ECOR VAP Flux Corrections, Gap-filling, and Results

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ABSTRACT

An eddy correlation (ECOR) value-added product (VAP) has been developed that uses ECOR temperature, humidity, and wetness state (or default values of the same) to determine corrections to and gap-filling of the flux measurements. An outlier routine is used to remove obvious incorrect data before gap-filling is performed. For each month, diurnal half-hour averages of correct measurements are calculated and used to perform the gap-filling. Therefore, it is anticipated that the VAP would be run for each month of collected data. A data quality flag is included for each half hour to indicate if any (and which) of the fluxes have been gap-filled (indicating an initial state of being incorrect or missing). Results of the VAP processing are shown and compared with the energy balance Bowen ratio (EBBR) flux measurements for the Southern Great Plains (SGP) Central Facility.

ECOR VAP CORRECTIONS

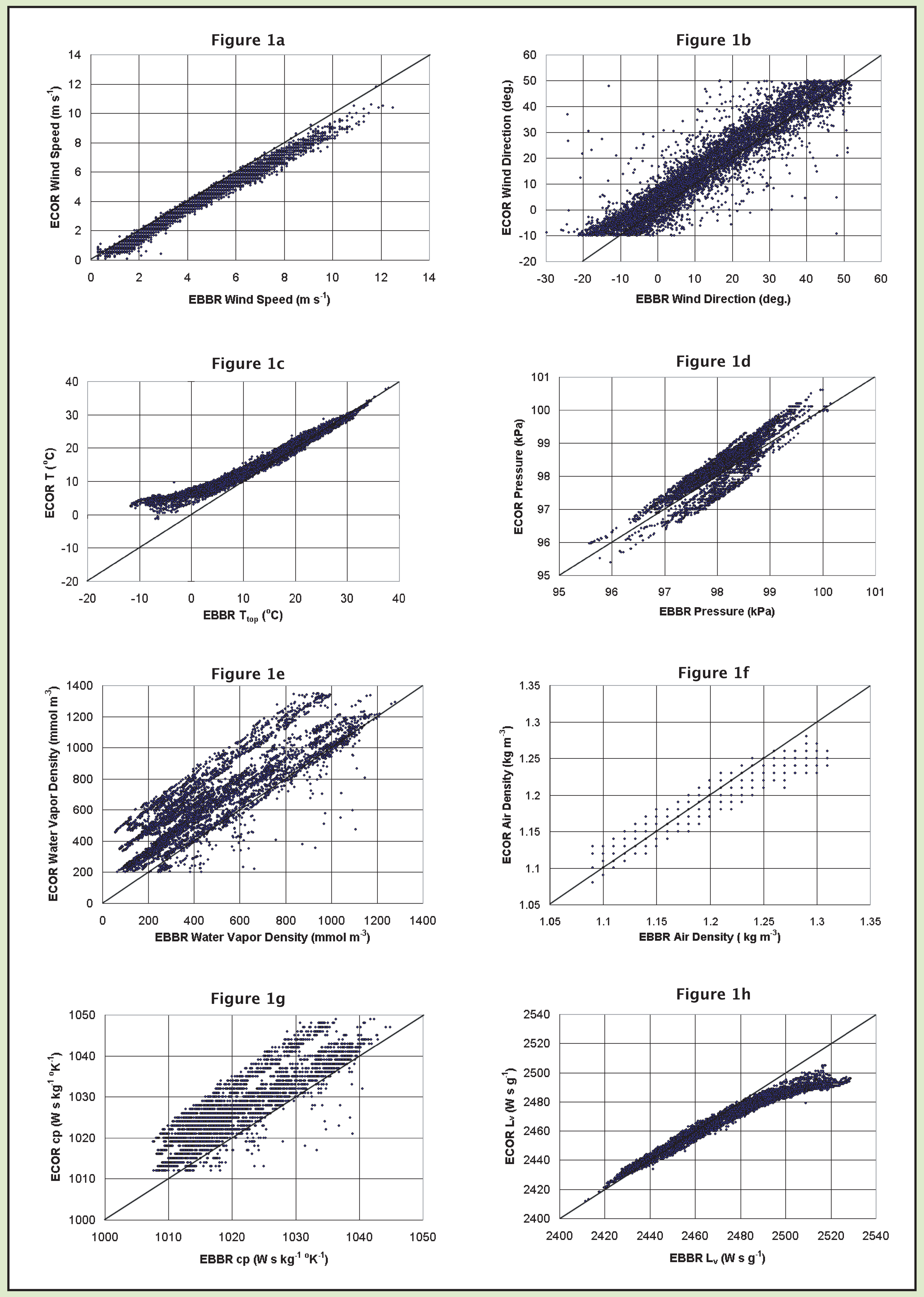
Corrections made to ECOR flux data in the VAP processing:

1) Sensor separation, high frequency losses, sensor volume averaging, sensor time constants (Massman 2000).

2) WPL (Webb et al. 1980) corrections for heat flux buoyancy effects.

3) Outlier removal (using max/min limits and wetness sensor indication).

4) Gap-filling.



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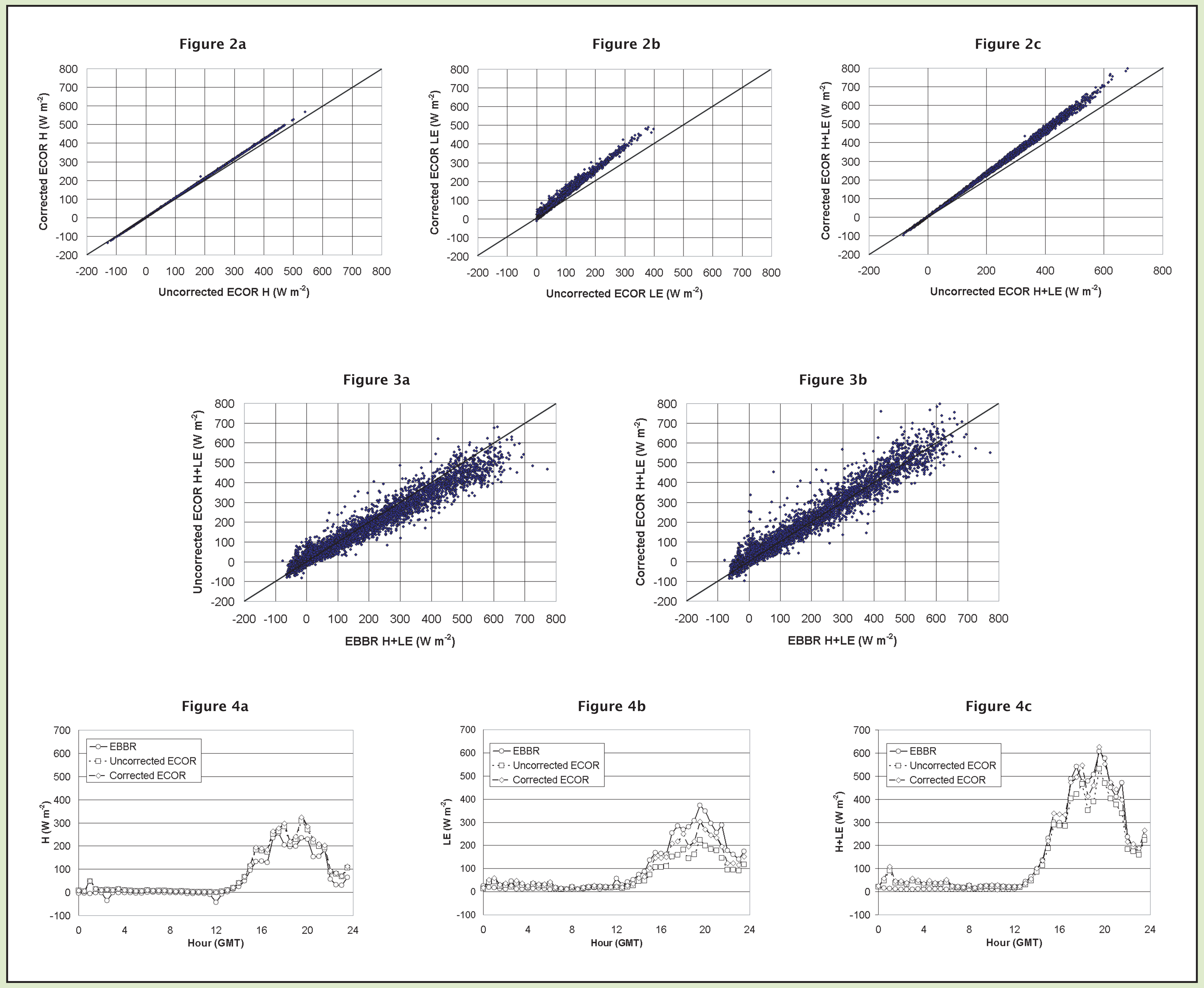


COMPARISON OF ECOR AND EBBR METEOROLOGICAL MEASUREMENTS

ECOR and EBBR measurements are compared using four years of SGP CF data for the small range of wind directions (350 - 50 degrees) for which the vegetation footprint (grassland) for the two systems is essentially the same. The basic meteorological measurements (Figures 1a-1h) for the two systems can be quite different, because of differences in measurement technology and quality of calibration.

1) ECOR horizontal wind speed (1a) is lower than the EBBR by 8%. If this extends to the vertical wind speed as well, it could cause the fluxes to be underestimated.

2) ECOR wind direction (1b) is systematically biased 4 degrees higher than the EBBR.

3) ECOR sonic temperature response (1c) deteriorates as temperature decreases because of the lack of a good temperature calibration in the Gill WindMaster Pro sonic anemometer. This flaw causes ECOR air temperature to be greatly overestimated in winter, with an accompanying overestimation of sensible heat flux (H) (see the monthly ratio of ECOR/EBBR air temperature in Figure 5).

4) ECOR and EBBR pressure (1d) do not always agree well; both are sufficiently accurate for the EBBR and ECOR calculations of fluxes, a 0.5% error at worst.

5) ECOR water vapor density (1e) was often biased well above the EBBR water vapor density, a result of not obtaining a good zero during calibration of the LI-7500 CO_2/H_2O sensor. This bias does not have a significant effect on the latent heat flux (LE) if the calibration slope is correct. However, water vapor density is used in the calculation of specific heat (1g) and therefore can bias H higher. It's also used in the WPL correction of LE and CO_2 flux, with greater effects on the former than the latter. The ECOR water vapor density was highly affected by day of year, as seen by the monthly ECORR/EBBR ratio in Figure 5; only during mid summer is the ECOR water vapor density nearly the same as that for the EBBR; normally it was much larger. More stringent calibration procedures have decreased the ECOR bias since mid 2006.

6) There is little difference between the air density calculated by the ECOR and EBBR (1f).

7) The specific heat at constant pressure (cp) is overestimated by the ECOR as a consequence of the biased water vapor density (1g).

8) The latent heat of vaporization, Lv, which is dependent on temperature and is used in the calculation of LE, shows the effects of the sonic temperature flaw (1h); this would tend to cause ECOR LE to be only slightly underestimated at higher LE.

COMPARISON OF UNCORRECTED AND CORRECTED ECOR FLUX MEASUREMENTS

The effect of corrections to the ECOR fluxes is seen in Figures 2 and 4.

1) ECOR H is increased by about 5% (for a 4 year average) by the correction (2a).

2) ECOR LE is increased by 32% (for a 4 year average) by the corrections (2b).

3) A 16% increase (for a 4 year average) in ECOR total heat fluxes (H+LE) results from the corrections (2c).

4) Figures 4a-c show the effect of the ECOR corrections on a July day in 2004, as well as H, LE, and H+LE measured by the EBBR.

COMPARISON OF ECOR AND EBBR FLUXES

ECOR and EBBR fluxes are compared in Figures 3a-b and 4a-c.

1) The regression slope of uncorrected ECOR to EBBR H+LE (3a) is 0.85, with ECOR H+LE biased about 10 W m-2 above the EBBR.

2) The regression slope of corrected ECOR to EBBR H+LE (3b) is improved to 0.98, with ECOR H+LE biased about 13 W m-2 above the EBBR. Therefore, the total corrected heat fluxes (H+LE) from the ECOR are, on a 4 year average, slightly larger than the EBBR.

3) Figures 4a-c for July 25, 2004 show a very typical scenario for a high heat flux period; ECOR H is greater than for the EBBR (4a) and ECOR LE is smaller than for the EBBR (4b). On this day, the total heat fluxes of the ECOR and EBBR are very similar, although they are partitioned differently into H and LE; this is a very common occurrence.

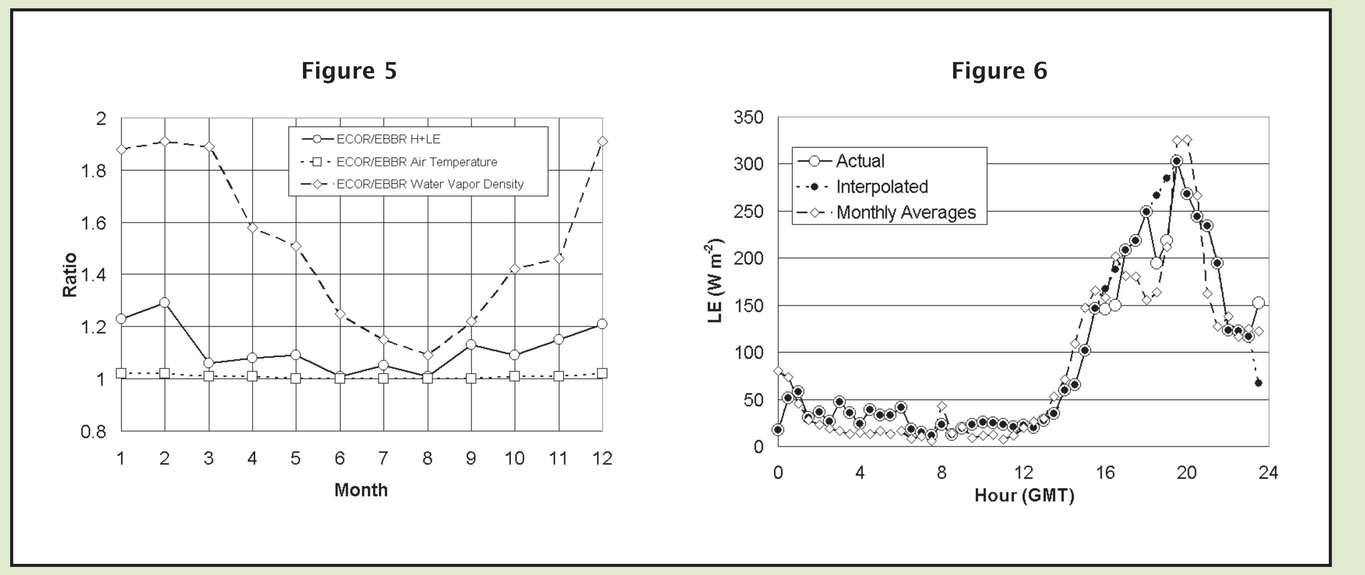
Surprisingly, substitution of the EBBR meteorological measurements in the calculation of the ECOR heat fluxes showed no improvement (~2% for a 4 year average) over the use of the ECOR meteorological information. The effect of using slightly inaccurate ECOR meteorological information is apparently minor.

SEASONAL VARIATION IN ECOR FLUX CORRECTIONS

Figure 5 shows the seasonal trend in the ratio of ECOR to EBBR temperature (^{o}K) and Water Vapor Density and the seasonal variation of ECOR to EBBR H+LE. During the winter months, the EBBR produces lower fluxes than the ECOR, partly because the relative humidity sensors used in the EBBR are not as sensitive to water vapor at lower temperatures and partly because the much higher ECOR water vapor density (particularly in winter) results in biasing of ECOR H to larger values (through the cp calculation). The reduced sensitivity of the ECOR air temperature in cold temperatures shows in the monthly temperature ratio.

GAP-FILLING OF ECOR FLUX DATA

Figure 6 shows the effect of gap-filling on ECOR LE, and H+LE, for July 25, 2004. Linear interpolation is used in the VAP for periods of one half hour to one hour of missing or incorrect data and monthly averages for the specific half hour are used otherwise. The figure shows that the use of interpolation to fill fortuitous gaps created at 1600, 1630, 1830, 1900, and 2330 GMT would result in a much smoother diurnal trend in LE and significantly increase the daily average LE. This is one of the possible unfortunate results of linear interpolation. The monthly half hour average LE shows a similar trend to the July 25 trend, partially because there were only 10 days (only two full days) of data from which to calculate the averages; only one day had data for one time period. Lack of data for monthly averages is a concern, from the standpoint of whether the averages calculated will properly represent the fluxes for that month.



CONCLUSIONS

For a four year average of ECOR and EBBR flux data when the wind direction was from a grassland, corrections to the ECOR flux data produce H and LE that are, on average, essentially the same as are produced by the EBBR. However, there is a significant seasonal variation in the ratio of the total heat flux (H+LE) for the two systems, with the best agreement occurring during the warmer months of the year. Recent improvement in the calibration zero of ECOR water vapor density should have resulted in a reduction of the bias of H and therefore a slight reduction in corrected ECOR total heat flux; this has not been investigated yet.

REFERENCES

Massman, W.J.,
A simple method for estimating frequency response corrections for eddy covariance systems. Agricultural and Forest Meteorology 104, 185-198 (2000).

Webb, E. K., Pearman, G. I., Leuning, R.,
Correction of flux measurements for density effects due to heat and water vapor transfer. Quarterly Journal of the Royal Meteorological Society, 106, 85-100 (1980).

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