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Airborne Validation of Laser Remote Measurements of Atmospheric Carbon Dioxide

Edward V. Browell (1), Jeremy Dobler (2), Susan A. Kooi (1), Yonghoon Choi (1), F. Wallace Harrison (1), Berrien Moore III (3), and T. Scott Zaccheo (4)

(1) NASA Langley Research Center, Science Directorate, Hampton, United States (edward.v.browell@nasa.gov), (2) ITT Geospatial Systems, Fort Wayne, Indiana, United States (jeremy.dobler@itt.com), (3) Climate Central, Inc., Princeton, New Jersey, United States (bmoore@climatecentral.org), (4) Atmospheric and Environmental Research, Inc., Lexington, Massachusetts, United States (szaccheo@aer.com)

Future space missions to globally map atmospheric carbon dioxide (CO_2) at all latitudes during the day and night, such as the ASCENDS (Active Sensing of CO_2 Emissions over Night, Day, and Seasons) mission, will require high-precision laser measurements of CO_2 columns across the troposphere from low Earth orbit. This paper discusses the development and measurement validation of a unique, multi-frequency, single-beam, laser absorption spectrometer (LAS) that operates at 1.57 μm, which has been developed for a future space-based mission to determine the global distribution of regional-scale CO_2 sources and sinks. A prototype of this space-based LAS system was developed by ITT, and it has been flight tested in eight airborne campaigns conducted over the last five years in Oklahoma, Michigan, New Hampshire, and Virginia under a wide range of atmospheric conditions.

This paper focuses on the results obtained during the last two years of flight testing where the remote LAS measurements of CO_2 were evaluated against high-quality airborne *in situ* CO_2 measurements made on spirals near the center of the LAS flight tracks. Flight tests over various land and water regions of Virginia in October 2007 showed the high correlation (R^2 = 0.995) of the LAS-measured CO_2 optical depths (ODs) with altitude, and a high correlation (R^2 = 0.996) between the remote and *in situ*-derived (modeled) CO_2 ODs. The average difference between measured and modeled ODs was less than 0.33% or the equivalent of about 1.25 ppmv of CO_2. The LAS measurement precision for a 10-s (1 km) average over land was found to be better than 0.7 ppmv and over water was better than 1.4 ppmv. During the flight tests in September-October 2008, improvements in the *in situ* sampling strategy were implemented, and the average difference between the measured and modeled CO_2 ODs was found to be 0.11% or 0.42 ppmv. A comprehensive multiple-aircraft flight test program was conducted over Oklahoma and Virginia in July-August 2009, and this resulted in an average difference between the remote and *in situ* CO_2 ODs for all six flights at all altitudes of 0.10% or 0.40 ppmv with a standard deviation of the results of 0.64% or 2.5 ppmv. LAS instrument improvements also led to a 10-s CO_2 measurement precision over land of better than 0.2 ppmv and over water of better than 0.3 ppmv. These high-precision, high-accuracy active remote CO_2 measurements represent a major step towards the realization of the needed capability for space-based laser measurements of the global distribution of CO_2. Details of the LAS flight tests and comparisons of the observed and modeled CO_2 measurements are discussed in this paper.