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Laser sounder for measuring atmospheric CO2 concentrations: Progress toward ASCENDS

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The next generation of space-based, active remote sensing instruments for measurement of tropospheric CO2 promises a capability to quantify global carbon sources and sinks at regional scales. Active (laser) methods will extend CO2 measurement coverage in time, space, and perhaps precision such that the underlying mechanisms for carbon exchange at the surface can be understood with sufficient detail to confidently project the future of carbon-climate interaction and the influence of remediative policy actions. The recent Decadal Survey for Earth Science by the US National Research Council has recommended such a mission called the Active Sensing of CO2 Emissions over Nights, Days, and Seasons (ASCENDS) for launch in 2013-2016.

We have been developing a laser technique for measurement of tropospheric CO2 for a number of years. Our immediate goal is to develop and demonstrate the method and instrument technology that will permit measurements of the CO2 column abundance over a horizontal path and from aircraft at the few-ppmv level. Our longer-term goal is to demonstrate the required capabilities of the technique, develop a space mission approach, and design the instrument for an ASCENDS-type mission.

Our approach is to use a dual channel laser absorption spectrometer (i.e., differential absorption in altimeter mode), which continuously measures from a near-polar circular orbit. We use several co-aligned tunable fiber laser transmitters allowing simultaneous measurement of the absorption from a CO2 line in the 1570 nm band, O2 extinction in the oxygen A-band (near 765 nm), and aerosol backscatter in the same measurement path. We measure the energy of the laser echoes at nadir reflected from land and water surfaces, day and night. The lasers have spectral widths much narrower than the gas absorption lines and are tuned on and off the selected CO_2 and O_2 lines at kHz rates. The gas extinction and column densities for the CO_2 and O_2 gases are estimated from the ratio of the on and off-line signals via the DIAL technique. We use pulsed laser signals, photon counting detectors, and time gating to isolate the laser returns from the surface, and to reject photons scattered from thin clouds and aerosols. High signal-to-noise ratios are required and the CO_2 estimates can be sensitive to small drifts or other errors in the instrument, so the absorption estimates need to be quite stable for hours.

We have constructed a breadboard version of the CO_2 sensor that uses a low-power fiber laser and a 20 cm diameter telescope. We have used it to make measurements of CO_2 absorption in the laboratory and over 200-m to 2-km long open horizontal paths. These have been done in several sessions extending over multiple days, which allows us to assess the measurement stability and to compare absorption variations to readings from an external in situ CO_2 sensor. We have also calculated characteristics of the technique for space including its expected measurement performance for different modulation types, and have performed an initial space mission accommodation study. We will describe these results in the presentation.