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Intercomparison of total column greenhouse gas measurements from low-cost portable spectrometers at Sodankylae

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The Total Column Carbon Observing Network (TCCON) is a network measuring accurate and precise total column abundances of atmospheric constituents including CO_2, CH_4, CO, N_2O, HF, H_2O, and HDO. The official instruments are Fourier Transform Spectrometers, namely the IFS 125HR from Bruker. These ground-based instruments record direct solar spectra in the near-infrared spectral region, covering 4000 to 9000 cm^{-1} with the resolution of 0.02 cm^{-1}. TCCON provides an essential ground-based validation dataset for GHG-measuring satellites, in particular OCO-2, GOSAT and the recently launched Sentinel-5 Precursor. Currently, there are around 23 stations distributed globally, but there are still gaps in global coverage, especially in remote regions or at sites with high or low surface albedo. Meanwhile, the costs and logistical requirements for new stations limit further expansion of the network. Infrastructure, internet, power, etc. are required and at least one trained personnel is needed for operation and maintenance on site. Relocation of a TCCON station is a major effort, requiring manpower and heavy tools.

Recently, different cheaper and portable spectrometers have been developed and are now available for GHG measurements, with the potential to complement the TCCON network. However, the performance of these instruments has not yet been fully characterized. Therefore, an intercomparison campaign called Fiducial Reference Measurements for Green House Gases (FRM4GHG) at Sodankylae, Finland, has been funded by ESA. The TCCON spectrometer operated at this site by the Finnish Meteorological Institute (FMI), serves as a reference. In addition, regular AirCore launches are performed on site for providing in-situ accurate reference profiles of the target species.

Four remote-sensing instruments are tested in the framework of this campaign. The EM27/SUN FTIR spectrometer offering 0.5 cm^{-1} resolution was developed by the Karlsruhe Institute of Technology (KIT) (Gisi et al., 2012), in collaboration with Bruker Optics, Ettlingen, Germany. The University of Bremen and the Royal Belgian Institute for Space Aeronomy are responsible for a Bruker Vertex 70 (resolution of 0.16 cm^{-1}). The University of Wollongong, Australia, contributes with a fiber-coupled Bruker IR Cube (resolution of 0.5 cm^{-1}) and the Rutherford Appleton Laboratory designed a mid-IR Laser Heterodyne Radiometer with a spectral resolution currently set to 0.02 cm^{-1}.

Continuous measurements from March to October 2017 with all these instruments have allowed to build a comprehensive database for understanding the variability of column-averaged atmospheric CO_2, CH_4 and CO in the boreal forest region near the Arctic Circle. FRM4GHG contributes to the CO and CH_4 validation efforts for ESA Sentinel-5P, as well as other satellites and models. Meanwhile, different characteristics like precision, accuracy, stability, portability, etc., are investigated by comparing the participating spectrometers and each dataset with the TCCON reference. The results of this campaign will help to improve the availability of high-quality ground-based observations of GHGs and for supplementing the TCCON core stations with light infrastructure. Here we provide an overview of the campaign results for the different portable instruments.