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

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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.

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

• 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., PM$_{10}$/PM$_{2.5}$, 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
After DA

Before DA

WRF-Chem under-predict AOD

Minimization

Cost function

Gradient norm

12th WRF Workshop, 6/23/2011
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Dust storm affected Nanjing on Mar. 21, 2010
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:
  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.
“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

(a)

- BIAS
- Valid Time in March 2010 (UTC)

(b)

- RMSE
- Valid Time in March 2010 (UTC)
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

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 ...