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A Lidar Approach to Measure Atmospheric CO2 Concentrations from Space for the NASA ASCENDS Mission

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The National Research Council of the U.S. National Academies has recommended a future space mission called Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS) in its Decadal Survey. This mission aims "*to produce global atmospheric column CO_2 measurements without seasonal, latitudinal, or diurnal bias using simultaneous laser remote sensing of CO_2 and O_2*." NASA Goddard Space Flight Center is developing a lidar approach as a candidate toward this mission.

Our lidar measurement approach uses the 1570 nm CO_2 absorption band and samples one strong absorption line in this band, chosen for minimum temperature sensitivity, at typically 8 wavelengths. The lasers measure pointed at nadir to better see through clouds and higher signal-to-noise ratios, meanwhile allowing glint measurements over the water and enhanced signals over land surfaces and vegetation with "opposition effect". The pulsed laser wavelengths are extremely narrow and can be locked within a MHz for high-fidelity measurements. The lasers are pulsed and the surface echo signal can be well separated from the atmosphere backscatter by using time gating in the receiver. Thus, this pulse approach can dramatically reduce the influence of atmospheric scattering, which otherwise is a major error source in CO_2 retrievals.

The technique uses all wavelengths to model and correct for (flatten) any residual wavelength variability in the lidar's measurement response. It then uses the ratio of the on-line to off-line signal to retrieve CO_2 column density. Measurements at different on-line wavelengths have vertical weighting functions peaking at different altitudes of interest for atmospheric CO_2. The primary wavelengths near the line midpoints have vertical weighting functions which peak nearly uniformly in the planetary boundary layer, which responds nearly uniformly (regardless of boundary layer mixing) to CO_2 sources and sinks at the surface. The wavelength samples nearer the line peak have weighting function peaking in the mid-troposphere, yielding CO_2 transport information in the free atmosphere.

In order to compute the column mixing ratio, a simultaneous O_2 column density measurement is needed. Our approach uses a line region in O_2 A-band near 760 nm for this with a column differential absorption method. It measures column absorption and line shape at several on-line and off-line wavelengths near line pair centered at 764.7 nm. This pair was also selected for minimum sensitivity to atmospheric temperature. The on-line wavelength is selected in the valley between the O_2 doublet lines for the least temperature sensitivity, vertical weighting function peaking at the surface. The offline regions are selected on the wings of the line pair. Measurements and analysis have shown the online absorption is almost a linear function of surface pressure.

In addition to atmospheric temperature profiles, atmospheric water vapor profiles are also needed to compute the dry air column. Water vapor data are especially important in the tropics and summer seasons, and should been known better than 10%.

For a given sensor design the surface returned pulse strength and hence signal-to-noise ratio (SNR) depends strongly on laser peak power, orbit altitude, the atmospheric transmission and surface reflectivity. The relative error of retrievals inferred from on-line to off-line ratio decreases to less than 0.003 or 0.3% (measurement precision target) when laser peak power increases to 3000 watts or greater. Meanwhile, lower orbit altitude, higher surface reflectivity and atmospheric transmission will enhance SNR and reduce retrieval errors. Modeling results using MODIS BRDF-adjusted surface reflectance and CALIPSO aerosols and clouds optical depth data will be presented and discussed in the presentation.