On the Linkage of Global and Regional Models to Assess Climate Change–Air Quality Interactions

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2009 AMAD Peer Review: Session 4
Climate Change and Air Quality Interactions

Environmental Issue

Air quality is known to be highly sensitive to meteorological conditions, including temperature, precipitation frequency, and atmospheric stability. Air quality management plans have traditionally been developed using recent meteorology, yet emission controls are implemented over several decades. Climate change could potentially affect the efficacy of emission control strategies designed to meet the National Ambient Air Quality Standards.

Research Objectives

The Division's Climate Impact on Regional Air Quality (CIRAQ) research program was developed as part of the USEPA/ORD national air quality and climate assessment. Given the risks that future climate could impose on air quality management, the project has focused on these questions:

- How might climate change impact future U.S. air quality?
- How might climate change impact the effectiveness of emission control strategies (i.e., what is the "climate penalty")?
- What co-benefits exist for air quality and climate?

Modeling Approach

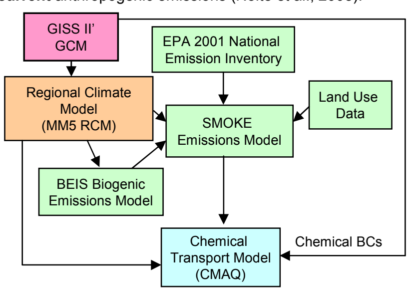
Figure 1. Collaborations were established with academic and federal partners to link global and regional models for this pilot study:

Global Climate: Goddard Institute for Space Studies (GISS) II' 4° × 5° following IPCC A1B scenario (Mickley et al., 2004).

Global Chemistry: Harvard unified chemistry model driven by GISS II' GCM A1B (Mickley et al., 1999)

Regional Climate: MM5 regional-scale (36km × 36km, continental U.S.) downscaling from GISS II' A1B (Leung and Gustafson, 2005; Gustafson and Leung, 2007).

Regional Air Quality: Community Multiscale Air Quality (CMAQ) model for current and future (ca. 2050) climate + **current** anthropogenic emissions (Nolte et al., 2008).



These results contributed to a model inter-comparison (NCEA, 2007; Weaver et al., in review) discussed in Poster 4.2.

Evaluation under Current Climate

Summer (Jun-Aug) Surface Temperature

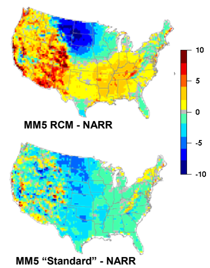


Figure 2. Summer temperature (18Z) comparisons between the MM5 regional climate simulation (Leung et al., 2005) and NARR reanalysis data (1996-2003). A "standard" MM5 simulation (2001-2006) with analysis nudging shows much smaller regional biases.

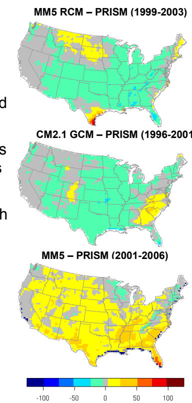


Figure 3. Summer precipitation predictions versus PRISM gridded observations shows:

- ♦ MM5 regional climate scenarios under-predict precipitation across much of the U.S.
- ♦ These biases are similar to high resolution (50km × 50km) CM2.1 global climate model (Stouffer et al., 2006) simulations.
- ♦ Precipitation biases in the "standard" MM5 simulation have larger over-predictions, perhaps related to convective scheme options.

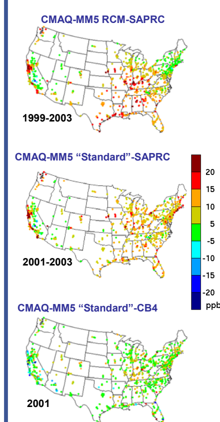


Figure 4. Maximum daily 8-hour average (MDA8) O_3 predictions are compared to observations. CMAQ results using the MM5 climate scenario, the MM5 "standard" simulation, SAPRC and CB4 chemical mechanisms show:

- ♦ SAPRC99 results in O_3 high biases, regardless of MM5 regional climate scenario or "standard" MM5 meteorology (top, middle).
- ♦ CB4 O_3 predictions agree better with observations (bottom).

SAPRC's O_3 response to meteorological variability has evaluated better than CB4's (Gilliland et al., 2008), suggesting that SAPRC may still be better for climate sensitivity studies.

Predictions under Future Climate

The following plots show differences (future – current) in CMAQ results with the MM5 RCM scenario and changes in boundary conditions and methane levels.

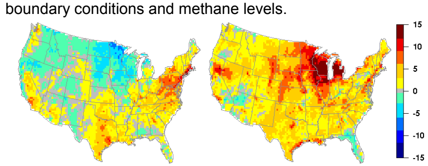


Figure 5. (Future – Current) 95th percentile MDA8 O_3 concentrations for summer (Jun-Aug) and fall (Sep-Oct). Larger Sep-Oct increases suggest lengthening of O_3 season.

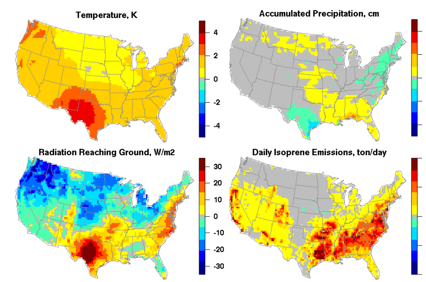


Figure 6. Differences (future – current) in average summer conditions. Temperature and surface solar radiation appear to be largest drivers of MDA8 ozone changes predicted above. At least for the SAPRC chemical mechanism used in CIRAQ, future ozone concentrations in the Southeast are not sensitive to isoprene emissions increases because that region is NO_x-limited.

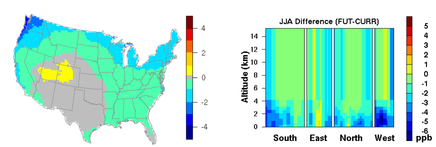
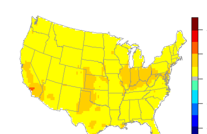


Figure 7. Model sensitivity tests for July 2048 show that boundary conditions under future climate contribute less O_3. This suggests that O_3 sensitivity results in Figure 4 would be even higher if boundary conditions had been constant.

Figure 8. MDA8 O_3 results for July 2048 with current CH_4 (1.85 ppm) versus 2050 IPCC A1B (2.40 ppm). CH_4 serves as a precursor to O_3 under higher NO_x conditions.



Conclusions

- MM5-GISS II' downscaled regional climate simulations show biases in temperature and precipitation
- Precipitation differences are smaller than seen in "standard" MM5 simulations
- Temperature and precipitation biases contribute to O_3 over-prediction biases; however, chemical mechanism has larger influence on over-predictions.
- Predictions suggest future climate could cause 95th percentile (i.e., 4th highest) MDA8 ozone increases of 10-15 ppb in some regions.
- Large MDA8 O_3 increases over the central U.S. for the months of September and October, suggesting a lengthening of the ozone season could occur.
- Future climate could lead to Increased frequency of ozone exceedances and increased severity of pollution episodes.
- Boundary conditions from global chemistry model have lower O_3 under future climate.
- O_3 increases under future climate would be even larger without accounting for global chemistry boundary conditions.
- Methane increases under IPCC A1B scenario contribute to larger O_3 background increases than biogenic emission increases.

Future Directions

- Develop alternate U.S. emissions projection scenarios.
- Develop alternate future climate simulations by using more advanced GCMs (with partners at NOAA/GFDL and NASA/GISS) under different greenhouse gas scenarios.
- Investigate alternative downscaling techniques with the Weather Research and Forecasting (WRF) model.
- Use WRF-CMAQ coupled climate and chemistry model to investigate feedbacks of future emission scenarios on radiative budget.

Impact

- This research has contributed to the EPA/NCEA Interim Assessment and the Climate Change Science Program Synthesis and Assessment Product 3.2.
- EPA's Office of Air Quality Planning and Standards is developing plans to take climate change into account in devising future regulations.

Contributors/Collaborators

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