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An Open-Path Tunable Diode Laser Sensor for Measurement of Greenhouse Gases at the Bonanza Creek Long Term Ecological Research Site near Fairbanks, Alaska

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Permafrost makes up one-quarter of the Earth's terrestrial surface and, as global temperatures continue to increase, it is at risk of thawing. Thawing permafrost has the potential to release twice the amount of carbon than is currently in the atmosphere. A multi-year field campaign has begun in collaboration with the University of Alaska – Fairbanks, NASA Goddard Space Flight Center, and our group at George Washington University to study carbon feedbacks during a springtime thaw at the Bonanza Creek Long Term Ecological Research site near Fairbanks, Alaska.

Here we present initial results from our near-infrared open-path instrument for the detection of ground-level concentrations of carbon dioxide (in subsequent field campaigns a second channel for methane detection will be added). The optics *launch-box* portion of the instrument couples a near-infrared distributed feedback laser operating near 1605 nm for carbon dioxide detection with a visible laser for alignment purposes. The outgoing beam is directed through a 3.2-mm hole in a parabolic mirror and the *launch-box* is oriented using a two axis, alt-azi telescope mount so that the beam will hit the retroreflector target at a set distance downfield. The beam then retraces the path back to the launch-box where the light is collected on the surface of the parabolic mirror and focused onto a multi-mode fiber for detection. Using a National Instruments data acquisition system we are able to collect 500 scans per second which allows for long-term data averaging and subsequently increases the signal-to-noise ratio (SNR) of our signal. In June 2015, the instrument was deployed to a thermokarst collapse scar bog in the Bonanza Creek Experimental Forest. With a 90 meter total pathlength we were able to resolve carbon dioxide absorption signals on the order of 0.5% utilizing direct-absorption spectroscopy.

We also present the lab-scale implementation of wavelength modulation spectroscopy to increase the sensitivity of our instrument. Wavelength modulation spectroscopy entails applying a small amplitude modulation (on the order of the width of a spectral feature) to a laser's emitted frequency as it tunes through a spectrum. By sampling the detector's signal at a multiple of the modulation frequency, the resulting signal takes on the appearance of the spectrum's derivative. Typically, this is accomplished using a lock-in amplifier. To avoid the power burden of this electrical component we are exploring the use of digital signal processing using a microcontroller embedded in the sensor. Spectral simulations suggest that at ambient levels of CO_2 and CH_4 (400 and 2 ppmV, respectively) we will observe extinction coefficients of $\approx 10^{-4}$ m^{-1} or $\approx$ 1% absorption over a 200 m path. Prior work in our laboratory suggests that a SNR in excess of 100 will be achievable at these absorption levels using wavelength-modulation techniques.