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Space-Based CO_2 Active Optical Remote Sensing using 2-μm Triple-Pulse IPDA Lidar

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Sustained high-quality column CO_2 measurements from space are required to improve estimates of regional and global scale sources and sinks to attribute them to specific biogeochemical processes for improving models of carbon-climate interactions and to reduce uncertainties in projecting future change. Several studies show that space-borne CO_2 measurements offer many advantages particularly over high altitudes, tropics and southern oceans. Current satellite-based sensing provides rapid CO_2 monitoring with global-scale coverage and high spatial resolution. However, these sensors are based on passive remote sensing, which involves limitations such as full seasonal and high latitude coverage, poor sensitivity to the lower atmosphere, retrieval complexities and radiation path length uncertainties. CO_2 active optical remote sensing is an alternative technique that has the potential to overcome these limitations. The need for space-based CO_2 active optical remote sensing using the Integrated Path Differential Absorption (IPDA) lidar has been advocated by the Advanced Space Carbon and Climate Observation of Planet Earth (A-Scope) and Active Sensing of CO_2 Emission over Nights, Days, and Seasons (ASCENDS) studies in Europe and the USA. Space-based IPDA systems can provide sustained, high precision and low-bias column CO_2 in presence of thin clouds and aerosols while covering critical regions such as high latitude ecosystems, tropical ecosystems, southern ocean, managed ecosystems, urban and industrial systems and coastal systems.

At NASA Langley Research Center, technology developments are in progress to provide high pulse energy 2-μm IPDA that enables optimum, lower troposphere weighted column CO_2 measurements from space. This system provides simultaneous ranging; information on aerosol and cloud distributions; measurements over region of broken clouds; and reduces influences of surface complexities. Through the continual support from NASA Earth Science Technology Office, current efforts are focused on developing an aircraft-based 2-μm triple-pulse IPDA lidar for independent and simultaneous monitoring of CO_2 and water vapor (H_2O). Triple-pulse IPDA design, development and integration is based on the knowledge gathered from the successful demonstration of the airborne CO_2 2-μm double-pulse IPDA lidar. IPDA transmitter enhancements include generating high-energy (80 mJ) and high repetition rate (50Hz) three successive pulses using a single pump pulse. IPDA receiver enhancement include an advanced, low noise (1 fW/Hz1/2) MCT e-APD detection system for improved measurement sensitivity.

In place of H_2O sensing, the triple-pulse IPDA can be tuned to measure CO_2 with two different weighting functions using two on-lines and a common off-line. Modeling of a space-based high-energy 2-μm triple-pulse IPDA lidar was conducted to demonstrate CO_2 measurement capability and to evaluate random and systematic errors. Projected performance shows <0.12% random error and <0.07% residual systematic error. These translate to near-optimum 0.5 ppm precision and 0.3 ppm bias in low-tropospheric column CO_2 mixing ratio measurements from space for 10 second signal averaging over Railroad Valley reference surface using US Standard atmospheric model. In addition, measurements can be optimized by tuning on-lines based upon ground target scenarios, environment and science objectives. With 10 MHz detection bandwidth, surface ranging with an uncertainty of <3 m can be achieved as demonstrated from earlier airborne flights.