Variable Grid Urban Airshed Modeling System (UAM-V, UAM-VPM)

Reference

Systems Applications International, 1999. User's Guide to the Variable-Grid Urban Airshed Model (UAM-V), Systems Applications International, Inc./ICF Consulting, 101 Lucas Valley Road, Suite 160, San Rafael, California 94903.

Availability

The UAM-V modeling system software, test application, user's guide, and other supporting software are publicly available on the UAM-V web site at uamv.saintl.com or from Systems Applications International, 101 Lucas Valley Road, Suite 160, San Rafael, CA 94903 (415-507-7108) at no cost.

Abstract

The UAM-V Model is a three-dimensional, multi-scale photochemical grid model that calculates concentrations of pollutants by simulating the physical and chemical processes in the atmosphere. The model is the latest of the Urban Airshed Model (UAM) lineage, which was initiated in the early 1970s and has undergone nearly continuous cycles of application, performance evaluation, update, extension, and improvement. The basis for the UAM is the atmospheric diffusion or species continuity equation. This equation represents a mass balance that includes all of the relevant emissions, transport, diffusion, chemical reactions, and removal processes in mathematical terms. Because it accounts for spatial and temporal variations as well as differences in the reactivity of emissions, the UAM is useful for evaluating the air-quality effects of emission control scenarios. It does this by first replicating a historical ozone episode to establish a base-case simulation. Model inputs are prepared from observed meteorological, emission, and air quality data for the episode days using prognostic meteorological modeling and/or diagnostic and interpolative modeling techniques for the meteorological fields and emissions models to prepare daily, hourly and location specific emissions fields. The model is then applied with these inputs, and the results are evaluated to determine its performance. Once the model results have been evaluated and determined to perform within prescribed levels, the same base-case meteorological inputs are combined with *projected* emission inventories to simulate possible future emission scenarios.

The model contains the following features: capability of simulating multiple nested grids of variable resolution, two-way communication between nested grids, multiple coordinate system capabilities, and plume-in-grid (PiG) treatment. The UAM-V also includes Process Analysis capabilities that allow the user to quantify the contributions from the physical and chemical processes to simulated concentrations in selected grid cells. The model employs an updated version of the original Carbon Bond IV chemical kinetics mechanism (Gery, at al., 1989). Version 1.24 contains an update to the isoprene chemistry suggested by Carter (1996). Version 1.30 contains the CB-Tox mechanism (Ligocki and Whitten, 1992, Ligocki et al., 1992), which, in addition to the isoprene update, includes an expanded chemical treatment for aldehydes and selected toxic species. The UAM-V has been applied to simulate tropospheric ozone concentrations on multiple scales for a range of time periods (days, months, seasons, year). The model requires input data specifying the emissions and initial and boundary concentrations of gaseous precursors of ozone (VOC, NOx, and CO). The model also

requires a full set of three-dimensional meteorological inputs, which can be provided by dynamic meteorological models (such as MM5) or diagnostic models (such as DWM). The UAM-V also has the capability of running without photochemistry (nonreactive), to simulate urban- or regional-scale CO concentrations. A version of the model, UAM-VPM, provides the capability of simulating primary and secondary aerosol and particulate matter (PM) concentrations. The UAM-VPM model includes a versatile chemical mechanism generator that is capable of efficiently generating the required code to simulate various PM aerosol chemical production reactions. The code is generated as specified in user input files. In addition to the gaseous ozone precursors, UAM-VPM requires emissions of primary particulates and precursors, such as oxides of sulfur (SOx), ammonia (NH3), sulfuric acid (H2SO4), and dimethyl sulfide (DMS).

a.Recommendations for Regulatory Use

The UAM-V modeling system is designed to simulate the production and fate of ozone concentrations, emissions and fate of CO. The UAM-VPM model simulates the emissions, production, transformation, and deposition of primary and secondary PM concentrations on scales ranging from local to regional. Simulated hourly concentrations can be used to generate 8-hour, daily, monthly, seasonal, and annual estimates.

The UAM-V model has a number of options for choice of chemical mechanism, coordinate system, grid configuration, cloud/rain inputs, and PiG specifications. The reviewing agency should be consulted on selection of specific options for regulatory applications.

b.Input Requirements

Meteorological data required by the model include hourly, three-dimensional inputs of horizontal winds, temperature, pressure, water vapor, and vertical turbulent exchange coefficients. Hourly, gridded two-dimensional inputs are required for: landuse, total ozone column, turbidity, and albedo. In addition, the model requires information regarding the heights (above ground) of the specific layers used in the simulation and the pressure at the layer midpoints. Estimates of cloud cover, liquid water concentration, and rainfall rate are optional.

Air quality data are required to specify the initial concentration fields and the concentrations along the boundaries (top and lateral) of the modeling domain.

The emission inputs include gridded, hourly estimates of gaseous species required by the CB-IV, including speciated hydrocarbons (VOC), NOx as NO and NO2, and CO for all anthropogenic and biogenic sources. The model requires specific source information for stationary sources, including stack location coordinates, height, diameter, exit velocity, and exit temperature for calculating plume rise. For CO modeling, sources of CO emissions are all that is required. For UAM-VPM, the emissions inputs are dependent on the chemical mechanism selected by the user. An example set of emissions may include primary PM species (including size distribution), oxides of sulfur (SOx), ammonia (NH3), sulfuric acid (H2SO4), and dimethly sulfide (DMS).

Other input requirements of UAM-V include the chemical reaction rates file, a file that specifies the selected cell aggregation and grid nesting attributes, and a file that specifies the attributes of the simulation, including grid definition, time step, output options (such as Process Analysis), and other options.

c.Output

The output provided by the UAM-V model includes a three-dimensional array of pollutant concentrations for all species simulated in two files: an average file provides hourly (or other averaging period specified by the user) concentrations that are an average of the concentrations at each advection time step; and an instantaneous file, that provides concentration fields at the beginning of the hour (or other user-specified time period). The model also provides a full list of input specifications, including emission summaries, mass fluxes across boundaries, history of the simulation, and a record of useful diagnostic parameters for each time step of the simulation.

d.Type of Model

The UAM-V is numerical, three-dimensional photochemical grid model capable of simulating multi-scale processes. The UAM-VPM is a version that is capable of simulating the emissions and fate of primary particulates and the production, chemical and physical transformation, and deposition of secondary aerosols.

e.Pollutant Types

The UAM-V model may be used to model the chemical and physical process involved in the production and fate tropospheric ozone from emissions of NOx, VOC, and CO precursors. The model is capable of simulating wintertime CO concentrations fields in a nonreactive mode. The UAM-VPM version may be used to simulate a variety of primary and secondary particulate matter components (PM10, PM2.5) and species (nitrates, sulfates, chlorides, acids, ions).

f.Source-Receptor Relationship

Anthropogenic and biogenic emissions are spatially allocated and provided to the model in gridded form. The emissions are temporally allocated throughout the simulation period to emulate the temporal features of the total daily emissions. Sources with no (or small) plume rise are injected into the first layer of the model. Emissions of sources with plume rise are emitted into the upper layers of the model, depending on the hourly effective plume rise. Specific sources can also be treated (user-specified) with a subgrid-scale plume-in-grid algorithm, which better treats the diffusion, transport, and chemistry of the emissions by minimizing near-source dispersion.

Concentrations of each pollutant are calculated for all grid cells within the modeling domain. The Process Analysis feature allows the user to quantify the contribution of the physical and chemical processes to the concentration in one or more user-specified cells.

g.Plume Behavior

The plume rise for user-specified sources is calculated based on the plume rise treatment developed for the Gaussian dispersion model TUPOS (Turner et al., 1986). For user-specified sources, the dispersion, diffusion, chemical transformation, and transport of emissions are calculated with the Plume-in-Grid algorithm. Emissions are released from the source in a series of "puffs". When the user-specified plume size in the puff is equal to a portion of the grid cell, the plume mass is injected into and handled henceforth by the grid model.

h.Horizontal Winds

The UAM-V requires gridded, three-dimensional winds in the form of u and v components, which must be specified either at each grid cell center or staggered to horizontal cell interfaces.

i.Vertical Wind Speed

The UAM-V model calculates vertical winds at each layer interface using the mass-continuity relationship using the horizontal wind components.

j.Horizontal Dispersion

Horizontal diffusivities are calculated with the UAM-V based on deformation characteristics of the horizontal wind (Smagorinsky, 1963).

k.Vertical Dispersion

Vertical turbulent exchange coefficients are estimated using either output from a prognostic meteorological model, such as MM5, or a preprocessor that utilizes gridded UAM-V input wind and temperature information.

l.Chemical Transformation

The UAM-V uses Version IV of the Carbon Bond Mechanism (CB-IV), with updated isoprene chemistry (Whitten et al., 1996). Version 1.30 also treats toxics (Ligocki and Whitten, 1992, Ligocki et al., 1992).

m.Removal Processes

The UAM-V dry deposition algorithm is based on a scheme by Wesely (1989), where the deposition velocity is a function of aerodynamic, boundary layer, and surface resistance. The aerodynamic resistance is dependent on the surface characteristics and atmospheric stability conditions. The boundary or quasilaminar resistance represents the process of molecular diffusion of the transport of pollutant around solid objects and is dependent on the ratio of the air kinematic viscosity to the molecular diffusivity. The surface resistance is a set of resistances associated with vegetation types and surface soil, litter, and water, and are derived based on the input land use characteristics. Wet deposition,

which is optional, calculates the removal of aerosol and soluble gas species using gridded, hourly rainfall rates.

n.Evaluation Studies

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o.References Cited

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