Comprehensive Air Quality Model with Extensions (CAMx)

Reference

ENVIRON, 1998. User's Guide to the Comprehensive Air Quality Model with Extensions (CAMx) Version 2.00. ENVIRON International Corporation, 101 Rowland Way, Suite 220, Novato, California 94945-5010.

Availability

The model source code, user's guide, test problem, and documentation on example applications are publicly available from the CAMx website at www.camx.com or from ENVIRON International Corporation, 101 Rowland Way, Novato, CA 94945 (415/899-0700) at no cost.

Abstract

CAMx is a multi-scale, three dimensional photochemical grid model. The model contains two-way grid nesting, subgrid-scale Plume-in-Grid (PiG), fast accurate chemistry solver, a chemical mechanism compiler, generalized coordinate system to accommodate multiple map projections, and options for using more accurate solvers for transport and diffusion. CAMx unique attributes include an ozone source apportionment capability whereby the contributions of emissions from geographic source regions and different source categories to ozone concentrations can be calculated within a single simulation. The model incorporates two options for condensed photochemical kinetics mechanisms: the Carbon Bond Version IV (CB-IV) mechanism and the 1997 version of the mechanism from the State Air Pollution Research Center (SAPRC97). The CAMx is designed for computing hourly ozone (O_3) concentrations at the regional, mesoscale, and urban scales for periods ranging from a day up to months. CAMx also incorporates a capability to compute primary and secondary particulate matter (PM) concentrations. For O3 calculations, emissions of oxides of nitrogen (NO_x), volatile organic compounds (VOC), and carbon monoxide (CO) are required. The simulation of PM requires emissions of sulfur oxides (SO_X), ammonia (NH_3), and primary PM species in addition to those needed for O_3. The model treats VOC emissions as either their CB-IV or SAPRC97 surrogates. CAMx can also be run in a "nonreactive mode" to predict carbon monoxide (CO) and other inert or semi-inert species concentrations.

a. Recommendations for Regulatory Use

CAMx is appropriate for simulating hourly ozone, CO, and PM concentrations from the urban-scale to regional-scale; the hourly concentration estimates can be used to generate mean ozone, CO, and PM concentrations at longer than hourly time-scales, including 8-hour, daily, monthly, seasonal, and annual.

CAMx has many options, such as the CB-IV (Gery *et al.*, 1989) with enhanced isoprene chemistry (Carter, 1990) or SAPRC97 (Carter 1990;1996) chemical mechanisms, three optional advection solvers (Smolarkiewicz, 1983, Bott, 1989, or the Piecewise Parabolic Method, PPM), grid resolution (< 1km to > 100km), map projections (e.g., Lat/Long, UTM, Lambert Conformal Projection, Polar Stereographic Projection), cloud inputs, PiG configuration, but no specific recommendations can be made at this time on all options. The reviewing agency should be consulted on selection of options to be used in regulatory applications.

b. Input Requirements

Source data for ozone modeling include gridded, hourly emissions of CB-IV or SAPRC97 speciated VOC, CO, NO, and NO_2 for low-level and elevated sources along with stack coordinates, stack height, stack diameter, exit velocity, and exit temperature for elevated sources. For PM modeling, hourly emissions from low-level and elevated sources include those necessary for ozone modeling, along with SO_X, NH_3, and primary PM, which can be optionally resolved by size (e.g., PM-2.5 and PM-10) and composition (e.g., elemental carbon, organic carbon, and crustal). For CO modeling, only CO emissions for surface and elevated sources need be specified.

Meteorological data needed are hourly, gridded, three-dimensional horizontal winds, temperature, pressure, vertical turbulent exchange coefficients, and optionally either total opaque cloud cover or cloud cover fraction, depth, and liquid water content. Additional hourly, gridded two-dimensional inputs for rainfall rate (optional), land use cover fractions, total ozone column, albedo, and turbidity are also needed.

Air quality data needed include concentration of all species at the beginning of the simulation for each grid cell (initial concentrations) and hourly concentrations of each pollutant at each level along the lateral boundaries and top boundary of the modeling region (boundary conditions).

Additional input data needed include the chemical reaction rates file and simulation control file which describes the number and definitions of any nested-grids and the definitions of the model options. If the source apportionment option is specified, then additional inputs are required on the type of source apportionment, the geographic regions for which source attribution will be calculated, and separate emissions files for each source category for which separate ozone apportionment will be calculated.

c. Output

Output includes three-dimensional gridded hourly (or other user--specified averaging period) average and instantaneous concentrations. Information on mass fluxes for all species and all grids are also output along with job summary and diagnostic information.

d. Type of Model

CAMx is a numerical multi-scale three dimensional, photochemical and particulate matter grid model.

e. Pollutant Types

CAMx may be used to model ozone (O_3) formation from oxides of nitrogen (NO_x) and volatile organic compound (VOC) emissions. Optionally, CAMx may also be used to simulate PM-2.5 and PM-10 and PM components (e.g., sulfate, nitrate, ammonium, secondary organic carbon, and primary elemental carbon, organic carbon, and crustal). It can also be used to model carbon monoxide (CO).

f. Source-Receptor Relationship

Low-level area and point source emissions are specified within each surface grid cell. Emissions from major point sources are placed within cells aloft in accordance with calculated effective plume heights; emissions from point sources may be optionally simulated using the subgrid-scale PiG algorithm. An optional ozone source apportionment algorithm allows for the calculation of the ozone contributions due to user-specified source regions and source categories.

Hourly average concentrations of each pollutant are calculated for all grid cells at the surface and optionally at each vertical level.

g. Plume Behavior

Plume rise is calculated for major point sources using relationships in the TUPOS Gaussian model (Turner *et al.*, 1986). For user-specific point sources, the early plume dynamics and plume-scale chemistry is calculated using a subgrid-scale Plume-in-Grid (PiG) algorithm; when the plume size is commensurate with the grid cell size the PiG algorithm releases the plume mass to the grid model for further computation.

h. Horizontal Winds

Hourly, gridded, three-dimensional horizontal (U and V) winds are required (see *Input Requirements*).

i. Vertical Wind Speed

Calculated at each vertical grid cell interface from the compressible mass continuity relationship using the input gridded horizontal wind field (assumes conservation of local density).

j. Horizontal Dispersion

Hourly, gridded three-dimensional horizontal eddy diffusivities are calculated internally in the model based on the deformation of the wind field (Smagorinsky, 1963).

k. Vertical Dispersion

Hourly, gridded, three-dimensional vertical eddy diffusivities are provided as input to the model and are usually based on output from a prognostic meteorological model.

l. Chemical Transformation

CAMx employs two options for photochemistry: Version IV of the Carbon Bond Mechanism with updated isoprene chemistry (CB-IV); and the 1997 chemical mechanism developed at the State Air Pollution Research Center (SAPRC97).

m. Physical Removal

Dry deposition of pollutants are calculated using the resistance approach algorithm developed by Wesely (1989). Grid cell dependent surface roughness and surface resistance is calculated based the fractional coverage of the input land use categories. Wet scavenging is calculated based on hourly rainfall rate in each grid column using a species-dependent Henry's Law solubility.

n. Evaluation Studies

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