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Project Summary

Green River Air Quality Model Development: MELSAR—A Mesoscale Air Quality Model for Complex Terrain

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Pacific Northwest Laboratory has developed an air quality model for application in valleys as part of the U.S. Environmental Protection Agency (EPA) Green River Ambient Model Assessment program. The purpose of the program is to provide air quality assessment tools applicable to the Green River Oil Shale Formation region of western Colorado, eastern Utah, and southern Wyoming. This region has the potential for large-scale growth because of its vast energy resources, especially oil shale.

MELSAR is a mesoscale air quality model for predicting the concentrations of air pollutants released from multiple sources. The model is a Lagrangian puff model for application in complex terrain, principally at long source-to-receptor transport distances (tens to hundreds of kilometers) and for short pollutant averaging times (1 to 24 h). Terrain influences are treated explicitly by using a three-dimensional mass-consistent flow model with an account for the influences of terrain roughness on diffusion, terrain-following plume trajectories with optional corrections for the plume ascending hills, and a parameterized treatment of pollutant sources located in valleys. The model handles releases from both point and area sources and makes the conservative assumption that the pollutants released are inert and nondepositing. MELSAR was developed for application in a region encompassing western Colorado, eastern Utah, and southern Wyoming. However, the computer code itself is not site specific and could conceivably be applied anywhere provided if the proper inputs were developed and the parameterizations within MELSAR are applicable to the region to be modeled.

This Project Summary was developed by EPA's Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in two separate volumes (see Project Report ordering information at back).

Introduction

An air quality model was developed to predict short averaging time (≤24 h) pollutant concentrations resulting from the mesoscale transport of pollutants released from multiple sources in complex terrain. The Mesoscale Location Specific Air Resources (MELSAR) model was developed for application in the complex terrain of the Green River Oil Shale formation region of Colorado, Utah, and Wyoming. Its purpose is to aid in assessing the air pollution potential from development of the extensive oil shale reserves and other industrial, mining, manufacturing, or power production development within this region. The project report consists of two volumes: volume 1 contains the computer model overview, technical description, and user's guide, and volume 2 contains the appendices, which include listings of the FORTRAN code.

MELSAR is a Lagrangian puff model for application at long source-to-receptor distances (tens to hundreds of kilometers) and for short concentration averaging times (1 to 24 h). These distances and averaging times are important in estimating the pollutant concentrations at the Prevention of Significant Deterioration Class I areas in the region.

MELSAR was designed for application in a specific 500- by 450-km complex terrain region of the Green River Oil Shale Formation. It can compute concentrations for up to 20 sources and two pollutants at a time. The influences of the terrain on pollutant transport and diffusion are treated explicitly in MELSAR. The transport winds are computed from measured upper-air and surface weather data by using a mass-consistent, three-dimensional flow model. Steering of the winds around major terrain features during stable atmospheric conditions is accounted for, and the effects of terrain roughness on pollutant diffusion are treated. In addition, sources located in valleys are given special treatment. Pollutants trapped in valley-drainage flows during the nighttime are ventilated to the regional winds during the morning transition period. The pollutants trapped in the valley are treated as a line source at sunrise.

Overview

MELSAR is a mesoscale air quality model for predicting the concentrations of pollutants released from up to 20 point and area sources. Two pollutants can be treated during any run. MELSAR is a Lagrangian puff model for application in complex terrain, principally at long source-to-receptor transport distances (tens to hundreds of kilometers) and for short averaging times (1 to 24 h). The ground-level concentrations may be computed on up to four 25- by 25-receptor grids and at 10 individual receptors. The pollutants are assumed to be nondepositing and inert. This is a conservative assumption for computing air concentrations of primary pollutants.

MELSAR is set to operate on a 500- by 450-km region encompassing western Colorado, eastern Utah, and southern Wyoming. This region is referred to as the Green River Ambient Model Assessment (GRAMA) region. The coordinate system for the GRAMA region is a rectangular system, and input data can be specified in either the GRAMA, Universal Transverse Mercator (UTM) or latitude-longitude coordinate systems.

Simulation periods from hours to days (maximum 30 days) can be accommodated by MELSAR. In addition, intermediate meteorological and terrain output files can be saved and cataloged for later applications of MELSAR; this saves the cost and time of regenerating these files. A file tracking and cataloging system is provided with MELSAR.

MELSAR utilizes a three-dimensional, mass-consistent flow model to determine the time-varying and space-varying winds over the region. The model is diagnostic and uses upper-air data from up to 10 stations and surface weather data from up to 15 stations as input. The flow model also accounts for flow channeling around major terrain features during stable atmospheric conditions by using the concept of a dividing streamline height. This height is calculated from available upper-air data and from analysis of the terrain data. The winds are specified on up to nine levels above the terrain surface. Using the same upper-air and surface weather data that are used to determine the winds, MELSAR produces hourly gridded fields of temperature, pressure, friction velocity, convective velocity, Monin-Obukov length, mixing height, and stability classification. These gridded quantities are written to disk files and can be used during other applications of MELSAR.

The pollutant puffs diffuse in a Gaussian fashion in which the vertical distribution is modified by multiple reflections from the ground and an upper mixing lid. The horizontal and vertical diffusion coefficients are computed as functions of travel time and the standard deviations in the horizontal and vertical winds, σ_v and σ_w, respectively. The following two options are available in MELSAR for computing σ_v and σ_w: (1) empirical equations relating to σ_v and σ_w to boundary layer parameters (e.g., friction velocity and convective velocity), in which the required boundary layer parameters are determined from the input meteorological data and (2) empirical equations relating σ_v and σ_w to terrain roughness. The effects of wind shear on horizontal diffusion are treated, and initial diffusion caused by buoyant plume rise is incorporated.

Sources located within valleys are treated in a special way in MELSAR. If an analysis of the meteorological data shows that the valley atmosphere is "decoupled" (primarily nighttime) from the regional flow, the pollutants released into the valley remain in the valley. These pollutants travel down-valley in mean down-valley winds until sunrise, at which time the valley winds are stopped and MELSAR immediately begins ventilating pollutants from the valley. Pollutants are ventilated from the valley to the regional winds at a rate determined by the rate of inversion destruction within the valley.

The MELSAR code was designed to operate on any subdomain of the GRAMA region, although the code has not been fully tested for this application. In addition, some of the meteorological and diffusion algorithms were adapted or developed for MELSAR considering only regional-scale applications. Consequently, these parameterizations may not necessarily be appropriate for local-scale applications. Because of these regional-scale parameterizations and large terrain averaging intervals for regional-scale applications of MELSAR, concentrations computed at receptors near (within 10 to 20 km) a source may not be dependable estimates of impacts from that source.

Application of MELSAR to sites other than the GRAMA region would require examination of some parameterizations in MELSAR that were developed from site-specific data. In particular, the ventilation rate of pollutants from valleys is based on empirical relations developed from data collected in Colorado valleys.

MELSAR consists of four main programs: TERRAIN, MET, POLUT, and POLPRC. TERRAIN uses a base terrain file and produces files of spatially averaged terrain statistics for use by MET and POLUT. MET produces values for hourly winds, gridded mixing heights, stabilities, friction velocities, convective velocities, Monin-Obukov lengths, temperatures, pressures, and valley coupling coefficients by using upper-air and surface weather observations. POLUT uses the output files from MET and TERRAIN and produces pollutant concentrations, corrected to standard conditions, on a specified receptor network for each time step of a simulation. The concentration fields are used by POLPRC to compute moving-average concentrations of pollutants for up to three averaging times. The output data from POLPRC are presented as tables listing highest and second highest pollutant concentrations at each receptor; these tables list the sum concentration from all sources and the contribution of each source to the sum. Also, tables listing highest and second highest pollutant concentrations are generated for each receptor grid and set of individual receptors considering each source individually.

For multiple applications of MELSAR, it may not be necessary to run TERRAIN, MET, and POLUT for each application. The output files for one application may be used during other applications. An approach for naming and tracking the input and output files from MELSAR is provided with the model. Tracking the files will ensure that documentation is available for future reference and that all the input and output files will be available and retrievable for future MELSAR runs.

The TERRAIN program produces gridded fields of terrain statistics from the base terrain file, which contains 500 by 450 terrain heights; each terrain height is the average height of a 1-km^2 area. This program enables users to compute the necessary terrain statistics for any subdomain in the GRAMA region that they want to model. In addition, TERRAIN provides the necessary flexibility to investigate the effects of terrain smoothing on ground-level concentrations during any sensitivity testing of MELSAR.

MET is a very flexible meteorological data processor. It is designed to receive up to one month's worth of upper-air and surface weather input data from up to 10 upper-air and 15 surface stations over different time periods and sampling intervals. It can handle missing data and was designed to handle any data that are available for a specified period of time. Observations from National Weather Service stations, special studies, or intensive field programs can be used.

POLUT is a Lagrangian puff model in which the pollutant distribution is described in a Gaussian fashion about the puff's center of mass. The distribution in the vertical is modified by the treatment of multiple reflections from the ground and an upper mixing lid. Ground-level concentrations for each modeling time step for two pollutants can be computed for pollutants released from up to five sources, either point or area sources. The area sources are treated as virtual point sources. Concentrations are computed on up to four 25- by 25-receptor grids and to 10 individual receptors specified anywhere at ground level in the modeling domain.

POLPRC computes moving-average concentrations of pollutants at each receptor for up to three user-specified averaging times. The averaging times can range from 1 to 24 h. Up to 20 sources can be processed at one time. The output data are presented as tables of highest and second highest pollutant concentrations for the duration of the simulation at each receptor for each pollutant for each averaging time. The highest and second highest moving-average concentrations resulting from the sum of all sources and the contribution of each source to the highest and second highest sum are computed. Highest and second highest moving average concentrations can also be computed for each source individually. Additional tables list the time of occurrence of the highest and second highest values.

Data Requirements

The input data required by MELSAR are the following:

1. gridded terrain data
2. upper-air weather data
3. surface weather data
4. points from which to interpolate wind data (primarily for boundary conditions)
5. gridded land-use categories (for determining surface roughness)
6. source valley characteristics
7. pollutant source inventory
8. receptor layout

All but the upper-air and surface weather data must be specified within the modeling region. Data from weather stations outside the modeling region can be used by MELSAR.

The gridded terrain data for the GRAMA region are provided with MELSAR and do not have to be developed by the user. Also included with MELSAR are four files of surface and upper-air weather data, one file of wind interpolation points for runs using the entire GRAMA region, and one file of gridded land-use categories for runs using the entire GRAMA region.

New upper-air and surface weather data files can be developed if meteorological periods other than the ones provided are desired for model runs. For applications in which the modeling domain is a subset of the GRAMA region, a new wind interpolation point file and a new land-use categories file must be constructed. For each group of sources to be modeled, a new source inventory file and a new source valley characteristics file must be constructed. New receptor layout files must be constructed for each new receptor configuration.

Conclusions and Recommendations

The model shows promise for use as a planning tool and, eventually, as a regulatory tool. MELSAR has not undergone any rigorous operational testing, sensitivity analyses, or evaluation studies. Three major steps are required before MELSAR is ready for general use in the region of western Colorado, eastern Utah, and southern Wyoming: (1) operational and sensitivity testing, (2) testing for upgrading, if necessary, of specific algorithms by using the limited tracer data sets available for the region, and (3) a regional-scale tracer experiment to provide a data set for further testing and validation of MELSAR. MELSAR has a highly modularized computer code, which facilitates upgrades and additions to the code. The addition of chemistry and deposition parameters to MELSAR would be straightforward and would enable MELSAR to be used as a tool for estimating contributions to acid deposition.

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The complete report consists of two volumes, entitled "Green River Air Quality Model Development MELSAR—A Mesoscale Air Quality Model for Complex Terrain:"
"Volume 1. Overview, Technical Description and User's Guide," (Order No. PB 85-247 211/AS; Cost: $16.95)
"Volume 2. Appendices," (Order No. PB 85-247 229/AS; Cost: $28.95)
The above reports will be available only from: (costs subject to change)
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