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First Airborne Laser Remote Measurements of Atmospheric Carbon Dioxide for Future Active Sensing of Carbon Dioxide from Space

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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 flight demonstration 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 successfully flight tested in six airborne campaigns conducted in different geographic regions over the last four years. Flight tests were conducted over Oklahoma, Michigan, New Hampshire, and Virginia under a wide range of atmospheric conditions. Remote LAS measurements were compared to high-quality in situ measurements obtained from instrumentation on the same aircraft on spirals at the center of the LAS ground tracks. LAS flights were conducted over a wide range of land and water reflectances and in the presence of scattered clouds.

The LAS flight tests resulted in the first demonstration of high-precision, high-accuracy, remote laser measurements of CO_2 made from an airborne platform. The LAS CO_2 column measurements were found to have a precision of better than 2 ppm for a 100-m horizontal average over land and a 1-km average over water. Absolute comparisons of CO_2 remote and in situ measurements showed agreement to better than 0.75 percent (<3 ppm of CO_2). LAS oxygen (O_2) measurements, which are needed to convert LAS CO_2 density measurements to CO_2 mixing ratios (XCO_2), have been demonstrated in the 1.26-μm region in horizontal ground-based experiments. Details of the LAS flight tests and comparisons of the observed versus modeled CO_2 measurements are discussed in this paper.