Differences in Evapotranspiration from Eddy Covariance Systems and Lysimeters in Advective Conditions

Seth Kutikoff*, Xiaomao Lin*, Steven Evett+, Prasanna H. Gowda^, Paul Colaizzi+, Jed Moorhead+, Gary Marek+, David Brauer+, and Robert Aiken*

* Kansas State University, Manhattan, KS   + USDA-ARS, Bushland, TX   ^ USDA-ARS, El Reno, OK

Introduction

- Typical eddy covariance (EC) averaging times are 30 minutes or 1 hour, but fluxes may calculated on shorter timescales. This can be justified using ogive analysis.
- Wind loading has been observed for weighing lysimeters, since they function on mass balance near the ground, where drag is particularly strong with a short or sparse canopy (Evett et al. 2011; Nolz et al. 2013).
- Advection of dry, hot air transported from outside the field of interest may enhance evapotranspiration; this horizontal flux divergence of sensible heat may be estimated using micrometeorological towers (Evett et al. 2012; Leuning et al. 2012).

Objectives

- Quantify differences between lysimeter and EC evapotranspiration at two flux averaging timescales, and
- Investigate causes related to sensible heat advection and dynamic pressure (wind) effects

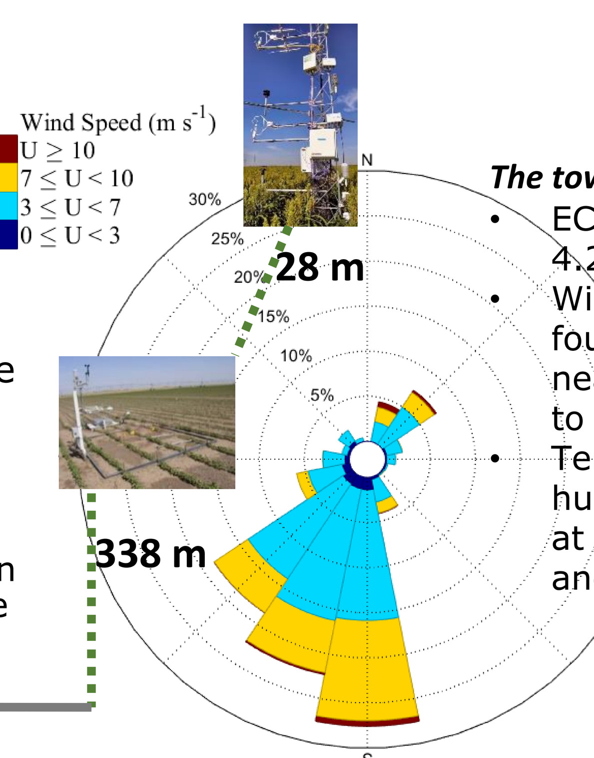
Experimental Design

The lysimeter:

- 3m x 3m x 2.3m deep
- Mass of soil water measured at 0.5 s, stored as 5 minute change in water storage

The field:

- Sorghum, max height of 1.14 m
- Sub-surface drip irrigation
- East-west crop rows were furrow diked



The tower:

- EC systems at 2, 4.2, and 8.4 m
- Wind measured at four heights, from near the canopy up to 12 m
- Temperature and humidity measured at same heights and in canopy

Figure 1: Daytime wind rose for study period, with relative position of EC system and lysimeter indicated.

Methods

Data Selection:

- 19 non-consecutive days (midnight to midnight LST) in August and September 2015 were selected
  - QC data from all measurement systems
  - Did not have to be clear sky days, but no rainfall or irrigation permitted

Data processing:

- Converted 5 minute lysimeter storage to equivalent moisture flux
  - 30 minute fluxes were calculated using this storage with time-centered averages
- Latent heat fluxes calculated using EddyPro (LI-COR, Lincoln, NE)
  - 5 and 30 minute block average
  - Filtered, removed low turbulent fluxes (Mauder and Foken, 2004)
  - Filled gaps using interpolation function
- Power spectral density computed using a Hamming window for all days and advective days separately

Data analysis:

- Determined advective periods on both 5 and 30 minute basis with 12 m wind direction, available energy, and latent heat
- Effect of wind loading determined using residual between ET from lysimeter (ET_{Lys})and EC system (ET_{EC}) as function of mean wind speed
  - Selected two days with similar ET but contrasting wind speeds

Table 1: Mean and standard deviation of daytime wind speed and total ET from the 4m EC system on two selected days.

Advective Conditions Summary	DOY 238	DOY 243
Daytime $U_{1.3m}$ (m s^{-1})	1.2	3.2
Daily ET_{30min} (mm)	5.3	6.1
Daily ET_{5min} (mm)	5.1	6.0

Results – ET comparison

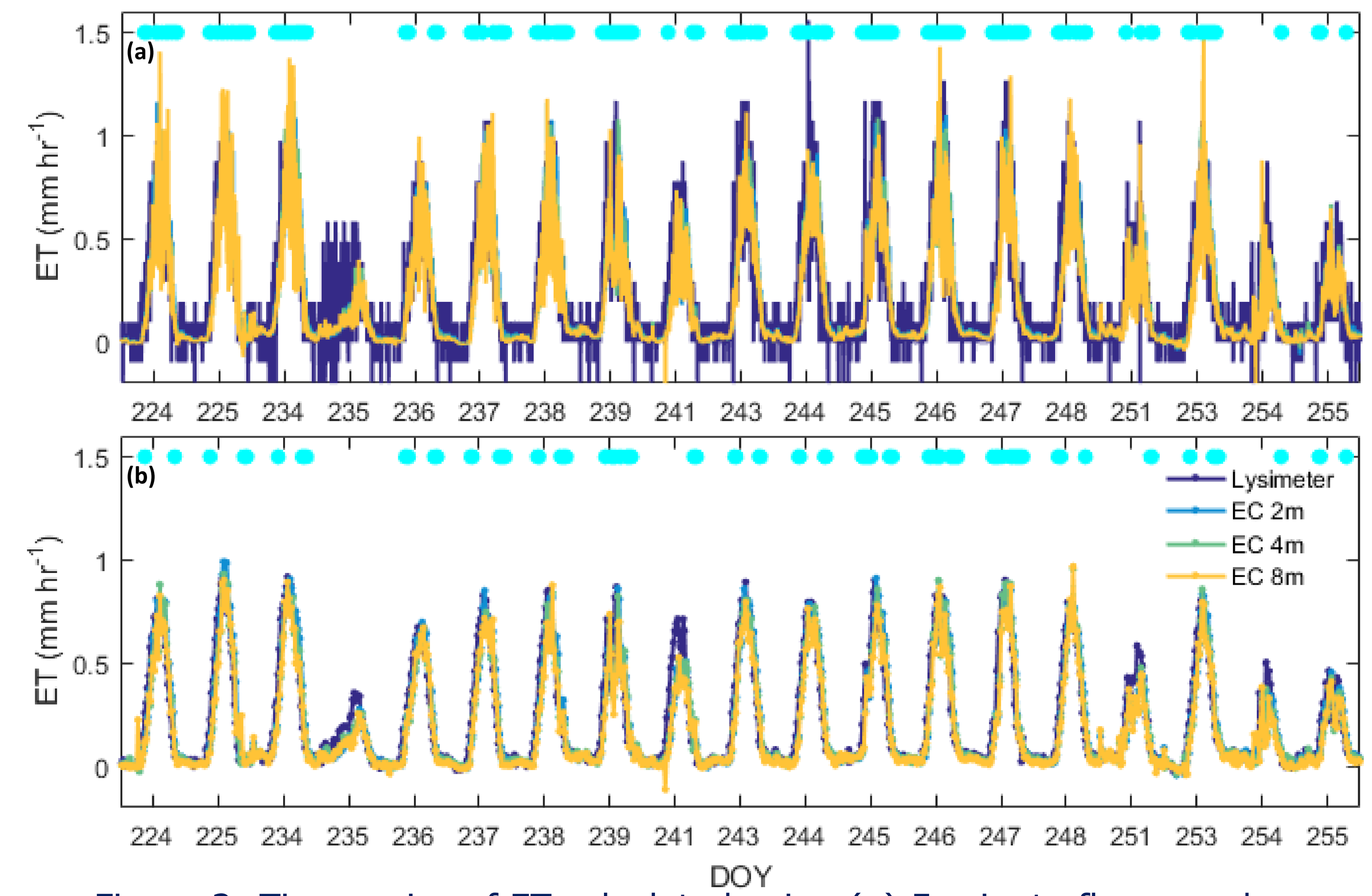


Figure 2: Time series of ET calculated using (a) 5-minute fluxes and (b) 30-minute fluxes from lysimetric and EC measurements. Advective periods are indicated with cyan markers.

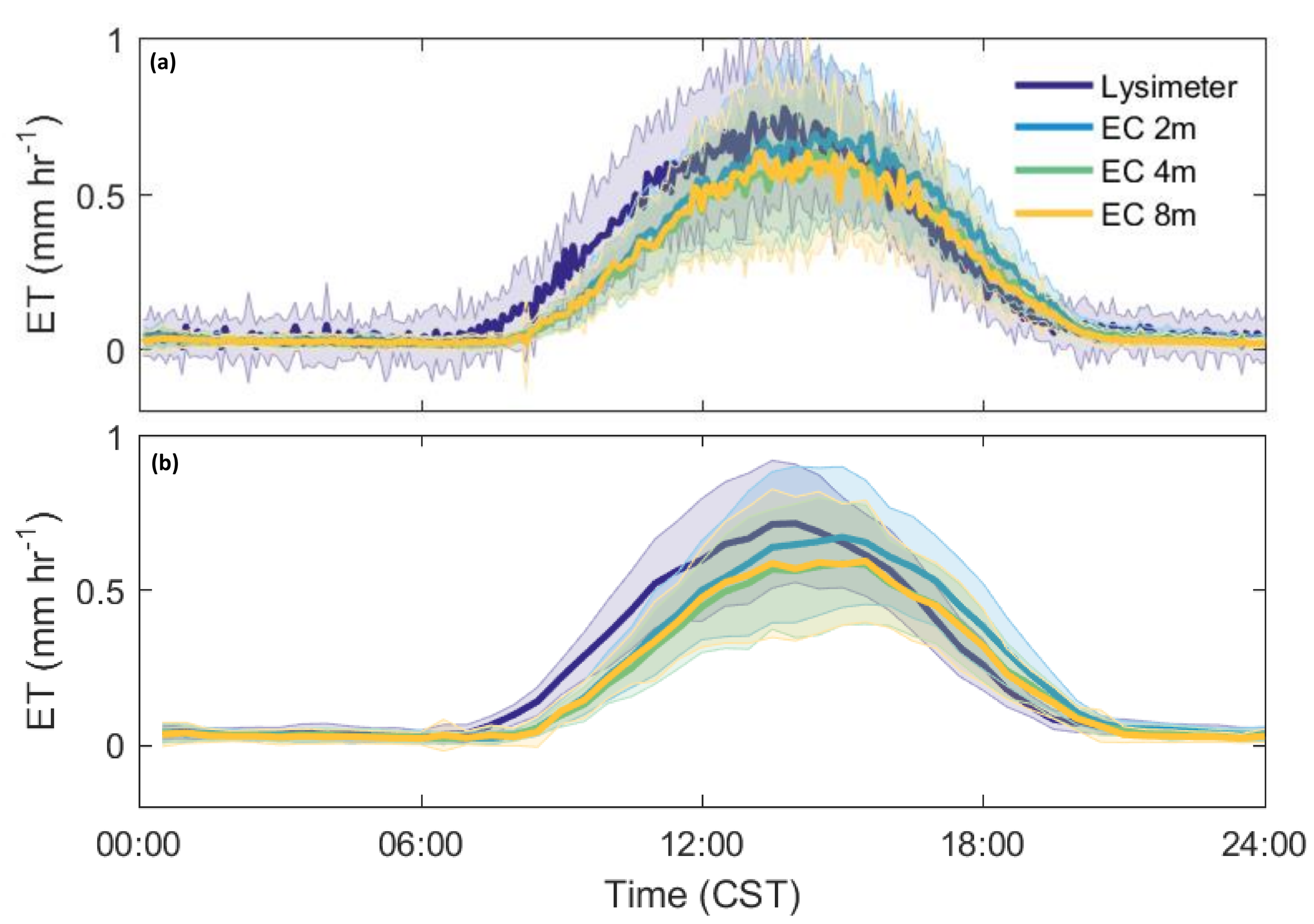


Figure 3: Diurnal cycle of ET using (a) 5-minute fluxes and (b) 30-minute fluxes from lysimetric and EC measurements. Shaded area represents ET uncertainty as approximated using one standard deviation from the mean at each time point.

Results – Sensible Heat Advection

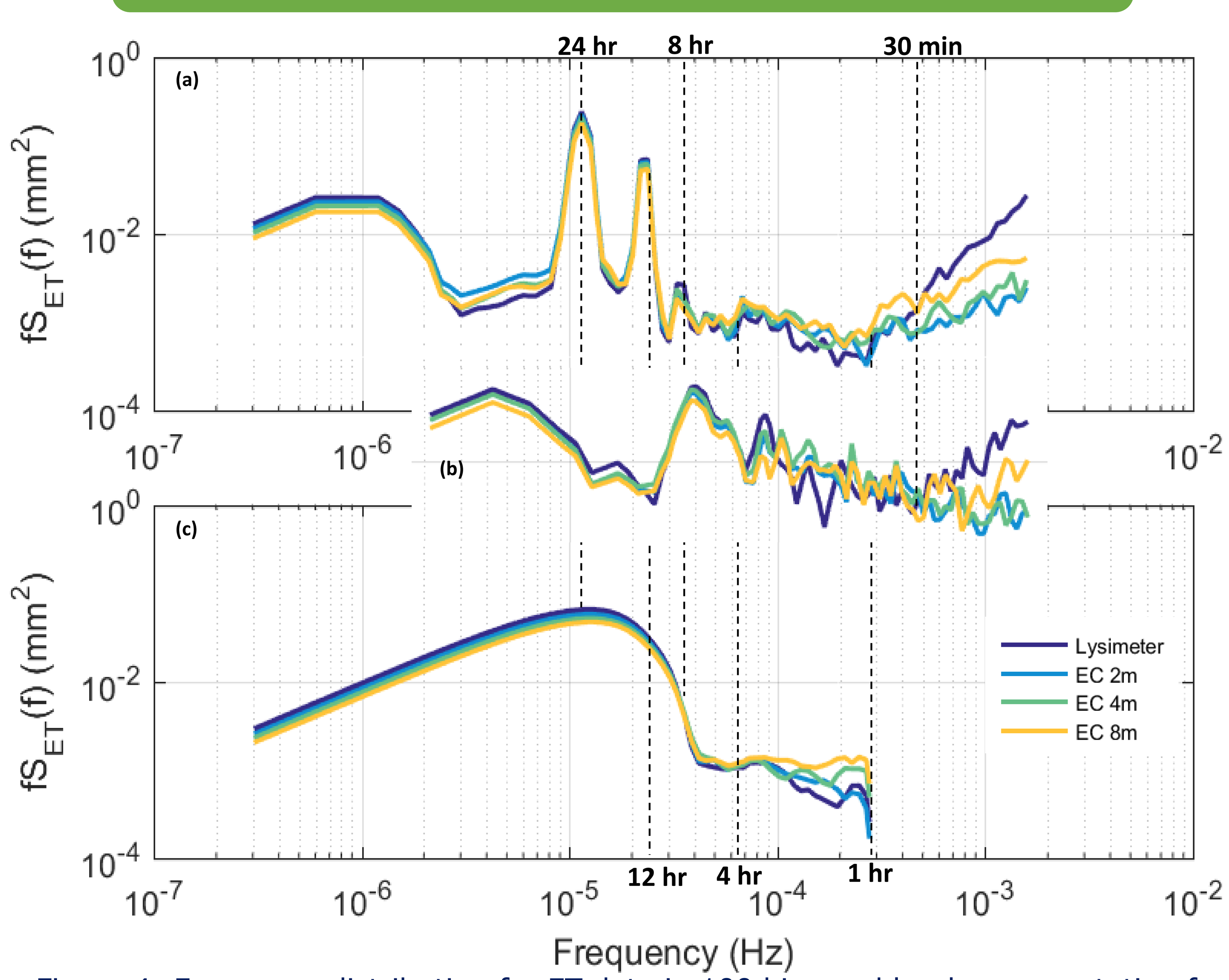


Figure 4: Frequency distribution for ET data in 100 bins and log-log presentation for (a) all 5 minute fluxes, (b) advective 5 minute fluxes, and (c) all 30 minute fluxes.

Results – Wind Effects

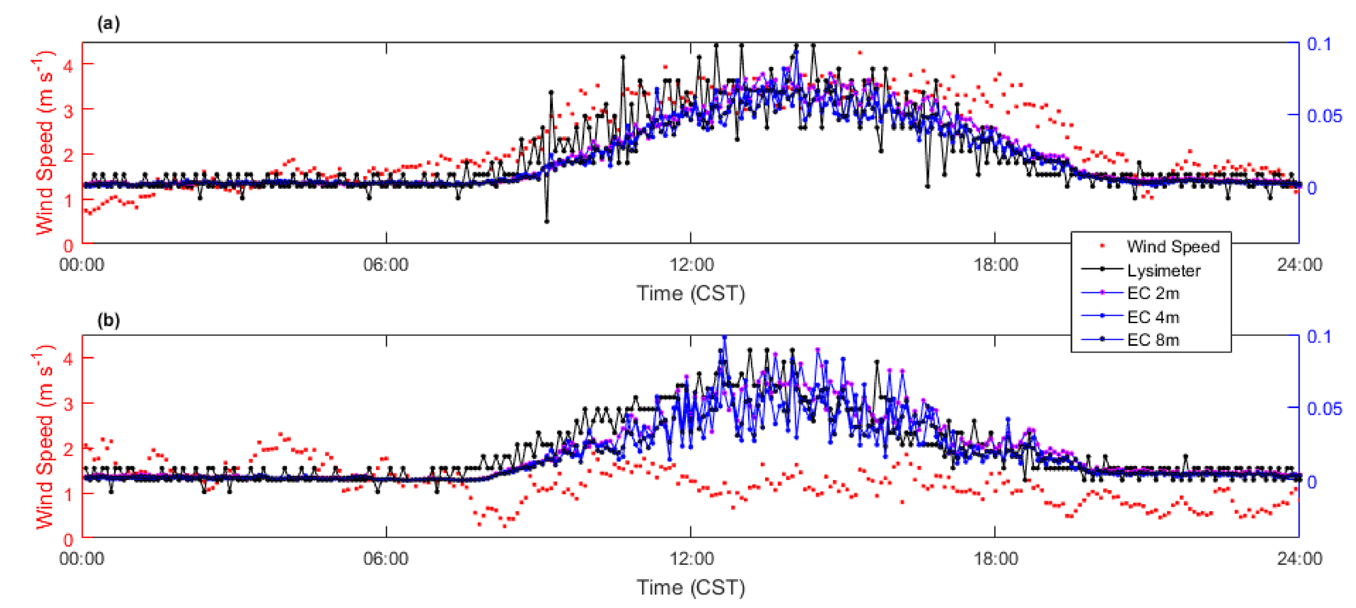


Figure 5: 5-minute fluxes and 1.3m wind speeds are shown for (a) DOY 243 and (b) DOY 238.

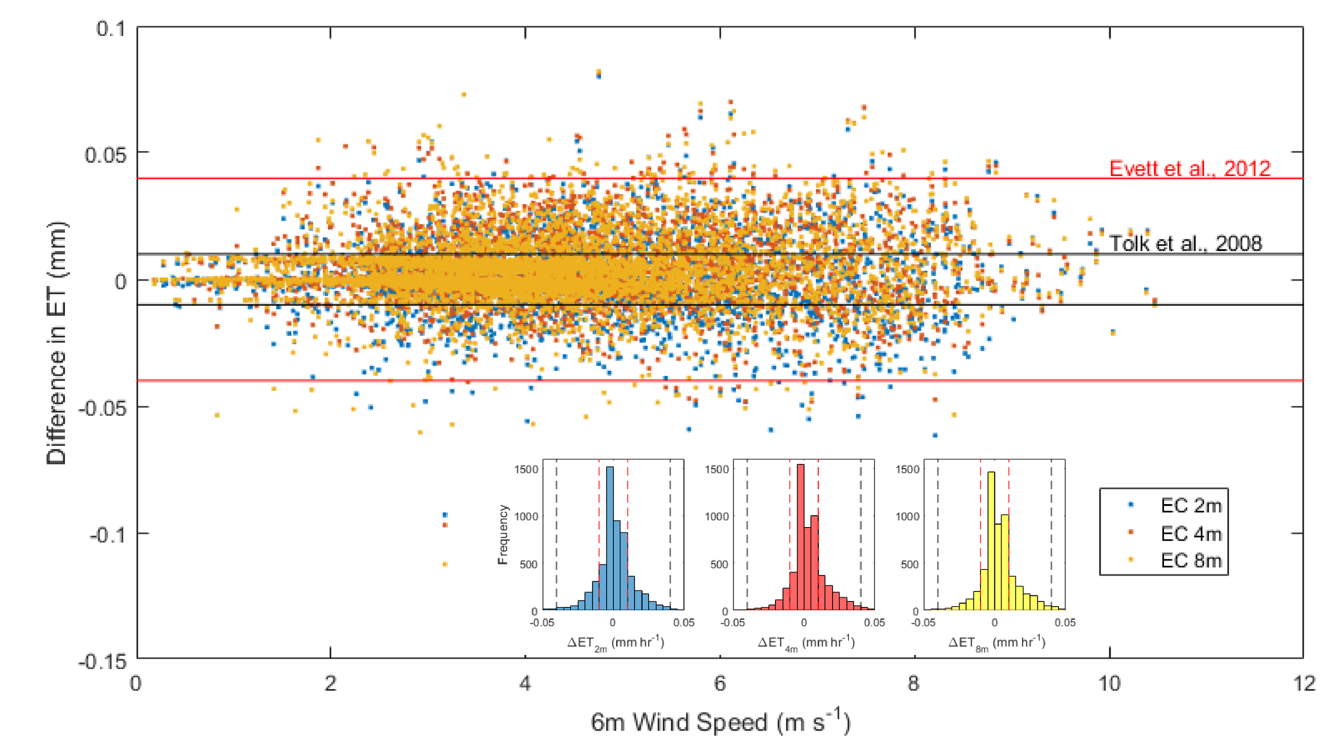


Figure 6: Residuals for 5-minute fluxes are plotted as a function of wind speed. Frequency distributions are provided for each EC system comparison, with a bin interval of 0.005 mm.

Table 2: ET error rate for each EC system for all observations in the study based on two observed weighing lysimeter load cell calibrations.

Error Rate	0.04 mm	0.01 mm
EC 2m	1.04%	31.01%
EC 4m	1.22%	30.06%
EC 8m	1.92%	30.24%

Conclusions

- The same windy conditions that reduce measurement uncertainty among EC systems creates much noisier lysimeter data.
- When wind speeds are relatively light, variability of lysimeter storage is low and the differences between lysimeter and EC systems are in line with expectation relative to the calibrated precision.
  - With wind speeds above a threshold of only around 2 m s^{-1}, a small, positive bias in ET exists.
  - At very high wind speeds, accuracy increases.
- Our results for the comparison between ET_{EC} and ET_{Lys} are consistent with previous studies with systematic underestimation by EC systems
  - Generally errors increased with increasing measurement height, although by root mean square error, the 4m and 8m systems performed similarly.
- Although only between 10 and 13% of the study period was classified as advective, these conditions occurred in all but one day.

References

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