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## **Pulsed Airborne Lidar measurements of Atmospheric CO<sub>2</sub> Column Absorption and Line Shapes from 3-13 km altitudes**

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We have developed a pulsed lidar technique for measuring the tropospheric CO<sub>2</sub> concentrations as a candidate for NASA's planned ASCENDS space mission. Our technique uses two pulsed laser transmitters allowing simultaneous measurement of a CO<sub>2</sub> absorption line in the 1570 nm band, O<sub>2</sub> extinction in the Oxygen A-band and surface height and backscatter. The lidar measures the energy and time of flight of the laser echoes reflected from the atmosphere and surface. The lasers are rapidly and precisely stepped in wavelength across the CO<sub>2</sub> line and an O<sub>2</sub> line region during the measurement. The direct detection 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 CO<sub>2</sub> and O<sub>2</sub> gases are estimated from the ratio of the on- and off- line signals via the DIAL technique. Time gating is used to isolate the laser echo signals from the surface, and to reject laser photons scattered in the atmosphere. The time of flight of the laser pulses are also used to estimate the height of the scattering surface and to identify cases of mixed cloud and ground scattering.

We have developed an airborne lidar to demonstrate the CO<sub>2</sub> measurement from the NASA Glenn Lear-25 aircraft. The airborne lidar steps the pulsed laser's wavelength across the selected CO<sub>2</sub> line with 20 steps per scan. The line scan rate is 450 Hz, the laser pulse widths are 1 usec, and laser pulse energy is 24 uJ. The time resolved laser backscatter is collected by a 20 cm telescope, detected by a photomultiplier and is recorded by a photon counting system. We made initial airborne measurements on flights during fall 2008. Laser backscatter and absorption measurements were made over a variety of land and water surfaces and through thin clouds. The atmospheric CO<sub>2</sub> column measurements using the 1572.33 nm CO<sub>2</sub> lines. Two flights were made above the US Department of Energy's (DOE) SGP ARM site at altitudes from 3-8 km. These flights were coordinated with DOE investigators who flew an in-situ CO<sub>2</sub> sensor on a Cessna aircraft under the path. The increasing CO<sub>2</sub> line absorptions with altitudes were evident and comparison with in-situ measurements showed agreements to 6 ppm.

In spring 2009 we improved the aircraft's nadir window and during July and August we made 9 additional 2 hour long flights and measured the atmospheric CO<sub>2</sub> absorption and line shapes using the 1572.33 nm CO<sub>2</sub> line. Measurements were made at stepped altitudes from 3-13 km over a variety of surface types in Nebraska, Illinois, the SGP ARM site, and near and over the Chesapeake Bay in North Carolina and eastern Virginia. Strong laser signals and clear CO<sub>2</sub> line shapes were observed at all altitudes, and some measurements were made through thin clouds. The flights over the ARM site were underflown with in-situ measurements made from the DOE Cessna. Analysis shows that the average signal levels follow predicted values, the altimetry measurements had an uncertainty of about 4 m, and that the average optical line depths follow the number density calculated from in-situ sensor readings. The Oklahoma and east coast flights were coordinated with a LaRC/ITT CO<sub>2</sub> lidar on the LaRC UC-12 aircraft, a LaRC in-situ CO<sub>2</sub> sensor, and the Oklahoma flights also included a JPL CO<sub>2</sub> lidar on a Twin Otter aircraft. More details of the flights, measurements, analysis and scaling to space will be described in the presentation.