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Airborne Lidar measurements of Atmospheric CO2 Column Absorption and Line Shapes from 3-11 km altitudes

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Accurate measurements of tropospheric CO2 abundances with global-coverage are needed to quantify processes that regulate CO2 exchange with the land and oceans. The 2007 Decadal Survey for Earth Science by the US National Research Council recommended a space-based CO2 measuring mission called ASCENDS. We have been developing a technique for the remote measurement of tropospheric CO2 concentrations from aircraft and as a candidate for the ASCENDS mission. It uses the 1570-nm CO2 band and a dual channel laser absorption spectrometer (ie DIAL used in altimeter mode). It uses several tunable laser transmitters allowing simultaneous measurement of the absorption from a CO2 absorption line in the 1570 nm band, O2 extinction in the oxygen A-band, and surface height and aerosol backscatter in the same path. It directs the narrow co-aligned laser beams toward nadir, and measures the energy of the laser echoes reflected from land and water surfaces. During the measurement, the lasers are stepped in wavelength across the CO2 line and an O2 line (near 765 nm) at a $\sim$ 1 kHz rate. The receiver uses a telescope and photon counting detectors, and measures the background light and energies of the laser echoes from the surface along with scattering from any aerosols in the path. The gas extinction and column densities for the CO2 and O2 gases are estimated from the ratio of the on- and off- line signals via the DIAL technique. We use pulsed laser signals and time gating to isolate the laser echo signals from the surface, and to reject photons scattered from thin clouds and aerosols in the path.

Previously we had constructed breadboard versions of our CO2 and O2 sensors, using tunable diode lasers, fiber laser amplifiers and 20 cm diameter telescopes. We have used them to make measurements of gas absorptions over 0.2, 0.4 and 1.3 km long outdoor paths. We also have also calculated several characteristics of the technique for space and have performed an initial space mission accommodation study.

During 2008 we reconfigured our lidar for airborne use and made measurements of atmospheric CO2 absorption in the nadir column from the aircraft to the surface during 5 flights. The airborne lidar sweeps the laser wavelength across the CO2 line in either 10 or 20 steps per measurement. The line scan rate is $\sim$ 1 KHz and the laser pulse widths are 1 usec. The time resolved laser backscatter is collected by the telescope and detected by a photomultiplier and recorded by a photon counting timing system. We installed our lidar on the NASA Glenn Lear-25 aircraft in October and first made measurements using the 1571.4 nm CO2 absorption line while flying in northern Ohio. We made laser backscatter and absorption measurements over a variety of land surface types, water surfaces and through thin clouds, broken clouds and to cloud tops. Strong laser signals were observed at altitudes from 2.5 to 11 km on two flights. We completed three additional flights during December 2008 and gathered over 6 hours of atmospheric CO2 column measurements using the 1572.02 and 1572.33 nm CO2 lines. Airborne CO2 line shape and absorption measurements were made while flying at 3-11 km altitudes over southwestern Ohio. Subsequently two flights were made from Ponca City OK, just east of the US Department of Energy's (DOE) ARM site. We made 4 hours of airborne measurements in square patterns around the ARM site at altitudes from 3-8 km. The increased CO2 line absorptions at higher altitudes were evident in all flights. The December flights were also coordinated with DOE investigators who flew an in-situ CO2 sensor on a Cessna aircraft inside the CO2 sounder's flight pattern. These yielded two height resolved profiles of CO2 concentrations from 5 km to the surface, which are being analyzed with radiosonde measurements for comparisons. More details of the flights, measurements and their analysis will be described in the presentation.