Pulsed Lidar Measurements of Atmospheric CO2 Column Absorption and Range during the ASCENDS 2009-2011 Airborne Campaigns

J. B. Abshire (1), C. J. Weaver (2), H. Riris (1), J. Mao (2), X. Sun (1), G. R. Allan (3), W. E. Hasselbrack (3), E.V. Browell (4)

(1) NASA Goddard, Solar System Exploration Division, Greenbelt, MD 20771, USA
(2) GEST, NASA Goddard, Code 613.3, Greenbelt MD 20771, USA
(3) Sigma Space Inc., Greenbelt MD 20771, USA
(4) NASA Langley Research Center, Hampton VA 23681, USA

February 2012

Abstract:
We have developed a pulsed lidar technique for measuring the tropospheric CO2 concentrations as a candidate for NASA's ASCENDS mission and have demonstrated the CO2 and O2 measurements from aircraft. Our technique uses two pulsed lasers allowing simultaneous measurement of a single CO2 absorption line near 1572 nm, O2 extinction in the Oxygen A-band, surface height and backscatter profile. The lasers are stepped in wavelength across the CO2 line and an O2 line doublet during the measurement. The column densities for the CO2 and O2 are estimated from the differential optical depths (DOD) of the scanned absorption lines via the IPDA technique.

For the 2009 ASCENDS campaign we flew the CO2 lidar only on a Lear-25 aircraft, and measured the absorption line shapes of the CO2 line using 20 wavelength samples per scan. Measurements were made at stepped altitudes from 3 to 12.6 km over the Lamont OK, central Illinois, North Carolina, and over the Virginia Eastern Shore. Although the received signal energies were weaker than expected for ASCENDS, clear CO2 line shapes were observed at all altitudes. Most flights had 5-6 altitude steps with 200-300 seconds of recorded measurements per step. We averaged every 10 seconds of measurements and used a cross-correlation approach to estimate the range to the scattering surface and the echo pulse energy at each wavelength. We then solved for the best-fit CO2 absorption line shape, and calculated the DOD of the fitted CO2 line, and computed its statistics at the various altitude steps. We compared them to CO2 optical depths calculated from spectroscopy based on HITRAN 2008 and the column number densities calculated from the airborne in-situ readings.

The 2009 measurements have been analyzed in detail and they were similar on all flights. The results show clear CO_2 line shape and absorption signals, which follow the expected changes with aircraft altitude from 3 to 13 km. They showed the expected nearly the linear dependence of DOD vs altitude. The measurements showed ~1 ppm random errors for 8-10 km altitudes and ~30 sec averaging times.

For the 2010 ASCENDS campaigns we flew the CO2 lidar on the NASA DC-8 and added an O2 lidar channel. During July 2010 we made measurements of CO2 and O2 column absorption during longer flights over Railroad Valley NV, the Pacific Ocean and over Lamont OK. CO2 measurements were made with 30 steps/scan, 300 scans/sec and improved line resolution and receiver sensitivity. Analysis of the 2010 CO2 measurements shows the expected ~linear change of DOD with altitude. For measurements at altitudes > 6 km the random errors were 0.3 ppm for 80 sec averaging times. For the summer 2011 ASCENDS campaigns we made further improvements to the lidar's CO2 line scan and receiver sensitivity. The seven flights in the 2011 Ascends campaign were flown over a wide variety of surface and cloud conditions in the US, which produced a wide variety of lidar signal conditions. Details of the lidar measurements and their analysis will be described in the presentation.