TCCON Observations and Data Protocol

TCCON Science Team
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Overview

- A global Total Carbon Column Observing Network (TCCON) is being developed. Australia, the US, Germany, Japan, Spain, and New Zealand are involved so far.
- Hi-resolution FTS in near-IR solar absorption will measure column densities of greenhouse gases CO_2, CH_4, H_2O, and N_2O, along with CO. Observations of O_2 and HF in the same spectra will be used to convert column densities to mean mixing ratios.
- The column observations, in combination with the existing surface measurements, will improve estimates of surface flux of GHG, allowing improved predictions of their future concentration, and ultimately climate. .
- In addition to their direct use for carbon flux studies, TCCON measurements will be used to validate satellite column measurements.
- Several of the TCCON sites have been either fully or partly funded for validation of the NASA Orbiting Carbon Observatory (OCO) satellite.

Organization

TCCON will be overseen by its Science Team, which will consist of all TCCON PIs. The Science Team will:

- Establish, refine, and maintain standards for TCCON data products, and their precision and accuracy
- Define which software and spectral linelists will be used for 'standard' TCCON data products
- Exchange software and other information needed for data acquisition and analysis, enabling PIs to assess and improve their data quality
- Facilitate and assist where possible, in science studies using TCCON data
- Evaluate and accept new members.

Desirable site characteristics

For carbon science and satellite validation:

- Relatively uniform surroundings (topography, albedo, temperature), remote from local pollution
- Latitude and geographical locations that complement the other TCCON sites
- Ancillary meteorological and aerosol measurements
- On-site technical support; active scientific support

Uniform surroundings and aerosol measurements are mainly important for satellite validation, rather than for direct use in carbon science.

Solar observations and ancillary data

- FTS systems will consist of high spectral resolution measurement capability covering, at a minimum, the spectral range 4000-9000 cm^{-1} at 0.02 cm^{-1} spectral resolution (45 cm OPD).

- Sufficient S/N to retrieve the oxygen column from the 1.27 μm O_2 band with 0.1% precision. Some of the stations will also have capability for O_2 A-band observations near 0.7 μm.
- FTS sun tracker pointing with an accuracy of 1 mrad (~.05º, or 3 arcminutes)
- A surface pressure measurement accurate to better than 0.3 mbar.
- A surface temperature measurement accurate to better than 1 K.
- Accurate knowledge and reporting of the interferogram zero point crossing time (within 1 sec)
- A line shape monitoring device in the solar beam during all or a continually repeated subset of observations capable of characterizing the modulation efficiency to at least 10% (which implies 0.1% O2 column).

The tracker requirement corresponds to an airmass error of 0.2% at 63º SZA, or 0.1% at 45º SZA. This is less strict than the other requirements, because of the practical limitations of available trackers, and may limit overall accuracy. 0.2 mrad, or 0.01º, corresponds to 0.1% airmass error at 80º SZA, and would be ideal. Tracker accuracy should be routinely monitored in 1 dimension using the solar-telluric shift.

Instruments demonstrating the necessary precision to date have been Bruker 120/125 HRs, with CaF_2 beamsplitters and room-temperature InGaAs detectors, and with Si detectors for the O_2 A-band if equipped for dual-beam acquisition.

Archiving

- A TCCON archive and website will be established at Caltech. XCO_2 (and if desired XCH_4, XN_2O, XH_2O, XHF and XCO) and supporting data TBD sufficient to allow calculation of the tropospheric average mixing ratio (e.g. averaging kernels, a priori profiles) will be archived there.
- Archived data will include a 'public access' flag. Said flag will identify which data are deemed of sufficient quality for eventual public release. The Science Team will approve simple, objective criteria to determine what is 'sufficient'.
- Each TCCON PI will be responsible for archiving spectra and ancillary information at their own site sufficient to allow the data to be reprocessed when necessary.
- The central processing facility for OCO at NASA JPL will archive data processed by it.

Delivery

- For sites either fully or partly funded by OCO, a subset of the interferograms collected by the FTS, including all satellite overpasses, will be delivered to the central processing facility at JPL, along with 'sunrun' files containing the site specific, ancillary data required for processing the interferograms. Sites not running OPUS (Park Falls, Darwin, and Pasadena/Oklahoma) will also provide the ipp-slice input file.
- For all sites, retrieved vertical column abundances of CO_2, O_2, CO, N_2O, CH_4, H_2O, and HF using validated software must be provided to the Caltech archive in the agreed format. In addition, the time, location, and surface pressure must be supplied. Diagnostics of the difference between the observed and

calculated frequencies of the solar lines (relative to the telluric gas lines) must be provided.

Processing

- The software used at Caltech to process the interferograms and sunrun files will be made available to Network PIs.
- An 'open source' model will be followed, such that investigators are encouraged to improve the code and share the improvements with other TCCON investigators. The Science Team will discuss adoption of version control software to manage this process.
- There may be both 'standard' and 'experimental' versions of this software (including spectral linelists) available at any one time. Individual PIs are responsible for processing their data with the current standard. They are encouraged to compare results from the experimental version to aide accuracy improvements.
- The spectral linelist used in data processing will be uniquely identified in the output files. The details of the identification will be decide by the Science Team.
- Individual PIs will be responsible for demonstrating that their on-site processing is consistent with that done at the central processing facility, and for routinely producing XCO_2 (and if desired XCH_4, XN_2O, and XCO)
- Each site must demonstrate that their low-airmass (<3), clear sky solar spectra can produce retrievals of XCO_2 with a precision of 0.2% or better.
- Each site must demonstrate that their low-airmass, clear sky solar spectra can produce retrievals of XO_2 with an accuracy of TBD.
- We encourage calibration of CO2 by aircraft flights whenever/wherever possible

Data Access and Reciprocity

- All PIs will have access to all data in the TCCON archive. Use of these data implies an agreement to reciprocate. PIs agree to make their own data available to the TCCON community.
- Data will be submitted to the archive within 12 months of acquisition if at all possible
- Data in the TCCON archive, which has been flagged for public release, will become public 2 years after acquisition
- Data to be released publicly as "TCCON data" will meet the precision and accuracy requirements above.