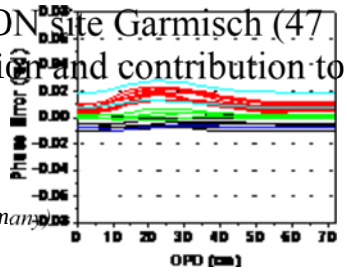
High-precision measurements of column-averaged CO_2 and CH_4 derived from near-infrared FTS at the TCCON site Garmisch (47 °N, 11 °E, 744 m a.s.l.): First year of operation and contribution to OCO and GOSAT validation



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ABSTRACT: Since July 2007 at Garmisch, Germany (47.48 °N, 11.06 °E, 744 m a.s.l.) a Bruker IFS125HR near-infrared Fourier-Transform-Spectrometer is operated as part of the Total Carbon Column Observing Network (TCCON; http://www.tccon.caltech.edu). Solar absorption spectra in the wave number range 4000 - 16 000 cm-1 are recorded continuously during clear sky conditions using dual acquisition from an InGaAs detector and a Si diode. From these spectra, accurate and precise column-averaged mixing ratios of CO_2 and CH_4 are retrieved using measured column ratios CO_2/O_2 and CH_4/O_2. These observations are used to validate measurements of the NASA Orbiting Carbon Observatory (OCO) satellite mission and the JAXA Greenhouse Gases Observing Satellite (GOSAT) and will also provide input data for the inverse modeling of sources and sinks of these Kyoto gases. Due to the high atmospheric background columns of CO_2 and CH_4 a single-column-measurement precision of better than 0.1% is required to be able to detect the relatively small effects from the sources and sinks of these species. This paper describes the observatory set up and shows an analysis of the first year of measurement data with a focus on quality control, and on annual as well as diurnal cycles of CO_2/O_2 and CH_4/O_2.

1 OBSERVATORY SET UP

The bruker IFS 125 HR instrument at Garmisch, Germany (47.48 °N, 11.06 °E, 744 m a.s.l.) is equipped with both an InGaAs detector and a Si diode (Fig. 1a) to cover the spectral range displayed in Fig. 1b, where besides CH_4 and CO_2 also O_2 shows prominent absorption bands. The DC detectors are operated in dual acquisition mode.
The instrumental line shape (ILS) is permanently monitored using a low density HCl cell located in the solar beam (Fig. 2).
To achieve a single-column-measurement precision of better than 0.1% accurate solar tracking (Fig. 3), surface pressure measurements (Fig. 4a) and time synchronization (Fig. 4b) are required.
Traceability to the global in situ network is achieved via airborne profile measurements over TCCON sites (Washenfelder et al., 2006). Such an aircraft campaign will be performed for the Garmisch site in summer/fall 2009.

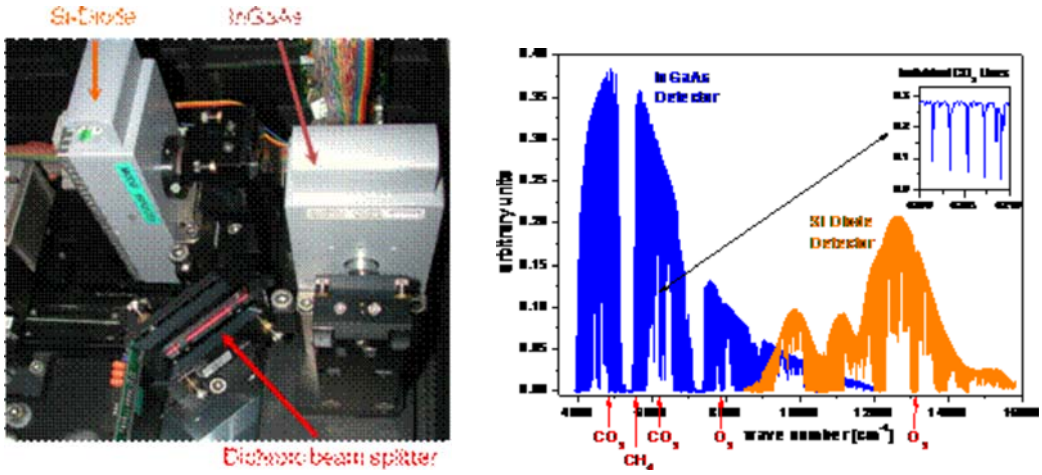

Fig. 1. (a) NIR Detectors for Garmisch Bruker 125 HR TCCON FTIR system. (b) Frequency ranges.

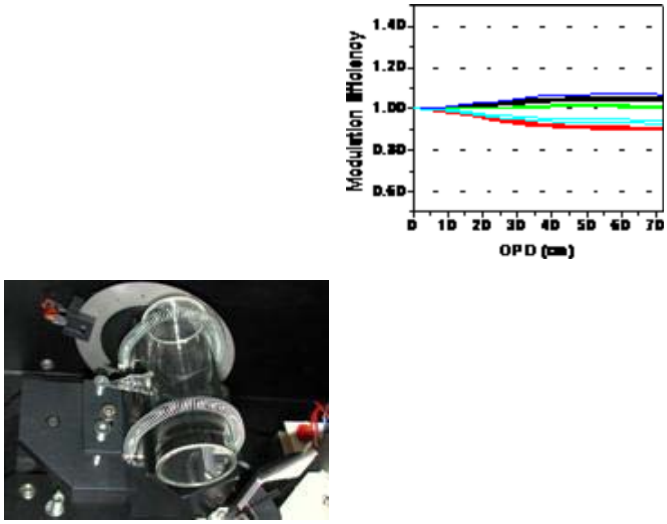

Fig. 2. Low density HCl cell to monitor the instrumental line shape.

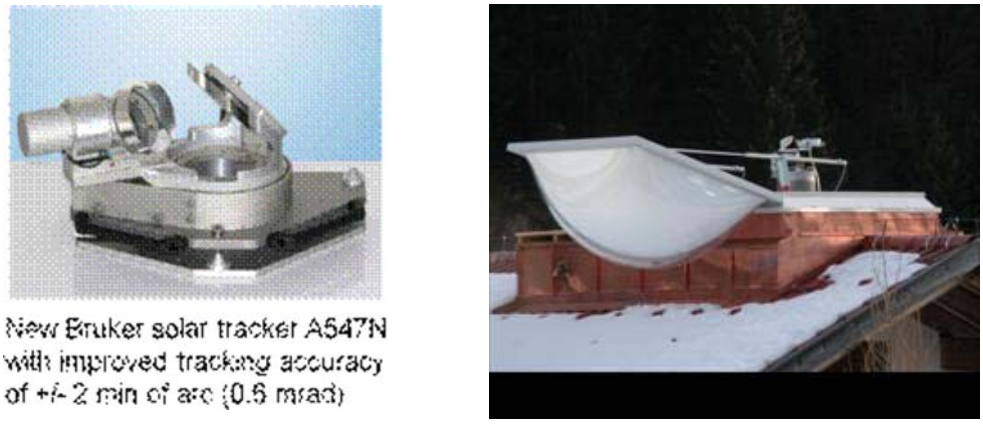

Fig. 3. Solar tracker and dome of the Garmisch TCCON FTS.

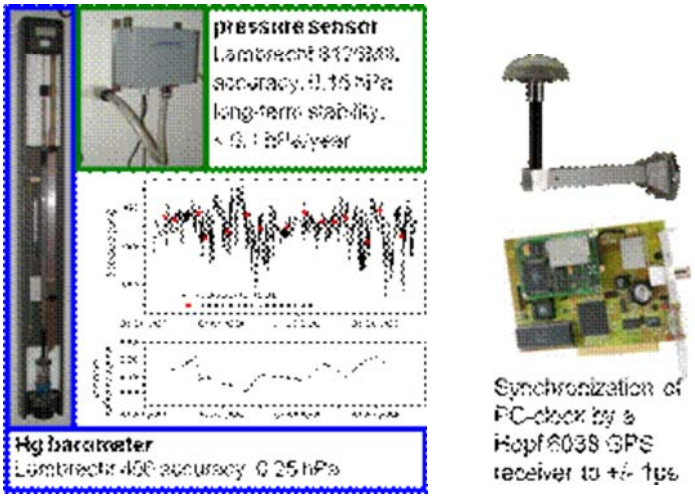

Fig. 4. (a) High-accuracy pressure measurements and (b) time synchronization.

2 MEASUREMENT RESULTS

The nonlinear least squares spectral fitting algorithm (GFIT) is used to retrieve CO_2, CH_4, O_2 column densities. The O_2 retrieval is used to convert the column densities to column averaged mixing ratios.
Figure 5 shows the effect of DC correction to eliminate artifacts due to clouds upon the retrieved columns based upon the approach of DC correction of the interferograms proposed by Keppel-Aleks et al. (2007). We used a slightly modified approach, i.e., a mathematical smoothing out of the center burst of the DC interferograms instead of an fft and subsequent low pass filtering to eliminate the center burst as proposed by Keppel-Aleks et al. (2007). Our modified approach avoids both a forward and inverse fast-Fourier transformation and thereby saves computation time.

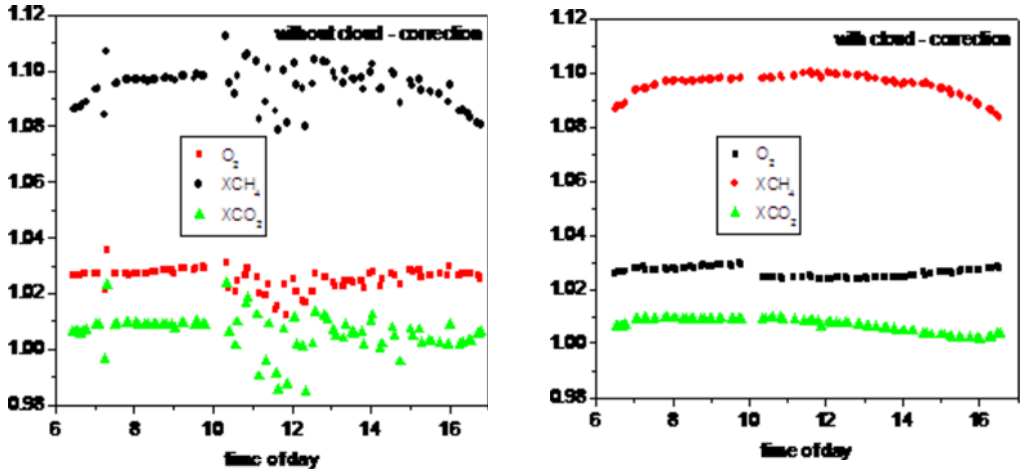

Fig. 5. Diurnal variation of O_2, CH_4 and CO_2 columns without (a) and with (b) DC cloud correction.

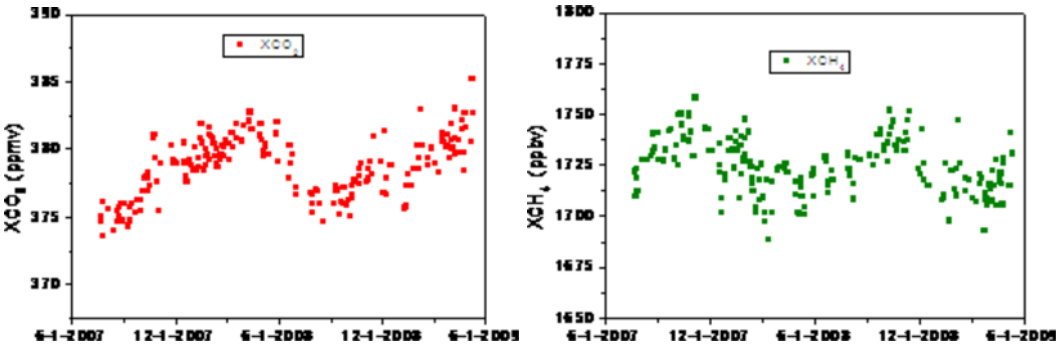

Fig. 6. Time series of column-averaged carbon dioxide (a) and methane (b) at the TCCON site Garmisch (daily means).

The time series of column-averaged carbon dioxide and methane retrieved by the TCCON algorithm GFIT ver. 4.3.2

(using the O_2 retrievals as a reference) are displayed in Fig. 6.

3 SATELLITE VALIDATION

At Zugspitze/Garmisch there is a long tradition in satellite validation, e.g., the first validation of column-averaged methane of ENVISAT/SCIAMACHY has been performed by the Zugspitze mid-infrared FTIR system (Sussmann et al., 2005).
Ground-based validation measurements in the near infrared are performed since spring 2009 correlative to overpasses of the JAXA Greenhouse Gases Observing Satellite (GOSAT) with the TCCON FTIR at Garmisch. These correlative measurements will be continued on the time scale of the next 5 years and beyond. These data are archived at the TCCON data base, and will be used to quantify potential biases, temporal drifts, and possible errors in the annual cycle in the GOSAT level-2 data (FTS SWIR and TIR).

Unfortunately, the NASA Orbiting Carbon Observatory (OCO) mission failed during launch in early 2009. However, validation support will be provided to planned NASA replacement missions in the future.

SUMMARY

The NIR-FTS site Garmisch, Germany (47.48 °N, 11.06 °E, 744 m a.s.l.) has become operational in July 2007 as one of the first 10 TCCON sites worldwide (Toon at al., 2009). It contributes to GOSAT validation since spring 2009.

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