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Community Multiscale Air Quality (CMAQ) Modeling System

Innovative Science for a Sustainable Future

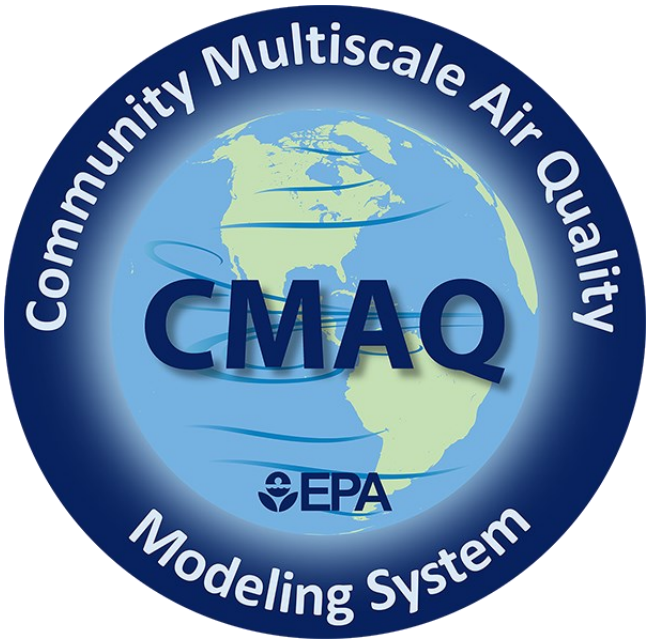
What is CMAQ?

The Community Multiscale Air Quality (CMAQ) Modeling System is EPA's premier modeling system for studying air pollution from global to local scales. For nearly a quarter century, EPA and states have used CMAQ—a powerful computational tool for translating fundamental atmospheric science principles to policy scenarios—to support air quality management. CMAQ is continually updated to incorporate new knowledge on the state-of-the science and use high performance computing power to characterize air quality more accurately and efficiently and to protect human health and the environment.

States use CMAQ to develop and assess implementation actions needed to attain National Ambient Air Quality Standards (NAAQS) defined under the Clean Air Act. CMAQ simulates air pollutants of concern—including ozone, particulate matter (PM), and the most prevalent air toxics—to optimize air quality management. Deposition values from CMAQ are used to assess ecosystem impacts such as eutrophication and acidification from air pollutants. In addition, the National Weather Service uses CMAQ to produce twice-daily forecast guidance for ozone air quality across the U.S. CMAQ has also been used to quantify potential impacts of climate change on air quality and human health.

CMAQ—when coupled with a meteorology model such as the Weather Research and Forecasting (WRF) model—unites the modeling of meteorology, emissions, and chemistry to simulate the fate of air pollutants under varying atmospheric conditions. Other kinds of models—including crop management and hydrology models—can be linked with the CMAQ simulations, as needed, to describe pollution more holistically across environmental media.

CMAQ can be configured to simulate meteorology and atmospheric chemistry in a sequential fashion (i.e., one model at a time), or it can be "coupled," where CMAQ is embedded in the meteorology model. In the latter case, the impacts of atmospheric chemistry can be reflected actively in the clouds and radiation simulated by the meteorology model. There are options to connect CMAQ to regional and global meteorology models for coupled simulations.



CMAQ is a sophisticated numerical modeling system that runs on multi-processor Linux computing systems. CMAQ requires tens of gigabytes to tens of terabytes of disk space to accommodate input and output files. CMAQ is also under development to operate in a cloud computing environment.

What's new in CMAQ?

CMAQ version 5.4 includes the following new features:

Updated chemistry for ozone and PM formation from global-to-local scales: CMAQv5.4 updates the science behind the interactions of chemicals in the air and clouds. These advances target better representation of key environmental conditions important for polluted areas of the United States. CMAQv5.4 also introduces the Community Regional Atmospheric Chemistry Multiphase Model (CRACMM), an innovative approach to describe atmospheric chemistry that considers all reactive organic carbon emitted to the atmosphere to fully examine potential impacts of emissions on ozone and PM formation.

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Biogenic emissions algorithm options have been expanded: The BEIS biogenic emissions model (default in CMAQ) has been updated with new, highly detailed land parameters. Additionally, the MEGAN biogenic emissions model is now available within CMAQ, and biogenic emissions can now be estimated during the CMAQ simulation for any spatial domain.

Improved modeling of aerosol dry deposition: A more realistic aerosol dry deposition model has been developed for CMAQv5.4. By adding a new process representation for impaction of aerosols on leaf hairs and other microscale features, the new model compares better to observed aerosol dry deposition velocity than the previous version. The new model increases deposition in forested areas, thereby reducing accumulation mode aerosol concentrations. Additional options for aerosol dry deposition are also available in CMAQv5.4.

Simplified model evaluation workflows: The Atmospheric Model Evaluation Tool (AMET) version 1.5 is released with new analysis options for meteorology and air quality. New interactive scripts and improved error checking are also included, resulting in more effective tools to evaluate CMAQ results.

Improved visualization of meteorology and air quality model data: The Visual Environment for Rich Data Interpretation (VERDI) version 2.1.4 is released with new features including the option to plot vertical profiles for the Model for Prediction Across Scales (MPAS) files, as well as user customized plotting options such as data range, plot symbols, and symbol sizes.

Streamlined coupling of CMAQ with meteorological models: The process of building model code for coupling CMAQ with WRFv4.4+ has been revised and better documented. The software connections to couple CMAQ with WRF are now released with the WRF model, which minimizes the intervention required for CMAQ users to enable this option.

Improved efficiency, accuracy, and user experience for CMAQ instrumented model extensions: The Integrated Source Apportionment Method (CMAQ-ISAM) and Direct-Decoupled Method (CMAQ-DDM) have both been streamlined to achieve faster runtimes. Both extensions are now distributed in the same repository as the base model. Furthermore, CMAQ-ISAM has been expanded to include new options for representing different approaches for apportioning secondary products of NO_x and VOC chemistry.

Diagnostic and output tools: Transparency of model assumptions and overall numerical and computational efficiency are improved in CMAQv5.4. Also, a new tool is available to quantify the impact of individual model processes on each atmospheric species across the modeling domain. New approaches were introduced for organizing species output, which enables an option for bulk metrics like $PM_{2.5}$ to be directly output by the model.

Community Engagement

The CMAQ community has thousands of users in more than 50 countries. These users include scientists and air quality managers across government, academia, and the private sector. Their input has contributed to developing a more robust model.

To support the CMAQ user community, EPA contracts with the University of North Carolina at Chapel Hill to host the Community Modeling and Analysis System (CMAS) Center, which provides user training and support for the CMAQ modeling system. CMAS hosts an online user forum to connect users with model developers and the international user community to collaborate on using CMAQ and to share feedback for science and feature improvements.

For more information, visit:

EPA's CMAQ website: https://www.epa.gov/cmaq

CMAQ source code and documentation on GitHub: https://github.com/USEPA/CMAQ

FAQ for upgrading to CMAQv5.4: https://github.com/USEPA/CMAQ/wiki/CMAQv5.4-Series-FAQ

CRACMM Fact Sheet: https://www.epa.gov/cmaq/cmaq-fact-sheets

AMET source code on GitHub: https://github.com/USEPA/AMET

VERDI website: https://www.cmascenter.org/verdi

CMAQ Support Tools: https://www.epa.gov/cmaq/cmaq-resourcesutilities-model-users

CMAS Center at UNC-Chapel Hill: www.cmascenter.org

CMAS User Forum: https://forum.cmascenter.org

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