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Effects of biased CO_2 flux measurements by open-path sensors on the interpretation of CO_2 flux dynamics at contrasting ecosystems

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Long-term measurements of net ecosystem exchange of CO_2 (NEE) are conducted across a global network of flux tower sites. These sites are characterised by varying climatic and vegetation conditions, but also differ in the type of CO_2/H_2O gas analyser used to obtain NEE.

Several studies have observed a systematic bias in measured NEE when comparing open-path (OP) and closed-path (CP) sensors with consistently more negative daytime NEE measurements when using OP sensors, both during the growing and non-growing season. A surface heating correction has been proposed in the literature, but seems not to be universally applicable. Systematic biases in NEE measurements are particularly problematic for synthesis papers and inter-comparison studies between sites where the “true” NEE is small compared to the potential instrument bias. For example, NEE estimates for boreal forest sites derived from OP sensors show large, ecologically unreasonable winter CO_2 uptake.

To better understand the causes and the magnitude of this potential bias, we conducted a sensor inter-comparison study at the Mer Bleue peatland near Ottawa, ON, Canada. An eddy covariance system with a CP (LI7000 & GILL R3-50) and an OP sensor (EC150 & CSAT3A) was used. Measurements were made between September 2012 and January 2013 and covered late summer, fall, and winter conditions. Flux calculations were made as consistently as possible to minimise differences due to differing processing procedures (e.g. spectral corrections).

The latent (LE, slope of orthogonal linear regression of LE_{OP} on LE_{CP}: 1.02 ± 0.01 & intercept: -0.2 ± 0.6 W m^{-2} and sensible heat fluxes (H, slope of H_{CSAT3A} on H_{GILL}: 0.96 ± 0.01 & intercept: 0.1 ± 0.03 W m^{-2}) did not show any significant bias. However, a significant bias was apparent in the NEE measurements (slope of NEE_{OP} on NEE_{CP}: 1.36 ± 0.02 & intercept: -0.1 ± 0.05). The differences between NEE_{OP} and NEE_{CP} were linearly related to the magnitude of H_{CSAT3A} with a slope of -0.02 ± 0.001 μmol CO_2 m^{-2} s^{-1} and an intercept of -0.1 ± 0.03 μmol CO_2 m^{-2} s^{-1} (R^2 = 0.82, p = 0.001) indicating a consistent overestimation of CO_2 uptake during the day and an overestimation of ecosystem respiration during the night. Air temperatures did not have a significant effect on NEE differences. Winter NEE measurements at two boreal forest, one boreal wetland, and one tundra site show similar relationships with H further supporting the findings of this study.

In contrast to OP sensors, CP sensors are less affected by high frequency air temperature fluctuations and do not require a correction for air density fluctuations to obtain NEE. Our results point toward a consistent bias in NEE_{OP} that is likely related to the magnitude of H, the main input to the WPL term. The additional findings from five contrasting ecosystems suggest that the bias in NEE_{OP} depends on the site-specific H regime, questioning the accuracy of comparison studies across contrasting ecosystems. Since the absolute magnitude of the bias seems to be directly related to the magnitude of H rather than to the magnitude of NEE, the relative error is likely larger for sites with small NEE. These findings are therefore particularly important for NEE studies at high latitude sites.