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Development and Evaluation of the 2-Way Coupled WRF-CMAQ Model

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A new 2-way coupled meteorology and air quality model composed of the Weather Research and Forecasting (WRF) model and the Community Multiscale Air Quality (CMAQ) model is being developed and tested by the Atmospheric Modeling and Analysis Division at the USEPA. The new model system runs as a single executable with 2-way data communication between the WRF and CMAQ components via IOAPI_3 buffer files. This design requires minimal changes to either model which allows for easy updating and maintenance of compatibility with the “off-line” system. The main purposes of the coupled model are: 1) to allow efficient frequent data exchange for high resolution (down to 1 km grid cell size) simulations, 2) to allow feedback of gases and aerosols from CMAQ to WRF where they can affect radiation and microphysics processes, 3) to allow for more integrated treatment of chemical and physical processes.

The direct effects of aerosols on shortwave radiation and the direct effects of tropospheric ozone on longwave (LW) radiation have been implemented in the CAM and RRTMG radiation schemes in WRF. A new Mie scattering algorithm has been developed for a wider range of wavelengths including LW. New model simulations of the 2-way WRF-CMAQ using the latest versions of both models have been evaluated for a summer month in the eastern US and an outbreak of wild fires in California in 2008. Comparisons between runs with and without direct feedbacks show significant impacts on solar radiation, 2-m temperature, PBL height, and ozone and PM2.5 concentrations, especially in areas affected by smoke plumes.

The 2-way WRF-CMAQ also includes an experimental implementation of indirect effects where aerosols from CMAQ are activated as cloud condensation nuclei which determine the droplet number concentration for the cloud microphysics model. The resulting effective droplet radius is used in the radiation model to compute cloud optical properties. The indirect effects are being tested by evaluation of cloud radiative forcing compared to satellite measurements.

The 2-way WRF-CMAQ is being evaluated for its ability to accurately represent changes in direct and indirect radiative forcing due to large emission reductions of aerosol precursors, such as SO_x and NO_x, over the last 20 years in North America and Europe. These emission reductions present a unique opportunity for testing coupled meteorology and chemistry modeling systems. This study involves 20 years of continuous simulation at high-resolution (12 km) over North America using historical emission inventories developed by the USEPA. Aerosol concentrations and ground based radiation measurements will be used for evaluation of model response to emissions trends.