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The effect of a permafrost disturbance on growing-season carbon-dioxide fluxes in a high Arctic tundra ecosystem

Alison E. Cassidy et al.

Correspondence to: A. E. Cassidy (alison.cassidy@geog.ubc.ca)

On the use of a tilted LI-7500 in moderately cold environments

Under very cold conditions instrument surface heat may critically affect the ability to measure CO_2 fluxes with the Li-7500 open-path sensor, in particular with an upright mounted sensor (Burba *et al.*, 2008). The EddyPro® manual summarizes "When CO_2 and H_2O molar densities are measured with the LI-7500 in cold environments (low temperatures below -10°C), a correction should be applied to account for the additional instrument-related sensible heat flux, due to instrument surface heating/cooling."[1]

This correction was not applied because of the following three reasons:

- Our measurements were made during July, with 24 hour sunlight. Our average air temperature was +10ºC. Temperatures never dropped below 2°C, and reached as high as 16°C. Hence, ambient temperatures did not fall within the critical range of < -10ºC, where fluxes are affected, mentioned in Burba et al. (2010).
- In addition, our sensors (Li-7500) were mounted at an angle of 30º to minimize issues associated with heating and reduce pooling of moisture on the windows. The correction cannot be employed with a tilted sensor. Burba et al. (2008) note that the correction "… assumes that the instrument is mounted in a near-vertical orientation". Analysis of a to-date unpublished dataset has shown that a tilted sensor does not cause measurement differences between open-path and closed-path systems. A comparison between fluxes measured with a tilted Li-7500 sensor and a closed path system as function of temperature is attached below.
- In our current approach (i.e. without correction) closed chamber measurements and the EC approach match well (RMSE = 0.6 µmol m^{-2} s^{-1}). If one would correct fluxes using the equations in Burba et al. (2008) and assume the sensor was mounted upright, the correlation between chamber measurements and EC measurements would become significantly worse (RMSE = 1.4 µmol m^{-2} s^{-1}). This is regarded as a strong indication that the correction would incorrectly distort measured fluxes (because assuming a vertically mounted sensor and low temperatures).

Additional supporting dataset

Demonstration that a tilted sensor mounting of the Li-7500 sensor causes no sensor disagreement to a closed-path system between 2ºC and 16ºC.

To investigate whether there are any systematical differences between measuring CO_2 fluxes with a tilted open-path (OP, Li-7500) vs. a closed-path (CP) analyzer in the range of the currently observed temperatures, a dataset sampled by the Biometeorology group at the University of British Columbia, UBC was used (Prof. A. Black, pers. comm.). This dataset was recorded over a forest clear-cut in Saskatchewan, Canada (Fluxnet site HJP02, Zha et al. 2009, Figure 1) at a comparable height to our systems. Data from June – December 2004 were used, when both a Li-7500 open path analyzer tilted by about 30º (same tilt we used in our measurements) and a closed path analyzer (Li-7000, Fluxnet

[1] https://www.licor.com/env/help/eddypro6/Content/Calculating_Off-season_Uptake_Correction.html

Canada standard) were operated simultaneously. Air temperatures during this time covered the range from -15 to +20ºC.

Figure 1: Tilted open-path and inlet for closed-path system at the HJP02 Fluxnet Canada site (Photo by Zoran Nesic, UBC)

The half-hourly differences between F_{CO2} measured by the tilted OP and F_{CO2} measured by the CP were binned by air temperature (2 K bins). Figure 2 shows that for the range between 0 and 20ºC, the systems are not systematically different, while below 0ºC the OP instrument starts to systematically underestimate fluxes, which indeed becomes a major issue < -10ºC - presumably due to the sensor heating effect. Temperatures during measurements for the current study (bdg-12-19781-2015) in the High Arctic were always between 2ºC and 16ºC, with an average of 10ºC, so we do not expect that our fluxes were compromised with a tilted sensor mounting of the Li-7500.

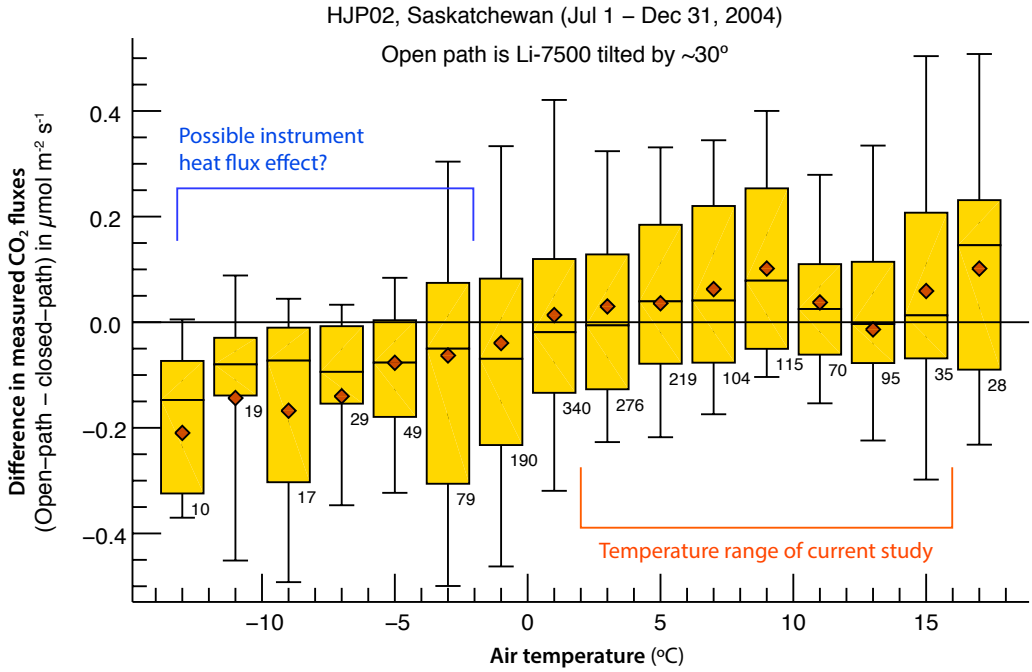

Figure 2: Difference between CO_2 fluxes determined by open path and closed-path system from July 1, to December 31, 2004 at the Canada Fluxnet Site HJP02. Diamonds are mean values in each bin, the boxes cover the 25% and 75% percentiles, with the horizontal bar being the median. The whiskers show the 5 and 95% percentiles. Numbers are the number of half hourly values in each bin (when both systems provided high quality data).