23 May 2017

Improved Flux Measurements from Campbell Scientific Open-Path Gas Analyzers: Utilizing Sonic Temperature to Account for Spectroscopic Effects on CO_2 Density

Campbell Scientific manufactures two open-path eddy covariance instruments for measuring CO_2 flux; the EC150/CSAT3A and the IRGASON. Recent data from these instruments at several northern latitude flux sites, have shown an apparent CO_2 uptake which is not reasonably explained by plant or soil physiological activity. Historically, un-reasonable CO_2 uptake measured by open-path gas analyzers in similar ecosystems during periods of frozen conditions, has been attributed to sensor body heating (Amiro, 2010, Järvi et al., 2009). Although we considered sensor self-heating to explain this apparent CO_2 uptake (Burba et al., 2008), the relatively low power consumption and aerodynamic small-diameter symmetric design of our open-path gas analyzers motivated us to look for a different cause. This letter summarizes our findings related to a spectroscopic explanation and details a method to improve the CO_2 flux accuracy on archived and newly measured data.

The EC150 and IRGASON compensate for air temperature and pressure effects on the absorption line shape and strength by scaling absorption by the gas temperature and pressure within the sensing path. In collaboration with Campbell Scientific, Inc., Helbig et al. (2016) and Wang et al. (2016) demonstrated that this apparent CO_2 uptake was due to an inadequate correction for spectroscopic effects associated with high-frequency temperature fluctuations and is proportional to the magnitude of the sensible heat flux (bias as much as 0.013 $\mu mol\ m^{-2}\ s^{-1}/W\ m^{-2}$ to 0.014 $\mu mol\ m^{-2}\ s^{-1}/W\ m^{-2}$). We concluded that in northern latitude ecosystems dominated by sensible heat, the measurement of CO_2 flux could be improved by using a sonically derived fast-response air temperature to correct for temperature-induced spectroscopic effects.

With the release of EC100 OS version 7.01, Campbell Scientific now includes an additional CO_2 density output from the EC100 electronics (output 13 from the EC100 instruction using output mode 2). The newly available CO_2 density measurement uses water vapor density-corrected sonic temperature rather than the ambient temperature measured by the EC100 temperature probe to convert from absorption measurements to CO_2 density. This approach is made possible by our collocated and rigid design allowing for synchronized highly accurate fast response temperature measurements in the same volume as the gas measurements. By using this new CO_2

density output for CO_2 flux computations, the spectroscopic effects during high sensible heat flux regimes are accounted for.

For CO_2 flux data collected prior to the release of EC100 OS version 7.0.1, data can be reprocessed to examine spectroscopic effects for a specific gas analyzer head. This can be accomplished by: a) uploading the new OS, b) modifying the program to collect in the time series table CO_2 density from both the standard thermistor and vapor density corrected sonic temperature, c) collecting enough data to span a range of sensible heat fluxes up to at least 100 W m^{-2}, d) calculating fluxes from both CO_2 densities and e) deriving a linear regression of the difference between CO_2 fluxes using the two CO_2 densities (based on fast and slow-response air temperature) against the sensible heat flux. The slope of the regression is a correction multiplier that should be multiplied to past sensible heat fluxes and then added to the CO_2 flux (Bogoev et al. 2015 and Wang et al. 2016).

Campbell Scientific does not make a recommendation about whether to re-process past data. This decision likely depends on the site, significance of sensible heat flux, and other factors. Rather, we want our customers to be aware of these improvements going forward.

We have implemented an updated EC100 OS (7.01 available from our web site) that accounts for the spectroscopic effect on the gas analyzer by deriving a CO_2 density based on the vapor density corrected fast-response sonic temperature. We encourage our open-path customers to implement this new OS and modify their programs to take advantage of the new CO_2 density output. Additionally, we will soon be releasing our new EasyFlux-DL program for the CR6. This program will have the option to output the CO_2 flux with either density while saving both density outputs in in the raw data table.

We continue to investigate and seek to better understand the interactions of our instruments with the various environments in which they are used, and if you have any questions, please feel free to contact a member of the micrometeorology group at Campbell Scientific, Inc (435.227.9100).

Sincerely,
Ben Conrad
Micrometeorology Market Manager
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