Abstract

In a collaboration between NASA GSFC and GWU, a low-cost, surface instrument is being designed that can continuously monitor key carbon 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 Park Falls, Wisconsin; 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 latest test, the absorbance noise is approaching 0.002 optical density (OD) noise on a 1.8 OD signal.

An overview of the measurement campaigns and the data retrieval algorithm for the calculation of column concentrations will be presented. For light transmission through the atmosphere, it is necessary to account for variation of pressure, temperature, composition, and refractive index through the atmosphere that are all functions of latitude, longitude, time of day, altitude, etc. For temperature, pressure, and humidity profiles with altitude we use the 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 GW. Column concentrations are extracted by minimizing residuals between observed and modeled spectrum using the Nelder-Mead simplex algorithm.

Future Plans

While development of the miniaturized LHR began in 2009, beyond ongoing testing at Goddard Space Flight Center, regular measurements in the atmospheric column did not begin until September 2012. The instrument has been field tested at the TCCON site in Park Falls, WI where it was compared with their Fourier Transform Spectrometer (September 2012), at Castle Airport in Atwater, CA during the ASCENDS DC-8 field campaign (February 2013), and at NOAA’s Mauna Loa Observatory, HI where it operated in April and May of 2013.

Over the development and field-testing period, the mini-LHR has undergone significant improvements. Over the first field campaign at Park Falls, the scan time was ~20 minutes and the lowest absorbance noise of 0.004 was reached during a single scan (~2.5 minutes of data). Once again, referring to Figure 4 an estimated precision of ~0.2 ppmv is determined.

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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). Instrument broadening is then added to the simulated spectrum, with an initial assumption of 3 GHz (0.025 nm). The experimental spectrum is then fit to the instrument-broadened simulated spectrum using a Nelder-Mead simplex algorithm. Figure 3 shows data for a typical synthetic spectrum (blue line) and measured spectrum (red symbols).

Affect of Absorbance Noise

Figure 4: To estimate the uncertainty in this fitting algorithm, absorbance noise was added to a simulated spectrum and the resulting “experimental” spectrum was fit. This process was repeated for 100 trials at several absorbance noise levels. The results of these Monte Carlo trials, shown above, indicate that a noise level of 0.01 OD leads to an uncertainty of just over 1 ppmv in CO2 column mixing ratio.