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Project Summary

Green River Air Quality Model Development: Meteorological and Tracer Data—July/August 1982 Field Study in Brush Valley, Colorado

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Special meteorological and atmospheric tracer studies were conducted during a three-week period in July and August of 1982 in the Brush Creek Valley of northwestern Colorado. The experiments were conducted by the U.S. Department of Energy's Pacific Northwest Laboratory (PNL as part of the U.S. Environmental Protection Agency's (U.S. EPA) Green River Ambient Model Assessment (GRAMA) project. The objective of the field experiments was to obtain data to evaluate a model, called VALMET, which is being developed at PNL under the GRAMA project to predict dispersion of air pollutants released from an elevated stack located within a deep mountain valley in the post-sunrise temperature inversion breakup period. Three tracer experiments were conducted in the valley during a two-week period. In these experiments, sulfur hexafluoride (SF_6) was released from a height of approximately 100 m, beginning before sunrise and continuing until the nocturnal down-valley winds reversed several hours after sunrise. Dispersion of the SF_6 after release was evaluated by measuring its concentrations in ambient air samples taken from sampling devices operated within the valley. These samplers were stationed from the source to about 8 km down-valley. An instrumented research aircraft was also used to measure concentrations in and above the valley. Tracer samples were collected by using a network of radio-controlled bag sampling stations, two manually operated gas chromatographs, a continuous SF_6 monitor, and a vertical SF_6 profiler. In addition, basic meteorological data were collected during the tracer experiments. Frequent profiles of vertical wind and temperature structure were obtained with tethered balloons operated at the release site and at a site 7.7 km down the valley from the release site. Experiments were conducted in cooperation with the U.S. Department of Energy's Atmospheric Studies in Complex Terrain (ASCOT) program. A great deal of supplementary meteorological data is available from the ASCOT program, including additional tethered balloon data, data from a network of meteorological towers, acoustic sounder data, and data from laser anemometers.

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

A Atmospheric tracer experiments were conducted in the Brush Creek Valley in the oil shale region of northwestern Colorado during a three-week period in July and August 1982. This report presents the resulting data, which were collected to evaluate the initial version of an atmospheric transport and diffusion model, called VALMET, developed for individual valleys. The VALMET model is being developed for the U.S. Environmental Protection Agency (U.S. EPA) at the U.S. Department of Energy's (U.S. DOE's) Pacific Northwest Laboratory. The U.S. EPA tracer experiments were conducted as a supplement to a large meteorological field study that was designed by the U.S. DOE's Atmospheric Studies in Complex Terrain (ASCOT) program.

The Brush Creek Valley is a 25-km long valley located about 50 to 70 km NNE of Grand Junction in northwestern Colorado. Brush Creek is a tributary to Roan Creek, a major valley draining the south side of Colorado's Roan Plateau, located at the southern edge of the Piceance Basin. The Brush Creek Valley is a nearly linear, unobstructed valley, draining from NW to SE. The valley is deep (~650 m), narrow 3 km or less between the upper sidewalls) and, other than short box canyons on the east side, has no major tributaries; average sidewall slopes are 30 to 40 degrees. The topography of Brush Creek is unusual in that the valley floor has a rather steep slope and the altitude of the ridgetops changes little with up-valley distance. The lowest 10 km of Brush Creek has a slope of about 14 m/km. Upvalley from the release site, the valley floor rises more steeply, sidewalls become steeper, and the valley attains a "v-shaped" cross section.

The Brush Creek tracer experiments were designed to provide the initial data required to evaluate VALMET. The approach taken was to collect meteorological and tracer data to test the full range of meteorological assumptions and parameterizations used in modules within the model. For example, the model predicts that convective boundary layers, will grow over heated surfaces after sunrise, that upslope flows will develop within these boundary layers, that pollutants from the elevated nocturnal plume will fumigate into the convective boundary layers, and that they will be transported out of the valley by the upslope flows. Thus, within the restraints of the resources available, it was necessary to observe the development of convective boundary layers over the slopes, the upslope wind systems, fumigation of pollutants, and transport of pollutants up the slope. This required a continued, elevated tracer release within the valley during periods when a strong nocturnal temperature inversion had formed, and observation of the subsequent transport and diffusion of the tracer plumes as the valley temperature inversion broke up the following sunrise. Multiple experiments were run during clear weather periods with a variety of measurement systems to record the changing meteorological and tracer plume structure in the valley. The experiments focused on the plume breakup during the short post-sunrise inversion breakup period Good spatial time resolution of the observations was necessary to record features of the inversion breakup adequately. Manually operated portable gas chromatographs and a continuous tracer gas analyzer were used to provide this time resolution Good spatial resolution of the instruments was necessary on a valley cross section to view the expected convective boundary layer and tracer plume structure. To meet this need, a network of surface-based bag samplers was located throughout the valley, including the valley sidewalls. Vertical profiles were made through the elevated plume using a vertical sulfur hexafluoride (SF_6) profiler balloon-borne sampling device. A continuous tracer gas monitor was operated from an aircraft to monitor tracer gas concentrations in the upper valley atmosphere. Finally, tethered balloon systems were used to make observations of the changing atmospheric structure within the valley.

This report describes the experimental design and presents the meteorological and tracer data collected in the U.S. EPA's tracer experiments conducted in the Brush Creek Valley of Colorado during July and August, 1982. First, recommendations for future work are presented. Next is an initial evaluation of the VALMET model. Then, the experimental design is discussed, including information on the topography of Brush Creek Valley, the types and location of instrument systems used, and the weather conditions encountered during the field experiments. A chapter is provided on each of the data collection and analysis systems, including the tracer release system, the mobile analysis laboratory, the bag sampling system, the vertical SF_6 sampling system, the tethered ballon data collection system, the portable gas chromatograph system, the continuous tracer gas analysis system, and the aircraft data collection system.

Special features of the SF_6 tracer data set include:

- use of a vertical SF_6 profiling system to determine how the vertical structure of the SF_6 plume varied with time
- extension of the bag-sampling network to include tracer observations high (150 m) on the valley sidewalls
- use of portable gas chromatographs and SF_6 monitors to observe rapid variations in tracer concentrations that occur during the post-sunrise period when fumigations of the elevated nocturnal plume occur on the valley sidewalls
- use of a research aircraft to determine how pollutants are dispersed into the upper reaches of the valley following sunrise

Conclusions and Recommendations

There were several advantages to choosing the Brush Creek Valley for the initial evaluation of VALMET. First , the valley has a rather simple topography. The narrow, 25-km-long valley has no major changes in valley orientation along its length. It has nearly equal sidewall inclinations. The valley drains a plateau, so that the ridges are at a constant altitude regardless of location along the valley axis. The valley has no major tributaries. Second, the valley axis is oriented from NW to SE so that the sidewalls will be exposed to quite different isolation during the post-sunrise temperature inversion breakup period. The effect of this unequal heating was a major uncertainty in the model formation On the basis of meteorological data collected in wider Colorado valleys, and numerical model results, the VALMET model was developed under an assumption of horizontal homogeneity of atmospheric structure on a valley cross section. This assumption could be readily tested in the Brush Creek Valley, where the narrowness of the valley and the NW-SE orientation of the valley would clearly maximize any horizontal gradients in atmospheric structure between the sidewalls. Third, the Brush Creek Valley was heavily instrumented with meteorological sensors by the ASCOT program. Access to their meteorological data was a great benefit to the model evaluation effort.

Along with the above advantages, there was a major disadvantage to conducting an initial evaluation of VALMET with data from the Brush Creek Valley. This disadvantage was related to the short segment of the valley that was accessible for tracer instrumentation. VALMET is a two-dimensional model, predicting concentrations on a cross section oriented perpendicular to the valley axis some distance down-valley from a source. Restrictive assumptions are present in VALMET regarding a required homogeneity of the temperature and wind structure in the along-valley direction. The Brush Creek Valley, however, is a short tributary valley that flows into the Roan Valley a few kilometers below the valley cross section where most measurements are made. Consequently, tracer plume carried down the Brush Creek Valley during the night is carried into Roan Creek. Reversal of the down-valley winds (to up-valley) after sunrise results in a large part of the tracer plume being carried up the Roan Creek Valley, rather than being carried back up the Brush Creek Valley as assumed in the model. Evaluation of VALMET was complicated by this violation of a major assumption in the model, which had been designed for longer valleys.

The nocturnal plume was carried down the valley, as expected. The nocturnal plume, although released above the valley center, was found to be displaced towards one sidewall as it was transported down the valley. The valley is not strictly linear, but turns slightly with down-valley distance. Because the plume was displaced towards the "outside" of the turn , it is conceivable that inertial effects were responsible for the displacement of the plume from the valley centerline. The nocturnal plume was carried down the valley in a rather strong "jet" of down-valley winds, with the level of maximum winds at about release height. The nocturnal model, based on the Gaussian formulation, is incapable of treating vertical shears in transport winds but it approximates transport and diffusion along the valley direction fairly well when winds at release height are used for transport.

Assumptions in the daytime portion of the model were verified with actual meteorological and tracer data. The post-sunrise period was characterized by the growth of convective boundary layers over the sunlit valley surfaces. The tracer plume fumigated the valley sidewalls as convective boundary layers grew upwards into the remnants of the nocturnal temperature inversion containing the elevated tracer plume. Tracer was carried from the valley by upslope flows, which developed within the growing convective boundary layers. Corresponding subsiding motions over the valley center were noted in the temperature profiles at several of the tethered balloon sites, but the limited vertical resolution of the tracer plume did not allow this feature to be seen in the tracer concentration analyses.

Due to the northwest-southeast orientation of the deep, steep-walled valley, very significant differences occurred in the timing and rates of convective boundary layer growth on the opposing sidewalls following sunrise. As a result of the unequal heating of the different sidewalls, a cross-valley flow developed, carrying the elevated plume towards the warmer sidewall. Due to the cross-valley advection, tracer concentrations were higher on this sidewall than predicted by the model. A future modification of the VALMET model will be required to handle this situation properly in narrow valleys where post-sunrise insolation on the opposing sidewalls is quite different. The Brush Creek tracer experiments were the first direct experimental confirmation of the importance of this physical effect on tracer plume dispersion

The short length of the Brush Creek Valley, as expected, affected the results of the tracer experiments. The primary effect, from initial analyses, seems to be that the tracer concentrations in the valley fell more rapidly than expected after the post-sunrise wind reversal. This is thought to be due to the nocturnal plume being carried largely up Roan Creek after the wind reversal rather than reversing direction to come back up Brush Creek

The experiments described in this report should be considered as initial experiments designed to provide a better understanding of the basic physics of valley meteorology. The VALMET model appears to have promise in predicting air pollution concentration in deep valleys. Further work is recommended to complete a full analysis of the data from the 1982 experiment, and to evaluate and improve the VALMET model with these data.

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The complete report, entitled "Green River Air Quality Model Development: Meteorological and Tracer Data—July/August 1982 Field Study in Brush Valley, Colorado," (Order No. PB 85-125 490; Cost: $16.00, subject to change) will be available only from:
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