1.9 **Turbulence Spectra Over Open Water During a Thunderstorm Outflow Event**

J. H. Prueger[1], L.E. Hipps[2], J.R. Cleverly[3], W. Eichinger[4], D.I. Cooper[5], J.L. Hatfield[1], S. Bawazir[6] and W.P. Kustas[7]

[1]USDA-ARS National Soil Tilth Laboratory Ames, Iowa 50011
[2]Plant, Soils and Biometeorology Utah State University Logan, Utah 84322-4820
[3]University of New Mexico, Albuquerque, New Mexico
[4]University of Iowa, Iowa City, Iowa
[5]Los Alamos National Laboratory, Los Alamos, New Mexico
[6]New Mexico State University, Las Cruces, New Mexico
[7] USDA-ARS National Hydrology Laboratory Beltsville, Maryland 20705

1. INTRODUCTION

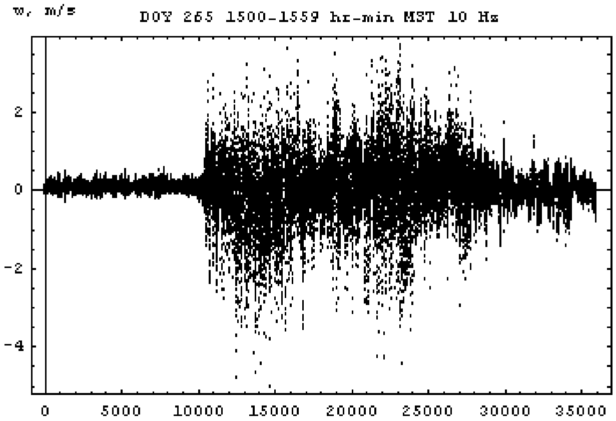
The allocations for water from the Rio Grande River in New Mexico are approaching nine times its prescribed capacity. Efficient river management requires knowledge of daily evaporation losses from open water surfaces. Current estimates rely on simple approaches developed over 30 years ago. In an effort to improve these estimates, we have initiated a study making eddy covariance measurements over a large reservoir in southern New Mexico. The general goal is to examine evaporation rates and develop appropriate models for open water in semi-arid regions. In addition to yearlong monitoring of energy fluxes from the reservoir surface, short-term intensive data acquisition campaigns were conducted in conjunction with a water vapor scanning Lidar. The objective is to gain further insight into the turbulent processes affecting evaporation over an open water surface surrounded desert environment. During the course of one campaign, turbulence from an intense outflow of a localized convective cell moved over the site, and greatly altered the turbulence and fluxes. Here we report the interesting results of this event.

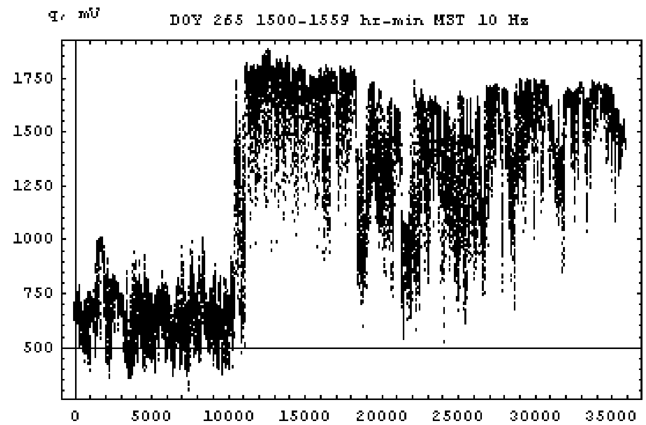
2. SITE, INSTRUMENTATION, AND DATA

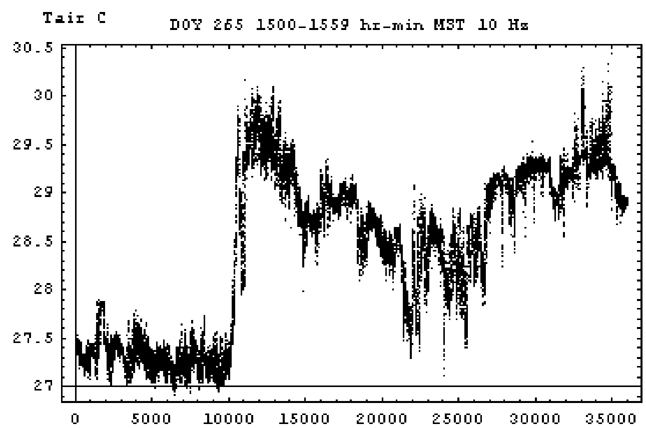
A 25 m tower was erected near the middle of a northern section of Elephant Butte Reservoir, where an eddy covariance (EC) system was mounted 3 m above the water surface. The EC system was comprised of a 3-dimensional sonic anemometer and a krypton hygrometer (Campbell Scientific Inc.). Net radiation, wind speed and direction, air temperature and humidity were also measured on the tower. In addition a 15-meter water temperature profile was deployed to monitor water temperature changes so that monthly heat storage may be computed. The first intensive field campaign took place in September of 2001, to study and evaluate turbulence structures over the open water surface. Analyses of the data included surface flux calculations as well as power and co- spectra of turbulence components. A unique and unexpected event took place during a short afternoon period. The site came under the influence of a strong outflow from an isolated thunderstorm located nearby. The intense part of the event lasted approximately 32 minutes. The eddy covariance system continued monitoring data throughout the event. Results of this event are presented.

4. RESULTS

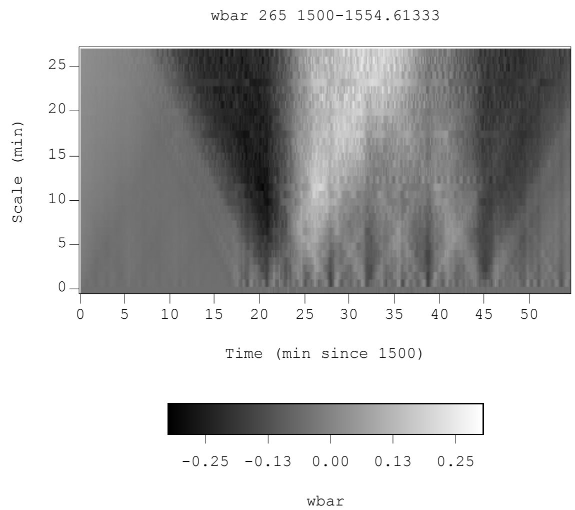
The Figure 1_a shows the time series of the vertical wind velocity (*w,* m s^{-1}) sampled at 10 Hz during this interesting period. The data points represent 36000 measurements of *w* beginning at 1500 hours MST and ending at 1600 hours. For approximately 10 minutes into the hour *w* values were typical to those observed in most other periods or days ranging from about 0.1 –0.5 m s^{-1}. The onset of the outflow event can be identified as approaching suddenly. Vertical velocities increased by a factor of 4–16 times from the first 10 minutes into the hour. Peak vertical velocities of over 5 m s^{-1} were recorded. During the last 10 minutes the event gradually dissipated and w values begin to recede toward values prior to the event. Figure 1_b show the time series for the krypton hygrometer voltages in mV. The lower mV values indicate more water vapor in the air while higher mV values indicate drier air. Figure 1_c show the air temperature measured with a fine wire thermocouple. Hygrometer mV data were observed to oscillate between a typical range of 500 and 1000 mV for this type of surface in September. Air temperatures averaged 27 °C and were typical for this time of year.







Note the relatively steady appearance of w, mV, and T during the first 10 minutes into the hour. At nearly exactly the same moment, all three measurements respond to the onset of the outflow event. Substantially drier and warmer air enters the region over the water surface. Hygrometer mV increased by over two fold. Air temperatures increased nearly 3 °C. These properties reflect origin of the cell over the hot, dry mountains to the west of the reservoir. As it approached the site, the flows introduced warm, dry, and highly turbulent air over the water near the tower. Fourier and Wavelet transforms were applied to evaluate turbulence characteristics during the outflow event. Because of space limitations, power and co-spectra plots will be shown and discussed in the presentation rather than in the pre-print volume. However, the last figure shows an example of a half-plane wavelet transform applied to the vertical velocity data to investigate structure in the w time series. This method performs a time series analysis that is localized in times as well as in space, permitting visualization of transient events (Scanlon and Albertson, 2001). Average vertical wind velocity at various temporal scales was not constant over the 54.6-minute period. Long-term sustained downdrafts dominated the time series during and following the perturbation event at beginning at 1516 hours. Thereafter, vertical wind speed entered into a period of greater turbulence at all scales, in which updrafts showed less structure and occurred at a larger scale than many of the downdrafts. The next figure shows an example of a wavelet half-plane showing the variance of w (which is approximately = to w') with respect to scale and time since 1500 hours.



With respect to evaporation fluxes, typical 30-minute latent heat flux values at he same time of the outflow event for days prior to DOY 265 averaged 80-250 W m^{-2}. During the outflow event the two 30-minute latent heat fluxes for the 1500-hour period were 908 and 530 W m^{-2} respectively. The advection of the warm dry air greatly enhanced the evaporation rates. Such convective cells are not unusual during the monsoon season in this region. Further analyses are being conducted on the turbulence and fluxes during this event.

5. REFERENCES

Scanlon, T.M. and J.D. Albertson, 2001. Turbulent transport of carbon dioxide and water vapor within a vegetation canopy during unstable conditions: Identification of episodes using wavelet analysis. Journal of Geophysical Research, 106(D7): 7251-7262.

John H. Prueger, USDA-ARS National Soil Tilth Laboratory, 2150 Pammel Drive, Ames Iowa 50011; prueger@nstl.gov