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PGEMS - AN ATMOSPHERIC DISPERSION MODEL FOR EMERGENCY RESPONSE

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ABSTRACT

PGEMS is an atmospheric transport and diffusion model for emergency response applications in regions of non-uniform terrain. It is fully documented and operationally tested, runs on personal computers, and has been validated using tracer and meteorological data from experiments conducted in a complex terrain region near San Luis Obispo, California. The model is currently being installed as the emergency response model at a nuclear power station in the United States. A three-dimensional diagnostic wind model is used in PGEMS to specify the time- and space-varying winds over the modeling domain. A special feature of the wind model is that it accounts for flow channeling and blocking from major terrain features during stable atmospheric conditions. PGEMS predicts ground-level concentrations and deposition fields of air contaminants released from point sources. Both wet and dry deposition and radioactive decay of the released material can be treated. A Lagrangian puff formulation is used to describe the concentration fields. PGEMS is applicable at source-to-receptor transport distances from a few hundred meters to a few hundred kilometers. A brief description of PGEMS is given followed by an example simulation of the flow model demonstrating transport wind patterns in complex terrain during stable nighttime conditions.

INTRODUCTION

Predicting the dispersion of accidental releases of material to the atmosphere in regions of nonuniform terrain can be very challenging. Wind patterns 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, layered flows. During the nighttime terrain effects can dominate the atmospheric motion, especially near the surface. Consequently, an important component of any emergency response model is the wind model which 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.

The best approach for determining the winds in the modeling domain is to use a wind model that can incorporate all the available meteorological observations and treat all the pertinent physics. However, certain requirements of these models limit the equations set that can be solved, thus the physics that can be treated. These requirements are that the model must be robust, well tested, fast, and can be run by individuals not necessarily familiar with the theoretical foundation of the model. Full physics models do not at this time meet these requirements; however, considerable advances are being made in computer hardware, software, numerical techniques, and familiarity with the codes that mat allow these models to be viable emergency response tools within a few years. The PGEMS model bridges the gap between full physics models and commonly used diagnostic models and meets the requirements given above.

A brief description of the PGEMS model is given next followed by a demonstration of the utility of the flow model during nighttime stable conditions with few input wind observations. The flow modeling component of PGEMS is the focus of this paper because of the importance of winds in predicting the transport direction of the release.

MODEL DESCRIPTION

PGEMS is an atmospheric transport and diffusion model for complex terrain applications and is used to predict ground-level concentrations, time-integrated concentrations, and deposition fields of air contaminants released from point sources. Both wet and dry deposition and first-order chemical transformations (or radioactive decay) of the released material can be treated. A Lagrangian puff formulation is used to describe the concentration fields. PGEMS is applicable at source-to-receptor transport distances from a few hundred meters to a few hundred kilometers.

A three-dimensional wind model is used in PGEMS to specify 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 treated in a highly parameterized fashion in the flow model. For example, flow channeling and blocking from terrain features during stable atmospheric conditions are treated using the concept of a dividing streamline height. Nighttime drainage flows are also accounted for by specifying the surface winds as a function of terrain slope and orientation. The model can be run 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 code consists of three main programs and several subroutines written in standard FORTRAN. The main programs are a terrain processor for calculating the average terrain elevations and mean obstacle heights, a meteorological processor for calculating fields of winds, mixing heights, stabilities, and precipitation categories, and a transport and diffusion model for calculating the ground-level concentration and deposition fields. The terrain processor is run only once during the setup of an emergency response system. The resulting files are stored on disk for subsequent use by the meteorological processor and transport and diffusion model. The terrain program requires as input commonly available digital elevation models (DEMs) in longitude-latitude coordinates.

The meteorological processor is installed as a module of a meteorological data acquisition and processing system with the execution of the meteorological processor controlled by the data acquisition system software. The meteorological processor is launched after each data acquisition cycle (typically 15 minutes to one hour) and produces output files of quantities required by the transport and diffusion model, using the most recently acquired meteorological data. The outputs are written to a "circular" disk file that keeps up to several days of historical meteorological fields available for use by the transport and diffusion model. The meteorological fields are produced using only seconds of CPU time.

The transport and diffusion model can be launched at any time and uses the available terrain and meteorological files. Certain features of the model would be preset for a particular site or response scenario. Once set, this model initialization information would reside on a disk file and be read each time the transport and diffusion model is executed. The preset features include principally the potential release locations and the locations of the receptors. The possible receptor layout can be any combination of up to three 25x25 rectangular grids, one 36x5 polar grid, and up to 100 individual receptors. Given release information by the user, the model produces disk files of concentrations and deposition amounts as a function of time at the receptor locations.

PGEMS was developed by Battelle, Pacific Northwest Laboratories, for Pacific Gas and Electric Company for their use in emergency response needs and routine air quality assessments in their service region of California and western Nevada.[1] The model is based on the wind model from MELSAR,[2] a complex terrain dispersion model developed for the U.S. Environmental Protection Agency, and MESOI,[3] an emergency response dispersion model developed for the U.S. Nuclear Rugulatory Commision. PGEMS has recently been evaluated against tracer data from a field study conducted in the vicinity of PG&E's Diablo Canyon nuclear power plant near San Luis Obispo, California.[4] The results of the study were 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."

FLOW MODEL EXAMPLE - STABLE ATMOSPHERE

An example run of the flow model is given here to demonstrate two important features of the flow model--the nested operation, and the treatment of terrain channeling and blocking with a minimum of meteorological input. The model is driven by one input wind profile of 5 m/s west winds. Figures 1 and 2 show the 1-m AGL winds on the outer and inner grids, respectively, superimposed on terrain contours of the southern California coast near San Luis Obispo. The larger domain (Figure 1) allows for emissions from a source (in this example the Diablo Canyon Power Plant) to be tracked for more than 50 miles in any direction from the plant. If there were no nested grid, tracking releases to these distances is at the expense of adequately resolving the winds (and thus the plume transport) in the vicinity of the plant, as is shown in Figure 1, where the winds are deflected by the larger coast range mountains but are not affected by Davis peak (the small hill directly to the east of the plant). However, with grid nesting the winds in the vicinity of the plant are adequately resolved on the inner grid (Figure 2) where the winds are shown to diverge around Davis peak, in addition to being diverted to the southeast by the northwest-southeast running ridgeline to the east of San Luis Obispo. The flow patterns given in the figures are qualitatively observed at various times in the region during stable conditions.

The results given in Figures 1 and 2 clearly show the utility of representing the winds on two nested grids--distant transport can be estimated without sacrificing the required resolution of the winds in the vicinity of the source, or

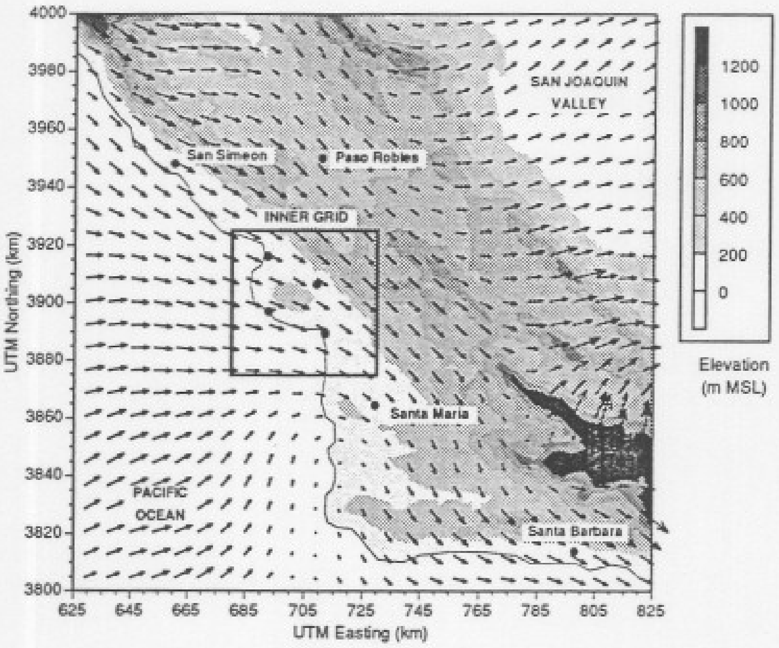

Fig. 1: Winds on Outer Grid from the Flow Model in PGEMS Driven by a Single Input Station of 5 m/s Winds from the West.

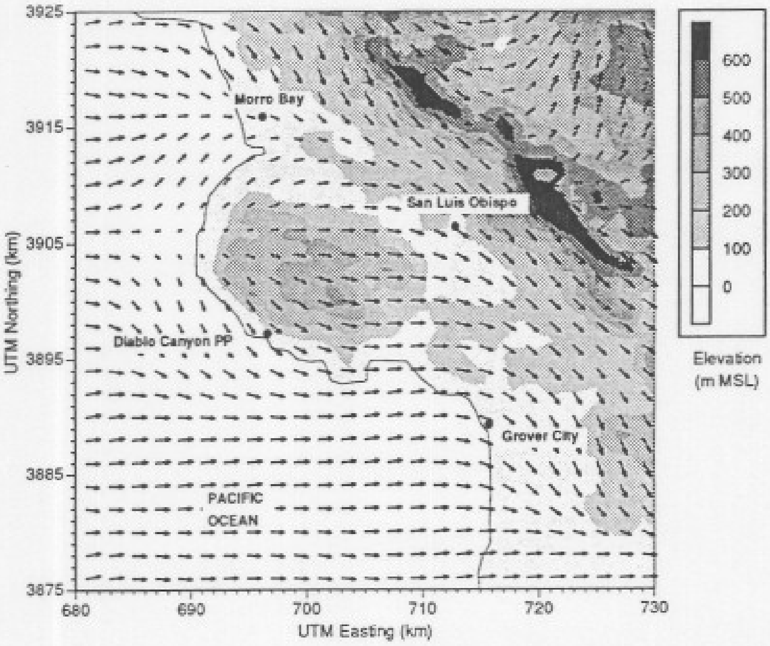

Fig. 2: Winds on Inner Grid from the Flow Model in PGEMS Driven by a Single Input Station of 5 m/s Winds from the West.

without increasing the computation requirements in order to resolve all important scales of motion on one grid. Calculation of the wind fields shown in the figures required a few seconds of CPU time on a personal computer.

SUMMARY AND CONCLUSIONS

PGEMS is an atmospheric transport and diffusion model that can be used as an emergency response model in complex terrain environments. It has been validated using tracer data for a compex terrain setting near San Luis Obispo, California.[4] The flow model in PGEMS is especially suited for operation in complex terrain and is able to treat transport during stable flows with few observations, as is demonstrated in this paper. The flow model accounts for flow channeling and blocking from major terrain features during stable atmospheric conditions. PGEMS is written in standard FORTRAN, is documented, operationally tested, and runs in minutes on personal computers.

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REFERENCES

1. K. J. ALLWINE and G. F. ATHEY, "User's Guide to the Pacific Gas and Electric Modeling System (PGEMS) - An Interactive Atmospheric Transport and Diffusion Model for Application in Complex Terrain," Prepared for PG&E by Battelle, Pacific Northwest Laboratories, Richland, Washington (1986).

2. K. J. ALLWINE and C. D. WHITEMAN, "MELSAR: A Mesoscale Air Quality Model for Complex Terrain. Volume 1 - Overview, Technical Description and User's Guide," PNL-5460 Vol. 1, Pacific Northwest Laboratory, Richland, Washington (1985).

3. J. V. RAMSDELL, G. F. ATHEY, and C. S. GLANTZ, "MESOI Version 2.0: An Interactive Mesoscale Lagrangian Puff Dispersion Model with Deposition and Decay," NUREG/CR-3344, U.S. Nuclear Regulatory Commission, Washington, D.C. (1983).

4. R. H. THUILLIER, "Evaluation of a Puff Dispersion Model in Complex Terrain," *J. AWMA 42*, 290 (1992).