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High-resolution profile measurements

of wind speed and scalars within and above short canopies:

Applicability to flux measurement, source partitioning and process understanding

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Motivation

Vertical profiles of scalars in the surface layer were long used to determine the associated land-atmosphere fluxes. While we typically determine the latter with eddy-covariance (EC) measurements now, profiles extending from the surface layer down to the ground provide a range of extra information not yielded by EC - particularly in dense canopies when determining storage terms or informing forward models about the microclimate and gas concentrations next to leaves. Profiles have also been suggested as a means to determine the vertical source profile (e.g., *Warland & Thurtell* 2000). This implies they provide an independent, non-invasive partitioning between evaporation and transpiration for the latent heat flux or (aboveground) net primary production NPP and (soil) respiration (*R*). We present first tests on how such methods perform on scalar profiles with a high vertical resolution determined with an elevator-based technique (*Ney & Graf* 2018).

Methods

The portable setup measures CO_2, water vapor (H_2O), temperature and wind profiles from the soil surface to the surface layer above low (e.g., crop) canopies. The end of a tube connected to a differential closed-path gas analyzer is continuously moved up and down over the profile height (~ 2 m) while concentrations are logged at a frequency of 20 s^{-1}. Temperature and wind speed are measured at the same frequency by a ventilated finewire thermocouple and a hotwire, and all measurements are duplicated as a continuous fixed-height measurement at the top of the profile. Time delays by flow through the tubes and other sources are accounted for by a hysteresis-minimizing algorithm.

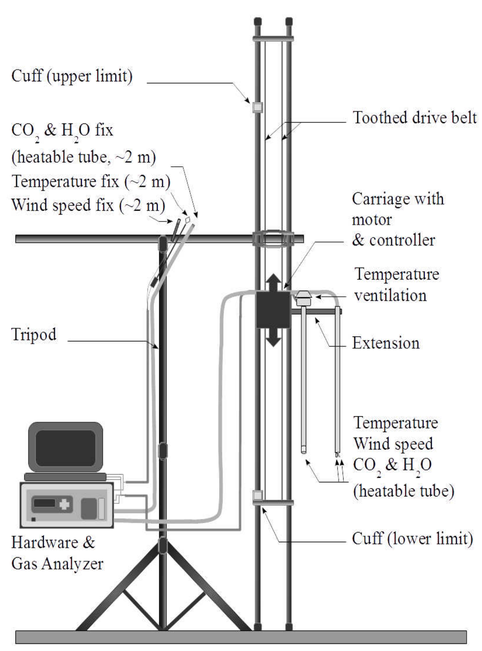


Fig. 1: Sketch of profile-measurement set-up , profile and EC system at the TERENO test site Selhausen (50° 52'09"N, 06 ° 27'01"E, 104.5 m MSL, ICOS code DE-RuS).

I Post-harvest measurements over bare soil and short intercrop canopy (<20 cm) are analyzed in the framework of Monin-Obukhov similarity theory (MOST), and the inferred fluxes compared to EC fluxes.

II Example profiles throughout higher crop canopies are qualitatively associated with sink and source processes near the soil surface, near the canopy top and between them.

III Inversions after *Warland & Thurtell 2000, Santos et al. 2011*, and *Cava et al. 2006* are applied to such profiles to estimate source profiles and flux partitioning. Here (other than in literature), we use a simple optimization method (Nelder-Mead) to fit four parameters: soil source, total canopy source, and shape parameters p and q of a beta distribution describing the vertical source distribution within the canopy.

Results I

Fitted MOST-profiles of *u*, *T*, H_2O and CO_2 (Fig. 2) and their inferred according fluxes match well with the measured profiles and EC-based fluxes (Fig. 3).

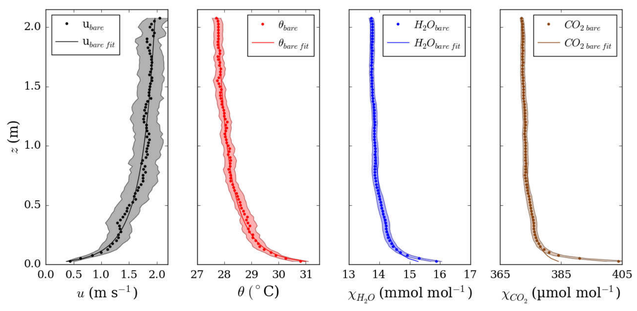


Fig. 2: Profiles measured over bare soil and model profiles after fitting u, z_0, scalar fluxes, scalar surface values at z_{0T} (assuming $z_{0T} = 0.1z_0$) and L.*

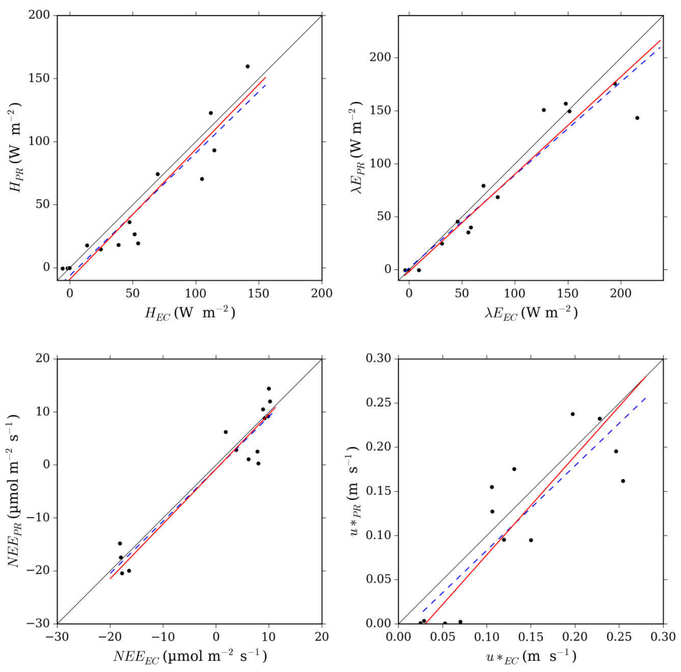


Fig. 3: profile-derived fluxes and u_* vs. observed fluxes and u_* (EC station).

Results II

With a higher plant canopy, profiles above the canopy are still approximately logarithmic and indicate the net flux. Within the canopy, sinks and sources become visible:

	near noon	low sun angle	night	dew night
CO_2*	canopy sink	canopy top sink	canopy source	
H_2O	canopy source, soil (here) always source			canopy sink**
heat	canopy source	canopy top source	soil source	

*soil always CO_2 source ** soil H_2O source in this night

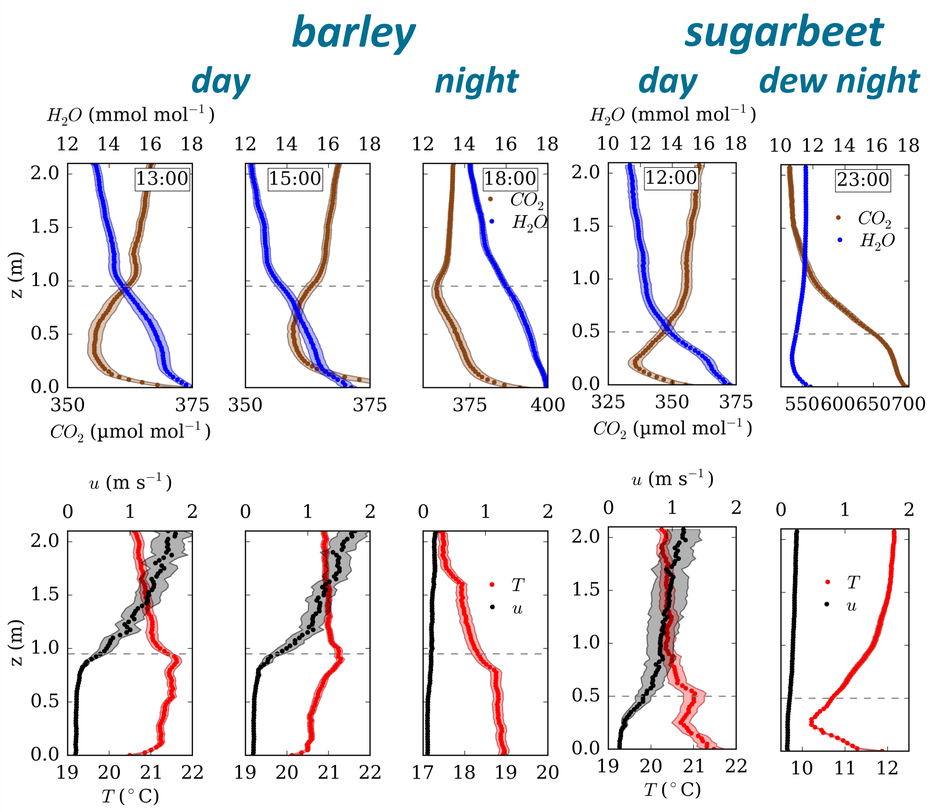


Fig. 4: Half-hourly mean profiles of CO_2, H_2O, wind speed u and temperature T; shaded areas refer to 95% confidence intervals (left: barley, 2016-06-09, right: sugarbeet, 2017-08-21).

Results III

A similar correlation between profile- and EC-derived net fluxes was found for *Warland and Thurtell* (2000)/ *Santos et al. (*2011) and *Cava et al.* (2006), but systematic deviations (regression slope < 0.8) of both underline their parameters are less accurately known than those in MOST. Diurnal cycles (Fig. 6) of profile-derived Evapotranspiration and soil evaporation on the dew night of Fig. 4 reasonably indicate dewfall (vapor flux from atmosphere to surface) as well as distillation (soil evaporation condensing in canopy).

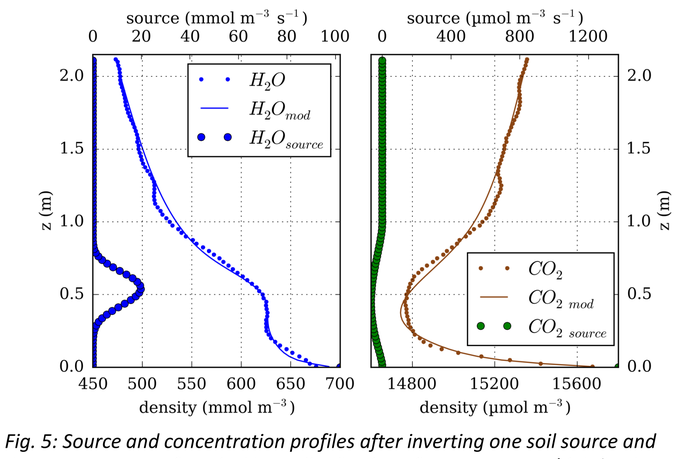


Fig. 5: Source and concentration profiles after inverting one soil source and three parameters of vertical beta distribution of canopy source/sink (barley 2016-06-10 10:15). The inverted soil source is indicated at the right bottom.

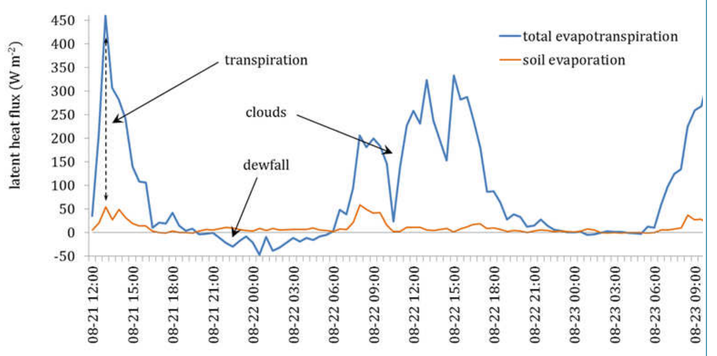


Fig. 6: Time series of the evapotranspiration components inferred from profiles

Acknowledgements

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