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New challenges and opportunities in the eddy-covariance methodology for long-term monitoring networks

Dario Papale (1) and Gerardo Fratini (2)

(1) University of Tuscia, DIBAF, Viterbo, Italy (darpap@unitus.it), (2) LI-COR Biosciences GmbH, Bad Homburg, Germany (Gerardo.Fratini@licor.com)

Eddy-covariance is the most direct and most commonly applied methodology for measuring exchange fluxes of mass and energy between ecosystems and the atmosphere. In recent years, the number of environmental monitoring stations deploying eddy-covariance systems increased dramatically at the global level, exceeding 500 sites world-wide and covering most climatic and ecological regions. Several long-term environmental research infrastructures such as ICOS, NEON and AmeriFlux selected the eddy-covariance as a method to monitor GHG fluxes and are currently collaboratively working towards defining common measurements standards, data processing approaches, QA/QC procedures and uncertainty estimation strategies, to the aim of increasing defensibility of resulting fluxes and intra and inter-comparability of flux databases.

In the meanwhile, the eddy-covariance research community keeps identifying technical and methodological flaws that, in some cases, can introduce - and can have introduced to date - significant biases in measured fluxes or increase their uncertainty. Among those, we identify three issues of presumably greater concern, namely: (1) strong underestimation of water vapour fluxes in closed-path systems, and its dependency on relative humidity; (2) flux biases induced by erroneous measurement of absolute gas concentrations; (3) and systematic errors due to underestimation of vertical wind variance in non-orthogonal anemometers. If not properly addressed, these issues can reduce the quality and reliability of the method, especially as a standard methodology in long-term monitoring networks.

In this work, we review the status of the art regarding such problems, and propose new evidences based on field experiments as well as numerical simulations. Our analyses confirm the potential relevance of these issues but also hint at possible coping approaches, to minimize problems during setup design, data collection and post-field flux correction. Corrections are under implementation in eddy-covariance processing software and will be readily applicable by individual investigators as well as by centralized processing facilities of long-term research infrastructures.

This new understandings suggest that a reanalysis of eddy-covariance data collected in the last 20 years may be appropriate in order to obtain more accurate and consistent flux time series. The availability of dedicated powerful computing facilities at the research infrastructures today makes this goal achievable at an affordable cost.