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Spatial averaging leads to less underestimation of eddy fluxes

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A lack of energy budget closure is found for many field experiments when using the temporal eddy-covariance method. This can probably be ascribed to an underestimation of turbulent energy fluxes. Computing turbulent fluctuations by subtracting a spatial instead of a temporal average may be one way to obtain more accurate flux estimates. Such eddy fluxes based on spatial averaging were derived for two different datasets collected from airborne measurements and a multi-tower experiment. The aircraft measurements were conducted over a boreal forest to determine fluxes of sensible heat, latent heat, carbon dioxide, and ozone. A wavelet analysis was applied to these data in order to quantify transport on scales larger than 2 km, which can hardly be detected by conventional tower measurements. Additional flux contributions of 10-30% of the turbulent flux were found for all scalar fluxes. In a different experiment, a multi-tower set-up was deployed. Over agricultural land, 25 temperature sensors were evenly distributed over a 3.5 km x 3.5 km area to determine the spatial average, and one sonic anemometer was placed at the center of this grid in order to measure the sensible heat flux. Eddy flux estimates from both temporal and the spatial averaging agreed quite well for some days. However, for 8 days during the 34 day observation period, additional flux contributions of more than 50 W m^{-2} were found, and for four more days, sensible heat flux estimates from the spatial method were more than 25 W m^{-2} larger. The additional fluxes usually reached a maximum in the afternoon

when convective conditions were developed. The results of the aircraft study show that mesoscale transport can be significant for measurement heights of around 30 m over ground in heterogeneous terrain. The results of the multi-tower study show that convective transport contributes significantly to the surface energy budget for measurement heights as low as 2-3 m. For future experiments aiming at closing the energy budget, the spatial eddy-covariance method may be preferred to the temporal method. Experimental determination of horizontal advection of sensible and latent heat should also be considered, since such transport must occur due to convergence and divergence related to large-scale organized structures.