地上設置高分解能フーリエ変換分光計を用いた地球大気温室効果ガス観測ネットワーク: TCCON (Total Carbon Column Observing Network)

（国立環境研究所 [a], 名古屋大学太陽地球環境研究所 [b]、宇宙航空研究開発機構 [c]、http://tccon-wiki.caltech.edu[d]、*現在:秋田県立大学生物環境科学科）○森野勇 [a]、井上誠 [a,*]、町田敏暢 [a]、内野修 [a]、大山博史 [b]、川上修司 [c]、TCCON partners[d]

Network of ground-based high-resolution Fourier transform spectrometers measuring atmospheric greenhouse gases: TCCON (Total Carbon Column Observing Network)

(National Institute for Environmental Studies (NIES)[a], Solar-Terrestrial Environment Laboratory , Nagoya University [b], Japan Aerospace Exploration Agency (JAXA)[c], http://tccon-wiki.caltech.edu[d], * now at Department of Biological Environment, Akita Prefectural University) Isamu Morino[a], Makoto Inoue[a, *], Toshinobu Machida[a], Osamu Uchino[a], Hirofumi Ohyama[b], Shuji Kawakami[c], and TCCON partners[d]

The Total Carbon Column Observing Network (TCCON) [1], founded in 2004, is a network measuring greenhouse gases with ground-based high-resolution Fourier Transform Spectrometers (FTSs), that record atmospheric spectra in the near-infrared spectral region using the sun as an external light source. From these spectra, accurate and precise column-averaged abundances of atmospheric constituents including CO_2, CH_4, N_2O, CO, H_2O and other molecules are retrieved. Measurements with unprecedented high-accuracies in spectroscopic remote sensing (2σ uncertainties: 0.8 ppm for CO_2 and 7 ppb for CH_4) are achieved through stringent conditions on instrumentation, measurement procedure, data processing, and calibration to the World Meteorological Organization's (WMO) scale. Today, the TCCON data are widely used for carbon cycle studies and have been firmly established as an important validation resource for satellite-based data from GOSAT (Greenhouse gases Observing SATellite), OCO-2 (Orbiting Carbon Observatory), SCIAMACHY (Scanning Imaging Absorption spectrometer for Atmospheric CHartographY), and other satellite missions.

In this talk, we will present scientific objectives, network, instrument and measurement, data processing and calibration, scientific application, and recent progress in the Japanese science groups involved.

1. Network

The first TCCON measurements started at Park Falls, USA, at Lauder, New Zealand, and at Ny-Ålesund, Spitsbergen. Since then, new TCCON sites have been established, and there are now more than twenty sites worldwide (see Figure 1). TCCON sites cover the latitudes from the equator to the high Arctic, including continental, littoral, and island regions, and in clean and polluted areas. In Japan, the Tsukuba site started operating in Dec. 2008 as the first site in East Asia (NIES, Tsukuba, 36.0513 N, 140.1215 E). The next site, Saga, owned by JAXA, started in Jun. 2011(Saga University, Saga, 33.2410 N, 130.2882 E). The third site in Japan, Rikubetsu, operated by NIES, started in Nov. 2013 and is now in preparatory status (Rikubetsu Integrated Stratospheric Observation Center, NIES, Asyoro, Hokkaido, Japan, 43.4567 N, 143.7661 E). In Jan. 2014, a calibration of TCCON FTSs at Tsukuba and Rikubetsu sites were conducted using aircraft vertical profile data.

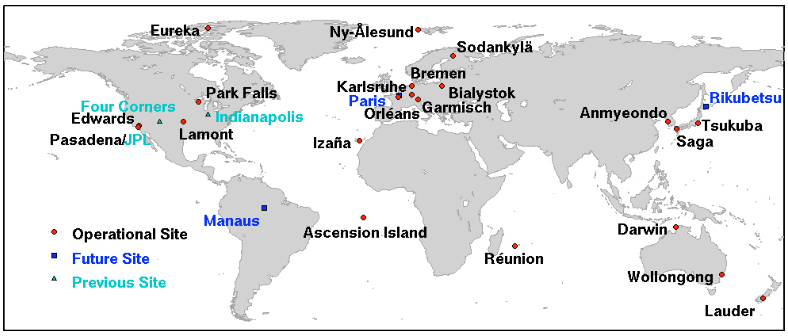

Figure 1. TCCON site locations (http://tccon.ornl.gov).

2. Instrument and measurement

The Bruker IFS 125 HR (Bruker Optics) has been found to be the most robust and stable high-resolution FTS available commercially instrument, and is now the primary instrument in TCCON. The spectra are recorded with 45 cm maximum optical path length (approximately 0.02 cm^{-1} spectral resolution) and 3900 – 15500 cm^{-1} coverage, using InGaAs and Si detectors simultaneously and a CaF_2 beamsplitter. One scan takes about one minute. A sun tracker is used with better than 3 arcmin of tracking precision. Ancillary measurements at each site include surface pressure with better than 0.3 hPa precision and temperature with better than 1 K precision.

3. Data processing and calibration

In TCCON, a common software package (GGG, the present version is GGG 2014) is used for data processing. The central part of the data processing is the GFIT nonlinear least-squares fitting algorithm. GFIT scales an a priori profile to make the best spectral fit and compute the column abundance from the derived scaling factor. The computed column abundances are converted to column-averaged dry-air mole fractions by dividing them by the dry-air columns, which are computed by retrieving the oxygen column abundances from the same spectra. The column-averaged dry-air mole fractions are corrected for the constant systematic error caused by spectroscopic inadequacies and calibrated to the WMO scale by comparison with aircraft profile data [2].

4. Scientific application

The TCCON data are available on our archive (http://tccon.ornl.gov/), hosted by the Carbon Dioxide Information Analysis Center (CDIAC). The TCCON data are widely used for carbon cycle studies and are vital for validating satellite-based data from past, current and future missions. GOSAT column-averaged dry-air mole fractions of CO_2 and CH_4 (XCO_2 and XCH_4) are retrieved from the Short-Wave InfraRed (SWIR) spectral data observed with the Thermal And Near-infrared Sensor for carbon Observation - Fourier Transform Spectrometer (TANSO-FTS) onboard GOSAT. The present NIES full physics SWIR retrieval algorithm (ver. 02.xx) are compared to TCCON data. Smaller biases and standard deviations are found (-1.48 ppm and 2.09 ppm for XCO_2 and -5.9 ppb and 12.6 ppb for XCH_4, respectively) [3].

[1] D. Wunch et al., Phil. Trans. R. Soc. A, **369,** 2087-2112 (2011); http://tccon-wiki.caltech.edu/

[2] For example, D. Wunch, et al., Atmos. Meas. Tech., **3,** 1351-1362 (2010); J. Messerschmidt, et al., Atmos. Chem. Phys., **11**, 10765-10777 (2011); M. C. Geibel, et al., Atmos. Chem. Phys., **12**, 8763-8775 (2012).

[3] Y. Yoshida, et al., Atmos. Meas. Tech., **6,** 1533-1547 (2013).