Update on the Emergency Response Model PGEMS

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ABSTRACT

A recently enhanced complex terrain dispersion model, PGEMS 2.0, is formulated to operate on personal computers. PGEMS computes ground-level concentrations and deposition fields of air contaminants released from point sources. The model treats both wet and dry deposition and radioactive decay (or first-order chemical transformation) of the released material. The model operates at two "nested" grid resolutions; a fine grid to resolve the dispersion within a few kilometers of the release, and a coarse grid to track plume transport tens to hundreds of kilometers from the source.

PGEMS is currently being adapted and tested by Pacific Gas & Electric Company in support of emergency response activities at their Diablo Canyon nuclear power plant. This paper briefly describes the history of PGEMS development, the basic features of the model, and the status of current model activities by Pacific Gas & Electric Company.

INTRODUCTION

Simulating dispersion in complex terrain situations is required for numerous applications ranging from routine air quality assessments for regulatory compliance to predicting the direction of transport of toxic materials for emergency response planning. Predicting the dispersion of material released to the atmosphere in regions of nonuniform terrain can be very challenging. For example, Allwine[1,2] discusses the complicated behavior of the dispersion of tracers released in mountainous regions of Colorado and Virginia. Wind patterns in complex terrain can be highly variable in time and space, because of synoptic influences, the influences of nonhomogeneous surfaces (sea breeze, heat island), and terrain-induced processes such as slope flows, channeling, blocking, mountain-valley winds, stagnations, and layered flows. During the nighttime terrain effects can dominate the atmospheric motion, especially near the surface. Consequently, an important characteristic of any complex terrain dispersion model is that terrain influences be formulated explicitly in the model. For example, the wind model component of complex terrain dispersion models must reasonably represent the winds in complex terrain using a limited number of input wind observations that are generally not of sufficient coverage to completely define the winds in the modeling domain.

A recently developed model for application in complex terrain, PGEMS 2.0, is formulated with important terrain influences treated explicitly. The history of PGEMS development is described next followed by a brief description of the model. This paper concludes with the status of current modeling activities by Pacific Gas & Electric Company.

PGEMS DEVELOPMENT HISTORY

In 1986, Battelle, Pacific Northwest Laboratories developed Version 1.0 of the Pacific Gas and Electric Modeling System[3] (PGEMS) for Pacific Gas and Electric Company for use in PG&E's emergency response needs and routine air quality assessments in their service region of California and western Nevada. The MELSAR[4] model, a complex terrain dispersion model developed for the U.S. Environmental Protection Agency, and the MESOI[5] model, an emergency response dispersion model developed for the U.S. Nuclear Regulatory Commission, formed the basis of PGEMS 1.0.

Thuillier[6] compared PGEMS 1.0 with data from tracer experiments conducted in the vicinity of PG&E's Diablo Canyon nuclear power plant near San Luis Obispo, California. On the basis of the results of these field comparisons Battelle modified the model by incorporating a building wake diffusion algorithm, by adding a puff splitting algorithm to better represent diffusion in shear flows, and by expanding the modeling domain to cover more of PG&E's service area. Battelle completed and delivered this modified model (PGEMS 1.1) to PG&E in 1989. Thuillier[7] then evaluated PGEMS 1.1 against the Diablo Canyon tracer data and found that, "The model performed well under a variety of meteorological and release conditions within the test region of 20-km radius surrounding the nuclear plant, and turned in a superior performance in the wake of the nuclear plant."

In 1992, PG&E initiated a program to upgrade the emergency response model at their Diablo Canyon nuclear power plant. Under contract to PG&E, Battelle modified PGEMS 1.1 to accommodate multiple radionuclides, a variable receptor configuration, and grid nesting; nesting was required in order to resolve potential impacts near the facility (within a few kilometers) in addition to calculating impacts as far as 100 km from the facility. The revised model, PGEMS 2.0, with complete documentation[8] was delivered to PG&E in June 1995.

Recently PG&E initiated a contract with Allwine Environmental Services to assist PG&E staff in incorporating this new version of PGEMS into their emergency response system for the Diablo Canyon nuclear power plant. Currently a user interface is undergoing development and testing, the model is being interfaced with the Diablo Canyon nuclear power plant meteorological network, and is being optimized for fast execution.

PGEMS DESCRIPTION

PGEMS predicts ground-level concentrations, time-integrated concentrations, and deposition fields of air contaminants released from point sources given the contaminant release rates, source configurations, and meteorological observations of winds, mixing heights, precipitation rates and atmospheric stabilities. The model is applicable at source-to-receptor transport distances from a few hundred meters to a few hundred kilometers. PGEMS uses a Gaussian puff formulation to mathematically describe the concentration distribution of the released material as it moves in the mean wind field. Mathematical reflections of the concentration distribution from the ground and the top of a mixed layer modify the initial Gaussian distribution. The mixed layer height can change spatially and temporally just as all the other meteorological and release inputs. The model treats both wet and dry deposition and radioactive decay (or first-order chemical transformation) of the released material. The code is written in standard Fortran and can easily be implemented on various computers. Modules of PGEMS read the appropriate text files of release rates, source configurations, radionuclides, receptor coverage, terrain statistics, meteorological data and run conditions. These input text files can easily be edited for other applications of the model.

A three-dimensional wind model in PGEMS specifies the time- and space-varying winds over the modeling domain. It is a diagnostic model and uses upper-air and surface meteorological data as input. Some dynamic effects are parameterized in the flow model. For example, the model treats flow channeling and blocking from terrain features during stable atmospheric conditions using the notion of a dividing streamline height. In addition, the flow model sets the surface winds to the local downslope direction to approximate drainage flows during stable atmospheric conditions. The model runs in a nested mode allowing for finer resolution near the source while covering a broader region without exceeding typical memory and CPU resources of personal computers. The PGEMS modeling domain in a nested configuration for PG&E's Diablo Canyon nuclear power plant is given in Figure 1. This domain configuration allows for potential releases from the Diablo Canyon power plant to be tracked effectively in the vicinity of the power plant in addition to allowing potential released to be tracked to more than 100 km from the source.

PGEMS consists of three main computer programs named TER, MET and TDM. TER uses a base terrain file (typically a USGS digital elevation model in latitude-longitude coordinates) for the region of interest and produces disk files of gridded spatially-averaged terrain statistics (e.g., heights, drainage direction) in Universal Transversal Mercator coordinates (the primary coordinate system of PGEMS) for use by the MET and TDM programs. MET produces wind fields, gridded mixing heights, stabilities, and precipitation categories, using upper-air and surface weather observations. TDM uses the output files from MET and TER and produces concentration and deposition fields on a user-specified receptor network for each time step of a simulation. The concentration and deposition fields are written to a binary disk file for later analysis and viewing by post processing programs.

The terrain processing program TER needs only to be run once for any site. The resulting terrain files are then available for multiple runs of MET and TDM for a given site. The minimum amount of meteorological data required for MET operation is data from at least one upper-air station and one surface station. The upper-air station data can range from wind data from a tower measuring winds at two levels, to wind data at multiple levels from a sodar or radar profiler. MET can accommodate data from numerous surface and upper-air stations.

CURRENT ACTIVITIES

PGEMS 2.0 is currently being adapted and tested by PG&E in support of emergency response activities at their Diablo Canyon nuclear power plant. The specific work being accomplished is: 1) a graphical-user interface is being written to allow the operator to create and modify input files, specify run conditions and view results; 2) the MET model is being interfaced with the Diablo Canyon nuclear power plant meteorological network for automatic retrieval of meteorological data and generation of meteorological fields for use by TDM; and 3) the TDM code is being optimized for fast execution. This work is to be completed in June 1996.

This emergency response version of PGEMS will run unattended producing an animation of plume movement every 30 minutes. The animation will show the movement of the plume from the current time through a 4-h forecast period. The operator will be able to intercede in the model operation to change run parameters, rerun the model with updated meteorological and/or release data, and view the concentration, deposition and wind fields in more detail.

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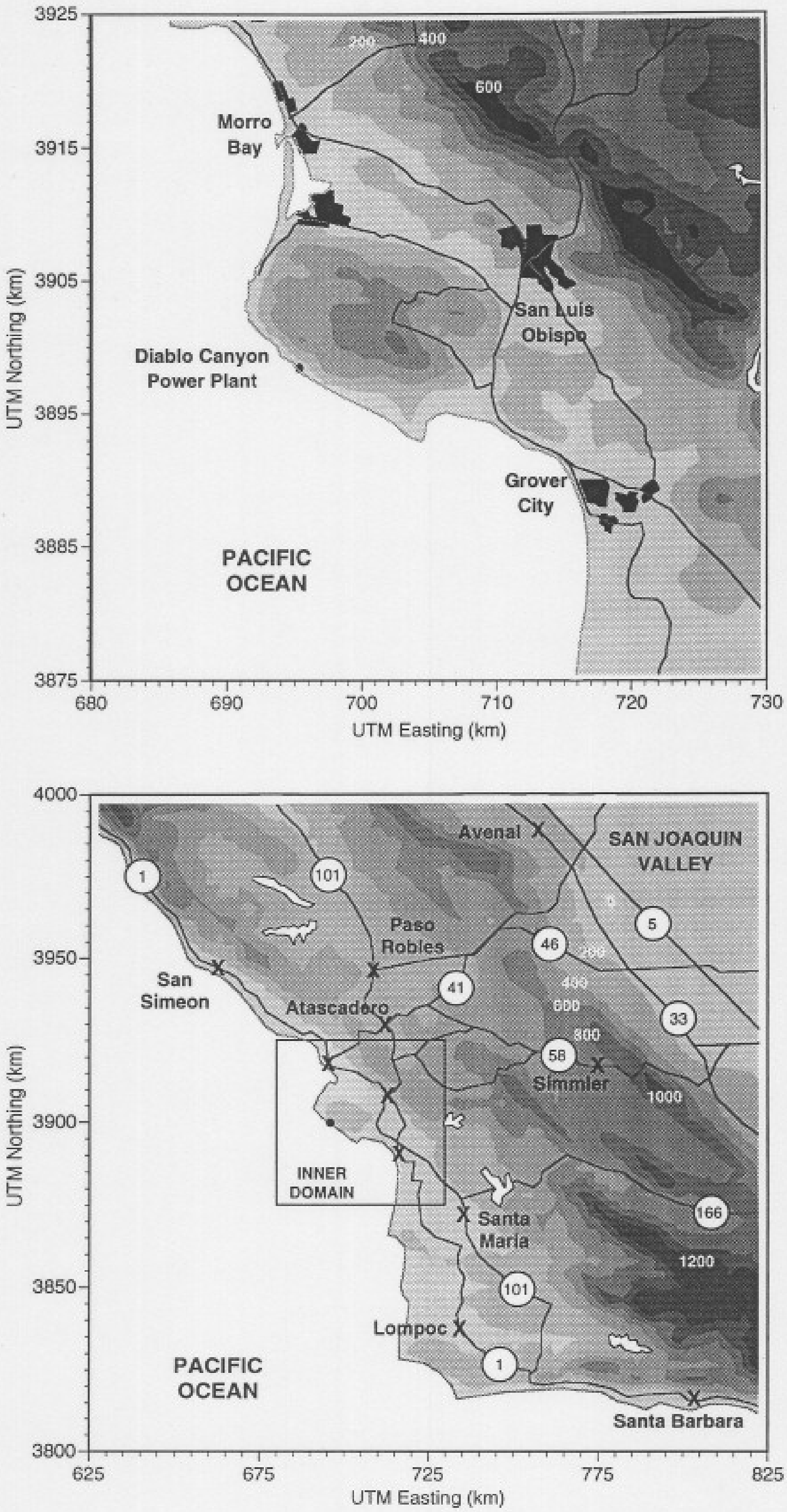

Figure 1. The nested-grid configuration used by PGEMS. The top panel shows the inner grid and the bottom panel shows the outer grid for the Diablo Canyon power plant modeling domain in the vicinity of San Luis Obispo, California. The terrain contour interval in the top panel is 100 m and the contour interval in the bottom panel is 200 m.