Introduction

MERRA-2 is the latest Aerosol Reanalysis produced at NASA’s Global Modeling Assimilation Office (GMAO) from 1979 to present. This reanalysis is based on a version of the GEOS-5 model radiatively coupled to GOCART aerosols and includes assimilation of bias corrected Aerosol Optical Depth (AOD) from AVHRR over ocean, MODIS sensors on both Terra and Aqua satellites, MISR over bright surfaces and AERONET data. In order to assimilate lidar profiles of aerosols, we are updating the aerosol component of our assimilation system to an Ensemble Kalman Filter (EnKF) type of scheme using ensembles generated routinely by the meteorological assimilation. Following the work performed with the first NASA’s aerosol reanalysis (MERRAero), we first validate the vertical structure of MERRA-2 aerosol assimilated fields using CALIOP data over regions of particular interest during 2008.

Summary of GEOS-5 Reanalysis Activities

<table>
<thead>
<tr>
<th>Name</th>
<th>Nominal Resolution</th>
<th>Period</th>
<th>Aerosol Data</th>
<th>Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERRA-1</td>
<td>50 km</td>
<td>1979-present</td>
<td>NONE</td>
<td>Now</td>
</tr>
<tr>
<td>MERRAero</td>
<td>50 km</td>
<td>2002-present</td>
<td>MODIS CS</td>
<td>Now</td>
</tr>
<tr>
<td>FP for Instrument</td>
<td>50 km</td>
<td>1997.</td>
<td>MODIS CS</td>
<td>In progress</td>
</tr>
<tr>
<td>MERRA-2</td>
<td>50 km</td>
<td>1997-present</td>
<td>AVHRR, MODIS</td>
<td>Now</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CS/CC, MISR</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>AERONET</td>
<td></td>
</tr>
<tr>
<td>MERRA-2</td>
<td>12.5 km</td>
<td>2000-2015</td>
<td>AVHRR, MODIS</td>
<td>Q2 2016</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CS/CC, MISR</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>AERONET</td>
<td></td>
</tr>
</tbody>
</table>

MERRA-2 vertical structure: comparisons with CALIOP

Below: JJA 2008 regional averages of CALIOP 532 nm total attenuated backscatter coefficients (aerosols + molecular) and the corresponding attenuated backscatter coefficients sampled from the model during day. For the sake of comparison, the molecular scattering component has been added to the MERRA-2 profiles.

Aerosols in MERRA-2

In MERRA-2 ensembles are created using the Local Displacement Ensembles method (LDE)

- Construct perturbation ensembles by means of isotropic displacements around central grid box.
- Weigh each ensemble member by its fit to 2D AOD analysis.

MERRA-2 550 nm AOD

Aerosols Data assimilation in MERRA-2:

3D Aerosol Concentration Analysis:

\[ a = x + PP' H' \delta Y \quad (O-F) \]

where \( y \) is AOD and \( x \) is aerosol concentration.

2D AOD analysis:

Since the AOD observable is 2D, it is common to solve the AOD analysis equation:

\[ y = x + PP' H' \delta Y \]

Projecting AOD into Concentration Increments:

The 3D concentration increments is related to the 2D AOD increments by:

\[ \delta x = PP' H' \delta Y \]

If the background error covariance \( P \) is parameterized in terms of ensemble perturbations:

\[ X = (x_1, x_2, \ldots) \]

so that:

\[ Y = (y_1, y_2, \ldots) = (y_3, y_4, \ldots) \]

it follows that:

\[ \delta x = X P Y^{-1} \delta Y \]

Resolving the analysis equation using an EnKF scheme and meteorological ensembles generated by the GEOS-5 hybrid system: How much spread do we get?

The implementation of the EnKF in the GEOS-5 model is currently in progress. Initial tests are performed by first assimilating AOD from MODIS, MISR and AERONET, using GEOS-5 produced meteorological ensembles and by comparing the results with the current reanalysis from MERRA-2.

Conclusion and future work

The ensemble-based data assimilation system for aerosols is under development for use in GEOS-5. Currently tests are being performed by assimilating AOD from MODIS, MISR and AERONET using the meteorological ensembles generated by the hybrid system which are compared with the current results from MERRA-2.

Next we will be assimilating CALIOP attenuated backscatter observations in the data assimilation system.

Acknowledgements: We would like to thank Cynthia Randles for her help in the validation of MERRA-2 aerosols and Ricardo Todling and Amal El Akkraoui for helpful discussions during the EnKF implementation.