Abstract

In collaboration with NASA GSFC and GWU, a low-cost, surface-based instrument is being developed that can continuously monitor key carbon dioxide cycle gases in the atmospheric column: carbon dioxide (CO2) and methane (CH4). The instrument is based on a miniaturized, laser heterodyne radiometer (LHR) using near-infrared (NIR) telecom lasers. Despite relatively weak absorption line strengths in this spectral region, spectrally-resolved atmospheric column absorptions for these two molecules fall in the range of 60-80% and thus sensitive and precise measurements of column concentrations are possible. In the last year, the instrument was deployed for field measurements at four sites: Fairbanks, Alaska; Castle Airport near Atwater, California; and at the NOAA Mauna Loa Observatory in Hawaii. For each subsequent campaign, improvement in the figures of merit for the instrument has been observed. In the future, we will present an assessment of uncertainty in the reported concentrations from assumed instruments in the meteorological data. LHR instrument and auxiliary noise, and radio frequency bandwidth to describe additional future goals in instrument development and deployment targets.

Background

Laser heterodyne radiometry (LHR) is a technique for detecting weak signals that was adapted from radio receiver technology. In a radio receiver, a weak input signal from a radio antenna is mixed with a stronger local oscillator signal. The mixed signal (beat frequency) has a frequency equal to the difference between the input signal and the local oscillator. The intermediate frequency is amplified and sent to a detector that extracts the audio from the signal. In a laser heterodyne radiometer, the weak input signal is light that has undergone absorption by a trace gas. The local oscillator is a laser at a nearby frequency—in this case a low-cost distributed feedback (DFB) telecommunications laser. These two light waves are superimposed in either a beamsplitter or in a fiber coupler (as is the case in this design). The beams are mixed in the detector, and the RF beat frequency is extracted. Changes in the column concentration of the trace gas are read out through analyzing changes in the beat frequency amplitude. By bandwidth filtering the RF and tuning the laser through an absorption feature, trace gas concentrations can be found as a function of altitude.

Simulating Spectra

Atmospheric spectra are simulated for the column using the SpecSyn spectral simulation package developed at The George Washington University (GWU). This software uses physical parameters from the HITRAN Spectral database (2008 edition) to model CO2 spectra. The integrated path absorption spectrum is calculated using the initial sun angle and pressure and temperature profiles taken from Modern-Era Retrospective Analysis for Research and Applications (MERRA) data. Spectral simulation is accomplished by integrating short-path segments along the trajectory using the SpecSyn spectral simulation suite developed at GWU. Column concentrations are extracted by minimizing residuals between observed and modeled spectrum using the Nelder-Mead simplex algorithm. We will also present an assessment of uncertainty from the simulated concentrations in the meteorological data. LHR instrument and auxiliary noise, and radio frequency bandwidth to describe additional future goals in instrument development and deployment targets.

Affect of Absorbance Noise

Future Plans

New opportunities for mini-LHR deployment are currently being explored including:

- A multi-disciplinary, multi-scaled study to measure methane (CH4) and carbon dioxide (CO2) above thawing permafrost at three sites near Fairbanks, AK.
- A regional network of sensors in the Washington DC area to help validate higher resolution grid simulations of GEOS-5 data.
- CubeSat deployment of a mini-LHR system for Limb measurements of CO2 in arctic regions.

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