Portable, low-cost, column carbon dioxide and methane measurements for validating satellite observations in remote locations

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We present a low-cost (~$10K per instrument), portable solution to ground-based validation of satellite observations for difficult to reach locations with precisions of 1 ppm XCO_2 and 10 ppb XCH_4 for hourly data products. While Total Carbon Column Observing Network (TCCON) is the gold-standard for ground validation, there are locations where a ground column validation data point would be useful but conditions are not conducive to a permanent station. Examples include wetlands, thawing permafrost, the tropics, the Amazon, sub-Saharan Africa, as well as locations without a power grid or with geopolitical conflict. In addition, the low-cost and portability mean a geographical region can be studied in depth with multiple instruments. This passive, sun-pointing instrument is a miniaturized, laser heterodyne radiometer (mini-LHR) that has been under development by our team since 2009. It can be operated either in tandem with AERONET (a global network of 500 instruments that measure aerosol optical depth), or as a stand-alone instrument with a low-cost (~$3K), light-weight sun tracker.

One of the main benefits of the mini-LHR is that it can quickly reach remote locations and provide a validation measurement even if there is limited or no infrastructure at the site. The instrument weighs ~10 lbs, fits into a backpack, and is powered by two folding solar panels and a battery pack. In clear conditions, the instrument can be set-up in under an hour. Portability means that mini-LHRs can be easily moved for side-by-side comparisons with other mini-LHRs and with TCCON which simplifies assessing instrument bias as well as accuracy. Like TCCON, the mini-LHR points directly at the sun with a narrow field-of-view and is its insensitivity to cloud and aerosol scattering that is common to nadir-pointing passive satellite approaches.

Here we present a collection of sample data sets to demonstrate performance from locations that vary in climate, altitude, solar zenith angle, hours of sun per day, etc., as well as data from side-by-side TCCON comparisons. Retrievals of CO_2 and CH_4 were completed using the NASA/Goddard's Planetary Spectrum Generator (PSG) that incorporates meteorological inputs from Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) data set.

Plain language summary:

This instrument measures the amount of methane (CH_4) and carbon dioxide (CO_2) in the Earth's atmosphere in a region called the atmospheric column which is basically from the surface to the top of the atmosphere (column measurements are denoted with an "X" in front of the formula). This data can then be compared with satellite measurements of these gases to validate their accuracy. The instrument is a miniaturized laser heterodyne radiometer (mini-LHR) which works similarly to an FM radio – except instead of collecting radio waves, the mini-LHR collects sunlight in the infrared that contains absorption of the gases. How much the gases are absorbed by infrared sunlight correlates to their concentration in the atmosphere which is reported in parts-per-million for CO_2 and parts-per-billion for CH_4.