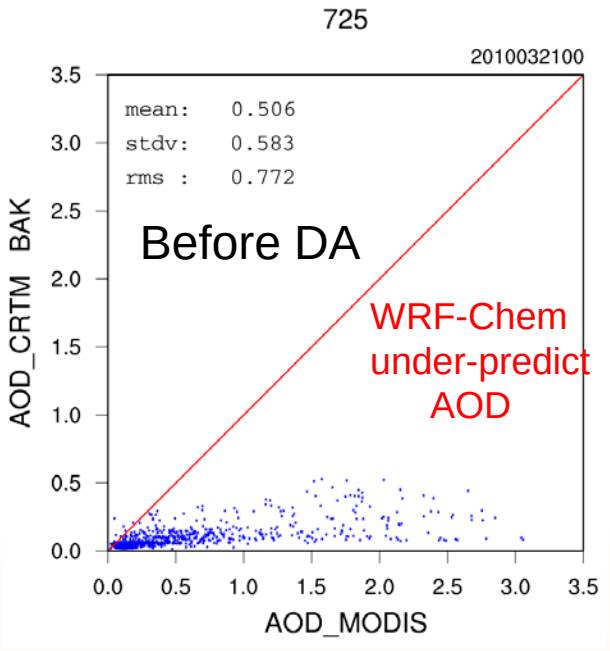
Standard AOD product over ocean & land

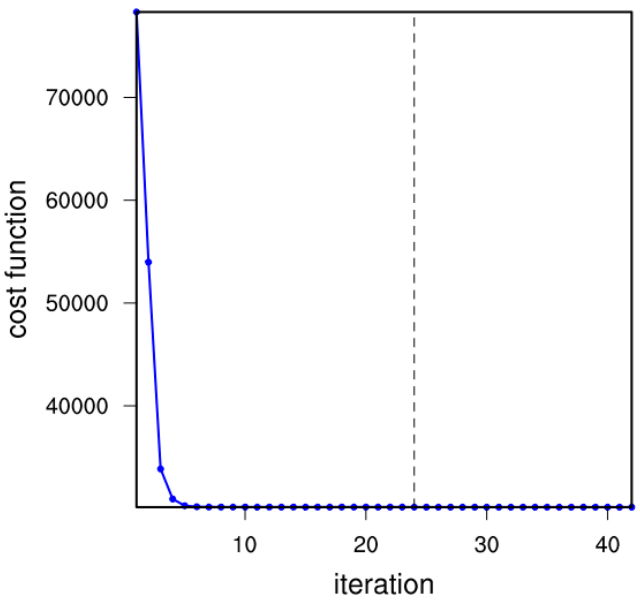
Assimilate only 0.55 μm band from both Terra and Aqua.
L2: 10km x 10km resolution.

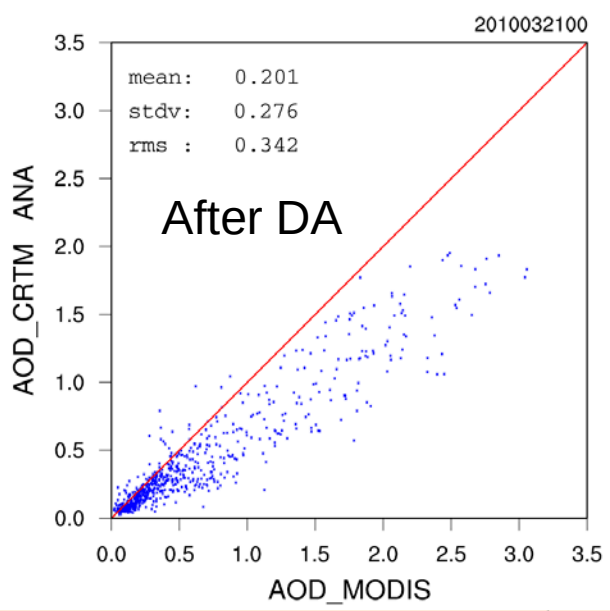


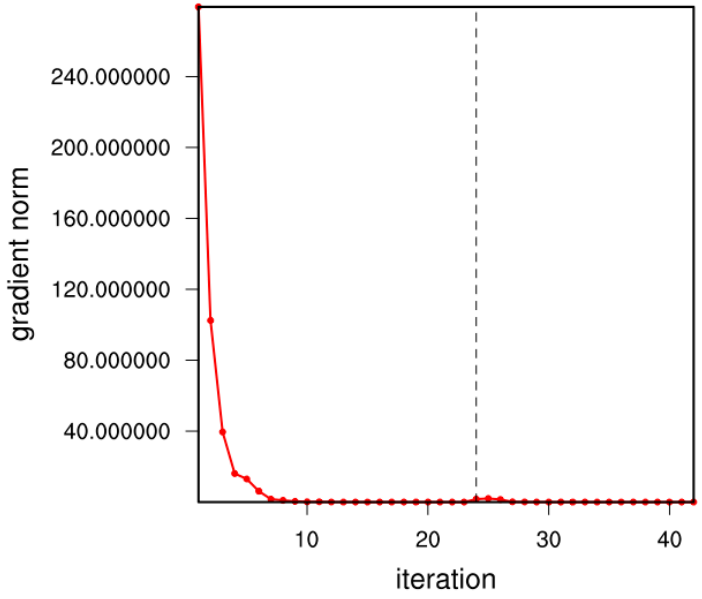
"Deep Blue" AOD product over bright land surface

Minimization









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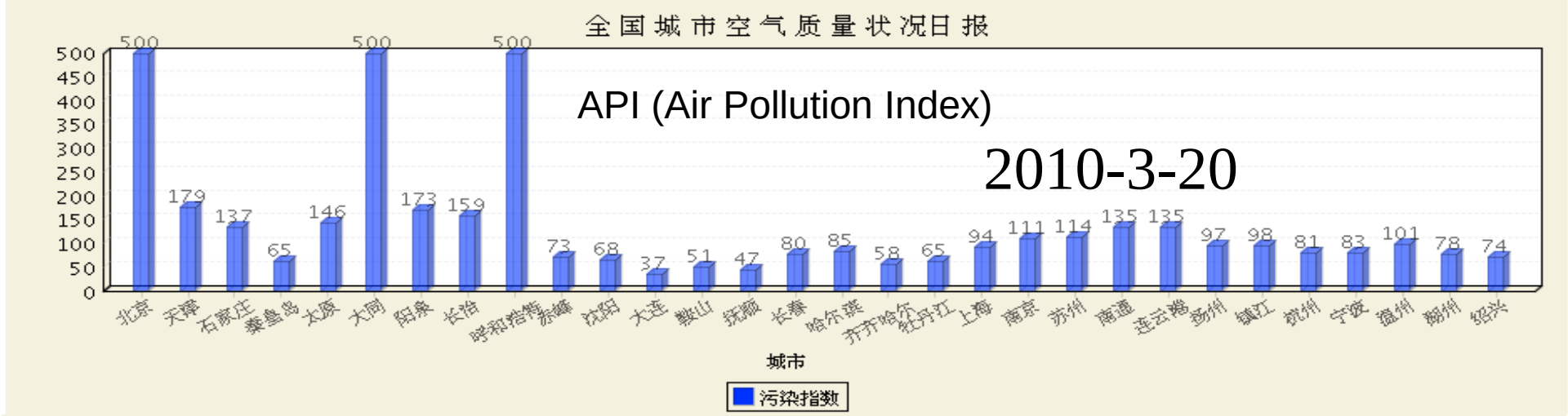
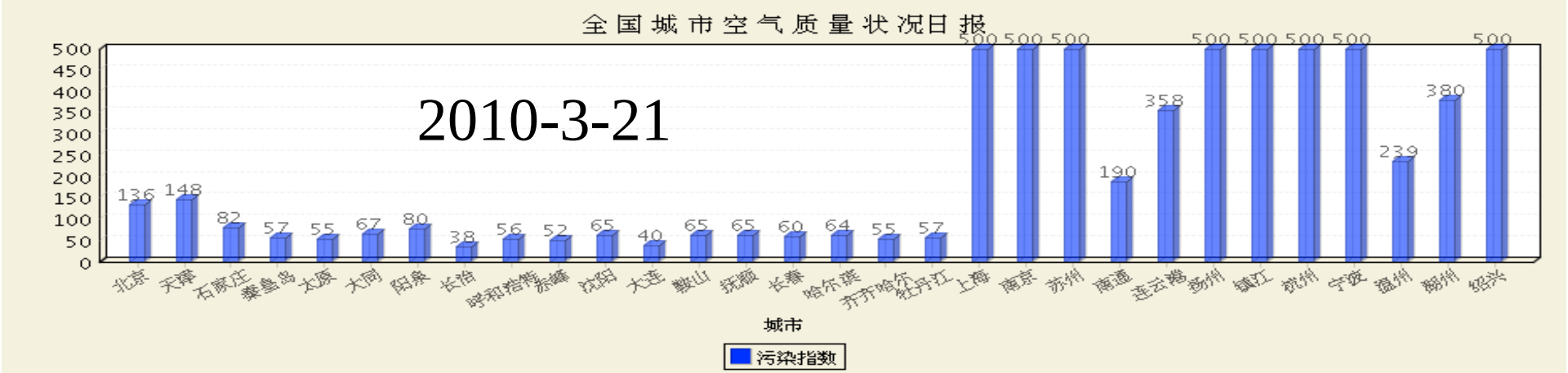
Dust storm affected Nanjing on Mar. 21, 2010

昨天北方沙尘来到南京，使南京蒙上灰蒙蒙的"沙怅"。张鸽 摄


全国城市空气质量状况日报
API (Air Pollution Index)
2010-3-20
城市
污染指数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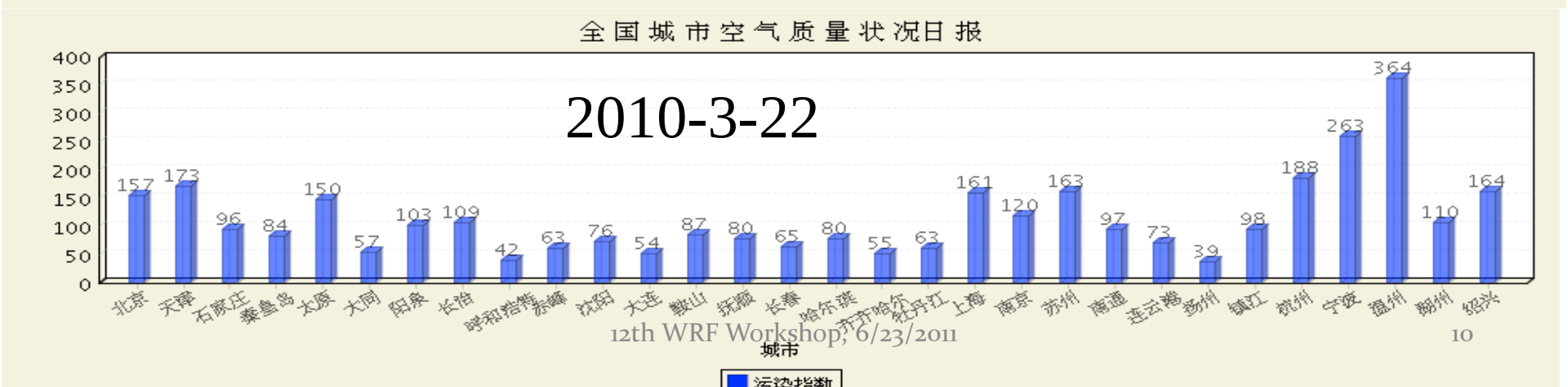
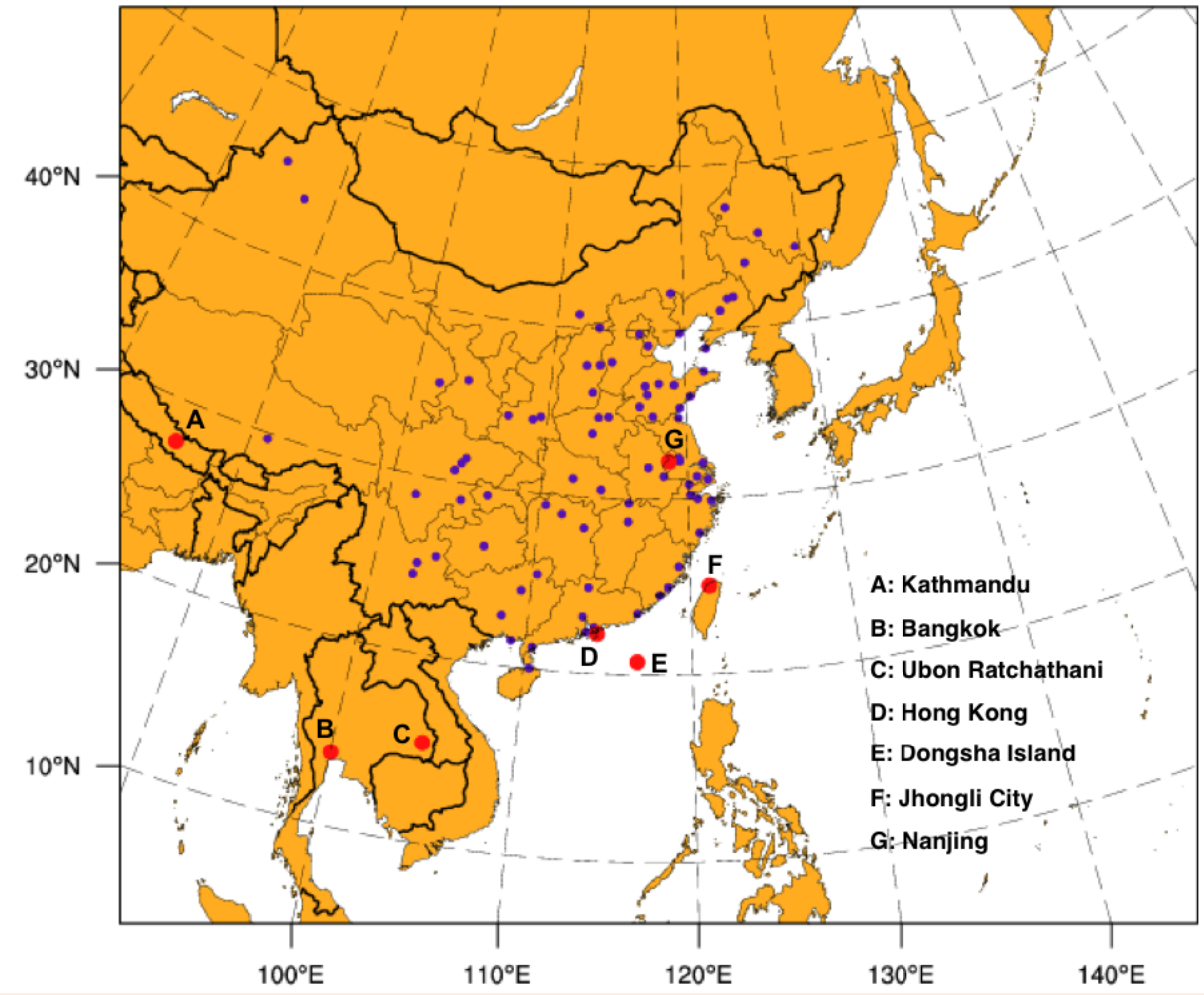
2010-3-21
城市
污染指数


全国城市空气质量状况日报
2010-3-22
城市
污染指数

East Asia domain



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

Validation observations:
7 AERONET sites

chem_opt=301:
GOCART+RACM

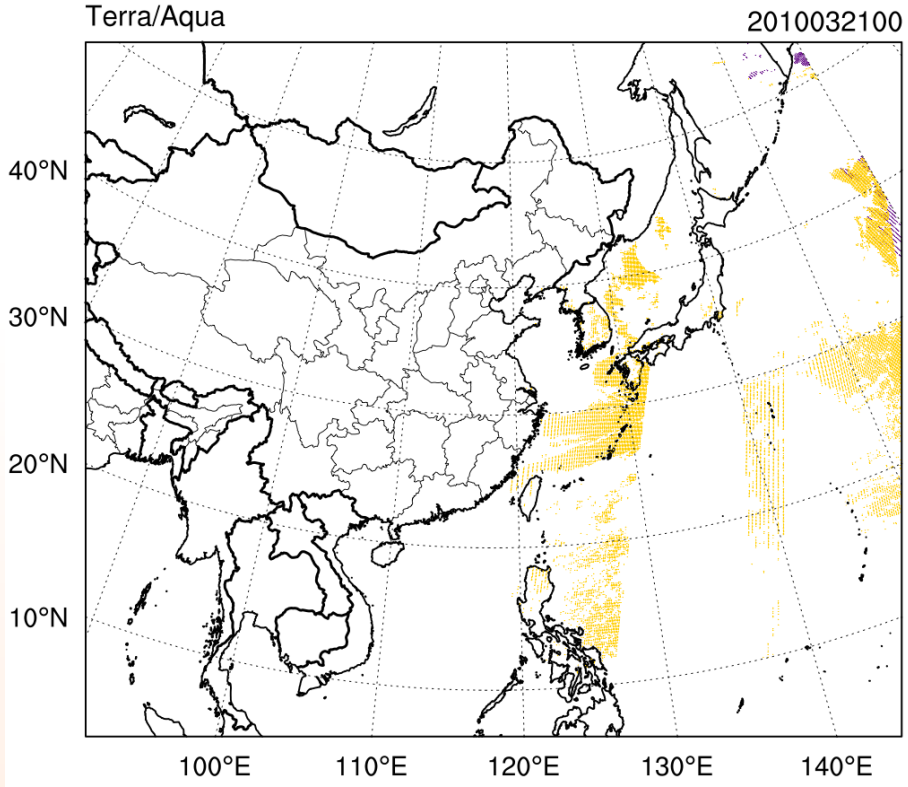
Emissions:
Online biogenic
RETRO+"Streets" anthropogenic

LBC: NCAR CAM-Chem

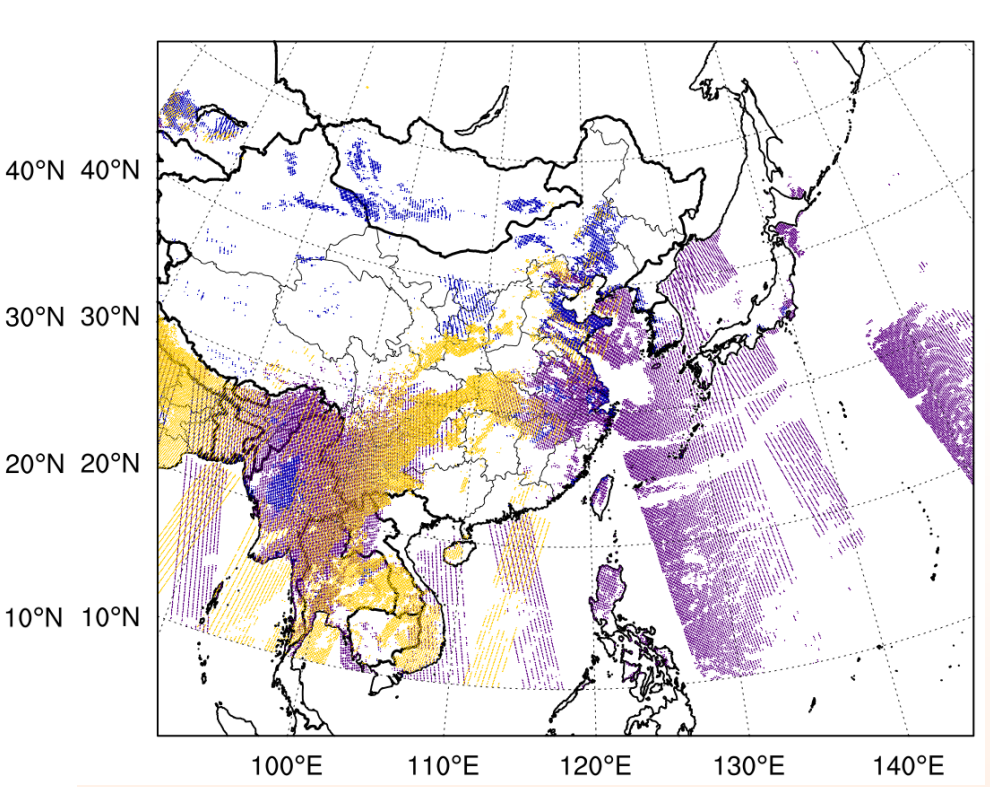
6-hr cycling DA/FC experiment:
17~24 March, 2010.
MET fields updated from GFS.
Aerosol fields updated from AOD DA.

L2 MODIS AOD@0.55µm coverage

0000 UTC, 21 March 2010



0600 UTC, 21 March 2010



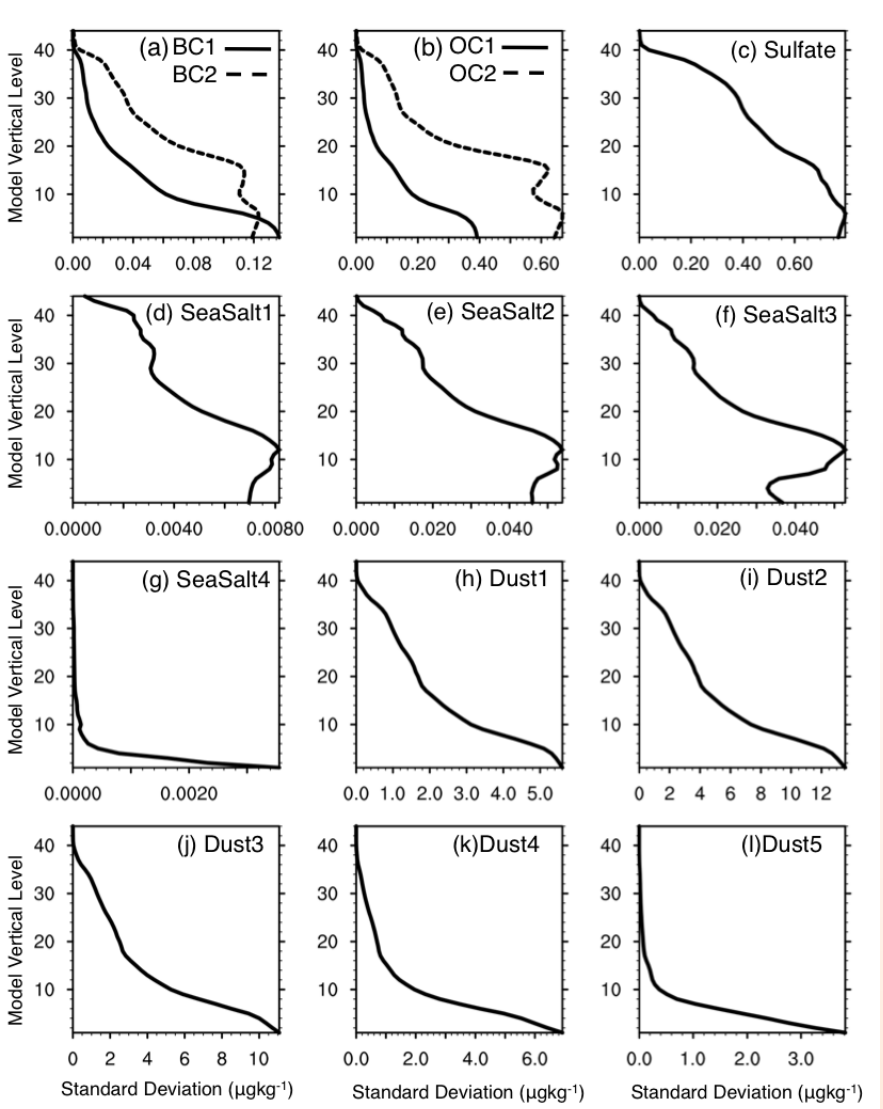
Data only available at day time (00Z and 06Z), visible band.

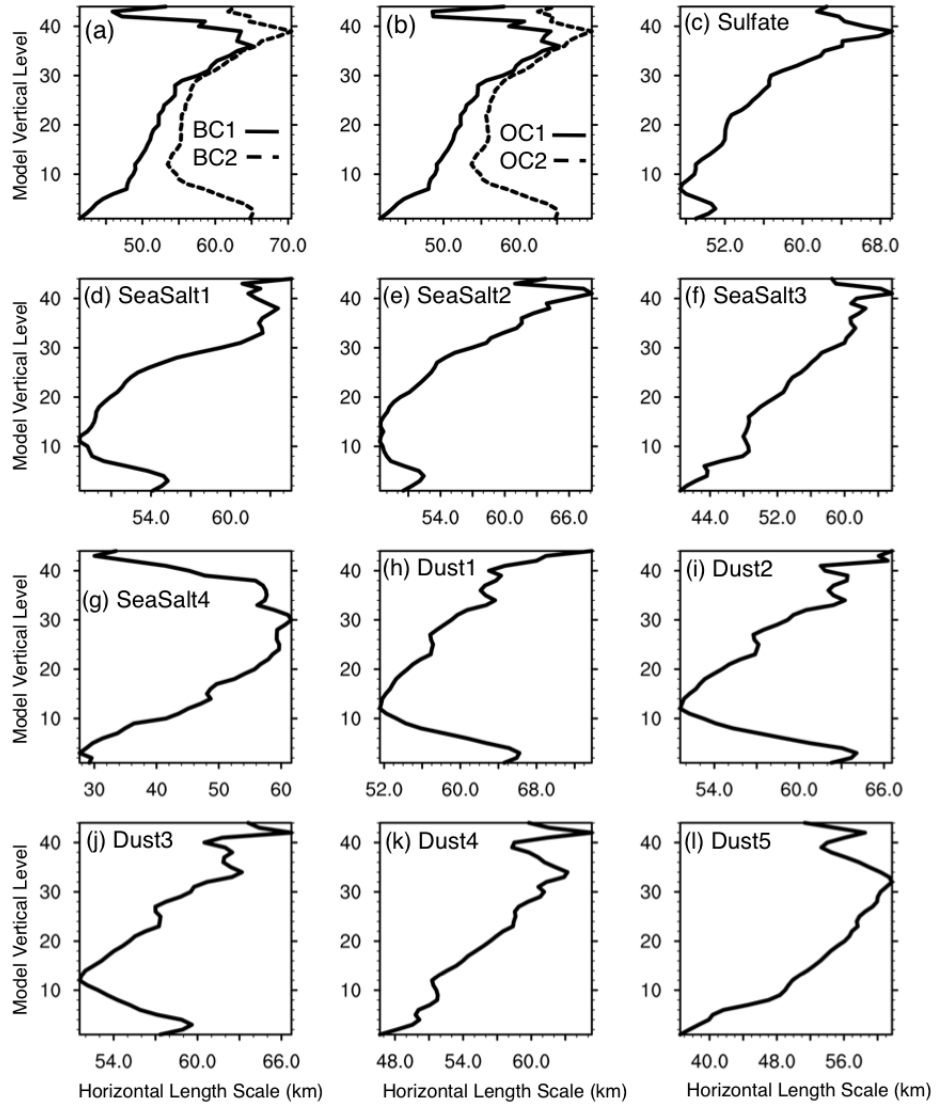
purple: dark-surface retrievals from Aqua;
gold: dark surface from Terra;
blue: deep-blue produced from Aqua.

Estimate B for Aerosol Species

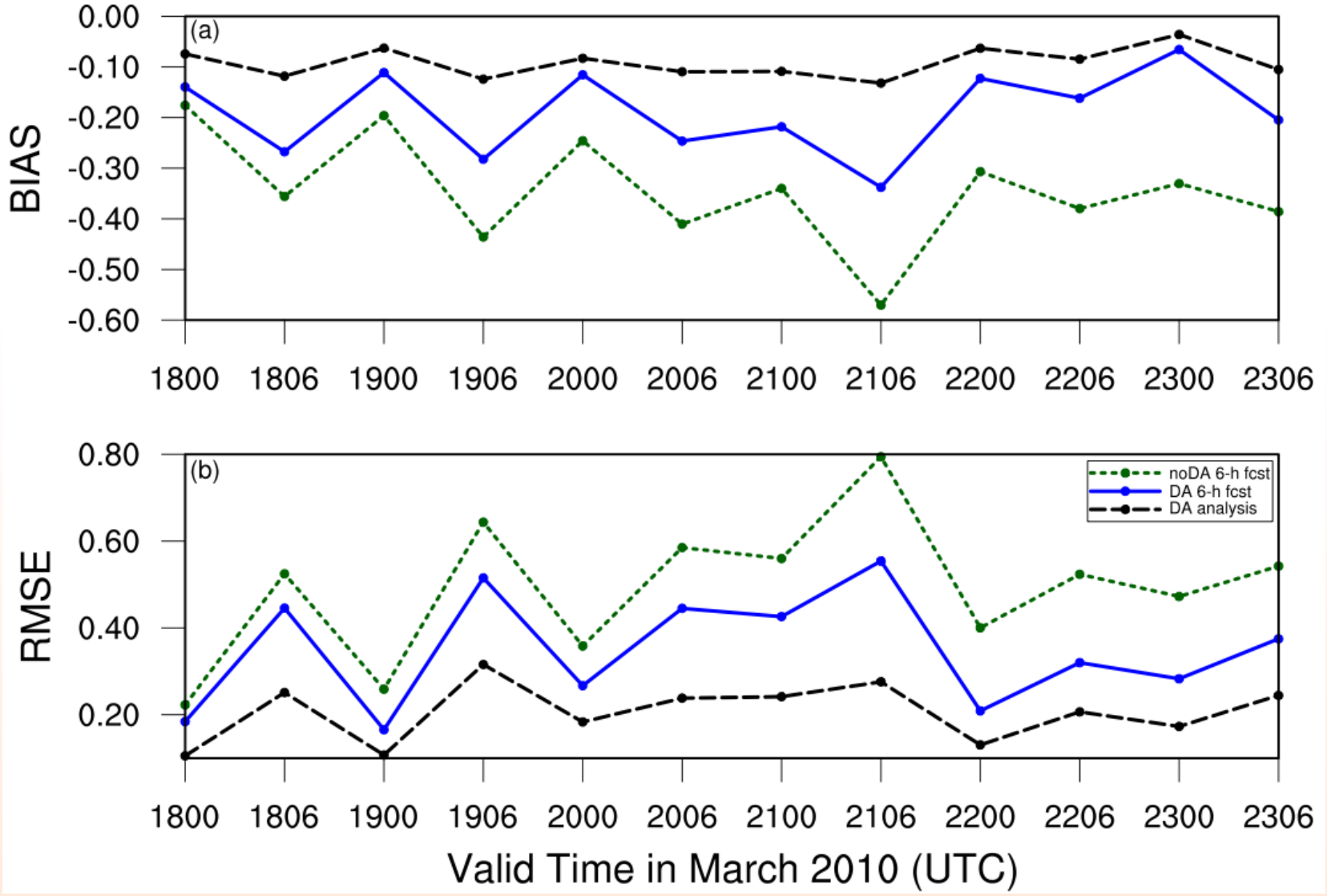
- "NMC" method was used to compute aerosol background error covariance (B) statistics using WRF-Chem model forecasts (at 00Z and 12Z) in March.
  - Uses differences between 24- and 12-hr forecasts valid at the same time
  - Compute standard deviation, vertical and horizontal length-scale for 14 GOCART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

Matrix B: Standard deviation & horizontal length-scale

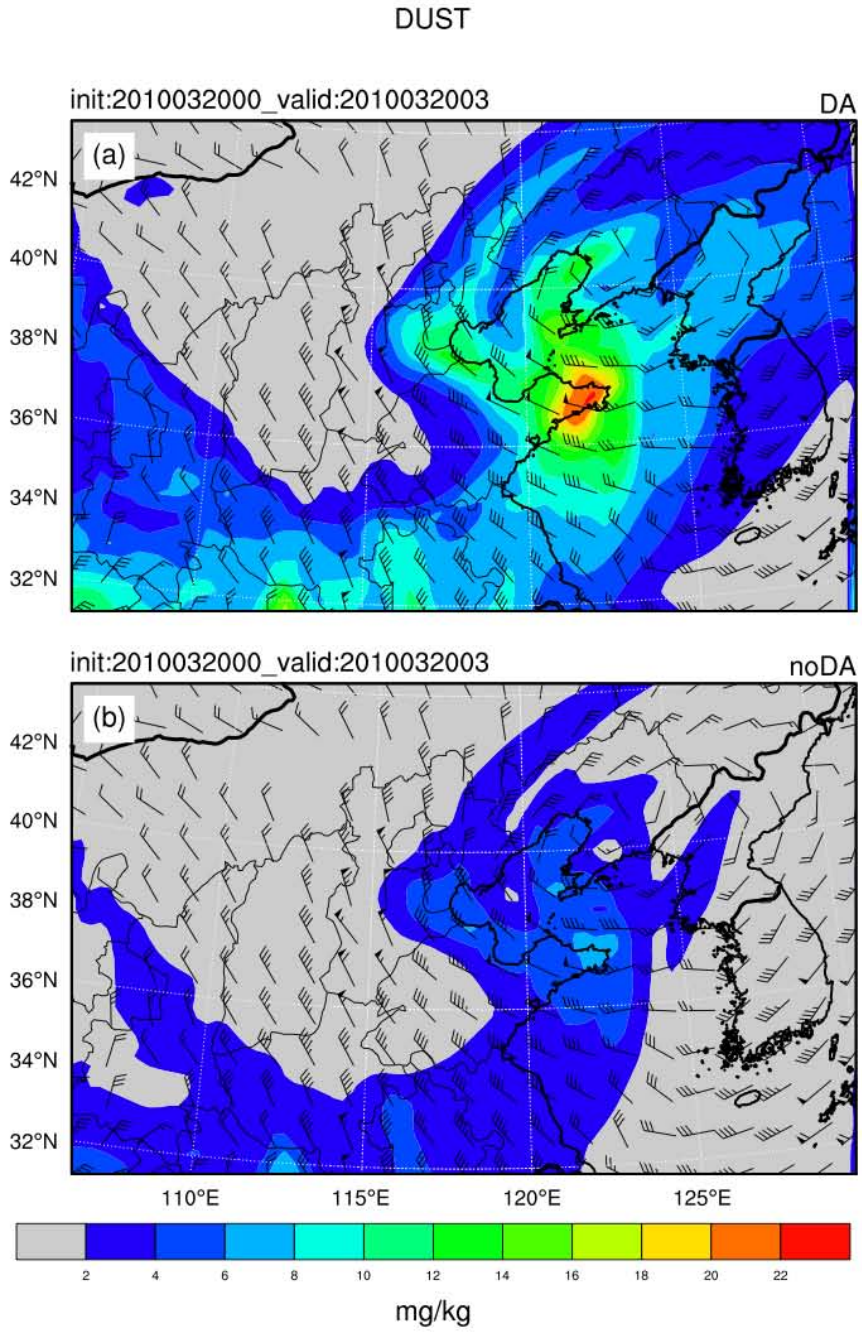


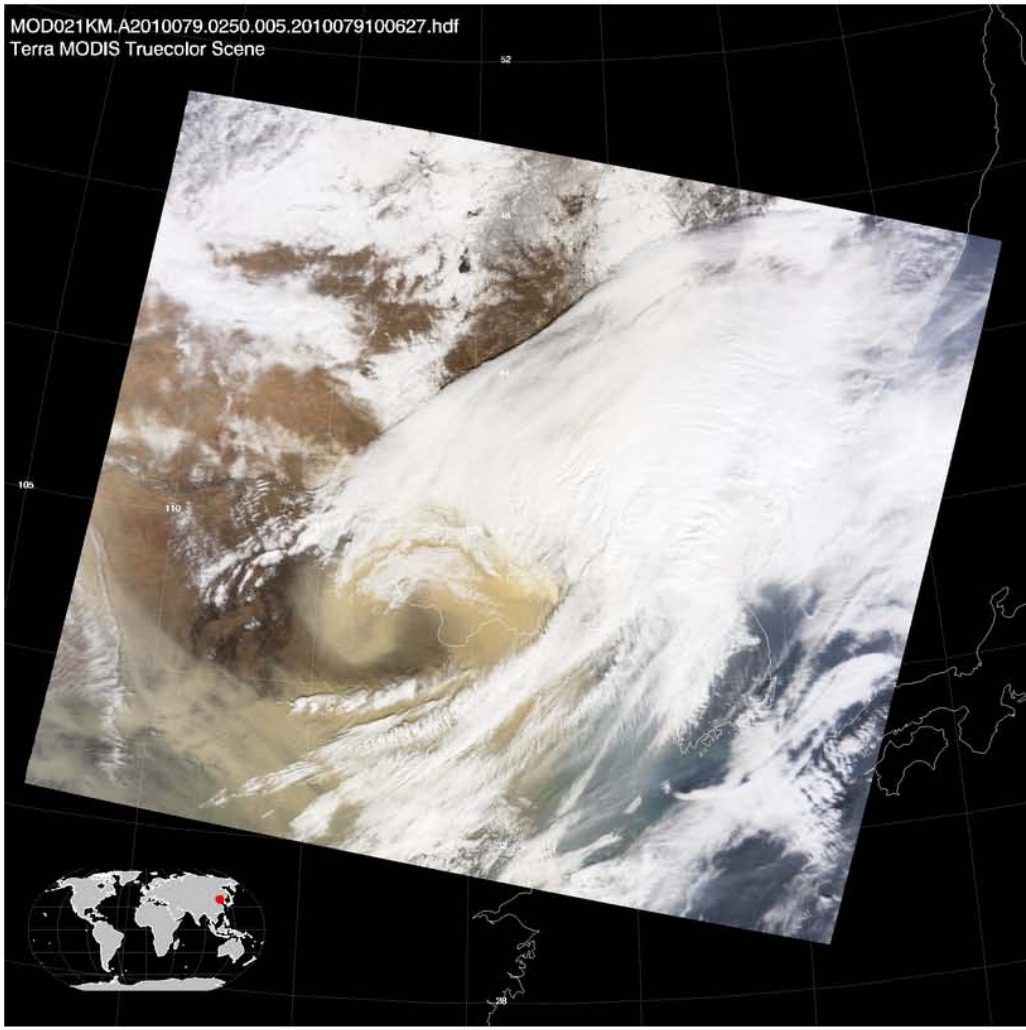


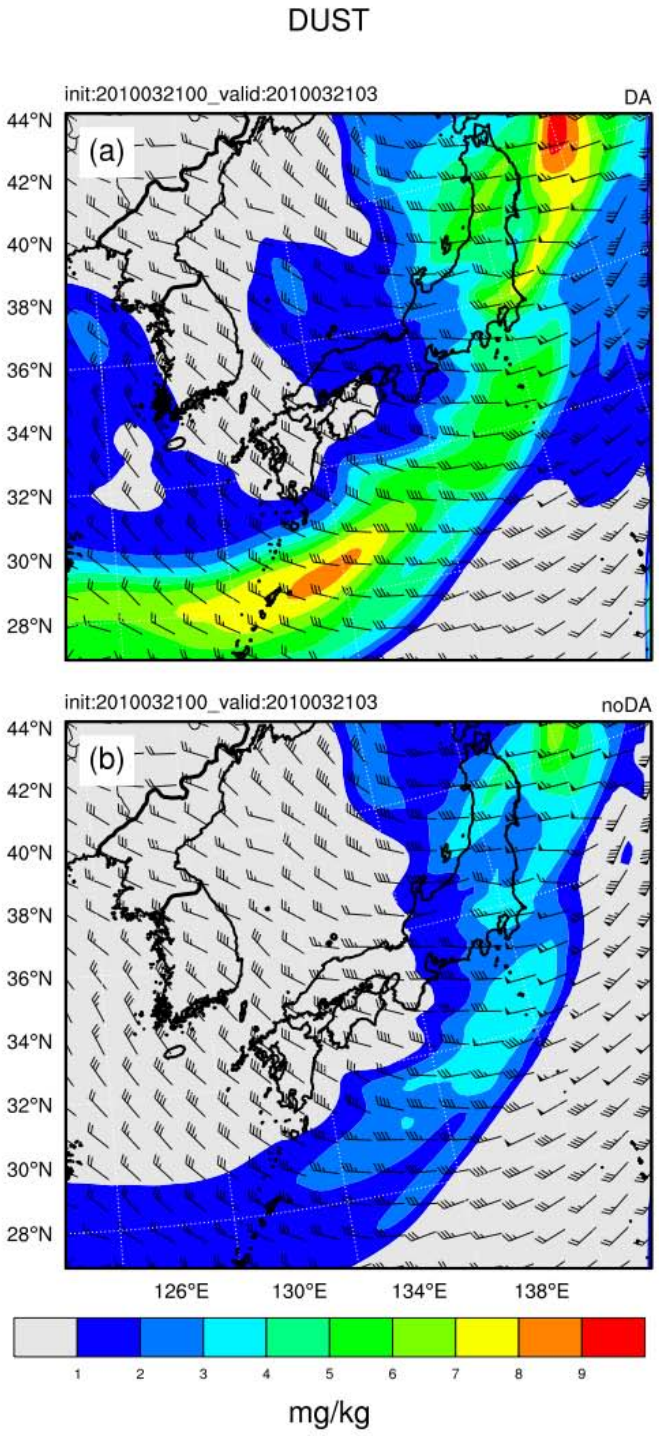
OMB/OMA of MODIS AOD



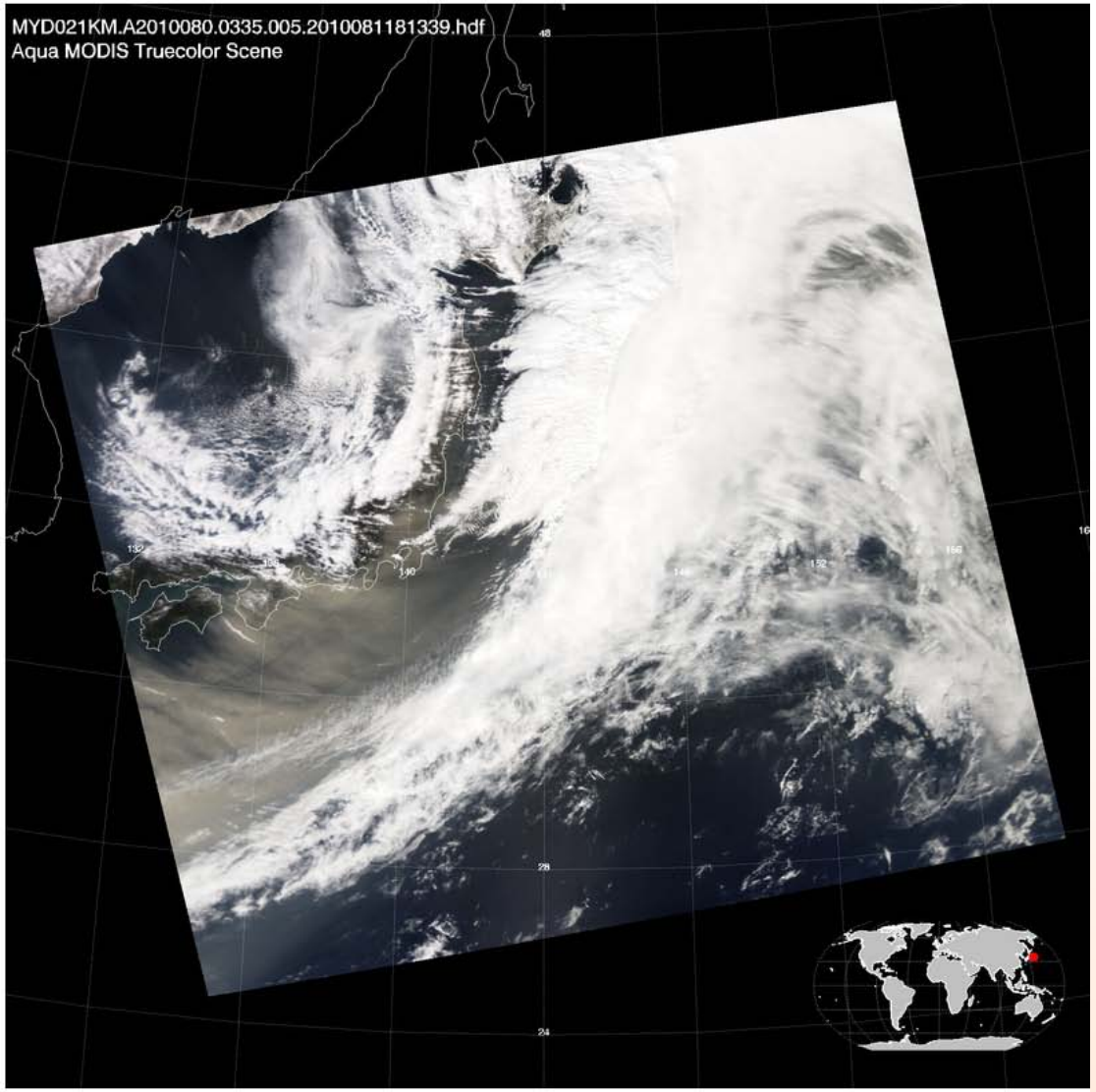
Column dust vs. MODIS true color image. 2010032003



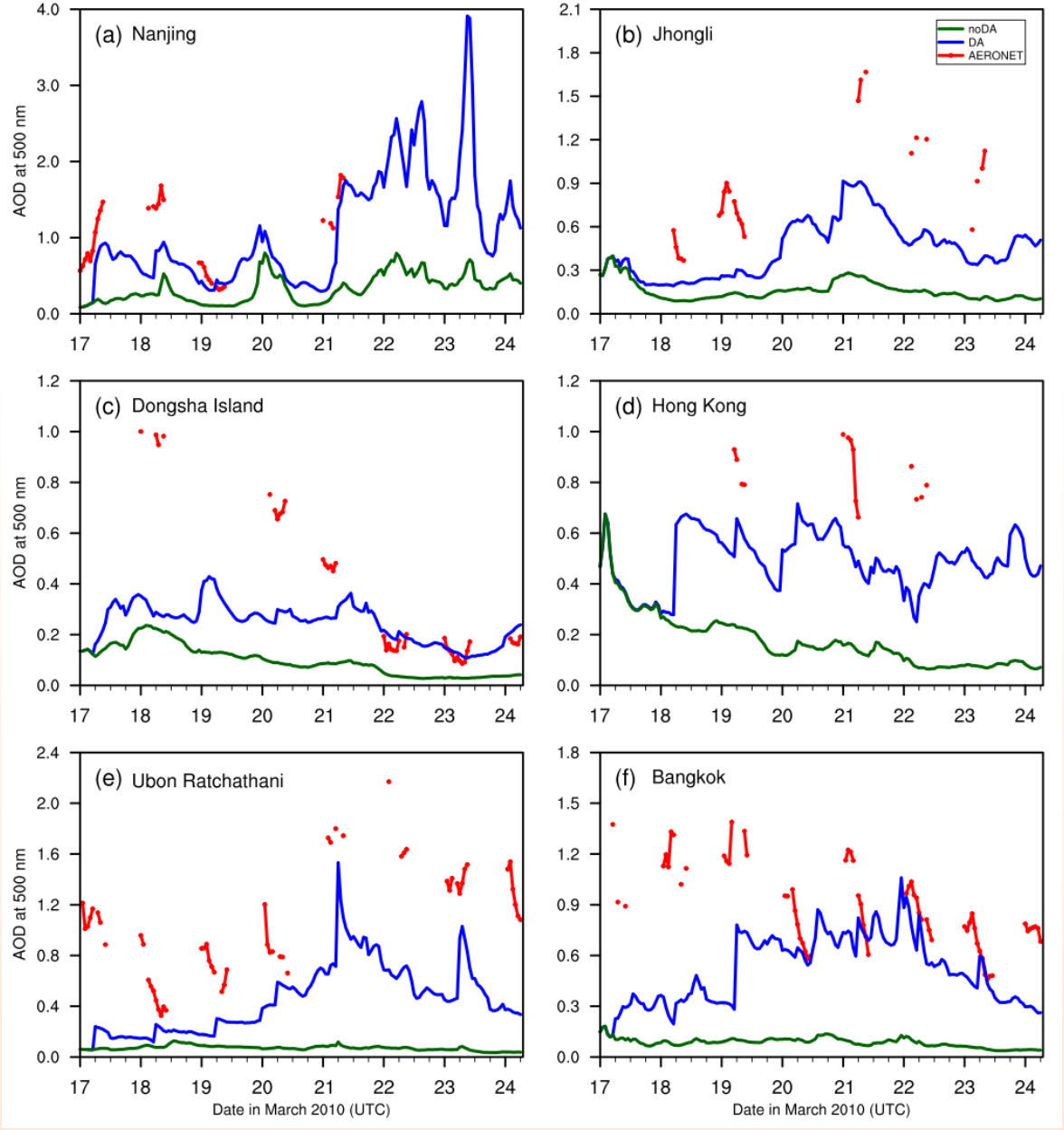




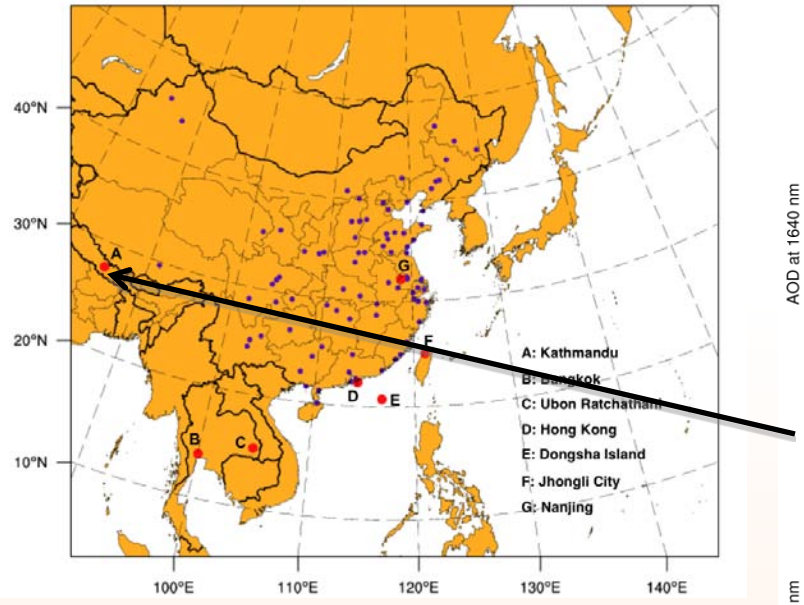
Column dust vs. MODIS true color image. 2010032103



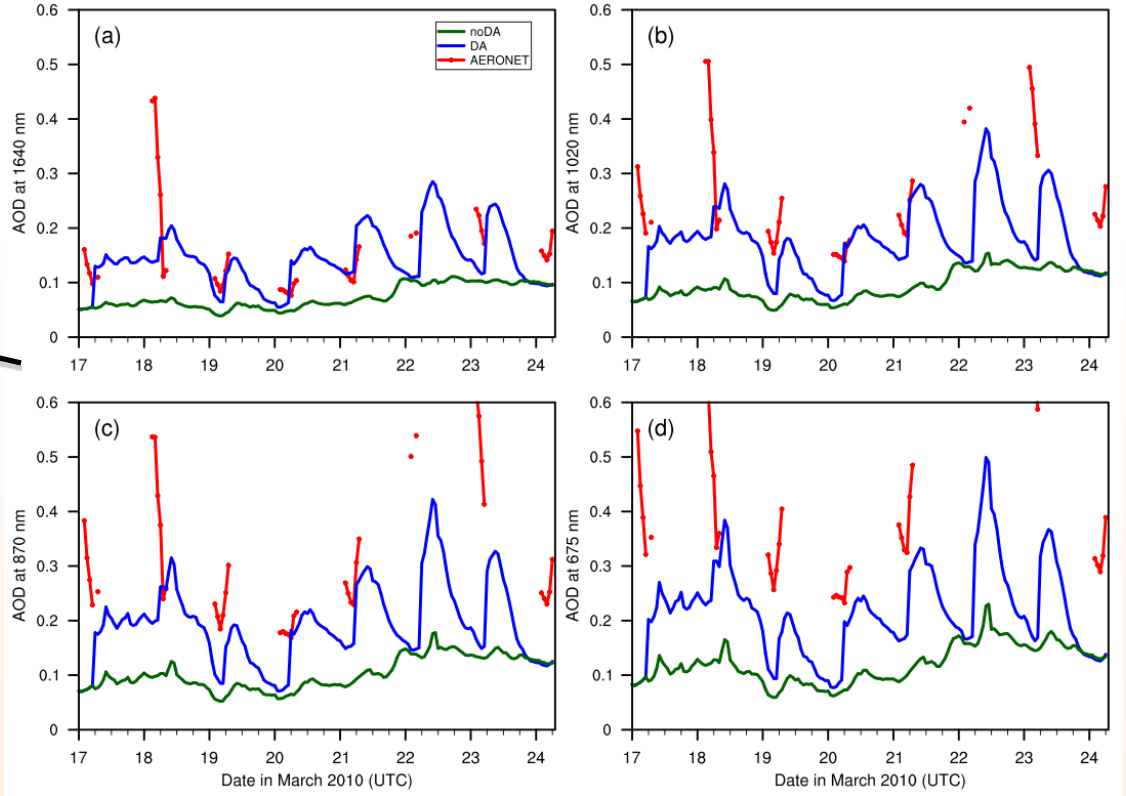
Verify @550nm at other 6 AERONET sites



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



Kathmandu of Nepal

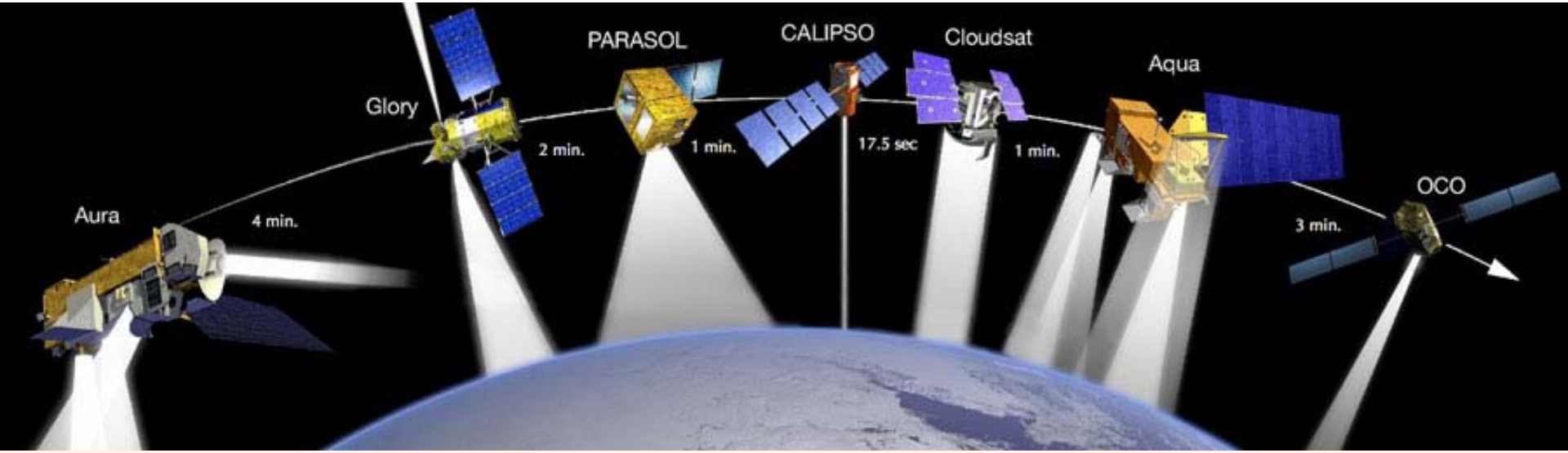


AERONET obs and DA likely reflect air-pollution variation due to the traffic.

Verify vs. CALIPSO AOD

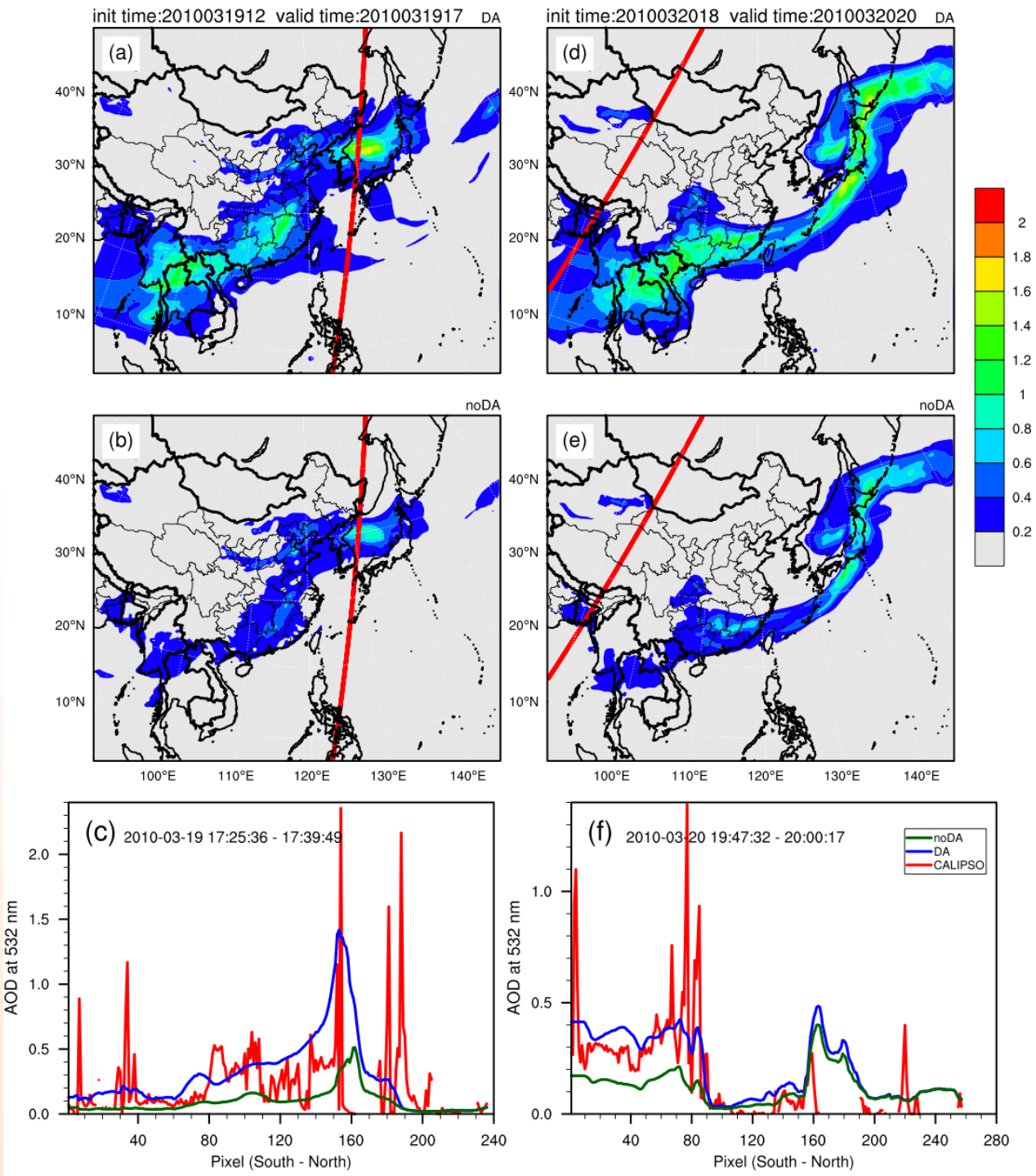
CALIPSO: Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations

Instrument CALIOP: Cloud-Aerosol Lidar with Orthogonal Polarization



“A-train” Constellation

Verify vs. CALIPSO AOD



Future work

- Assimilate multi-spectral/sensor/angle AOD products
  - Improve QC and observation error modeling
  - 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 approaches for aerosol analysis
- Extend to general chemical DA
- More applications
  - Dust, air-quality, biomass burning, volcanic ash, weather-aerosol interaction …