



Airborne CO₂ Remote Measurements with 1.57-μm Laser System

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Abstract

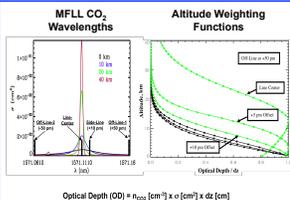
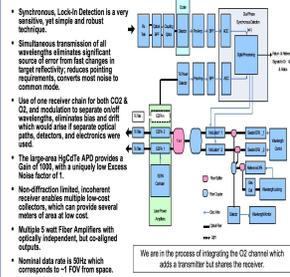
This paper discusses the flight test validation of a unique, multi-frequency, intensity-modulated, single-beam laser absorption spectrometer (LAS) that operates near 1.57 μm for remote column CO₂ measurements. This laser system is under development for a future space-based mission to determine the global distribution of regional-scale CO₂ sources and sinks, which is the objective of the NASA Active Sensing of CO₂ Emissions during Nights, Days, and Seasons (ASCENDS) mission. A prototype of this LAS system, called the Multi-Frequency Fiber Laser Lidar (MFL), was developed by ITT, and it has been flight tested in nine airborne campaigns since May 2005. This paper focuses on the most recent results obtained over the last two years of flight-testing where the MFL remote CO₂ column measurements were evaluated against airborne *in situ* CO₂ profile measurements traceable to World Meteorological Organization standards.

A comprehensive multiple-aircraft flight test program was conducted over Oklahoma and Virginia in July-August 2009. The MFL obtained surface reflectance and average CO₂ column variations along the 50-km flight legs over the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Central Facility (CF) in Lamont, Oklahoma; over rural Virginia and North Carolina; and over the Chesapeake Bay. For a flight altitude of 4.8 km, the average signal to noise ratio (SNR) for a 1-s CO₂ column measurement was found to be 760, which is the equivalent of a CO₂ mixing ratio precision of 0.60 ppmv, and for a 10-s average the SNR was found to be 2002 or 0.20 ppmv. Absolute comparisons of MFL-derived and *in situ*-derived CO₂ column measurements were made for all daytime flights conducted over Oklahoma and Virginia with an average agreement to within 0.32 ppmv.

A major ASCENDS flight campaign was conducted using the NASA DC-8 during 6-18 July 2010. The MFL system and associated *in situ* CO₂ instrumentation were operated on DC-8 flights over the Central Valley of California; the desert of southeastern California/Nevada; the Pacific Ocean off of the Baja Peninsula; Railroad Valley, Nevada; and the DOE ARM CF in Lamont, Oklahoma. Remote CO₂ column measurements were made from altitudes of 2.5 to 13 km, and *in situ* CO₂ profiles were obtained on spirals from the highest altitude on each flight to as low as 30 m at the center of the flight track. Radiosondes were also launched in conjunction with these flights to constrain the meteorological conditions for the validation of the MFL CO₂ column measurements. This poster deals with the results from the 2009 and 2010 Flight Test Campaigns.

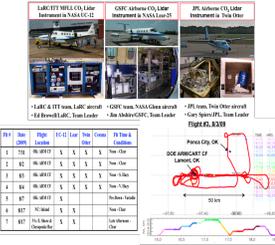
1.57-μm Multifrequency Fiber Laser Lidar (MFL)

MFL Architecture

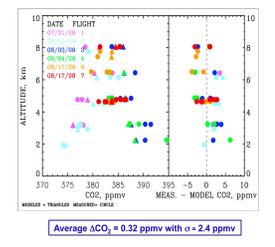
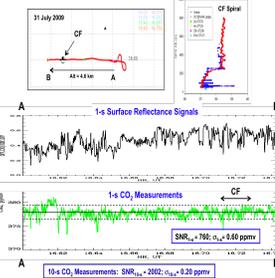


Coordinated Flight Tests 31 July-17 Aug. 2009

Participants, Flights, & Sample Fit. Plan



MFL CO₂ Precision & Accuracy Measurements



2009 MFL Flight Test Results

- Demonstrated high-precision, high-accuracy, remote measurements of CO₂ from the UC-12 during both the OK and VA deployments.
- Demonstrated CO₂ measurements with 10-s average (~1 km) over land with SNR > 2000 (σ_{CO₂} < 0.2 ppmv) and over water with SNR > 1300 (σ_{CO₂} < 0.3 ppmv).
- Absolute accuracy of CO₂ column measurements over last two campaigns found to be within 2.5 ppmv (1σ) with less than 0.4 ppmv average bias.
- Extensive data sets were collected over wide range of surfaces and atmospheric conditions for additional analysis and instrument model validation.

DC-8 Flight Test Campaign, 6-18 July 2010

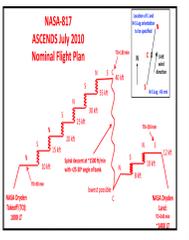
Flight Test Participants



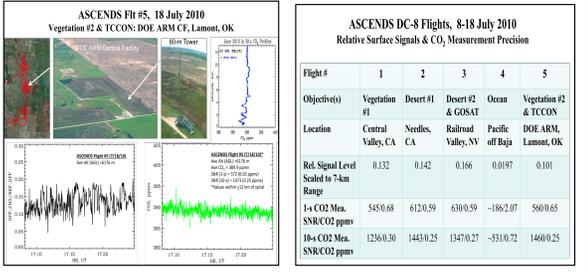
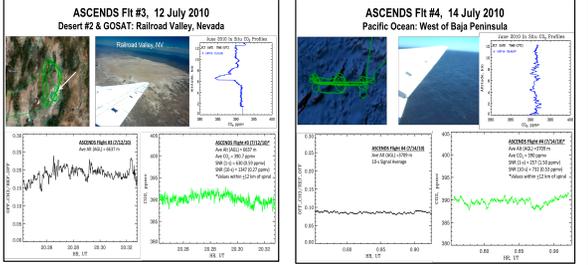
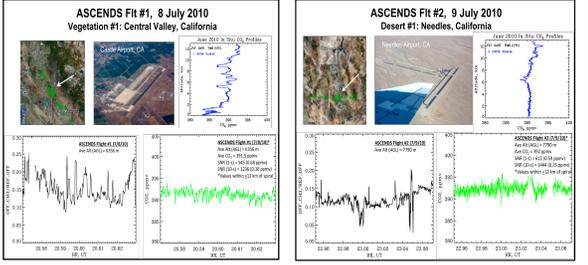
Flight Test Locations



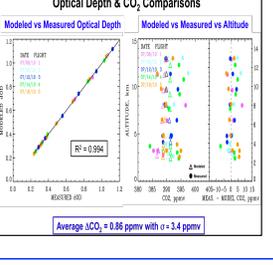
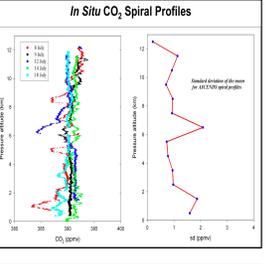
Nominal Flight Plan



MFL Surface Reflectance & CO₂ Precision Measurements



Comparison of In Situ & MFL CO₂ Measurements



2010 MFL Flight Test Results

- MFL performed very well and obtained CO₂ column measurements from all aircraft altitudes on all ASCENDS DC-8 engineering and data flights.
- Land surface signal levels comparable to those obtained during previous flight tests. Low ocean signals were attributed to depointing system alignment.
- CO₂ measurement over land from 7-km altitude for 1-s average had SNR > 500 (σ_{CO₂} < 0.78 ppmv) and for 10-s average SNR > 1240 (σ_{CO₂} < 0.3 ppmv). Over ocean 10-s SNR ~ 530 (σ_{CO₂} < 0.72 ppmv).
- Absolute accuracy of CO₂ column measurements had linear correlation with altitude and preliminary results for measurements from all altitudes on all flights indicate avg. bias of < 1 ppmv with std. dev. of < 4 ppmv.