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Low-cost eddy covariance measurements of evapotranspiration: a case study over agroforestry in Germany

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Eddy covariance (EC) has evolved as the method of choice for measurements of ecosystem-atmosphere exchange of water vapour, sensible heat and trace gases. Under ideal conditions EC provides direct and precise flux observations, commonly approximated from single point EC measurements. That is appropriate over uniform terrain of infinite extent, but many real-world land surfaces and ecosystems are heterogeneous. Such conditions potentially violate the methods assumptions and compromise the representativity of single point measurements as a predictor for ecosystem-wide fluxes. Therefore heterogeneous surfaces require multiple measurement units for spatially adequate sampling and representative fluxes. The complexity and cost of traditional EC instruments typically limits the feasible number of sampling points. Here we investigate a small sensor for EC measurements of evapotranspiration, which due to it's low-cost design and acceptable performance allows for spatial replicates.

Our objective is to improve the representativity of flux measurements through optimizing the trade-off between the high accuracy and precision but low spatial representativity of single-point conventional high-cost EC systems versus a lower accuracy and precision but potentially higher spatial representativity of multiple-point low-cost EC (EC-LC) systems.

We performed continuous EC-LC and meteorological measurements over agroforestry and conventional agriculture for reference, at five sites across the Northern Germany, i.e. a total of ten EC towers, over a duration of two years from 2016 to 2017. Our EC-LC instrumentation comprises a conventional ultrasonic anemometer and a compact low-cost pressure, temperature and relative humidity sensor. Humidity data digitally sampled at 8 Hz were merged with nearest-neighbour wind samples, originally sampled at 20 Hz. To assess the performance of the EC-LC we conducted side-by-side measurements using a roving enclosed-path EC setup, providing at least four weeks of parallel measurements at each site.

Latent heat (LE) fluxes measured with EC-LC compared well with fluxes from conventional EC. Diurnal cycle of evapotranspiration were well represented at a 30-min resolution. The differences between the two methods at 30-min resolution were small relative to the diurnal amplitude of the fluxes. R^2 values from linear regressions for LE comparing low-cost and conventional EC methods ranged from 0.83 to 0.95, indicating a close correlation of the two methods. The slopes of the linear regressions ranged from 0.8 to 1.1 for seven out of ten sites. We further observed that LE obtained from the two methods matched more closely at high relative humidity. For low relative humidity the low-cost method underestimated LE from conventional EC by up to 25 %. Future work will be needed to investigate the effects of radiative heating of the enclosure of the humidity sensor and its effects on LE estimates. An improved shield design will help to minimize such effects.

We conclude that low-cost EC sensors are an alternative to conventional EC sensors when resources are limited or sampling replicates are required. The new low-cost EC method is a viable alternative when the spatial variability of fluxes of the ecosystem of interest is larger than above reported method specific differences in fluxes.