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Unraveling an apparent winter CO_2 uptake at a larch forest by coupling different eddy covariance systems

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Measuring ecosystem CO_2 fluxes is of foremost importance to quantify and model the global carbon cycle, and a core objective of flux networks, such as FLUXNET and ICOS, is to improve the measurement standards. However, over the years, cold sites have presented challenges to the flux community in understanding/quantifying land-surface interactions: from site maintenance to measurement issues such as energy balance closure in the presence of snow cover, very low winter CO_2 fluxes and apparent winter CO_2 uptake. In theory, during the off-season, photosynthetic activity is suppressed, and only respiratory fluxes should be measured by the eddy covariance system at the top of the canopy. Nevertheless, apparent CO_2 winter uptake was observed at a number of the cold sites where open-path eddy covariance systems were used. This apparent CO_2 uptake is small in absolute magnitude but significant in comparison with the very low winter CO_2 efflux, and if not corrected, it could account for a large percentage of the annual carbon budget at such sites, depending on the length of the off-season period.

Coupling open-path (LI-7500) and closed-path (LI-7200) gas analyzers in a two-years-long experiment, we illustrate several possible reasons for apparent winter CO_2 uptake at a cold European larch forest in the Alps. At this site, apparent CO_2 winter uptake is consistently measured during daytime with the open-path system, despite the application of the self-heating correction. In contrast, fluxes measured with closed-path system exhibit low positive ($\sim$ 0.4 μmolm^{-2}s^{-1}) values. Being a deciduous forest with understory vegetation covered by a snowpack, this ecosystem is physiologically expected to exhibit low CO_2 emission fluxes, and the observed winter uptake is highly unlikely. Evidence from this study reveals that in addition to self-heating, other causes can lead to apparent CO_2 uptake, among which, underestimation ($\sim$30%) of the relatively large WPL terms in association with relatively small CO_2 respiratory fluxes. By analyzing the broader scope of factors which could lead to an apparent winter uptake, we test modelling and machine learning based approaches on the closed-path data to better correct the past open-path measurements in cold environments with small emission fluxes. Differences in the results of the tested approaches are discussed.