EMPIR Call 2016 – Energy, Environment, Normative and Research Potential

Selected Research Topic number: **SRT-v17**
Version: 1.0

Title: Metrology for improved greenhouse gas column retrievals in atmospheric remote sensing

Abstract

The Total Carbon Column Observing Network (TCCON) is a global network of Fourier transform infrared (FTIR) spectrometers that provide column measurements of CO_2 and other greenhouse gases (GHGs). All satellite instruments for GHGs currently rely on TCCON for calibration however the accuracy requirements for the TCCON are not currently met by the accuracy of the spectral parameters. The reason for this and the main limitations are due to O_2 spectroscopic parameters and interfering H_2O spectral lines. Therefore the TCCON has to rely on costly aircraft calibration measurements. To address this issue, knowledge from European NMIs, TCCON members, and spectral modelling experts needs to be integrated in order to allow the determination of traceable spectral line data for molecular O_2 and H_2O, which can then be used to improve the accuracy of the TCCON and the satellite instruments that depend on it for calibration.

Keywords

Spectral line data; TCCON; water vapour; ; FTIR spectroscopy; remote sensing; GHGs; satellite and airborne sensor networks; climate change

Background to the Metrological Challenges

Following the 2015 UN Climate Change Conference (COP21), there was an increased need from the World Meteorological Organization Global Climate Observing System (WMO-GCOS) for international standards for monitoring GHG emissions, including their quantities, sources and transport routes. The availability, transparency, traceability and credibility of atmospheric monitoring data has become critical for policy making, negotiations about emission levels, emission verification, and carbon taxing. However, global satellites as well as ground based remote sensing observations need traceable spectroscopic information in order to be linked to existing surface in-situ observations and the results of atmospheric chemical transport models.

Current spectroscopy of target GHG species, as well as O_2, are not accurate enough to reach the TCCON's requirements. Therefore, the TCCON has to be calibrated against altitude-resolved species profiles, which are derived from in-situ measurements on-board of aircraft or balloons that overpass the sites, and is a very costly endeavour. In addition, the correction factors derived from these airborne measurements are approximately 2 %.

A metrological framework is needed for providing traceability to O_2 spectral line data, in order to calibrate the retrievals of major GHGs such as CO_2 and CH_4, using ground based TCCON networks, as well as existing and upcoming satellite missions. A new air mass standard derived from traceable O_2 line parameters would also ensure consistent datasets of comparable quality with known uncertainties for current and future ground based and satellite observations of GHG emissions: which is a formal requirement by the WMO for all datasets used in Environmental assessments.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the traceable measurement and characterisation of GHG column retrievals in atmospheric remote sensing.

EURAMET MSU, Hampton Road, Teddington, Middlesex, TW11 0LW, UK
Phone: +44 20 8943 6666 Email: msu@npl.co.uk
msu.euramet.org

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The specific objectives are

1. To improve the precision and accuracy of spectral data for:
   a) molecular oxygen (O_2), in particular the absorption bands 1268 nm (7886 cm^{-1}) and 760 nm (13158 cm^{-1}) using spectrometric laboratory measurements at room temperature over the full atmospheric pressure range and over a large fraction of the atmospheric temperature range in order to improve the accuracy of the temperature dependence of the spectral parameters of O_2.
   b) critical water vapour lines including their weaker isotopologues i.e. HDO, $H_2{}^{18}O$ that interfere with the main target bands used for CO_2 and CH_4 retrieval by the TCCON as well as by satellite instruments.
2. To improve the reliability, data compatibility and comparability of measured spectral data through metrological intercomparisons of spectral line parameters (from objective 1). The intercomparison should include FTIR, cavity ring down spectroscopy (CRDS), and cavity enhanced absorption spectroscopy (CEAS) techniques and the target retrieval accuracy is 0.3 %.
3. To develop a validated TCCON-compatible spectral code for parameter retrievals of O_2, CO_2, CH_4, etc., which is capable of using the International Union of Pure and Applied Chemistry (IUPAC)-recommended line shape model (i.e. Hartmann-Tran profile) with line-mixing in order to achieve a target retrieval accuracy of < 1 %.
4. To use the spectral parameters and higher order line parameters in TCCON retrieval software to improve the retrieval accuracy of the air mass factor and the air-mass-dependent greenhouse gas concentrations. The improvement should be verified, in particular for high solar zenith angles (SZA) (high air mass) and should reduce or eliminate the need for calibrating TCCON observations against secondary in-situ measurements in order to account for systematic errors. In addition, this should include error analysis of the TCCON retrieval algorithm with respect to the SZA, O_2 spectral line parameters, and line shape functions.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the accredited laboratories, standards developing organisations (e.g. ISO, CEN, environmental monitoring and regulation bodies (e.g. WMO-GCOS), and end-users (e.g. European Space Agency (ESA)), in order to strengthen the synergy between the metrological and atmospheric (climate) science community within Europe.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art, and explain how their proposed research goes beyond this. In particular, proposers should outline the achievements of the EMRP project ENV06 EUMETRISPEC and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.0 M€, and has defined an upper limit of 2.3 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 35 % of the total EU Contribution to the project.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,

- Transfer knowledge to the climate change, air monitoring and environmental sectors.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.