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# An Analysis of Spectral Simulation Methods for Laser Heterodyne Radiometry for the Vertical Profiling of Greenhouse Gas (GHG) Mixing Ratios

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George Washington University and Mesa Photonics are developing and deploying a Laser Heterodyne Radiometer (LHR) that simultaneously measures $CO_2$, $CH_4$, $H_2O$, and $O_2$ mixing ratios throughout the troposphere and lower stratosphere. Spectral fits are constrained by fitting the oxygen spectral line shape – which depends only on pressure and temperature – to improve GHG retrieval precision and provide dry-air corrections. This constraint is achieved by fitting pressure and temperature profiles obtained from the meteorology data measured by radiosondes (vertical resolution ranging from 5-500 m) as part of NOAA's Integrated Global Radiosonde Archive (IGRA).

Atmospheric spectra are simulated for the column using a spectral simulation package ("LahetraSim") that uses parameters from the HITRAN spectral database to model spectra through the HITRAN Application Programming Interface (HAPI). Integrated path absorption spectra are calculated using the initial sun angle and estimated radiosonde pressure and temperature profiles. Concentration profiles for $CO_2$, $CH_4$, and $H_2O$ can then be iterated on their vertical distributions and refining the pressure and temperature profiles to best fit the oxygen spectrum.

Here we present a comparison of our spectral simulation software to that of an alternative method that has been presented for LHR data processing which makes use of the Planetary Spectrum Generator (PSG) API. Spectral simulations are generated using several atmospheric databases, templates, and transfer models. This tool allows for the extraction of Modern Era Retrospective Analysis, Version 2 (MERRA-2) vertical profiles of pressure and temperature and species abundances from HITRAN. Two limitations of the MERRA-2 database are the latency of approximately 2 months for the latest data availability and the coarse vertical resolution (~1 km) of the available data. Another benefit of our approach is that approximation of both Planetary Boundary Layer (PBL) and Tropopause Heights can be extracted from the temperature and pressure profiles and these heights can be iterated to refine atmospheric layers; thus increasing their relevance of LHR to GHG modeling.