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DETERMINATION OF THE AREAL AVERAGED FLUXES IN CLASIC: A SYNTHESIS OF METHODOLOGIES

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1. Introduction

The Cloud and Land Surface Interaction Campaign (CLASIC) took place in Oklahoma during June, 2007. The Fort Cobb (FC) site consisted of agricultural land under both irrigated and non-irrigated conditions. FC01 was a tilled field in which an eddy-covariance (EC) station, a large aperture scintillometer (LAS), and a tethersonde system were co-located. This provides a unique opportunity to investigate the spatial averaging of sensible and latent heat fluxes as a function of the contributing source area.

The field observations are combined with remotely sensed data from the Moderate Resolution Imaging Spectroradiometer (MODIS) in order to extend these observations to the regional scale. By coupling the satellite observations with a soil-vegetation-atmosphere-transfer (SVAT) scheme we investigated how representative the FC01 field was in terms of the regional land surface fluxes.

2. Methodology

The LAS measurements are collected at 1 Hz. The EC system was collecting data at 20 Hz. The tethersonde system was active intermittently throughout the intensive observing period. All measurements were used to compute 30 minute fluxes for comparison.

For the purposes of this discussion, we focus exclusively on the sensible heat flux (H). The LAS measures variations in the refractive index structure parameter (C_n^2) which is related to the structure parameter for temperature (C_T^2). Assuming Monin-Obukhov Similarity theory holds, H can be determined by iteratively solving three equations:

$$\frac{C_T^2 (z-d)^{2/3}}{\theta_*^2} = f_T\left(\frac{z-d}{L}\right) = c_{T1}\left(1 - c_{T2}\frac{z-d}{L}\right)^{-2/3} \quad (1)$$

$$\theta_* = \frac{H}{\rho c_p u_*} \quad (2)$$

$$L = -\frac{u_*^3 \rho c_p T}{g \kappa H} \quad (3)$$

where z is the height (m), d is the displacement height (m), L is the Obukhov length (m), u_* is the friction velocity (m/s), ρ is the air density (kg/m^3), cp is the heat capacity (J/kg/K), g is gravity (m/s^2), H is the sensible heat flux (W/m^2), and cT1 and cT2 are constants for the stability function (e.g. de Bruin et al. 1995).

Assuming energy balance closure and ancillary measurements of net radiation (Rn, W/m^2) and soil heat flux (G, W/m^2) the latent heat flux (LE, W/m^2) can be solved as a residual:

$$LE = Rn - G - H \quad (4)$$

3. Field Setup

In CLASIC, FC01 is a tilled field with no vegetation. The eddy covariance system was located in the NE corner, the tethersonde system was in the SW and the LAS transect crossed the middle of the field in an E-W direction with a path length of 990 m. (Figure 1).

Figure 1. Experimental setup at FC01 showing EC tower (NE corner), Sonde location (SW corner) and the LAS path (middle of field).

The first four days were relatively dry, while precipitation was common after day 166. DOY 164 had a clear MODIS scene which was used to examine the spatial distribution of the H.

4. Results

Sensible heat was measured with the LAS for days 162 through 172. Figure 2 illustrates the time series of H for the LAS, EC and sonde systems. Figure 3 illustrates the general agreement between the EC and LAS sensible heat fluxes. In general, the LAS measures larger fluxes than the EC system. The precipitation events after DOY 166 had a marked influence on the diurnal pattern of H.

DOY 164 was chosen to examine different methods of flux determination due to the fact that it had a clear MODIS scene. Figure 4 shows H determined from the LAS, EC, the sonde using either LDAS or EC tower measured Rn and LDAS derived fluxes. Generally, as the support of the measurement system increases, the flux decreases.

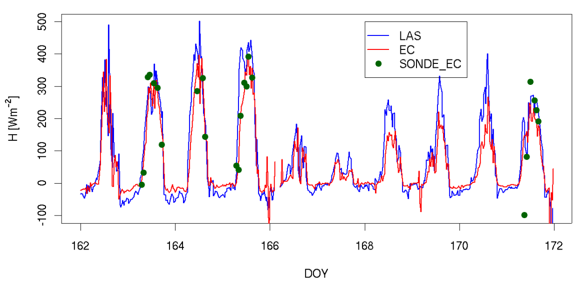

Figure 2. Time series of sensible heat flux (H) during CLASIC at FC01 using scintillometry (LAS), eddy covariance (EC) and tethersondes (SONDE_EC) over DOY 162-172.

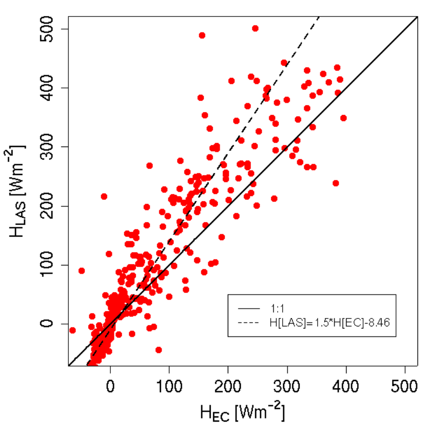

Figure 3. Comparison of sensible heat fluxes between the LAS and EC systems.

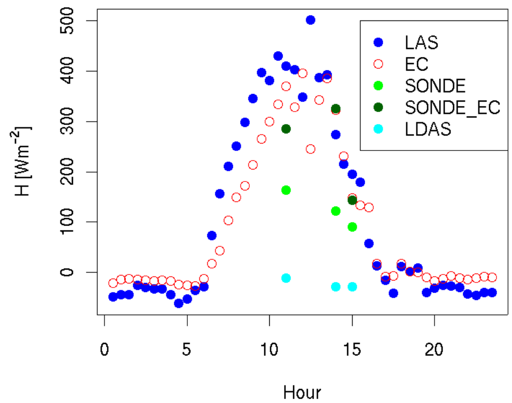

Figure 4. Comparison of H by different methods for DOY 164: LAS, EC, Sonde using LDAS Rn, Sonde using the EC tower Rn and LDAS derived flux.

In an attempt to characterize the regional distribution of H, MODIS derived fractional vegetation (Fr) and radiometric temperature (Tr) are used to determine the fluxes via the 'Triangle Method' (Gillies et al. 1997). This method utilizes the triangular shape of Fr-Tr joint distribution (Figure 5). This shape is assumed to correspond to variability in near surface soil moisture, ranging between a cold-wet edge and a warm-dry edge. This moisture availability and fractional vegetation are used as inputs to a SVAT which can be iterated over all Fr/moisture possibilities. Using input Fr and output radiometric temperature and fluxes, a polynomial regression of the form:

$$H = \sum_{i=0}^{3} \sum_{j=0}^{3} a_{i,j} Fr^i Tr^j \qquad (5)$$

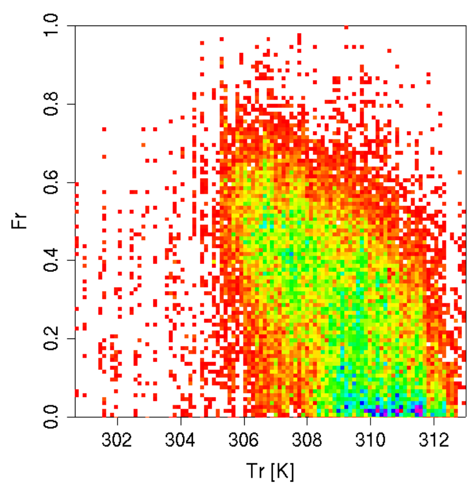

Figure 5. Joint pdf of the radiometric temperature – fractional vegetation space from MODIS for DOY 164.

Where H is the modeled flux, Tr is the modeled radiometric temperature, Fr is the input fractional vegetation and $a_{i,j}$ are the regression coefficients. This regression equation can then be applied to the MODIS Fr and Tr to compute the spatially distributed flux (Figure 6).

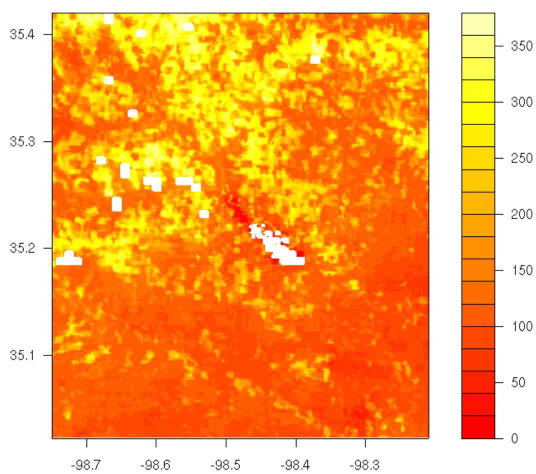

Figure 6. Spatially distributed sensible heat flux derived from MODIS for DOY 164 over the Ft. Cobb, OK. area.

The MODIS derived H varies considerably across the Ft. Cobb area for this particular day. The pixels corresponding to FC01 resulted in sensible heat fluxes on the order of 170 W/m^2 placing the MODIS derived flux on par with the sonde derived using the LDAS available energy.

5. Conclusions

Using a variety of techniques we have computed the surface energy fluxes during the CLASIC campaign in Oklahoma. Focusing on one day we observe that a large variance in the estimates of the flux. In general, as the level of support (i.e. resolution) of the measurement system increases we observe a decrease in the measured flux. Since FC01 is a bare soil field surrounded by irrigated agriculture, this is not necessarily surprising in that as the resolution increases, more contribution is made from the portion of the landscape which is irrigated.

This study highlights the need for careful site selection and an understanding of the regional scale vs. micro scale factors which will impact measurements. In addition, care should be taken in understanding to what extent the site is representative of regional interactions, particularly when measurement systems with smaller levels of support (i.e. eddy covariance towers) are employed.

References

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Gillies, R. R., T. Carlson, J. Cui, W. Kustas and K. Humes, 1997: A verification of the 'triangle' method for obtaining surface soil water content and energy fluxes from remote measurements of the Normalized Difference Vegetation Index (NDVI) and surface radiant temperature. *International Journal of Remote Sensing*, 18, 3145-3166.