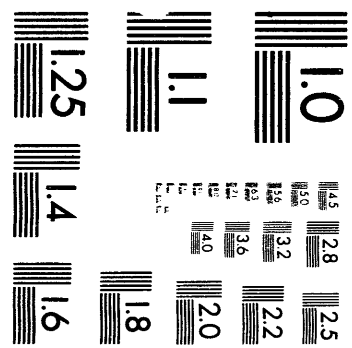
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PNL-SA-22351

AN OVERVIEW OF THE ASCOT PROGRAM

J. C. Doran

September 1993

Presented at the
AMS Topical Meeting on Environmental
Transport and Dosimetry
~~September 1-3, 1993~~ Aug 31 - Sept 3, 1993
Charleston, South Carolina

Work supported by
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

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J.C. Doran
P.O. Box 999, MSIN K6-11
Pacific Northwest Laboratory
Richland, Washington
(509)376-4734

ABSTRACT

ASCOT (Atmospheric Studies in Complex Terrain) is a multi-laboratory U.S. Department of Energy research program studying the properties of atmospheric boundary layers over non-uniform terrain and the interactions among various scales of motion that influence those properties. Within this context, one of the principal goals of the ASCOT program is to provide information necessary for an accurate description of transport and diffusion processes for atmospheric pollutants that may be released in regions of complex terrain. Three examples from past ASCOT research relevant to this goal are presented. Current and proposed research in the Front Range region of Colorado in the vicinity of the Rocky Flats Plant is also described.

INTRODUCTION

The U.S. Department of Energy's (DOE) Atmospheric Studies in Complex Terrain (ASCOT) Program is a basic research program studying the properties of atmospheric boundary layers over non-uniform terrain and the interactions among various scales of motion that influence those properties. ASCOT has two principal goals: 1) to characterize, understand, and predict boundary layer structure and evolution over inhomogeneous terrain, with scales of motion of order 1 km to 100 km, and 2) to develop methodologies needed to apply this knowledge to DOE mission needs, both site-specific and generic, including site safety, air quality, and climate change. Within this context, one of the principal goals of the ASCOT program is to provide information necessary for an accurate description of transport and diffusion processes for atmospheric pollutants that may be released in regions of complex terrain. This discussion will briefly present several examples of past ASCOT research that have provided information of this kind. It will then describe some current and planned activities in the program.

At the outset, it is useful to note that it is not ASCOT's function to develop emergency response models for use at specific sites. Rather, the scope of the program's research is typically more basic and generic, and is often long-term in nature. It frequently deals with phenomena that are not well represented in routine operational models. In many cases, analysis of complex terrain phenomena are carried out with "full-physics" models that are not yet suitable for such routine operational use. Sometimes, understanding gained from these studies may subsequently be incorporated into applied diffusion models by ASCOT or other scientists. In other cases, ASCOT studies serve to illustrate the errors or uncertainties that may be expected when the "full-physics" is not explicitly taken into account. In still other cases, the information gained simply serves to help identify and analyze important physical processes in the atmosphere.

EXAMPLES OF PAST ASCOT STUDIES

To illustrate some of the work ASCOT has undertaken in the past, three examples of complex terrain flow phenomena studied in the ASCOT program will now be considered. The first example is the effect of differential heating on valley sidewalls and its role in plume transport. Data taken for the U.S. Environmental Protection Agency during an ASCOT field experiment in Brush Creek Valley in western Colorado in 1982 showed that a tracer released near the center of a deep valley generally flowed down the middle of the valley during the night. Shortly after sunrise, however, one sidewall of the valley was heated by the sun while the other sidewall remained in shade, and convective updrafts originating over the heated sidewall caused the plume to migrate toward and up the heated wall [1] (Figure 1). Subsequent numerical simulations with a nonhydrostatic mesoscale model were able to reproduce the principal features revealed in the tracer analysis [2] and helped elucidate some of the details of the mechanisms responsible for the behavior.

It is probably safe to say that most plume transport and dispersion models do not explicitly include the effects of differential heating over inclined surfaces and, therefore, would be unable to predict such a result. Because the cross-valley circulations that cause this behavior are so weak, even a diagnostic model using a variety of observations to drive the model might fail to capture such behavior unless the measurement sites were chosen very carefully. This case provides an example of an important modification of local atmospheric flow patterns by a combination of thermal and topographic factors that are unlikely to be well-represented except in "full-physics" models or models specifically designed to represent this phenomenon. Such models have now, in fact, been constructed and are being applied in other contexts.

A second example is provided by a study of the coupling of valley winds with winds above ridgetop levels in the Tennessee Valley, the site of an ASCOT field experiment in the winter of 1990. In many deep valleys, there is a pronounced tendency for the winds to blow upvalley during the daytime and downvalley during the night, in response to the temperature differences that develop between the valley atmosphere and the air over the plains outside the valley. However, five years of wind records from four 100-m towers in the Tennessee Valley showed that in most regions of the valley there is a roughly equal probability of winds flowing up or down the valley during both the day and the night (Figure 2).

An extensive analysis of climatological data was carried out using the tower data and five years of rawinsonde observations from four locations. The analysis was supplemented by a series of computer simulations using a mesoscale model to determine the response of the valley winds to changes in the speeds and directions of the ridgetop winds. Above the valley, the Coriolis force will cause winds in geostrophic balance to blow perpendicular to the synoptic pressure gradient. Results from the data analysis and computer simulations showed, however, that the direction of the winds in the valley are strongly dependent on pressure-driven channeling, in which the winds in the valley are driven by the component of the geostrophic pressure gradient parallel to the valley's axis, with little effect from the Coriolis force. This mechanism was initially proposed by Fiedler [3] and was used by Gross and Wippermann [4] to explain narrow bi-directional wind direction frequency distributions observed in Germany's wide Rhine Valley. The along-valley component of the pressure gradient force will be zero only when the geostrophic wind is directed along the valley's axis, and winds in the valley will shift from up- to downvalley or from down- to upvalley when the geostrophic wind direction shifts across the valley axis. A remarkable feature of pressure-driven channeling, then, is that winds in the valley can blow in opposition to the along-valley wind direction components above the valley, e.g., winds in the valley can have a significant northeasterly component when the winds aloft are from the south or southwest (Figure 3). By explaining the relation between the synoptic wind directions and the local wind directions, this study thus provides a potentially valuable forecasting tool for the prediction of plume transport in the valley.

The final example is from a study of the development of circulation patterns over the Hanford Site in southeastern Washington. From observations it is known that a convergence zone often forms over the Site. The location of this zone and the resultant directions of the wind over the northern part of the Site show significant variations under wintertime inversion conditions but the cause of the differences was unclear. Computer simulations used to study the various forcing mechanisms influencing the flow patterns [5] have shown how slight changes in the direction of the geostrophic winds are amplified by terrain features as far away as 100 km and can result in much larger shifts in the directions of the near-surface winds at Hanford (Figure 4). Thus, by monitoring upper air flows with remote sensors such as radar profilers, it may now be possible to obtain more accurate wind forecasts for the subsequent evolution of the wind patterns closer to the surface. The study also showed the importance of resolving critical terrain features well removed from the local forecast area and pointed out possible pitfalls in applying grid nesting to modeling domains without careful testing of the sensitivity of the results to such procedures. Studies of this kind reveal effects that operational forecasting models must be able to predict for optimum reliability.

CURRENT AND FUTURE STUDIES

A current focus of ASCOT activities is the Front Range of the Colorado Rocky Mountains, in the vicinity of DOE's Rocky Flats Plant (RFP). The properties of the boundary layers in the Front Range area are strongly affected by local terrain features as well as by larger-scale terrain and synoptic influences. In this area, ASCOT's objectives are to characterize, understand, and predict selected topographically and thermally driven local and regional circulation patterns, especially those patterns that, in the event of a release of hazardous material from DOE's Rocky Flats Plant (RFP), may affect the region's air quality.

ASCOT carried out an initial experiment in the Front Range area in the winter of 1991 that coincided with a tracer experiment conducted by others as a validation test for an emergency response model used by the RFP. Some results from the ASCOT portion of the experiment are presented in this conference. For this discussion, we will limit ourselves to a description of the area and some of the phenomena of interest to the ASCOT program. Figure 5 shows a contour plot of the topography of the Front Range area in the vicinity of the RFP. For its first study, ASCOT investigated the relative strengths of drainage flows emanating from canyons to the north and south of the RFP and the slope flows off the mountains directly to the west. An interesting feature discovered during the course of the measurements was the presence of an elevated jet issuing from the mouth of Eldorado Canyon several hundred meters above the canyon floor. The canyon exit lies approximately 5 km to the northwest of the RFP boundary. Both observations and numerical simulations with a nested mesoscale model indicate that the direction of this jet oscillates and may have an important influence on the wind fields over the RFP.

To investigate this phenomenon further, the ASCOT program will be returning to the Front Range this summer for a three-month period in an effort to quantify the frequency with which this elevated jet occurs and the extent of its influence on the RFP environment. Figure 6 shows the proposed instrument deployment. A sodar will be located just outside the canyon's mouth, and an additional three sodars will be placed along a north-south line a few km to the east. The southernmost sodar will be located less than 1 km northwest of the RFP boundary, so it should be possible to determine how often and to what degree the Eldorado Canyon winds blow over the site. When the jet does not affect the winds there, it should also be possible to determine if the jet has dissipated as it flows east or is simply blowing in another direction.

At the same time, an array of 915-MHz radar wind profilers, most equipped with radio acoustic sounding systems (RASS) to measure temperatures, will be located along a line extending up Eldorado Canyon and over the Continental Divide. Additional profilers will be placed on the plains, with one unit at the Boulder Atmospheric Observatory (BAO) and one farther east, near Fort Lupton. These instruments will be used to study the larger scale mountains-plains circulations within which the drainage flows from the local canyons develop. They will help identify those conditions that are most favorable for the formation of the drainage jet as well as those times when the jet is most likely to influence flow fields around RFP.

Preliminary plans are also being made for further studies near the RFP in subsequent years. An obvious area of concern is the region to the east of the site, where airborne contaminants might be transported in the event of an accidental release. During the

1991 tracer releases, most of the sampling stations were located within approximately 16 km of the RFP. However, a sampler located at Platteville, about 50 km to the northeast, showed significant quantities of tracer. A likely route for this material is down Big Dry Creek and into the South Platte Valley (Figure 7). Studies such as the Denver Brown Cloud Study [6] have shown that the South Platte drainage has a significant effect on the air quality in Denver, and ASCOT is now considering a study to look at this drainage as a possible pathway for RFP effluents. Figure 7 shows a potential deployment of sodars for such a study. Radar profilers and RASSes would again be used to study the effects of larger scale boundary layer structure and atmospheric circulations on the local flow patterns.

SUMMARY

This discussion has been an attempt to describe the ASCOT program briefly, show that much of its research is directly related to the problem of atmospheric transport of contaminants in complex terrain, give a few examples of results from some of its past studies, and provide an outline of its current and proposed activities in the Rocky Flats region. We feel that the program has a great deal to offer in the area of environmental transport, and we look forward to future collaboration with the American Nuclear Society and other groups interested in this field.

ACKNOWLEDGMENT

This work was supported by the U.S. Department of Energy under Contract DE-AC06-76RLO 1830 at Pacific Northwest Laboratory under the auspices of the Atmospheric Studies in Complex Terrain program. Pacific Northwest Laboratory is operated for the U. S. Department of Energy by Battelle Memorial Institute.

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Figure Captions

1. Rise of SF_6 tracer up heated sidewall in Brush Creek, Colorado on 4 August 1982. Concentrations are in ppt.

2. Histograms of wind directions at 0600 and 1800 LST for 5-yr period at Oak Ridge, Tennessee.

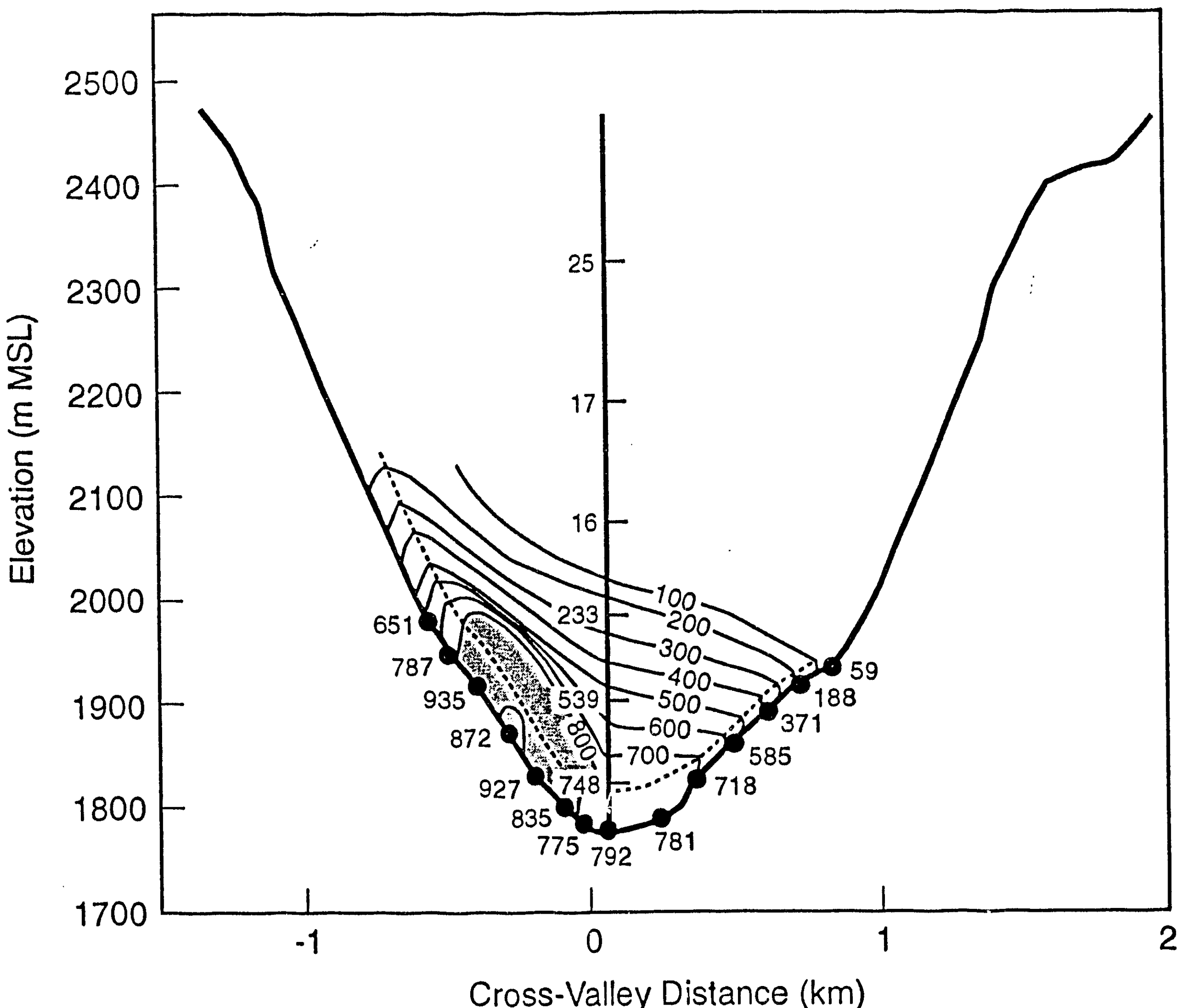
3. Joint probability distribution of geostrophic and valley wind directions at Oak Ridge, The solid line shows the locus of maximum probability. The dashed line shows a secondary maximum.

4. Simulated surface wind patterns over Washington State for geostrophic winds from 225° (a) and 255 ° (b). Note differences in flow fields over Hanford Site (cross-hatched area). Areas shaded in gray have elevations > 1000 m.

5. Contour plot of Front Range topography in vicinity of Rocky Flats. Eldorado Canyon is the canyon immediately to the northwest of Rocky Flats.

6. Proposed instrument deployment for observational study in Front Range during the summer of 1993. Radar wind profilers are to be located at Fraser, Eldora, Gross Reservoir, the Boulder Atmospheric Observatory (BAO), and Fort Lupton.

7. Proposed sodar deployment for future observational study east and northeast of the Rocky Flats Plant.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2000
1900
1800
1700
-1
0
1
2
Cross-Valley Distance (km)
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16
100
200
300
400
500
600
700
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233
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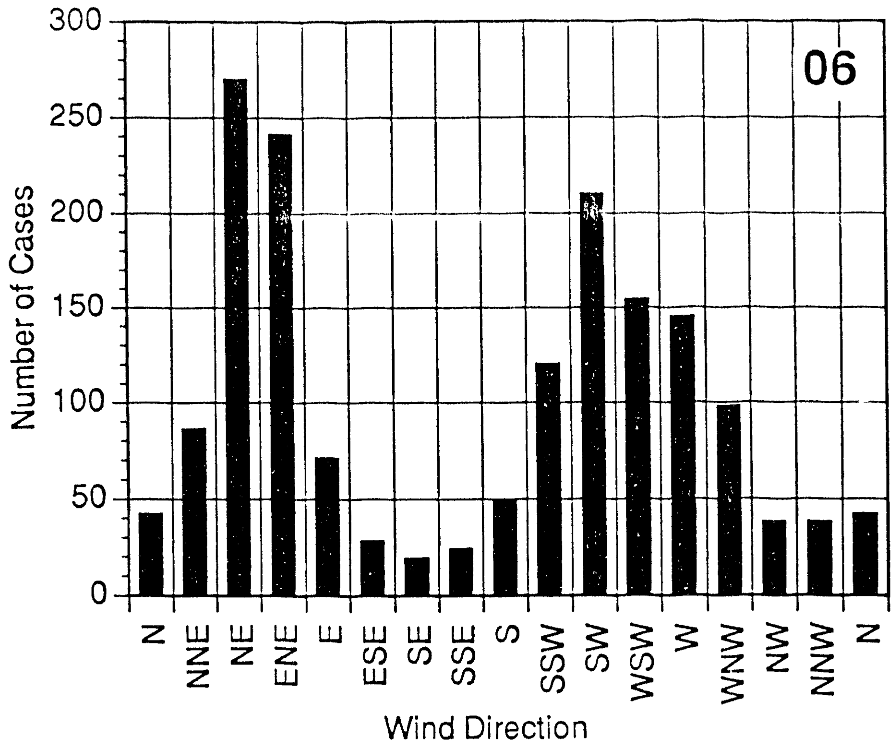
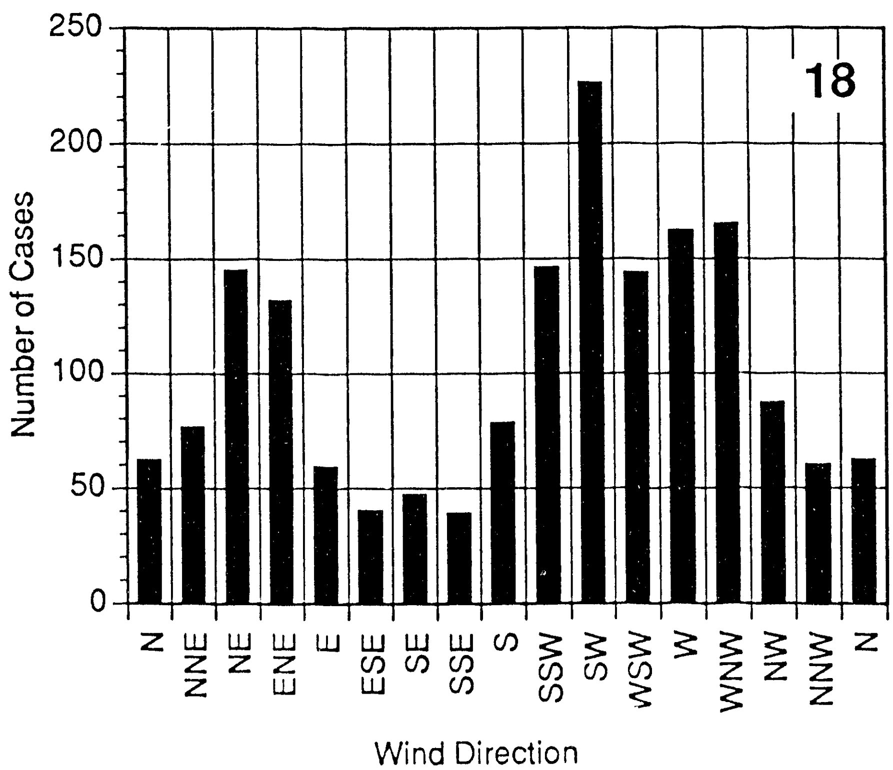
100 m Tower





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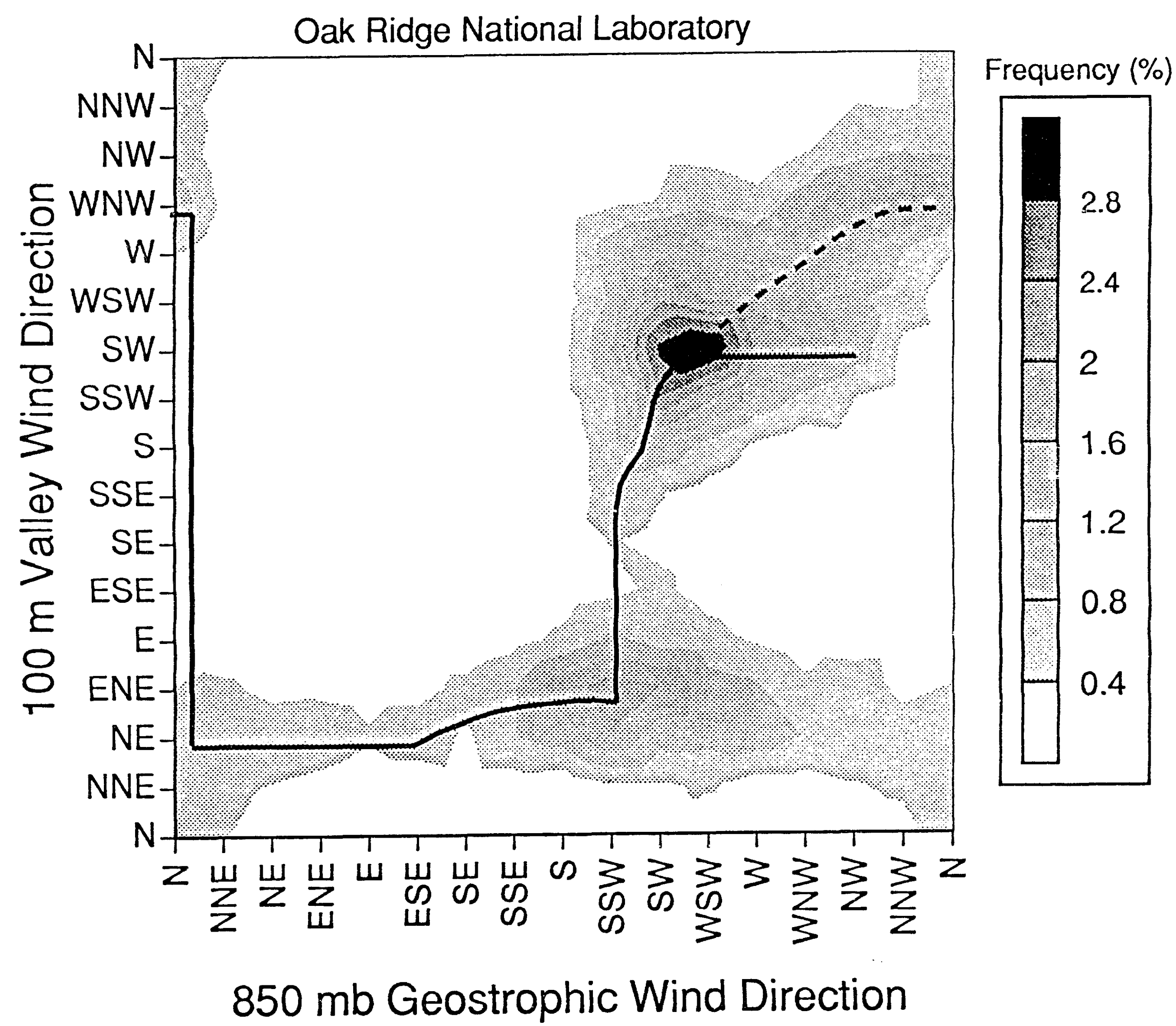
Oak Ridge National Laboratory
100 m Valley Wind Direction
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NNE
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850 mb Geostrophic Wind Direction
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ENE
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ESE
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SSE
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SSW
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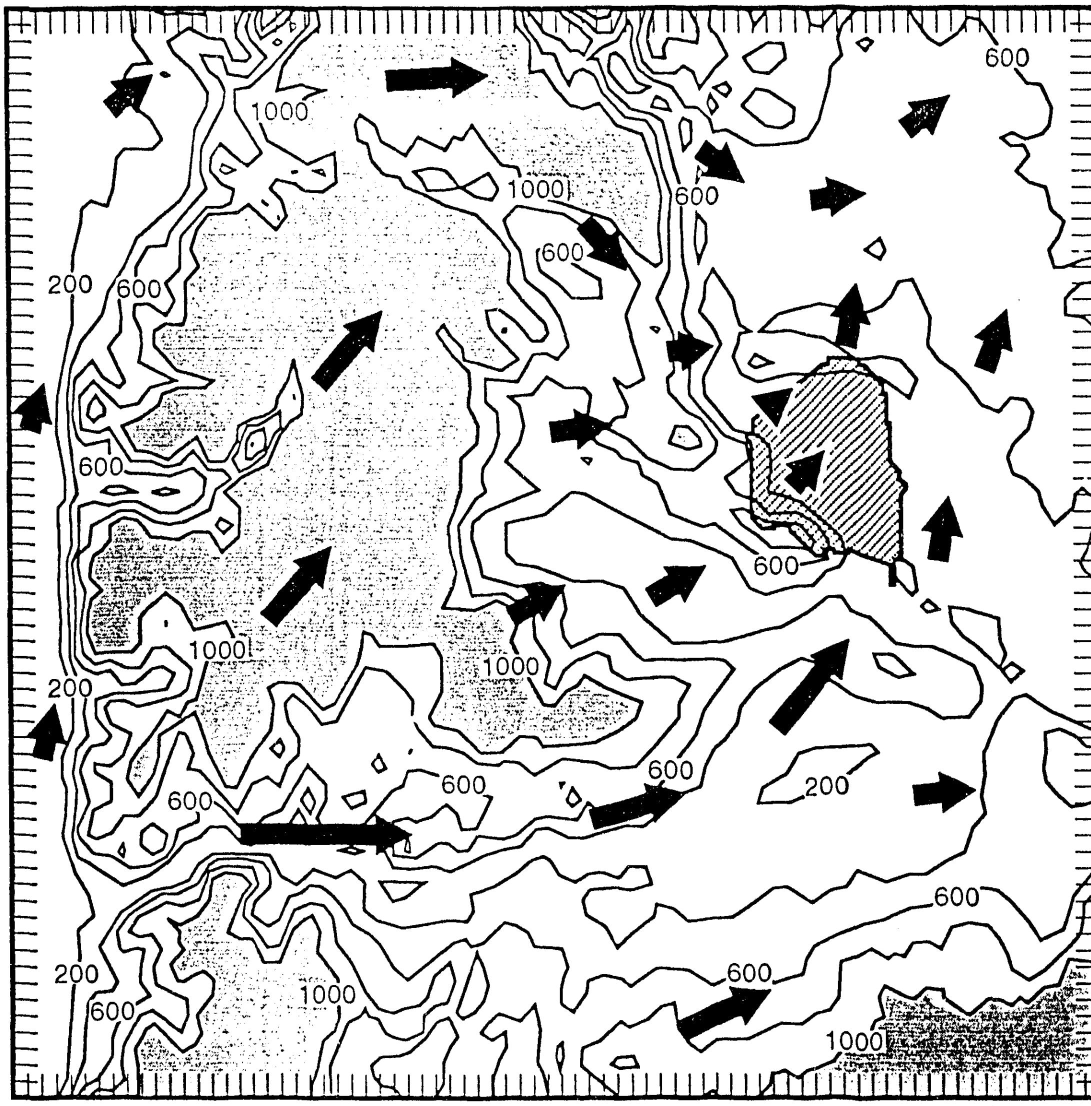

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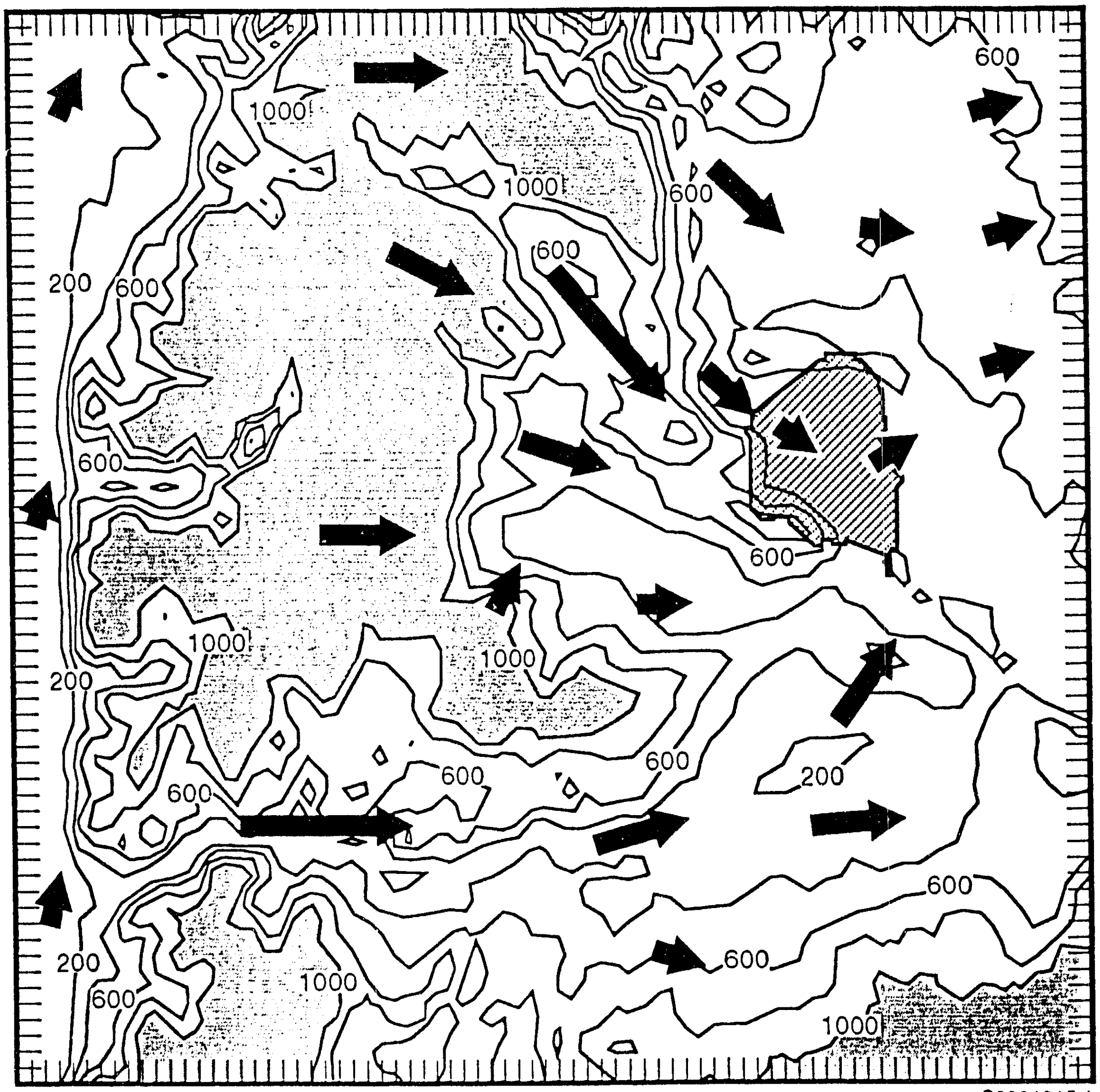

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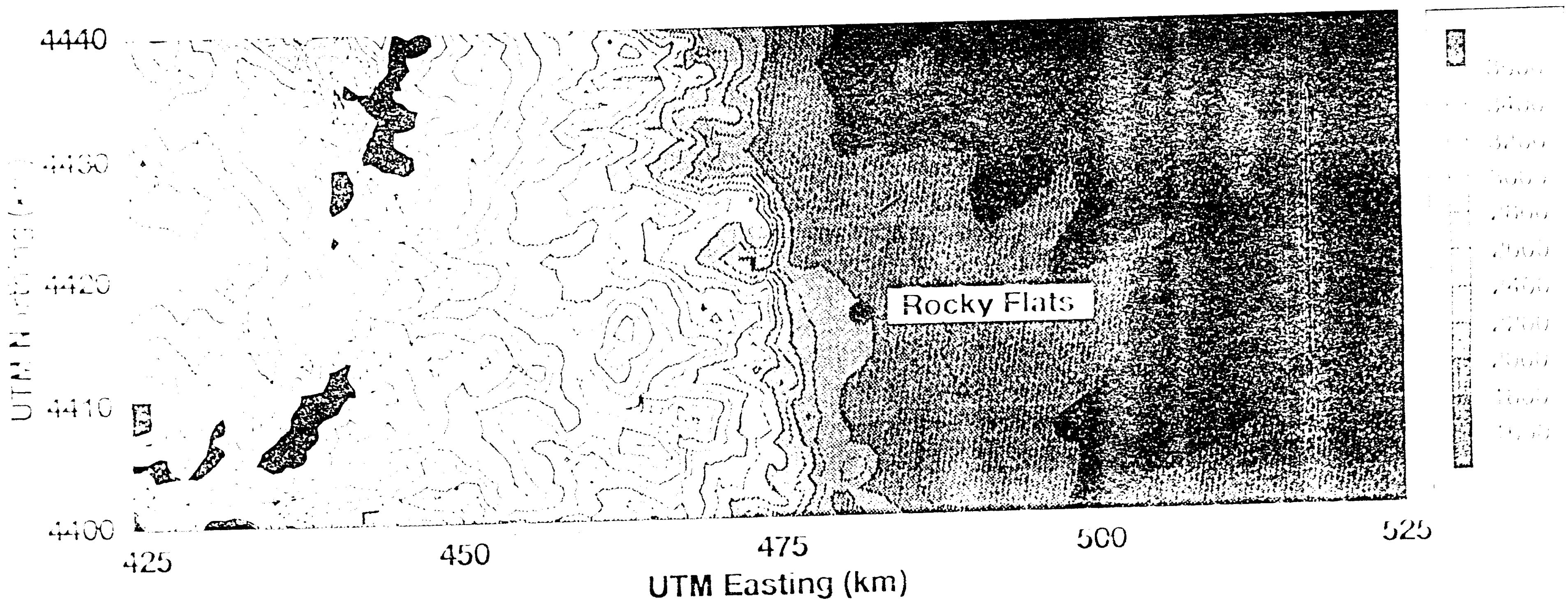

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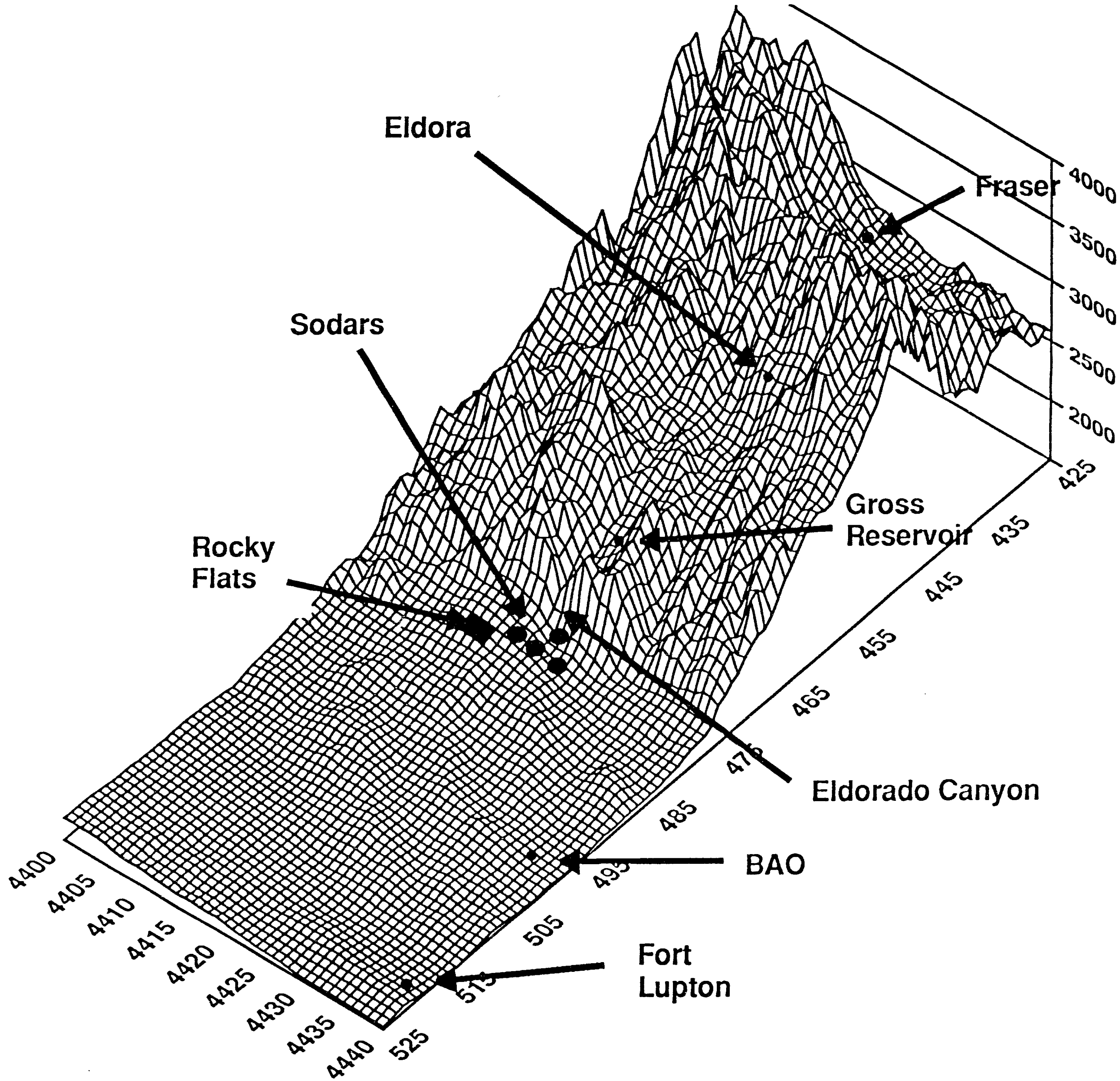
UTM Easting (km)
Rocky Flats


Eldora
Fraser
Sodars
Gross Reservoir
Rocky Flats
Eldorado Canyon
BAO
Fort Lupton
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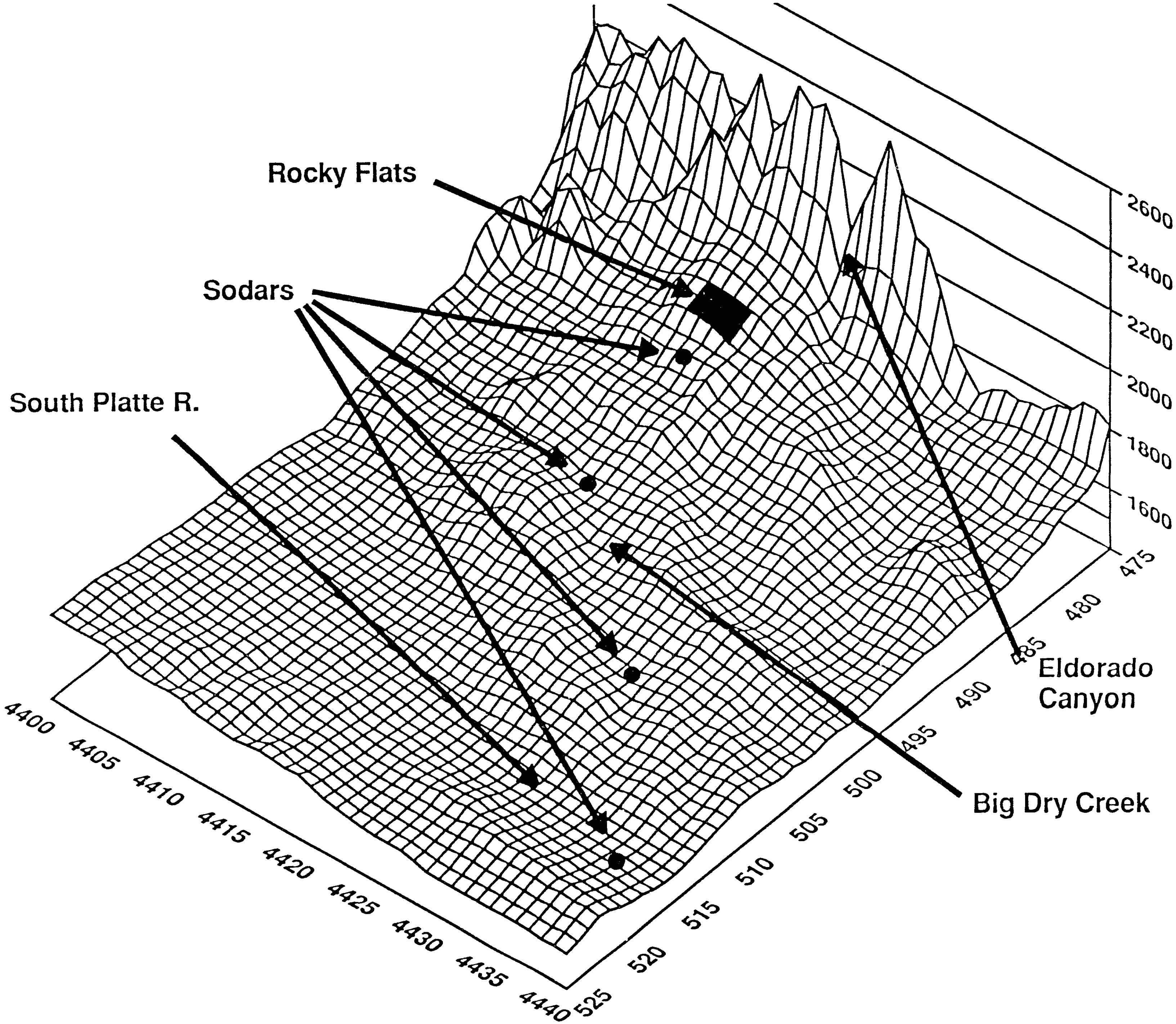
Rocky Flats
Sodars
South Platte R.
Eldorado
Canyon
Big Dry Creek
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