On the importance of high-frequency air-temperature fluctuations for spectroscopic corrections of open-path carbon dioxide flux measurements

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Overview
The IRGASON flux system consists of an open-path infrared H2O and CO2 gas analyzer and a collocated 3D sonic anemometer. The IRGASON measures CO2 mixing ratio in situ by using the fast-response humidity corrected sonic temperature measurement to account for the temperature related density fluctuations. CO2 flux can be computed directly using instantaneous CO2 mixing ratio, eliminating the need for density (WPL) corrections in post processing.

Findings
1. During periods of high sensitive heat flux, the IRGASON measures more negative CO2 flux. Under negative heat flux regimes, the IRGASON measures more positive CO2 flux (Figure 1).
2. Hourly mean CO2 concentrations measured with the EC155 and the IRGASON agree to within 3% (Figure 2).
3. During daytime under high sensible heat flux conditions, CO2 spectra measured by the two analyzers agree well in the 0 to 0.006 Hz range, but the IRGASON measures increased CO2 variations above 0.01 Hz (Figure 3).
4. Nighttime CO2 spectra agree well in the frequency range 0 to 0.1 Hz. The EC155 measured increased CO2 variations above 0.1 Hz (Figure 4).
5. Compared to the EC155, under high sensible heat flux conditions, the co-spectral response of the IRGASON is increased (Figure 5).
6. During nighttime the agreement of the co-spectral responses extends to higher frequencies up to 0.1 Hz (Figure 6).

Hypothesis: Inadequate correction of fast temperature related spectroscopic effects
The strength and the half-width of the CO2 absorption lines are affected by temperature. Single-path, dual-wavelength, non-dispersive infrared gas analyzers use air temperature measurements to correct for these spectroscopic effects. The probes used for the comparison have limited frequency response due to their thermal mass and are inadequate to compensate CO2 absorption measurements for fast temperature variations.

Motivation
A growing number of studies report systematic differences in CO2 flux estimates obtained with the two main types of gas analyzers, open and closed path. Compared to eddy-covariance systems based on closed-path (OP) gas analyzers, systems with open-path (OP) gas analyzers consistently overestimate CO2 uptake during daytime periods with high positive sensible heat fluxes.

Field experiment
We conducted a field inter-comparison with IRGASON (open-path) and EC155 (closed-path) systems operating side-by-side and using a common sonic anemometer.

Instrumentation
1. IRGASON – Integrated CO2 & H2O open-path flux system with collocated sonic and gas sensing volumes
2. EC155 – CO2 & H2O closed-path analyzer
3. CSA34 – Stand-alone sonic anemometer/thermometer
4. Temperature probe in a five plates radiation shield
5. Quad-Disk Pressure Probe (Nishiyama et al., 1989)

Site Details
Location: +41° 46’ 3.89” N, –111° 51’ 21.19” E
Measurement height: 1.65 m – IRGASON, 2.00 m – CSA34
Sampling rate: 20 Hz

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Conclusions
Using fast air temperature measurements to correct for the absorption line broadening effects of open-path CO2 flux measurements, reduces the differences with fluxes measured by a closed path analyzer.

Literature