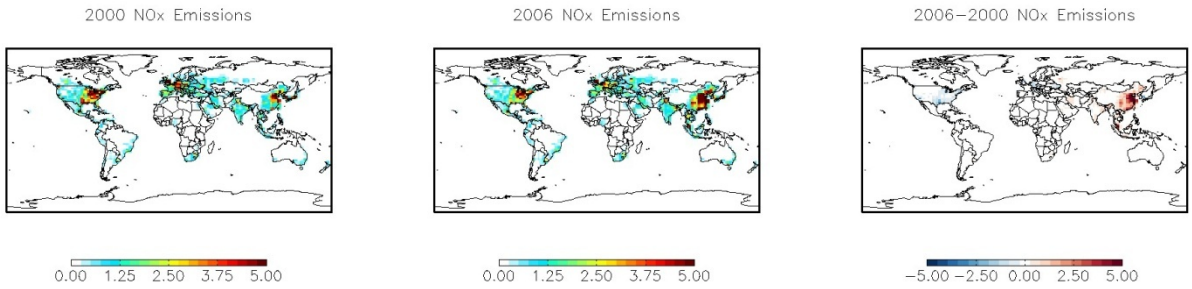
Consistent MERRA-Trace Gas Distributions: Summary of Achievements

Development of consistent MERRA-atmospheric trace gas distributions in part of the Progress towards and Integrated Earth System Analysis (PIESA) project. We describe several milestones achieved in developing consistent trace gas distributions. These include the development and testing of trace gas emissions, an examination of the impact of horizontal resolution, and model validation against observations. We also describe preliminary results of the replay simulation.

1. Emission specification and documentation

Emissions vary from year to year and are an important driver of inter-annual variability. Year-specific emissions are therefore an important component of this multi-year simulation of trace gas distributions. The first stage of this project was to update the emission inputs to the GEOS5 CCM to represent the current state of scientific knowledge and to include year to year variability in the fossil fuel emissions. The updated emissions are documented in detail on the GEOS5 Wiki and summarized here.

We updated the emission inputs based on methods and inventory data provided by the Harvard GEOS-Chem modeling group. This includes annual scaling factors (*Van Donkelaar et al.*, 2008) that we apply to the global and regional inventories to scale them from the inventory year to the simulation year. The figure below shows the updated fossil fuel NOx emissions for 2000, 2006, and the change between 2000 and 2006. The increase in East Asian emissions and decrease in U.S. emissions over this time period are evident.



The emissions are based on a global inventory overwritten with regional inventories where available, with annual and seasonal scaling factors. We developed an IDL program to combine the inventories and scaling factors offline and generate a single emission file as required by the CCM.

We tested the model with the updated emissions by conducting two sets of multi-year GCM simulations, one with 2000 emissions and one with 2005 emissions. Comparing the two sets of simulations, we find that ozone concentrations increase in East Asia and decrease in the eastern United States in 2005 compared to 2000. This is consistent with change in the emissions of ozone precursors.

Another finding from the GCM experiments with the updated emissions was the need to remove ship emissions of NO_x. While ships contribute less than 10% of the NO_x emissions, they play an exaggerated role in ozone formation in the model because the model does not include ship plume chemistry. This excess ozone formation leads to high OH concentrations that in turn lead to a negative bias in CO compared to observations. Consequently, we removed ship NO_x emissions in subsequent experiments.

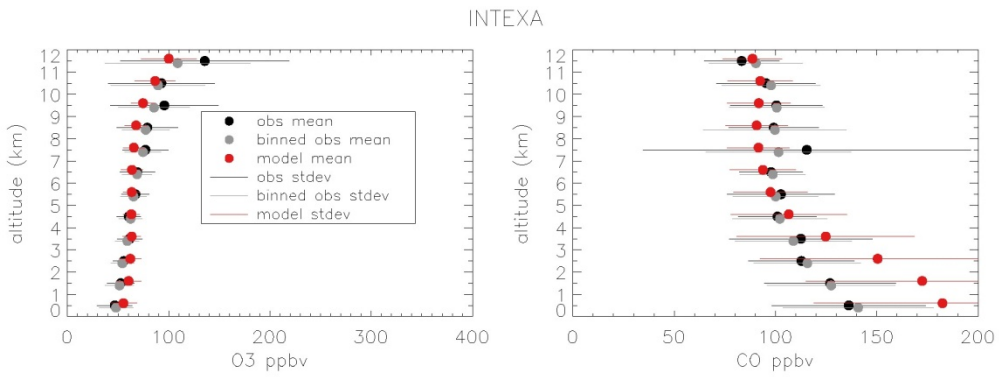
2. Impact of horizontal resolution

The simulations described in section 1 had a horizontal resolution of 2x2.5 degrees. To determine the impact of horizontal resolution, we also conducted a GCM simulation at 1x1.25 degrees. We used the same 2005 emission as in the 2x2.5 degree simulation, except that the resolution of the emissions was increased to match the model grid.

The trace gas distributions in the 1x1.25 degree simulation were similar to those of the lower resolution simulation, and the bias due to ship emissions remained. One feature that improved in the higher resolution simulation was the outflow of CO from South America over the tropical Pacific, which is too high in the model. Additional years of simulation would be valuable for testing the robustness of this finding.

3. Model validation against observations

We conducted a time-dependent simulation from 2001-2004 using Fortuna-2_1 in GCM mode with the GMI combo chemistry, the updated emissions specific to each year of the simulation, and the aerosols coupled to GOCART. We compared the model to ground-based, aircraft, and satellite observations to validate the model performance. The following figure shows a comparison of the model to observations from the DC8 aircraft during the 2004 INTEX-A campaign (*Singh et al.*, 2006) over North America.



Overall, the tropospheric trace gas distributions of CO, NO_x, and ozone look reasonable compared to observations. We have also identified some areas for future improvement, such as a positive bias in CO concentrations over United States and excessive outflow of biomass burning CO from South America to the Pacific.

4. Preliminary results from replay simulations

We conducted a simulation for 2001-2003 using the model configuration described in section 3, but replayed to the MERRA analysis in the intermittent replay mode. We identified several major issues with the results of this simulation. In the early part of the simulation, the peak concentration in stratospheric ozone exceeded the peak concentration present in the free-running GCM and in a previous simulation with the MERRA model replayed to the MERRA analysis, while ozone concentrations in the lower stratosphere were much lower than in the free-running GCM. The second issue occurred later in the simulation, with ozone concentrations throughout the stratosphere and troposphere dropping to unrealistic levels. Other tracers were impacted by the second issue as well.

We are currently testing several possible solutions to the replay issues. These include removing a replay-specific mass adjustment, using a later Fortuna-2_1 tag, and running Pchem along with the GMI chemistry to use for the radiation. Preliminary results from removing the mass adjustment show improved comparison with the free-running GCM.

5. Summary

We have achieved several important steps in developing consistent MERRA-trace gas distributions. We now have the ability to include year-specific anthropogenic emissions in a multi-year model simulation. Model simulations using these emissions show reasonable agreement with observations.

We validated the simulation against surface, aircraft, and satellite observations with a focus on CO, NO_x, and ozone. We have also identified areas in which we could improve the model in the future to further refine the trace gas distributions.

6. References

Singh, H. B., W. H. Brune, J. H. Crawford, D. J. Jacob, and P. B. Russell (2006), Overview of the summer 2004 Intercontinental Chemical Transport Experiment–North America (INTEX-A), J. Geophys. Res., 111, D24S01, doi:10.1029/2006JD007905.

van Donkelaar, A., R. V. Martin, W. R. Leaitch, A.M. Macdonald, T. W. Walker, D. G. Streets, Q. Zhang, E. J. Dunlea, J. L. Jimenez, J. E. Dibb, L. G. Huey, R. Weber, and M. O. Andreae (2008), Analysis of Aircraft and Satellite Measurements from the Intercontinental Chemical Transport Experiment (INTEX-B) to Quantify Long-Range Transport of East Asian Sulfur to Canada, Atmos. Chem. Phys., 8, 2999-3014.