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Sensitivity studies for a space-based CO_2 laser sounder development

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There is great need for global high spatial- and temporal-resolution remote sensing of atmospheric CO_2 concentration for global and regional studies of the carbon cycle. The biggest challenge for CO_2remote sensing is to achieve high measurement precision so that such measurement is valuable to reduce uncertainties about carbon sources and sinks [1-2]. Compared to the strong CO_2thermal infrared bands such as 15 μm and 4.3 μm used by the Atmospheric Infrared Sounder (AIRS) on Aqua, the 1.6 μm CO_2 band in the near-infrared allows higher sensitivity of variability near the Earth's surface and thus greater potential to achieve valuable remote sensing of CO_2 concentration near the Earth's surface. The Orbiting Carbon Observatory (OCO [3]) is using this band to make atmospheric CO_2 measurement via reflected sunlight.

However, a major hurdle to obtaining high-precision CO_2 measurement using sunlight is the influence of aerosols and cirrus clouds in the sunlight path. Scattering by particles will modify the path length of sunlight and thus changes the total column CO_2 absorption [4]. Even with the help of a correlative measurement approach using multiple bands as adopted by OCO, the scattering effect could cause errors larger than the target CO_2 measurement precision requirement (0.3% or 1 ppmv).

NASA Goddard Space Flight Center is developing a laser technique for a mission to follow OCO [5]. Its aim is to use lasers to overcome many of the CO_2 measurement error sources, including scattering effects in order to meet the ultimate measurement precision goal. The laser technique uses the same CO_2 absorption band. It uses 6 laser wavelengths across one strong absorption line centered at 1.572 μm. The focus of the laser measurement is on the CO_2 in the lower troposphere atmosphere CO_2. The lasers are pulsed and the surface return echo signal can be well isolated from those scattered by the atmosphere. It uses a common nadir-zenith measurement path and a small receiver field of view which further reduces the effect of scatter, which also greatly reduce the influence of scatter.

In this paper, we report the results of our line-by-line radiative transfer calculation results for this laser technique. These include those of absorption line selection, selection of laser frequencies for vertical atmospheric CO_2 information in association with their weighting functions, and the measurement sensitivity to atmospheric temperature and pressure.

In addition, the simultaneous measurement of surface pressure is required in order to compute the CO_2 mixing ratio from the CO_2 column abundance and to separate actual CO_2 flux from variations in atmospheric density. The measurement technique for surface pressure will be similar to that for CO_2 but uses the O_2 A-band near 0.768 μm. The radiative transfer calculations for the surface pressure measurement will be also reported in the paper.

Our work to date shows that the optimal absorption line for the laser technique is at the center of the R-branch of the CO_2 vibration-rotational absorption band ($\sim$ 1.572 μm). Selection of a few laser wavelengths along the line allows absorption peaked at different altitudes relative to the vertical distribution of CO_2. Among them, one weighting function is peaked in the atmospheric boundary layer where the carbon sources and sinks are located, thus providing an enhanced sensitivity to quantify the near-surface processes controlling the global and regional carbon budget. Results so far show that this band has weak but still significant sensitivity to atmospheric temperature and that it is required to have simultaneous atmospheric temperature measurements (i.e., by AIRS) for both CO_2 and surface pressure retrievals. The atmospheric scattering effects on both CO_2 and surface pressure measurements will be assessed and discussed.