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Project Summary

EPA Complex Terrain Model Development: Description of a Computer Data Base from the Full Scale Plume Study, Tracy Power Plant, Nevada

Lawrence E. Truppi

As part of the U.S. Environmental Protection Agency's effort to develop and demonstrate a reliable model of atmospheric dispersion for pollutant emissions in irregular mountainous terrain, the Complex Terrain Model Development Program was initiated in 1980 with Environmental Research and Technology as the prime contractor. Four field tracer studies were designed and directed by the model developers to test model estimates of plume impaction with observed tracer concentrations. The first study was conducted in October-November 1980 at Cinder Cone Butte, a roughly axisymmetrical, isolated 100-m hill near Boise, Idaho, and the second was performed along a 1.5-km section of Hogback Ridge, a 90-m high ridge near Farmington, New Mexico. Studies three and four occurred at the Tracy Power Plant near Reno, Nevada and were designed as realistic, full scale plume studies in a region of irregular and complicated terrain with tracer gas released through the smokestack of an active power plant. Tracer study number three in November 1983 was conceived as a modest feasibility study for a more comprehensive fourth study, but enough useful meteorological and tracer data were assembled to support additional model development and evaluation. The fourth study, designated the Full Scale Plume Study, was conducted in August 1984, and the data collected, along with data from the third study, comprise the data base described in this report.

The Full Scale Plume Study comprised 14 experiments from August 6 to 27, 1984 for a total of 128 hours of data collection, mainly during late evening or early morning hours. The power plant was maintained in a warm stand-by condition as SF6 tracer gas and oil-fog were injected into the base of a 91.4-m smokestack. Also, CF3Br tracer gas was released from one of three levels on a 150-m tower located about 1.2 km east of the power plant and upwind of the main targeted terrain. Meteorological data recorded on the 150-m tower included wind, from triaxial propeller anemometers at six levels, cup and vane anemometers at three levels, sonic anemometers at three levels, and temperature from sensors at six levels. Four 10-m towers and two electronic weather stations occupied sites on surrounding terrain to record wind and temperature, and two vertical doppler acoustic sounding systems operated near the smokestack. Tethersonde soundings were flown near the 150-m tower to compliment data from the tower and the nearby doppler sounding system. Two radar-tracking balloon systems recorded wind profiles up to 4 km during periods of tracer release. A LIDAR system was use to sample quasi-perpendicular transects through the oil-fog plume emitted with SF6 tracer gas from the top of the smokestack, and a

program of plume photography established plume-to-terrain interactions. Prolonged periods of anticipated stable conditions with westerly flow occurred with frequent plume impaction on sampler instrumented terrain east of the stack. A tracer concentration data base of over 11,000 hourly samples was accumulated for both tracer gases at 110 sites in surrounding terrain. Tables of tracer gas release data including emission rates, smokestack plume heights, and tower release heights were compiled to assist modeling efforts.

Data acquired during the preliminary full scale plume study, tracer study number three, from November 7 to 27, 1983 are also included with the Full Scale Plume Study's data base. Ten experiments were performed for a total of 90 sampling hours employing a network of 53 samplers, however only one tracer gas, SF6, was used for smokestack injection. Meteorological data from the same 150-m tower, 10-m towers, electronic weather stations, doppler acoustic sounders and tethersondes were also recorded. Meteorological data recording on the 150-m tower was continued from the end of study number three, November 1983, until the start of the Full Scale Plume Study, August 1984, and these data are included in the data base. All meteorological and tracer gas concentration data have been edited and placed on magnetic tape and are now available either as tape copies or by interactive computer access.

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 a separate report of the same title (see Project Report ordering information at back).

Introduction

The extensive development of energy resources, especially in the mountainous terrain of the Western United States, has generated concern about the resulting impact on air quality (as well as on water and land quality). Even in relatively simple situations, it has been difficult to produce reliable calculations of atmospheric transport and diffusion. For complex terrain, mathematical modeling is confounded because physical processes are more complicated and meteorological measurements are less representative than for level terrain settings. Responding to this fundamental problem, the U.S. EPA has initiated the Complex Terrain Model Development Program (CTMD), a major effort to develop and demomstrate reliable models of atmospheric diffusion for emissions in mountainous terrain.

An early step in the development of this program was the convening of a workshop concerned with these particular problems. Following recommendations of the workshop report, EPA's CTMD Program involved a coordinated effort in mathematical model development, field experimentation, and scaled physical modeling. The program's basic objective was to produce practical models with demonstrated reliability. Initially, the CTMD Program focused on the problem of stable plume impaction/interaction with elevated terrain. This phenomenon was singled out because of the likelihood of relatively high concentrations on the slopes of hills or ridges and because models now in use have been challenged extensively on this subject. The approach has been to study stable plume interactions in relatively simple terrain settings, and then study them in more complex situations.

EPA's prime contractor for the CTMD Program is Environmental Research and Technology, Inc. (ERT). Significant contributions were also provided by EPA's Fluid Modeling Facility (FMF), the National Oceanic and Atmospheric Administration's (NOAA) Wave Propagation Laboratory (WPL) through their sophisticated measurement capabilities, and NOAA's Air Resources Field Laboratory Research Division (ARLFRD) which conducted the flow visualization and tracer experiments and operated the real-time data acquisition and analysis system. The first field experiment, a comprehensive tracer study designated as Small Hill Impaction Study No. 1 (SHIS #1) was carried out on Cinder Cone Butte, a roughly axisymmetric. isolated 100-m hill near Boise, Idaho, during October-November 1980. Data observed at SHIS #1, as tracer gas, SF6 and Freon 13B1 (CF3Br), emission rates, locations and heights of release, tracer concentrations, and meteorological data from a 150-m tower and five 10-m towers, tethersondes and free balloons were subsequently delivered to EPA to form an accessible computer data base. The second field experiment, SHIS #2, was performed along a 1.5 km section of the Hogback Ridge near Farmington, New Mexico to extend the modeling data base to include a study of flow around a two-dimensional ridge. As in SHIS #1, tracer gas release data, tracer concentration data from a network of samplers on the ridge, and meteorological data from a 150-m tower, three 10-m towers, two tethersonde systems and a three-path crosswind optical anemometer system were delivered to EPA as another accessible computer data base.

This is a summary of a report that describes CTMD field experiments three and four conducted at the Tracy Power Plant, Nevada designed to simulate pollutant emissions from the smokestack of an operating power plant in mountainous terrain. Experiment three in November 1983 was conceived as modest feasibility study for a more comprehensive fourth experiment, or Full Scale Plume Study, but enough meteorological and tracer data were recorded to support additional model development. The Full Scale Plume Study occurred in August 1984, and the data collected, along with data from the third, or preliminary Full Scale Plume Study, comprise the computer data base described in the report.

The report describes the setting of the Tracy Power Plant, the experimental approach, and the following types of data archived on magnetic tape for both the preliminary and Full Scale Plume Study (FSPS):

- Tower meteorological data, — recorded as 5-min and 1-h averages of wind, temperature, and turbulence scales (sigma-u, -v, -w) at four to six levels on a 150-m tower, and four 10-m towers located in the surrounding terrain.
- Tracer gas concentrations — recorded as 1 h averages of SF6 and Freon 13B1 (CF3Br) from a network of samplers on targeted terrain.
- Tethersonde meteorological data, — two profiles per hour, instantaneous data of wind, temperature, relative humidity, mixing ratio, pressure and height.
- Doppler acoustic sounder data, — 10-min averages, wind and heights.
- Sonic anemometer data, — 5-min, 1-h averages, wind, temperature, turbulence scales (sigma-u, -v, -w) at three levels on the 150-m tower.
- Radar balloon wind data, — two profiles per hour to 3 km, instantaneous data, wind, heights.
- Electronic weather station data, — 1-h averages, wind and temperature.
- Optical crosswind anemometer data, — 5 or 10-min averages, wind components, speed and direction.

- Minisonde data, — one profile per hour up to 3 km, instantaneous data, winds, heights, temperature.

Table of tracer gas release data, emission rates, and location and heights of release are included for the CF3Br tracer gas in the Full Scale Plume Study, however, since the SF6 tracer was released through the smokestack of an active power plant, the height of release must be considered to be the effective height reached by the lofted plume. In the FSPS, this height was obtained with LIDAR transects of the plume, and included with the other release data. In the preliminary FSPS, November 1983, the LIDAR system was not available, so the height of the SF6 tracer release must be estimated.

Results

Preliminary FSPS — November 7 to 19, 1983

All data are contained on the first 14 files of the FSPS data base magnetic tape. These files hold all meteorological measurements, SF6 tracer concentrations, and geographical coordinates (x,y,z) of sampler sites.

Meteorological Tower Data

File 1 has meteorological data from the 150-m tower located upwind from the targeted terrain. Triaxial propeller anemometers recorded wind components at four levels, 5 m, 10 m, 100 m and 150 m along with temperature and temperature difference. Wind data are presented as 5-min averages of vector resultant speed and direction, the vertical component w, sigma-w, and sigma-theta. File 9 has data recorded on two 10-m towers as 5-m values of temperature and wind speed and direction from cup-and-vane anemometers

Tracer Gas Concentration Data

File 2 holds coordinates of 53 sampler locations on the targeted terrain surrounding the Tracy Power Plant. Files 3 and 4 have values of SF6 tracer concentrations detected during the two weeks of operation. Concentrations are values of CHI, parts per trillion (ppt), 1-h averages.

Minisonde Data

Files 5 through 8 contain minisonde data observed by two operating systems located near the power plant. Data are instantaneous values of wind, temperature, and height up to 3 km.

Optical Anemometer Data

File 10 has 5-min path-averaged optical anemometer measures of wind components and wind speed and direction along two paths near targeted terrain features. Data are 10-min averages of wind components, speed and direction.

Electronic Weather Station Data

File 11 contains 1-h averaged meteorological from two electronic weather stations established near targeted terrain. Data includes temperature, wind speed and direction.

Doppler Acoustic Sounder Data

A doppler acoustic sounding system was installed near the Tracy smokestack to test the feasibility of obtaining real-time information on vertical wind structure. Measurements of wind direction and speed were made at 25-m height intervals from 50 m to 400 m. File 12 holds 10-m values of doppler wind data.

Tethersonde Data

File 13 holds data recorded by the WPL system located east of the Tracy smokestack and upwind of the targeted terrain, and file 14 has data from the ARLFRD system near the smokestack. Meteorological data include values of height, wind, temperature, relative humidity and mixing ratio.

150-M Tower Data — October 14, 1983 to July 10, 1984

ERT erected and instrumented the 150-m tower at four levels and supplied a data acquisition system for the tower in October 1983, a month before the preliminary FSPS began. Data were recorded continuously through the preliminary FSPS until July 1984, a month before the FSPS started, as 1-h averages of the same meteorological instrumentation in operation during the preliminary FSPS. Data recorded during this extended period are stored on ten files, files 15 to 24, each with one month's data, October 1983 to July 1984.

FSPS — August 6 to 27, 1984

150-m Meteorological Tower Data

Two sets of meteorological data are stored on magnetic tape. Files 25 to 40 hold 5-min averaged data; Files 41 to 56 has the recorded data averaged at 1-h intervals. Data are recorded at six levels, 10 m, 50 m, 75 m, 100 m, 125 m, 150 m, with triaxial propeller anemometers, cup-and-vane anemometers, temperature and temperature difference sensors. Values include wind components, vector wind direction and speed, turbulence scales (sigma-u, -v, -w) and temperature and temperature difference. In addition, values of solar and net radiation were recorded at a 1 m level.

Tracer Gas Concentration Data

Tracer gas concentrations, SF6 and CF3Br, detected by a network of 110 samplers on surrounding terrain at 1-h intervals, are contained in two sets of tape files. Files 57 to 70 have concentrations of SF6 tracer, one file for each of 14 experiments, and files 71 to 84 have values of CF3Br tracer for each experiment. Concentrations are presented as normalized values, CHI/Q (ns/m3) rather than CHI (ppt) as is the preliminary FSPS. Coordinates of each sampler are included with tracer concentration values.

10-m Tower Data

Files 85 to 87 have 5-min averages of wind and temperature from three 10-m towers located in surrounding terrain, and files 88 to 90 hold 1-h averages of the same measures. Data from a fourth 10-m tower instrumented at 2 levels, 1 m and 10 m, for wind measures and temperature are held in file 91 as 2-min averages and in file 92 as 1-h averages.

150-m Tower Sonic Anemometer Data

Sonic anemometer data of wind components, temperature and turbulence scales (sigma-u, -v, -w) are recorded at three levels, 10 m, 100 m, 150 m, on the 150-m tower. Files 93 to 95 have 5-min averages for each level; files 96 to 98 have the 1-h averages.

Doppler Acoustic Sounder Data

WPL operated two acoustic doppler systems that had proven reliability during the preliminary FSPS. One system was located near the Tracy smokestack and the other near the targeted terrain, close to the Eagle Pitcher Industries, Inc. plant. Profiles of wind speed and direction were taken at 25-m levels from 50 m to 400 m as 10-min averaged data. File 99 has data from the Tracy stack site, and file 100 has data from the Eagle Pitcher location.

Radar Balloon Wind Data

ARLFRD operated two radar-tracked balloon (RABAL) systems, north and west of the Tracy stack. Radar wind data were acquired every 10 seconds during each ascent, scheduled at 30-min intervals throughout the 14 experiments. Data consist of values of height, time, wind speed and direction at each level. Files 101 to 113 hold data from the western site, R-2, for 13 experiments, and files

114 to 125 have data from the northern site, R-4, for experiments 3 to 14.

Tethersonde Data

Files 126 to 139 contain tethersonde data from profiles flown at the WPL system near the 150-m tower during all 14 experiments. Values are measures of height, wind speed and direction, temperature, relative humidity and mixing ratio.

Electronic Weather Station Data

File 140, the last file on the magnetic tape, holds hourly data from two electronic weather stations located near targeted terrain. Data are measures of temperature, wind speed and direction.

Conclusion

All data files are stored at the National Computer Center, Environmental Research Center, Research Triangle Park, North Carolina, on the Sperry UNIVAC 1100/83 system's magnetic tape, nine-track, odd parity, ASCII characters, 6250 BPI, tape number 007654. UNIVAC users or users with interactive access may assign the tape with UNIVAC Executive Control Language statement, @ASG, T FSPS,U9S//////Q,007654. Copies of the tape can be produced and translated into formats acceptable to any computer using nine-track tape drives.

*The EPA author, **Lawrence E. Truppi**, is on assignment from the National Oceanic and Atmospheric Administration, to the Atmospheric Sciences Research Laboratory, Research Triangle Park, NC 27711.*
***Peter L. Finkelstein** is the EPA Project Officer (see below).*
The complete report, entitled "EPA Complex Terrain Model Development: Description of a Computer Data Base from the Full Scale Plume Study, Tracy Power Plant, Nevada," (Order No. PB 87-133 476/AS; Cost: $18.95, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Atmospheric Sciences Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

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