4.2 EDDY COVARIANCE AND BOWEN RATIO ESTIMATES OF WATER VAPOR AND CO_2 FLUXES OVER CRESTED WHEATGRASS

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1. INTRODUCTION

Recent studies of CO_2 exchange for various terrestrial ecosystems include a global network of sites called FLUXNET (Baldocchi et al., 2001). These sites use the eddy covariance approach. There is also a network in the US operated by the USDA estimating CO_2 fluxes with the Bowen Ratio technique (Svejcar et al., 1997). This approach is most valid for uniform surfaces, but may have problems in heterogeneous landscapes (Hipps et al., 1998). Since some sites are in regions not covered by FLUXNET, it would be valuable to integrate the two sets of data. However, consistency between the two approaches must be determined. We address this issue by comparing energy balance and CO_2 fluxes over crested wheatgrass (*Agropyron desertorum*) measured with Bowen Ratio (BR) and eddy covariance (EC) systems. The uniform nature of this community, makes it ideal to examine the agreement between the systems. The specific goals of this study are:

1. Measure the energy, water, and CO_2 fluxes over crested wheatgrass from early spring to late fall with both a BR and EC system.

2. Quantify energy balance closure for the EC system, and examine the effects of forcing the fluxes to match the available energy.

3. Compare fluxes from the two systems, and examine how agreement varies with season and environmental conditions.

2. METHODS

The site was a large crested wheat grass (*Agropyron desertorum*) field. Height of the vegetation, ranged from 0 to 0.3 m. Instruments had an upwind fetch of about 350 m.

Eddy covariance measurements utilized a 3-D sonic anemometer (CSI-CSAT3) and an open-path fast response CO_2 and water vapor analyzer (LiCor 7500), mounted 2.10 meters above the surface, and sampled at 10 Hz by a CR23X data logger (CSI, Logan, Utah). Fluxes were calculated as 30 minute averages, and corrected for density effects as described in Webb et al. (1980).

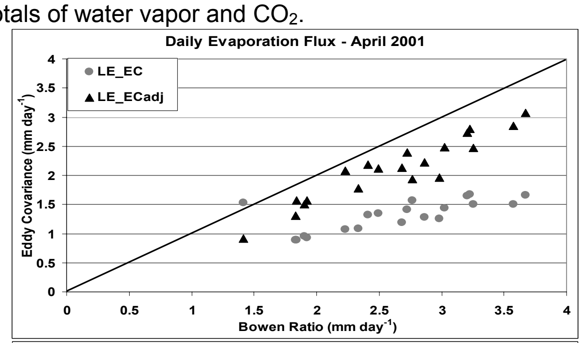
A net radiometer (Kipp & Zonen-NR Lite) was mounted at 2.0 meters to measure net radiation. Soil heat flux was estimated using two heat flux plates (Huxeflux HFP01) buried at 0.08 m. Average temperatures combined with soil moisture data determined heat storage in soil above the plate.

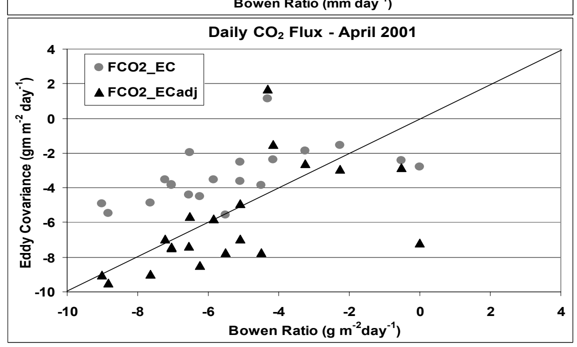
The theory and operation of the BR system (Model 023/CO_2, CSI) is described by Dugas et al. (1999). CO_2 and water vapor concentrations were measured with an infra-red gas analyzer (LI-6262) at 0.7 and 1.7 m above the soil surface. Fluxes of heat, water vapor, and CO_2 were calculated as 20 minute averages. Net radiation was measured with net radiometer (Model Q*7.1-REBS, Seattle, WA, USA). Soil heat flux was measured with two soil heat flux plates (Model HFT3, REBS) and 4-probe averaging soil temperature probes.

3. RESULTS

Energy balance closure values for EC increased over the season from 0.65 in spring up to 0.84 in the early fall. The effects of forcing closure were examined by adding to the water vapor and CO_2 fluxes according to the ratio of sensible to latent heat as described in Twine et al., (2000).

The agreement between EC and BR in spring when water was available is illustrated below for daily totals of water vapor and CO_2.





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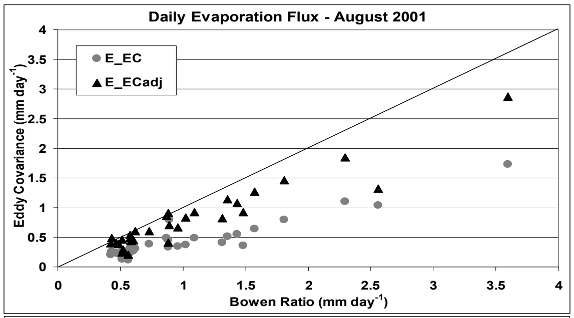
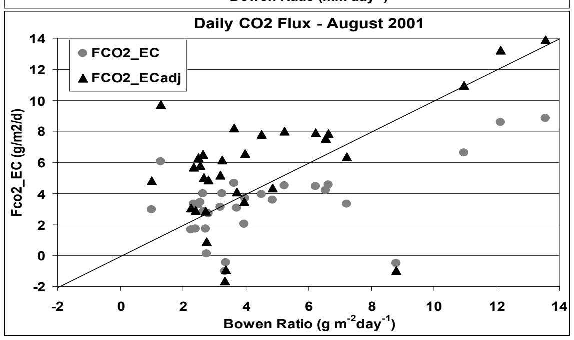
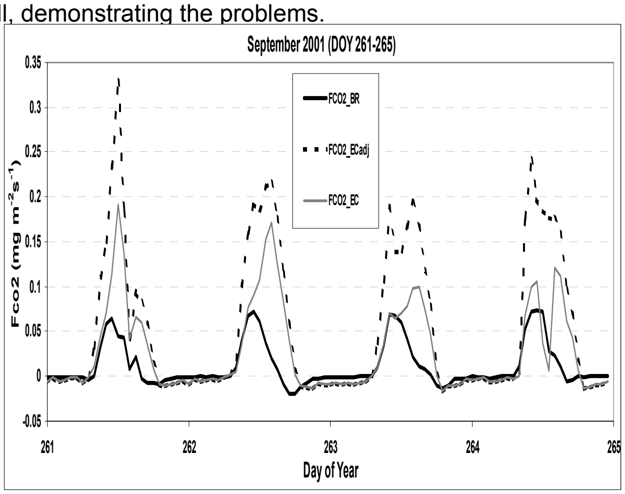
The values adjusted for energy balance closure conform well with those from the BR, though a bias is still present. There is more scatter in CO_2, though a reasonable agreement is still present.
The next figure illustrates the results for August. Again, the agreement for water vapor is good, while more scatter is present for CO_2. A distinct bias is observed for larger CO_2 fluxes from eddy covariance.





Both systems encountered difficulties quantifying CO_2 fluxes at night. Below is a sample of a few days in the fall, demonstrating the problems.



The upward fluxes in the day are captured by both systems, though the eddy covariance is much larger. During the night, the BR reports near zero flux, while the eddy covariance observes a negligible downward flux. Both systems fail to capture the upward flux at night. The reasons for this require attention, but are likely related to the very low values of turbulence. Seasonal totals are shown below for water vapor and CO_2 fluxes.

Even with forcing closure, E is about 20% lower for the EC in both seasons. Interestingly, CO_2 fluxes

DAY						
	LE			FCO2		
Season	EC [mm]	EC_adj [mm]	BR [mm]	EC [g/m^2]	EC_adj [g/m^2]	BR [g/m^2]
Spring (24 days)	27	43	54	-88	-146	-209
Summer (109 days)	55	89	113	369	574	263
Fall (58 days)	16	32	42	121	223	73
TOTAL DAY TIME (191 days)	**98**	**164**	**208**	**402**	**651**	**127**
NIGHT						
Spring (24 days)	1	1	3	8	8	55
Summer (109 days)	2	0	2	14	14	64
Fall (58 days)	1	0	1	-11	-11	6
TOTAL NIGHT TIME (191 days)	**4**	**1**	**6**	**11**	**11**	**125**
TOTALS						
Spring (24 days)	28	44	56	-80	-138	-154
Summer (109 days)	57	89	115	383	588	327
Fall (58 days)	17	33	43	109	212	79
TOTALS 2001 (191 days)	**102**	**165**	**215**	**412**	**661**	**252**

are always higher for EC. The fluxes not corrected for closure were closer to those of the BR, but still significantly larger.

4. CONCLUSIONS

The two systems have reasonable agreement for water vapor fluxes for each season, especially when EC values adjusted for closure. However, EC fluxes are biased lower. The EC CO_2 fluxes were always larger than those of BR. Adjusting CO_2 fluxes for energy balance closure in an analogous way as water vapor reduced the agreement. Both methods indicate that the crested wheatgrass was a net source of carbon over the season, which was abnormally warm and dry. Clearly we need evaluate further the causes of the discrepancies between these approaches before the two data sets can be easily integrated.

5. REFERENCES

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