LASER SOUNDER FOR GLOBAL MEASUREMENTS OF CO2 CONCENTRATION FROM AN ORBITING PLATFORM.

Graham R. Allan, William Hasselbrack, Haris Riris[§], James B. Abshire[§], Clark Weaver[*], Jianping Mao[†] & Xiaoli Sun[§].

graham.allan@nasa.gov

Sigma Space Inc., Lanham MD 20706 USA

[§]NASA Goddard Space Flight Center, Mail Code 694, Greenbelt Maryland 20771 USA

[*]GEST, University of Maryland, College Park Maryland, USA

[†]Science Systems & Applications Inc., Lanham, Maryland 20706

Abstract

Accurate measurements of tropospheric CO2 abundance to the "parts per million" (ppm) level with global coverage and a high degree of spatial and temporal resolution are needed to quantify processes that regulate atmospheric CO2 exchange between land and ocean. To measure trace gases globally to the ppm level with high-spatial and temporal resolution, measuring in both high and low latitudes, in all seasons and over both day and night requires a new class of instruments -the laser sounder[1]. We report on the development of a laser sounder at NASA-GSFC that is an active, laser-based, optical-sensing system designed to measure the integrated column abundance of CO2 globally to better than 1 ppm from low Earth orbit, at all latitudes over both day and night[2]. We have currently built, tested and flown an aircraft-based instrument on the NASA-GRC Learjet 25 and successfully demonstrated measurements of CO2 column abundance up to 12 km altitude.

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 the 1572 nm CO2 absorption band in pulsed mode. The receiver consists of a modified 8" Schmidt-cassegrain telescope fiber coupled (multi-mode) to either a InGaAs pin diode or photomultiplier tube and detects the strong surface return echo. The 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 CO2.

All optical systems that measure absolute absorption are subject to systematic errors that arise from interference effects, dispersion, frequency dependent gain and reflection losses, and in open atmospheric measurements, aerosol and cloud scattering. These effects introduce structure, easily mistaken for the desired signal. These frequency dependent noise sources are time varying and difficult to eliminate. Our system, like most, is designed to minimize these effects. However, any error in determining the background greatly effects the absorption accuracy. We have modified both our hardware and software that in real-time tracks the noise and background structure and minimizes these effects on the data. The addition of a wedged beam splitter and integrating sphere as a transmitter power monitor minimizes the introduction of any interference effects and enables reliable ratios of the signal and monitor to better determine the systems background structure. Aerosol and cloud scattering can be readily identified since we are using a time resolved pulsed system.

We have improved on the standard on-line off-line determination of absorption since we directly measure the absorption line shape. We have made simple, yet significant improvements to our laser-sounder instrument and real-time data processing that now enables absolute absorption measurements to better than ± 0.05% for over 10 hours before re-calibration. This corresponds to approximately six low Earth orbits and a better chance of a successful calibration passes over the southern polar region.

We will present data from both ground and aircraft based campaigns. In particular, data comparisons with height-resolved spot measurements from the Boulder Atmospheric Observatory showing correlation, diurnal cycle and rush-hour variations in CO2. In addition we will present data from our Winter 2008 flight tests and science missions. We will compare the airborne laser sounder with calibrated instruments of Department of Energy-Atmospheric Radiation Monitoring site (DOE-ARM Oklahoma, USA) and CO2 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 will also present data showing detection of CO2 in an exhaust gas plumes from fossil fueled electricity generating power station.

REFERENCES

[1] 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

[2] Abshire, J.B., Riris, H., Allan G.R., Numata, K., Sun, X., Krainak M.,Yu A., Mumma M. *Small orbital Lidar Approach for Measuring Trace Gases in the Mars Atmosphere*, 24 ILRC 23-27 June 2008