Uncertainty analysis of National Emission Inventory 2005 over the US by utilizing top-down approach

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Goals: Analyzing Uncertainty of National Emissions Inventory 2005 NO_X emissions

- Today, EPA's National Emission Inventory (NEI) 2005 is widely used in the global and regional chemical transport models (CTMs) for model simulation over the United States. The NEI 2005 was produced by a bottom-up approach to estimate an emissions inventory, which could have a large uncertainty of 0.3 to a factor of two (e.g., Napelenok et al., 2008).

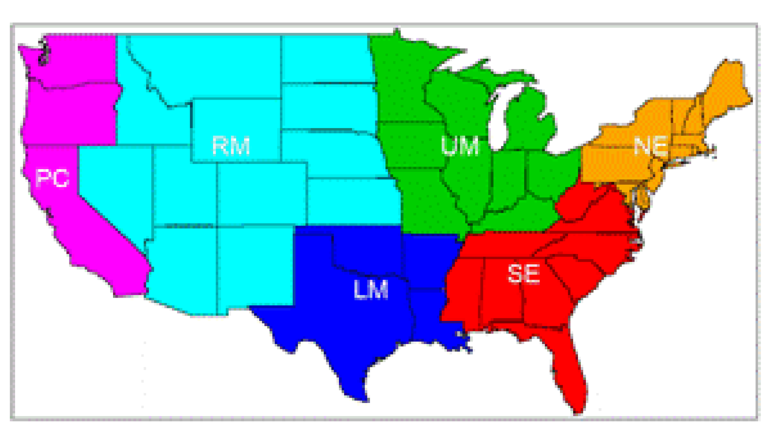
- Several previous studies have showed the feasibility of utilizing satellite column for yielding a better NO_x emissions inventory with the consideration of a uncertainty of top-down satellite retrieval products and/or bottom-up emissions inventory for global CTMs (e.g., Martin et al., 2003; Jaegle et al., 2005) and regional CTMs (e.g., Choi et al., 2008; Napelenok et al., 2008; Chai et al., 2009). Additionally, the other studies about NO_x emissions inventory of EPA's National Emissions Inventory (NEI) 2005 have focused on investigating the change of the amount of NO_2 columns caused by NO_x emission regulation over the eastern US (e.g., Kim et al., 2006; Choi et al., 2009) or extreme weather over coastal urban regions near the Gulf of Mexico (e.g., Yoshida et al., 2010).

- One possible reason for disagreement between simulated and observed NO_x is an error in emissions – here we test that hypothesis.

Approaches: the Community Multi-scale Air Quality (CMAQ) model version 4.7.1 and satellite resources

1. Model Setup and Method

- Time period: August 2009 (the greatest O_3 biases from NOAA National Air Quality Forecasting Capability (NAQFC) were shown during 2007 through 2009)
- Version : CMAQ4.7.1 (12km with 22 vertical layers to 100 hPa)
- In this study, we modify NO_x emissions inventory with the assumption of the proportionality of NO_x emissions to NO_2 column density. After performing a simulation with modified NO_x emissions derived from the comparison of GOME-2 and CMAQ NO_2 column densities, we investigate how the changed NO_x emissions affect simulated surface NO_x concentrations at EPA's AQS stations over six geological regions. Instead of performing this analysis at local scale, we analyze the uncertainty of NEI 2005 NO_x emissions inventory over six geological regions (at regional scale), in order to avoid a uncertainty caused by chemical transport and chemical lifetime at the local scale.



Six geological regions: PC, RM, LM, UM, SE and NE

2. Measurements

2.1 Satellite measurement

- Satellite NO_2 column density: from GOME-2 sensor on EUMETSAT MetOp-A satellite
- GOME-2 NO_2 column products (http://www.temis.nl/airpollution)

2.2 In-situ ground measurement

- Hourly NO_x data: 265 US EPA's AQS stations
- Hourly O_3 data: 1100 US EPA's AQS stations

Results:

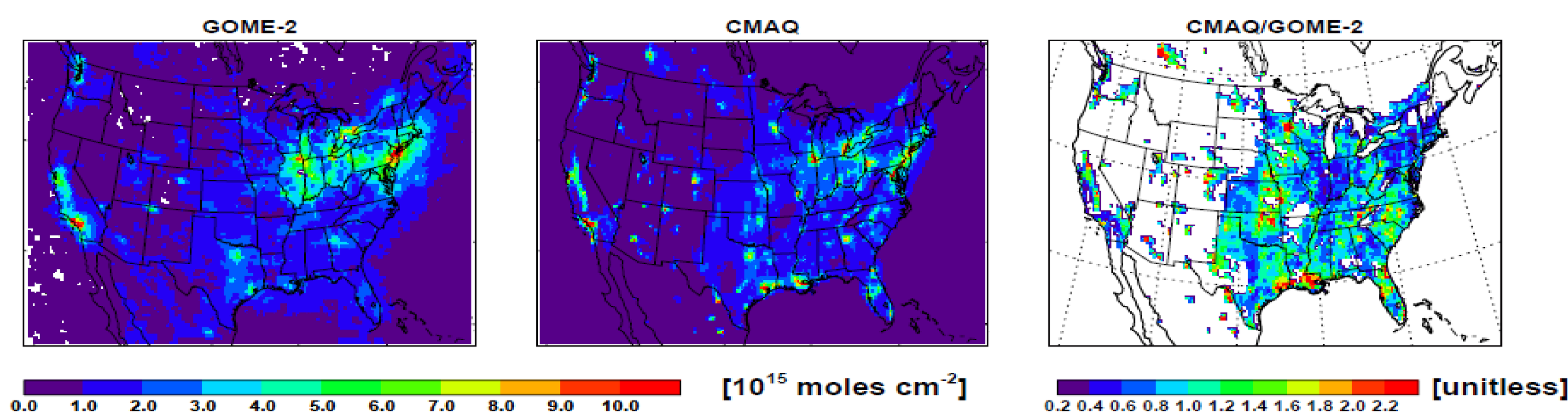


Fig1. The monthly-averaged NO_2 column density from GOME-2 and CMAQ and the ratio of two column data for August 2009.

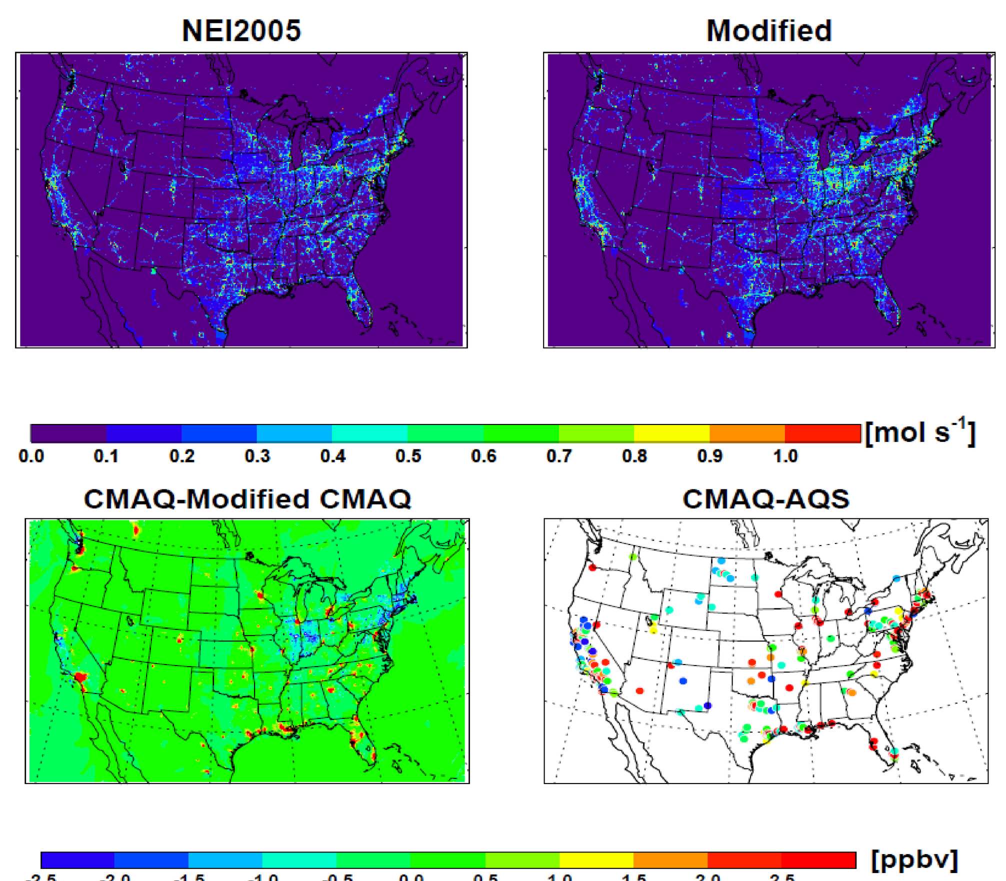


Fig2. Monthly-averaged NO_x emissions (in unit mol s^{-1}) from EPA NEI 2005 (upper left panel) and its modified emission inventory (upper right panel) using the ratio of CMAQ NO_2 column density to GOME-2 NO_2 column density (Figure 1), the difference of surface NO_x concentrations between baseline CMAQ and CMAQ with the modified emissions inventory (lower left panel), and the difference of surface NO_x concentrations between baseline CMAQ and corresponding EPA's AQS observations (lower right panel).

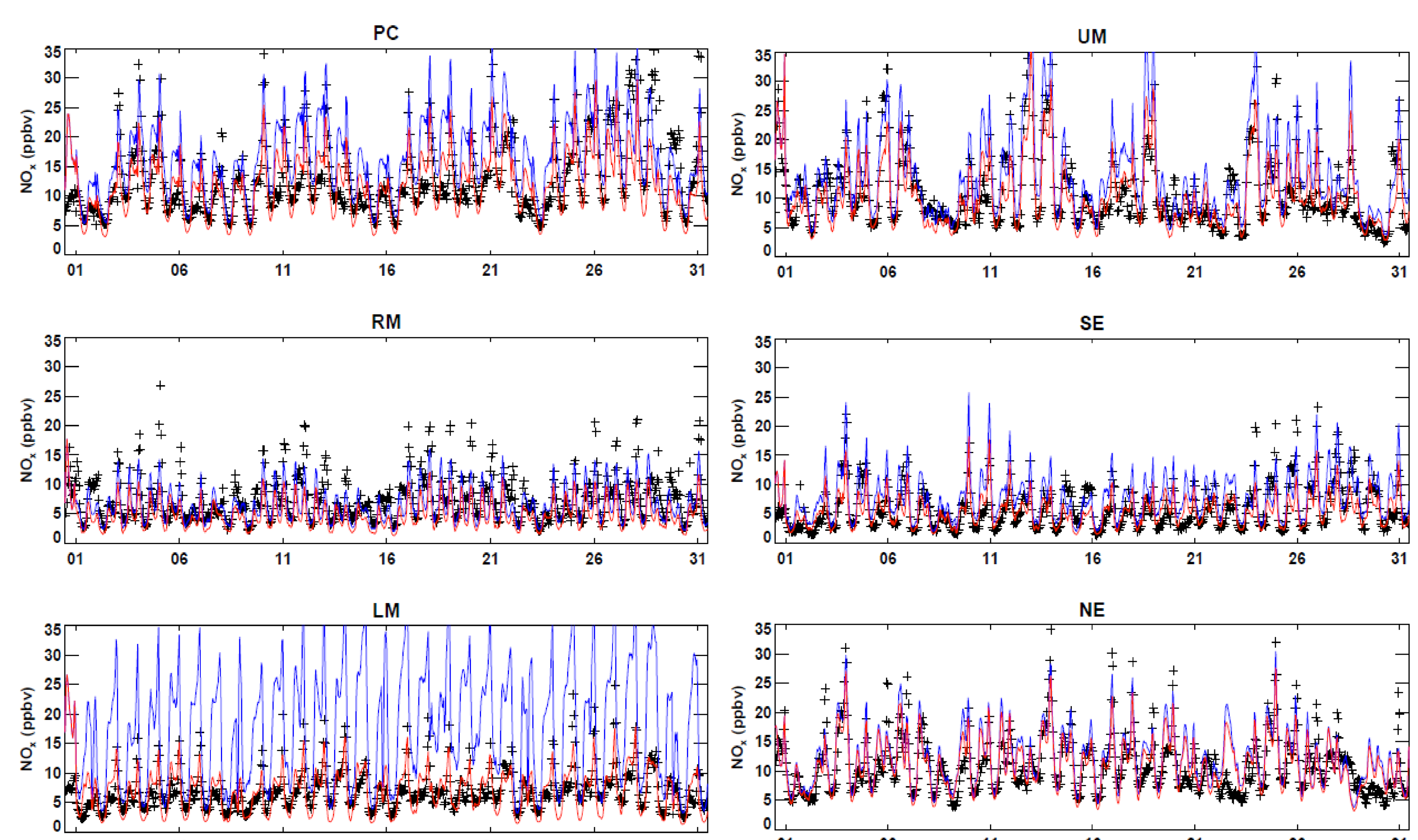


Fig.3 Surface NO_x concentrations from EPA's AQS stations (black crosses), baseline CMAQ simulation results (blue colored), and CMAQ simulation results utilizing modified NO_x emissions inventory (red colored) for August 2009.

Results con.:

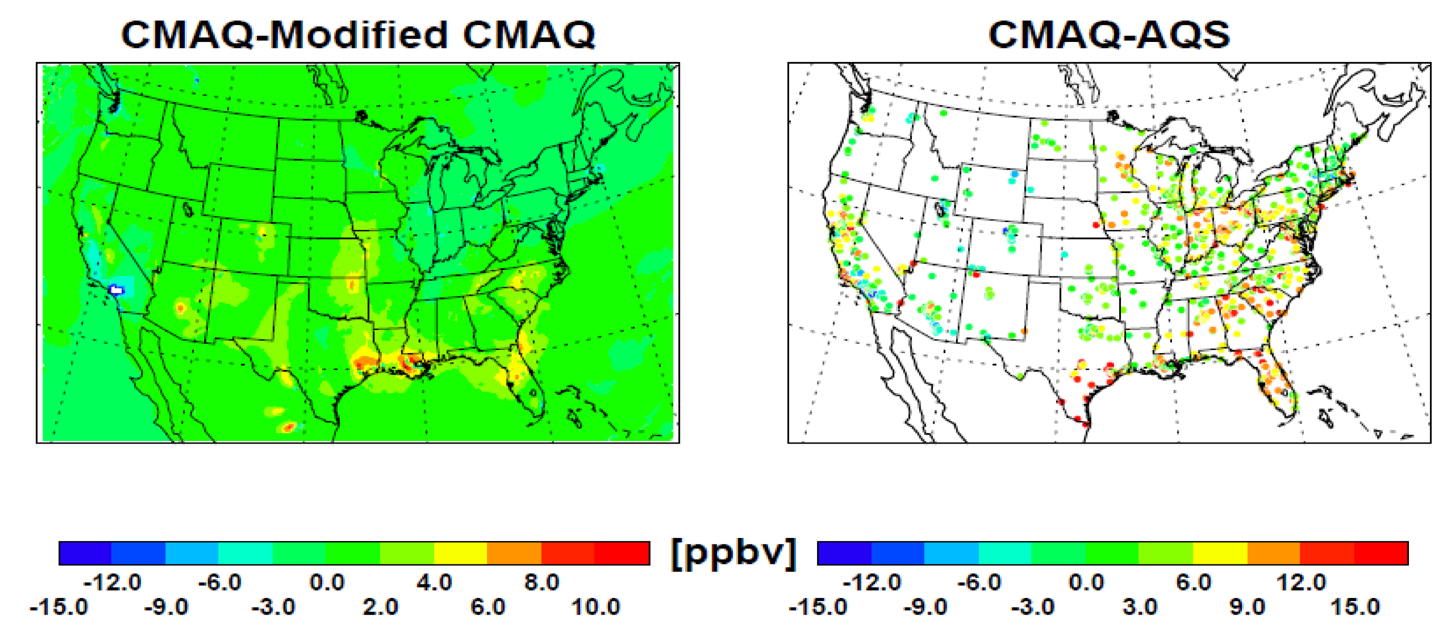


Fig 4. The difference of surface O_3 concentrations between baseline CMAQ model and CMAQ simulation results by utilizing modified NO_x emissions (left panel), and between baseline CMAQ model and EPA's AQS measurement stations (right panel).

Conclusions:

Simulation results from the Community Multiscale Air Quality (CMAQ) model version 4.7.1 over the Conterminous United States (CONUS) for August 2009 are analyzed to evaluate EPA's National Emissions Inventory (NEI) 2005 over six geological regions (i.e., Pacific Coast=PC, Rocky Mountain=RM, Lower Middle=LM, Upper Middle=UM, Southeast=SE, and Northeast=NE). The NO_x emissions from NEI 2005 are simply scaled by comparing the Global Monitoring Experiment 2 (GOME-2) and CMAQ NO_2 column. There is noticeable more significant emissions reduction over the LM US as compared to other regions. With the emissions reduction, more than 50% of surface NO_x concentrations are reduced and the reduced NO_x concentrations are as much as those from EPA's AQS stations over the region. Further, CMAQ with scaled NO_x emissions better captures in-situ observed daytime (1-5 PM, local hour) O_3 concentrations from the measurements over the LM US. The model predicted monthly-averaged daytime surface O_3 concentrations decreases significantly by up to 10 ppbv with the modified emissions, particularly over neighboring areas of Houston in Texas, New Orleans in Louisiana, and Tampa and Jacksonville in Florida. These results imply that NO_x emissions inventory from EPA NEI 2005 has a large uncertainty and overpredicts NO_x emissions over the southern US.

ACKNOWLEDGEMENTS

This work is dedicated to the memory of Dr. Daewon Byun (1956-2011), whose leadership and pursuit of scientific excellence as the leader of the NOAA Air Resources Laboratory (ARL) Air Quality Group continue to inspire us. We also acknowledge the free use of tropospheric NO_2 column data from the GOME-2 sensor from www.temis.nl.

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