EFFICACY OF USING EDDY COVARIANCE METHOD FOR GAS AND ENERGY FLUX MEASUREMENTS IN DISCIPLINES BEYOND MICROMETEOROLOGY

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INTRODUCTION

The Eddy Covariance (EC) method is a micrometeorological technique for high-speed flux measurements within the atmospheric boundary layer, above the soil, plant canopy, or industrial and urban terrains.

Fluxes, emission and exchange rates can be carefully characterized from single-point *in situ* measurements using a permanent or mobile tower, or moving platforms such as vehicles, helicopters, airplanes, ships, boats, etc.

EC 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.

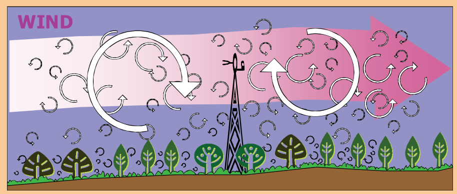
The new book presents guidelines for the EC technique of high-speed measurements of water, gas, heat, and momentum fluxes within the atmospheric boundary layer.

WHY EDDY COVARIANCE?

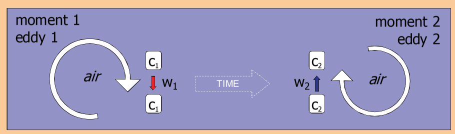
The EC method is one of the most straightforward and defensible ways to measure and calculate ecosystem fluxes, emissions, and exchange rates of gas and energy inside the atmospheric boundary layer.

- Nearly direct way to measure transport in the atmosphere
- Observes scales from 20-40 times per second to years
- Represents exchange over an 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
- Instrument 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 goals, and data processing

PHYSICAL DESCRIPTION



- 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 can compute the flux

BASIC DERIVATIONS

$F = \overline{\rho_a w s}$ In turbulent flow, vertical flux: $s=\rho_c/\rho_a$ 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 to break into means and deviations

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

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

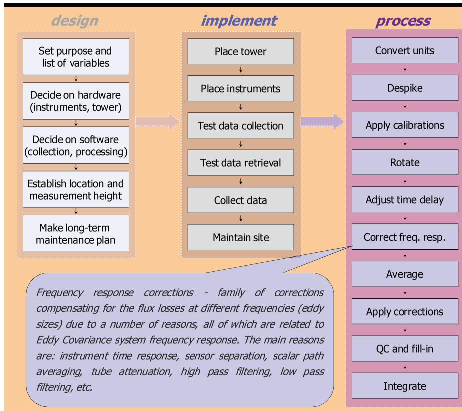
$F = (\overline{\rho_a}\,\overline{w}\,\overline{s} + \overline{\rho_a}\,\overline{w's'} + \overline{w}\,\overline{\rho'_a s'} + \overline{s}\,\overline{\rho'_a w'} + \overline{\rho'_a w's'}) = \overline{\rho_a}\,\overline{w}\,\overline{s} + \overline{\rho_a}\,\overline{w's'}$ Density fluctuations assumed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

MAJOR ASSUMPTIONS

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

ACCESS TO RESOURCES

The new book on the key aspects of EC for non-micrometeorologists is at www.licor.com/env/applications/eddy_covariance/book.jsp:

Free Electronic Resource - Adobe PDF Book

Traditional Resource – Printed Textbook

The information covered in the book may be especially useful to the following groups:

- Undergraduate students in EC course
- Non-meteorology graduate students
- Field technicians, research assistants
- Non-micrometeorology scientists and faculty interested in using EC in their research
- Facility managers from industrial areas (landfills, feed lots, *etc.*) interested in quantifying the emissions
- Regulating bodies (environmental protection agencies, state and local air quality boards, *etc.*) interested in EC as an official method

The authors intend to keep the content of this book dynamic and current. Please send your suggestions/updates to george.burba@licor.com with subject "EC book-2"

ADDITIONAL INFORMATION

Arya S., 2001. Introduction to Micrometeorology. Academic Press/Elsevier, Burlington, USA. 420 pp.

Burba, G., and D. Anderson, 2010. A Brief Practical Guide to Eddy Covariance Flux Measurements. LI-COR Biosciences, Lincoln, USA. 211 pp.

Foken T., 2008. Micrometeorology. Springer-Verlag, Berlin, Germany. 308 pp.

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

Monteith J., and M. Unsworth, 2008. Principles of Environmental Physics (Third Edition). Academic Press/Elsevier, London, UK. 434 pp.

Rosenberg N., B. Blad, and S.Verma, 1983. Microclimate: The Biological Environment. Wiley-Interscience Publishers, New York, USA. 495 pp.

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