A Drone in Search of Methane

Project Summary – February 2016

Chris Hugenholtz, PhD
Thomas Barchyn, MSc, PGeo
University of Calgary

SUMMARY. *This overview outlines initial research to establish the viability of using a small drone to measure atmospheric concentrations of released methane. Drones offer a new and unexplored perspective for understanding methane emissions. Potential applications of the technology include: methane monitoring, baselining, compliance auditing, inventorying, leak detection, and air emission model testing and refinement.*

We conducted a field test to evaluate whether a small drone equipped with a gas detector could resolve a methane plume from a controlled release. The system was developed by Ventus Geospatial Inc. and Boreal Laser Inc. During the field test we acquired allied measurements of methane concentration and wind velocity at ground level downwind from the well. Results indicate the system was successful in locating the point source emission. Future testing is planned to further benchmark and mature this emergent and promising technology.

THE PROBLEM

Methane (CH_4) is the primary component of natural gas and the second most important greenhouse gas (GHG) released by human activities. Through the production, processing, and transmission of natural gas, CH_4 is released into the atmosphere from known emission sources (e.g. venting) and fugitive sources (e.g. leaks). Once in the atmosphere, CH_4 is highly effective in trapping solar radiation, significantly more so than the equivalent amount of carbon dioxide (CO_2) on decadal timescales. However, like other GHGs, CH_4 rapidly disperses when released into the atmosphere, making it particularly challenging to locate unknown leaks and measure known sources. Reducing human-caused emissions of CH_4 is an important component of new climate change policies and emission targets aimed at slowing the pace of global warming[1,2]. For example, studies in the Barnett Shale (TX, USA) suggest that 1.5% of natural gas production is lost to the atmosphere[3]. Encouragingly, most of this was attributed to a few particularly potent sources. Achieving significant reductions in CH_4 emissions will depend on a foundation of cutting-edge measurement and leak detection technology.

There are a number of ways to measure CH_4 emissions, broadly classified as top-down (TD) or bottom-up (BU). TD approaches involve atmospheric sampling downwind from the source, whereas BU approaches involve source-based estimates. Both approaches have limitations. Satellites and piloted aircraft resolve a regional picture of methane concentration, but in most cases the data are only amenable to the identification of the largest fugitive sources[4]. Piloted aircraft are expensive and less routinely used. Mobile and *in situ* ground-based methods are effective at measuring sources, but require good road access immediately downwind of the source and cannot position sensors in the same locations as aircraft. Drones present a low-cost and flexible option, producing close range airborne CH_4 measurements inexpensively and safely.

WHY A DRONE?

Drones are pilotless aircraft that are also commonly referred to as uninhabited/ unmanned aerial vehicles (UAVs), uninhabited/ unmanned aircraft systems (UAS), or remotely-piloted aircraft systems (RPAS). Despite their military origins, they are rapidly gaining

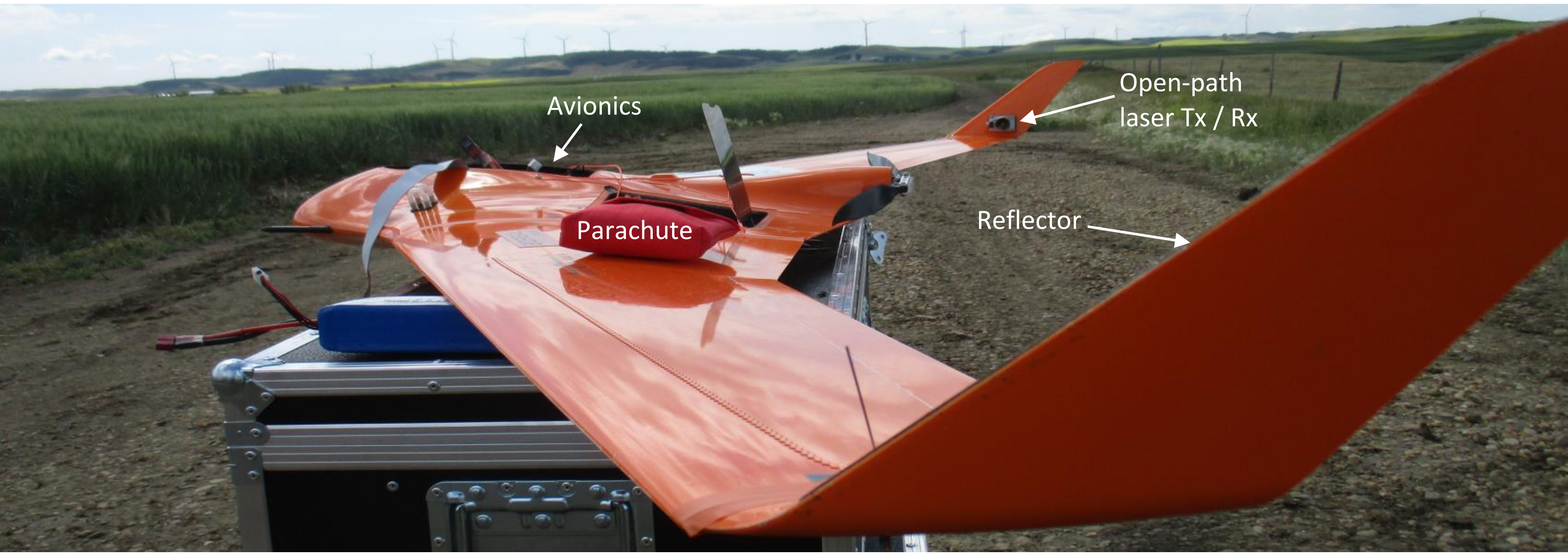
[1] https://www.whitehouse.gov/sites/default/files/strategy_to_reduce_methane_emissions_2014-03-28_final.pdf
[2] http://www.alberta.ca/climate-methane-emissions.cfm
[3] Zavala-Araiza, D. *et al*., 2015, Reconciling divergent estimates of oil and gas emissions, *PNAS* 112, 15597-15602.
[4] Kort, E.A. *et al*., 2014. Four corners: the largest US methane anomaly viewed from space. *Geophys. Res. Lett.* 41, 6898-6903.

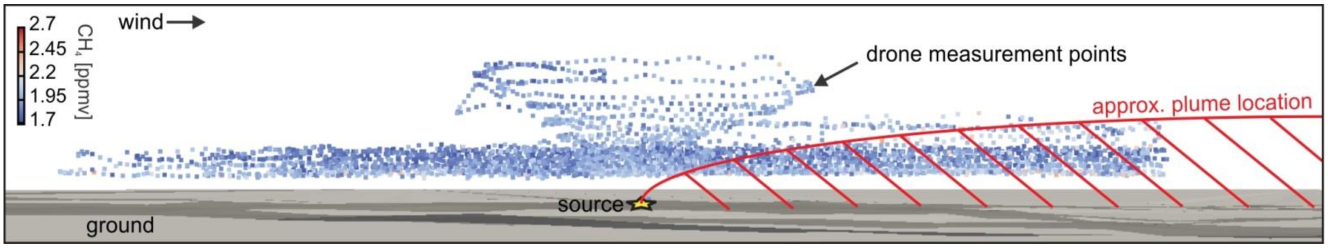
traction in a wide array of non-military and commercial applications. In the context of atmospheric GHG measurement, drones have a number of inherent advantages over conventional approaches, whether ground-based or aerial: (i) they have low capital and operating costs compared to piloted aircraft, particularly for the smaller drones commonly used in environmental monitoring (<25 kg); (ii) they can fly low and slow, which enhances the capacity to sample and locate fugitive emissions; (iii) they can be deployed on demand with limited logistical support; and (iv) they have autonomous capabilities during flight, which means they can fly pre-programmed missions, with on-the-fly adjustments as needed. Although drones hold promise for measuring CH_4 when equipped with appropriate sensors, they have yet to be deployed in an operational capacity for routine measurement. Following the preliminary work described herein, there is strong scientific basis for considering drones as a viable technology for measuring GHGs.

TECHNOLOGY

The drone technology used in this project consists of two integrated components: (i) the aircraft platform and (ii) the CH_4 sensor. The aircraft used here is a fixed-wing (2.3 m wingspan) battery-operated platform with a flight endurance of 90 minutes and a cruise speed of 16 m/s. The drone flies completely autonomously, but can be over-ridden by a ground pilot at any time. Flight control and monitoring are performed in real-time with a ground control station with radio communication (30 km range). The drone launches with a catapult and lands with a parachute. Once the drone is transported on-site, it can be prepared for takeoff by a qualified operator within 15-20 minutes. This project specifically targeted an aircraft platform that has a proven track record operating in harsh environments, is reliable, and safe.

The CH_4 sensor onboard the drone is a miniaturized version of the GasFinder system, developed by Boreal Laser Inc. The sensor is an open-path laser gas monitor with an integrated transmitter/receiver unit and a remote, passive retro-reflector. The transmitter is attached to one of the winglets on the drone, while the other winglet, serving as the retro-reflector, is coated with reflective material. Changes in the laser signal and light intensity received by a photo detector are used to estimate the gas concentration.





***Above:** The raw flight data viewed horizontally. The wind direction spread the plume to the right (general location of plume is marked in red). Due to variability in CH_4 concentrations within the plume, drone measurements require dedicated post-processing.*

The total weight of the drone and gas sensor is 3.8 kg. During flight, the system operates autonomously, acquiring averages of raw measurements at approximately 1 Hz, with a resolution of 0.0455 ppm. The onboard measurement and control unit (MCU) for the gas sensor is integrated with the drone avionics in order to provide time-stamped and geo-tagged concentration measurements, and to provide real-time flight adjustments when concentration exceeds a pre-determined threshold.

EXPERIMENT

An experiment was conducted in southern Alberta (Canada) to understand the capabilities of the sensor and develop post-processing software. A total of 3790 data points were collected over a known CH_4 source located on a natural gas pipeline. Winds and atmospheric conditions were monitored with both ground-based meteorological instruments and data logged from the drone. A ground-based GasFinder system was also used to benchmark the source emissions immediately downwind from the source.

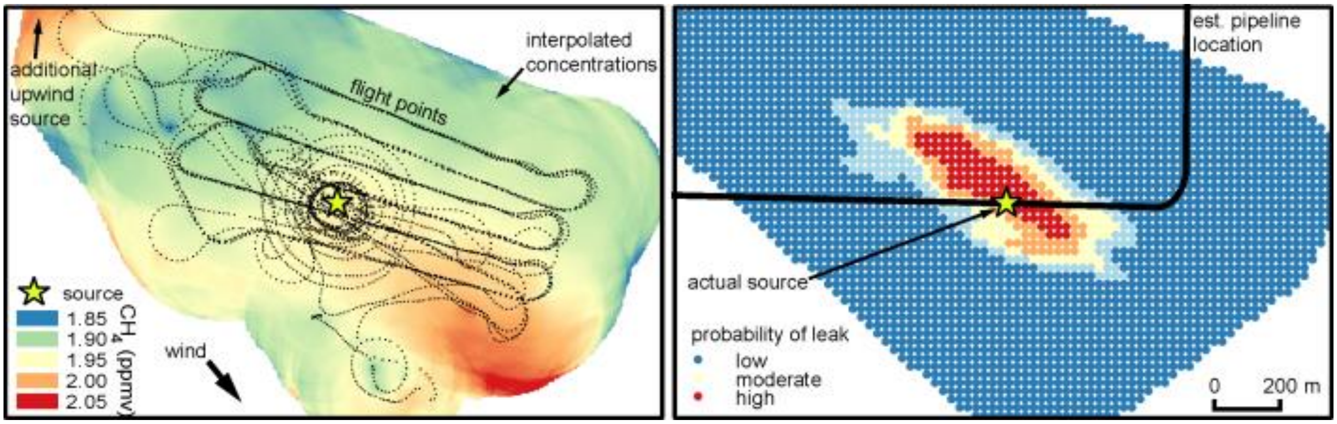
Flight levels ranged from 40 m to 186 m above the launch location. Data were collected in a series of lines to collect both upwind 'clean' conditions, and conditions within the plume, producing 3790 independent CH_4 measurements over 56 minutes of flight time.

Post-processing of drone measurements facilitates extraction of information about source locations. At a close range downwind from a source, there is high spatial and temporal variability in pollutant mixing ratios as a result of wind turbulence. Drone data can measure this variability, necessitating special data analysis techniques and custom analysis software. Drone measurements were first interpolated in 3D space to better visualize the systematic distribution of gas concentrations. This revealed the plume location, but also exposed additional sources that were previously unknown. These sources are likely vented tanks upwind from the study site.
To simulate a leak detection survey, the data were inverted to rank the probability of 3504 potential sources. The fit between the measured concentration data and the expected concentration data from the hypothetical source gives an indication of the source location. The highest probabilities were associated with a band centered on the actual source location. Combined with an estimate of the actual pipeline location, the location of the simulated leak could be estimated to within approximately 100 m – close enough range for ground crews to further investigate.

OTHER APPLICATIONS

Aside from natural gas production and distribution, open-area sources such as tailings ponds and landfills are important emitters of CH_4. Drones are particularly well suited for these applications, allowing large scale data collection easily and inexpensively[5]. Future field trials are required to benchmark this system for use with conventional mass-balance

[5] Environment Agency, UK, 2015. Measuring landfill methane emissions using unmanned aerial systems: field trial and operational guidance. Environment Agency Report SC140015.



Left: *Post-processed interpolated CH_4 concentrations viewed from above at 60 m above ground: red colors correspond to regions with higher concentrations. The plume from the source is visible in the data, but there are clearly additional plumes from unknown upwind sources.* ***Right:*** *The drone data can be used to estimate an unknown leak location. Drone data were inverted to rank probabilities of 3504 potential sources (marked by dots). Red colors indicate a location is more likely to be the leak location. With an estimated pipeline location, the drone data in this study could locate the source to within ≈100 m. Maps are identical scale and extent.*

post-processing methods.

Concentrated animal feeding operations ('feedlots') are similarly important CH_4 emissions sources. Head-based, bottom-up measurements are subject to important uncertainties. Using drones to measure emissions may facilitate deeper understanding into the variability of emissions and provide guidance of emissions reductions and inventorying[6].

Together, the technology developed in this project shows promise for widespread application. Careful testing and benchmarking of capabilities is planned in 2016 to further mature this technology into operational readiness.

Disclaimer: The data and results presented here are intended to provide a broad overview of the project, and as such are preliminary and have not undergone peer-review. All technology presented here is under active development and subject to change.

Drone regulations: *All commercial and research drone operators must be aware of the exemption conditions under sections 602.41 and 603.66 of the Canadian Aviation Regulations. When the take-off weight of the drone is > 25 kg, a Special Flight Operations Certificate is required; however, for drones < 25 kg the requirements are less stringent, and even more so when < 2 kg. Although the ability to fly beyond visual line of sight is possible with the system described here (tested up to 30 km), and is highly desirable for certain applications involving CH_4 emissions, Transport Canada regulations are evolving for this type of mission and are expected to be completed soon.*

[6] Miller D.J., *et al*., Ammonia and methane dairy emission plumes in the San Joaquin Valley of California from individual feedlot to regional scales, *J. Geophys. Res.: Atmospheres* 120, 9718-9738.