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Effects of horizontal site heterogeneity on turbulent CO_2 flux measurements assessed with two independent empirical approaches

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Horizontal heterogeneity can be a major problem for turbulent flux measurements above forest that is difficult to quantify in the field. We use directional analyses with two different empirical approaches in order to quantify the systematic effects of source area heterogeneity on CO_2 flux measurements above a Danish beech forest. The forest fetch around the tower varies from 400 m to more than 700 m depending on direction. On average 20% of the forest cover are irregularly distributed conifer plantations. Our hypothesis is that if the fetch had a considerable effect on the flux measurement in 43 m, i.e. ca. 21 m above the displacement height, this will be seen as systematic variability across fluxes measured from different forest sectors.
A complication when testing this hypothesis is that the wind direction is correlated with the weather type and that the frequency distribution of the wind direction has two strong maxima, i.e. from SW and E. To consider this, we normalised the flux with its average value within comparable weather conditions. For this we build appropriate air temperature (Tair) x solar radiation (Rg) classes and calculated the flux averages for the elements of this 2 D matrix. The flux values from 8 different forest sectors were then normalised with the flux average within similar combinations of Tair and Rg. Weighting with the frequency compensated for the non-uniform distribution of observations within the weather variable space when calculating an average normalised flux value for each of the 8 forest sectors. These values are interpreted as a measure of systematic effects of site heterogeneity.
To further test the validity of this approach, we compared CO_2 flux measurements in 43m height with CO_2 flux measurements at 34 m height. As the footprint is narrower for the 34m height measurement, effects of horizontal fetch limitation and stand inhomogeneity can be expected to cause systematic spatial patterns of the ratios between the flux measurements from the two heights. The horizontal variability of the ratio is an independent measure of the effects of horizontal heterogeneity on the fluxes estimation.
The results of both approaches will be presented and compared. Systematic differences due to site heterogeneity were in the order of 4% relative standard variation during daytime but increased to values of 11% when only night time data were considered. Further comparison with the spatial distribution of the forest fetch and the tree species composition will be used to explain the observed effects. The presented simple empirical approach enables estimation of horizontal homogeneity from a single tower measurement.