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WRF-CMAQ two-way coupled system with aerosol feedback: software development and preliminary results

D. C. Wong[1], J. Pleim[1], R. Mathur[1], F. Binkowski[2], T. Otte[1], R. Gilliam[1], G. Pouliot[1], A. Xiu[2], J. O. Young[1], and D. Kang[3]
[1]US Environmental Protection Agency, Research Triangle Park, NC, USA
[2]University of North Carolina, Chapel Hill, NC, USA
[3]Computer Sciences Corporation, Research Triangle Park, NC, USA

Abstract. Air quality models such as the EPA Community Multiscale Air Quality (CMAQ) require meteorological data as part of the input to drive the chemistry and transport simulation. The Meteorology-Chemistry Interface Processor (MCIP) is used to convert meteorological data into CMAQ-ready input. Key shortcoming of such one-way coupling include: excessive temporal interpolation of coarsely saved meteorological input and lack of feedback of atmospheric pollutant loading on simulated dynamics. We have developed a two-way coupled system to address these issues. A single source code principle was used to construct this two-way coupling system so that CMAQ can be consistently executed as a stand-alone model or part of the coupled system without any code changes; this approach eliminates maintenance of separate code versions for the coupled and uncoupled systems. The design also provides the flexibility to permit users: (1) to adjust the call frequency of WRF and CMAQ to balance the accuracy of the simulation versus computational intensity of the system, and (2) to execute the two-way coupling system with feedbacks to study the effect of gases and aerosols on short wave radiation and subsequent simulated dynamics. Details on the development and implementation of this two-way coupled system are provided. When the coupled system is executed without radiative feedback, computational time is virtually identical when using the Community Atmospheric Model (CAM) radiation option and a slightly increased (~8.5%) when using the Rapid Radiative Transfer Model for GCMs (RRTMG) radiation option in the coupled system compared to the offline WRF-CMAQ system. Once the feedback mechanism is turned on, the execution time increases only slightly with CAM but increases about 60% with RRTMG due to the use of a more detailed Mie calculation in this implementation of feedback mechanism. This two-way model with radiative feedback shows noticeably reduced bias in simulated surface shortwave radiation and 2-m temperatures as well improved correlation of simulated ambient ozone and $PM_{2.5}$ relative to observed values for a test case with significant tropospheric aerosol loading from California wildfires.

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