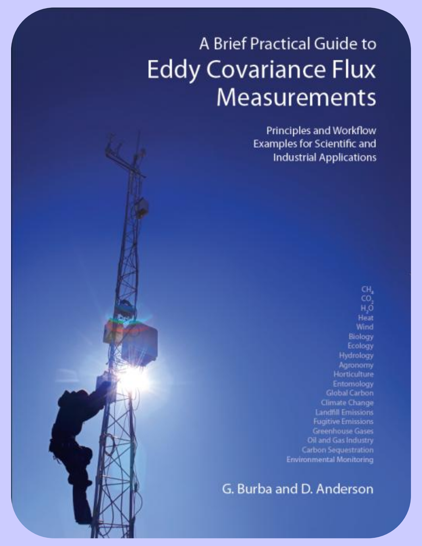

BRIEF PRACTICAL GUIDE TO EDDY COVARIANCE FLUX MEASUREMENTS

Principles and Workflow Examples for Scientific and Industrial Applications

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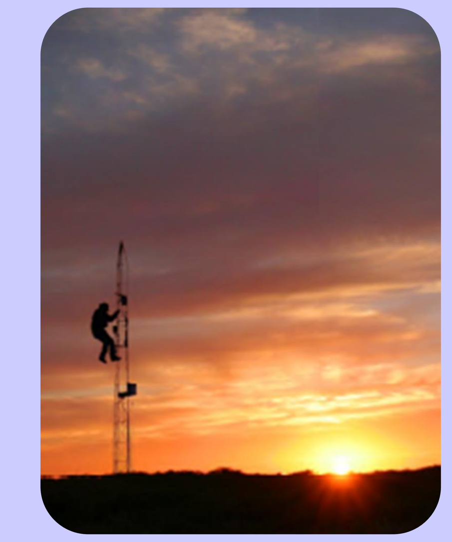


INTRODUCTION

The new book presents guidelines for the Eddy Covariance technique of high-speed measurements of water, gas, heat, and momentum fluxes within the atmospheric boundary layer.

Eddy Covariance is widely used by micrometeorologists all over the globe. However, a number of scientists from related disciplines may not be familiar enough with this technique to assess its usefulness within their research.

Modern instruments and software can expand the use of this method beyond micrometeorology and prove valuable for plant physiology, hydrology, biology, ecology, entomology.

WHY EDDY COVARIANCE

Flux describes how much of the entity of interest moves through a unit area per unit time. For example, gas flux is often presented in mg per square meter per second.

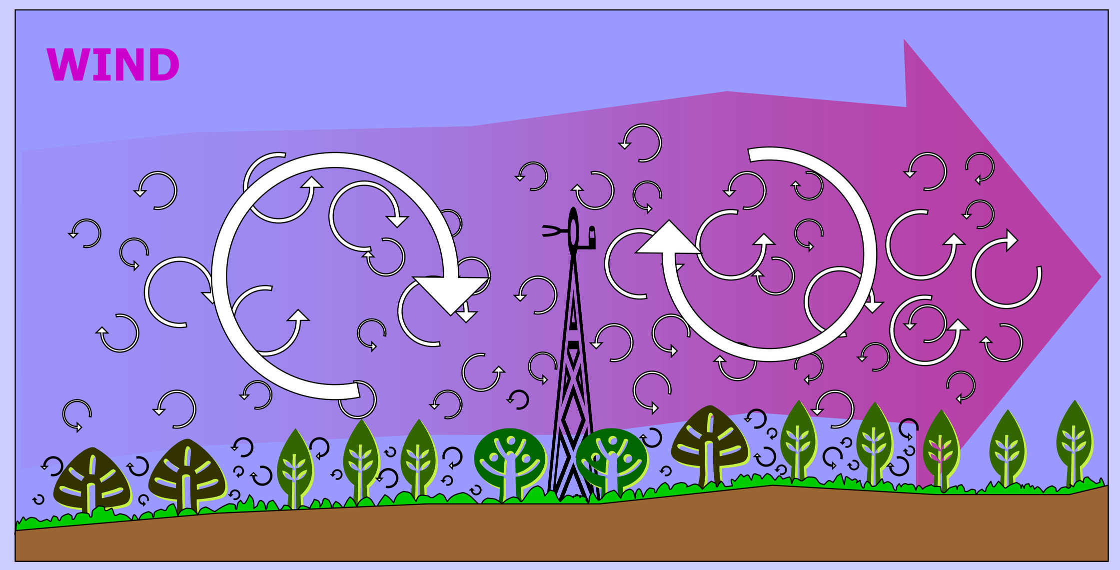
Measurements of ecosystem fluxes are important for constructing energy, water and carbon budgets, understanding key factors governing ecosystem functioning, and modeling the processes of water, and gas exchange.

The Eddy Covariance method is one of the most direct, defensible ways to measure and calculate ecosystem fluxes within the atmospheric boundary layer.

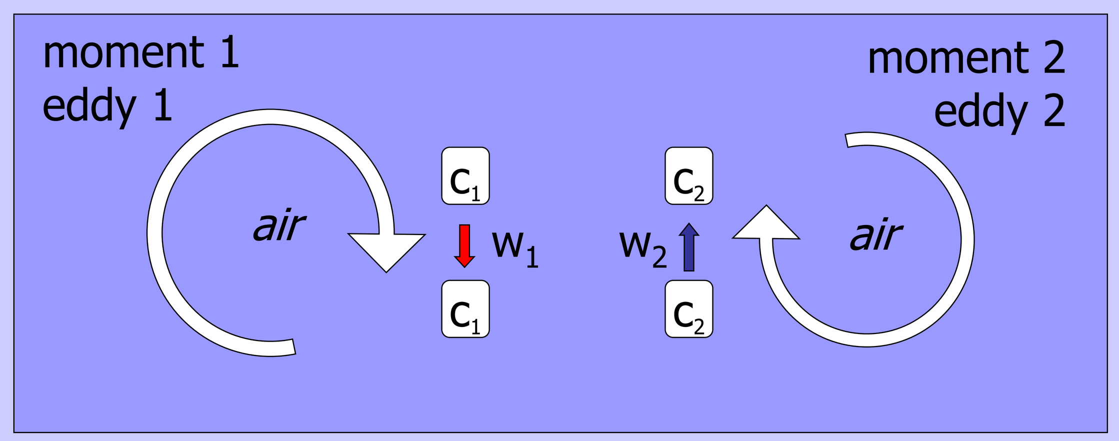
ADVANTAGES OF THE METHOD

- Nearly direct way to measure transport in the atmosphere
- Observes scales from 20-40 times per second to years
- Represents exchange over area, and not at a single spot
- Represents entire ecosystem exchange, not just soil layer
- Very flexible set-up to fit wide range of scientific goals
- Instrumental systems are available and ready-to-use
- World-wide network available: data sharing and integration
- Challenges include mathematical complexity, care during system design for specific goal, and data processing

PHYSICAL MEANING



- Air flow can be imagined as a horizontal flow of numerous rotating eddies of various sizes
- Each eddy has 3D components, including a vertical wind component
- Diagram looks chaotic but components can be measured from the tower, including gas concentration, temperature and humidity



- At moment 1, on the tower, eddy 1 moves air parcel c1 downward with the speed w1
- At moment 2, on the tower, eddy 2 moves air parcel c2 upward with the speed w2
- Each parcel has instantaneous concentration, temperature, humidity
- If we know these and vertical wind speed – we could compute the flux

BASIC DERIVATIONS

$$F = \overline{\rho_a w s}$$

In turbulent flow, vertical flux can be presented as: *($s=r_c/r_a$ is a mixing ratio of substance 'c' in the air)*

$$F = \overline{(\overline{\rho_a} + \rho'_a)(\overline{w} + w')(\overline{s} + s')}$$

Reynolds decomposition is used then to break into means and deviations:

$$F = \overline{(\overline{\rho_a}\,\overline{w}\,\overline{s} + \overline{\rho_a}\,\overline{w}s' + \overline{\rho_a}w'\overline{s} + \overline{\rho_a}w's' + \rho'_a\overline{w}\,\overline{s} + \rho'_a\overline{w}s' + \rho'_a w'\overline{s} + \rho'_a w's')}$$

Open parenthesis

Averaged deviation from the average is zero

$$F = (\overline{\rho_a}\,\overline{w}\,\overline{s} + \overline{\rho_a}\,\overline{w's'} + \overline{w}\,\overline{\rho'_a s'} + \overline{s}\,\overline{\rho'_a w'} + \overline{\rho'_a w's'})$$

Equation is simplified

$$F = (\overline{\rho_a}\,\overline{w}\,\overline{s} + \overline{\rho_a}\,\overline{w's'} + \overline{w}\,\overline{\rho'_a s'} + \overline{s}\,\overline{\rho'_a w'} + \overline{\rho'_a w's'}) = \overline{\rho_a}\,\overline{w}\,\overline{s} + \overline{\rho_a}\,\overline{w's'}$$

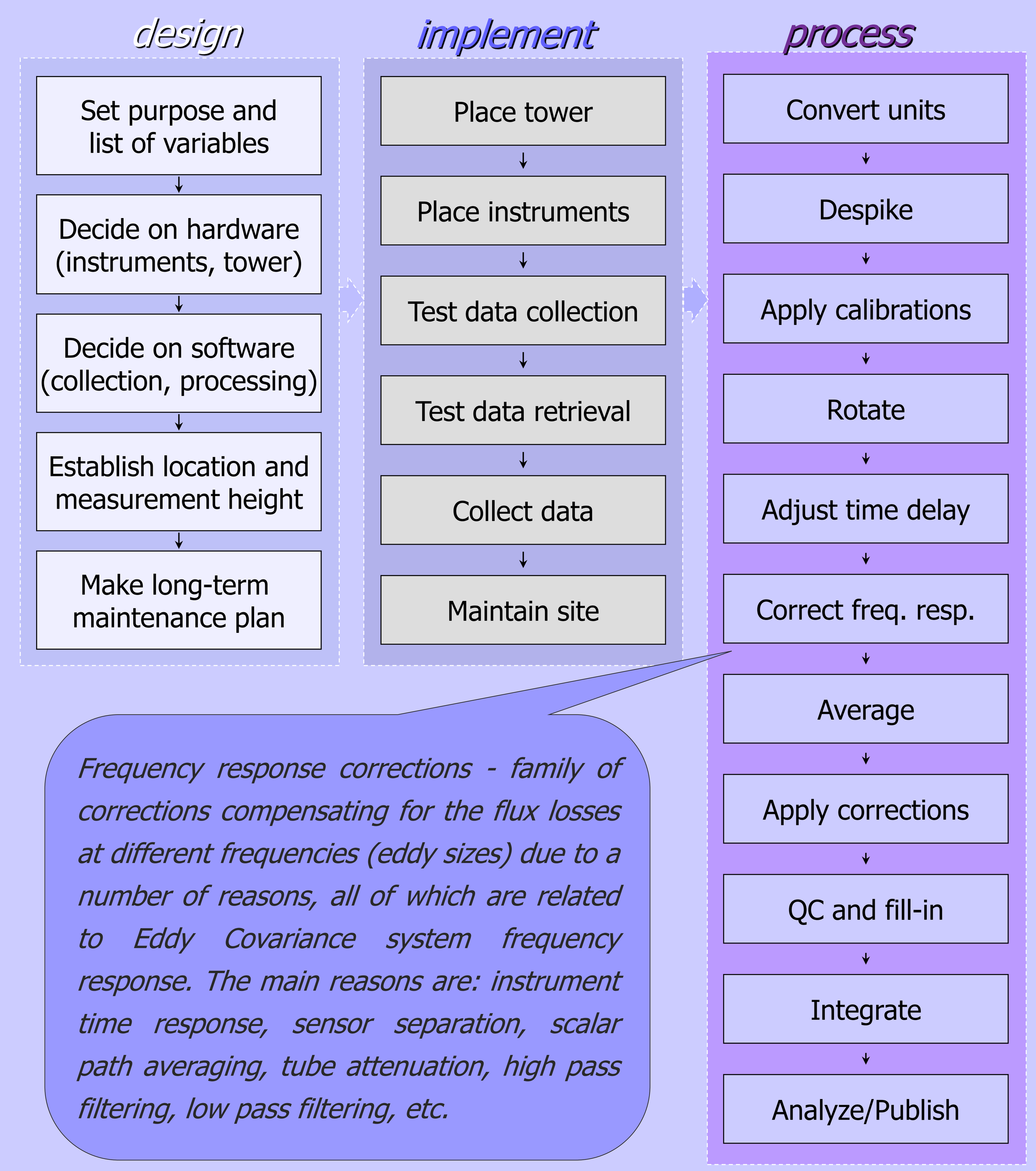
Density fluctuations assumed negligible

$$F \approx \overline{\rho_a}\,\overline{w's'}$$

'Eddy flux'

Mean vertical flow is assumed negligible for horizontal homogeneous terrain: no flow divergence or convergence

TYPICAL WORKFLOW



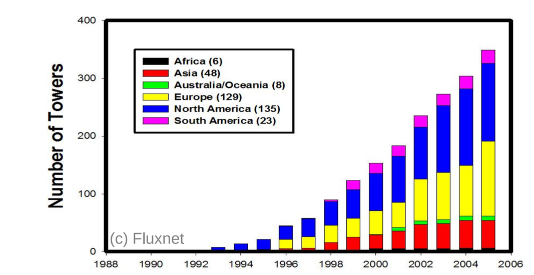
Proper execution of the workflow is perhaps the second biggest challenge after mastering the theoretical part. There are several different ways to execute the method and get the same result. Here is an example of one traditional sequence of actions needed for successful experimental setup, data collection, and processing. This sequence may not fit your specific scientific goal, but it provides general understanding of what is involved in an Eddy Covariance study

MAJOR ASSUMPTIONS

- Measurements at a point can represent an upwind area
- Measurements are done inside boundary layer of interest
- Footprint is adequate: fluxes are from an area of interest
- Flux is fully turbulent: most of the transfer is by eddies
- Terrain is horizontal, uniformed, with steady-state flow
- Atmospheric pressure, air density fluctuations negligible
- Convergence and divergence of the air flow are negligible
- Instruments can detect small changes at high frequency

FUTURE DEVELOPMENT

- Progress in the world data coverage by the flux networks
  - data sharing and integration
  - increase in number of sites
  - unification of terminology
  - standardization of processing



- Expansion to disciplines beyond micrometeorology
- Expansion to many gases beyond CO_2, to dust & aerosols
- Expansion in ecosystem types: mountains, urban, complex
- Expansion in geographic scales of studies: regions

ON-LINE ACCESS TO MANUAL

A detailed book on the Eddy Covariance methodology can be accessed online. Two formats are available:

(1) Electronic - Adobe Acrobat PDF to print
(2) Hardcopy - softbound paper copy to order

Access to both: http://www.licor.com/eddycovariance

Authors intend to keep the content of this book dynamic and current, and will periodically incorporate any updated information and literature references. Please send your suggestions to george.burba(at)licor.com with subject "EC Book"

ADDITIONAL INFORMATION

Baldocchi, D., 2010. "Advanced topics in Biometeorology and Microclimatology". Department of Environmental Science, University of California - Berkeley: http://nature.berkeley.edu/biometlab/espm228/

Burba, G., and D. Anderson, 2010. A Brief Practical Guide to Eddy Covariance Flux Measurements: Principles and Workflow Examples for Scientific and Industrial Applications. LI-COR Biosciences, Lincoln, Nebraska, USA, 212 pp.: http://www.licor.com/eddycovariance

FluxNet and regional networks' plans, protocols, and courses: http://daac.ornl.gov/FLUXNET/

Lee, X., W. Massman, and B. Law (Eds.).2004. "Handbook of Micrometeorology: A Guide for Surface Flux Measurement and Analysis". Springer-Verlag, 250 pp.

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