Urban Flux and Other Micrometeorological Applications of the Picarro G2311-*f* Methane, Carbon Dioxide, and Water Vapor Analyzer[1]

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Abstract

As requirements for flux measurement of greenhouse gases become more demanding, the need for testing new technology in diverse research settings is imperative for full characterization of instrument performance & capability. Picarro has developed a new, high speed, Cavity Ring-Down Spectroscopy (CRDS) based analyzer for measuring carbon dioxide (CO_2), methane (CH_4) and water (H_2O), the G2311-*f*. Concentration measurements are taken at a 30-Hz rate with the result that all three species are measured at 10 Hz with extremely high precision and accuracy. The new flux analyzer has recently been deployed for testing and validation in three different flux research settings: On the largest green roof in New York City with Dr. Wade McGillis, at a desert site in Railroad Valley, Nevada with Dr. Emma Yates, and at the Wetzstein spruce site with Dr. Olaf Kolle from the Max Plank Institute in Germany. Summaries of these deployments to date are presented to show the instrument's actual performance in highly varied field sites.

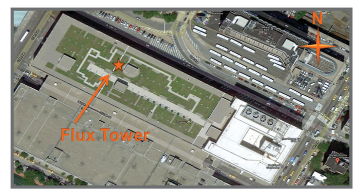
The new flux instrument has proven capable of meeting the specified performance of raw 10 Hz precision (one standard deviation) better than 110 parts-per-billion (ppb) for carbon dioxide, better than 3 ppb for methane and better than 6 ppm + 0.3 % of reading for water vapor. Dry mol fractions of CO_2 and CH_4 are reported in real time with corrections for both dilution and spectroscopic effects made automatically. Low level carbon fluxes have been measured even during periods of high latent heat flux. A key additional feature tested is the automatic time-synch and integration of concentration with 3D sonic anemometer data streamed directly to the Picarro via RS232. Multiple measurement modes provide flexibility for measuring fluxes using the eddy-covariance technique, or for use with other techniques that require the high accuracy and precision inherent to the time-based CRDS method such as the gradient flux method, relaxed eddy-covariance, or long-term tall-tower measurements.

Urban Green Roof Flux: Instrument Deployment #1

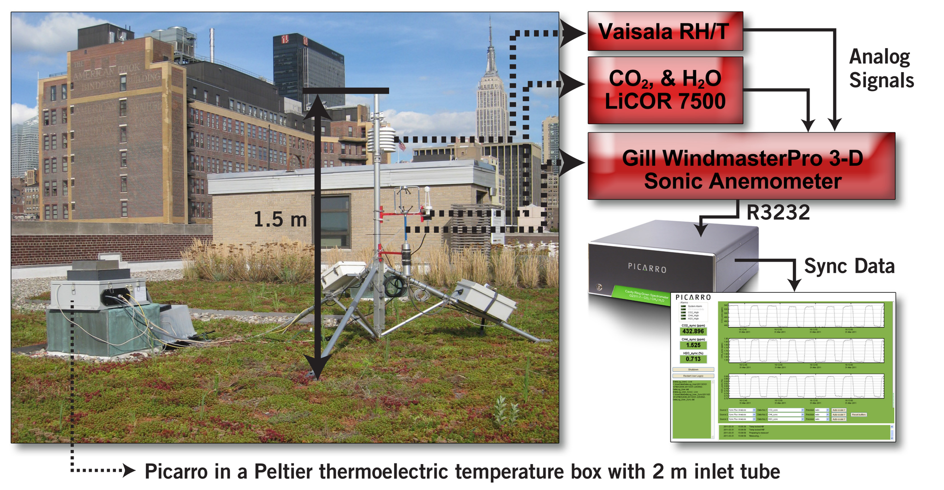
Data and Analysis courtesy of Dr. Wade McGillis

Summary

A partnership of Columbia University, the USPS, and TectaAmerica has undertaken a project where seven greenroofs in New York City are being evaluated for their effectiveness at reducing the heat island effect, reducing the amount of rainwater reaching storm drains, improving run-off water quality and functioning as a potential carbon sink. Wade McGillis from Columbia University's Lamont-Doherty Earth Observatory has deployed the Picarro flux instrument (G2311-*f*) on the largest greenroof, the main post office building in Manhattan. The rooftop ecosystem is dominated by sedum, a plant that is widely used in such applications for its drought tolerance and hardiness. The Picarro flux analyzer has been deployed to help quantify the net flux of water from the roof to the atmosphere, as well as the low level daily CO_2 respiration of the plants. Also of interest is discovering if the rooftop garden is a source or sink for methane. To date, the Picarro shows excellent frequency response and low drift, which enables the measurement of CO_2 fluxes as low as + 2 μmol $m^{-2}s^{-1}$ even during periods of high latent heat flux up to 64 Wm^{-2}. Diurnal, hourly methane fluxes between + 0.004 and (-) 0.01 μmol $m^{-2}s^{-1}$ are observed with errors typically less than 0.001 μmol $m^{-2}s^{-1}$. As expected for the relatively arid, hot conditions, no discernible trends in methane flux emerged, indicating the roof is not a significant methane source or sink.



Instrument Set Up



A 1.5 meter tall flux tower is located on the USPS green roof such that the footprint of the tower only encompasses the rooftop sedum. The Picarro G2311-*f* analyzer is in a weather proof, Peltier temperature controlled box near the base of the tower and is connected to a 2 meter long sample tube with the inlet located within 0.15 m of the Gill WindmasterPro 3-D ultrasonic anemometer mounted on the tower. Also mounted on the tower are a Vaisala relative humidity (RH) and Temperature meter and an open path CO_2, & H_2O LiCOR 7500 sensor.

Analog signals from the RH meter and LiCOR are fed to the Gill Anemometer, which sends all data via RS232 to the Picarro. The Picarro on-board computer acts as a data-logger by using its unique software to automatically parse, time-synchronize, and integrate the analyzer's concentration data with the incoming data stream and store them a single user file. The L7500 was calibrated by NOAA gas standards and Licor Dew Point generator and the Picarro was deployed with the factory calibration. Picarro factory calibration consists of a 6-point calibration with secondary standards referenced to a gold standard instrument calibrated at NOAA.

Railroad Valley: Instrument Deployment #2

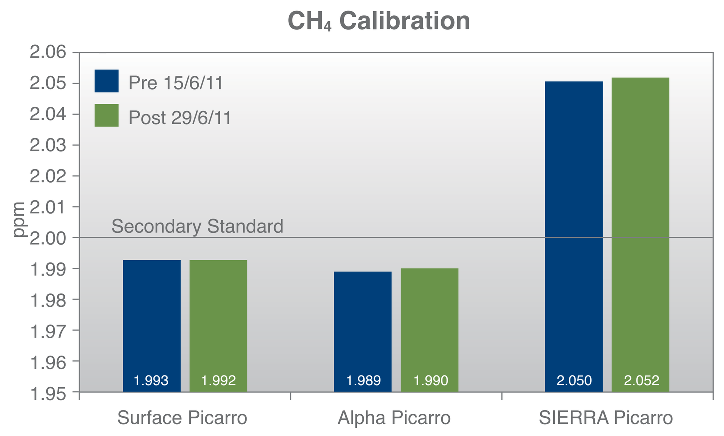
Data courtesy of Dr. Emma Yates

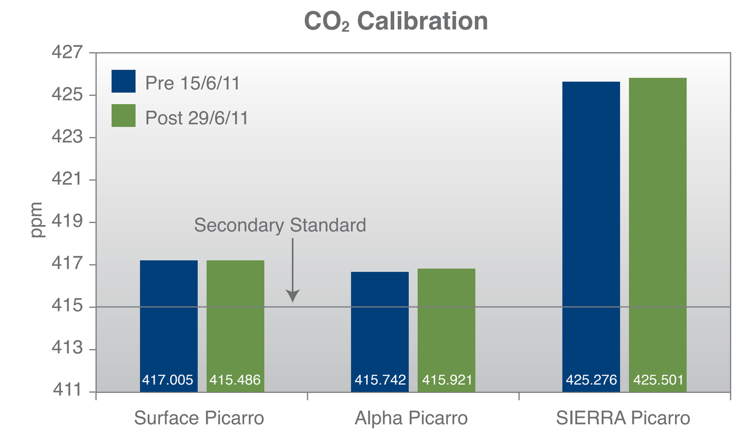
Summary

The Railroad Valley Vicarious Calibration Campaign, a collaboration between the Japan Aerospace Exploration Agency (JAXA), and NASA's Jet Propulsion Laboratory (JPL), Pasadena, Calif., is an international, multi-year effort to calibrate space-based observations of CO_2 and CH_4 collected by the Japanese Greenhouse Gases Observing Satellite (GOSAT), using ground and airborne data. It involves more than 30 scientists and engineers from JAXA, the University of Wisconsin, Madison, Colorado State University, Fort Collins and JPL. Railroad Valley is on a dry lake bed, or playa, in Nevada. The NASA Ames team deployed the new Picarro flux instrument at ground level and two additional Picarro analyzers in aircraft (UAV, SIERRA and NASA Alpha Jet). This deployment tested the stability of the new Picarro flux instrument as well as its performance in Nevada desert conditions. Daily average drift of the G2311-*f* over the 15 days was 109 ppb for CO_2 and 0.01 ppb for CH_4.

Instrument Set Up

The surface Picarro was deployed in a small tent (Picture left) and air was drawn from a short (< 2 meter) tower. The Picarro was operated in slow flow mode (gas cell turnover of 0.5 Hz). The Picarro synchronized and stored concentration measurements with 10 Hz data from an RM Young 3D Sonic Anemometer.





Time Series

Time series plots for water and CO_2 are shown in figures 1 and 2 below for the Picarro, L7500 and Vaisala. Except for an excursion on year day 221 due to a rain event, the short-term trends track very well. An offset appears between the L7500 and the other two instruments beginning on year day 223, which may be instrument drift, but the root cause investigation is still in progress.

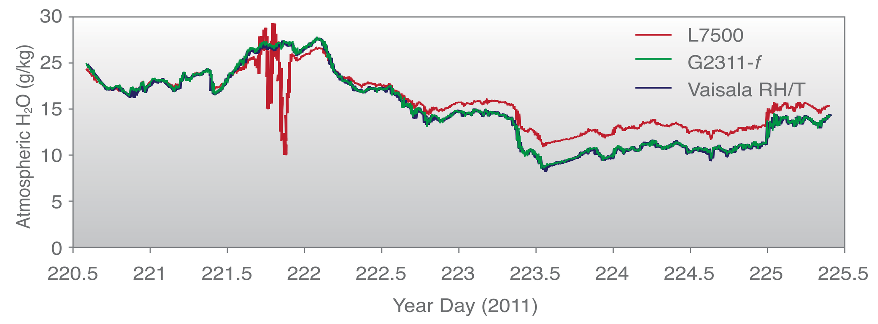


Figure 1: *H_2O Time Series of the L7500 and Picarro (5 days)*

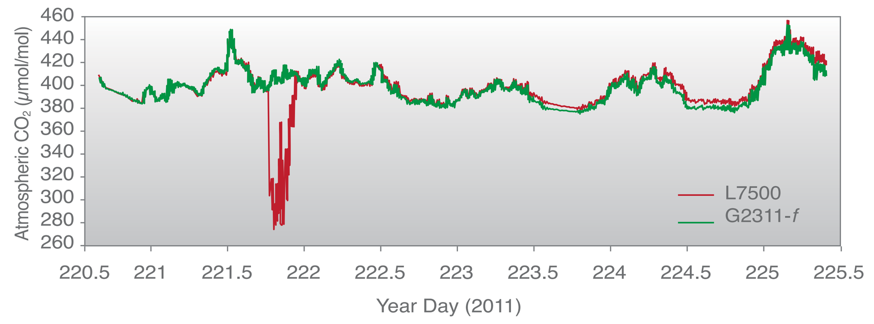


Figure 2: *CO_2 Time Series of the L7500 and Picarro (5 days)*

Frequency Response

Spectral analysis performed on the 10 Hz time series for water and CO_2 and the averaged results are shown in Figure 3. The raw spectral density of water is plotted (left) while the log space bin average of CO_2 is plotted in order to illustrate the difference in response characteristics.

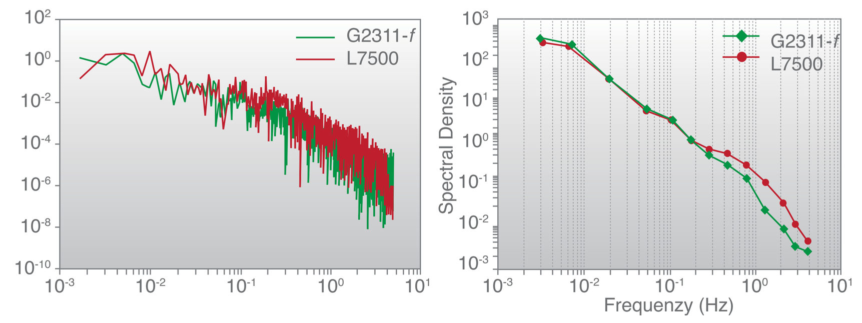


Figure 3: Spectral Density of H2O and CO_2. *The low frequency response of the instruments is well matched. The L7500 is high in the flux frequency response range.*

Fluxes

45 min average fluxes were computed and a five day composite is shown in figures 4 and 5 to illustrate the diurnal cycle on the rooftop. The water flux during the day is very high, but CO_2 respiration is low, which is expected for this type of vegetation and relatively small biomass. Laboratory studies done by Michigan State University on sedum showed little to zero net carbon uptake[2]. During periods of high water flux, the L7500 CO_2 signal becomes enhanced producing an over-estimate of the carbon uptake. For more details and methane fluxes please see the Picarro Application Note on this deployment.

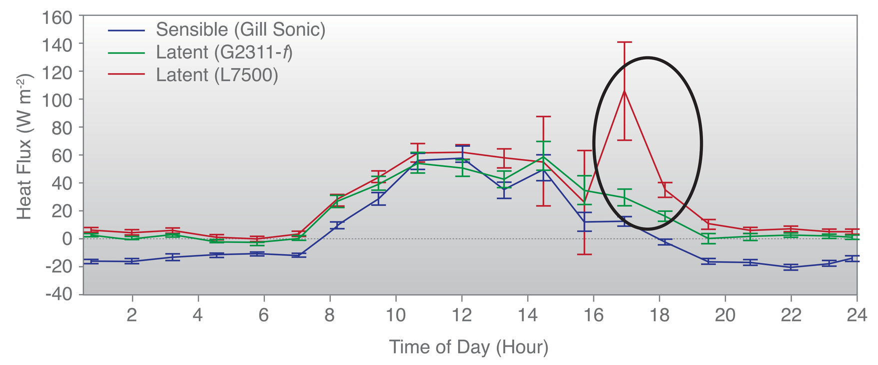


Figure 4: Latent and Sensible Heat Flux (5 day composite) *There is generally good agreement between the two instruments during the observation period except for the circled excursions in the L7500 data due to liquid water accumulating on the mirrors. During this period daily temperatures ranged between 92 and 115 degrees F, which created large fluxes during the day.*

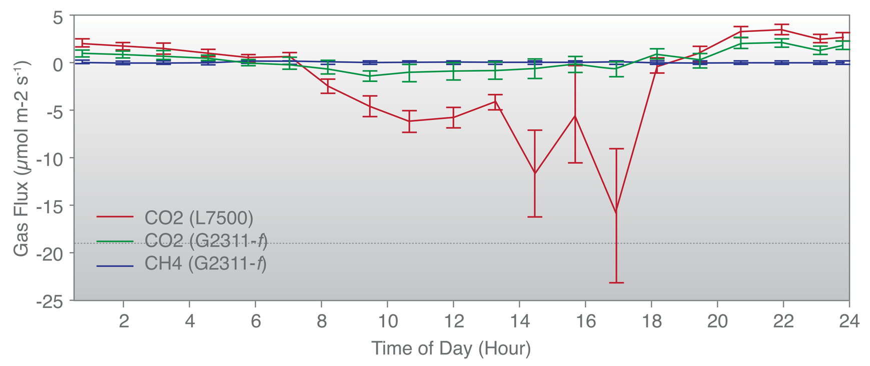


Figure 5: CO_2 and CH_4 diurnal fluxes (5 day composite). *WPL correction is applied to 7500 data*

Instrument Stability Data

The Picarro was calibrated at NASA lab before and after deployment with. Primary standard calibrations were done to ascertain the instrument offset and precision. The average (of pre & post) precision was found to be 110 ppb for CO_2 and 0.9 ppb for CH_4. Secondary standards were used to calculate the total and daily average drift of the instruments (shown in above graphs) with a comparison to the other Picarro instruments. The total (15 day) measured drift of the instrument (post – pre) was 1.52 ppm for CO_2 and 0.17 ppb for CH_4. Resulting in daily average drift of 109 ppb for CO_2 and 0.01 ppb for CH_4.

Further results from this deployment can be found in an upcoming NASA publication and will also be presented at AGU in San Francisco.

Wetzstein: Instrument Deployment #3

Pictures & Deployment by Dr. Olaf Kolle

Summary

The Wetzstein spruce site, in Thuringia, Germany was established as part of the CarboEurope-IP Flux Network and has been making eddy covariance measurements since December 2001. The site is located on a hill subject to strong winds and high levels of turbulence for continuous periods, and thus will be a good test of the new flux analyzer's capability to measure high frequency eddies. The new Picarro flux instrument was deployed along side an existing Picarro G2301-*f*, installed in 2010, as well as two LiCOR instruments, the new open path LI7700 for measuring CH_4 as well as the closed path LI7000 for measuring CO_2 and H_2O. The inlets are collocated with the Gill 3D Sonic Anemometer and air is pulled down 35 m meters of DECABON tubing of 1/4 of an inch outer diameter (approx. 4.2 mm inner diameter) at a flow rate of 7 to 8 l/min. The data from all instruments is collected on a single data logger and analyzed using the Eddysoft program. The deployment began on August 27 and the data analysis will be available at AGU in December.

Picarro G2301-f and G2311-f Analyzers at the base of Wetzstein

Gill 3D Sonic Anemometer Picarro Sample Inlets at 30 m

[1] This material is based upon work supported by the Department of Energy SBIR Program under Grant No. DE-FG02-07ER84902 and does not constitute an endorsement by DOE of the views expressed in this presentation.

[2] Carbon Sequestration Potential of Extensive Green Roofs, Environ. Sci. Technol. 2009, 43, 7564–7570