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Application of WRF/Chem-MADRID in Europe: Model Evaluation and Aerosol-Meteorology Interactions

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Atmospheric aerosols can affect short-term meteorology and long-term climatology via various feedback mechanisms including direct effects through changing shortwave and longwave radiation and photolysis, semi-direct effects through altering planetary boundary layer meteorological processes and variables, and indirect effects via acting as cloud condensation nuclei (CCN) and affecting precipitation. Accurately simulating these feedbacks requires the use of online-coupled meteorology-chemistry models; among which the Weather Research and Forecast Model with Chemistry (WRF/Chem) represents the state-of-the-science.

In this work, WRF/Chem with the CB05 gas-phase mechanism and MADRID aerosol module is applied to Europe for January and July 2001 to examine the aerosol direct and indirect effects via various feedback mechanisms. Model simulations with and without aerosols are being conducted at a horizontal grid resolution of $0.5^\circ \times 0.5^\circ$ over Europe and $0.125^\circ \times 0.125^\circ$ over a nested domain covering France, Germany, Switzerland, and portions of Italy, Austria, Czech Republic, Slovenia, Croatia, and Poland, both with a vertical resolution of 23 layers. Anthropogenic emissions are based on the European Monitoring and Evaluation Programme (EMEP) expert inventory for 2001. Biogenic emissions are generated using an online biogenic module in WRF/Chem. Chemical initial and boundary conditions are provided by the NCSU's Global-through-Urban WRF/Chem (GU-WRF/Chem) that uses the same gas-phase chemical mechanism and aerosol module to ensure consistency across spatial scales. Model results are evaluated using available surface and satellite datasets and compared with results from an offline-coupled model, Polyphemus, which uses the same meteorological and chemical initial and boundary conditions and emissions as WRF/Chem. The European surface networks include EMEP, the European Air quality dataBase (AirBase), the "Base de Données de la Qualité de l'Air" (BDQA, the French Database for Air Quality). Satellite datasets include the Measurements Of Pollution In The Troposphere (MOPITT), the Global Ozone Monitoring Experiment (GOME), the Total Ozone Mapping Spectrometer/the Solar Backscatter Ultraviolet (TOMS/SBUV), and the MODerate resolution Imaging Spectroradiometer (MODIS). Seasonal variations in simulated gaseous and aerosol concentrations as well as aerosol direct, semi-direct, and indirect feedbacks are analyzed and contrasted with those previously simulated over North America and Asia. Major challenges in accurately representing these feedbacks along with recommendations for future development and improvement of online-coupled models are discussed.