



Eddy Covariance Method for CO₂ Emission Measurements: CCS Applications, Principles, Instrumentation and Software

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The Eddy Covariance method is a micrometeorological technique for direct high-speed measurements of the transport of gases, heat, and momentum between the earth's surface and the atmosphere. Gas fluxes, emission and exchange rates are carefully characterized from single-point in-situ measurements using permanent or mobile towers, or moving platforms such as automobiles, helicopters, airplanes, etc.

Since the early 1990s, this technique has been widely used by micrometeorologists across the globe for quantifying CO₂ emission rates from various natural, urban and agricultural ecosystems [1,2], including areas of agricultural carbon sequestration. Presently, over 600 eddy covariance stations are in operation in over 120 countries.

In the last 3-5 years, advancements in instrumentation and software have reached the point when they can be effectively used outside the area of micrometeorology, and can prove valuable for geological carbon capture and sequestration, landfill emission measurements, high-precision agriculture and other non-micrometeorological industrial and regulatory applications.

In the field of geological carbon capture and sequestration, the magnitude of CO₂ seepage fluxes depends on a variety of factors. Emerging projects utilize eddy covariance measurement to monitor large areas where CO₂ may escape from the subsurface, to detect and quantify CO₂ leakage, and to assure the efficiency of CO₂ geological storage [3,4,5,6,7,8].

Although Eddy Covariance is one of the most direct and defensible ways to measure and calculate turbulent fluxes, the method is mathematically complex, and requires careful setup, execution and data processing tailor-fit to a specific site and a project. With this in mind, step-by-step instructions were created to introduce a novice to the conventional Eddy Covariance technique [9], and to assist in further understanding the method through more advanced references such as graduate-level textbooks, flux networks guidelines, journals and technical papers. A free open-source software package with a user-friendly interface was developed accordingly for computing final fully corrected CO₂ emission numbers [10].

The presentation covers highlights of the eddy covariance method, its application to geological carbon sequestration, key requirements, instrumentation and software, and reviews educational resources particularly useful for carbon sequestration research.

References:

- [1] Aubinet, M., T. Vesala, and D. Papale (Eds.), 2012. Eddy Covariance: A Practical Guide to Measurement and Data Analysis. Springer-Verlag, 442 pp.
- [2] Foken T., 2008. Micrometeorology. Springer-Verlag, 308 pp.
- [4] Finley, R., 2009. An Assessment of Geological Carbon Sequestration in the Illinois Basin Overview of the Decatur-Illinois Basin Site. MGSC, http://www.istc.illinois.edu/info/govs_awards_docs/2009-GSA-1100-Finley.pdf
- [5] Liu, G. (Ed.), 2012. Greenhouse Gases: Capturing, Utilization and Reduction. Intech, 338 pp.
- [6] LI-COR Biosciences, 2011. Surface Monitoring for Geologic Carbon Sequestration Monitoring: Methods, Instrumentation, and Case Studies. LI-COR Biosciences, Pub. 980-11916, 15 pp.
- [7] Benson, S., 2006. Monitoring carbon dioxide sequestration in deep geological formations for inventory

verification and carbon credits, SPE-102833, Presentation

[8] Lewicki, J., G. Hilly, M. Fischer, L. Pan, C. Olden-burg, C. Dobeck, and L. Spangler, 2009. Eddy covariance observations of leakage during shallow subsurface CO₂ releases. *Journal of Geophys Res*, 114: D12302

[9] Burba, G., 2013. Eddy Covariance Method for Scientific, Industrial, Agricultural and Regulatory Applications. LI-COR Biosciences, 328 pp.

[10] LI-COR Biosciences, 2012. EddyPro 4.0: Help and User's Guide. Lincoln, NE, 208 pp.