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Project Summary

User's Guide to the Complex Terrain Dispersion Model

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The Complex Terrain Dispersion Model (CTDM) is a refined air quality model for use in stable and neutral conditions in complex terrain applications. Its use of meteorological input data and terrain information is different than current EPA models; considerable detail for both types of input data are required and are supplied by preprocessors specifically designed for CTDM. CTDM requires the parameterization of individual hill shapes using the terrain preprocessor and the association of each model receptor with a particular hill (except for receptors in flat terrain, which CTDM can also handle).

A central feature of CTDM is its use of a critical dividing-streamline height (H_c) to separate the flow in the vicinity of a hill into two separate layers. Flow in the upper layer has sufficient kinetic energy to pass over the top of the hill while streamlines in the lower layer are constrained to flow in a horizontal plane around the hill. Two separate components of CTDM compute ground-level concentrations resulting from plume material in each of these flows: LIFT handles the flow above H_c, and WRAP handles the flow below H_c.

Hourly profiles of wind and temperature measurements are used by CTDM to compute plume rise, the value of H_c, and the Froude number above H_c. The profiles of turbulence data (σ_θ or σ_v and σ_w values) are used to compute plume σ_y and σ_z values at plume height.

The model will calculate on an hourly basis how the plume trajectory and shape are deformed by each hill. The computed concentration at each receptor is then derived from the receptor position on the hill and the resultant plume position and shape.

The CTDM user guide is divided into two volumes: Volume 1 describes the model and how to use it, while Volume 2 contains code listings. Two auxiliary user manuals describe the CTDM terrain and meteorological preprocessors.

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

Introduction

The Complex Terrain Model Development (CTDM) project was initiated by the U.S. Environmental Protection Agency (EPA) to develop a practical refined plume model for elevated point sources near complex terrain. The result of this effort is the CTDM, which this user manual describes.

Complex terrain models presently recommended for regulatory use by EPA have been designated as screening models, as they tend to overpredict ambient concentrations and can therefore screen out situations which may not require further detailed analyses. These screening models (VALLEY, COMPLEX I, SHORTZ, and RTDM are deficient in several areas:

- Deflection and diffusion of plumes in the vertical is crudely treated by means of a plume height factor.
- Only the third-level screening model, RTDM, incorporates the concept of a dividing-streamline height.
- The screening models can accept only one level of input meteorology. Wind speed profiles are parameterized as a function of stability class. Wind direction is not allowed to vary with height.
- Explicit calculations of σ_y and σ_z from turbulence intensities are not done in the screening models.
- Plumes cannot be deflected horizontally around obstacles; a straight-line trajectory is assumed in the screening models.
- Screening models for complex terrain applications generally employ sector averaging in the horizontal for concentration calculations because of the inability of the model to depict the actual plume trajectory.
- Plumes embedded in a stable layer above a shallow unstable surface layer are ignored.
- The screening models make limited use of knowledge of the terrain shape.

CTDM addresses these deficiencies:

- The structure of the two-layer flow (above/below the dividing-streamline height) is explicit in the formulation, and plume material that straddles the interface remains in the respective layers (the plume is not treated as if it were all in one layer or the other).
- Above H_c, the material is deflected and distored, and the rate of dispersion is altered. Below H_c, the stagnation streamline divides the flow, and only material that diffuses onto the stagnation streamline is able to reach the surface of the hill. The stagnation streamline and the concentration pattern wraps around the terrain. Plumes that lie to one side of stagnation streamline pass around the terrain.
- The rate of plume growth depends on the turbulence and, in the case of σ_z, it also depends on the degree of stratification. Sector averaging in the lateral direction is not used.

The focus of the model development effort to date has been on the stable plume impingement problem. As a result, CTDM contains algorithms that are suitable for neutral and stably-stratified flows (i.e., Pasquill-Gifford stability classes, D, E, and F). However, the sequential hourly datasets required for regulatory applications contain hours characterized by classes A, B, and C as well. Rather than include an untested algorithm for these classes, or explicity include an algorithm from an existing screening model, CTDM writes out "null" concentrations (-999) for these hours.

Model Applicability and Technical Limitations

The CTDM is a point-source Gaussian plume dispersion model designed to estimate hourly-averaged concentrations of plume material at receptors near an isolated hill or near a well-defined segment of an array of hills. Primary emphasis is given to simulating situations in which the flow toward the hill is stably stratified, and in which the plume has not encountered significant terrain upwind. Receptors on terrain downwind of a point source will generally be associated with the greatest estimates of ground-level concentrations in stable conditions.

The following restrictions and assumptions about CTDM should be understood:

- CTDM contains no wake algorithms for simulating the mixing and recirculation found in cavity zones in the lee of a hill.
- CTDM contains no global flow calculation that accounts for the presence of many hills. The path taken by a plume through an array of hills cannot be simulated by the model. It relies on measurements of the flow obtained in the neighborhood of the source to define the incident flow field for each of the terrain segments independently.
- All hills that are explicitly modeled are done so in isolation; any changes to the plume size caused by one hill are not carried forward to subsequent simulations downwind.
- For situations when an individual hill is difficult to isolate from a complex terrain structure, caution must be used in interpreting the CTDM results.
- Real terrain features are approximated by ideal shapes. CTDM considers Gaussian shaped hills.
- CTDM does not simulate calm meteorological periods.
- CTDM assumes that the meteorological data are representative of the entire averaging period, and apply to the entire spatial domain. Spatial variability resolved by an array of meteorological towers cannot be used directly in the model.
- CTDM is designed for neutral to stable flow conditions; therefore the model does not predict concentrations during unstable hours when any plume is within the convective mixed layer.
- Hill slopes are assumed not to exceed 15°, so that the linearized equations of motion for Boussinesq flow are applicable.

These restrictions are consistent with the primary purpose of the model, namely, that of estimating pollutant concentrations on nearby terrain during stable (generally nighttime) atmospheric conditions.

Overview of CTDM Components

The CTDM package consists of:

- the Complex Terrain Dispersion Mode
- a terrain preprocessor (Mills et al. 1987)
- a meteorological preprocessor (Paine 1987)
- a receptor coordinate generator
- a graphical concentration displa program
- an interactive program which allow the user to modify model inputs easil and run CTDM in a case-study mode

All the programs, except the thre graphics programs, PLOTCON, RECGEI and CHIDIS, are written in FORTRAN 77 The graphics programs are written i BASIC.

The CTDM terrain preprocessor i made up of 3 programs which proces digitized contour data to provide hi shape parameters in a format suitabl for direct input to CTDM. The fir program, FITCON, asks the user to defir a hill in terms of its maximum elevatic and the (x,y) coordinates of the hill inp from a master file. After evaluation and editing, each contour is processed by numerical integration to determine the following parameters for an equivalent ellipse: semi-major and semi-minor axis lengths; contour centroid coordinates; and the orientation of the ellipse. The parameters are input to the second terrain preprocessor program, HCRIT, which determines, for the portion of the hill above several given elevations, the best-fit inverse polynominal profiles along the hill major and minor axes. CTDM uses the contour representations to provide hill shape information above the critical dividing streamline height for each hour and each hill using interpolation between two look-up table values. The third program, PLOTCON, generates screen displays to aid in the evaluation of the hill fitting process.

The CTDM meteorological preprocessor, METPRO, uses routine measurements to estimate the vertical structure of wind, temperature and turbulence in the lower atmosphere using surface layer similarity theory. Estimates of the friction velocity, u_*, the Monin-Obukhov length, L, and the mixed layer height, h, are provided by METPRO to CTDM. In the absence of measurements of profiles of wind, temperature, and turbulence, these variables are used by CTDM to compute values of wind, temperature and turbulence at any height within the nocturnal surface layer.

The receptor generator program, RECGEN, in an interactive program written in BASIC which will compute receptor coordinate information for receptors along user selected hill contours. The program will create a file containing the receptor information which can be directly input to CTDM. RECGEN will also display the contour lines and receptor locations on the terminal screen. The user can easily add receptors in addition to those produced by RECGEN using a text editor.

The main CTDM program performs the plume transport and dispersion calculations for the entire period of simulation. It takes the files prepared by the meteorological and terrain preprocessors together with the source and receptor files, and executes under the control of the options specified in an input file. Modeled concentrations can be stored in a binary or an ASCII output file, if desired. The model lists all of the control data describing the simulation, and pertinent source, receptor, and terrain data to the output list file. In case-study mode, extensive tables of selected variables are also listed for computations performed for each source, hill, and receptor.

The concentration display postprocessor consists of two separate programs. Both programs are interactive and will ask the user for the necessary file names and input data. These programs will display on the screen the predicted concentrations from CTDM on a map of unedited hill contours. Concentrations for a series of hours can be displayed sequentially, but each hill must be done individually.

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***Peter L. Finkelstein** is the EPA Project Officer (see below).*
The complete report consists of two volumes, entitled "User's Guide to the Complex Terrain Dispersion Model:"
"Volume 1. Model Description and User Instructions," (Order No. PB 88-162 128/AS; Cost: $19.95)
"Volume 2. Model Code Listings," (Order No. PB 88-162 136/AS; Cost: $25.95)
The above reports will be available only from: (cost subject to change)
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
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