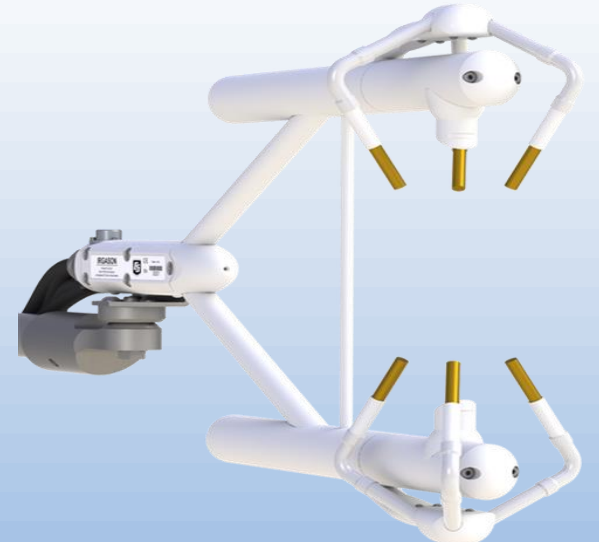

On the importance of high-frequency air-temperature fluctuations for spectroscopic corrections of open-path carbon dioxide flux measurements

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Overview

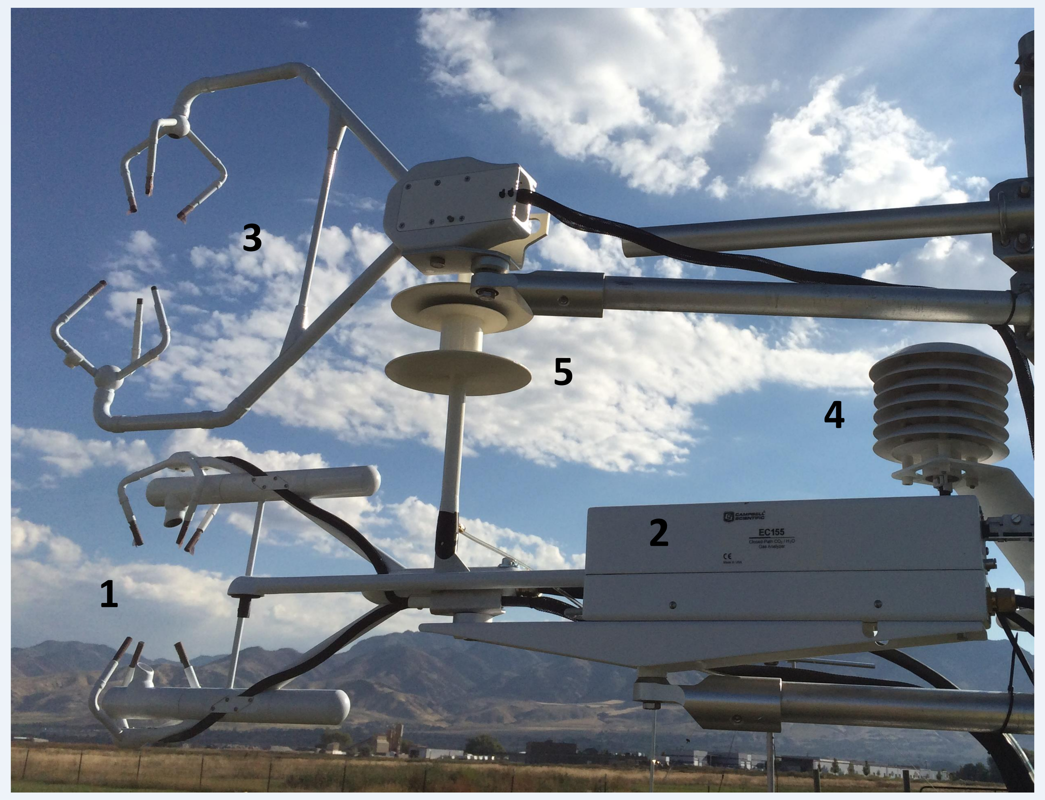
The IRGASON flux system consists of an open-path infrared H_2O and CO_2 gas analyzer and a colocated 3D sonic anemometer. The IRGASON measures CO_2 mixing ratio in situ by using the fast-response humidity corrected sonic temperature measurement to account for the temperature related density fluctuations. CO_2 flux can be computed directly using instantaneous CO_2 mixing ratio, eliminating the need for density (WPL) corrections in post processing.

Motivation

A growing number of studies report systematic differences in CO_2 flux estimates obtained with the two main types of gas analyzers, open and closed path. Compared to eddy-covariance systems based on closed-path (CP) gas analyzers, systems with open-path (OP) gas analyzers consistently overestimate CO_2 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 CO_2 & H_2O open-path flux system with colocated sonic and gas sensing volumes
2. EC155 – CO_2 & H_2O closed-path analyzer
3. CSAT3A – 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 – CSAT3
Sampling rate: 20 Hz

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Findings

1. During periods of high sensible heat flux, the IRGASON measures more negative CO_2 flux. Under negative heat flux regimes, the IRGASON measures more positive CO_2 flux (Figure 1).
2. Hourly mean CO_2 concentrations measured with the EC155 and the IRGASON agree to within 3% (Figure 2).
3. During daytime under high sensible heat flux conditions, CO_2 spectra measured by the two analyzers agree well in the 0 to 0.005 Hz range, but the IRGASON measures increased CO_2 variations above 0.01 Hz (Figure 3).
4. Nighttime CO_2 spectra agree well in the frequency range 0 to 0.1 Hz. The EC155 measured increased CO_2 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).

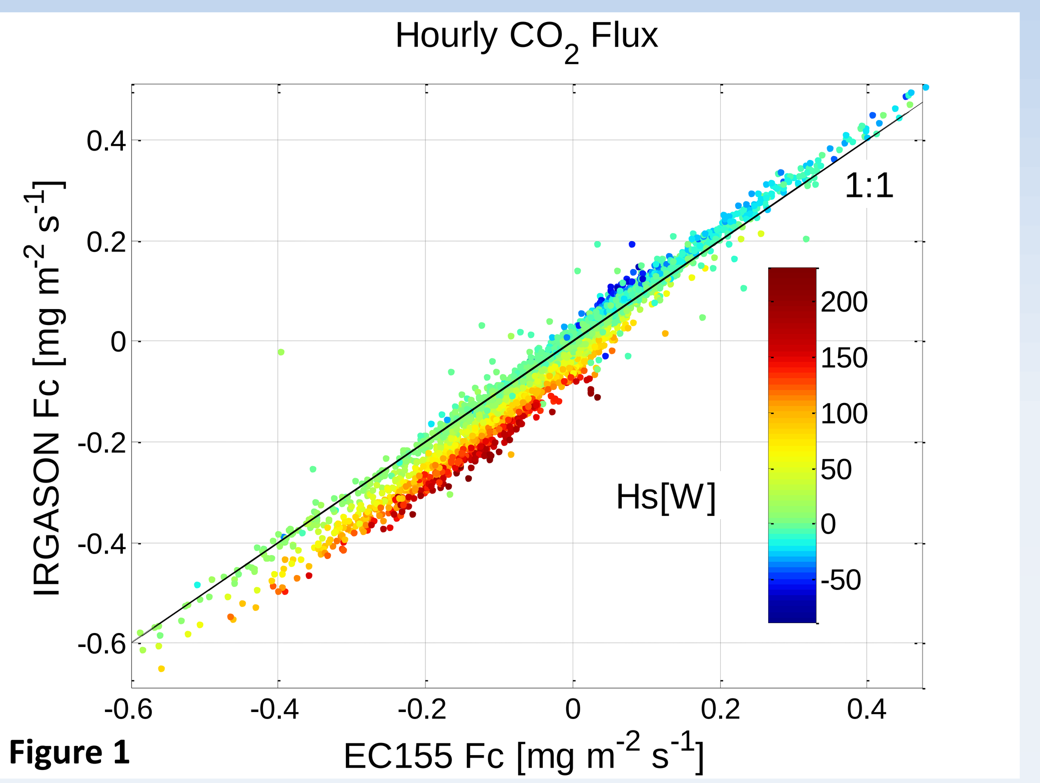


Figure 1

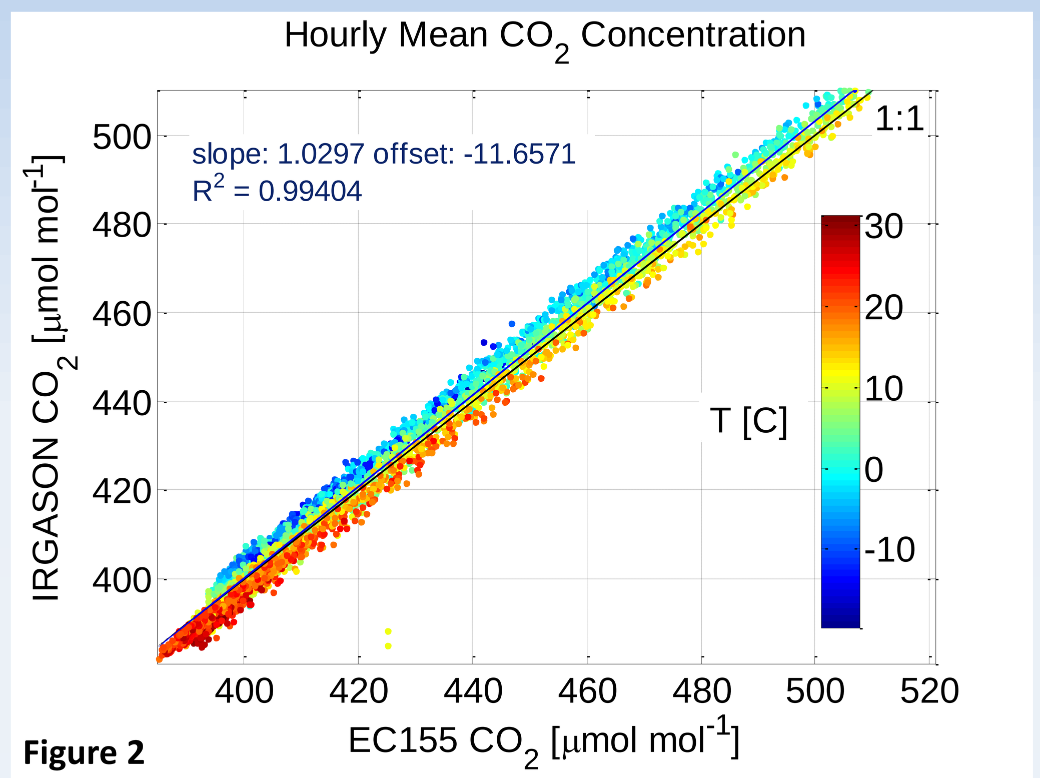


Figure 2

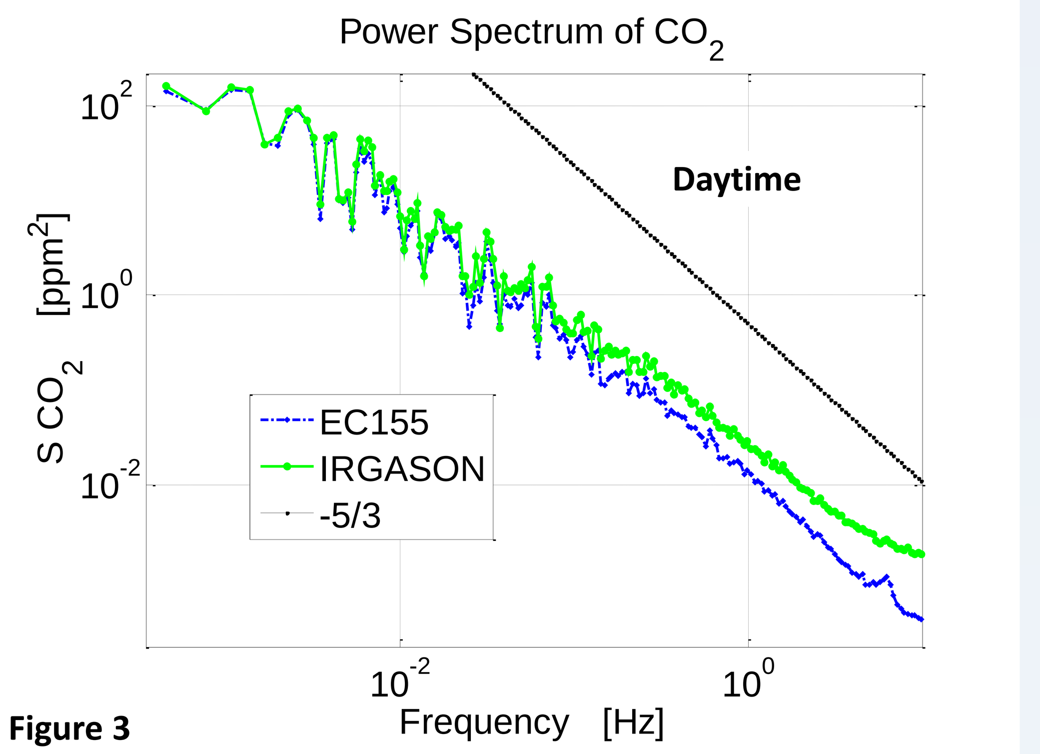


Figure 3

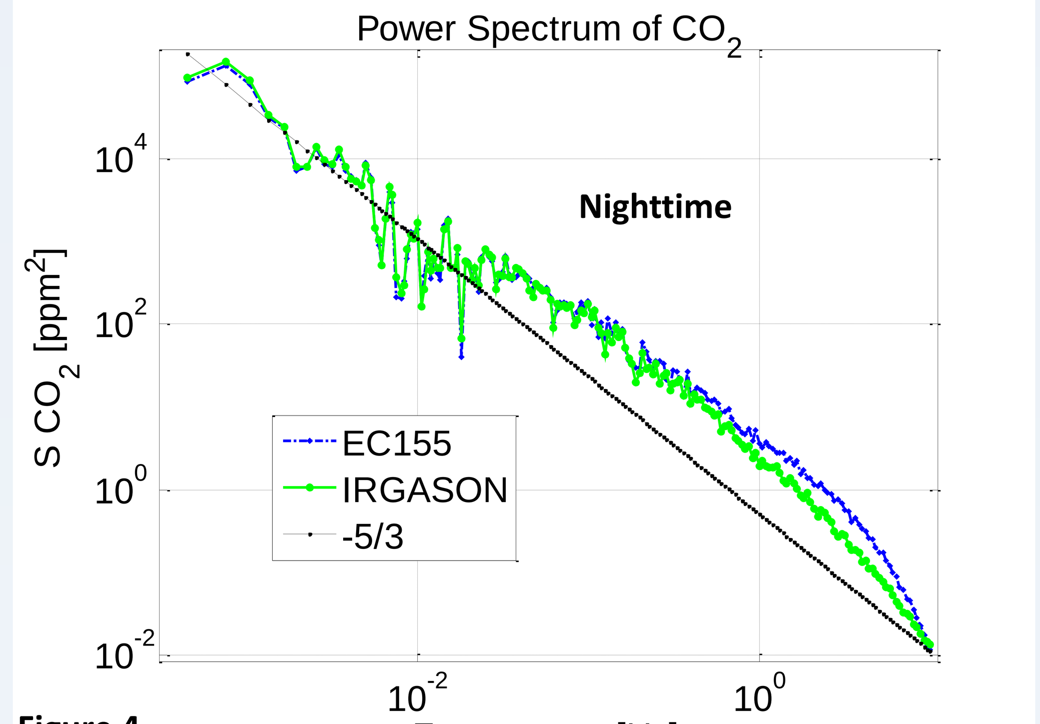


Figure 4

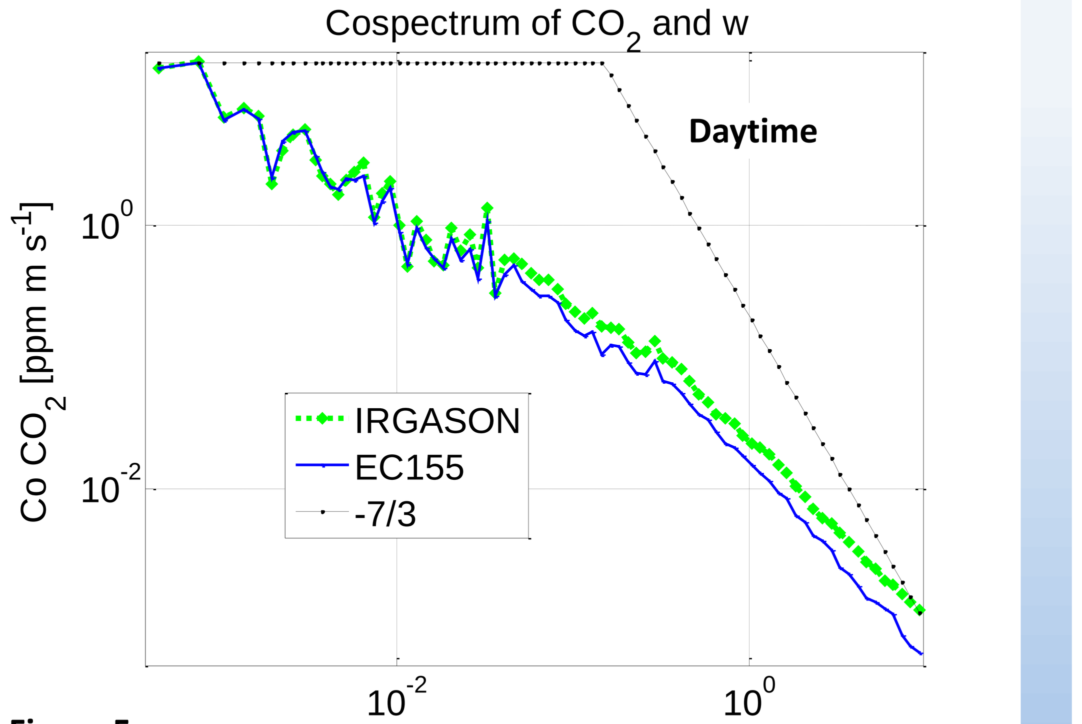


Figure 5

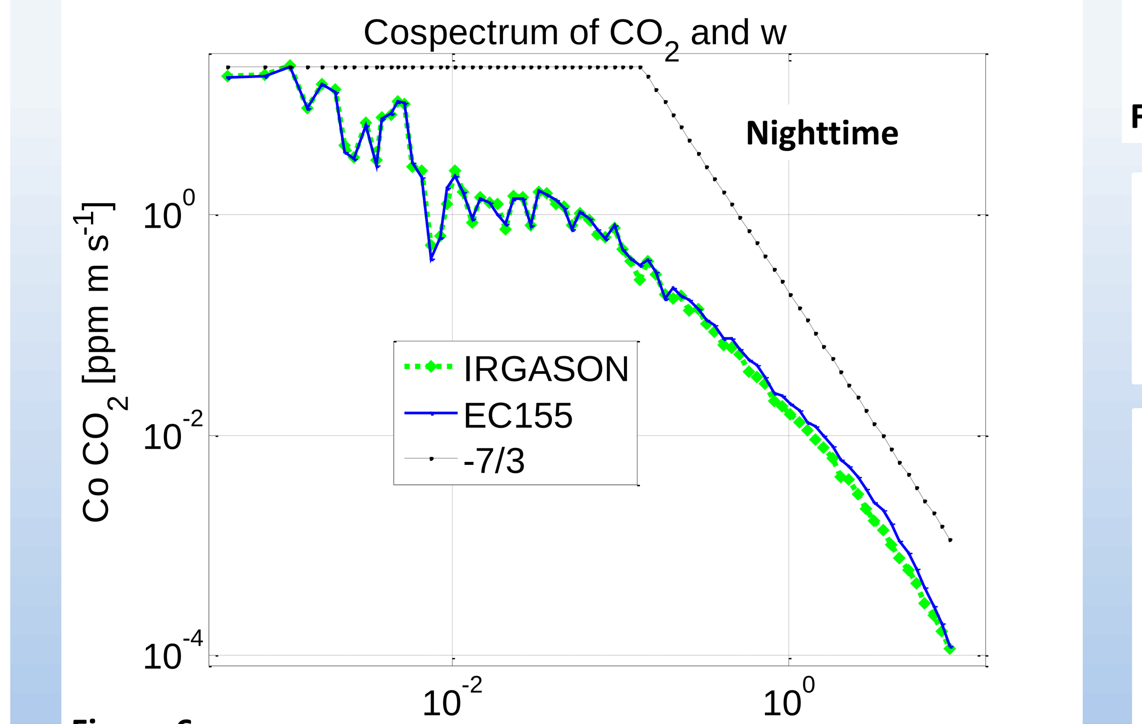


Figure 6

Hypothesis: Inadequate correction of fast temperature related spectroscopic effects

The strength and the half-width of the CO_2 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 compensation have limited frequency response due to their thermal mass and are inadequate to compensate CO_2 absorption measurements for fast temperature variations.

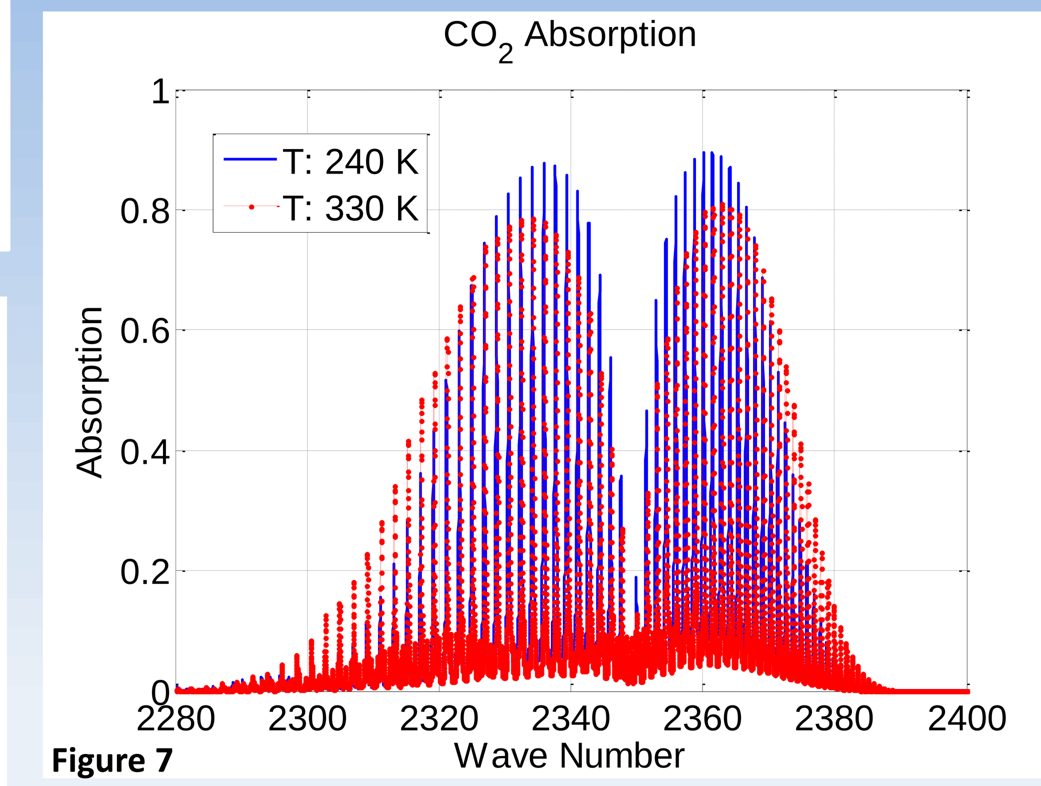


Figure 7

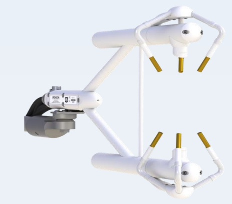
$$A = \frac{N}{(\Delta v)} \int_{v_1}^{v_2} \left\{ 1 - \exp\left(- \frac{S_i \alpha_i c L}{\pi \left[(v - v_0)^2 + \alpha_i^2 \right]} \right) \right\} dv$$

A = Absorbed light energy in the spectral interval
N = Number of absorption lines in the spectral interval
v = Wave number of the individual spectral line
c = Density of the absorbing gas
L = Path length
S_i = Strength of the individual line
α_i = Half-width of the individual line

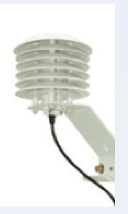
$\boldsymbol{S_i = f(T,P)}$ $\boldsymbol{\alpha_i = f(T,P)}$

T = Air temperature, P = barometric pressure

$$\alpha(P,T) = \alpha_0 \frac{P}{P_0} \left(\frac{T_0}{T} \right)^{1/2}$$



Fast-response air temperature measurement



Slow-response air temperature measurement

Results of using fast-response air temperature in the conversion of absorption into CO_2 density

The difference between OP and CP flux measurements is reduced and less dependent on sensible heat flux.

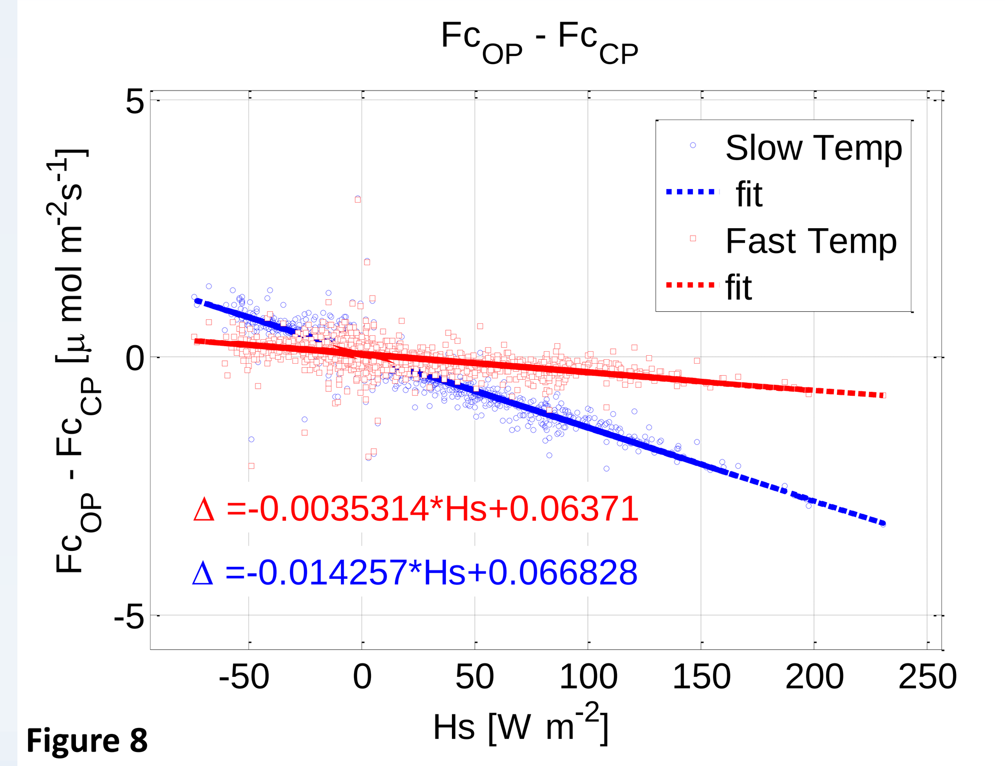


Figure 8

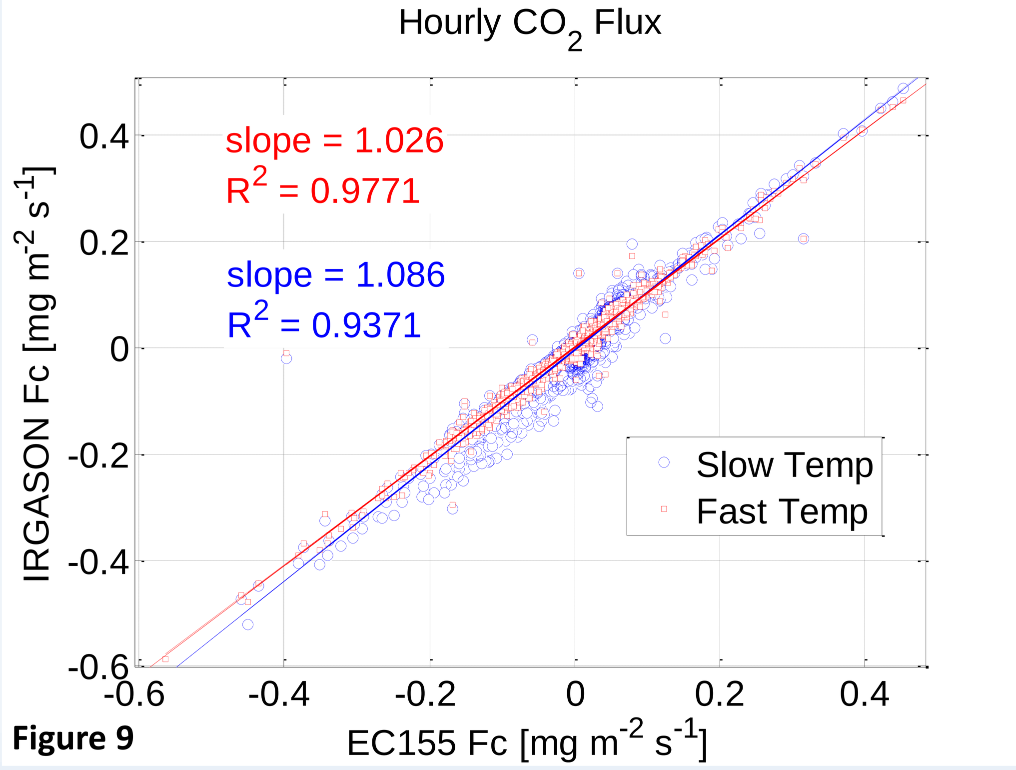


Figure 9

Conclusions

Using fast air-temperature measurements to correct for the absorption line broadening effects of open-path CO_2 flux, reduces the differences with fluxes measured by a closed-path analyzer.

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