Frequency Response of a Low-Power Closed-Path CO_2 and H_2O Eddy Covariance System

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Abstract

Accurate measurement of CO_2 and H_2O eddy covariance fluxes requires an analyzer with good frequency response. Closed-path analyzers offer improved rain performance and the option of automatic zero and span, but their frequency response is generally worse than open-path analyzers due to the residence time in the sample cell and mixing along intake tubes and in the sample cell. H_2O frequency response can suffer additional losses due to interactions with the surface of the intake tube and sample cell. The traditional approach to maintain good frequency response in a closed-path system is to use a high sample flow rate and/or reduced pressure in the sample cell. This approach requires a relatively high power pump that makes it difficult to operate without access to AC mains power.

A new, small, closed-path CO_2 and H_2O Eddy Covariance System (CPEC200, Campbell Scientific, Inc.) achieves good frequency response (5.8 Hz half-power bandwidth) at low power (12 W total). The analyzer resides close to the sonic path to keep the intake tube short (0.6 m) and reduce mixing in the intake tube. The sample cell volume is small (5.8 ml) to minimize residence time (50 ms at 7 LPM sample flow). The entire system is designed for low pressure drop to reduce pump power.

The frequency response of the CPEC200 was measured by injecting an impulse of CO_2/H_2O at the system inlet. This measured impulse response was then Fourier transformed and normalized to give the frequency response. This frequency response was compared to a simple model that included a term representing ideal plug flow through the sample cell and an exponential mixing term.

Instrumentation Setup

Gas Analyzer: EC155 CO_2/H_2O Infrared Gas Analyzer
Intake Tube: Stainless steel, 0.105” ID x 23” (similar to standard heated intake tube)
Pump: CPEC200 Pump Module (pump speed controlled at 7 LPM)
Datalogging: CR3000 Micrologger
Measurement Rate: 50Hz from EC155 to CR3000 via SDM
Gas Injection: 1.5% CO_2, with fast injection valve
Sample Cell Pressure: 84.1 kPa (3.3 kPa below ambient pressure)

Figure 1. EC155 CO_2/H_2O Infrared Gas Analyzer.

Results

Time series of injected CO_2 and H_2O pulses are in remarkable agreement with each other indicating that the H_2O suffered little frequency response loss. This can be attributed to small sample cell volume (5.8 ml) and short intake tube (0.6 m) implemented in CPEC200 closed-path eddy covariance system with EC155 closed-path IRGA.

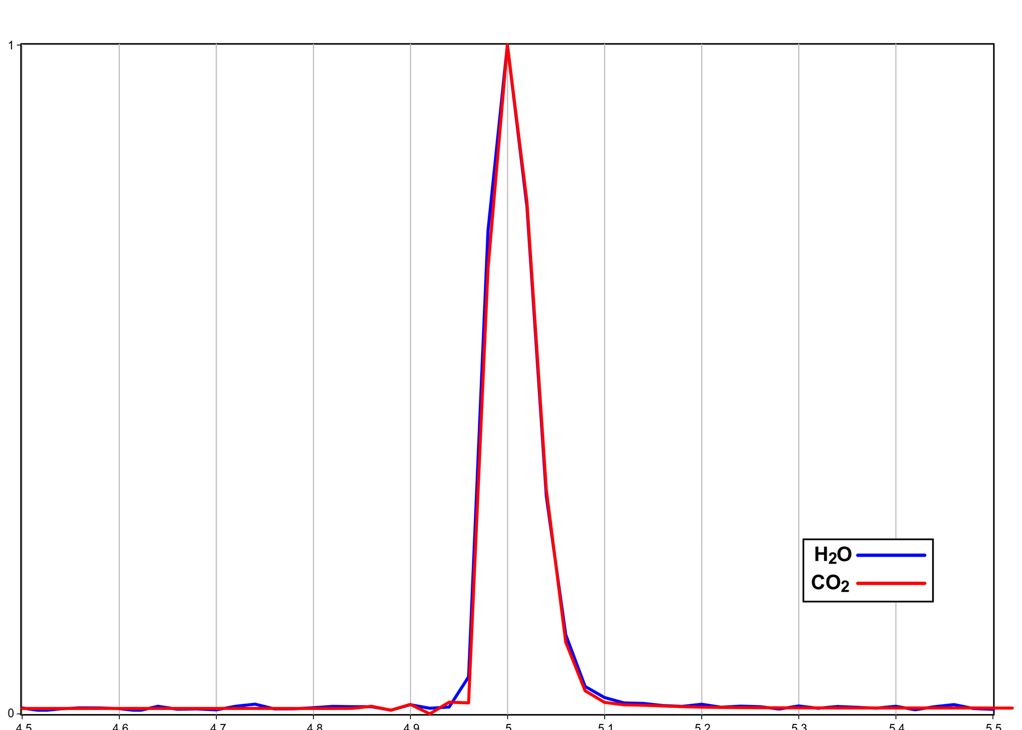

Figure 2. Normalized time series pulses. H_2O pulse has been inverted before overlaying with CO_2 pulse.

The graph shows good frequency response by both CO_2 and H_2O (5.8 Hz half-power bandwidth) which is excellent for low power used for the whole system (12 W total and 4 W for pump)

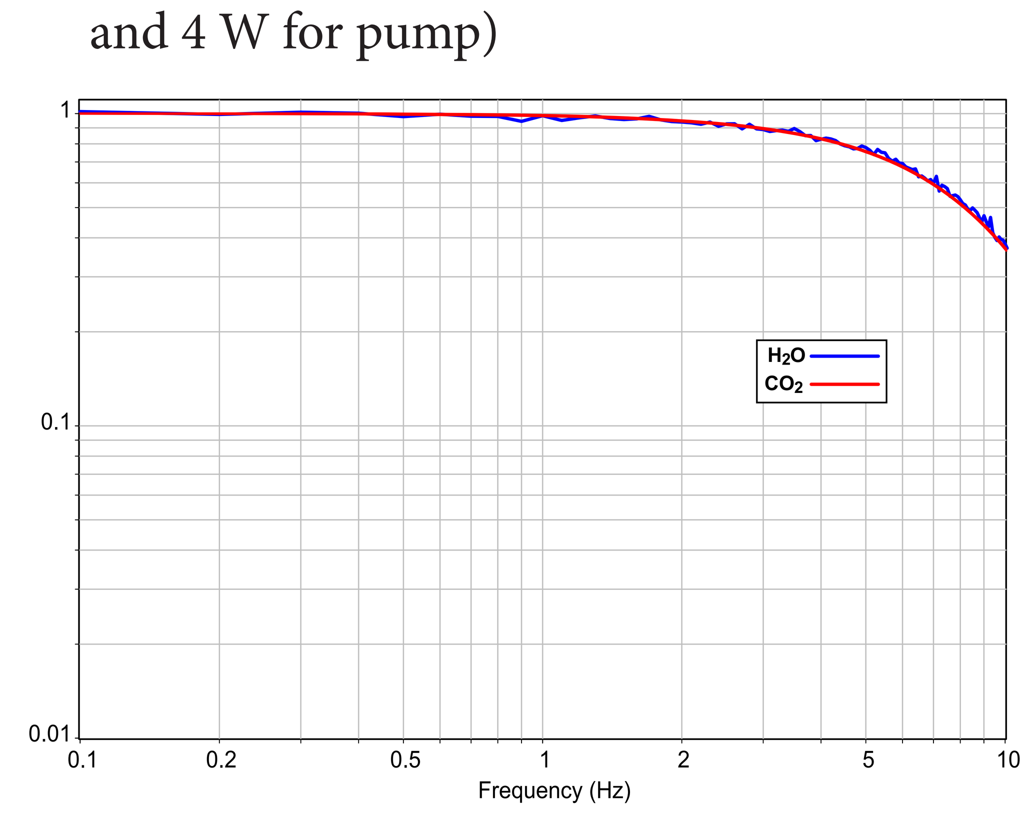

Figure 3. Overlay of CO_2 and H_2O spectra.

The CO_2 spectrum shows a good agreement with empirical model with a mixing term.

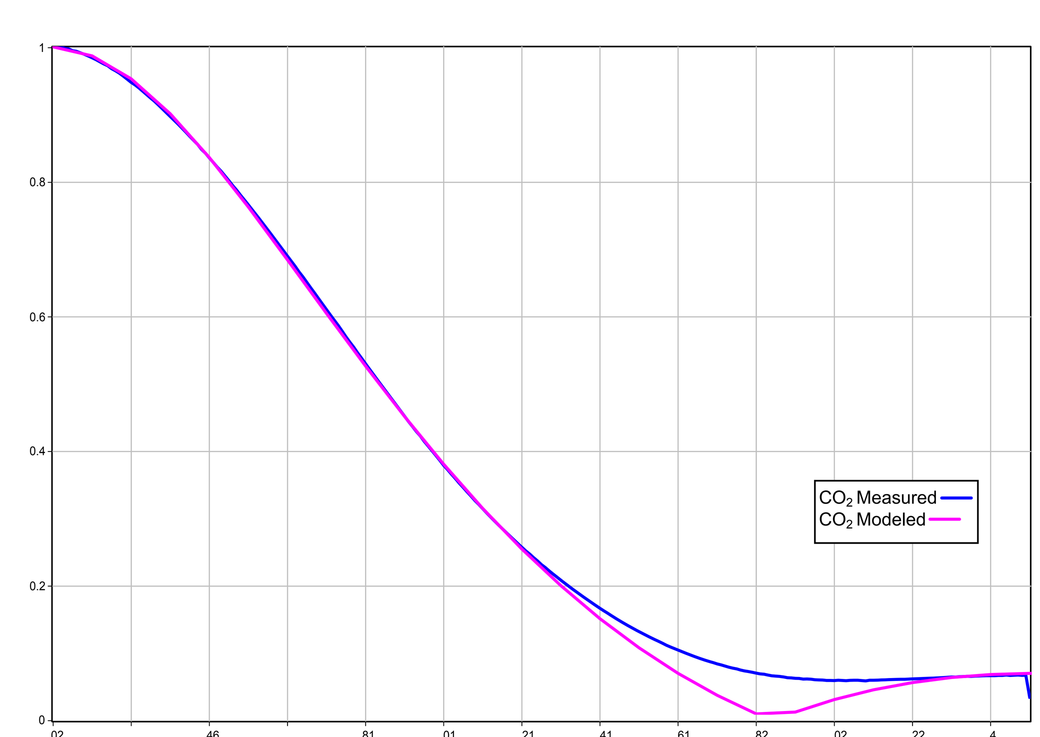

Figure 4. Display of CO_2 spectrum and empirical model with a mixing term.

Summary and Conclusions

- Excellent frequency responses were obtained for CO_2 and H_2O (5.8 Hz half-power bandwidth)
- Traditionally, frequency response of H_2O suffers loss due to interactions with the surface of the intake tube and sample cell. However, the frequency responses of CO_2 and H_2O show remarkable agreement with each other, indicating little loss in H_2O frequency response.
- Small sample cell volume and short intake tube preserve the frequency response of H_2O.
- The results show good agreement between the physical sample cell residence time (50 ms) and the modeled residence time (52 ms). The modeled exponential mixing time constant (18 ms) was much smaller than the residence time, indicating little mixing in the intake tube or the sample cell. H_2O frequency response was as good as that of CO_2 showing no difference between them.