GEO892 (Section 001), Fall 2017, 3 credits; Tu & Th 5:00-6:20 pm; Geography 126

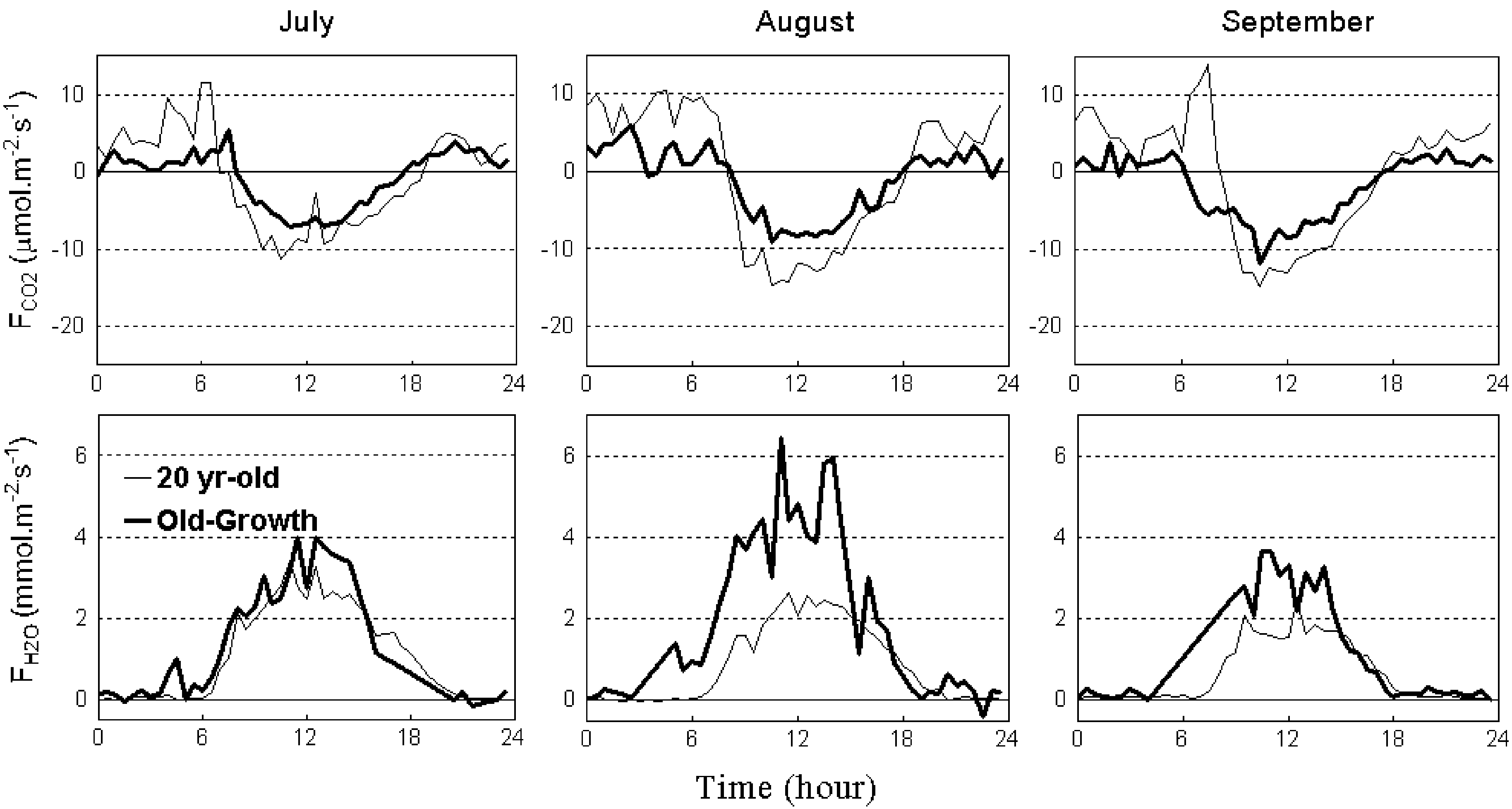
Micrometeorological Instrumentation & Measurements

Class Webpage: http://lees.geo.msu.edu/courses/Geo892

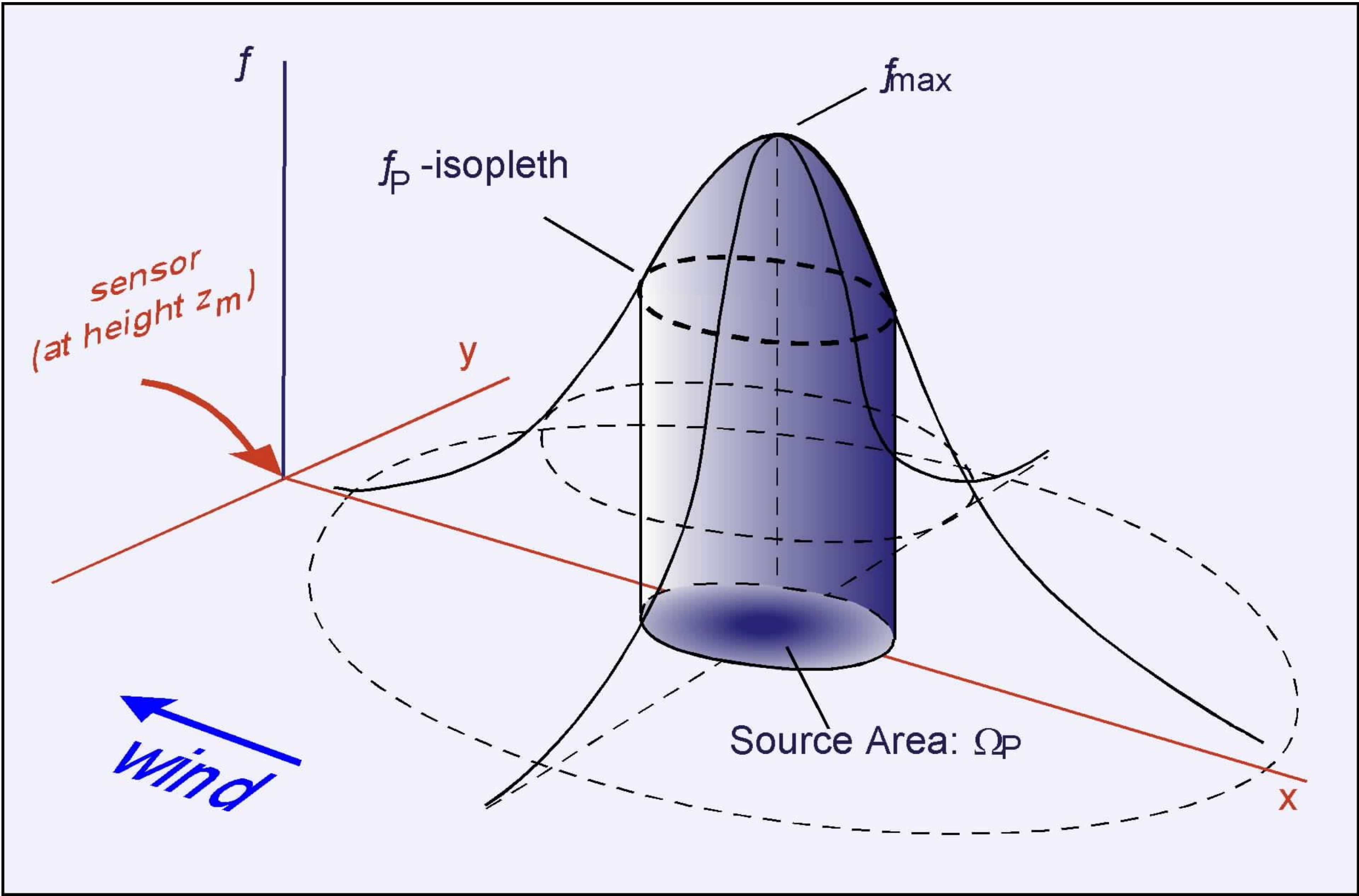
- Wind & Turbulent Transfer (Ch 5)
- Wind profile, aerodynamics, eddy-covariance method, Lagrangian method, surface renewal
- CRBasic by Dr. David Reed on Oct 3.

(b) EC tower at Site 2 (Corn)

Average diurnal fluxes of CO_2 and H_2O in Jul., Aug., and Sept. in 1999 in a 20 and a 500 year-old Douglas-fir forest (WA). Only data from good fetch (200-310°) directions were used. Negative and positive values indicate uptake and loss, respectively (Chen et al. 2002)



The source weight function, or footprint function, and its relation to the source area (Schimid 1997)



Data process & programming

- EC_Processor: LEES Lab
- eddy4R:
- EdiRe: http://www.geos.ed.ac.uk/abs/research/micromet/EdiRe
- etc.

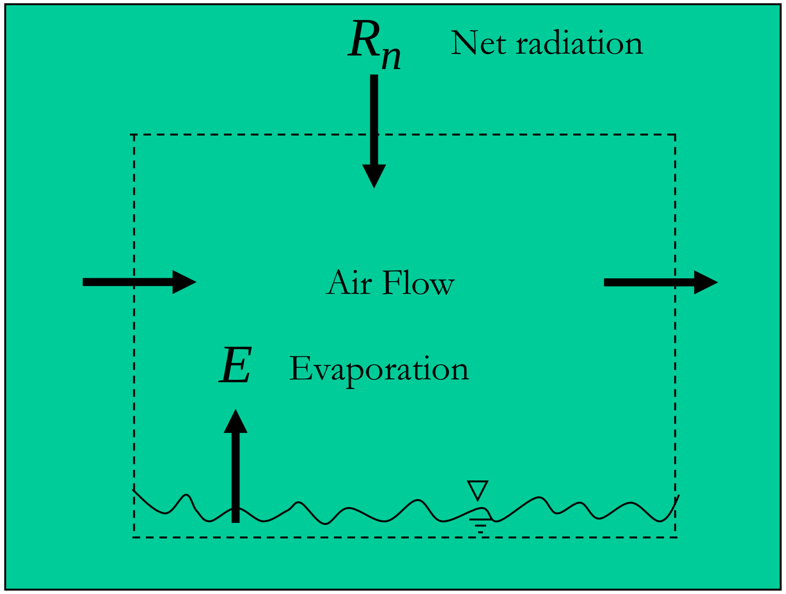
Aerodynamic Method

- Include transport of vapor away from water surface as function of:
  - Humidity gradient above surface
  - Wind speed across surface
- Upward vapor flux

$$\dot{m} = -\rho_a K_w \frac{dq_v}{dz} = \rho_a K_w \frac{q_{v_1} - q_{v_2}}{z_2 - z_1}$$

- Upward momentum flux

$$\tau = \rho_a K_m \frac{du}{dz} = \rho_a K_m \frac{u_2 - u_1}{z_2 - z_1}$$



$$\dot{m} = \tau \frac{K_w (q_{v_1} - q_{v_2})}{K_m (u_2 - u_1)}$$

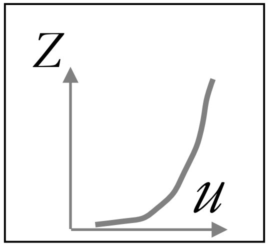
Slides prepared by Daene C. McKinney

Aerodynamic Method

$$\dot{m} = \tau \frac{K_w \left(q_{v_1} - q_{v_2}\right)}{K_m \left(u_2 - u_1\right)}$$

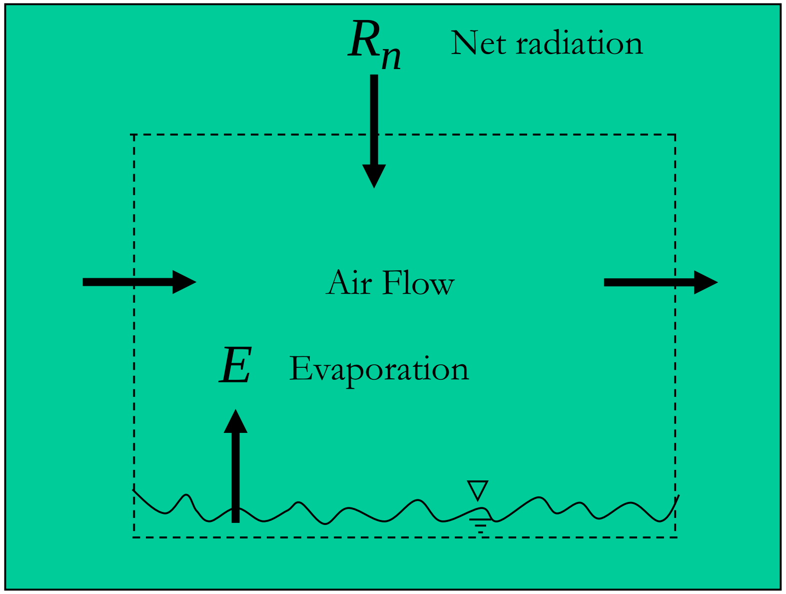
- Log-velocity profile

$$\frac{u}{u*} = \frac{1}{k} \ln\left(\frac{Z}{Z_o}\right)$$



- Momentum flux

$$\tau = \rho_a \left[\frac{k\left(u_2 - u_1\right)}{\ln\left(Z_2 / Z_1\right)}\right]^2$$

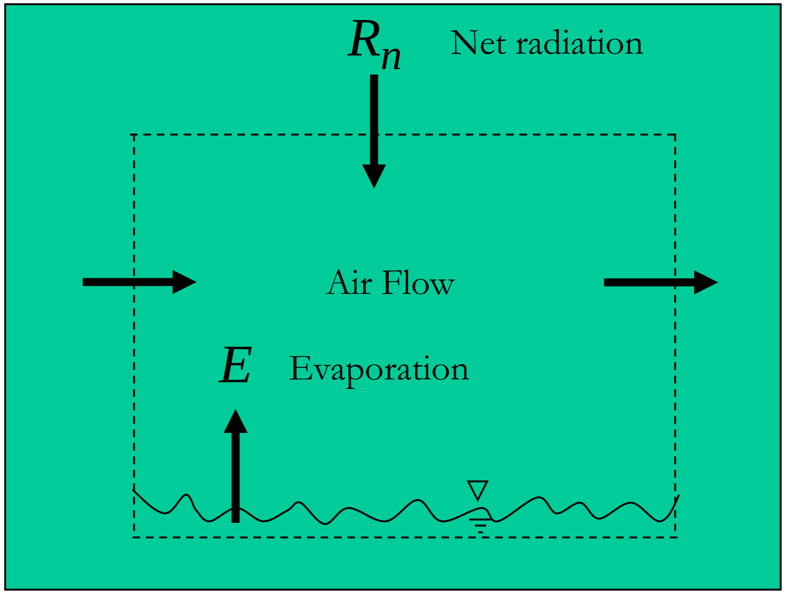


$$\dot{m} = \frac{K_w k^2 \rho_a \left(q_{v_1} - q_{v_2}\right)\left(u_2 - u_1\right)}{K_m \left[\ln\left(Z_2 / Z_1\right)\right]^2}$$

Thornthwaite-Holzman Equation

Aerodynamic Method

$$\dot{m} = \frac{K_w k^2 \rho_a \left(q_{v_1} - q_{v_2}\right)\left(u_2 - u_1\right)}{K_m \left[\ln\left(Z_2 / Z_1\right)\right]^2}$$



q_v and u

- Often only available at 1 elevation
- Simplifying

$$\dot{m} = \frac{0.622 k^2 \rho_a \left(e_{as} - e_a\right) u_2}{P\left[\ln\left(Z_2 / Z_o\right)\right]^2}$$

$$E_a = B\left(e_{as} - e_a\right)$$

$$B = \frac{0.622 k^2 \rho_a u_2}{P \rho_w \left[\ln\left(Z_2 / Z_o\right)\right]^2}$$

$$\dot{m} = \rho_w A E \qquad e_a = \text{vapor pressure @ } Z_2$$

Lagrangian method:

The Lagrangian framework is based on vertical changes of turbulence and concentrations of focal gases that are related to the statistics of air parcel displacement. The gradient is approximated by finite differences between two measurement heights z_i and z_j, as Dc_{ij}/Dz_{ij}. The gas diffusivity (K_c, also known as the K-theory) is estimated using either the heat flux and temperature gradient or friction velocity (u*):

$$Flux = -\frac{ku^{*} \bullet z}{\phi_h(z/L)} \frac{\Delta c_{ij}}{\Delta z_{ij}} \qquad [1]$$

Where *Flux* represents either the flux of gas, z is the aerodynamically effective height z_{ij} that is between z_i and $z_{j.}$, L is the displacement distance,

Also see gradient method at: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V8W-3YVDBP8-3&_user=7778205&_coverDate=04%2F28%2F2000&_rdoc=1&_fmt=high&_orig=search&_sort=d&_docanchor=&view=c&_searchStrId=1192863556&_rerunOrigin=google&_acct=C000062866&_version=1&_urlVersion=0&_userid=7778205&md5=a9f5412df195188103f4e5516e79d3b9

Additional requirements and tips within the FLUXNET

- Large, flat, and homogeneous site
- Fetch: >1.2-1.5 sensor height

Data processing

- Rotation: Planar rotation
- Air density correction (Webb–Pearman–Leuning, WPL)
- IRGA correction: temperature on CO_2 concentration
- Day/night time flux for GPP and Re
- Outliers (e.g., malfunction): 5-6 SDT, reasonable range,
- Gap filing:

$$\mathrm{NEE} = \frac{\alpha \times \mathrm{NEE}_{\max} \times \mathrm{PAR}}{\alpha \times \mathrm{PAR} + \alpha \times \mathrm{NEE}_{\max}} + \mathrm{ER}_{\mathrm{day}}$$

$$\mathrm{Re} = \mathrm{R}_0 * e^{k * T_s}$$

The Q_{10} is calculated as:

$$Q_{10} = \left(\frac{R_2}{R_1}\right)^{10^\circ/(T_2 - T_1)}$$

Energy Budget

$$R_n = S + L + G + \Delta S + P_n$$

$$(R_n - G) = (S + L)$$ Available energy

$$B = S:L$$ Bowen ratio

Type of surface	Range of Bowen ratios
Deserts	>10.0
Semi-arid landscapes	2.0-6.0
Temperate forests and grasslands	0.4-0.8
Tropical rainforests	0.1-0.3
Tropical oceans	<0.1

Data processing and gap filling

Half-hourly fluxes were computed using the software EdiRe (University of Edinburgh, v 1.5.0. 32, 2012) as a covariance of a scalar (sonic temperature, H_2O, or CO_2) and vertical wind speed (u_w). The raw data were screened using quality checks to remove out-of-range data generated due to bad weather, sensor, and/or logger malfunction; spikes greater than four standard deviations; and time lags between scalars (H_2O and CO_2) and u_w (McMillen, 1988). Planar fit rotation was used to align the three wind velocity components into a mean streamline coordinate system (Wilczak *et al.*, 2001). The sonic temperature was corrected for pressure and water vapor concentration fluctuations (Schotanus *et al.*, 1983). All eddy covariance outputs were computed using 30-min block averaging without detrending (Moncrieff *et al.*, 2004). H_2O fluxes were corrected for frequency response (Moore, 1986) and air density fluctuations using the Webb–Pearman–Leuning terms (Webb *et al.*, 1980), including the term for warming of the IRGA above ambient air temperature (Burba *et al.*, 2008). Finally, nonstationarity (dividing the 30-min time series into 5-min intervals), flux–variance similarity, and friction velocity thresholds (0.05 m s^{-1} and 0.1 m s^{-1} during the day and night, respectively) were used to ensure quality of the 30-min data by discriminating weakly developed turbulence (Foken & Wichura, 1996). Before friction velocity threshold selection criteria were applied, 17%, 18%, 26%, and 23% for 2009, 2010, 2011, and 2012, respectively, of the H_2O flux, data were either missing or did not pass the quality criteria test set as above and therefore were flagged as missing. A further 24%, 22%, 18%, and 21% of the H_2O fluxes from the respective years were also removed after friction velocity threshold criteria were applied. The 30-min data that did not pass the quality assurance and quality test were excluded from the analysis and replaced by standardized FLUXNET marginal distribution sampling (MDS) gap-filling algorithm by Reichstein *et al.* (2005; http://www.bgc-jena.mpg.de/~MDIwork/eddyproc/ accessed Dec. 2013).

To assess the overall quality of the computed fluxes, the energy balance closure was evaluated at 30-min intervals using the slope of the relationship between the turbulent fluxes (H + LE, where H and LE are sensible and latent heat energy flux densities, respectively) measured by eddy covariance and the independently observed available energy ($R_n - G$, where R_n and G are net radiation and soil heat flux density, respectively). Only good quality measurements were used in the analysis. The advected energy and physical and biochemical energy storage terms are not included in the equation, assuming that their values are negligible for croplands in relation to the other components of the equation (Wilson *et al.*, 2002b). We use the convention where radiative fluxes (R_n) directed toward the surface are positive, while nonradiative fluxes (all except R_n) are negative and *vice versa*.

Follow-ups

- EC on Baker Hall (acronym?)
- Gabriela: coordination (MSU) and supplies (compiling, purchasing)
- BJ: overall design
- Chase: testing and installation
- Cheyenne: programing, wiring, etc.
- Oct 3 (10 am – 5 pm): Lab testing, CR Basics (David R), roof visit, Pizza for lunch?
- Oct 10 (10 am - 5 pm): mock installation outside of Geography
- Oct 20 (10 am - ?): Installation in Baker Hall
- Others?