11.1 A PROJECT SUMMARY: WATER AND ENERGY BUDGET ASSESSMENT FOR A NON-TIDAL WETLAND IN THE SACRAMENTO-SAN JOAQUIN DELTA

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1. INTRODUCTION

Dating as far back as 1914, scientists have tried to capture the amount of actual evapotransiration (ETa) from wetlands and quantify the results through a universal cover coefficient (Kc) (Allen, 1995). Due to the variation of wetlands, characterized by their shape, size, species composition, and regional climate, multiple Kc values must be obtained for general use. By measuring ETa rates and comparing them to reference evapotranspiration or ETo (Walter et al., 2000), a Kc value is determined that can be multiplied by ETo to estimate crop evapotranspiration (ETc) in future years as long as the crop and climate conditions are similar. These values are especially important for water agencies in the Western United States that need to know the amount of ETa from wetlands to determine their water consumption and practicality (Drexler et al., 2004).

In this particular study, we established a micrometeorological tower over a non-tidal restored wetland, to quantify ETa rates and other surface energy fluxes for water and energy budget analysis. The wetland is located on Twitchell Island, in the mid-western portion of the Sacramento-San Joaquin river delta. In 1997, the United States Geological Survey (USGS) restored two permanently flooded 2.5 ha wetlands. The western pond has a constant water level of 25 cm, densely packed with common tules (*Schoenoplectus acutus*) and cattails (*Typha* spp.). The eastern pond has a constant water level of 55 cm, a more heterogeneous cover of cattail/tules, duckweed (*Lemna* spp.), and several submerged aquatic plants that have also colonized the site.

The micrometeorological tower is located in the eastern pond in a position that represents the heterogeneous cover of the pond's ecosystem, known as the footprint or source area (Schmid, 1994). Surrounding the wetland area is land used for agricultural crops such as tomatoes, feed corn, and safflower. Initial energy budget analysis began in 2001 using the Surface Renewal (SR) technique (Snyder et al., 1996) and we began to take eddy-covariance (EC) measurements from May of 2002 to the present. Figures 1 and 2, represent the EC surface energy budget for 2002.

In addition to providing the USGS with ETa rates to complete a water budget analysis, we are investigating the influence of varying wind properties. During the summer, this region receives prevalent westerly winds carrying cool, humid air from the Pacific Ocean (known in California as the Delta Breeze). On the other hand, California's Mediterranean summers often bring northerly winds that contain hot, dry air that can increase the rate of ETa. This report describes the methods used to obtain Kc values during the summer of 2002 and to investigate possible differences during changing wind patterns. These wetland Kc values will provide important information for specific wetland plant species and changes in growing season for several years of different meteorological conditions (Drexler et al., 2004).

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2. MATERIALS AND METHODS

The EC system from Campbell Scientific, Inc. includes a CR23X datalogger, CSAT3 three dimensional sonic anemometer, fine wire thermocouple (0.005 inch dia.), LiCor7500 open path infrared gas analyzer, HMP45C temperature and humidity probe, Q7.1 net radiometer, three CS107 temperature probe, and HFT-3.1 heat flow transducer manufactured by Radiation and Energy Balance Systems, Inc. The sampling frequency is 10 Hz and the analysis program was developed by Ed Swiatek at Campbell Scientific. The flux values were corrected for the variation of air density fluctuations (Webb et al., 1980).

The surface energy budget of ecosystem is described by:

$$R_n = \lambda E + G + H \qquad (1)$$

where R_n is the net radiation, λE is the latent heat flux, H is the sensible heat flux, and G is the ground (or water) heat flux. In the wetland, G is mainly energy flux into and out of the water.

In addition to the EC system, mobile SR stations were set up within the smaller areas of heterogeneous cover to capture their individual energy budgets. The SR technique (Paw U et al., 1995) records 4 Hz data to estimate the sensible heat flux (H) and provide the latent heat fluxes (λE) as the residual of the energy balance equation:

$$\lambda E = R_n - G - H \qquad (2)$$

The SR system uses a Q7.1 net radiometer, three CS107 temperature probe, a HFT-3.1, and two fine wire thermocouples (0.03 inch diameter).

Included with the surface energy budget measurements, wetland Kc values were calculated by dividing the EC-derived actual evapotranspiration (ETa) rates by the California Irrigation Management Information System (CIMIS) hourly reference evapotranspiration (ETo) rates. The hourly Penman-type equation used by CIMIS is from Pruitt and Doorenbos (1977) and the values are similar to those computed using the hourly Penman-Monteith ETo equation (Walter et al., 2000). Kc values are computed as:

$$Kc = \frac{ETa}{ETo} \qquad (3)$$

Much of the discussion in this paper relates to the effects of wind speed and direction. Wind speed and direction were measured at a CIMIS station (Snyder and Pruitt, 1992) that was about 1 km west of the wetland site. North wind events were identified as values when the wind came from 310 to 45 degrees, whereas delta winds, which bring cooler temperatures and higher humidity, were identified as those from 225 to 310 degrees.

3. RESULTS AND DISCUSSION

Figure 1 represents the surface energy budget for hourly average data measured by the EC system during the period May 23 through November 6, 2002. The data showed a surface energy budget closure of 85% for 3181 samples for a regression forced through the origin. Figure 2 is for daily average data from the same period. There was 75% closure for 110 samples.

At the conference a table of Kc values will be presented for several varying conditions including: (1) all of the data from May 23 through November 6, 2002,(2) all midseason data from July 1 – October 1, 2002, (3) all north wind episodes, (4) all midseason north wind data, (5) all delta breeze (i.e., westerly wind) periods and (6) all delta breeze data during midseason. The majority of the wetland consists of tall tule and cattail structures and we assume that most of the ETa during midseason will come from those plants. However, there are small contributions from the short emergent aquatic plants.

During the north wind events, the humidity fell and temperature often increased. Conversely, the Delta Breeze has higher humidity and cooler temperatures that should lower ETa rates due to the decrease in the vapor pressure deficit (VPD), an important factor for ETa rates for emergent macrophytes (Allen, 1995). Therefore, Kc values should be lower during westerly than northerly winds events during the midseason period due to the reduced vapor pressure deficit.

4. CONCLUSION

The Twitchell Island wetland is not considered to be a closed system and along with ETa, there is seepage and a constant flux of cold water to maintain the wetland's water level. This cold-water flow into the wetland may cause the water heat flux (G) to be underestimated. Figure 1, shows that the Rn - G is larger than the LE + H, but over the course of one hour we can assume a closed system and the G term is properly estimated. However, figure 2 shows that Rn – G term becomes even larger on a daily time scale and the energy closure grows worse to 75%. This may be from the underestimation of the G term or that another storage term must be added to the surface energy budget. In 2003, we began to investigate the possibility of an additional storage term, water advection.

5. REFERENCES

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6. ACKNOWLEDGEMENTS

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7. FIGURES

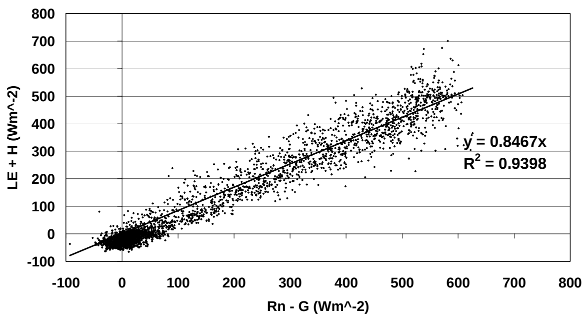

Figure 1. Hourly surface energy budget closure for the growing season period: May 23 – November 6, 2002.

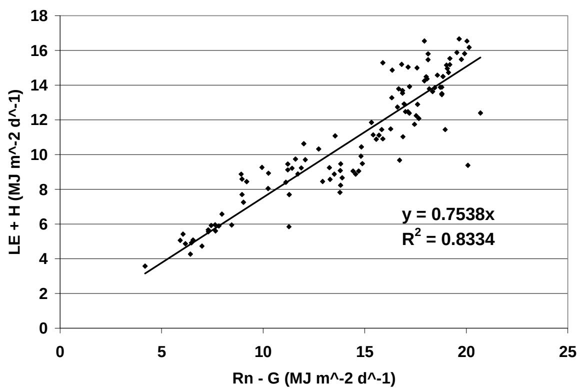

Figure 2. Daily surface energy budget closure for the growing season period: May 23 – November 6, 2002.