REMOTE SENSING ATMOSPHERIC CO_2 COLUMN ABUNDANCE USING AN AIRBORNE PULSED LASER SOUNDER AT 13 KM ALTITUDE

Graham R. Allan, William Hasselbrack, Haris Riris[1], James B. Abshire[1], Clark Weaver[2], Jianping Mao[3], Xiaoli Sun[1] & Arlyn E. Andrews[4]

Sigma Space Inc., Lanham MD 20706 USA
[1]NASA Goddard Space Flight Center, Mail Code 694, Greenbelt Maryland 20771 USA
[2]GEST, University of Maryland, College Park Maryland, USA
[3]Science Systems & Applications Inc., Lanham, Maryland 20706
[4]NOAA ESRL GMD, 325 Broadway, Boulder, CO 80305 USA

1. ABSTRACT

Accurate global measurments of tropospheric CO_2 abundance to the "parts per million" (ppm) level is required to better quantify processes that regulate CO_2 exchange between atmosphere, land and ocean. To this end NASA has planned the ASCENDS mission, Active Sensing of CO_2 Emissions over Nights, Days and Seasons. We report on an airborne laser-based remote sensing instrument we have developed at NASA-GSFC and flight tested to 13 km altitude which is a viable candidate for the ACENDS mission.

2. INTRODUCTION & EXPERIMENTAL

We at NASA-GSFC have developed a Lidar that is an active remote optical-sensing system designed to measure the integrated column abundance of CO_2 globally to better than 1 ppm from low Earth orbit, at all latitudes over both day and night[1]. We will report on the current status of this work. We have built, tested and flown an aircraft-based version on the NASA-GRC Learjet 25 and successfully demonstrated measurements of CO_2 column abundance to better than 6 ppm [2] from 13 km altitude.

The instrument consists of transceiver head and two half racks of instrumentation. The transmitter is a tunable, narrow-linewidth (MHz) diode-laser which is externally modulated, seeding a 10 W Erbium Doped Fiber Amplifier in a Master Oscillator Power Amplifier configuration, step-tunable through a selectable CO_2 absorption line around 1572 nm. The number of pulses per line scan is user configurable and is currently set at 20 pulses. The line-scan rate is 450 Hz and the laser pulse widths are 1 μs with a 1% duty cycle. The time resolved laser backscatter is collected by a modified 20 cm Schmidt-Cassegrain telescope and detected by a multimode-fiber coupled photomultiplier. The strong ground return, aerosol and cloud backscatter are unambiguously resolved by the system. Great care is taken to ensure that the return signals are within the bounds of the linear counting regime of the detection system. The overall system is light weight, efficient and easily scalable to higher optical powers. The frequency scanning system measures the line shape, removes background structure and instrument effects, and determines the integrated column abundance of CO_2[3].

3. RESULTS

We reported our initial measurements of a cw-ground based system at IGARSS-07. In figure 1 we show, for the first time, the relative change in CO_2 dry mixing ration measured by the laser-sounder overlaid on the height resolved CO_2 dry mixing ratio measured by the in-situ instruments of NOAA's 300m tall BAO tower. These 18 hours of continuous data are are in excellent agreement with variations one would expect when comparing point measurements to column averages.

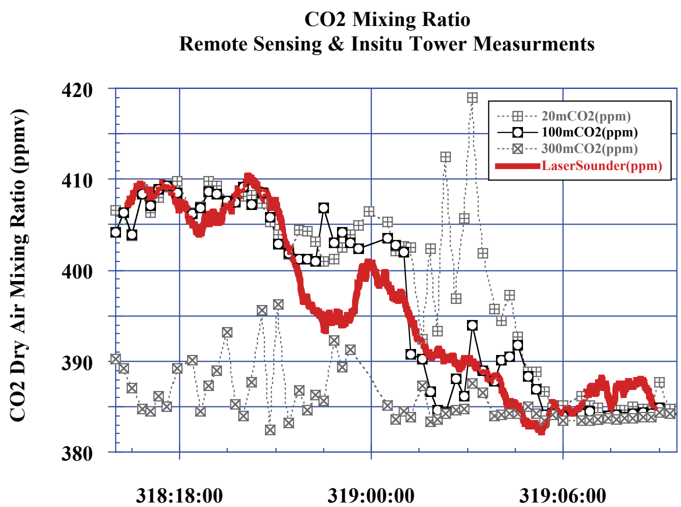

Figure 1. Eighteen hours of continuous ground-based cw-laser sounder measurement of the relative change in CO_2 dry mixing ratio overlaid on height-resolved absolute CO_2 dry mixing ratio measured by the in-situ instruments of NOAA's 300m tall BAO tower.

At IGARSS-09 we presented initial airborne measurements of flights during October and December of 2008 where laser backscatter and absorption measurements were made over a variety of land and water surfaces and through thin cirrus and broken cumulus layer. At this conference we will report on 9 additional flights of ~2 hour duration during July and August 2009 where we measured the atmospheric CO_2 absorption and line shapes using the 1572.33 nm CO_2 line. Measurements were made at stepped altitudes from 3-13 km over a variety of surface types in Nebraska, Illinois, the DOE SGP ARM site, and near and over the Chesapeake Bay in North Carolina and Virginia. Strong laser signals and clear line shapes, figure 2, were observed at all altitudes, and some measurements were made through thin clouds.

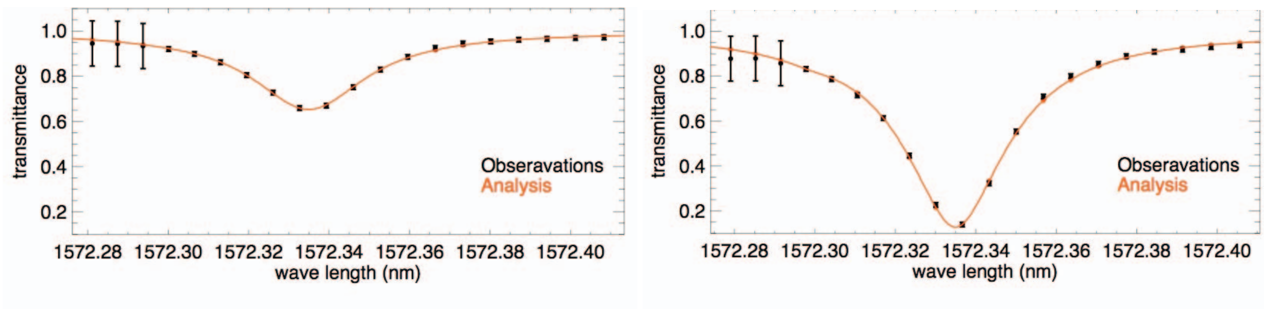

Figure 2. Measured line shapes of the 1572.335 nm line for two different altitudes, 3Km and 12.7Km. These profiles clearly show the increase in absorption with altitude. Each scan consists of 20 transmission measurements (black squares) across the absorption. The red line is a Voigt fit to the data for the measured altitude, atmospheric temperature profile and pressure.

The flights over the ARM site were underflown with in-situ measurements made from the DOE Cessna. We will compare the airborne laser sounder with calibrated instruments of Department of Energy-Atmospheric Radiation Monitoring site (DOE-ARM Oklahoma, USA) figure 3 and CO_2 vertical profiles provided by an airborne sensor flown in loose formation on the DOE Cessna Stationair courtesy of Sebastian Biraud of DOE/Lawrence Berkley National Labs. We show good agreement with the total column number density of CO_2 as measured by the in-situ sensors (red curve) and the sounder measurements from various altitudes, figure 3.

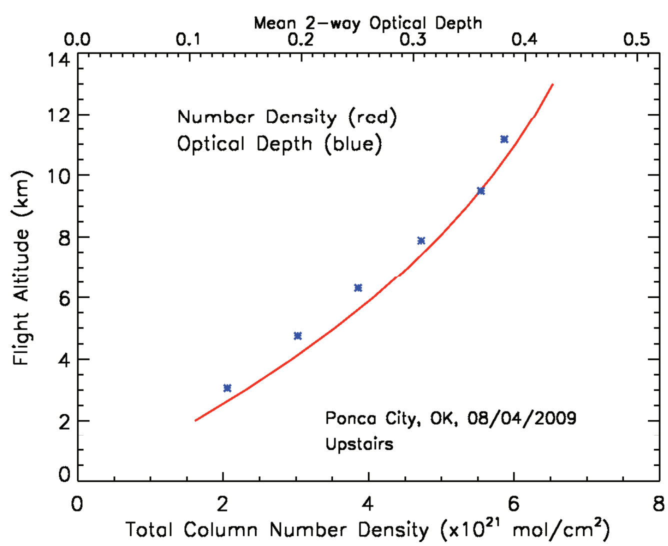

Figure 3. Comparison of total column number density of CO_2 as measured by the in-situ sensors (red curve) and the laser sounder (blue cross) for various altitudes.

The Oklahoma and east coast flights were coordinated with the NASA-LaRC/ITT CO_2 lidar on the LaRC UC-12 aircraft, a LaRC in-situ CO_2 sensor, and the Oklahoma flights also included a JPL CO_2 lidar on a Twin Otter. Ed Browell and Gary Spiers led the LaRC and JPL teams. More details of the flights, measurements and analysis will be presented.

4. SUMMARY

We will present data from our ground and aircraft based campaigns concentrating on data from both our Winter 2008 flight campaign and Summer 2009 coordinated science mission.

5. REFERENCES

[1] Riris, H., J. Abshire, G. Allan, J. Burris, J. Chen, S. Kawa, J. Mao, M. Krainak, M. Stephen, X. Sun, E. Wilson, "A laser sounder for measuring atmospheric trace gases from space," *Proc. of SPIE* Vol. 6750, 67500U, (2007) doi: 10.1117/12.737607.

[2] James B. Abshire, Haris Riris, Graham R. Allan, Clark Weaver, William Hasselbrack & Xiaoli Sun, "Pulsed Airborne Lidar measurements of Atmospheric CO2 Column Absorption and Line Shapes from 3-13 km altitudes," *2009-Fall AGU.*

[3] Graham R. Allan, Haris Riris, James B. Abshire, Xiaoli Sun, Emily Wilson, John F Burris & Michael A. Krainak, "Laser sounder for active remote sensing measurements of CO2 concentrations", *2008 IEEE AEROSPACE CONFERENCE, VOLS 1-9* Book Series: IEEE AEROSPACE CONFERENCE PROCEEDINGS Pages: 1534-1540 Published: 2008.