Satellite trace gas sensing modeling for missions such as ASCENDS

- Simulation framework to predict performance of laser gas sensing in the atmosphere from space
- Ground-based validation (field site/ground truth) and lidar analysis
- Applicable to other sensing missions such as ASCENDS and a variety of molecules including CO, CH4, N2O etc.
- Predicted ozone source distributions

ASCIENDS mission overview

Requirements and approach
- ASCENDS is intended as a successor to the Aura MLS instrument and is currently slated for 2019 launch.
- ASCENDS will deliver laser-based remote sensing measurements of global CO2 mixing ratios
- ASCENDS will provide nadir measurements of CH4, O3, N2O, and CO2 mixing ratios
- ASCENDS is a ground-based extension of JPL and EOS/MODIS

Benefits for climate science
- Quantify global spatial distribution of CH4, CO2, and other species
- Quantify global spatial distribution of meridional and zonal ozone and column O3 during day/night over all seasons
- Provide additional data for future projections of CH4, CO2, and CO through data-driven enhancements of Earth system process modeling

NASA Luce ASCENDS approach
- A 5.4% accuracy (1σ) in CO2 mixing ratio is required NASA Langley Research Center (LaRC) to develop an intensity-modulated and continuous wave quantum cascade laser absorption lidar (IMCWL-ACL) sensor to construct a robust remote sensing scheme for the detection of CO2 at 3.94 and 2.63 microns from space-based platforms.
- Multiple laser wavelengths with differential absorption (DIAL) techniques are used at 3.94 and 2.63 microns based on sensitivity and stray light considerations in order to retrieve CO2 mixing ratios.
- A 1.6% einstein standard and 0.4% spectral accuracy are required for CO2 sensing in the stratosphere.
- For our requirements, the scan wavelength in this band will be 262 nm.
- Terms: wave number, 262 nm.
- Each band is being further analyzed for sensitivity to environmental parameters.

Modeling framework for integrated path space lidar performance estimates

- A method for calculating the signal from each layer is used to calculate estimates for each layer.
- Temperature profiles and pressure profiles are obtained from numerical models.
- The simulation models are used to calculate the signal from each layer.
- The calculated signal is then used to calculate the sensitivity of the lidar.

Pre-analyzed atmospheric data for error analysis

Analysis and processing of the MERRA dataset

Combining individual layer error estimates

- The calculated signal from each layer is used to calculate the sensitivity of the lidar.
- The calculated sensitivity is then used to calculate the total path relative uncertainty.

Global annual temperature sensitivity analysis for CO2 and O2 bands

Wavelength instability effects

Data table

Global annual temperature sensitivity analysis for alternative CO2 bands

Conclusions and further work

- Framework applicable to any solute
- Framework operated in the lab using 970 nm laser, further validation and improvements are ongoing
- Simulation programs are used for the analysis of temperature sensitivity, wavelength stability effects and the need for high sensitivity to environmental parameters
- Further analysis and simulation are under consideration
- Validation of the modeling framework is planned
- For the simulation of the model, an improved methodology to reduce the required number of calculations (ordinary PC may be used)

References