Simultaneous Carbon Dioxide and Methane Eddy-Covariance Flux Measurements Using a High-Speed WS-CRDS Analyzer: Field Comparisons to Conventional AmeriFlux Systems

Sze Tan1, Aaron Van Pelt1, Christoph Thomas2

1Picarro Inc. 2Oregon State University Department of Forest Science

Abstract

The eddy-covariance (EC) flux method is currently employed to study biogeochemical scalar fluxes of greenhouse gases between the land surface and the atmosphere. The carbon exchange of gas species between terrestrial ecosystems and the atmosphere, particularly in areas with stagnant water or poorly drained and heavy soils, represents a substantial portion of the atmospheric budget of both CO2 and methane (CH4), and so quantifying such exchanges of both gases is critical in our understanding of the carbon cycle. Recently, a novel closed-path analyzer has been evaluated against conventional instrumentation for performing not only CO2 flux measurements, but for making simultaneous CO2 and CH4 flux measurements. We present field data evaluating the performance of this high-frequency fast-response (10Hz) gas analyzer based on Wavelength-Scanned Cavity Ring Down Spectroscopy (WS-CRDS) that was developed for simultaneous, dual-gas eddy-covariance flux measurements. The performance of this analyzer was evaluated in terms of what is required for appropriately high-quality measurements involving the exchange of both CO2 and CH4, between terrestrial ecosystems and the atmosphere. The WS-CRDS analyzer was deployed at Hypolp Crop Science Field Research Laboratory outside of Corvallis, OR and was compared in real-time with the AmeriFlux Portable Eddy-Covariance System for measuring CO2 fluxes using conventional infrared open- and closed-path CO2 and water vapor analyzers. Data comparing the performance of this WS-CRDS analyzer against this commonly-used AmeriFlux instrumentation is presented.

Instrumentation

Field Measurements of CO2 & CH4 Flux

Wavelength-Scanned Cavity Ring Down Spectroscopy (WS-CRDS) – How it Works

Light intensity is a function of time in a WS-CRDS system with and without a sample having resident absorbance. This demonstrates how optical loss (or absorption by the gas) is measured in this time measurement (left) by using a patented wavelength scanning methodology. A spectrum is continuously acquired at a number of well-controlled points in wavelength (right).

Data Analysis

Analysis of both the power spectra of the amplitude and phase of the observed spectral estimates during the measurement campaign was carried out (results presented in figures below). These field results are also presented along with the theoretically-predicted characteristic features of atmospheric turbulence spectra. Overall, the observed discrepancies in the measurements between the analyzers (and deviation from ideal response) is attributable to differences in sample delivery which were addressed subsequent to this analysis. The loss in spectral energy at the highest frequencies arises through non-uniform transport of the air sample through the tubing (in the case of the closed-path analyzers) which results in attenuation of the smallest eddy sizes and therefore higher frequency perturbations. Higher flow rates, shorter tubing, and better tubing geometry can ameliorate this effect.

Summary & Conclusions

• Setup and operation of Picarro analyzer is remarkably straightforward, no long-term drift of the mean concentrations of CO2 and CH4, no repeated calibrations were necessary.
• Spectrally integrated climatologically weighted carbon and methane concentrations on the LL7000 were comparable to those of the Li7000. Theoretical data in Figure 8 show that the attenuation frequency range for the LL7000 is approximately 0.5 Hz vs. 0.2 Hz for the Picarro analyzer. The difference is significant in the higher frequency range because (1) the LL7000 acts as a high-pass filter for this high frequency response of the Picarro analyzer is likely due to insufficient sample flow rate through the instrument resulting in laminar rather than turbulent flow in the tubing and measurement cavity.

Field Measurements of CO2 & CH4 Flux

OSU Hypolp trial: comparison of Picarro and LL7000 measurements: mean concentration, standard deviation and flux of CO2.


OSU Hypolp trial: concentration time series data, Picarro vs. LiCOR7000. N=183

OSU Hypolp trial: concentration standard deviation time series data, Picarro vs. LiCOR7000. N=183

OSU Hypolp trial: comparison of turbulent CO2 fluxes. No other methane flux instrument similar to the LL7000 was available to enable a comparison (similar to that shown in Figure 6). The attenuated high-frequency response of the Picarro analyzer is likely due to insufficient sample flow rate through the instrument resulting in laminar rather than turbulent flow in the tubing and measurement cavity.