Eddy Covariance Method

Most of these slides are from:
www.licor.com/env/products/eddy_covariance/resources.html

Airflow in Ecosystems

Typical Variables

- Minimal Eddy Station
  - Product flux of 1 gas and H₂O + supporting weather data
  - concentration of 1 gas
  - concentration of H₂O

- Typical Eddy Station
  - Product flux of 1 gas and H₂O + supporting weather data
  - concentration of 1 gas
  - concentration of H₂O
  - precipitation, etc.

- Full Eddy Station
  - Product flux of 1 gas and H₂O + supporting weather, radiation, and soil data
  - concentration of 1 gas
  - concentration of H₂O
  - precipitation, etc.

Approximate list of variables provided by commonly used eddy covariance stations

Minimal station contains a list of essential variables needed in every application

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Major Assumptions

- Measurements at a point can represent an upwind area
- Measurements are done inside the boundary layer of interest
- Fetch/footprint is adequate – fluxes are measured from the area of interest
- Flux is fully turbulent – most of the net vertical transfer is done by eddies
- Terrain is horizontal and uniform: average of fluctuations of w is zero, air density fluctuations, flow convergence and divergence are negligible
- Instruments can detect very small changes at high frequency
- Air flow is not distorted by the installation structure or the instruments

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Typical Workflow

- Design
  - Set purpose and variables

- Implement
  - Place tower
  - Place instruments
  - Test data collection
  - Test data retrieval
  - Collect data
  - Test data processing
  - Keep up maintenance

- Process
  - Convert units
  - Derive
  - Apply calibrations
  - Rotate
  - Correct for time delay
  - Die trend if needed
  - Average
  - Apply corrections
  - Quality control & fill-in
  - Integrate
  - Analyze/publish

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Instrumentation – Sonic Anemometer

- Omni-directional Sonic Anemometer
- Open-path CO₂ / H₂O Gas Analyzer

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Measurement Principles

\[ F_c = (m \, s^{-1}) \times (mg \, m^{-3}) = mg \, m^{-2} \, s^{-1} \]

**Sonic Anemometer**
- Uses difference in time it takes for an acoustic signal to travel the same path in opposite directions
- ATCI, Campbell, Metek, R.M. Young, Koshin Denki, Gill Instruments, etc.

**Gas Analyzer**
- Non-dispersive infrared (NDIR) sensor
- Broadband infrared beam transmitted through cell, with absorption band of 4.26 μm for CO₂ & 2.59 μm for H₂O
- Beam is modulated to distinguish it from the background using a chopper wheel

Importance of Footprint

![Diagram showing importance of footprint](image)

Effect of Measurement Height

![Diagram showing effect of measurement height](image)

Effect of Station Height

![Diagram showing effect of station height](image)

Instrument Placement – Rules of Thumb

![Diagram showing instrument placement rules of thumb](image)

Practical Formulas

- Any gas (CO₂, CH₄, NH₃, H₂O, etc.):
  \[ F = \rho C_w s \approx \int w' \rho_e' \]
- Sensible heat flux:
  \[ H = \rho C_w T' \]
- Traditional H₂O flux:
  \[ E = \frac{M_e}{P} \rho_x w' e' \]
- Latent heat flux (H₂O flux in energy units):
  \[ LE = \lambda E = \frac{M_e}{P} \rho_x w' e' \]
Eddy Covariance
Flux density: mol/m²/s or J/m²/s

\[ F = \rho_a ws = \rho_a \cdot w's' \]

where \( s \) is the mixing ratio of the density of \( \text{CO}_2 \) (\( \rho_c \)) to the density of dry air (\( \rho_a \))

Reynolds Decomposition

\[ \bar{\rho}_a w s = (\bar{w}+w')(s' + s')\bar{\rho}_a \bar{\rho}_a' \]

Flux Averaging Rules

\[ \bar{xy} = \bar{x} \bar{y} + \bar{x'}y' \]
\[ \bar{x'} = 0 \]
\[ \bar{x} + y = \bar{x} + \bar{y} \]

Example of “fast” Data

Example of “fast” Data

Connecting Tower to Basin Flux Estimates

- Determine trunk density
- Measure Sap flow flux at several trees
- Study allometric relationships between tree size and trunk DBH (dia. @ breast height)
- More info: baskar mitra – UA postdoc

References
