Variational and Ensemble Aerosol Data Assimilation for Regional Air-Quality Forecasts Using WRF/Chem: an Overview

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In the past three years, aerosol data assimilation (DA) capability has been developed within NCEP GSI-3DVAR system at the NCAR MMM division. The system allows simultaneous assimilation of multiple aerosol observation types from both satellite platforms and ground-based networks to constrain 3D aerosol initial conditions for regional WRF/Chem model forecasts using the NASA GOCART aerosol module. 3DVAR control variables are 3D mass concentration of individual aerosol species (organic and black carbon, sulfate, sea salt, and dust) and the background error covariance (variance, horizontal and vertical correlation scales) for each species is obtained using the NMC method with no multivariate correlation considered.

The newly-developed system was firstly applied to a dust storm over East Asia by assimilating MODIS 0.55 μm total aerosol optical depth (AOD) retrieval products using the JCSDA's CRTM as the observation operator which led to substantial improvement for WRF/Chem air-quality forecasts when compared to independent aerosol data sources (Liu et al., 2011). Simultaneous assimilation of AOD and surface PM2.5 observations was then demonstrated over North American for a month-long period (Schwartz et al., 2012). The deficiency of assimilating MODIS AOD over western US desert area, where retrieval quality is problematic, was identified. Another noticeable thing is that the impact of assimilating surface PM2.5 is rapidly diminished with forecast range. This issue was also found when assimilating PM10 over China (Jiang et al., 2013). Process analysis for PM10 formation indicates that the rapidly-diminishing DA impact on aerosol forecasts, especially in early forecast hours, was caused by stronger vertical mixing created by surface aerosol DA.

More recent development has focused on ensemble-based aerosol DA. Initial results using an EnKF did not show superior performance compared to 3DVAR (Schwartz et al., 2013), likely attributed to the inefficiency of EnKF when dealing with biased WRF/Chem forecasts. GSI-hybrid assimilation technique, however, exhibits some benefit. Efforts have also been made to directly assimilate MODIS visible radiances as an alternative to AOD assimilation, with encouraging initial results (Liu and Lin, 2013). These published and fresher results will be presented in the meeting.

References

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