J3.6 Joint Observational Research on Nocturnal Atmospheric Dispersion of Aerosols: The JORNADA Study

David R. Miller* and April L. Hiscox,
University of Connecticut, Storrs, CT.

Carmen J. Nappo
Air Resources Laboratory, NOAA, Oak Ridge, Tenn.

Dragan Zajic
Arizona State University, Tempe, AZ.

Junming Wang and James Ross
New Mexico State University, Las Cruces, NM

Young Yee, Edward Creegan, Ronald Cionco and Robert Dumais, Jr.
U.S. Army, Atmospheric Science Laboratory, White Sands Missile Range, NM

1. ABSTRACT

In April of 2005 a joint field campaign was undertaken at the Jornada Desert Research Range outside of Las Cruces, New Mexico. Its purpose was to quantify the nocturnal PBL structure, its dynamics, its turbulence, its wave structures and the effects of these on plume dispersion and meander. A suite of instruments provided a data set which includes simultaneous micrometeorological measurements of the boundary layer structure, turbulence, and wave activity along with continuous lidar measurement of aerosol plume releases. An overview of the project, its goals and data sets are presented as well as initial results of the study

2. INTRODUCTION

The dynamics of the stable Planetary Boundary Layer (PBL) are complex and still under investigation. This complexity includes, for example: the effects of density currents, intermittent turbulence, surface-layer decoupling, internal gravity waves, cold air pooling, and katabatic flows. If each of these phenomena had a unique impact on plume transport or dispersion, then plume diffusion models could be modified to account for these effects. However, it is doubtful that analyses of 'causes' and 'effects' using data from existing tracer tests are possible. Turbulence and vertical diffusion are weak in the stable PBL, and consequently elevated plumes show little vertical spread. Accordingly, ground samplers may not detect the plume. Another characteristic of the stable PBL are large low-frequency oscillations of the horizontal wind direction, often referred to as plume meander. Because of plume meander and the necessarily long sampling times due to low concentration values at the sampler, attempts to relate observed plume diffusion to dispersion at plume height can be uncertain. The JORNADA (Joint Observational Research on Nocturnal Atmospheric Dispersion of Aerosols) campaign is an attempt to provide data to make possible, perhaps for the first time, comparisons of observed plume dispersion in the stable PBL with model results. The general goals are:

1. To analyze and quantify the nocturnal PBL structure, its dynamics, its turbulence, its wave structures and the effects of these on plume dispersion and meander.

2. To identify and quantify the physical processes responsible for model error.

3. To develop techniques to improve nocturnal dispersion models.

3. FIELD LAYOUT AND MEASURMENTS

3.1 The Site

The field campaign was conducted in April of 2005, at the USDA/NMSU Jornada Research Ranch located about 12 miles north of Las Cruces, NM. The site was a large flat basin with the San Andres Mountains on the East and Dona Anna mountains on the west. The vegetation consists of partial cover of low desert shrubs. Figure 1 shows

* *Corresponding author address:* David R. Miller, UCONN, Department of Natural Resources Management and Engineering, 1376 Storrs Road, U-4087, Storrs, CT 06269-4087; e-mail: David.R.Miller@uconn.edu

the basin with uninterrupted fetch for 30 KM in all directions from the measurement site. At the site, the basin floor sloped to the Southeast at about 1^o.

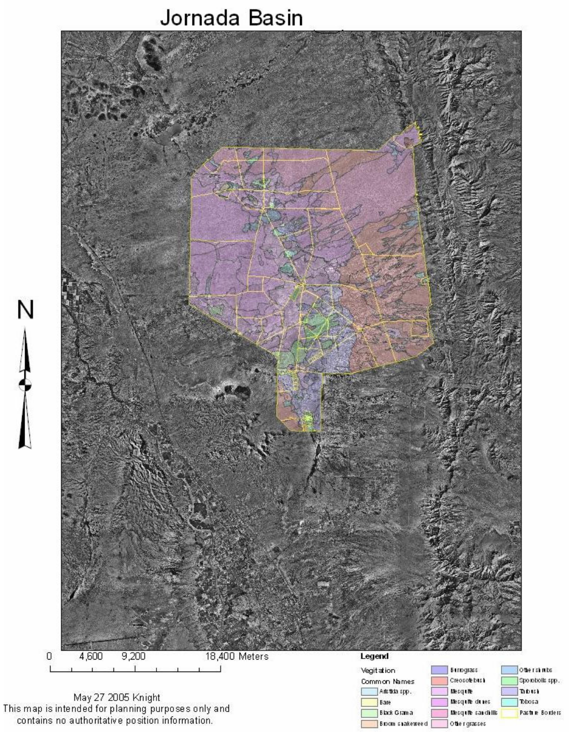

Figure 1. Vegetation, Topography and Jornada Ranch Boundaries.

3.2 The Measurements

The JORNADA field campaign provided data sets from six nights of contrasting meteorological conditions.

The study utilized profiles of tower mounted CSAT3 3-D sonic anemometers (at 1.5 and 11 m) to characterize the wind and temperature time series. A tracer aerosol plume (VMD [Volume Mean Diameter] was 12.9 microns, $DV_{0.1}$ was 11.5 microns, $DV_{0.9}$ was 14.1 microns) was continuously released from the 11 m height on the tower. The time variability and dispersion of the tracer plume was measured with the UCONN elastic backscatter aerosol lidar using the methods described in Hiscox et al. (2006). In addition, a set of instruments, designed to resolve the atmospheric wave and turbulence activity interactions with the tracer plumes was also used. Triangulated pressure sensors (70 m separation) were used to characterize the direction, phase velocity, frequency and amplitude of the larger scale waves after Nappo (2002). Triangulated fine-wire thermocouples (4 m separation) were used at 11 meters on the tower to characterize the smaller scale wave activity after Lee et al. (1997). All the UCONN sonic and pressure sensors were sampled at 20 Hz.

Boundary layer characteristics were monitored using the Arizona State University Vaisala DigiCORA Tethersonde System and The Army Research Laboratory Scintec, model FAS, Wind Pofiler Sodar. The tethersonde system was used to measure a detailed profile of the atmospheric boundary layer by raising and lowering a single Vaisala tethersonde about once an hour during the run periods. Profiles of temperature, relative humidity, pressure, wind speed and wind direction were measured up to z=250 m. The Wind Profiler Sodar was provided continuous 10-minute average wind speed and wind direction profiles to 50m>z>100m. In addition, ASU sonics were located at 1.5 and 2.5 m above ground level near the tethersonde, and these were sampled at 10 Hz.

Figure 2 shows the physical arrangement of the sensors at the site. The UCONN tower and the triangulated pressure sensors were located ~500 m west of the Lidar/Sodar/Tethersonde site.

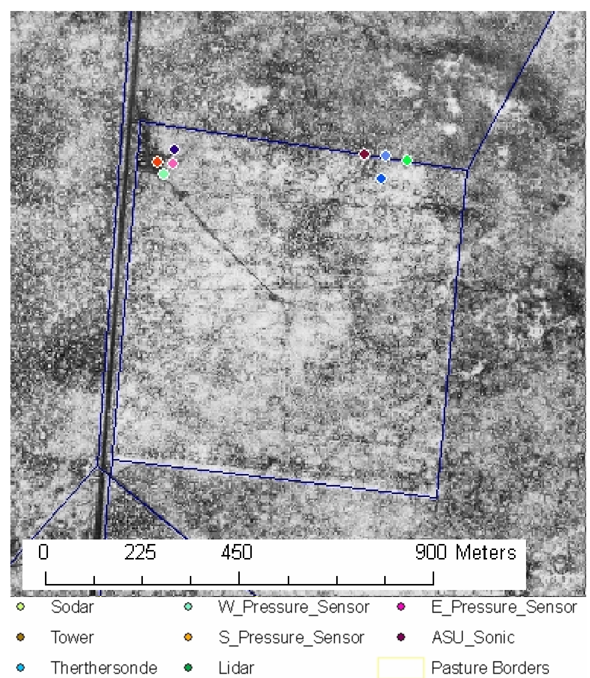

Figure 2. Instrument locations at the Experimental site. The UCONN tower was 500 m East of the Lidar.

4. ANALYSES

Previous field campaigns such as CASES-99 or VTMX obtained data suitable for the study of intermittent turbulence. What makes JORNADA unique is the real-time monitoring of an elevated plume with a LIDAR. For the first time, we can see actual plume dispersion for extended periods of time (Figure 3). The six nights of nights of contrasting meteorological conditions gives us a significant opportunity to analyze some of basic features of the nocturnal PBL, for example, its mean structure, its dynamics, its turbulence, its wave structures and the effects of these on plume dispersion and meander. These conditions included strong stratification with surface layer decoupling, weak thermal stratification with deep surface layers, high wind speeds with strong gusts, near-calm conditions dominated by katabatic flows, intermittent turbulence, gravity wave activity, and frontal passages.

4.1 Specific Analyses

Specific analyses will be organized to answer 10 carefully posed questions.

1. What are the appropriate time scales for plume diffusion, and turbulence fluxes?

2. How do these time scales change with PBL structure and stability?

3. Under what PBL conditions does a spectral gap exist?

4. Is there a relation between plume meander and low frequency gravity waves?

5. Is there a relation between gravity waves and intermittent turbulence?

6. How does intermittent turbulence affect plume diffusion?

7. Do low frequency horizontal eddies exist?

8. How large are the differences between observed and calculated plume dispersion, and how are these related to PBL conditions and averaging times?

9. Can statistical dispersion models be corrected or improved?

10. What turbulence estimates can be derived from lidar observations of the smoke plumes?

Through the process of answering these questions, our general goals will be approached.

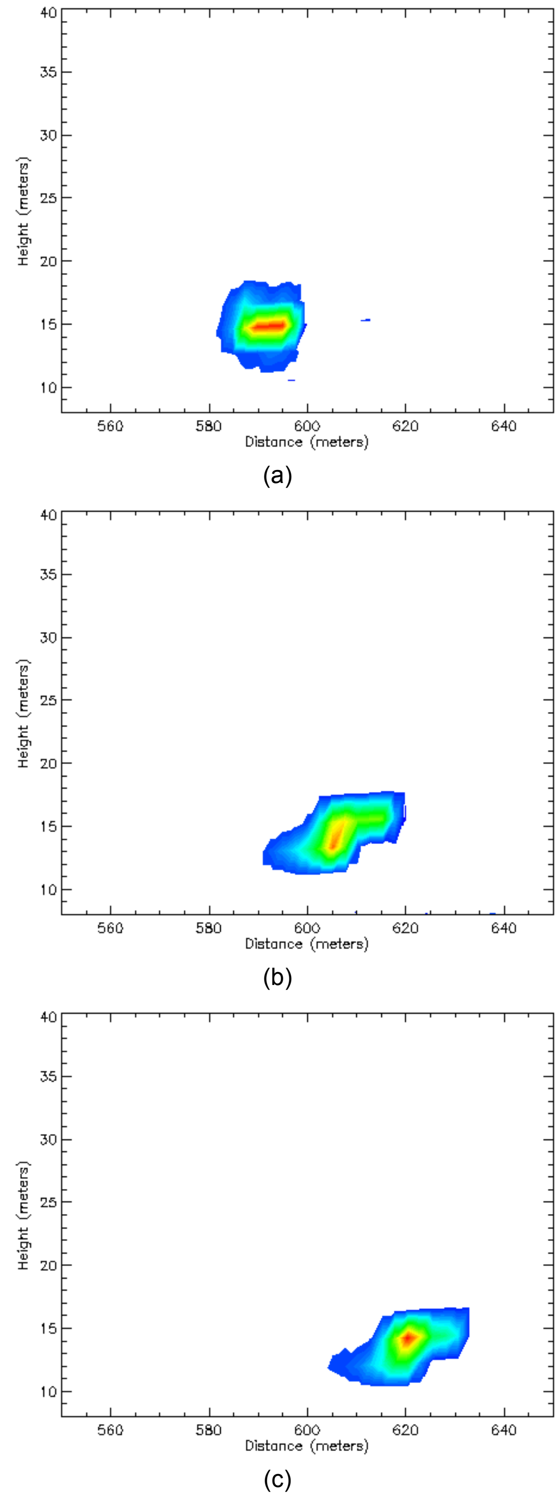

Figure 3: Selected lidar slices of the elevated smoke plume. The images are 21.6 seconds apart and show that short time scale changes exist in both the plume dispersion and meander.

5. ACKNOWLEDGMENTS

This research was funded by the U.S. Army, Atmospheric Science Laboratory and the University of Connecticut, Storrs Agriculture Experiment Station. Thanks to Dr. Barbara Nolen at the Spatial Data Laboratory, United States Department of Agriculture, Agricultural Research Service, Jornada Experimental Range, Long-Term Ecological (LTER) program, for providing the spatial GIS coverage.

6. LITERATURE CITED

Hiscox, A. L., D. R. Miller and C. Nappo, 2006. A Note On The Use of Lidar Images of Smoke Plumes to Measure Dispersion Parameters in the Stable Boundary Layer. *J Atmospheric and Oceanic Technology* (In Press).

Lee, X., H.H.Neumann, G. Den hartog, J. D. Fuentes, T. A. Black, R. E. Mickle, P.C. Yang and P.D. Blanken, 1997: Observation of Gravity Waves in a Boreal Forest, *Boundary-Layer Meteorolog*y, 84, 383-398.

Nappo, C.J., 2002: *An Introduction to Atmospheric Gravity Waves*, Academic Press, pp260.