9.3 ADVECTION, EDGE, AND OASIS EFFECTS ON SPATIAL MOISTURE AND FLUX FIELDS FROM LIDAR, THERMAL IMAGERS AND TOWER-BASED SENSORS

Daniel Cooper*, W. Eichinger[2], L. Hipps[3], M. Leclerc[4], C. Neale[3], J. Prueger[5] and S. Bawazir[6].

2. University of Iowa, Iowa City, IA
3. Utah State University, Logan, UT
4. University of Georgia, Griffin, GA
5. National Soil Tilth Laboratory, Ames, IA
6. New Mexico State University, Las Cruces, NM

1. INTRODUCTION

Relatively narrow forest stands such as the riparian Tamarisk bordering the Rio Grande are subject to dry air advection from the adjacent semi-desert environment. The transport of warm dry air into the canopy has a profound effect upon the spatial properties of the moisture field and associated latent energy flux. The Los Alamos National Laboratories' scanning Raman lidar was used in conjunction with an array of point sensors and an airborne thermal scanner to measure and interpret the three dimensional moisture fields over the Tamarisk canopy. These measurements were used to quantify how the micrometeorological scalar and gradient moisture fields are modified by intensive advection.

2. SITE, INSTRUMENT, AND LIDAR OVERVIEW

The study site was in the riparian corridor at the Bosque Del Apache Wildlife Refuge (hereafter called the Bosque) adjacent to the rio Grande in the semiarid south-central part of New Mexico, 25 km south of Soccoro, NM at approximately 34° N latitude, 107° W longitude, at an average elevation of 1376 m. During the study period, the local climate was typically characterized by clear skies in the morning with stratocumulus clouds developing in the afternoon hours. The vegetation at the Bosque consisted almost entirely of a uniformly dense riparian *Tamarisk* (salt cedar) 5 m tall with a height variation of ±1 m. The riparian corridor is adjacent to the western side of the river to a width between 500 m to 700 m and extends both north and south for several kilometers. During September the salt cedar canopy was closed with a green LAI ≈ 2.

Two, 12 m tall micrometeorological towers were positioned about 300 m from the river in the salt cedars and separated in the North-South direction by 685 m. They were instrumented at 2.7 m above the canopy with 3-D sonic anemometers, fine wire thermocouples, Krypton hygrometers, temperature-humidity probes and net radiometers sampling at 20 Hz. Five soil heat flux plates were buried 0.08 m below the soil surface, and spatially distributed to represent the range of shade below the canopy.

The lidar was situated approximately at the mid-point between the two towers on the western edge of the Tamarisk at the top of an adjacent levee. In addition, an airborne visible/near IR imaging camera operated by the Utah State University acquired imagery of the study site. The sand levee runs roughly North-South and the lidar, sodar, and profiling radar where located in the center of the levee. The lidar azimuthal scan range covered 110° from North to South in 5° increments over 15 minutes, and acquired data from the top of the canopy to 40 m into the atmospheric boundary layer (hereafter referred to as the ABL) in 35 s. The LANL Raman lidar generates volume images from two-dimensional scans of range-resolved water vapor.

* Los Alamos National Laboratory, MS J577,
Los Alamos, NM 87545

3. ADVECTION AND STABILITY

Periodically in the mid-afternoon, the wind direction would change from the north to the west. Westerly winds import dry warm air from the sparsely vegetated desert to the relatively moist, cool salt cedar canopy, creating locally stable atmospheres. Stability is determined here from eddy covariance measurements of the Monin-Obukhov length; $\mathcal{L}$. The effect of "hot to cold" advection on the stability of turbulent heat and moisture fluxes in semi-arid environments are sometimes referred to as the "oasis effect". The oasis effect is where hot dry air blows over a vegetated field in a desert, such as at the Bosque. The dry air moving over the moist canopy increases the local vapor pressure deficit which in-turn has a profound effect upon the temperature gradient and the sensible heat flux, in that the direction of the gradient and thus the flux will change from going away from the surface to going into the surface.

A change in the direction of the flux was observed by the eddy covariance sensors between 1430 and 1530 hours on September 12th,1998. In this one hour period the wind direction changed from northerly (parallel to the river) to southwestern (from the desert into the Bosque) and as expected, when $\mathcal{L}$ became positive, the sensible heat went into the canopy, from +62 Wm^{-2} at 1430 hours to -22 Wm^{-2} at 1530 hours.

The process of advection is used to explain some of the observed structures in the lidar data, as well as the afternoon stable conditions observed by the micrometeorological instruments. High-moisture-containing structures in the lidar scans appear to be spatially limited to heights between 15 and 20 m above the canopy were found during a stable period. In order to evaluate how these structures developed, additional lidar and micrometeorological data were used to support the hypothesis that the observed local stability is due to dry air transported over the salt cedar canopy. These lidar scans are used to illustrate how the source of the relatively dry air that was advected over the canopy was ultimately the cause of the local stability and associated structures found in the lidar data.

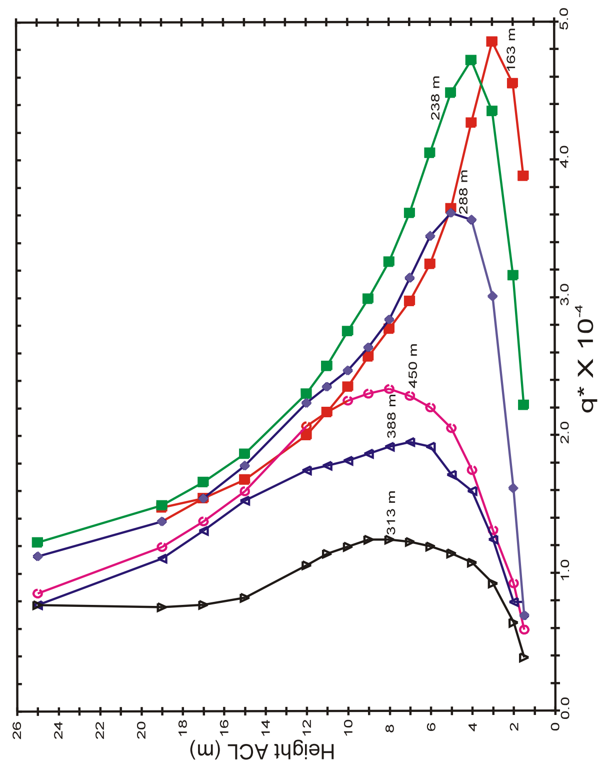
A lidar scan was acquired almost perpendicular to the mean wind showing the affect of dry air being advected into the salt cedar, as the dynamic range of this data is almost 50% higher than that during unstable convective conditions. The air near the canopy surface is found to have the expected high moisture levels of 13 to 14 g/kg, while the upper portions of the scan are relatively dry- between 8.5 and 11 g/kg.

From footprint analysis for a stability of z/L = +0.16 an expected source-area footprint will be about 450 m to achieve 90% of the cumulative water vapor flux. Using this footprint result, advected air from the desert moving towards the region where the lidar data was taken will be an admixture of high moisture from the salt cedars and the dry air from the desert. This mixing was observed in the lidar data which is spatially in an intermediate position between a "dry" scan and a "moist" scan. The moist structures observed between 10 and 15 m height have concentrations up to 14 g/kg, while at similar heights in the dry scan, the structures have water vapor concentrations between 12 and 13 g/kg; the background moisture below these features is drier still, having water concentrations between 9.5 and 11 g/kg.

A theoretical structure for surface layer "hot to cold" advection was developed using potential temperature profiles as a function of distance between two surface roughness conditions, such as from bare soil to irrigated fields as outlined by Kaimal and Finnigan (1994). What they predicted is the development of an advective inversion, measured with temperature profiles as a function of distance from the dry region into an irrigated field. The affect of stability and mass advection is also estimated for water vapor moisture variables as: $u(\partial q/\partial x) \cong -(\partial q_*/\partial z)$.

The development of advectively driven inversions under daytime convective conditions should be observable in water vapor scalar profiles from lidar, from heat or moisture flux profiles, or from profiles of q_*. Profiles of q_* were created from the lidar and micrometeorological data that was within a given 75 m wide vertical section of the lidar scans and coincident measured u_* and ζ observations from the north tower, using the similarity equation for non-dimensional moisture. The first of these profiles are located near the inner edge of the riparian zone and progress through the salt cedar stand toward the edge of the study site directly adjacent to the Rio Grande. The q_* profiles were acquired at 1430 hours under convective conditions when $\zeta < 0$. The unstable conditions are evident in the increasing values of q_* with height above the canopy, small inversions are seen at 3 to 4 m in height presumably where eddy mixing occurs between moist rising plumes and drier down-welling air. In contrast, when $\zeta > 0$ dry air advection creates deep inversions 2 to 3 m above the canopy, the intensity of the inversion decays as a function of distance into the riparian forest as the dry air is mixed with the more moist canopy air. Wind tunnel studies by Charnay et al., (1979) show similar sensible heat flux profiles for "hot-to-cold" advection that are in good agreement with Fig. 1. The biggest discrepancy between the lidar observations over the Tamarisk and the wind tunnel studies is the change in profile structure between 288 m and 313 m. It appears from thermal IR aircraft data acquired over the site that there is a 100 m wide drainage system on the eastern edge of the Tamarisk that brings ground water close to the surface, this in turn reduces the surface temperature and the vapor pressure deficit in the Tamarisk thus, reducing the inversion intensity.

Figure 1. q* profiles derived from lidar data at 15:30 LST over the Bosque when ζ = +28.85.



4. CONCLUSION

This work is an initial step in improving our understanding of the spatial processes involved in advection. While the analysis was performed on data acquired under ideal conditions of large, homogeneous, closed, uniform canopy that resided on nearly level terrain, it gives some insight into the affects of step changes in roughness and hydrologic properties upon advection and turbulent fluxes. Future work will concentrate on more complex terrain and environments.

5. REFERENCES

Charnay, G., Schon, J.P., Alcaraz, E., Mathieu, J., 1979. Thermal characteristics of an internal boundary layer with an inversion of wall heat flux, In *Turbulent Shear Flows* I, Spinger-Verlag, 104-118 pp.

Kaimal, J.C. and Finnigan, J.J., 1994. *Atmospheric Boundary Layer Flows*. Oxford Press, NY, PP 289.