sUAS Imagery & Atmospheric Data Collection for improved Agricultural Emissions Monitoring

Lindsay Barbieri[1] Lindsay.Barbieri@uvm.edu -- **@barbieriiv**

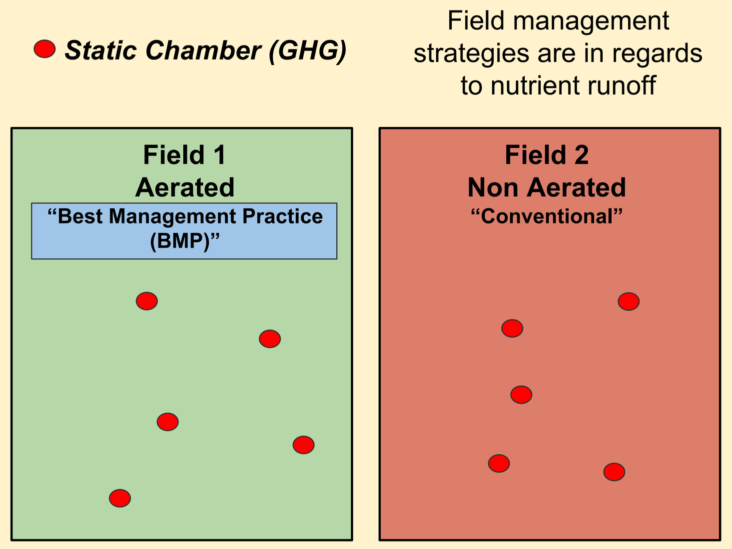
Dr. Carol Adair[1], **Dr. Gillian Galford**[1], **Dr. Jane Wyngaard**[2]

[1] Rubenstein School of Environment and Natural Resources & Gund Institute for Environment, University of Vermont [2] University of Notre Dame

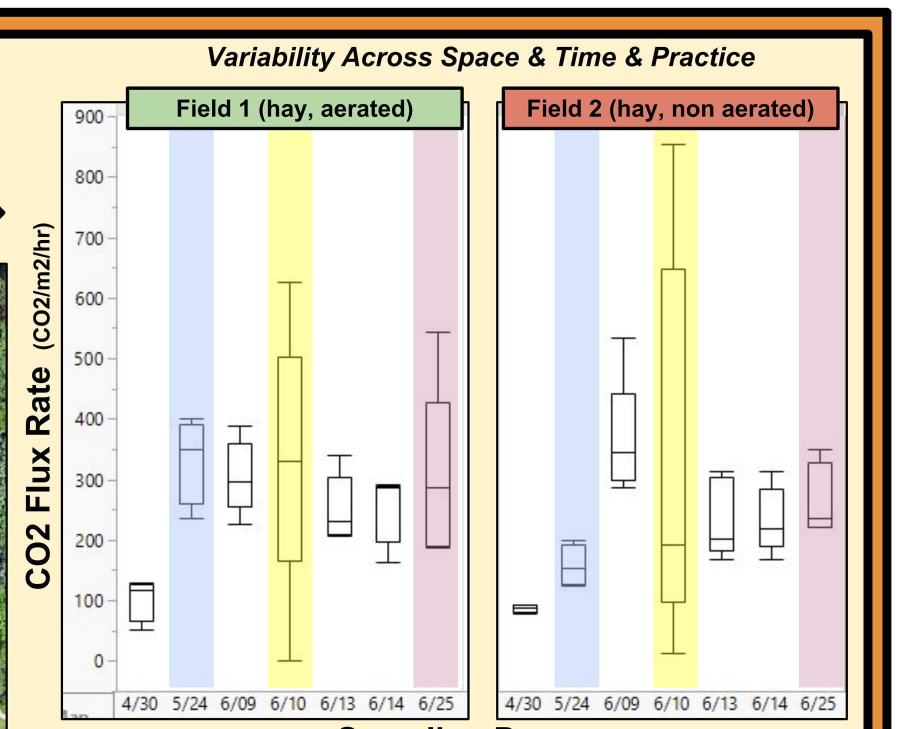
Introduction

Agriculture, Forestry and Other Land Uses (AFOLU) constitute the second largest anthropogenic source of greenhouse gas (GHG) emissions globally. **Agriculture is the dominant source of emissions** within that sector. There are a variety of **agricultural management strategie**s that can be implemented to **reduce GHG emissions**. However, **determining the best strategies is challenging as emissions estimates** are **currently** derived from monitoring methods (e.g., static chambers) that **lack the flexible, spatio-temporal monitoring necessary** to reduce the high uncertainty in regional emissions estimates. **Small Unmanned Aerial Systems (sUAS)** provide the **rapid response data collection needed** to monitor management events (e.g., manure spreading). The ease of deployment of sUAS makes monitoring large regional extents over full-seasons more viable. **Here we present test flights** over **agricultural areas under various management practices**. The suite of data includes field-based GHG measurements paired with sUAS overpasses for imagery and CO_2 concentrations for a comprehensive assessment of methods for use in **GHG emission hotspot detection across landscapes.**

Study Site: Shelburne Farms, Vermont



Static chambers are monitored for CO_2 and N_2O emissions in the field using a Photoacoustic Gas Monitor (PAS). GHG emissions **hot spots, hot moments** are variable across the landscape and across time, which are hard to capture in-field.

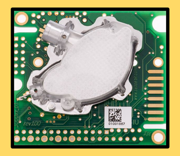


sUAS Plan: Sensors for Mitigation & Sampling Approach

Atmospheric GHG monitoring and imagery are combined and integrated to improve monitoring of agricultural land use for emissions estimates. Static chambers with a Photoacoustic Gas Monitor (PAS) and a meteorological station are both used for simultaneous in-field biophysical measurements.

Sampling Approach:			Sensors:	Ancillary Data:
(1) Horizontal survey (high): *Remotely sensed imagery*	1 Survey: 110m	Once per 16 Days	Canon S110 *(RGB, NIR)* Sequoia RedEdge	*Landsat Overpass, PAS*
(2) Horizontal survey (low): *Atmospheric measurements*	3 Surveys: 10m, 15m, 20m	Once per 2 weeks	K-30 CO2Meter IMetXQ	*Landsat Overpass, PAS, Met Station*
(3) Vertical profile: *Atmospheric measurements*	3 Profiles at 4 Points: 0m to 100m	Once Per 2 weeks	K-30 CO2Meter IMetXQ	*Landsat Overpass, PAS, Met Station*

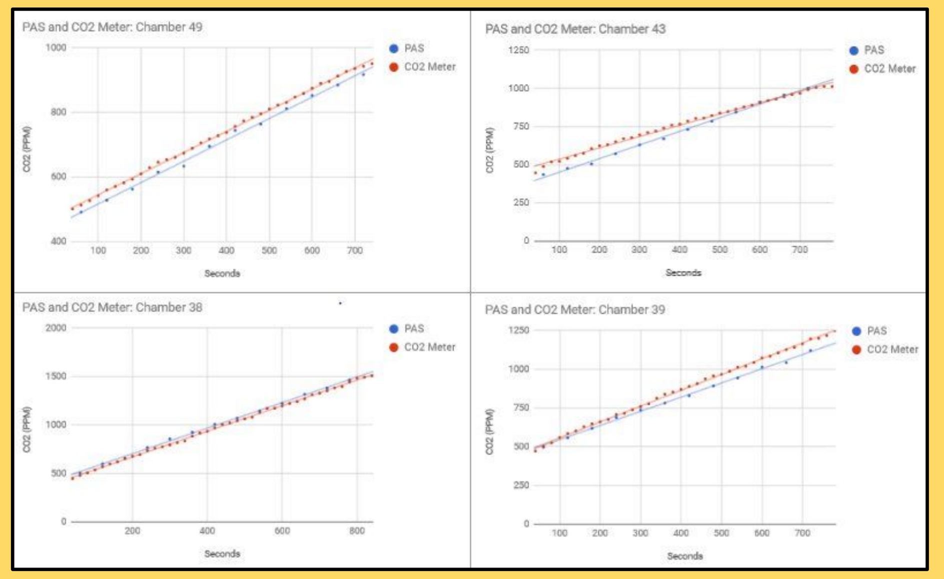
Atmospheric Sensor Testing:

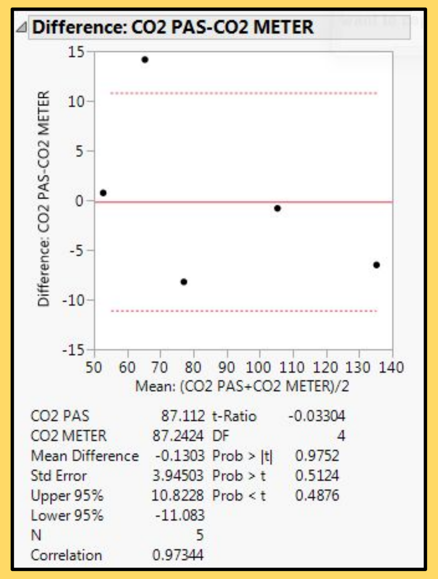


K-30 & PAS:

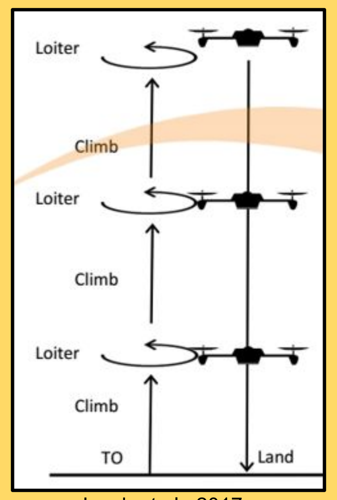
The K-30 was tested inside a static chamber while one a standard GHG analyzer, a **Photoacoustic Gas Monitor (PAS)** was simultaneously sampling for comparison. **Mean difference of .1303 mg/CO2/m2/hr**

DATE	CHAMBER	CO2 METER	CO2 PAS
07/06/2016	49	52.40993003	53.14981528
07/06/2016	32	138.5161627	132.0033779
07/06/2016	38	105.7867227	104.9689154
07/06/2016	39	81.20709991	72.99448345
07/06/2016	43	58.29191074	72.44359227



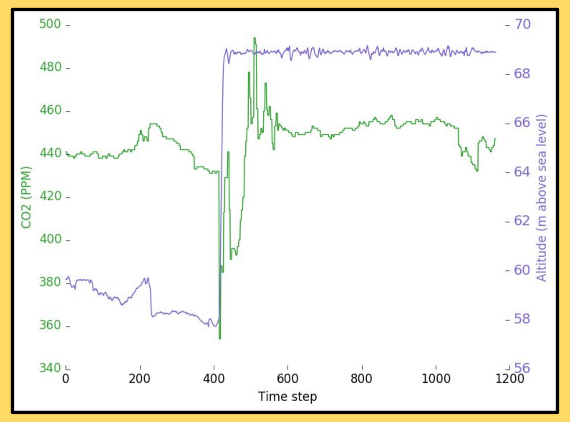


Vertical Sampling



Jacob et al., 2017

K-30 & Drone:



CO_2 variation with rapid altitude gains, after stable altitude is reached it took ~ 2 minutes to stabilize CO_2 measurements.

K-30 tested on drone hovering at stable altitude to test both the K-30 sampling in-flight and drone data logging

IMetXQ & Drone:

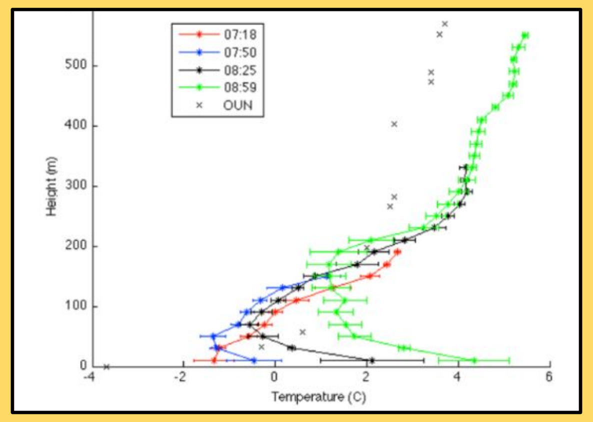
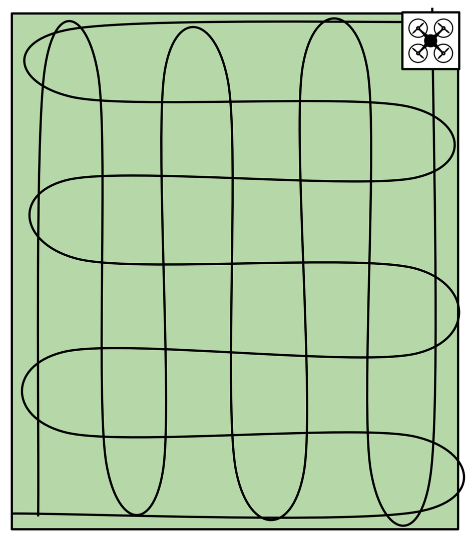


Figure from Chilson and Roberts, 2017: three different sUAS in-flight Temperature profiles taken over a one-hour period, compares sUAS measurements with an atmospheric radiosonde sensor.

Agricultural Emissions: sUAS in Action!

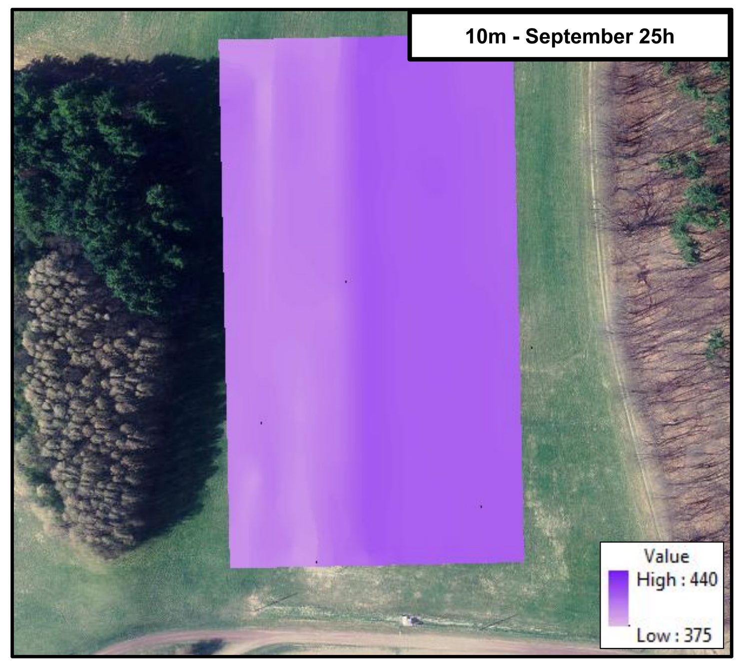
Hot spots are areas that show **high GHG emissions rates relative to the surrounding area**.
Hot moments are short periods of time that show **high GHG emissions rates relative to longer time periods**.
These dynamics are challenging to measure, monitor, and incorporate in biogeochemical modeling (McClain et al., 2003, Groffman et al., 2009). Here we explore two sUAS sampling methods that may help better monitor these dynamics:

Horizontal Surveys:



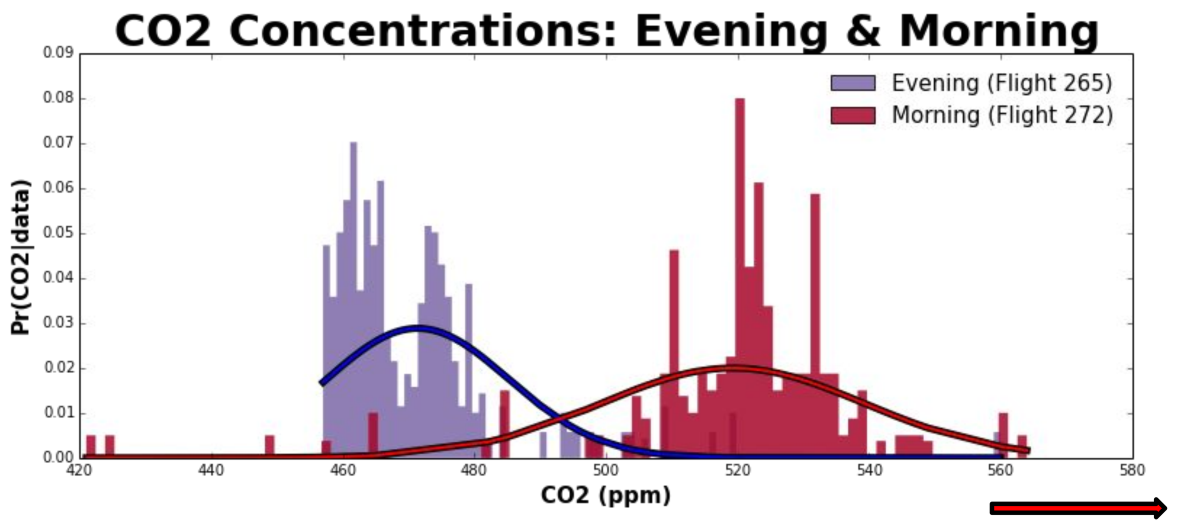
Three horizontal surveys were conducted: 2 on May 26th, flown at 5m and 10m above field, 1 on September 28th, flown at 9m above field.

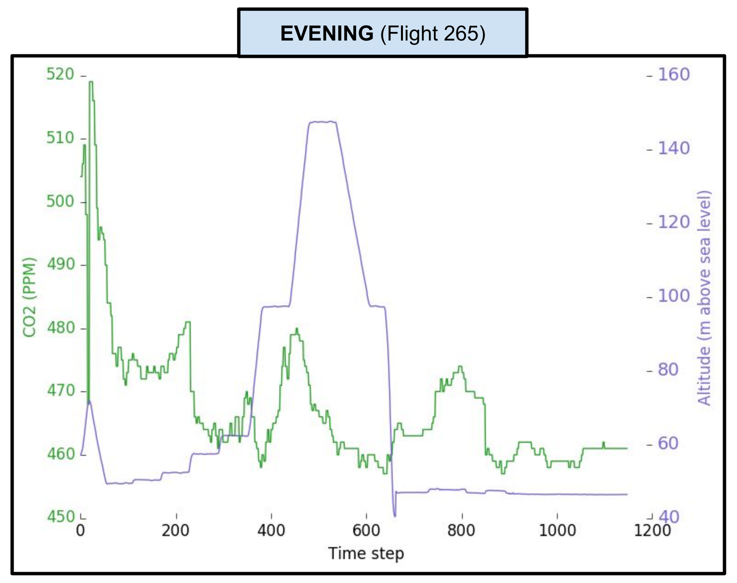
An **ANCOVA** found **spatial** (latitude and longitude) and **altitude** significant variables for CO_2 measurements.

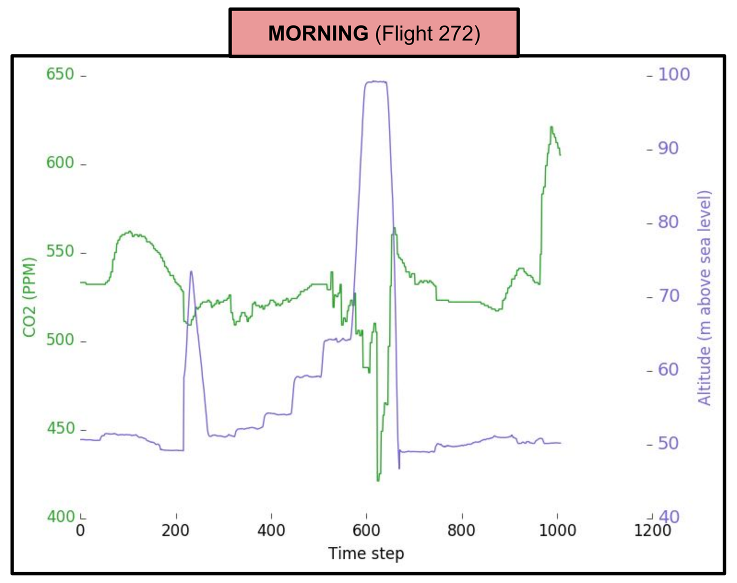


CO2 interpolated concentration maps flown at 10m above field level in spring and fall. Further work needed to link in-flight CO_2 concentrations with on-field CO_2 PAS flux rates.

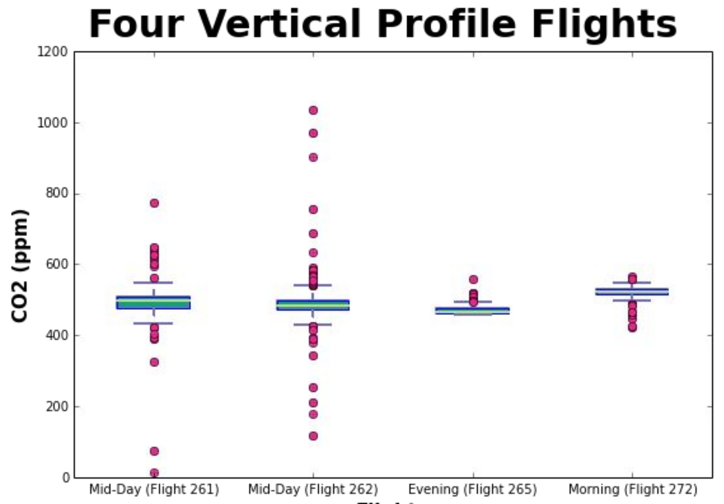
Vertical Profiles:







Example of Two vertical profiles: May 26th, May 27th. Evening and Morning CO_2 measurements have a significant difference (Mann-Whitney U Test). The higher morning CO_2 measurements, along with a **drop in CO_2 concentration with altitude** may be due to overnight pooling of CO_2.



Variability in CO_2 measurements may be attributed to time of day with a **SD 73 and 64** during midday flights, **SD 13 and 20** for evening and morning flights, during times of lower atmospheric mixing.

Take Home Points:

1. Better ways of monitoring agricultural GHG emissions are needed.
2. Remote sensing is useful, but higher spatial and temporal resolution measurements are necessary to fill gaps in agricultural emissions data.
3. sUAS collection of imagery and atmospheric data is a promising new way to measure landscape agricultural emissions.

References & Further Work

Report & Data published on OSF - https://osf.io/xcy7n/
Website for Presentations, References & Updates - www.LindsayBarbieri.com