9.3 BIOMICROMETEOROLOGICAL MEASUREMENT OF RIPARIAN VEGETATION EVAPOTRANSPIRATION

John Kochendorfer* and Kyaw Tha Paw U[1]
[1]University of California, Davis, California

1. INTRODUCTION

Along the Cosumnes River in California's Central Valley, a field study at two different riparian sites is in progress to provide evapotranspiration estimates for use in hydrological and ecological studies. Biomicrometeorological measurements of riparian ecosystems presents a challenge because of the vegetation lies along a narrow band, limiting fetch required of many traditional biomicrometeorological methods.

2. METHODS AND FIELD CONDITIONS

The first site (38°16'00"N, 121°23'39"W) is in a cottonwood forest and has enough fetch to allow for the use of eddy-covariance to measure water vapor flux. A 23 m tower has been in operation at this site since January 2004. The focus of this abstract, however, is on the second site at Deer Creek (38°22'01"N, 121°20'35"W). Using an energy budget technique similar to that developed by Paw U and Daughtry (1984), we have been gathering evapotranspiration estimates at the upstream site since July 2003.

The Deer Creek site has a narrow (2-5 tree heights) and heterogeneous band of vegetation. Furthermore, the prevailing wind direction is almost perpendicular to the river. A 23 m tower was erected within a 19 m tall thicket of willows, on the downwind side of the drainage. As we could not gain access to the upwind side of the river, the preferred technique of eddy-covariance with the inclusion of advection measurements was not feasible.

Our technique allows us to estimate the amount of evapotranspiration occurring at the upstream site by measuring surface temperature of the ecosystem, net radiation, air temperature, relative humidity and ground heat flux. The energy budget of the ecosystem is expressed as follows:

$$R_n - G = \overbrace{\frac{\rho \cdot C_p}{r_h}(T_s - T_a)}^{H} + \overbrace{\frac{\rho \cdot C_p [e_s(T_s) - e_a]}{\gamma (r_h + r_c)}}^{LE} \quad (1)$$

R_n is the net radiation – the sign is positive for energy entering the surface of the ecosystem. G is the ground heat flux of energy – positive going away from the surface into the ground. H is sensible heat flux and LE is latent energy flux – both are positive when energy is leaving the ecosystem into the atmosphere. r_h is the aerodynamic resistance to heat transfer, assumed approximately equal to the aerodynamic resistance to water vapor transfer and r_c is the net stomatal resistance of the ecosystem. Our approach is to solve for r_h under simplified conditions, describe this aerodynamic resistance as a function of wind velocity and stability parameters, and then use this estimated resistance value to calculate LE at ½ hour intervals during times when we cannot measure r_h, similar to the 'three-leaf' method of Paw U and Daughtry (1984).

The first method is to solve for aerodynamic resistance when the canopy is wet and stomatal resistance is assumed negligible:

$$r_h = \frac{\rho \cdot C_p}{(R_n - G)} \left\{ (T_s - T_a) + \frac{[e_s(T_s) - e_a]}{\gamma} \right\} \quad (2)$$

We placed a 500 gallon tank of water and a pump near the tower base and installed a sprinkler head at the top of the tower that sprays water in a 20 m radius. We covered the instruments on the tower to protect them from water while sprinkling and uncovered them again immediately after spraying.

On nights when it is dry enough to eliminate the possibility of condensation, we assume that the stomata are closed and LE is negligible. Using this second method we solve for r_h as the only remaining unknown in the energy budget:

$$r_h = \frac{\rho \cdot C_p}{(R_n - G)} (T_s - T_a) \quad (3)$$

The canopy resistance (r_c) can also be estimated as we can measure all of the remaining driving variables within the LE term.

3. RESULTS AND DISCUSSION

The estimates of aerodynamic resistance calculated using Equation 3 are consistent over different seasons and using different surface temperature sensors. Below is an example of 30 sec data taken from the first night the tower was operational in 2003:

Corresponding author address: John Kochendorfer, Atmospheric Science, Univ. of California, Davis, One Shields Ave., Davis, CA 95616;
email: jkoch@ucdavis.edu

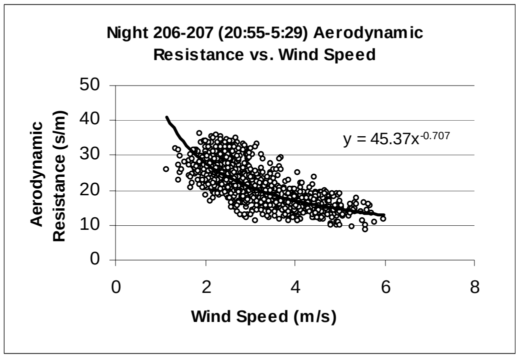

Figure 1. Aerodynamic resistance as a function of wind speed.

Aerodynamic resistance has an obvious relationship to wind speed in this plot. This relationship, in the combined ½ hour averaged data from multiple nights, is regressed to the wind speed to have the power of approximately -.75. Isolated objects have classically been modeled as having resistances related to wind speed by the inverse power of ½, while homogeneous canopies are described as having resistances related linearly to the inverse of wind speed. Of key importance is the fact that the stand of willows that are under observation are found to be aerodynamically between a canopy and an isolated object.

Preliminary evapotranspiration results indicate that during the summer the Bowen ratio is close to .2. This low Bowen ratio suggests a partial oasis effect. At times, the Bowen ratio is even observed to be negative during the day. The Bowen ratio during winter months varies greatly due to frequent precipitation events. When relatively dry, we see a higher Bowen ratio than during the summer because the willow stand has senesced. During the days after rain, we see much lower Bowen ratios. It is impossible to record accurate data while precipitation is occurring because water on the net radiation sensor clearly distorts the measurements taken by this thermal sensor.

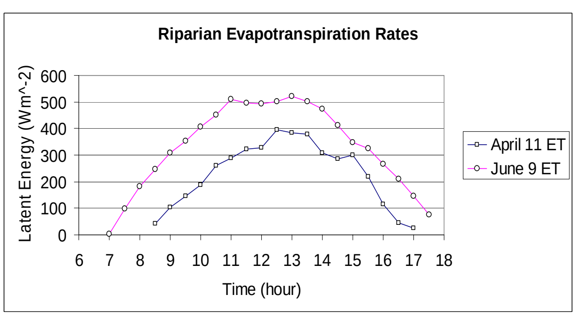

Figure 2. Latent Energy Flux density as a function of time-of-day in early and late Spring.

4. ACKNOWLEDGEMENTS

We thank Michael M. Mata, Liyi Xu, Shane Mottley and Patrick Wenzinger for their help in carrying out this research. This research was funded by CALFED and would not have been possible without the support of the John Muir Institute of the Environment, the Cosumnes Research Group, and Diana Cummings.

5. REFERENCES

Paw U. K.T. and C.S.T. Daughtry. 1984. A new method for the estimation of diffusive resistance of leaves. Agric. For. Meteorol., 33:141-155