A Portable, Low-Power Cavity Ring-Down Analyzer and Automated Soil Flux Chamber System for Measuring Wetland GHG Emissions

Nick Nickerson[1], David Kim-Hak[2], Gordon McArthur[1]

[1] Eosense Inc., Halifax, Canada. [2] Picarro Inc., Santa Clara, USA

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www.eosense.com

Abstract

Preservation and restoration of wetlands have the potential to help sequester large amounts of carbon due to the naturally high primary productivity and slow turnover of stored soil carbon. However, the anoxic environmental conditions present in wetland soils are also the largest natural contributor to global methane emissions. Therefore, uptake, storage, and loss of CO_2 and CH_4 need to be carefully considered when evaluating the climate effects of land-use change.

Here we present data using an automated chamber system coupled to a new low power and portable laser-based greenhouse gas analyzer (Picarro GasScouter, G4301). The focus of this presentation will be on the methodological and field deployment benefits of the automated system over a manual system including: improved ability to run on limited in-field power resources; reduced disturbance on the soil during chamber closure; good spatial coverage (30 meters radially); excellent temporal resolution; and, enhanced minimum detectable flux limits. These advantages will be demonstrated through the deployment of the instrumentation at a constructed wetland site in Nova Scotia, Canada, where the system monitored CO_2 and CH_4 fluxes continuously over a 10-day period in August.

Equipment Overview

Picarro Gas Scouter:

- Power: 25 W (avg.)
- Weight: 10.4 kg / 23 lbs
- Precision (CO_2): 0.4 ppm
- Precision (CH_4): 3 ppb

Eosense eosAC:

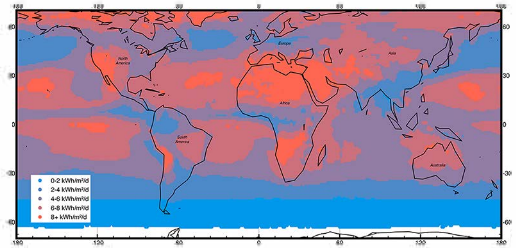
- Power: 8 W (max.)
- Weight: 5 kg / 11 lbs
- Volume: ~2.5 L
- Area: 182.4 cm^2

Eosense eosMX-P:

- Power: 12 W (max.)
- Weight: 17 kg / 38 lbs
- Ports: 12 eosAC ports
- Reach: 30 m radially (max.)

Solar Requirements and System Setup

The Picarro GasScouter and Eosense eosAC/eosMX-P system draws about 34 W of power **on average**. This means to run the two systems for a full day of operation it will need about 816 Wh of energy (34 W * 24 h). The solar panels have to be sized based on this number, and the peak sun for the location of our study. Below is a map of the global peak sun (kWh/m^2/d) values during the summer solstice (see the Eosense blog for winter solstice values).



A quick calculation based on the summer in Nova Scotia (4-6 kWh/m2/d):

- Summer = 816 Wh/4-6 kWh/m2/d = 136-204 W

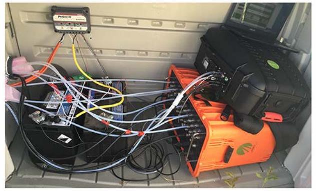
Suggests that we need approximately 200W of solar power for the system. Similarly a quick calculation assuming we want the system to sustain itself over a 3-day period of power outage:

- Battery Capacity = 816 Wh/day * 3 days = 2450 Wh / 12 V = 204 Ah

With a safety factor of 50% about 300 Ah of battery capacity is required, which for commonly available 12V deep-cycle batteries means about 3 batteries total (each 100 Ah).

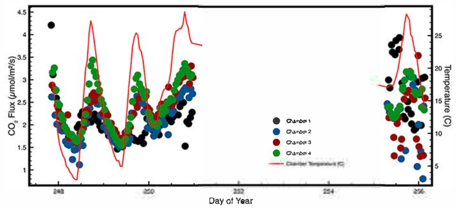
In order to protect the GasScouter and Eosense eosAC/eosMX-P system from the elements we also constructed a custom, inexpensive enclosure made from commonly available building materials.

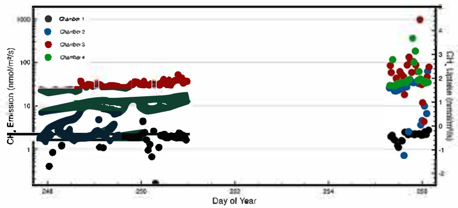
Details for the construction of the enclosure and wiring for the solar charge controller and battery bank can be found in the Eosense blog post *"Running your Picarro GasScouter and eosAC Off Grid - Part 2"*.



Field Deployment and Results

We observed a temperature correlated CO_2 flux in all plots; although the upland chamber (Chamber 1, below left plot) demonstrated a weaker temperature response due to very dry soil. There was consistent methane uptake from the upland chamber (black dots, right axis, right hand plot), whereas the wetland chambers showed consistent methane emission with an average rate of 19.85 nmol/m^2/s (σ=54.7 nmol/m^2/s) with a positively skewed distribution. A small rainfall event drove massive increases in methane flux for the wetland chambers (see below, right) with almost no change in the methane dynamics for the upland chamber (black dots). It's unclear if this was an event that caused a short-term increase in the production of methane or if the rainfall drove ebullition by volume replacement.





System Advantages and Comparison

The combination of low power, high-resolution concentration measurements and a fully automated flux chamber system offers researchers several benefits over other commercially available systems.

1. Enhanced Minimum Detectable Flux

Conservatively, the minimum detectable flux (MDF) for the GasScouter, eosAC and eosMX-P system ranges between 37.0 to 2.5 nmol/m^2/s for chamber closure times ranging from 1 to 15 minutes for CO_2 and 0.02 to 0.28 nmol/m^2/s for CH_4. The table below shows the MDF limit (nmol/m^2/s) for various chamber closure times.

	15 min	10 min	5 min	1 min
CO_2	2.5	3.7	7.4	37.0
CH_4	0.02	0.03	0.06	0.28

For CO_2 and CH_4, the MDF limits presented in the above table are 2 to 100 times smaller than other available automated chamber and analyzer pairs.

2. Improved Measurement Frequency

Due to the small MDF limits, created by the combined effects of the accuracy of the GasScouter analyzer and the geometry of the eosAC chambers, researchers can substantially improve the measurement frequency achievable in the field. Even one minute of chamber closure can yield results comparable to other commercially available systems and will be sufficient to measure accurate fluxes from most environments. This can enhance researchers ability to characterize both spatial and temporal variability, as well and improve the ability to detect sporadic flux events which are commonly observed with CH_4 and N_2O emissions.

3. Low Power, Autonomous Deployments

The substantially reduced power consumption (compared to earlier generation CRDS instruments) of the GasSouter, eosAC and eosMX-P creates logistically simple deployments for many environments. Taking Nova Scotia at summer solstice (5 kWh/m^2/day) as an example, the table below estimates the total solar panel and battery capacity requirements for the GasScouter as compared to the Picarro G2000 series analyzers and a range of competing portable and bench top greenhouse gas analyzers.

	GasScouter	G2000	Other Portable	Other Bench
Solar (W)	160	960	330-760	520-1000
Battery (Ah)	200	1190	410-950	650-1250
Battery (mass, kg)	55	325	110-260	180-340

Drawing attention to both the number of solar panels required (assuming 100 W each) the GasScouter requires 2 compared to a range between 4 and 10 for other systems. Similar for 3 days of autonomy without solar input, the GasScouter requires 2 batteries (assuming 100 Ah each) which weighs only 55 kg, again compared to the range for other systems being between 110 kg and 340 kg of batteries.

Acknowledgements

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