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On the role of advection for the net exchange of carbon dioxide at a subalpine grassland in complex terrain

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At the vast majority of FLUXNET sites, the net ecosystem carbon dioxide (CO_2) exchange is evaluated by means of the eddy covariance technique using a set of instruments on a single tower. This approach is assumed valid over flat, horizontally homogeneous terrain and stationary conditions. However, in complex terrain and during nighttime with low turbulent mixing and stable stratification, this assumption is likely to be violated resulting in an underestimation of the net CO_2 exchange. The daily net exchange of CO_2 is composed of net uptake during daytime, when plant photosynthesis exceeds respiration, and net emission of CO_2 during nighttime due to ecosystem respiration. The unaccounted presence of advective CO_2 fluxes thus may potentially bias net daily and longer-term flux measurements towards too much net uptake.

We report on an advection experiment conducted during summer 2012 at a subalpine grassland site in Northern Italy (2160 m asl). The main flux tower at the site is on flat/slightly sloping terrain, however the surrounding area consists of a heterogeneous microtopography with slopes at various angles and expositions. Advection was quantified at several locations in the area along the main wind direction using measurements of horizontal and vertical CO_2 gradients and wind speed. Three flux towers were used to quantify the spatial variability in vertical eddy fluxes. An independent estimate of nighttime ecosystem respiration was obtained with a set of automated ecosystem chambers.

Our main findings are that (i) despite the complex terrain, advection (both horizontal and vertical) plays a negligible role for the net ecosystem CO_2 exchange during daytime conditions, (ii) during nighttime, advection represents an appreciable and not negligible fraction ($\sim$50%) of the total net ecosystem CO_2 exchange, and (iii) in this kind of complex terrain spatial variability in vertical eddy fluxes is large during nighttime with some spots catching only a small portion ($\sim$40%) of the total ecosystem CO_2 efflux. Finally, the relationships between advection and micrometeorological factors such as wind speed, friction velocity (u*) and the stability parameter (z/L) are presented. Moreover, post-hoc approaches applied to correct for the fraction of the net ecosystem CO_2 exchange carried by advection are discussed.