"Greenhouse Gas Concentration Data Recovery Algorithm for a Low Cost, Laser Heterodyne Radiometer"

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The goal of a coordinated effort between groups at GWU and NASA GSFC is the development of a low-cost, global, surface instrument network that continuously monitors three key carbon cycle gases in the atmospheric column: carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO), as well as oxygen (O_2) for atmospheric pressure profiles. The network will implement a low-cost, miniaturized, laser heterodyne radiometer (mini-LHR) that has recently been developed at NASA Goddard Space Flight Center. This mini-LHR is designed to operate in tandem with the passive aerosol sensor currently used in AERONET (a well established network of more than 450 ground aerosol monitoring instruments worldwide), and could be rapidly deployed into this established global network.

Laser heterodyne radiometry is a well-established technique for detecting weak signals that was adapted from radio receiver technology. Here, a weak light signal, that has undergone absorption by atmospheric components, is mixed with light from a distributed feedback (DFB) telecommunications laser on a single-mode optical fiber. The RF component of the signal is detected on a fast photoreceiver. Scanning the laser through an absorption feature in the infrared, results in a scanned heterodyne signal in the RF.

Deconvolution of this signal through the retrieval algorithm allows for the extraction of altitude contributions to the column signal. The retrieval algorithm is based on a spectral simulation program, SpecSyn, developed at GWU for high-resolution infrared spectroscopies. Variations in pressure, temperature, composition, and refractive index through the atmosphere; that are all functions of latitude, longitude, time of day, altitude, etc.; are modeled using algorithms developed in the MODTRAN program developed in part by the US Air Force Research Laboratory. In these calculations the atmosphere is modeled as a series of spherically symmetric shells with boundaries specified at defined altitudes. Temperature, pressure, and species mixing ratios are defined at these boundaries. Between the boundaries, temperature is assumed to vary linearly with altitude while pressure (and thus gas density) vary exponentially. The observed spectrum at the LHR instrument will be the integration of the contributions along this light path.

For any absorption measurement the signal at a particular spectral frequency is a linear combination of spectral line contributions from several species. For each species that might absorb in a spectral region, we have pre-calculated its contribution as a function of temperature and pressure. The integrated path absorption spectrum can then by calculated using the initial sun angle (from location, date, and time) and assumptions about pressure and temperature profiles from an atmospheric model. The modeled spectrum is iterated to match the experimental observation using standard multilinear regression techniques. In addition to the layer concentrations, the numerical technique also provides uncertainty estimates for these quantities as well as dependencies on assumptions inherent in the atmospheric models.