Utility of Satellite Observations in Improving Air-Quality Predictions

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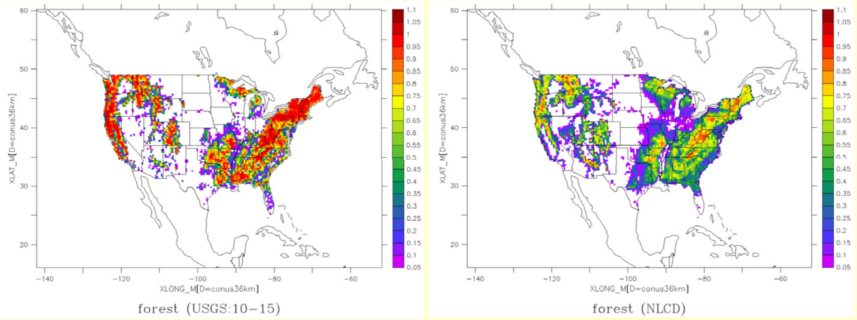
Motivation

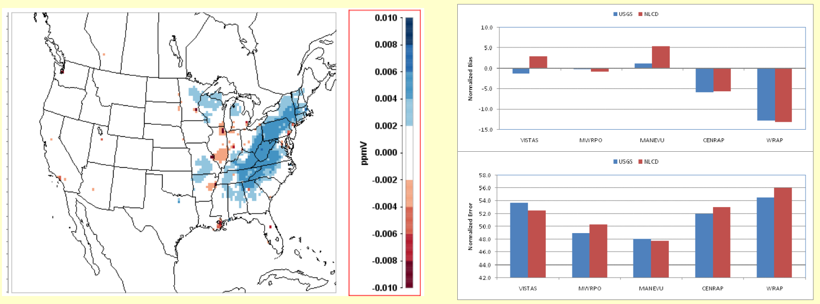
Air Quality Models are being widely used to inform public policy at various tiers of government. Their expanded use roughly coincides with rapid technological advancements in computer technology, and development of four-dimensional data assimilation techniques within mesoscale meteorological models. In the coming decade, availability of remotely sensed observations from space will propel further improvement in these systems. The most pressing research needs include better characterization of land surface dynamics and cloud-aerosol interactions. For air quality forecasting operations, data assimilation techniques that ensure more accurate characterization of land surface properties and dynamics will have a lasting impact on the model forecasts, while the use of land and satellite-based observations to bring about a better representation of the initial atmospheric state will improve the short term predictions.

Here we present few highlights of our ongoing research on the use of satellite observations aimed at improving model predictions in the retrospective mode. We demonstrate that the use of satellite observations reduces model uncertainties. Such improvements in the spin-up period can improve air quality forecasts.

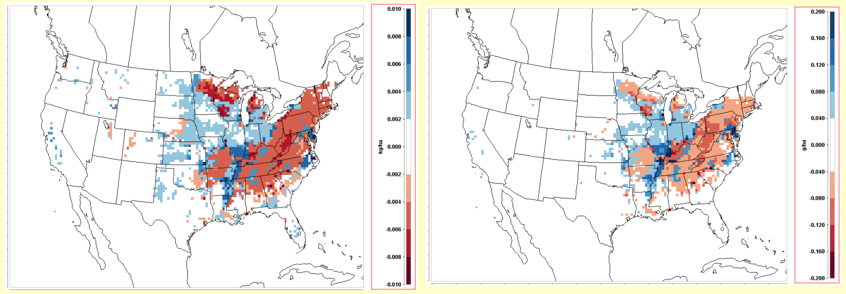
Impact of land surface characterization on air quality model predictions



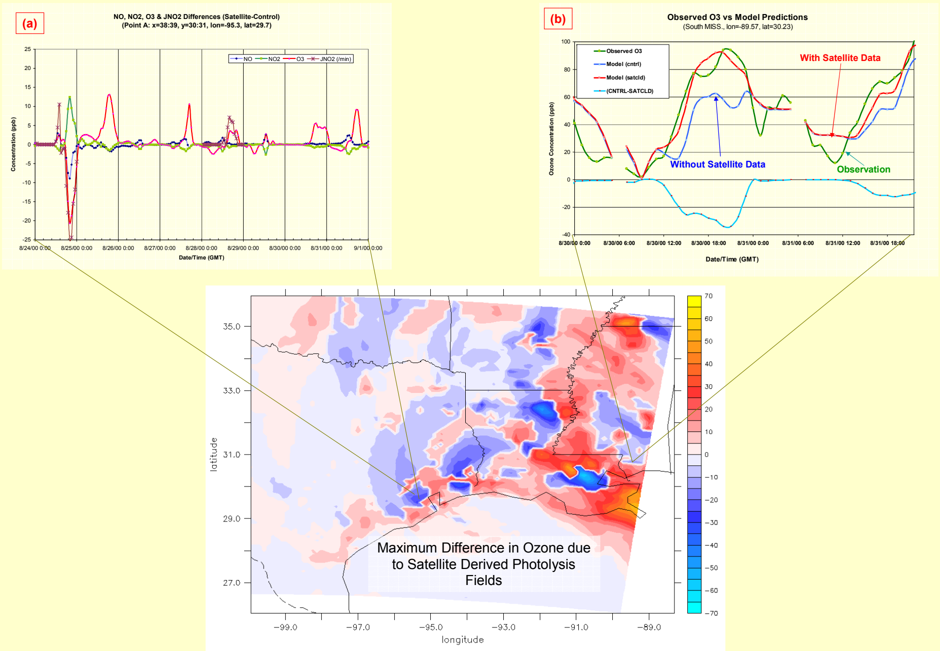
- Fractional land use/land cover at 36-km grid resolution over the CONUS domain as represented in USGS (left) and National Land Cover Datasets (NLCD) (right). NLCD suggests large spatial heterogeneity in forest cover compared to USGS



- Difference in monthly (August, 2006) mean ozone concentrations. Meteorological fields for these CMAQ simulations were produced using WRF modified to ingest NLCD dataset. Differences are shown above as monthly average ozone concentration using WRF-NLCD minus WRF-USGS fields. Change in land cover results in higher ozone concentration over forested area, and lower ozone concentration in cities.

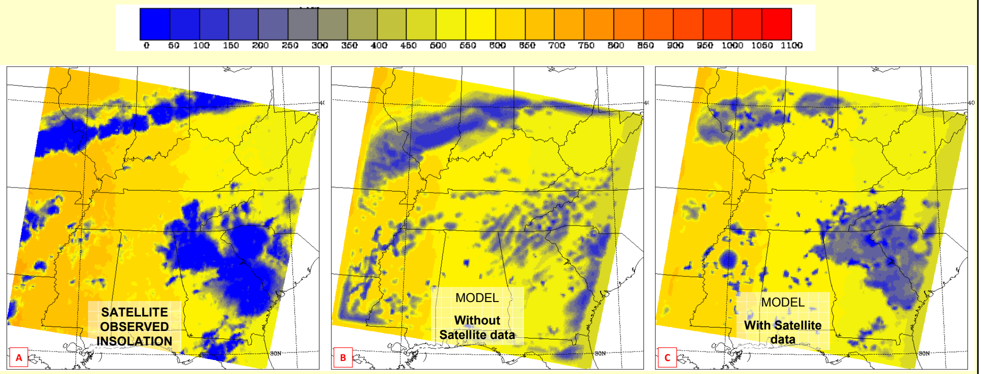


- Difference in monthly (August, 2006) mean ozone (left) and PAN (right) dry deposition. Meteorological fields for these CMAQ simulations were produced using WRF modified to ingest NLCD dataset. Differences are shown above as monthly average dry deposition predicted using WRF-NLCD minus WRF-USGS fields. Denser forest cover suggested in the USGS datasets causes CMAQ to predict higher deposition of these species, and lower atmospheric concentrations.



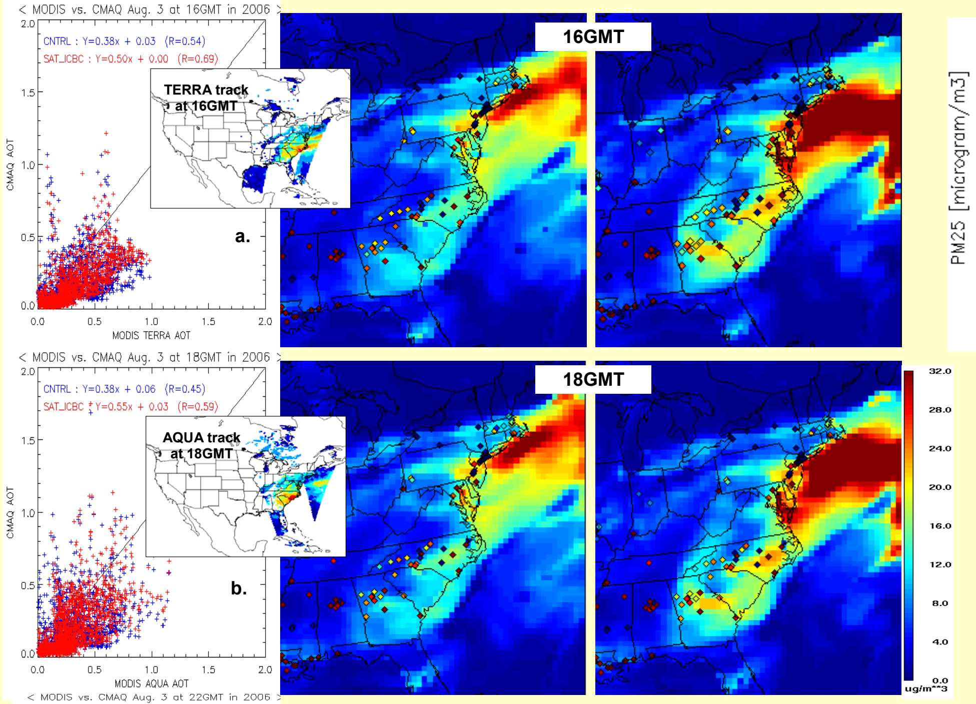
- Differences in ozone between two CMAQ runs with and without use of satellite derived photolysis fields. Note the maximum differences exceed 50 ppb. Inserts show **(a)** corresponding NO, NO2, O3, and JNO2 differences between the two model simulations over Houston-Galveston-Bay area , and **(b)** time series of ozone prediction from the model vs. observations at an EPA monitoring site in South Mississippi.

Use of GOES observations to correct photolysis rates for radiative impact of clouds and correcting model cloud fields in a dynamically consistent manner

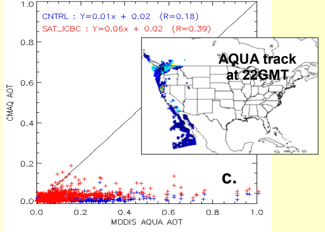


- Based on GOES observations and internal model statistics of key convective parameters, a target vertical velocity is identified and model wind fields are adjusted to achieve the target vertical velocity. Figures show downward shortwave radiation in W m^{-2} at 2200 UTC, 6 July 1999. (A) Derived from GOES–8 satellite. (B) Control run with no assimilation. (C) Run with assimilation of satellite cloud information.

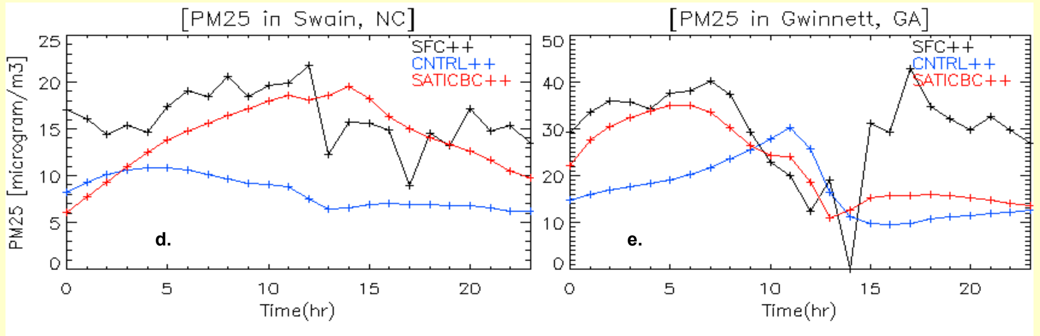
Improved PM2.5 model predictions using MODIS AOD



Baseline **Initialized using MODIS**



- Using MODIS AOD improved model predictions of PM$_{2.5}$, especially, in the Eastern U.S. (Figures a and b). Figure c shows small improvement even in West US regions in spite of low correlation



- Figures present time series of PM$_{2.5}$ mass concentration from surface observation (black), baseline CMAQ (blue), and CMAQ simulation utilizing MODIS data (red) for Swain in North Carolina and Gwinnett in Georgia.

Conclusion

1. Satellite data can improve the initial atmospheric state used in air quality forecasting.

2. Use of MODIS AOD for CMAQ initialization improved model predictions of PM2.5 in the eastern U.S.

3. Model predictions using MODIS AOD better represented diurnal variation of PM2.5 when compared to surface monitors.

4. Model evaluation at Gwinnett site shows the significance of initial condition to short term forecasting, as the use of MODIS data improves the model performance in the first 15 hours of simulation.

5. Use of NLCD data resulted in higher ozone concentration over forested regions in the eastern United States. This is due to lower dry deposition of ozone and nitrates over forested areas when NLCD is used.

6. Assimilation of GOES cloud observations can substantially improve ozone predictions when/where the meteorological model fails to predict clouds correctly.

7. Dynamical assimilation of clouds will allow to address several significant sources of uncertainty in the model by correcting the errors in the dynamical fields, as well as reducing errors in emissions and chemistry.

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