5.3 NIGHTTIME AEROSOL DISPERSION AND CONCENTRATION MEASUREMENTS IN THE STABLE BOUNDARY ALYER VIA ELASTIC BACKSCATTER LIDAR

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

Carmen J. Nappo
NOAA, ARL, ATDD, Oak Ridge, Tennessee

Junming Wang
New Mexico State University, Las Cruces, New Mexico

Dragan Zajic
Arizona State University, Tempe, Arizona

Young Yee, Edward Creegan and Ronal Cionco
Army Research Lab, WSMR, New Mexico

1. INTRODUCTION

Elastic backscatter lidar measurements of aerosol plumes have been used in to quantify the effects of nocturnal planetary boundary layer structure, dynamics, turbulence, and wave structures on plume dispersion. The dynamics of the stable 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. These phenomena all affect plume transport and diffusion, and a better understanding of these effects are needed for transport model development The JORNADA (Joint Observational Research on Nocturnal Atmospheric Dispersion of Aerosols) field campaign, conducted in the New Mexico desert during April 2005, seeks to address some of these issues.

The JORNADA data set includes simultaneous micrometeorological measurements of the boundary layer structure, turbulence, and wave activity along with continuous lidar measurement of aerosol plume releases. 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. Prior work has developed techniques for determining plume dispersion parameters, plume concentration and plume meander to help merge the lidar and micrometeorological measurements. The application of these techniques to the JORNADA data will allow for a more complete understanding of turbulence and wave structures. The details of these new lidar techniques as well as initial results of the joint study are presented here.

.

2. METHODS

During the JORNADA field campaign, a tracer plume was released continually from ~ midnight to 5 am local standard time. During this time vertical cross-sectional lidar scans of the plume were made at about 3-s intervals, from a distance of ~ 400 meters away from the release point. Sampling was continuous for several hours on several nights. Simultaneously, sonic anemometer measurements of horizontal and vertical wind components were made at the point of plume release. In addition, a triangulated array of three microbarographs was positioned surrounding the release tower and an array of four finewire thermocouples was positioned at the height of release. Figure 1 shows the instrumentation tower.

Hiscox *et al.* (2006a,b) have presented methods to quantify plume dispersion parameters and in plume concentrations from remote elastic backscatter lidar measurements. Both techniques are applicable to the repetitive vertical lidar slices of an aerosol plume taken at JORNADA.

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

Figure 1: Instrumentation tower. Tower height was 10 meters. At the top a 3D sonic anemometer and finewire thermocouple array took measurements at a rate of 20Hz, and the tracer plume was also release from this height. Microbarographs were located at ground level and a second 3D sonic anemometer was located at 1.5 meters above the ground.

To estimate vertical plume dispersion, σ_z, an inversion of the Gaussian plume equation is used:

$$\sigma_z^2 = \frac{\left(\frac{\Delta z_e}{2}\right)^2}{-2\ln\alpha} \qquad (1)$$

where Δz_e is the edge to edge width of the plume and α is the ratio of the lidar backscatter at the edge of the plume to the lidar backscatter at the center of the plume. (Hiscox et al., 2006a)

Total in-plume concentration, Q_{lidar}, can be estimated from a known source strength and plume size measurements from the lidar:

$$Q_{lidar}(t) = \frac{\beta_{lidar}(t)}{V_t} * \varepsilon \qquad (2)$$

where, $\beta_{lidar}(t)$, is the total lidar backscatter in the plume at time, t, V_t, is the plume's volume as sampled by the lidar, and ε, is a calibration factor found from the slope of the line relating lidar backscatter over time to the theoretical prediction of aerosol mass aloft based on initial drop size distribution measurements. (Hiscox et al., 2006b)

3. RESULTS

3.1 *Vertical Dispersion*

Figure 2 presents a preliminary time series of vertical dispersion, σ_z, during the first night of the study. Figure 2 shows a noticeable increase in the vertical plume dispersion just before 5:30 AM LST. This disturbance is also seen in the pressure sensor data and the event has been analyzed by Nappo et al., 2006.

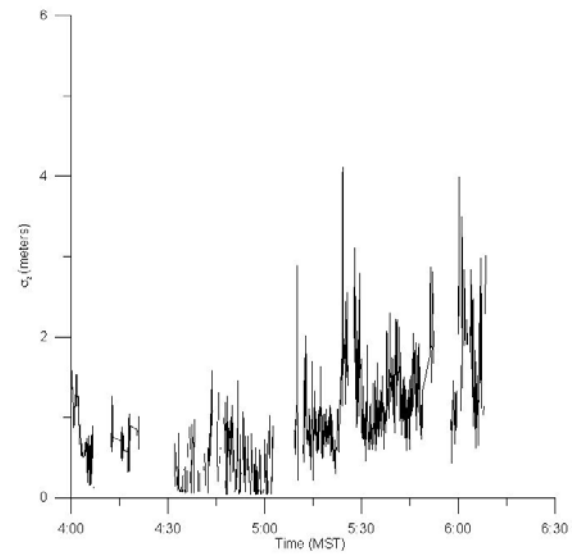

Figure 2: Time series of σ_z for the night of April 20-21, 2005.

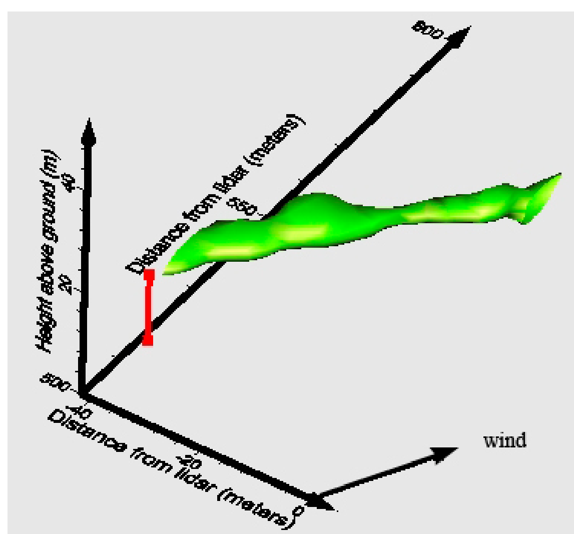

Figure 3: Three-dimensional composite plume

3.2 *Plume Movement*

Three-dimensional scans of the plume can be combined in post processing and examined for differences along the plume axis. Plumes moved in the general direction of the wind speed, although small deviations were seen. Figure 3 is an example of a full three-dimensional plume scan.

3.3 *In-Plume Concentration*

To determine in-plume concentrations, the initial drop size distribution of the tracer plume was measured in a high-speed wind-tunnel with a Malvern particle sizer. The methods of Hiscox et al., 2006b were applied using the measured meteorological conditions. This allows for a new drop size distribution to be calculated for any given measurement time. An example of the change in distribution for a 25 meter downwind location, a 1 m/s windspeed, a temperature of 15.36ºC, a relative humidity of 36.7% and an atmospheric pressure of 862.3 mbar is shown in Figure 4. The reduction in particle size is due to evaporation.

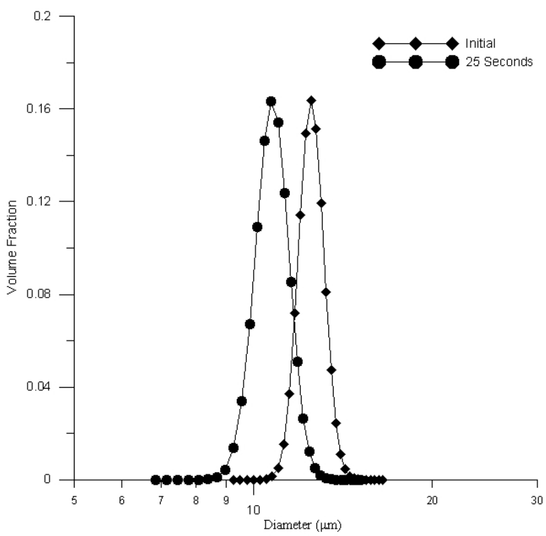

Figure 4: Example drop size distributions for plume. The diamonds indicate the initial distribution of the tracer plume and the circles indicate the calculated distribution 25 seconds after release.

4. ACKNOWLEDGEMENTS

This research was funded by the U.S. Army Research Office and supported by the New Mexico State University Agriculture Experiment Station and the University of Connecticut Storrs Agricultural Experiment Station.

5. REFERENCES

Hiscox, April L., Carmen J. Nappo, David R. Miller. 2006a: A Note on the use of lidar images of smoke plumes to measure dispersion parameters in the stable boundary layer, *J. Oceanic Atmos. Tech.,* **23**, 1150–1154.

Hiscox, April L. and David R. Miller, 2006b: Dispersion of fine spray from aerial applications in stable atmospheric conditions, *Trans ASABE*, **45**, 1513-1520.

Nappo, C.J., D.R. Miller, A.L. Hiscox, E. Creegan, Y. Yee, D. Zajic, 2006: An episode of intermittent turbulence in the nighttime PBL during the JORNADA field study, *17th Symposium on Boundary Layers and Turbulence/27th Conference on Agricultural and Forest Meteorology*, San Diego, CA, May 2006.