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

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Introduction

- Typical eddy covariance (EC) averaging times are 30 minutes or 1 hour, but fluxes may be 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; Noz 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

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, low turbulent fluxes (Mauder and Foken, 2004)
  - Filled gaps using interpolation function
- Power spectral density computed using a Hamming window for all days and advection days separately

Data analysis:
- Determined advection 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 (ETly) and EC system (ETEC) 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.

<table>
<thead>
<tr>
<th>Advection Conditions Summary</th>
<th>DOY 238</th>
<th>DOY 243</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daytime U10m (m s⁻¹)</td>
<td>1.2</td>
<td>3.2</td>
</tr>
<tr>
<td>Daily ETly (mm)</td>
<td>5.3</td>
<td>6.1</td>
</tr>
<tr>
<td>Daily ETsys (mm)</td>
<td>5.1</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Results – ET comparison

- 30 minute fluxes were calculated using this storage with time
- Our results for the comparison between ETly and ETsys 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 ETly and ETsys 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 advection, these conditions occurred in all but one day.

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

<table>
<thead>
<tr>
<th>System</th>
<th>Error Rate</th>
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<tbody>
<tr>
<td>EC2m</td>
<td>1.6%</td>
</tr>
<tr>
<td>EC4m</td>
<td>1.22%</td>
</tr>
<tr>
<td>EC8m</td>
<td>1.92%</td>
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</tbody>
</table>

Results – Wind Effects

- 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.

Conclusions

References