Water from Ground to Sky

New approaches to observing and predicting field to basin scale ET over crops and plantations

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The digital global map of irrigation areas
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The map shows area equipped for irrigation in percentage of cell area. For the majority of countries the base year of statistics is in the period 2000 - 2008.

War Over Water in a Land of Plenty
High Capacity Wells

Low Capacity Wells
Regionally, terrestrial evapotranspiration (ET) is a dominant component of the water cycle and hard to measure well!

Chapin, 2011, Principles of Terrestrial Ecosystem Ecology
Annual Average water Budget

Water balance Ratio

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<tr>
<td>Baseflow/Total Flow</td>
<td>0.79</td>
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<tr>
<td>ET/Precipitation</td>
<td>0.5</td>
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PET 874.5
Evaporation and Transpiration 491.2
Precipitation 981.7
Average Curve Number 58.48
Soil water demand trigger

- Saturation
- Field Capacity
- Wilting Point

Plant water demand trigger

- Wilting Plant

Average Monthly Streamflow (m³/s)
Evapotranspiration and recharge measurements
Infrared gas analyzer

\[ \rho \omega' q' = \omega' \xi' \]

\[ H = \text{Sensible Heat flux} = \rho \omega' t' \]

\[ LE = \text{Latent Heat flux} = \rho \omega' q' \]

Net radiation = Net solar + net Longwave
Some questions

• How tall? The taller the tower, the large area ET you measure (around 10-100x upwind of tower). Needs to be at least ~6 feet above canopy.

• How much power? Can be run on solar, continuously log data at ten times a second, output ET and carbon fluxes every 30 minutes

• Cost? $30-40K per system

• How reliable? As long as sample area is homogenous and uptime is good, eddy covariance is the gold standard for field-regional ET
Five days of observations

Net radiation = Net solar + net Longwave

Watts Per Square Meter
200 days of observations

Sylvania Wilderness site in UP Michigan (Watersmeet, MI), est. 2001

Example ET from flux tower in two seasons in mm per day (Tang et al., 2006)
17 years of observations
78 site-years of observations

Wolf et al., 2016
A flux station for **every need**

LI-COR eddy covariance systems are scalable—from basic systems that measure carbon dioxide exchange, evapotranspiration, and energy flux, to advanced systems that measure methane flux and additional biological and meteorological parameters. Each flux station automatically calculates flux results using EddyPro® Software on the SmartFlux® System. With optional FluxSuite™ Software, your results can be online—all the time.

Courtesy of D. Baldocchi
Paired site studies in Nebraska show us effect of irrigation on ET

- **Observed**

- **Model**

Molly Aufforth

Model: BIOCRO
Use data to constrain sensitive parameters
Flux towers have pros/cons

• PRO: Easy to deploy on a tripod in a field, on solar power, no moving parts, and mostly off-the-shelf technology, nearly 500 long running sites worldwide, “gold standard”

• PRO: It is one of the only ways to directly measure ET at hourly time scale, and at the same time, we also measure the surface heat exchange, carbon dioxide flux (productivity), and climate

• CON: It is relatively expensive (total around $40-50K to purchase), requires significant expertise (technical personnel), and regular maintenance

• CON: EC measures only upwind of the tower and when the atmosphere is “turbulent”, requiring application of methods to fill in data gaps and quality control data
Thank you

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