Open-path Spectroscopy to an Airborne Retroreflector on a Quadcopter

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Measuring trace gas emissions from spatially complex and temporally variable sources, such as leaking natural gas infrastructure, is challenging with existing measurement systems due to the associated variability. Small unmanned aerial systems (sUAS) could solve this challenge because of their ability to provide both horizontal and vertical spatial resolution. However, the payload restrictions of sUASs limit the available instrumentation. In particular, high-sensitivity trace gas measurement systems are currently too heavy and large to fly with most sUASs. Here, we present a new measurement system, based on the technique of dual frequency comb spectroscopy, that addresses this difficulty by simultaneously measuring the path-integrated concentration of multiple gases with high precision between a ground station and a retroreflector mounted on a small quadcopter. Currently, the frequency comb operates in the near-infrared spectral region from around 5900 to 6700 cm^{-1}, which allows rapid (~10-second) measurements of acetylene (C_2H_2), carbon dioxide (CO_2), methane (CH_4), water (H_2O), and hydrogen-deuterium oxide (HDO). The eye-safe frequency comb light is launched from a telescope on a fast azimuth/elevation gimbal to a lightweight retroreflector mounted on a small quadcopter, which also carries a GPS receiver and pressure, temperature, and humidity sensors. The motion of the quadcopter is tracked by the ground station using an image-processing-based feedback system. We will show results from field tests of this system for emissions quantification using simultaneous controlled releases of CH_4 and C_2H_2 in an approximately 200x200 m^2 area. Using a micro-meteorological mass-balance approach, we find good agreement with the known emissions rate with a scatter of ±20% for a single, ~10-min-long measurement.

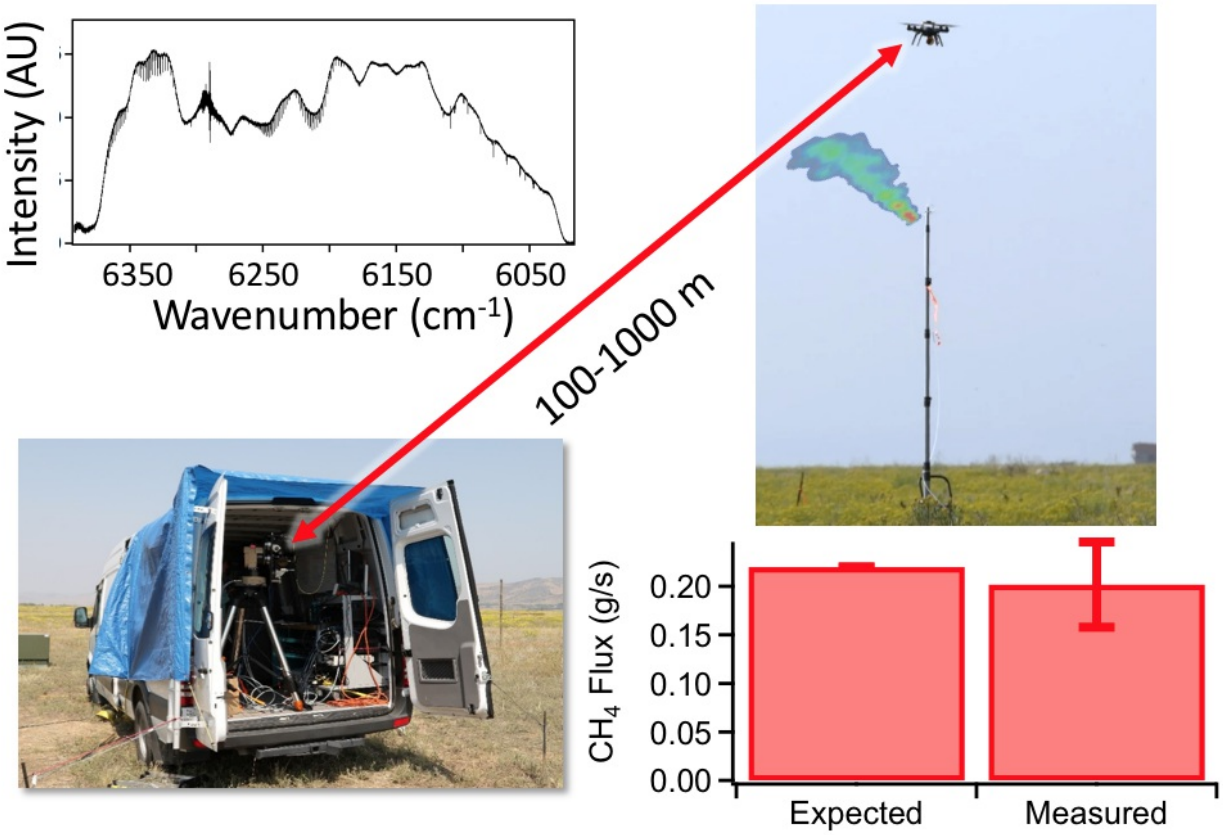

Figure 1. Mobile dual-comb spectroscopy for emissions quantification of controlled CH_4 releases. The frequency comb light is launched from a telescope in a van to a retroreflector on a quadcopter, which is flown downwind of a controlled CH_4 and C_2H_2 release. The returned spectrum **(upper left)** is processed to obtain the path-integrated gas concentration. By measuring a vertical profile downwind, the emissions rate can be determined **(lower right)**.