P2.5 Spatial variability of eddy covariance measurements: A comparison of two identical eddy correlation systems in adjacent plots

Jon Warland[1]and Kate Taillon
Dept. of Land Resource Science, University of Guelph

Introduction

There has been much discussion recent years about the possibility that eddy covariance measurements systematically underestimate energy fluxes. Some proposed reasons for this include advective effects, varying footprints, poor soil energy flux measurements or the existence of a mean vertical wind component. This study aimed to examine some of these possibilities by placing two identical eddy covariance units in adjacent plots within a large agricultural field. The two units were exposed to large, but quite different, fetches and distinct source areas to see if there was an impact on the energy budget closure.

Methodology

The eddy covariance units were placed in adjacent soybean plots at the end of July, 2001. The two plots were about 150 m × 100 m and bordered on the longer side. The two towers, placed approximately in the centre of each plot, were about 100 m apart. Unit 1 was in a plot under conventional management (CMP: normal tillage), while unit 2 was in a best management practices (BMP: no-till) plot. Summer 2001 was very dry, and the crop senesced 2–3 weeks after this experiment began. Harvest was at the beginning of October, following which both plots were bare for the remainder of the data presented here (through the beginning of March, 2002).

Each eddy covariance unit consisted of one 10 cm Campbell Scientific (CSI) C-SAT3 three dimensional sonic anemometer mounted alongside one LICOR-7500 open path CO_2/H_2O analyzer, separated by about 10 cm at a height of 1.8 m. The sensors were controlled at 20 Hz by a CSI CR23X datalogger using the SDM protocol and the data sent to a remote computer for permanent storage.

Net radiation R_n and soil heat flux G data were collected in the BMP plot approximately 5 m from the eddy covariance system. Two new Kipp and Zonen CNR1 radiometers and one older Solar Radiation Instruments SRI4 were mounted at 1.5 m. Net radiation was calculated as the mean of the three radiometers, which normally read within 5% of each other. Four soil heat flux plates (REBS, Inc.) were installed earlier in the year at a depth of 1 cm and scattered a few meters in each direction around the R_n tower.

Data were filtered to remove 1/2 h periods with less than 21 min of data, readings of negative concentration or dew point temperatures in excess of 35°C, and readings with relative humidity greater than 1.05. Coordinate rotations to remove the $\overline{v}$ and $\overline{w}$ components were applied, and Webb-Pearman-Leuning corrections performed. Sonic temperature, corrected for vapour density, was used for the sensible energy flux H. The spectral correction equations of Moore (1986), as well as an independent theoretical estimate (G. Thurtell, pers. comm., 2002), indicate that both H and latent energy flux λE would have been underestimated by about 5% over a wide range of conditions, and so both of these data have been adjusted by this value.

For the results shown here, we have further filtered for when the sonic reported questionable data (diagnostic word -6999) and when the mean wind was outside ±90° of both sonic axes. We have further excluded points where the two systems read fluxes differing by more than a factor of 3. This reduces noise in the analysis but does not change the results.

Results

Figures 1 and 2 show a comparison of the measured H and λE, respectively. Though there is more scatter in the points than when the units were run side-by-side, the agreement in the measured fluxes is excellent. Linear regressions produce slopes of 0.94 (r^2 =0.93) and 1.10 (r^2 =0.93) for H and λE respectively. From side-by-side data (Warland et al., 2002) the expected agreement for the two units under identical conditions is about 5%.

The three radiometers generally agreed closely, and we have therefore used the mean of the three in our energy budget closure tests. The soil heat flux plates also produced very consistent agreement, with two of the plates reading right around the mean of the four. This provides confidence that their mean is representative. In a separate experiment, R_n data was collected in a third CMP plot, and these data showed overall agreement of about 3% with the R_n data used here. It therefore is likely that little error is introduced by using R_n data from the BMP plot for both plots, and it also indicates that the 'footprint' for the radiometers is representative of these plots. As for flux divergence between the surface and the heat flux plates, significant error relative to the total budget would necessitate unrealistic daily changes in surface temperature.

The energy budget closures for each unit are shown in Figures 3 and 4. The mean slopes from linear regression of the data are 0.80 (r^2 =0.96) and 0.82 (r^2 =0.98) for systems 1 and 2, respectively. Both systems show the

[1]Corresponding author address: Jon Warland, Dept. of Land Resource Science, University of Guelph, Guelph, ON, N1G 2W1 Canada; e-mail:jwarland@lrs.uoguelph.ca.

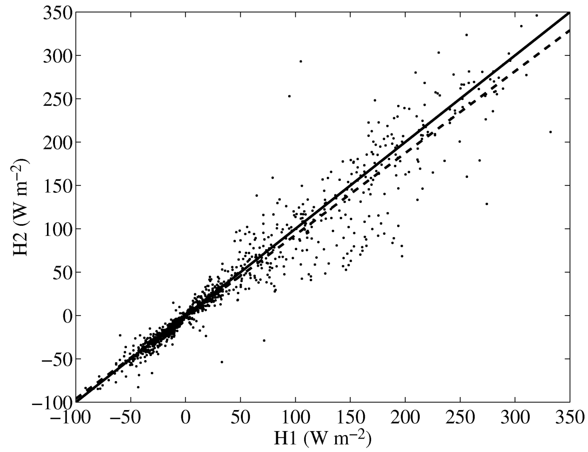

Figure 1: Comparison of sensible energy flux as measured by the two eddy correlation units. Linear regression shown by the dashed line.

same lack of closure, which is not surprising due to the close agreement of their measurements, but because of the separation between the units it seems unlikely that the lack of closure is due to either some sort of advective effect or to disagreements of footprint. As for other possible sources of error, the R_n instruments showed very close agreement between two different manufacturers with different systems, and G has already been discussed. Theoretical calculations indicate little spectral loss for these instruments (and that little has been corrected for), and examination of sample spectra has not indicated any obvious deviations from ideal shapes. Random error seems unlikely to produce the same underestimation in both units, and unlikely to leave such high r^2 values for the closure comparisons in Figures 3 and 4. The results shown here change by no more than a few percent if the coordinate rotations are not performed.

In conclusion, the data presented here support the notion of a systematic underestimate of flux by eddy covariance measurements. This underestimate is consistently seen in two units 100 m apart and cannot be easily explained by other measurement errors, footprint problems or advection. There is the possibility of a mean vertical wind, however we do not have an explanation for why this would produce such a consistent error.

References

Moore, C. J., 1986. 'Frequency response corrections for eddy correlation systems'. *Boundary-Layer Meteorology*, **37**:17–35.

Warland, J. S., K. Taillon and G. W. Thurtell, 2002. 'Comparison of two identical eddy correlation systems in various configurations'. In AMS 25th Conference on Agricultural and Forest Meteorlogy, Norfolk, VA.

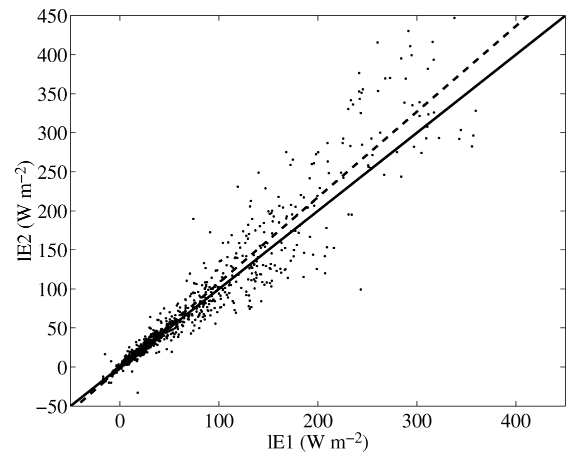

Figure 2: Comparison of latent energy flux as measured by the two eddy correlation units. Linear regression shown by the dashed line.

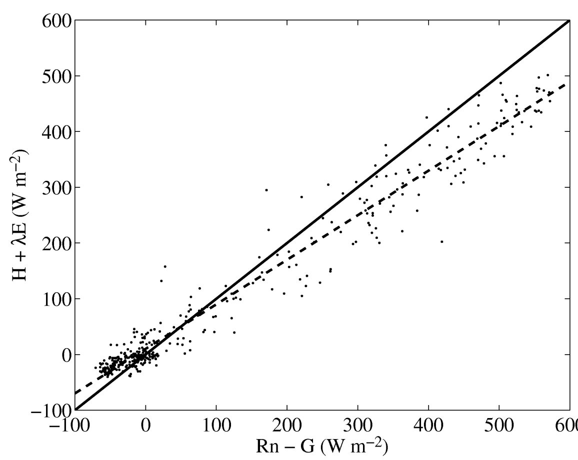

Figure 3: Energy budget closure of system 1. Linear regression shown by dashed line, one-to-one solid line.

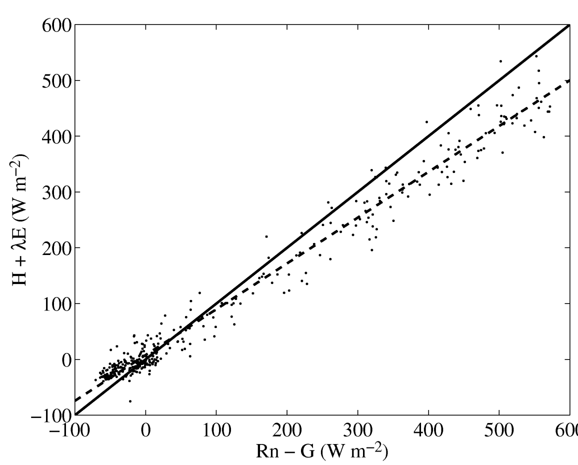

Figure 4: Energy budget closure of system 2. Linear regression shown by dashed line, one-to-one solid line.