1.10 RELATIONS BETWEEN ENVIRONMENTAL CONDITIONS AND THE ABILITY TO CLOSE THE ENERGY BALANCE

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1. INTRODUCTION

The eddy covariance approach is generally used to estimate turbulence fluxes of mass and energy to and from surfaces. A difficult but important issue remains to quantify estimates of the uncertainty of the reported flux values. These fluxes are in fact complex processes, and the estimates result from various measurements and calculations as well as numerous explicit and implicit assumptions. Hence, documenting the absolute accuracy of these values is somewhat problematic. However, one simple measure of internal consistency is to check for conservation of energy. So the sum of the turbulence fluxes of sensible and latent heat should balance the available energy. This check will provide estimates of the reliability of the fluxes, as well as the presence of bias.

$$Closure = \frac{H + LE}{R_n - G} \qquad (1)$$

Conventional notation here is used, where R_n is net radiation, G is soil heat flux, H is sensible heat flux, and LE is latent heat flux. In a perfect world, measurements would be perfect and all assumption met completely, and this value would be close to 1.

In practice, there must be an imbalance between estimated fluxes and available energy for several reasons. First of all these are covariances. So any error or noise in the entire measurement system will act to degrade the correlations and reduce the flux. Other possible factors include:

- Errors in available energy measurements
- Consumption of net radiation by photosynthesis
- Lack of steady state conditions
- Improper choice of averaging period
- Different footprints for energy and fluxes
- No perfect choice for coordinate rotation
- High frequency corrections are not perfect

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Experience has consistently indicated that closure values are generally significantly lower than 1. For example, Wilson et al. (2002) reported that the FLUXNET sites averaged about 80% for energy balance closure. This is a typical magnitude for values seen by many researchers. The fact that the bias nearly always is low, suggests that it is not explained mainly by problems with available energy measurements, since these would be likely to create bias in either direction. Instead, one is moved to conclude that the problem is that the turbulence fluxes are being systematically underestimated. This has implications for the interpretation of such measurements.

The objectives of this study are:

1. To quantify the energy balance closure for the SMACEX experiment. This involved flux measurements over various large agricultural fields in a watershed.
2. To document the variations in the bias of flux measurement.
3. Find any relationships between the size of the bias, and atmospheric conditions

The hypotheses are:

- closure values will exhibit variations between fields as well as hour to hour changes at a single site.
- changes in the bias will relate to some properties of the atmosphere and turbulence.

2. METHODS

The SMACES study is described in Kustas et al. (2005). Some flux results are also discussed in Prueger et al. (2005). As part of the study, eddy covariance measurements of momentum, sensible and latent heat, and CO_2 fluxes were made over a number of corn and soybean fields. There were 10 sites in which the raw time series data were recovered. Each system included a CSAT3 sonic anemometer, and a LiCor 7500 open-path water vapor and CO_2 sensor. Data were sampled at 20

Hz. Net radiation was measured with Kipp & Zonen CNR-01 4 way radiometers, and soil heat flux was determined using soil heat flux plates, and soil moisture sensors. The time series data were collected over a 20 day period from DOY 171 to 190.In this period the crops grew from partial cover to foliage densities close to their maximum values.

3. PRELIMINARY RESULTS

An example of hourly changes in the energy balance early in the study period is illustrated for a mostly sunny day in a corn field in Figure 1.

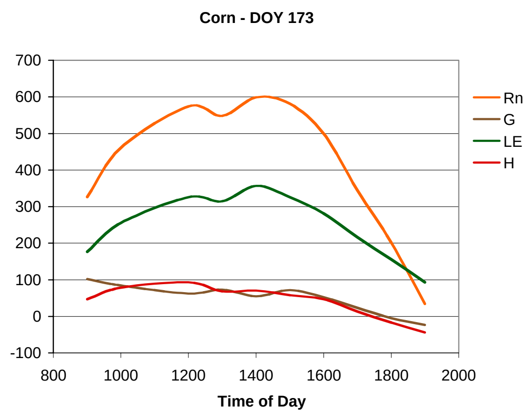

Figure 1. Energy balance for DOY 173.

The associated energy balance closure values are displayed in Figure 2.

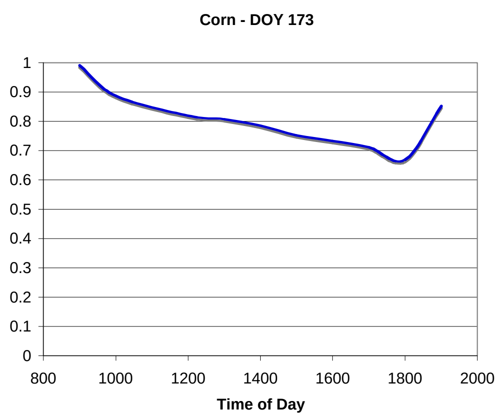

Figure 2. Energy balance closure for DOY 173.

There is a general decline in values as the day progresses, starting from just below 1, and falling to below 0.70 before rising again late in the day.

Figures 3 and 4 show the same analyses for DOY 189, when the crop had grown to LAI greater than 3.

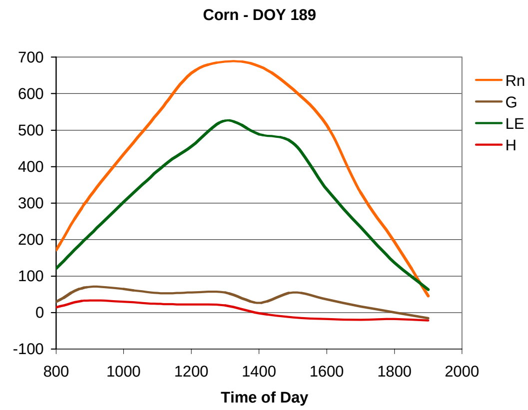

Figure 3. Energy balance for DOY 189.

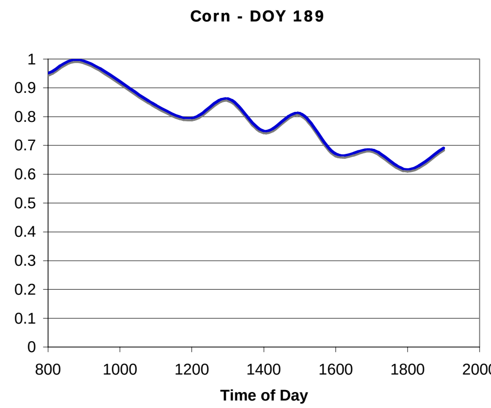

Figure 4. Energy balance closure for DOY 189.

In both cases, there appears to be lower closure values that are associated with changes in H, leading towards negative values, or advection of heat in the late afternoon. The Bowen ratio was somewhat lower on DOY 189, but there seems little correlation between the general closure behavior and Bowen ratio. However, the range of values of Bowen ratio here is rather small. However, there are distinct hourly fluctuations present in the closure values. These are of interest.

The daytime closure values for each day are shown in Figure 5. There is a gradual increase in closure over the period, which is associated to the increase in leaf area index of the crop. However, there are anomalies even at a daily scale. For example, DOY 178 had a value of only 0.68.

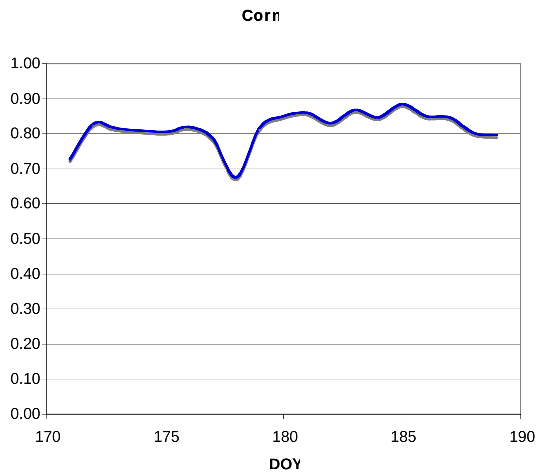

Figure 5. Daytime average closure values for corn.

4. FUTURE ANALYSES

Several questions remain:

- What causes the distinct bias in flux estimates?
- Why does it vary over short time periods?
- Which properties of the atmosphere seem to connect with this issue?
- Will values improve if changes are made in averaging periods?

The variations in closure will be integrated with other atmospheric analyses. One approach will consist of looking at cospectra of the fluxes to determine the importance of various scales of turbulence events, and providing evidence of appropriate averaging periods. There are radiosonde data available for some of the days, which will allow documentation of the growth of the ABL. If large structures are affecting the bias in fluxes, then there should be some connections with the behavior of the ABL.

5. REFERENCES

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