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A compact ground-based laser heterodyne radiometer for global column measurements of CO_2 and CH_4

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Implementing effective global strategies to understand climate change is hindered by a lack of understanding of both anthropogenic emissions and land and ocean carbon reservoirs. Though in situ surface measurements and satellites provide valuable information for estimating carbon fluxes, areas not well covered by current observing systems (e.g. high latitude regions, tropical forests and wetlands) remain poorly understood. Deficiencies in understanding the processes governing carbon flux introduce considerable uncertainty to predictions of climate change over the coming century.

Our vision is to enhance worldwide carbon monitoring by developing a low-cost ground network of miniaturized laser heterodyne radiometer (Mini-LHR) instruments that measure CO_2 and CH4 in the atmospheric column. Ground-based remote sensing has the potential to fill gaps in the satellite data record while providing a complementary long-term observational record. This uninterrupted data record, would both bridge gaps in data sets and offer validation for key flight missions such as OCO-2, OCO-3 and ASCENDS.

Mini-LHR instruments will be deployed as an accompaniment to AERONET. In addition to the complementary aerosol optical depth measurement, tandem operation with AERONET provides a clear pathway for the Mini-LHR to be expanded into a global monitoring network. AERONET has more than 500 instruments worldwide offering coverage in key arctic regions (not covered by OCO-2) where accelerated warming due to the release of CO_2 and CH4 from thawing tundra and permafrost is a concern. Mini-LHR instruments at AERONET locations could also greatly improve data coverage in regions with large flux uncertainties such as North America and Western Europe, and under-sampled areas such as South America and Asia. Currently, the only ground global network that routinely measures multiple greenhouse gases in the atmospheric column is TCCON with 18 operational sites worldwide and two in the US. Cost and size of TCCON installations will limit the potential for expansion.

The Mini-LHR implements telecommunications lasers to offer a low cost (<$30K/unit), suitcase sized, highly sensitive (< 1 ppm for CO_2 and <20 ppb for CH4), solution to supplement TCCON measurements. Laser heterodyne radiometry has been used since the 1970s to measure atmospheric gases such as ozone, water vapor, methane, ammonia, chlorine monoxide, and nitrous oxide. The Mini-LHR is passive and uses sunlight as the primary light source to measure absorption of CO_2 and CH4 in the shortwave infrared near 1.6 microns. Sunlight is collected with collimation optics that are mounted to the AERONET sun tracker, and superimposed with laser light in a single mode fiber coupler. The signals are mixed in a fast photoreceiver (InGaAs detector), and the RF (radio frequency) beat signal is extracted. Changes in mole fraction of the trace gas are realized through analyzing changes in the beat frequency amplitude. An analytical framework that is currently under development models the mini-LHR measured spectrum based on atmospheric conditions (pressure, temperature and water vapor profile), the solar zenith angle and the instrument response bandwidth. Efforts are underway to incorporate feedback from several field campaigns into improving precision and reducing systematic errors.