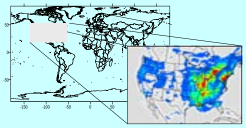
Examining the Impact of Climate Change and Variability on Regional Air Quality over the U. S.

Ellen Cooter*, Robert Gilliam*, Alice Gilliland*, William Benjey*, Jenise Swall* and Chris Nolte*
ASMD/ARL/NOAA/RTP

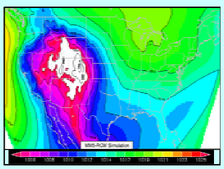
*In partnership with the U.S. Environmental Protection Agency, Office of Research and Development, National Exposure Research Laboratory

Global to Regional Linkages

NASA GISS II' GCM simulations were developed using the Intergovernmental Panel on Climate Change (IPCC) moderate A1B SRES greenhouse gas emission scenario: Rapid economic growth and globalization; Balance between fossil fuel and other energy sources. Intercontinental transport of chemical species such as aerosols or ozone can contribute to background concentrations; therefore, future climate scenarios should have a similar impact on both the meteorology and hemispheric scale air quality. Global chemical transport model (CTM) simulations, driven by the GISS II' A1B scenario for consistency, were completed by Harvard University and Carnegie Mellon for ozone and aerosol chemistry.



The GISS II' GCM results were used as initial and boundary conditions for the Penn State/UCAR Mesoscale Model (MM5). MM5 "downscaled" simulations were developed for 10 years current and 10 years into the future (~2050) for the continental United States at 36 km x 36 km horizontal grid resolution *(Ruby Leung, DOE/PNNL)*. EPA and DOE scientists then explore these scenarios to identify biases and to quantify uncertainty on temporal and spatial scales that are relevant to regional and national air quality assessment (e.g.blue panel)



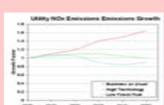
Mean (10-years) summer season surface sea-level pressure derived from the downscaled GISS present-day climate *[source: EPA/NERL]*

Current and Future Anthropogenic Emissions

The response of mobile source emissions of NO_x, NO_2, and SO_2 to temperature is simulated using the MOBILE6 emissions model. These gaseous mobile source emissions show less interannual variability with respect to temperature than biogenic emissions because of temporal and spatial averaging of the climate data and other non-meteorological influences. Emissions that do not directly respond to climate conditions are represented by a 2001 modeling version of the EPA National Emissions Inventory. A Phase I study will use this same inventory for both current and future time periods to assess the importance of climate-driven as opposed to technology-driven emissions change.

Diurnal patterns and interannual variability of one gaseous mobile emission component modeled by MOBILE6. The red line includes 5 years of GISS downscaled present day weather data for the eastern U.S. The blue line includes 5 years of western U.S. downscaled weather data. Both regions show strong diurnal, but little or no interannual variability.

Scientists from the EPA National Risk Management Research Laboratory are developing one or more future year U.S. technology scenarios for input to CMAQ. A Phase II CMAQ study planned for completion in 2010 will revisit future air quality results using these or other alternative emission scenarios.



Examples of Regional Climate Model Scenario Analyses

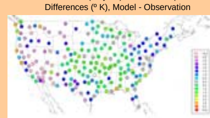
Regional Climate Model Uncertainty and Variability

How well do regional climate scenarios represent current climate conditions?

Summertime temperature is an important factor for the production of ozone. Aerosols formed secondarily in the atmosphere, such as sulfate and nitrate aerosols, also have a very pronounced seasonal variation with sulfate concentrations highest (lowest) in the summer (winter) and nitrate concentrations highest (lowest) in the winter (summer).

Comparison of GISS downscaled regional climate scenario mean spring and summer (shown below) temperatures show temperature differences that, with the exception of far western locations, are within the range of natural variability. Agreement is not as good for fall and winter season comparisons.

Mean Summer (10 year) 2 meter Temperature Differences (º K), Model - Observation

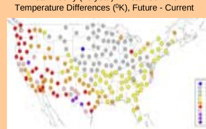


Locations at which 2 meter Summer Temperature Differences are Statistically Significant

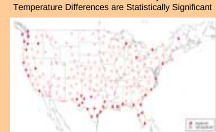
Should we expect to see temperature changes 50 years into the future?

Downscaled GISS GCM mean summer temperatures, are projected to increase throughout the U.S., but when variability is considered, most increases are not statistically significant. Future fall and winter temperature changes are highly variable, with some locations showing up to 10 ºK warming, while other locations show temperatures up to 10 ºK cooler. Nearly all winter and fall future temperatures changes appear to be statistically significant.

Mean Hourly (10 year) 2 meter Summer Temperature Differences (ºK), Future - Current



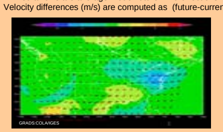
Locations at which 2 meter Hourly Summer Temperature Differences are Statistically Significant



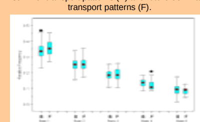
Might patterns of pollutant transport change 50 years in the future?

Future dominant atmospheric transport patterns at 700mb (~3000m) that reflect surface weather conditions and steer pollutant transport may look nearly the same as they do today, but may occur at different frequencies. During the summer (graphs below), such changes could impact the development, frequency and persistence of extreme (poor) air quality events.

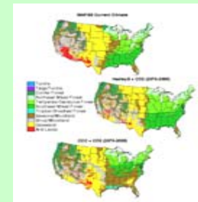
Black arrows are average model current wind directions. Red arrows are average model future wind directions. Velocity differences (m/s) are computed as (future-current).



Relative frequency distributions for current dominant summer transport patterns (B) and future dominant transport patterns (F).



Vegetation Change

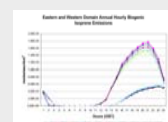


Potential distribution simulated by MAPSS, an equilibrium vegetation model, for current and for future (2070-99) climate conditions predicted by the Hadley (HadleyS) and Community Climate Model (CCC).
[Source:http://www.fs.fed.us/pnw/corvallis/mdr/mapss/]

Collaborators at the USDA Forest Service Pacific Northwest Research Station are using a 75 year continuous timeseries of downscaled climate scenarios, produced from the Parallelized Community Climate model supplied by scientists at DOE's Pacific Northwest National Laboratory, as input to a dynamic biogeochemical vegetation model (MC1) to consider the possible response of natural vegetation to projected climate changes. EPA scientists are exploring the impact of these projections on future biogenic emissions change and variability.

Biogenic Emissions

The influence of temperature change and variability on biogenic emissions are modeled using BEIS 3.13 within SMOKE 2.1. The average annual biogenic emissions using GISS downscaled current climate for anthropogenic and non-anthropogenic sources, are significantly higher in the eastern U.S. (EY#) than the western U.S. (WY#). The inter-annual variability of biogenic emissions across 5 modeled weather years is small, particularly in the western U.S.



Air Quality Modeling

Regional air quality simulations are now under development using the USEPA Community Multiscale Air Quality (CMAQ) model. Meteorology inputs are provided by the PNNL downscaled GISS model output. Initial and boundary chemical conditions derive from Harvard University and Carnegie-Mellon research. CMAQ simulations will be completed for 1999-2003 and 2049-2053 for the continental United States at 36 km x 36 km horizontal grid resolution. To isolate model sensitivity to the climate scenario, the future CMAQ simulations will first be based on the 2049-2053 regional climate simulations and current emission scenarios. Emissions scenario(s) for 2049-2053 will then be included to consider the additional impact of changing emissions on future air quality.

CMAQ
One Atmosphere Model

- EPA Rulemaking for PM2.5 and Mercury (CAIR, CAMR)
- Used by CDC and States for environmental public health tracking
- The model of choice for many Regional Program Offices and States for preparing State Implementation Plans (SIPS)
- Widely used by the international community
- Used by NOAA for operational air quality forecasts

DISCLAIMER:

A portion of the research presented here is being performed under the Memorandum of Understanding between the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) and under agreement number DW13921548. This work constitutes a contribution to the NOAA Air Quality and Global Climate Programs. Although it has been reviewed by EPA and NOAA and approved for publication, it does not necessarily reflect their policies or views.