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AN033

Picarro's New Flux Instrument Captures CO_2, CH_4 & H_2O Fluxes by Measuring Concentrations at 10 Hz with the Best Precision and Lowest Drift

Data & Analysis Courtesy of Wade McGillis (Columbia University LDEO, New York City)

Green Roof Deployment in New York City

Keywords:
Environment: Rooftop Garden, Greenroof, Urban Ecology, Sedum, Extensive Green Roof
Methods: Eddy Covariance, Latent Heat Flux, Methane Flux, Carbon Flux

Summary and Relevance:

Natural ecosystems have long been the focus of flux research, and while continued investigations into these areas is absolutely necessary for developing accurate climate & ecological models, characterizing the complexities of the urban environment is also critical to understanding global cycles. One research area gaining particular interest is quantifying environmental effects of green practices and technologies such as greenroofs. 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 that reaches the 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 low-level fluxes. CO_2 fluxes as low as + 2 μmol $m^{-2}s^{-1}$ are measured 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 0.001μmol $m^{-2}s^{-1}$. 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.

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Instrumentation:

A 1.5 meter tall flux tower is located on the 109,000 square foot roof such that the footprint of the tower only encompasses the rooftop sedum as shown in Figure 1. 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. The 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 containing data for all instruments on the tower. The voltages of the L7500 CO_2 were converted to concentration and corrected with the L7500 H_2O all onboard Picarro's computer. 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.

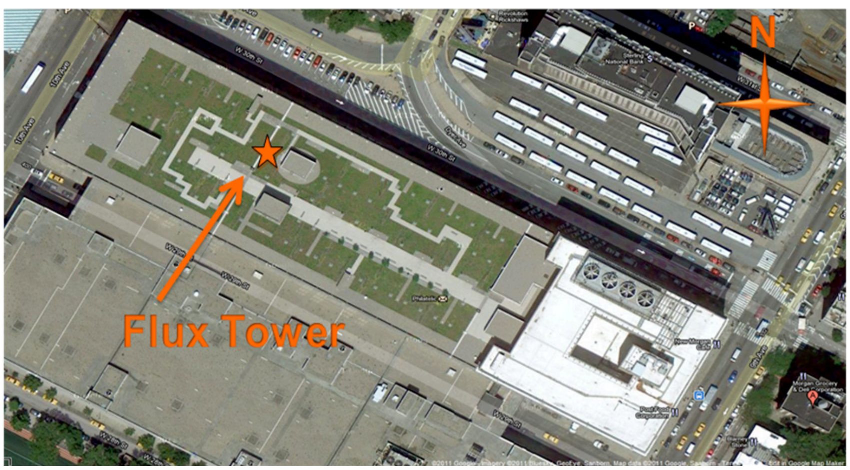
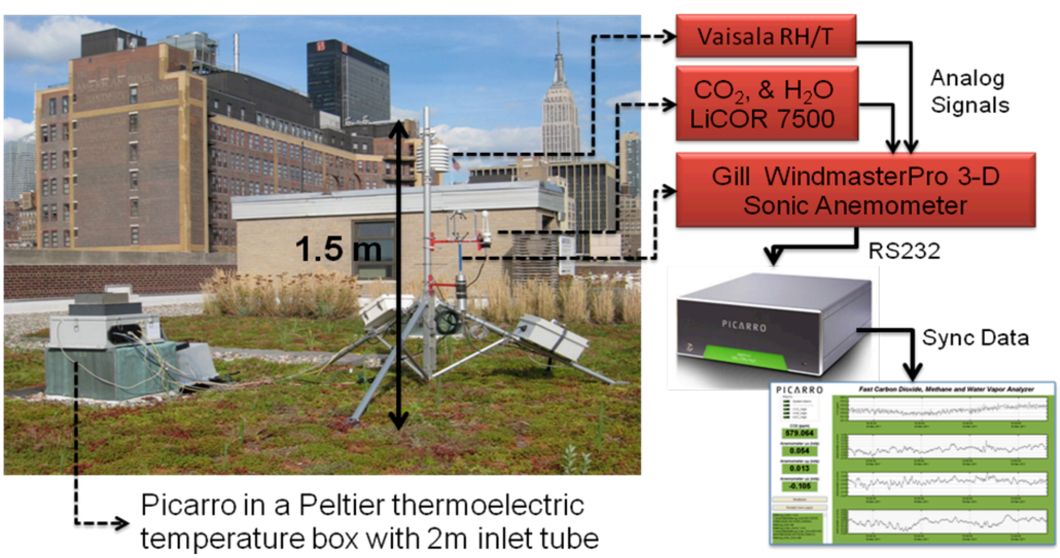


Figure 1: *Location of flux tower on USPS Greenroof 341 9th Ave, New York City indicated by star (top).*

Bottom: *Instrument configuration and data flow illustration*



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Results:

Time series plots for the L7500 and the Picarro are shown below in Figures 3, 4 & 5. Except for a few excursions and some offset, the two instruments track closely in terms of overall trends.

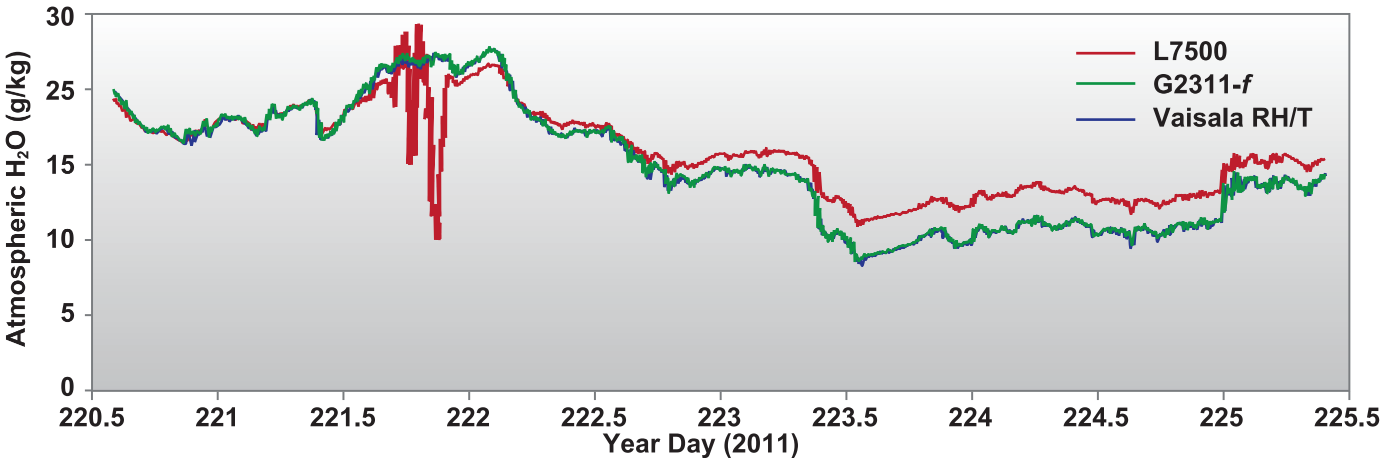

Figure 3: H_2O Time Series of the L7500 and Picarro (5 days)

Excursions on yearday 221 for both time series are explained by rain event affecting the open path L7500 (liquid water on the mirrors). After the rain event, an offset in the water flux appears between the LiCOR7500 and the other two instruments. The Picarro water measurement tracks with the Vaisala over the full five days. Excluding the rain event, both instruments track very closely for CO_2 until yearday 223, where an offset between the two instruments begins to appear. The root cause for the offset in water and CO_2 measurement may be instrument drift, but root-cause investigation is still in progress.

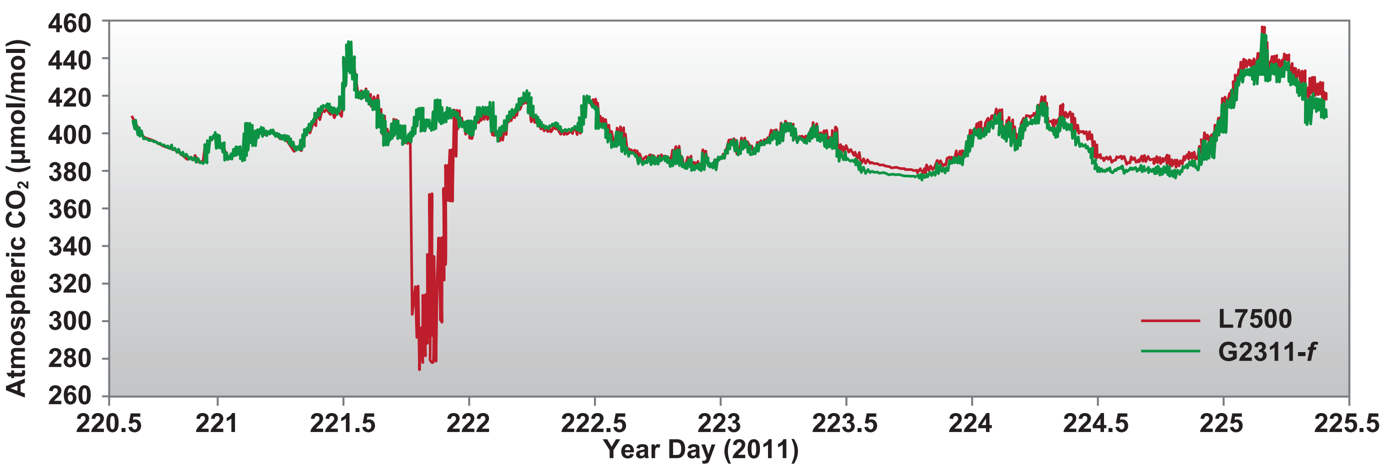

Figure 4: CO_2Time Series of the L7500 and Picarro (5 days): *night time build up or storage of CO_2 at night is observed due to mitigated dilution and a stable boundary layer conditions.*

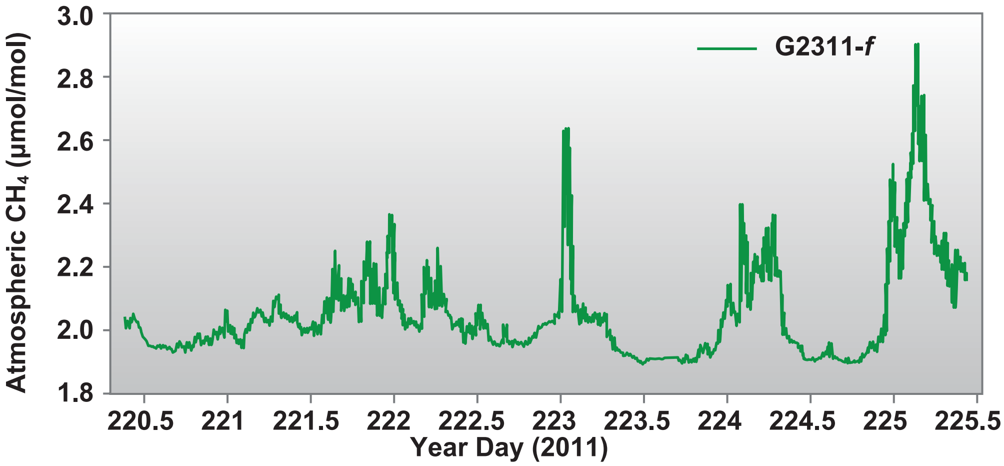

Figure 5: CH_4 Time Series of the L7500 and Picarro (5 days): *Consistent with CO_2 time series, methane buildup at night is observed. Methane fluxes, shown in Figure 10, are near zero, indicating the roof is not a methane source or sink.*

Spectral analysis was performed on the 10 Hz time series to produce the frequency response for CO_2 and water shown in figure 6 below. The spectral density is plotted in two ways; water is plotted as the raw spectral density to show data spread and the CO_2 is plotted as the log space bin average in order to more clearly show the difference in response characteristics over the frequency range. The highest frequency shown is 5 Hz due to a loss of half the frequency during spectral analysis i.e. from the time series at 10 Hz you get 5 Hz frequency and phase information. On the plot this appears as less than 5 Hz because the power spectrum is averaged in log space so it can be interpreted. If the 10Hz data is plotted on the graph it gets too crowded to see the relative trends.

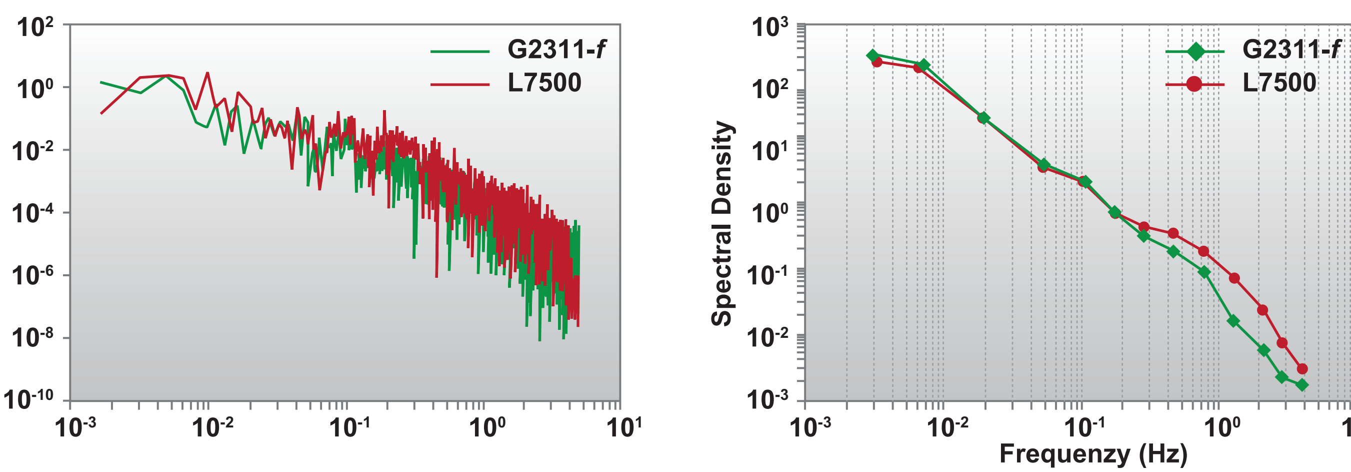

Figure 6: Spectral Density of H_2O & CO_2: *The low frequency response of the instruments is well matched. The L7500 is high in the flux frequency response range.*

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Fluxes: 45 min average fluxes were computed and a five day composite is shown in figures 7 and 8 to illustrate the diurnal cycle occurring 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[1].

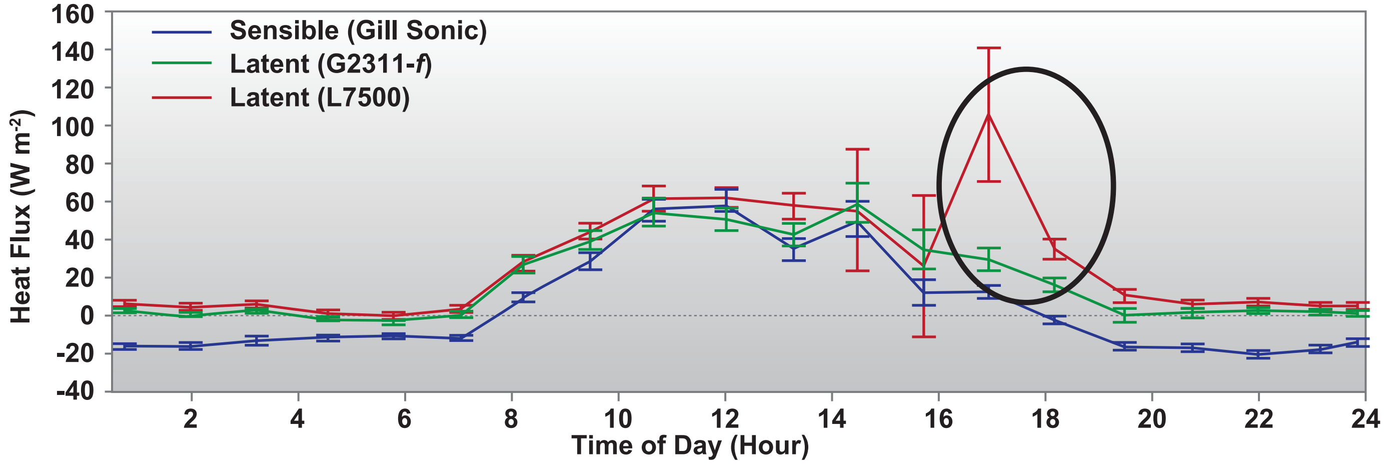

Figure 7: Latent and Sensible Heat Flux (5 day composite) *There is generally good agreement between the two instruments during the observation period except for the circled excursions in the L7500 data due to liquid water accumulating on the mirrors. During this period daily temperatures ranged between 92 and 115 degrees F, which created large fluxes during the day.*

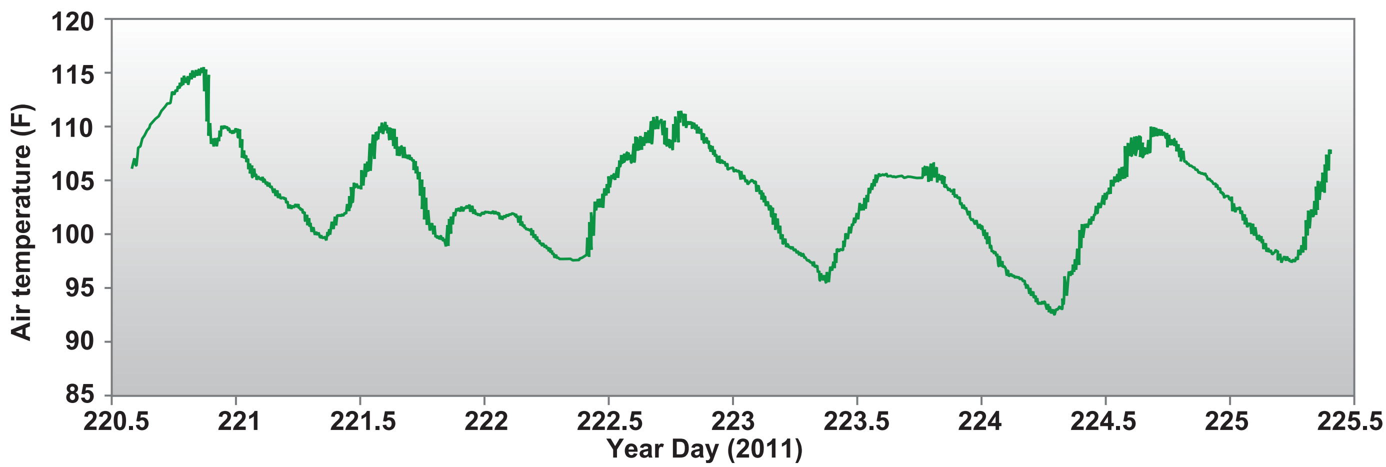

Figure 8: Rooftop Temperature Time Series

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

During periods of low water flux, there is good agreement between the two instruments. However, during periods of high water flux the CO_2 signal becomes enhanced in the L7500 producing an over-estimate of the carbon uptake.

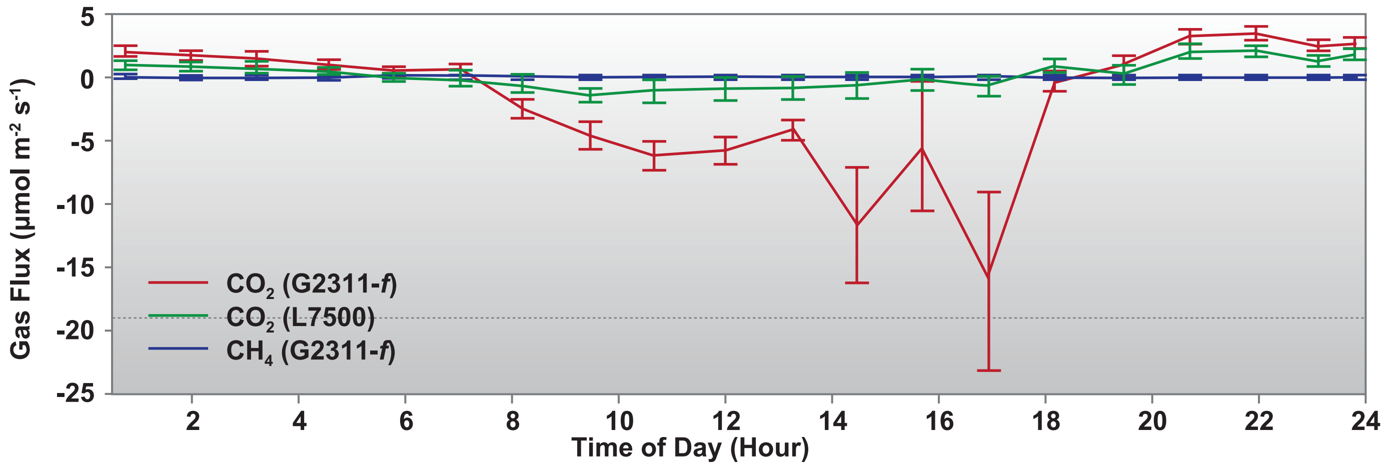

***Figure 9**: **CO_2 and CH_4 diurnal fluxes (5 day composite)**. WPL correction is applied to 7500 data*

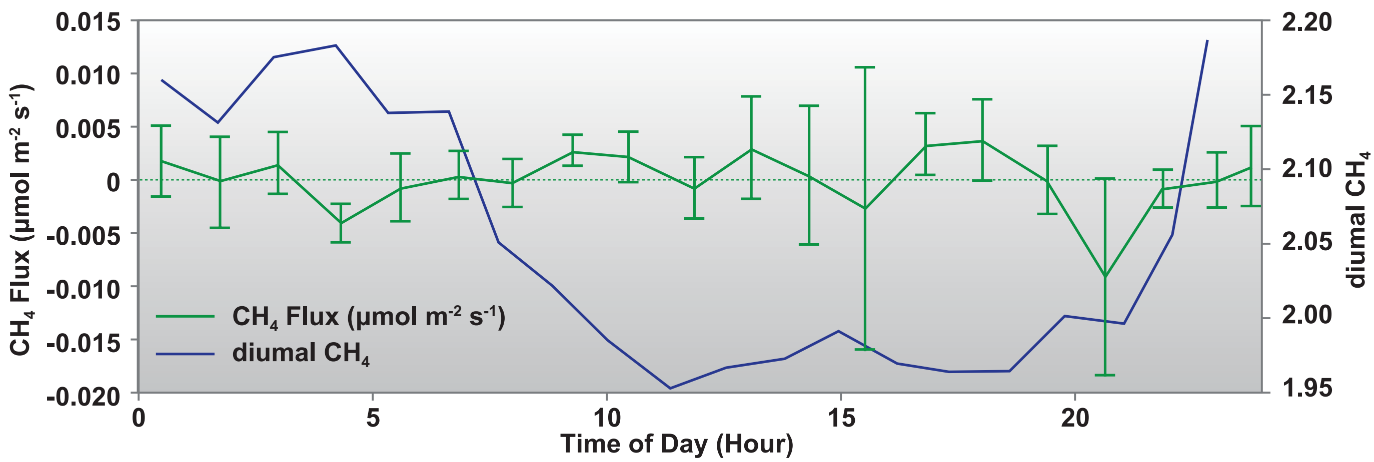

***Figure 10: Blow-up of low diurnal methane fluxes with errors and concentration profile.** Daytime dilution / nighttime storage effect is clearly present. As expected, the rooftop does not appear to be a source or sink for methane. The instrument exhibits stable performance in the low flux environment.*

Comments:

The new Picarro flux instrument is ideally suited for urban ecosystem measurements, such as the greenroof application due to its unique ability to precisely and accurately measure the concentration of three gas species, CO_2, CH_4 & H_2O at a data rate of 10 Hz for each molecule (overall data rate of 30 Hz) in a single instrument. The capability of the analyzer to auto-correct for the effects of water vapor (dilution as well as spectral) and report accurate dry mixing ratios, along with precise temperature and pressure control in the instrument enable low-level fluxes to be determined without the need to apply the WPL or

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other corrections during data post-processing. The concentration measurements can be made with a precision better than the guaranteed specifications of 200 ppb for CO_2, 3 ppb CH_4 and 6ppb + 0.3% of reading for water vapor with low instrument drift, which translates into accurate determination of both low and high level fluxes with far fewer calibrations and compressed gas reference measurements. The guaranteed minimum data rate of 10 Hz and minimum gas response of 5 Hz ensure excellent performance across all frequencies is achieved. This deployment shows equal or better frequency response compared to open path measurements. In addition, the Picarro's onboard computer and software enable anemometer and other peripheral data to be directly integrated & time-synchronized with the analyzer data via RS232 and saved in a single user file. In this deployment, this functionality eliminates the need for a separate datalogger and PC and greatly simplifies data analysis, which helps to eliminate potential errors due to relative clock drifts or data misprocessing.