Can a drone equipped with a miniature methane sensor determine methane fluxes from an Alaskan wetland?

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Abstract

Methane fluxes are often studied using eddy covariance flux towers or chambers placed on the soil surface. These measurement techniques have improved our understanding of methane emissions from wetlands. However, there are limitations with each measurement method. For example, chambers are fixed in place and have high maintenance costs, limiting spatial coverage and characterization of heterogeneity. Measurements taken in Interior Alaskan wetlands suggest that heterogeneity in methane fluxes from this region may increase during the fall and early winter, when the soils begin to freeze. Unfortunately, off-grid power limitations and freezing conditions complicate chamber operation during this time. Towers share similar demands with respect to maintenance and cost of operation, and, therefore, are not often replicated within a landscape. Moreover, towers provide an integrated measurement which masks any spatial heterogeneity in fluxes within the tower footprint. Therefore, although chamber and flux towers provide important insights into the carbon exchange between terrestrial and atmospheric pools, these methods have limitations, particularly when characterizing spatial heterogeneity. We tested a new technology that may be able to be counteract some of these limitations, thereby providing additional insights into methane emissions from wetlands. We outfitted a small-unmanned aerial system (sUAS, or drone), that can fly extremely close (<2 m) to the wetland's surface, with a miniature open-path laser spectrometer methane sensor, LIDAR, and a miniature anemometer. We then tested this system in several bogs near Fairbanks, Alaska. We tested if this system could detect spatial and/or temporal variability of methane emissions within a bog. We also compared methane fluxes calculated using this system to values obtained from tower and chamber measurements. Results of these missions will be presented and we will discuss the ability of this new technology to provide additional information regarding methane emissions from wetlands.

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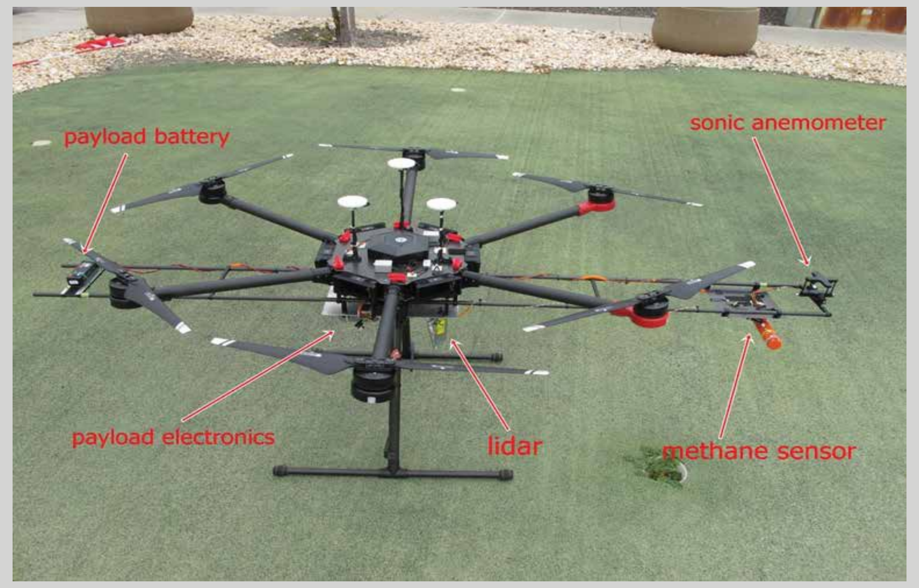
Background

Methane (CH_4) fluxes are often studied using eddy covariance flux towers or chambers placed on the soil surface. These measurement techniques have improved our understanding of CH_4 emissions from wetlands. However, there are limitations with each of these measurement methods. For example, chambers are fixed in place and have high maintenance costs, limiting spatial coverage and characterization of heterogeneity. Measurements taken in Interior Alaskan wetlands suggest that heterogeneity in CH_4 fluxes from this region may increase during the fall and early winter, when the soils begin to freeze. Unfortunately, off-grid power limitations and freezing conditions complicate chamber operation during this time. Towers share similar demands with respect to maintenance and cost of operation, and, therefore, are not often replicated within a landscape. Moreover, towers provide an integrated measurement which masks any spatial heterogeneity in fluxes within the tower footprint. Therefore, although chamber and flux towers provide important insights into the carbon exchange between terrestrial and atmospheric pools, these methods have limitations, particularly when characterizing spatial heterogeneity. Here we ask if specially outfitted small-unmanned aerial system (sUAS, or drone) can accurately measure CH_4 flux, thereby providing additional insights into CH_4 emissions from wetlands.



Configuration:

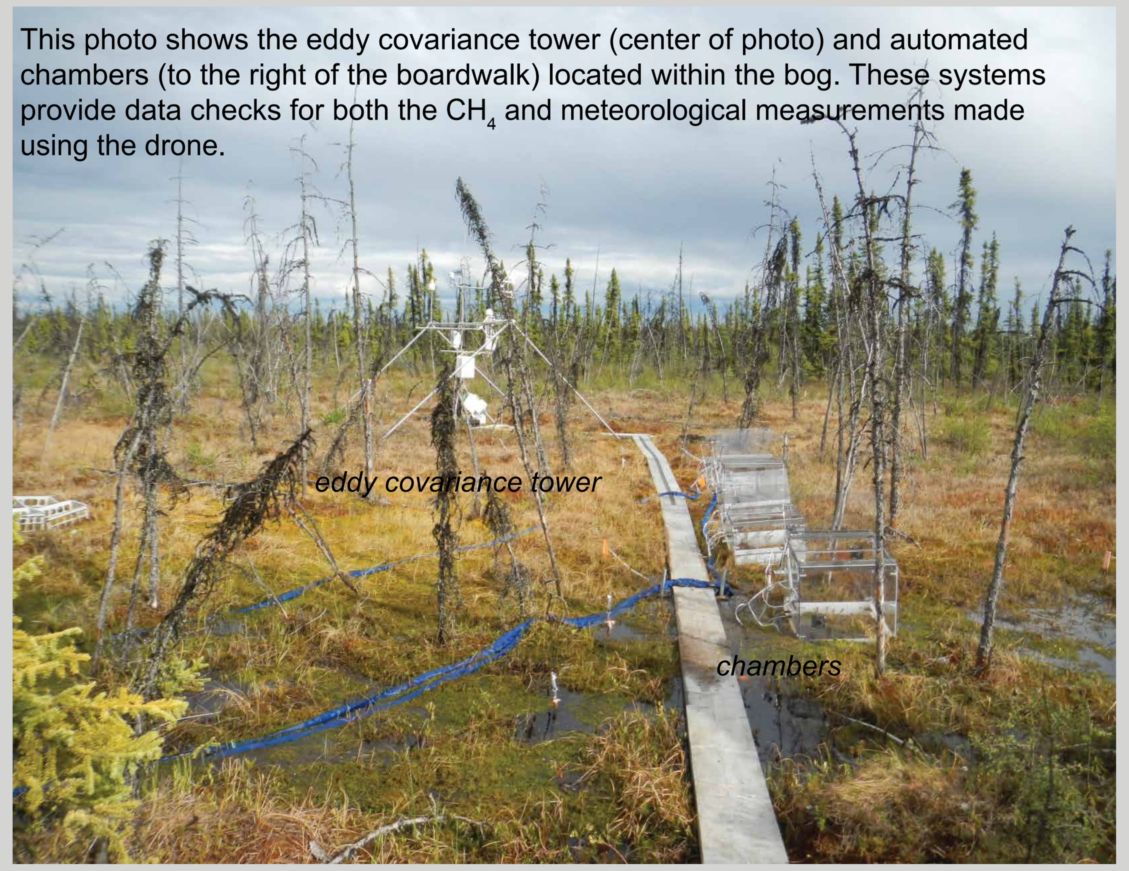
Drone:
DJI Matrice 600 multi-rotor (6-motor) sUAS with DJI A3 flight controller.

CH_4 detector:
Open-path laser spectrometer (OPLS) CH_4 sensor developed by Jet Propulsion Laboratory (JPL). This miniature gas sensor, similar to one developed for use on Mars, enables detection of CH_4 at 10 ppb s^{-1}, two orders of magnitude better than other instruments this size. It has mainly been used to discover and quantify leaks from natural gas pipelines.

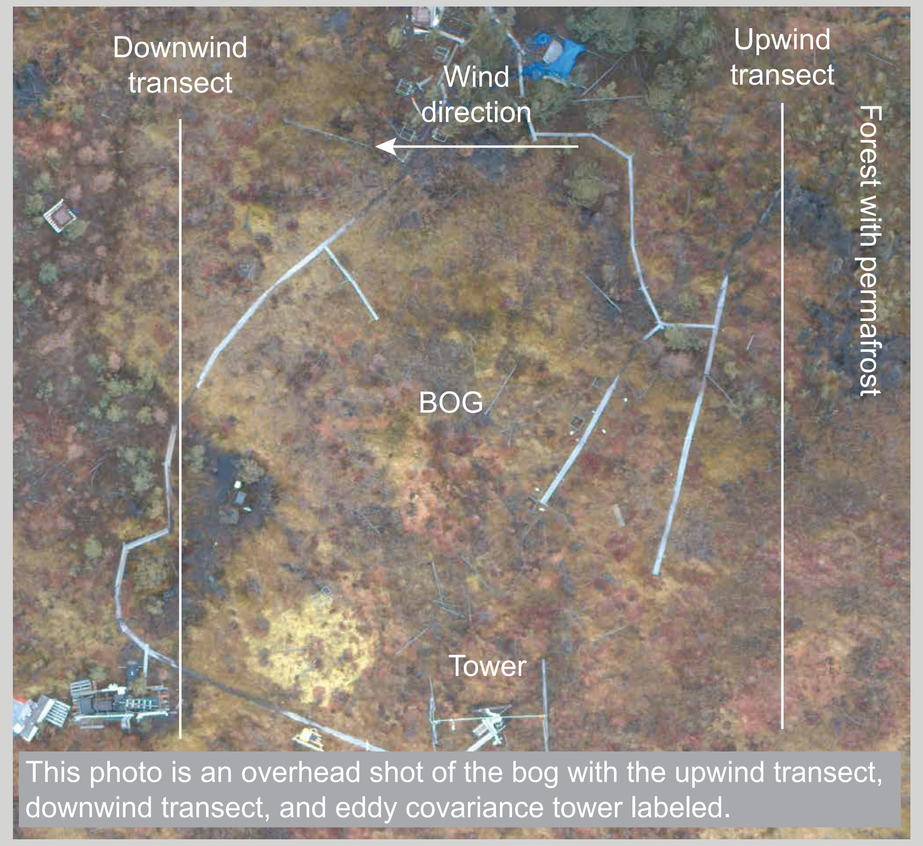
Other instruments:
Sonic 3D anemometer (wind speed and direction)
Garmin LTE LIDAR sensor (altitude)

Where we flew:

Flights were located in the Alaska Peatland Experiment (APEX) wetland complex, which is a part of the Bonanza Creek Long-Term Experimental Research Program. This site is located ~33 kilometers southwest of Fairbanks, Alaska. One of the bogs within this complex has both an eddy covariance tower and an autochamber system (left photo), providing data checks for both the CH_4 and meteorological measurements made using the drone. Within the bog we flew transects on both the upwind and downwind edges of the bog (right photo). These transects consisted of flights at different heights (2 m, 4 m, 6 m, etc.), creating a "wall" of data, from which one can calculate flux using the amount of CH_4 entering and leaving the system (known as the box model method). Challenges in flying were mostly based on finding clear flight paths that aligned with the direction of the wind.



This photo shows the eddy covariance tower (center of photo) and automated chambers (to the right of the boardwalk) located within the bog. These systems provide data checks for both the CH_4 and meteorological measurements made using the drone.



This photo is an overhead shot of the bog with the upwind transect, downwind transect, and eddy covariance tower labeled.

CH_4 measurements

With over 40 flights in 4 days we were able to test appropriate altitudes (both upper and lower limits), flying speeds, sensor orientation, and examine the impact of prop wash on CH_4 measurements in very light winds. Unfortunately, loose electronics introduced vibration-based variability into our measurements. This fact was discovered during post-trip tests comparing sensor data to Picarro data. Agreement between the two instruments was high, but once vibrations were introduced our sensor data became noisy. To account for this noise we filtered (removing data where point-to-point differences were outside of 2 standard deviations) and smoothed (averaged over 10 s) the sensor data. Despite this filtering, we see differences in the CH_4 signal with height (Figure 1) and between upwind and downwind transects (Figure 2).

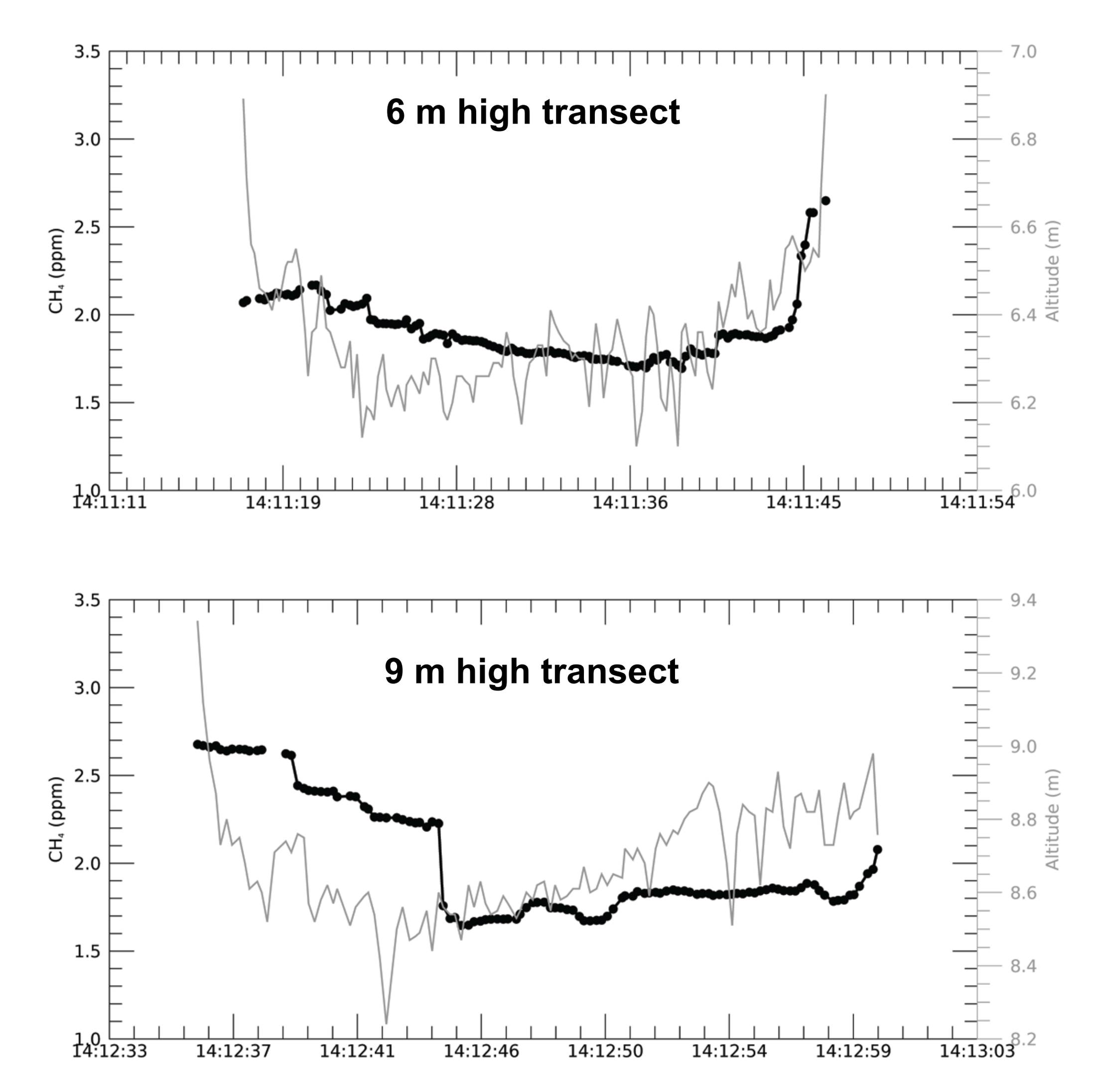


Figure 1. CH_4 (black) and altitude (gray) measurements. The measurements from 6 m are more similar to background measurements of CH_4 (~ 2 ppm), whereas there are elevated levels of CH_4 in the 9 m high transect. Rapid increases in CH_4 associated with the drone changing altitude (tail end of the 6 m data) are likely due to increased propeller speed in order to increase elevation. Such artifacts need to be removed from the data.

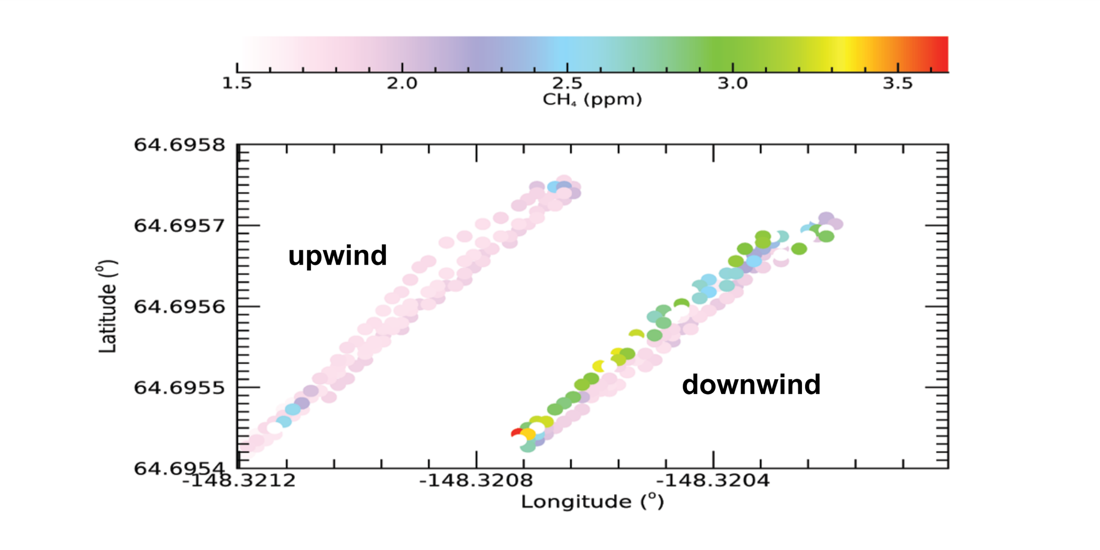


Figure 2. A comparison of CH_4 measurements from upwind (left) and downwind (right) transects. Higher and more variable amounts of CH_4 were found in the downwind leg, indicating that as long as flights extend into the boundary layer, we can use these data to calculate CH_4 flux.

Altitude and wind measurements

We compared altitude measurements using LIDAR to those measured by the drone to ensure that surface vegetation was not adversely affecting the LIDAR values. Figure 3A shows more variability with the LIDAR values (blue) than the drone values (red), but that overall values are the same. Instead, we had some issues with the altitude measurements of the drone. Over time the drone's surface value (altitude = 0 m) drifted, causing subsequent transects to be lower than what was programmed (Figure 3B). This problem was not consistent and was somewhat alleviated by having shorter flights (i.e., returning to home base between upwind and downwind transects.)

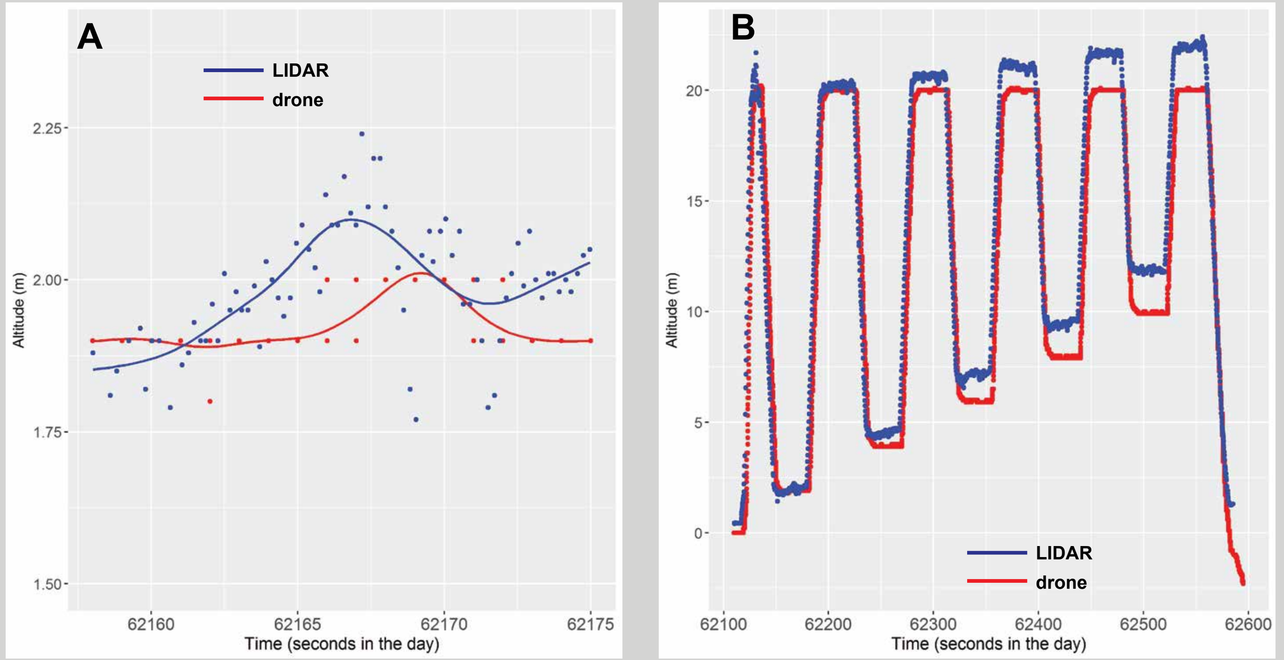


Figure 3. Two comparisons of altitude measurements from the LIDAR (blue) versus what the drone recorded (red). [A] The LIDAR recorded altitude fairly well, although its measurements were more variable than what was recorded by the drone, likely due to surface vegetation and uneven surfaces. [B] At times the drone had issues with shifting surface values (altitude = 0 m), which caused some of the flown altitudes to be lower than what was programmed. This error is caused an offset between the two measurements.

Unfortunately, the Sonic anemometer did not work during the majority of the flights. While it would start logging data, within the first few minutes of flight it would stop functioning correctly. We are still investigating what caused this problem.

Conclusions

- The CH_4 values obtained from our test flights show this system can provide the needed accuracy to calculate flux using the box method, even with the added noise due to sensor alignment issues. Future measurements, with a sensor that is fully operational, will be even more accurate.
- Mounting a CH_4 sensor on a drone appears to be an effective way to measure CH_4 flux from a wetland. In future flights we will confirm that these flux values are accurate by comparing these data against tower and chamber measurements taken within the same wetland.
- Many lessons were learned during these initial flights, including best practices for drone orientation and speed as well as modifications needed for our pre-flight checks to ensure correct functioning of the CH_4 sensor.
- Further work is needed to ensure accurate wind measurements.
- We are investigating the possibility of adding a CO_2 sensor to this configuration and plan to do further flights in both California and Alaska in 2019.

The team: Ric Kolyer, Jack McFarland, Kristen Manies, and Jonas Jonsson

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