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Lauder & Arrival Heights site reports

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Abstract

Lauder & Arrival Heights site reports

An intercomparison of solar MIR-FTS measurements of atmospheric gases between a Bruker 125HR and a Bruker 120M at Arrival Heights, Antarctica (78S).

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Abstract

A Bruker 125HR was installed at Arrival Heights in December 2014 to replace the aging Bruker 120M. An intercomparison campaign was undertaken overtwo austral summer seasons (2014-15 & 2015-16). A single solar tracker was available. Alternating measurements on each instrument were taken on clear days using a similar methodto that described in Batchelor (2009). Preliminary comparison oftotal column abundances of 8 species (O_3, HCl, HF, HNO_3, N_2O, CH_4, CO, HCN) from the two instruments show to be in agreement with mean differences of less than 2.1%. Mean differences of $ClONO_2$ and C_2H_6aregreater than 5%. Further investigation into the cause of these two large differences is required.

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Recent developments and items of (possible) interest at Lauder

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Abstract

A selection of recent developments at Lauder concerning MIR FTIR hardware and retrievals.

Contribution of oil and natural gas production to renewed increase in atmospheric methane after 2006: Top–down estimate from ethane and methane column observations

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Abstract

Harmonized time series of column-averaged mole fractions of atmospheric methane and ethane over the period 1999–2014 are derived from solar Fourier transform infrared (FTIR) measurements at the Zugspitze summit (47° N, 2964 m a.s.l.) and at Lauder (45° S, 370 m a.s.l.). Long-term trend analysis reveals a consistent renewed methane increase since 2007 of 6.2 [5.6, 6.9] ppb yr-1 at the Zugspitze and 6.0 [5.3, 6.7] ppb yr-1 at Lauder (95 % confidence intervals).

Several recent studies provide pieces of evidence that the renewed methane increase is most likely driven by two main factors: (i) increased methane emissions from tropical wetlands, followed by (ii) increased thermogenic methane emissions due to growing oil and natural gas production. In this talk, we quantify the magnitude of the second class of sources, using long-term measurements of atmospheric ethane as tracer for thermogenic methane emissions.

We present optimized emission scenarios for 2007–2014 derived from an atmospheric two-box model. Based on these results, the oil and natural gas emission contribution C to the renewed methane increase is deduced using three different emission scenarios with dedicated ranges of methane-to-ethane ratios (MER). Reference scenario 1 assumes an oil and gas emission combination with MER = 3.3–7.6, which results in a minimum contribution C > 28 % (given as lower bound of 99 % confidence interval). For the limiting cases of pure oil-related emissions with MER = 1.7–3.3 (scenario 2) and pure natural gas sources with MER = 7.6–12.1 (scenario 3) the results are C > 13 % and C > 53 %, respectively.

Our results suggest that long-term observations of column-averaged ethane provide a valuable constraint on the source attribution of methane emission changes and provide basic knowledge for developing effective climate change mitigation strategies.

Acknowledgments

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Hausmann, P., Sussmann, R., and Smale, D.: Contribution of oil and natural gas production to renewed increase in atmospheric methane (2007–2014): top–down estimate from ethane and methane column observations, Atmos. Chem. Phys., 16, 3227-3244, doi:10.5194/acp-16-3227-2016, 2016.

Comparison of the GOSAT TANSO-FTS TIR CH_4 volume mixing ratio vertical profiles with those measured by ACE-FTS, ESA MIPAS, IMK-IAA MIPAS, and 16 NDACC stations

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We present work on validating the GOSAT TANSO-FTS CH_4 VMR vertical column data product. This work has been submitted to Atmospheric Measurement Techniques and just completed the peer-review process. The manuscript can be found using the doi:10.5194/amt-2017-6.

The primary instrument on the Greenhouse gases Observing SATellite (GOSAT) is the Thermal And Near infrared Sensor for carbon Observations (TANSO) Fourier Transform Spectrometer (FTS). TANSO-FTS uses three short-wave infrared (SWIR) bands to retrieve total columns of CO_2 and CH_4 along its optical line-of-sight, and one thermal infrared (TIR) channel to retrieve vertical profiles of CO_2 and CH_4 volume mixing ratios (VMRs) in the troposphere. We examine version 1 of the TANSO-FTS TIR CH_4 product by comparing co-located CH_4 VMR vertical profiles from two other remote sensing FTS systems: the Canadian Space Agency's Atmospheric Chemistry Experiment-FTS (ACE-FTS) on SCISAT (version 3.5), and the European Space Agency's Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) on Envisat (ESA ML2PP version 6 and IMK-IAA reduced-resolution version V5R_CH4_224/225), as well as 16 ground stations with the Network for the Detection of Atmospheric Composition Change (NDACC). This work follows an initial inter-comparison study over the Arctic, which incorporated a ground-based FTS at the Polar Environment Atmospheric Research Laboratory (PEARL) at Eureka, Canada, and focuses on tropospheric and lower-stratospheric measurements made at middle and tropical latitudes between 2009 to 2013 (mid 2012 for MIPAS). For comparison, vertical profiles from all instruments are interpolated onto a common pressure grid, and the ACE-FTS, MIPAS, and NDACC vertical profiles are smoothed using the TANSO-FTS averaging

kernels. We present zonally-averaged mean CH_4 differences between each instrument and TANSO-FTS with and without smoothing, examine their information content, sensitive altitude range, correlation, a priori dependence, and the variability within each data set. Partial columns are calculated from the VMR vertical profiles, and their correlation is examined. We find that the TANSO-FTS vertical profiles agree with the ACE-FTS and both MIPAS retrievals' vertical profiles within 4 % below 15 km when smoothing is applied to the profiles from instruments with finer vertical resolution, but that the relative differences can increase to on the order of 25 % when no smoothing is applied. Computed partial columns are tightly correlated for each pair of data sets. We investigated whether the difference between TANSO-FTS and other CH_4 VMR data products varies with latitude. Our study reveals a small dependence of around 0.1 % per ten degrees latitude, with smaller differences over the equator, and greater differences towards the poles.

Trends in total column trace gases at Wollongong

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Abstract

We explore a 20 year record of total column amounts of trace gases from a ground-based FTIR at Wollongong, in South-East Australia. We provide trend analysis for a number of trace gases and use the results to infer changes in local and global factors affecting the composition of the Australian atmosphere, including CH_4 abundance, temperature and emissions from biogenics, biomass burning and anthropogenics. We find significant positive trends for N_2O, CH_4 and HF and significant negative trends for CO, C_2H_6, HCN and HCl. We also find a strong negative trend in HCHO at Wollongong that is counteracting a regional increase dominated by changes in global CH4 abundance. The decreasing trend can be partially attributed to changes in local biomass burning but is not fully attributable to changes in this source. The trend shows large decreases in all months except November where no trend was observed. This correlates to a regional temperature increase in November, which may cause increased emissions of HCHO precursors from biogenics, off-setting the decreasing trend for this month.

Keywords: formaldehyde; trends; biogenics

Two-decade monitoring of stratospheric and tropospheric trace gases using ground-based high-resolution FTIR instruments as an NDACC-certified measurement at Rikubetsu, Japan

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We report about long-term variations of trace gases (O_3, HCl, HF, HNO_3, $ClONO_2$, CH_4, C_2H_6, N_2O, CO, HCN) in stratosphere and troposphere measured in two decades at Rikubetsu (43.46°N, 143.77°E, 380 m a.s.l.), Japan. The measurements with ground-based high-resolution FTIR instruments (Bruker IFS120M up to 2010 and Bruker IFS120/5HR from 2014) have been carried out since 1995 as a part of the NDACC-certified measurements. The solar absorption spectrum is obtained with a resolution of 0.0035 cm^{-1} using 6 NDACC filters in 2-15 μm region . The vertical distribution of the trace gases is retrieved from the measured spectrum by using the SFIT4 (version 0.944 released on the IRWG website) software with the uniform retrieval parameters recommended by NDACC/IRWG. Retrieval results show the various temporal variations and the long-term trends since 1995. The observed partial column of O_3 in the stratosphere does not show any trend with significance, but in the troposphere, it seems to decrease in 2000s. After 2000, the negative trends in the time series of HCl and $ClONO_2$ total columns appear, being consistent with the global results.

In the presentation, we report the features of the seasonal variation and the trend of the species as well as the details of the measurements and retrievals.

Observation and simulation of ethane at 22 FTIR sites

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Ethane is the most abundant non-methane hydrocarbon in the Earth atmosphere. Its main sources are of anthropogenic origin, with globally 62% from leakage during production and transport of natural gas, 20% from biofuel combustion and 18% from biomass burning. In the Southern hemisphere, anthropogenic emissions are lower and so biomass burning is a more significant source. The main removal process is oxidation by the hydroxyl radical (OH), leading to a mean atmospheric lifetime of 2 months [1].

Until recently, a prolonged decrease of its abundance has been documented, at rates of -1 to -2.7%/yr, with global emissions dropping from 14 to 11 Tg/yr over 1984-2010 owing to successful measures reducing fugitive emissions from its fossil fuel sources [2].

However, subsequent investigations have reported about an upturn in the ethane trend, characterized by a sharp rise from about 2009 onwards (e.g., [3], [4]). The ethane increase is attributed to the oil and gas boom in North America (e.g., [5]), although significant changes in OH could also be at play.

In the present contribution, we report about the trend of ethane at 22 ground-based Fourier Transform Infrared (FTIR) sites spanning the 80°N to 79°S latitude range, focusing more specifically on the 2010-2015 time period. Dedicated model simulations by EMAC (1.8×1.8 degrees) implementing various emission scenarios are included in order to support data interpretation.

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Impact of circulation changes on the long-term trend of stratospheric hydrogen fluoride at five NDACC stations

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Hydrogen fluoride is mainly produced by the photolysis of anthropogenic source gases such as the chlorofluorocarbons (CFC), the hydrochlorofluorocarbons (HCFC) and the hydrofluorocarbons (HFC). These families of species are known for contributing to ozone depletion and/or to the greenhouse effect. It is thus essential to regulate and monitor their emissions. Despite the fact that the Montreal protocol (1987) has succeeded to reduce and then suppress the CFC emissions, HF is still increasing in the stratosphere because of ongoing emissions of the HCFC and HFC substitution products.

In the framework of the recent studies demonstrating the influence of stratospheric circulation changes on the trend of long-lived tracers (e.g. hydrogen chlorine), we decided to investigate the impact of these circulation changes on HF. To achieve this objective, the rates of changes over time of HF total/partial columns at various latitudes of the globe will be determined and critically discussed. Fourier Transform Infrared data produced at five NDACC sites (Kiruna – 68°N, Jungfraujoch – 46°N, Izana – 28°N, Lauder 45°S and Arrival-heights – 78°S) and satellite data (HALOE and ACE) will be used for this study. This preliminary selection of ground-based stations allows to cover both hemispheres and our period of investigation (last two decades). Finally, in order to support our data interpretation, two SLIMCAT simulations (standard and fixed dynamics) will also be included.

Integrated water vapor measurements at St. Petersburg site: comparison of FTIR, MW and GPS methods

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Abstract

The intercomparison of different techniques for atmospheric integrated water vapor (IWV) measurements is the important part of their validation and quality assessment. We analyze the simultaneous IWV measurements by Fourier-transform infrared (FTIR), microwave (MW) and global positioning system (GPS) methods at St. Petersburg site for the period between August 2014 and October 2016. Generally, all three techniques agree well with each other and therefore are suitable for monitoring IWV values at St. Petersburg site. However, the GPS and MW data quality depends on the atmospheric conditions; in dry atmosphere (IWV smaller than 6 mm), these techniques are less reliable at St. Petersburg site than the FTIR method. The upper bound of statistical measurement errors for compared datasets totals 2.0, 4.5 and 6.3% for FTIR, GPS and MW techniques, respectively. An accurate spatial and temporal matching of different IWV measurements is necessary for achieving the better agreement between various methods.

Keywords: integrated water vapor; FTIR spectrometer; MW radiometer; GPS receiver

1 Introduction

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3 Conclusions

References

[1] .

Redecrease of HCl total column density observed with Fourier Transform Infrared Spectroscopy at Tsukuba

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Abstract

Tohoku University and National Institute for Environmental Studies have observed the total columns of Hydrogen Chloride (HCl) with a high-resolution Fourier transform spectrometer (FTIR) at Tsukuba, Japan since 1998.

HCl is mainly distributed in the stratosphere. Chlorine species such as chlorofluorocarbon are transported to the stratosphere by the atmospheric circulation and usually saved as reservoir molecules such as HCl and $ClONO_2$ after some chemical reactions. Reservoirs are converted to active chlorine under the specific conditions in early spring in the South and the North Polar regions. Then it causes large-scale ozone depletion. Therefore the amount of stratospheric HCl is one of the potential indexes of ozone depletion.

Before the Montreal Protocol the total chlorine and also HCl in the stratosphere were increasing. They have begun to decrease worldwide from the second half of 1990's under the Montreal Protocol. But Mahieu et al. [2014] found the reincrease of HCl density at the Northern hemisphere lower stratosphere after 2007 by the ground based FTIR observations at 8 stations including Tsukuba under the Network for the Detection of Atmospheric Composition Change/Infrared Working Group from 1997 to 2011. They made it clear that the reincrease caused by the short-term deceleration of the atmospheric circulation in the Northern hemisphere for several years by comparing of atmospheric model and observational result.

In this study, we analyzed time series of HCl total column density at Tsukuba from 2001 to 2016 to make it clear that the reincrease of HCl total column density after 2007 is "short-term" phenomenon. SFIT4 spectral fitting program was used to derive the HCl total column from 3 spectral windows in the 3 micron region.

The temporal variation of derived HCl total column density shows decrease from 2001 to 2006, increase from 2007 to 2011, and again decrease from 2012 to 2016, which indicates that the increase after 2007 was really short-term. Furthermore, we confirmed that downward flow at the lower stratosphere at 36°north was strengthened from 2007 to 2012 and upward flow was strengthened after 2012 by analyzing zonal mean residual vertical velocity at 36°north using ERA Interim reanalysis datasets made by the European Centre for Medium-Range Weather Forecasts. Downward flow leads the increase of the column of stratospheric species such as HCl and upward flow leads the decrease. Therefore, this result is consistent with the temporal variations of HCl total column density. However, it'll be necessary to check the global residual-mean meridional circulation to see the variation of stratospheric general circulation which carries HCl. We will show the variation of the residual mass stream function at the poster.

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Temporal evolution of minor species observed with ground-based FTIR at Syowa Station, Antarctica in 2007, 2011, and 2016

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Improved Retrieval Strategy for Ozone Monitoring by Ground-Based FTIR Spectrometry

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Abstract

It is clear that monitoring the Earth's atmospheric composition helps us to understand the past and present climate of our planet and allows us to predict possible future changes on it. Ozone (O_3), one of the most important atmospheric gases that has major climate effects, plays a key role in the atmosphere by absorbing ultraviolet radiation, removing pollutants and acting as a green-house gas in the troposphere. Hence, consistent and high-quality long-term measurements of both total and vertical O_3 will be essential to try to understand the O_3 evolution in the next decades.

In this context, the work presented here examines ground-based FTIR (Fourier Transform InfraRed) O_3 measurements with the aim of providing an improved O_3 retrieval strategy that could be applied to any NDACC FTIR station. We analyze different retrieval approached combining the three most impacting parameters on the O_3 FTIR products: the spectral region used for the O_3 retrievals, the simultaneous fit of the atmospheric temperature profile and the characterization of the spectrometer's ILS (Instrumental Line Shape). By comparing to coincident independent O_3 data, we show how critical the choice of these parameters is and the scenarios that have to be considered in order to make the correct choice.

Keywords: ozone; FTIR; ILS

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Abstract

It is clear that monitoring the Earth's atmospheric composition helps us to understand the past and present climate of our planet and allows us to predict possible future changes on it. Ozone (O_3), one of the most important atmospheric gases that has major climate effects, plays a key role in the atmosphere by absorbing ultraviolet radiation, removing pollutants and acting as a green-house gas in the troposphere. Hence, consistent and high-quality long-term measurements of both total and vertical O_3 will be essential to try to understand the O_3 evolution in the next decades.

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Keywords: ozone; FTIR; ILS

Ground-based remote sensing activities over the Paris region (France) using the mid-resolution OASIS observatory

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Ground-based Fourier-transform infrared (FTIR) solar absorption spectroscopy is a powerful remote sensing technique providing information on the concentration and vertical distribution of various trace gases. This study reports measurements of atmospheric components: ozone (O_3), carbon monoxide (CO) and nitric acid (HNO_3) performed by OASIS for "Observations of the Atmosphere by Solar absorption Infrared Spectroscopy", an urban ground-based FTIR observatory over Paris suburbs (48.79°N, 2.44°E, France). The retrieval code PROFFIT (Hase et al., 2004) has been adapted to deal with spectra recorded at medium spectral resolution with a Bruker Optics Vertex 80 FTIR spectrometer. Even with mid-resolution (0.06 cm^{-1}) the information provided by OASIS ozone retrievals is clearly relevant to monitor both tropospheric (columns integrated from the surface up to 8 km) and stratospheric ozone amounts (Viatte et al., 2011). After this first analysis of the information content in OASIS ozone retrievals, the performance for tropospheric ozone monitoring by OASIS was confirmed by 7 years time series and the instrument is also suited for monitoring simultaneously total columns of CO (Chelin et al., 2015) and HNO_3.

References

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Hase F. et al., J. Quant. Spectrosc. Rad. Transf., 87, 25–52, 2004.
Viatte, C. et al., Atmospheric Measurement Techniques, 4 (10): 2323-2331, 2011.

First multi-year ground-based measurements of NH_3 total columns over the Paris region (France), from the OASIS FTIR solar observatory

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Ammonia (NH_3) is a reactive air pollutant strongly affecting both environment and human health. Massive industrial production of ammonia and the development of crops enhancing biological nitrogen fixation disturb the natural cycle and contribute to eutrophication, loss of biodiversity and acidification of various environments (soils, lakes, streams, etc.) (Galloway et al., 2003). Within the troposphere, NH_3 can react with SO_2 or HNO_3 to produce fine particulate matter ($PM_{2.5}$) of ammonium salts (Behera et al., 2013). Thus, measuring atmospheric ammonia is necessary to better constraint particulate matter formation and reactive nitrogen budgets in air quality models.

In the present study, we use the mid-resolution OASIS (Observations of the Atmosphere by Solar absorption Infrared Spectroscopy) ground-based FTIR solar observatory (Viatte et al., 2011 ; Chelin et al., 2015) to derive ammonia total columns over Paris suburbs (Créteil, 48.79°N, 2.44°E, France) using the PROFFIT inversion code (Hase et al., 2004). Thus, we have obtained the first multi-year time series of NH_3 ground-based measurements in Paris region (2009-2016).

We analyze diurnal and seasonal variabilities of NH_3 and study the relationship with meteorological variables. We also compare NH_3 total columns derived from OASIS and those from IASI satellite measurements (Whitburn et al., 2016).

References

Behera, S. N. et al., Environmental Science and Pollution Research, 20 (11) : 8092-8131, 2013.

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Trace gas observations within NDACC with a focus on tropical observations in Paramaribo and Palau

Justus Notholt[1](presenter), Mathias Palm[1], Yuting Wang[1], Thorsten Warneke[1], Matthias Buschmann[1], Christof Petri[1], Christine Weinzierl[1], Holger Winkler[1], Markus Rex[2]

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The tropical regions play a central role for understanding the global distribution of trace gases in the stratosphere. We are running two FTIR sites in the tropics, one on the east coast of South America in Paramaribo/Suriname (5° N, 55° W) and the other in the western Pacific on Palau (7° N, 134° O). In addition the tropical observations are accompanied by Polarstern cruises, passing the tropical regions on the Atlantic by transfer cruises from the Northern to Southern hemisphere.

The observations in Paramaribo allow studying the interhemispheric differences, since the ITCC passes the site twice per year. Palau is of great interest for studying the transport of tropospheric airmasses into the stratosphere, because mainly in this warm-pool region, tropospheric airmasses enter the stratosphere permanently.

During the talk I will present results from Paramaribo, Palau, and also add shortly results from our NDACC-sites in Bremen (53° N, 8° O) and Spitsbergen (78° N, 11° O).

Duration: 15-20 min

2017 ACE/OSIRIS Arctic Validation Campaign at Eureka

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on behalf of the Canadian Arctic ACE/OSIRIS Validation Campaign Team

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Ground-based measurements provide critical data for the validation of satellite retrievals of atmospheric trace gases and for the assessment of long-term stability of these measurements. As of March 2017, the Canadian-led Atmospheric Chemistry Experiment (ACE) satellite mission has been making measurements of the Earth's atmosphere for thirteen years and Canada's Optical Spectrograph and InfraRed Imager System (OSIRIS) instrument on the Odin satellite has been operating for fifteen years. As ACE and OSIRIS operations have extended beyond their planned two-year missions, there is an ongoing need to validate the trace gas data profiles from the ACE-Fourier Transform Spectrometer (ACE-FTS), the Measurement of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation (ACE-MAESTRO) and OSIRIS. In particular, validation comparisons are needed during Arctic springtime to understand better the measurements of species involved in stratospheric ozone chemistry.

To this end, fourteen Canadian Arctic ACE/OSIRIS Validation Campaigns have been conducted during the spring period (February - April in 2004 - 2017) at the Polar Environment Atmospheric Research Laboratory (PEARL) in Eureka, Nunavut (80N, 86W). For the past decade, these campaigns have been undertaken in collaboration with the Canadian Network for the Detection of Atmospheric Change (CANDAC). The spring period coincides with the most chemically active time of year in the Arctic, as well as a significant number of satellite overpasses. This presentation will focus on an overview of the measurements made by the ground-based, balloon-borne and satellite-borne instruments during the recent ACE/OSIRIS Arctic Validation campaigns.

CAMS Funding for RD NDACC FTIR data: implementation plans and schedule

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NDACC-IRWG cell exercise: status and further steps

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Altzomoni Site Report

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Activities around the FTIR measurements in Altzomoni will be reported. Some highlights of the results on ozone, HCHO and C_2H_6 retrievals will be presented.

Characterizing urban emissions of St. Petersburg: FTIR and in-situ measurements

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Abstract

Climate change and anthropogenic pollution affect not only the people's quality of life and health in the areas with high population density, but also increase pressure on sensitive ecosystems of Arctic and subarctic regions.

The accurate evaluation of carbon cycle gases fluxes (carbon dioxide, methane, carbon monoxide, ethane, etc.) from the Earth's surface into the atmosphere is critical for the correct climate forecast.

St. Petersburg site of IRWG/NDACC (St.Petersburg State University) is located in a suburb of greater St. Petersburg, ~35 km to the southwest from the city center, 59.88°N, 29.83°E, 20m asl. FTIR system together with other instrumentation for atmospheric monitoring is installed in buildings located at the University campus. It should be noted that St. Petersburg is the forth largest city in Europe with the population of 5 million people. The westerlies are the dominant winds for St.Petersburg, nevertheless our observational site is being covered from time to time by the pollution plume coming from the megacity center and its industrial suburbs. Site is equipped by a number of instruments that allow us to identify cases when atmospheric observations are carried out through polluted air, among them: in situ gas analyzers for continuous monitoring of NOx, O3, CO, CH4 and CO2 in the ambient air; OceanOptics spectrometer (HR4000-VIS) for zenith scattered measurements of NO2 tropospheric column; AERONET instrument (CIMEL CE 318-2) for aerosol optical depth observations.

Estimation of area fluxes for the suburban territory of St. Petersburg was carried out for 2014-2015 using the joint analysis of CO2, CH4 and CO mixing ratio nocturnal accumulation events in the boundary layer registered using LGR (Los Gatos Research) GGA-24r-EP и LGR CO 23r gas analyzers and a box model approach.

Methane area fluxes for the city center were evaluated by a coupling of box model and CH4 mixing ratios measurements performed simultaneously during 2013 at two observational sites located at the opposite sides of St. Petersburg: our site and Voeikovo site (operated by Voeikov Main Geophysical Observatory).

We widen our study of urban emissions by the analysis of CO, C2H6, CH4, CO2, H2CO and OCS total column time series retrieved from FTIR observations for the period of 2013-2016. Emission ratio values $E_{X/CO}$ (where X is C2H6, CH4, CO2, etc) were derived from those FTIR measurements which were performed under conditions of polluted troposphere. For the identification of air masses with different levels (background, moderate or highly polluted) and types (anthropogenic or wildfires) of contamination the following data were used:

- tropospheric columns of NO2 and AERONET aerosol optical thickness (when available) measured at the St.Petersburg site;
- satellite data on location and intensity of wildfires;
- OMI and OMPS satellite data on UV aerosol index;
- HYSPLIT (trajectory and dispersion) model results.

Investigations were funded by the Russian Science Foundation, project #14-17-00096. Measurement facilities were provided by Geo Environmental Research Center "Geomodel" of SPbU.

Keywords: FTIR; in-situ measurement; urban emissions of carbon cycle gases

CFC-11, CFC-12 and HCFC-22 ground-based remote sensing FTIR measurements near St. Petersburg

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Abstract

CFC-11 (CCl3F), CFC-12 (CCl2F2) and HCFC-22 (CHF2Cl) are the sources of chlorine in the stratosphere playing an important role in stratospheric ozone chemistry, besides, these atmospheric constituents belong to greenhouse gases. Therefore, the measurements of CFC's contents in the atmosphere are of prime interest.

Time series of CFC-11, CFC-12 and HCFC-22 total columns (TCs) have been obtained from the Fourier transform infrared (FTIR) solar radiation measurements which are being carried out at the St. Petersburg site (suburb of Saint-Petersburg, Russia,~ 30 ° E, ~60 ° N) since 2009. Spectra recorded by Bruker IFS 125 HR instrument were processed using SFIT4 software. For retrievals we used the following spectral intervals: 830 - 860 cm^{-1}, 922.5 - 933.6 cm^{-1} and 828.75 - 829.4 cm^{-1} for CFC-11, CFC-12 and HCFC-22, respectively . WACCM v6 profiles of atmospheric gases and NCEP temperature and pressure profiles were used as a priori information.

Error budgets estimated for investigated CFCs showed that systematic and random errors are ~7.5% and ~3.7% for the CFC-11, ~3.6% and ~3.2% for CFC-12, and ~4.3% and ~3.6% for HCFC-22. DOFS values for all three gases are close to 1, it does not allow obtaining the information on CFCs vertical distribution. The AVK analysis showed that FTIR data for all three species are sensitive to the whole troposphere and the lowermost stratosphere, with the highest sensitivity to the atmospheric layer between 5 and 10 km.

The mean value of CFC-11 TC is of 5.0 · $10^{15}cm^{-2}$, SD is of 0.27 · $10^{15}cm^{-2}$. For CFC-12, TC mean value is of 11.0 · $10^{15}cm^{-2}$, SD is equal to 0.65 · $10^{15}cm^{-2}$. For HCFC-22 the mentioned above values are of 4.4 · $10^{15}cm^{-2}$ and 0.59 · $10^{15}cm^{-2}$, respectively. Growth rates of CFC-11, CFC-12 and HCFC-22 total columns estimated over 2009-2016 are of (-1.3)%/yr, (-0.6)%/yr and 3.0%/yr, respectively. The above values do not contradict the independent data.

The ground-based FTIR measurements were compared with the spatially collocated satellite ACE-FTS data. It has been shown that for all three gases, the TC variability from ground-based measurements is much higher than in the case of satellite data. Besides, ground measurements for CFC-11 overestimate the satellite data by an average of 30%, and for CFC-12 by 12%. For HCFC-22, on average, there is a good agreement between satellite and ground-based data. Growth rates estimated using ground-based FTIR and satellite data are close each other for all three gases.

Investigations were funded by the Russian Science Foundation, project #14-17-00096. Measurement facilities were provided by Geo Environmental Research Center "Geomodel" of SPbU.

Keywords: FTIR; CFC-11, CFC-12 and HCFC-22 total columns.

O_3 Total and Partial Column amounts comparison between satellite-based Metop-IASI and ground-based NDACC FTIR at different locations

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Harmonized FTIR HCHO time-series across the network in view of satellite and model validation

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It has been shown earlier that NDACC (Network for the Detection of Atmospheric Composition Change) solar absorption Fourier-transform infrared (FTIR) measurements can provide high quality formaldehyde (HCHO) products (Paton-Walsh et al., 2005; Jones et al., 2009; Vigouroux et al., 2009; Viatte et al., 2014; Franco et al., 2015). These data can be considered reference measurements for validation of nadir satellite data since they represent comparable quantities, i.e. the integrated total columns.

The provision of consistent HCHO products from all NDACC FTIR stations would allow the sampling of high, mid- and low latitudes, as well as background, sub-urban and urban polluted conditions, which is crucial for satellite validation. This requires a harmonization of the HCHO products across the network, which had not been done up to now: the above five studies used different retrieval settings, which may lead to possible biases between the derived HCHO columns. Within our project NIDFORVal (S5P NItrogen Dioxide and FORmaldehyde Validation using NDACC and complementary FTIR and UV-Vis DOAS ground-based remote sensing data), 19 FTIR stations agreed to participate in a harmonization exercise in view of the TROPOMI validation. This harmonization covers the retrieval settings as well as the uncertainties calculation, the objective being to provide homogenized and well-characterized FTIR HCHO products across the network.

In this presentation, the harmonized (or not) retrieval settings and uncertainty budgets will be summarized. The launch of the Sentinel-5 Precursor being scheduled in August 2017, we will show the status of the HCHO network: how many and which stations are ready for the future validation exercise. The successful FTIR sites agreed to provide their complete HCHO time-series that are now available for the validation of past and present satellites as well as for model evaluation. We will show comparisons of these unprecedented time-series with the model IMAGES simulations at the various stations.

Re-analyzing Eureka DA-8 Spectra for Ozone Column Amounts

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From 1994 to 2008, a Bomem DA-8 high resolution Fourier Transform Spectrometer (FTS) recorded high-resolution absorption spectra of the atmosphere at one of the sites of what is today called the Polar Environment Atmospheric Research Laboratory (PEARL) located at approximately 80N, 86W near the Environment and Climate Change Canada (ECCC) Eureka Weather station on Ellesmere Island. Through out that period, the DA-8 was operated by ECCC and later the Canadian Network for Detection of Atmospheric Change (CANDAC) on an episodic basis. The data was analyzed with SFIT1 for column amounts only [Fast, et al., 2011] and is now being re-analyzed using SFIT4. Analyses of the spectral data set for the years from 2000-2008 have been completed for ozone using the standard NDACC micro-window. Effective apodization coefficients for each year are calculated based on a second smaller micro-window for days having both spectra and ozone sonde flights. This approach has in general lead to a decrease in the χ^2 value reported by SFIT4. Daily mean column amounts calculated using SFIT4 are compared to the originally archived values and to those produced by the Bruker IFS125HR which replaced the DA-8.

Fast, H., Mittermeier, R. L., and Makino, Y.: A Ten-Year Record of Arctic Trace Gas Total Column Measurements at Eureka, Canada, from 1997 to 2006, Atmosphere-Ocean, 49, 67–94, doi:10.1080/07055900.2011.562470, http://www.tandfonline.com/loi/tato20, 2011.

TCCON is playing an essential role in the validation of numerous column observations from space. Our utility depends critically on the continuing efforts to reduce and minimize site-to-site bias. I highlight several practices that produce such bias with implications for operations and retrieval algorithm improvement needs.

Computing methane emissions from TCCON measurements

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The South Coast Air Basin (SoCAB) in Southern California is a highly urbanized region in which there are significant methane emissions. Since 2007, we have been measuring SoCAB methane (CH_4), carbon monoxide (CO), and carbon dioxide (CO_2) with the Pasadena and JPL TCCON stations, and have used those measurements to compute the methane emissions (Fig. 1). In this presentation, I will describe our method of computing emissions from the TCCON measurements, and the results from some recent work showing the utility of simultaneous ethane (C_2H_6) measurements for attributing the source of the methane emissions to the SoCAB atmosphere [1].

Toward the end of the presentation, I will show some work-in-progress in which I endeavour to compute methane emissions from the region between the European TCCON stations. This part of the presentation will serve as an abstract-of-intent for the European TCCON partners to participate in a future paper.

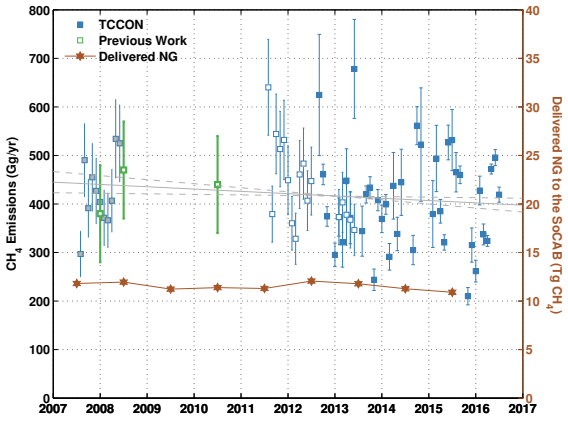

Figure 1: The left-hand axis shows methane emissions measured in the atmosphere by three TCCON FTS instruments that were located in the SoCAB since 2007. The grey solid line indicates the best-fit slope with standard errors indicated by the grey dashed lines. Previous measured emissions are indicated by green squares. The right-hand axis shows the delivered natural gas to the SoCAB, and is scaled such that if 2% of the delivered gas is released into the atmosphere, the atmospheric burden would be equal to the numbers (in Gg) on the left-hand axis.

References

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Current Status of GOSAT Product Validation

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Abstract

The Greenhouse gases Observing SATellite (GOSAT, called IBUKI) is the world's first satellite dedicated to measuring the concentrations of carbon dioxide (CO_2) and methane (CH_4) from space. GOSAT was launched on 23 January 2009. It has been operating successfully for eight years. The observation instruments onboard GOSAT are the Thermal And Near-infrared Sensor for carbon Observation Fourier Transform Spectrometer (TANSO-FTS) and the Cloud and Aerosol Imager (TANSO-CAI). TANSO-FTS observes the Short Wavelength InfraRed (SWIR) solar light reflected from the earth's surface and the Thermal InfraRed (TIR) radiation emitted from the atmosphere and the ground. It has three bands in SWIR region (760, 1600, 2000 nm) and a TIR band (5500-14300 nm) with a spectral resolution of 0.2 cm^{-1}. TANSO-CAI has four narrow bands of 380, 674, 870 and 1600 nm with a spatial resolution of 0.5-1.5 km.

Column averaged dry-air mole fractions of CO_2 (XCO_2), CH_4 (XCH_4) and H_2O (XH_2O) (hereafter we call GOSAT product) are retrieved from SWIR absorption spectra which are obtained from the TANSO-FTS interferogram data for clear sky points judged from the CAI data. We report the validation results of about eight-year GOSAT product (Ver.02.2x), using XCO_2, XCH_4, and XH_2O data obtained by the Total Carbon Column Observing Network (TCCON).

Keywords: GOSAT product;Validation;TCCON

ESA Project "Automation of TCCON Data Analysis"

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Abstract

The focus of the project is the time reduction for TCCON data to become publically available. At the end of the project the data measured with TCCON systems shall be processed and quality checked within three months instead of currently twelve months.

This shall be achieved for a selected number of nine TCCON sites for the data products CO and CH_4, as well as CO_2.

The main task to realize this objective is the automation of the TCCON data handling and processing steps, which are currently performed manually. Part of the activity is also to assess possibilities for harmonization in the data handling and processing steps across the TCCON sites.

The project partner institutions are:

• KIT/IMK-IFU, Garmisch-Partenkirchen, Germany

• KIT/IMK-ASF, Karlsruhe, Germany

• MPI-BGC, Jena, Germany

• IUP, University Bremen, Bremen, Germany

After the TCCON data are processed and before the data are released through the TCCON database, a thorough quality check is performed. This quality control task is shared between the TCCON teams and an expert at Caltech, who performs centrally a final visual quality check on all TCCON data sets on a regular monthly basis. Within this project a review of the whole QC process shall be undertaken in information exchange with Caltech, aiming to provide to ESA and all TCCON partners a detailed description of the QC process. Finally, a web-based application shall be implemented to allow the individual partners to perform the visualization QC for their own prior to submission to Caltech.

The project shall be concluded with a test period, demonstrating that the automation of the TCCON data analysis was successfully implemented and the data set can be used for e.g. satellite validation purposes three months after having been measured.

This talk will give an overview on the project work packages. The presentation shall be closed with a list of questions to the audience with possible feedback to be used as input to the project.

Milestones and Schedule:

TCCON data automation plan: KO + 2 months

QC process review: KO + 4 months

TCCON data automation verification

& Demonstration Test Plan: KO + 6 months

Demonstration Test Report & Final Report: KO + 10 months

Acknowledgments

We thank ESA for funding via Contract No. 4000120088/17/I-EF and Angelika Dehn (ESA) for accomplishing this project. Valuable support by Paul Wennberg and Coleen Roehl (Caltech) is gratefully acknowledged.

Validation of S5P methane and carbon monoxide with TCCON data within the TCCON4S5P project

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Long term stability of the portable EM27/SUN FTIR spec-trometer used as a travel standard for the TCCON

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Intercomparability of X_{CO_2} and X_{CH_4} from the United States TCCON sites

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(This is a follow-up to the presentation given at the 2016 TCCON meeting).

It is difficult to check for biases among TCCON sites because they cannot easily be co-located to compare measurements. There are few such empirical studies (e.g., Messerschmidt et al., 2010 [1]). There have also been analytical studies (e.g., Wunch et at., 2015 [2]). Here, we use a pair of portable EM27/SUN spectrometers to create an intercomparison dataset for the 4 U.S. TCCON sites and estimate site-to-site bias.

Measurements from the two types of instruments are not directly comparable. We use two methods to make the retrievals more comparable including 1) truncating the 125HR interferograms, and 2) correcting for different sensitivities including accounting for differences in averaging kernels ([3], Fig. 1). Pairwise comparisons using these 2 different methods differ, though the average estimated biases (compared with the median) are similar. Our estimates are similar to those from a direct comparison [1], and are less than the maximum error estimated from an analytical assessment [2].

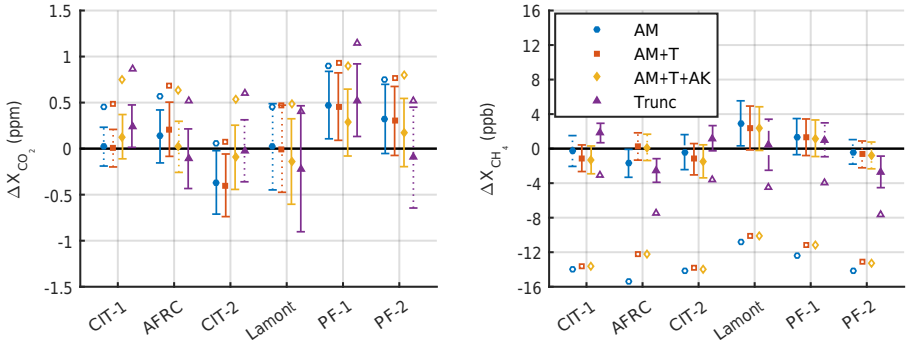

Figure 1: Estimates of site bias compared to overall median.

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Measurements of XCO_2 and XCH_4 using the portable

EM27/SUN FTIR spectrometer

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Abstract

A portable FTIR spectrometer EM27/SUN has been used at Hefei station, China to remotely measure CO_2 and CH_4. Total column measurements of atmospheric CO_2 and CH_4 have been successfully achieved from July 2016 to April 2017. Time series of XCO_2 and XCH_4 capture the daily variation. The observations were compared with the temporally coinciding measurements taken with the high-resolution FTS, IFS125HR, with small mean differences for daily averages. The mean difference of daily averages is 1.47±0.35 ppm (0.30 %±0.09 %) and -0.0084±0.0037 ppm (0.47 %±0.20 %) for XCO2 and XCH4, respectively. The results show the potential of the spectrometer as a promising addition to the TCCON FTIR sites, suitable for remote areas with low infrastructure.

Keywords: Carbon dioxide; Methane; EM27/SUN; FTIR

1 Introduction

Despite its many advantages, the high resolution IFS125HR spectrometers have their limitations. They are expensive, too heavy to transport, difficult to maintain, and need suitable infrastructure. So the portable spectrometers EM27 are very useful in field campaigns and remote areas with limited infrastructure.

2 Results

2.1 Data processing and analysis

GFIT is used for the EM27 spectra to retrieve the trace gases, with the same parameters as used for the high-resolution FTS spectra.

2.2 Time series of XCO_2 and XCH_4

XCO2 and XCH4 have been successfully achieved from July 2016 to April 2017.

3 Conclusions

The daily averages comparison results show that there are small mean differences between the observations of the EM27 and high-resolution FTS, IFS125HR.

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CO_2 profile retrieval from near-infrared spectra

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Variations in XCO_2 are partly driven by local surface fluxes of CO_2, and partly by transport from remote locations. Even though XCO_2 observations are precise, they lack information about the vertical distribution of CO_2 in the atmosphere, which is of interest for the validation of satellite measurements and model simulations.

The GFIT non-linear least-squares spectral fitting program is used for TCCON retrievals. A forward model computes an atmospheric transmittance spectrum using a priori knowledge of atmospheric conditions. An inverse method then compares the measured spectrum with the resulting calculation, and adjusts the retrieved parameters to obtain the best fit. In GFIT, the parameters include volume mixing ratio (VMR) scale factors for the different fitted gases. A single scale factor scales the a priori concentration profile of a given trace gas.

GFIT2 is an algorithm being developed to compute CO_2 profile retrievals on TCCON spectra [1]. GFIT2 allows the profile shape to vary during the retrieval process. The algorithm has thus more freedom to fit the observed spectra, but it is also more sensitive to uncertainties in the forward model calculations caused by spectroscopic errors and instrument misalignment, for example.

Steps to improve CO_2 profile retrievals will be presented. A more complex forward model including a speed-dependent Voigt line shape with line mixing is used, and a method to combine CO_2 retrieved in spectral bands of various opacities is being tested.

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CO2 emissions from Popocatepetl

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CO2 column anomalies from volcanic emissions of the Popocatepetl, Volcano, Mexico could be detected by solar absorption spectroscopy from the Altzomoni NDACC FTIR station at 4.0 km a.s.l. altitude (19.12°N 99.65°W). Retrievals of HCl column from the same spectra allow the proof of the volcanic origin of the CO2 anomaly.

On April 26th 2015, a strong volcanic anomaly was detected and the CO2 emission flux was determined. Based on the methodology shown for this day, we analysed a time series of 4 years of data in which 52 events with detectable volcanic gas-fluxes of HCl were found and in 21 events the $\frac{\Delta CO2}{HCl}$ gas ratios could be determined. These events allowed for an estimation of the mean annual CO2 emission of the Popocatepetl Volcano.

Volcanic CO2 anomalies is in the sub percentage range can typically be detected at the Altzomoni site during the early morning at high solar zenith angles, so that strategies reducing the effect of airmass dependence and pointing errors are needed for adequate quantification.

Philippines TCCON installation: towards quantifying atmospheric carbon in Southeast Asia

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Status of Tsukuba and Rikubetsu TCCON sites

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Paris TCCON site report

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The FTS-Paris based on a Bruker IFS-125 HR, has been operated at the Université Pierre et Marie Curie in the center of Paris since 2006 and has joined the TCCON network since September 2014. Here, we provide an overview of the activities related to the TCCON-Paris site and an update of the instrument specification.

Influence of the a priori profile on CO_2 total columns at Paris

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Abstract

Paris is a polluted TCCON site with major anthropogenic contributions to CO_2. We address the question in as much a priori profiles provided by GFIT are suited to retrieve CO_2 abundances under the particular conditions in Paris? A priori profiles from GFIT in summer 2015, for example, show an average value of 385 ppm at the ground, while in situ measurements [1] indicate values well above 395 ppm, which is due to human activities.

By modifying the GFIT a priori in the boundary layer, we are studying its influence on the retrieved CO_2 total column values. The modifications of the a-priori are based on LIDAR and in situ data, measured at the Paris station. We then compare the retrieved CO_2 column values to the outcome using the non-modified a-priori.

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Change characteristics of atmospheric methane total columns in Hefei, China

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Abstract:

We present about 2.5 years of atmospheric column-averaged dry-air mole fraction (DMF) of methane (X_{CH4}) time series retrieved in the near infrared spectral region using the ground-based Fourier Transform Spectrometer (g-b FTS) at Hefei, China. Obvious seasonal cycle and three typical diurnal variation modes were captured by these data. Change characteristics of atmospheric methane total columns in Hefei, China were analyzed by comparison with Greenhouse Gases Observing SATellite (GOSAT) and the GEOS-Chem global 3-D tropospheric chemistry model.

Airmass dependent correction factors and XAIR dependence

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Updates on lunar absorption measurements of xCO2 and xCH4 from Ny-Ålesund

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An update on the lunar absorption xCO2 and xCH4 measurements during the Polar Night in Ny-Ålesund is presented. Special emphasis is put on the adjustment of the atmospheric model and potential bias from lower resolution. Nighttime lunar measurements are compared to daytime solar measurements and the full seasonal cycle time series are compared to various models.

TCCON Site Report on Anmyeondo FTS Station

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The IFS-125HR has been operated at Anmyeondo, Korea since December 2012 and as a TCCON site since August 2014. At the same place, there is the regional Global Atmosphere Watch station as well. The instrument specification and its measurement are maintained under the TCCON requirements. Modulation efficiency was regularly estimated using HCl cell measurement. Modulation efficiency is recorded more than 99.98%. 33-day measurements were recorded in 2016. It's less than 58 days of 2015 due to longer rainy season and practical problem resulted from remote operation. Aircraft observation has been carried out by using the Cavity Ring-Down Spectroscopy analyzer manufactured by the Picarro, UAS since 2012.

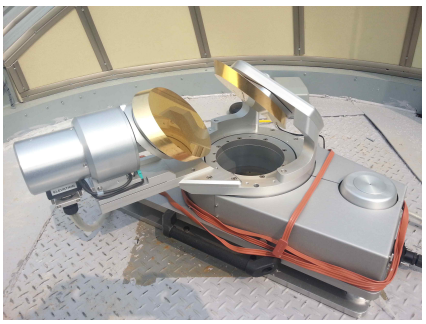
(a)  (b) 

Fig. 1. IFS-125HR and solar tracker manufactured by the Bruker that are installed at Anmyeondo TCCON station.

TCCON a priori tool with the movement of ITCZ

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Side-by side intercomparison between two TCCON instruments

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The Total Carbon Columnn Observing Network (TCCON) observes column-averaged dry-air mole fractions of CO_2 , CH_4 , CO, N_2O, and other trace gases at more than 20 stations worldwide. These measurements are the calibration basis for all current and many future satellite greenhouse-gas-observing missions. TCCON goal is to provide the most precise and accurate data with uncertainties better than 0.25%. Especially inter-station biases in the network are critical and should be reduced to a minimum.

TCCON uses Fourier Transform Spectrometers (FTS) which are comparatively large and expensive instruments that are not easily moved around. In the network, the typical distance between TCCON stations is hundreds to thousands of kilometers. Therefore, opportunities to directly compare the performance of TCCON instruments are very rare. In 2010, the TCCON instrument from the Max Planck Institute for Biogeochemistry (MPI-BGC) in Jena, Germany, was set up close to a TCCON instrument at the University of Wollongong, Wollongong, Australia, for six months. This was part of a test campaign before the final deployment of the MPI-BGC instrument to Ascension Island.

Due to problems with the acquisition and processing of TCCON data at the time, the results of the intercomparison were inconclusive at first. Spectroscopic artifacts known as ghosts affected TCCON data until 2011. The ghosts created relatively large biases between individual instruments that were in the range of TCCON precision and accuracy goals. The ghost problem was fixed by a hardware upgrade for all TCCON instruments in 2011 but still remained in older data. Only with the latest TCCON processing software GGG2014, the ghosts could finally be removed from the pre-2011 TCCON data. Therefore, a detailed side-by-side intercomparison between the two TCCON instruments at Wollongong in 2010 has now become possible.

The results agree well for all species. Especially for CH_4, no bias or scaling effect could be detected within a 0.1% unvertainty range. For CO_2, a small bias of 0.1% and more scatter might be the result of local effects as the instruments were set up about 2 km apart.

Biomass burning signals over the South Atlantic Ocean before and during the El Niño event of 2015/16

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Update on TCCON dataset DOI citations

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Saga, Japan site report 2017

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Abstract

GOSAT TANSO-FTS have been observing GHG column-average dry air mole fractions from space with high-resolved spectra of O_2, CO_2 and CH_4 since January 2009. JAXA has also been operating a high-resolved ground-based FTS at Saga for validation of the GOSAT XCO_2 and XCH_4 since June 2011. Currently, other GHG satellites such as OCO-2 are also on orbit. We collaborate the validation activities with ground-based and space-based GHG measurements.

Keywords: Saga; FTS; GHG; GOSAT; OCO-2

1 Introduction

JAXA has been operating the ground-based FTS with high spectral resolution (IFS125HR) at Saga University in the south-western part of Japan as a TCCON member since July 2011. Saga station is usually operated every 3 days at the GOSAT target observation, and OCO-2 target opportunities of 2 days in 16-day revisit. Saga is located near China over the sea, and thus aerosol and polluted air reach instantaneously.

2 Activity at Saga station

2.1 Saga station

The FTS is settled in the container at the Saga University campus. A sun tracker on the rooftop is in a glass case, which was originally set for ship measurements. The gold-coated mirror degrades gradually with the help of the glass case protection.
XCO_2 and XCH_4 are estimated from direct sunlight spectra with high accuracy and utilized to make validation for the satellite observations such as GOSAT and OCO-2 with simultaneous measurements. The GOSAT validation results at Saga station are 0.40+/-2.51 ppm and 7.6+/-13.7 ppb for XCO_2 and XCH_4, respectively [1].

2.2 Operation status

Status of the recent operation is summarized in Table 1. Observation has stopped only when the sliding roof was not able to open (Feb-Apr, 2015; Jun-Jul, 2016) and the metrology laser became out of order (Oct-Dec, 2015). A HCl gas cell was embedded in the before-optics to check the ILS or instrument performance while solar observation since May 2015. Currently, we have an ability of remote operation.

Table 1. Recent operation event at Saga station

Period	Operation status
Feb-Apr, 2015	Sliding roof problem (No observation)
May 2015 -	Embedment of the HCl gas cell in the before-optics
Oct–Dec, 2015	Metrology laser problem (No observation)
Jun–Jul, 2016	Sliding roof problem (No observation)
Oct–Dec, 2016	Vacuum pump stop (Observation at 1-atm condition)
Jan 2017	Establishment of remote operation

2.3 Recent results

All data of the Saga XCO_2 and XCH_4 since June 2011 are shown in Fig. 1. The data width shows diurnal variation and blanks are no operation. GOSAT overpass at Saga station is around 13:25. We compare with GOSAT retrieval and Saga station data at the coincidences.
GOSAT XH_2O retrieved individually from SWIR and TIR bands are also validated by Saga station data [2]. Saga XCO and GOSAT low tropospheric O_3 are correlated in seasonal variation after subtraction of long-term trend and seasonal cycles for investigating origins of air masses reaching Saga [3]. Large

CH_4 enhancement in summer 2013 was detected by GOSAT XCH_4 and Saga station XCH_4, which was transported to Japan from the major source area in east China [4].

Fig. 1. All data of time series XCO_2 and XCH_4 at Saga station from 2011 to 2016

3 Conclusions

Saga station has been in normal operation since July 2011. A HCl gas cell was embedded since May 2015. We normally make measurements at GOSAT and OCO-2 target days for their validation activities.

Acknowledgments

We thank to M. Sakashita, T. Fukamachi, C. Taura, who were Saga University students and A. Shishime, H. Ikegami, who were collaborators of Fujitsu FIP.

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Retrievals of XCO_2 and XCH_4 from low resolution spectra at Lauder and Arrival Heights

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Abstract

We present retrievals of XCO2 and XCH4 from lo-resolution, near infrared spectra recorded using an EM27/SUN portable spectrometer at Lauder (45 S) and Arrival Heights (78 S). Two different retrieval schemes are compared, GFIT and PROFFIT.

Further, retrievals at Lauder are compared with TCCON measurements at the same site.

Fiducial Reference Measurements for Greenhouse Gases (FRM4GHG): status of the project

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Fiducial Reference Measurements for Greenhouse Gases (FRM4GHG) is a European Space Agency (ESA) funded project aiming at the assessment of several ground-based spectrometer types for the precise measurement of greenhouse gases, with a focus on CH4, CO and CO2. To achieve this objective, several instruments have been collocated at Sodankyla, next to the TCCON Bruker 125HR instrument, and will be performing simultaneous measurements during a campaign covering all seasons during which there is enough sunlight. The ground-based spectrometric measurements are complemented with vertical profile data of the GHG from regular AirCore launches at the campaign site.

The campaign started in March 2017; since the end of April all instruments are up and running. The presentation will discuss the campaign set-up, the status of the instruments and the ongoing observations.

Calibration strategies for FTIR and other IRIS instruments for accurate $\delta^{13}C$ and $\delta^{18}O$ measurements of CO_2 in air

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Abstract

Over recent years the introduction of Isotope Ratio Infrared Spectroscopy (IRIS), based on various spectroscopic techniques, has advanced stable isotope analysis in the atmosphere, allowing in situ field measurements of the isotope ratio of CO_2 in air, performed in real time directly on the air sample without separation of CO_2 from air. These instruments also need to be calibrated with CO_2 in air standard mixtures, applying calibration strategies which exploit the specificity of IR absorption spectroscopy, namely its dependency on individual isotopologues amount fraction in the sample.

The BIPM has developed a novel methodology to calibrate a Fourier Transform infrared spectroscopy (FTIR) spectrometer using only two standards of CO_2 in air with different mole fractions but identical isotopic composition. A complete uncertainty analysis was performedand measurements of $\delta^{13}C$ and $\delta^{18}O$ with standard uncertainties of 0.09 ‰ and 1.03 ‰ respectively were demonstrated, at a nominal CO_2 mole fraction of 400 μmolmol^{-1} in air. A different strategy was chosen for another IRIS system (Thermo Delta Ray) which makes use of two standards of CO_2 in air of known but differing $\delta^{13}C$ and $\delta^{18}O$ isotopic composition, reaching standard uncertainties of 0.18 ‰ and 0.48 ‰, for $\delta^{13}C$ and $\delta^{18}O$ measurements respectively. Both calibration strategies were validated using a set of five Primary Reference Gas Mixtures of CO_2 in whole air or synthetic air in the mole fraction range of (378- 420) μmol mol^{-1}, prepared and/or value assigned either by the National Institute of Standards and Technology (NIST) or the National Physical Laboratory (NPL). The standards were prepared using pure CO_2 obtained from different sources, namely: combustion; Northern Continental and Southern Oceanic Air and a gas well source, with $\delta^{13}C$ values ranging between -35‰ and -1‰. All measurements were compared with values assigned independently on the same samples by Isotope Ratio Mass Spectrometry (IRMS) at the Max Planck Institute for Biogeochemistry Jena (MPI-Jena), providing the traceability to the VPDB-CO_2 scale for $\delta^{13}C$ and $\delta^{18}O$.

Keywords: FTIR-CO2-$\delta^{13}C$- $\delta^{18}O$.

Water vapor continuum absorption over the terrestrial and solar infrared: Results from the Zugspitze radiative closure experiment

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Abstract

Quantitative knowledge of water vapor radiative processes in the atmosphere throughout the terrestrial and solar infrared spectrum is still incomplete even though this is crucial input to the radiation codes forming the core of both remote sensing methods and climate simulations. Beside laboratory spectroscopy, ground-based remote sensing field studies in terms of so-called radiative closure experiments are a powerful approach, because this is the only way to quantify water absorption under cold atmospheric conditions. For this purpose, we have set up at Mt. Zugspitze (47.42 °N, 10.98 °E, 2964 m a.s.l.) a long-term radiative closure experiment designed to cover the infrared spectrum between 400 to 7800 cm^{-1} (1.28-25 µm). As a benefit for such experiments, the atmospheric states at Zugspitze frequently comprise very low integrated water vapor (IWV; minimum = 0.1 mm, median = 2.3 mm) and very low aerosol optical depth (AOD = 0.0024-0.0032 at 7800 cm^{-1} at airmass 1). All instruments for radiance measurements and atmospheric state measurements are described along with their measurement uncertainties. Based on all parameter uncertainties and the corresponding radiance Jacobians, a systematic residual radiance uncertainty budget has been set up to characterize the sensitivity of the radiative closure over the whole infrared spectral range.

Water vapor continuum quantification in the far infrared spectral region (400–580 cm^{-1}) has been performed via radiative closure using an AERI spectroradiometer. The resulting far-infrared foreign continuum coefficients are consistent with the MT_CKD 2.5.2 continuum model and also agree with the most recent atmospheric closure study carried out in Antarctica.

We present a first quantification of the mid- and near-infrared water vapor continuum absorption in the 2500 to 7800 cm^{-1} spectral range. Continuum quantification is achieved via radiative closure using radiometrically calibrated solar FTIR absorption spectra. The dry atmospheric conditions at the Zugspitze site enable continuum quantification even within water vapor absorption bands, while upper limits for continuum absorption can be provided in the centers of window regions. Throughout 75 % of the 2500 to 7800 cm^{-1} spectral range, the Zugspitze results are agree within our estimated uncertainty with the widely used MT_CKD 2.5.2-model (Mlawer et al., 2012). In the wings of water vapor absorption bands, our measurements indicate about 2-5 times stronger continuum absorption than MT_CKD, namely in the 2800 to 3000 cm^{-1} and 4100 to 4200 cm^{-1} spectral ranges. The measurements are consistent with the laboratory measurements of Mondelain et al. (2015), which rely on cavity ring-down spectroscopy (CDRS), and the calorimetric-interferometric measurements of Bicknell et al. (2006). Compared to the recent FTIR laboratory studies of Ptashnik et al. (2012, 2013), our measurements are consistent within the estimated errors throughout most of the spectral range. However, in the wings of water vapor absorption bands our measurements indicate typically 2 – 3 times weaker continuum absorption under atmospheric conditions, namely in the 3200 to 3400 cm^{-1}, 4050 to 4200 cm^{-1}, and 6950 to 7050 cm^{-1} spectral regions.

Acknowledgments

This project was funded by the Bavarian State Ministry of the Environment and Consumer Protection via grants TLK01U-49581 and VAO-II TPI/01. Andreas Reichert received a PhD grant of the Deutsche Bundesstiftung Umwelt (DBU). The authors are indebted to D.D. Turner (NOAA) and E. Mlawer (AER) for helpful conversations during the definition phase of the project.

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Estimating AOD from an EM27/SUN

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Aerosol optical depth (AOD) is a simple measure of the opacity of the atmosphere due to aerosols measured in the UV through near-IR range. A challenge in measuring OD is determining $I_0(\lambda)$, the wavelength dependent signal that would be obtained in the absence of atmospheric scattering and absorption. Typically a Langley extrapolation method is used over a full day in a low turbidity environment to determine I_0 for an instrument. However, our EM27/SUN has a changing optical system so I_0 is not constant from day-to-day. Further, our observations are made under high turbidity conditions which further complicates the I_0 estimate.

Here we present 5 different methods to estimate I_0 and evaluate with AERONET. Our methods have significant AOD variability compared with AERONET (0.041 (1σ) absolute (78% relative)). We discuss sources and ranges of uncertainties. About 20 % of the AOD estimates are negative. An example of results from one of the more reliable days is shown in Fig. 1.

Despite the uncertainties, these AOD estimates can be utilized using solar zenith angle anomalies, short-time (∼10 min) analysis, and stringent filtering. From these, we estimate an AOD increase of ∼20 % for a 10 % increase in column water content in the California South Coast Air Basin.

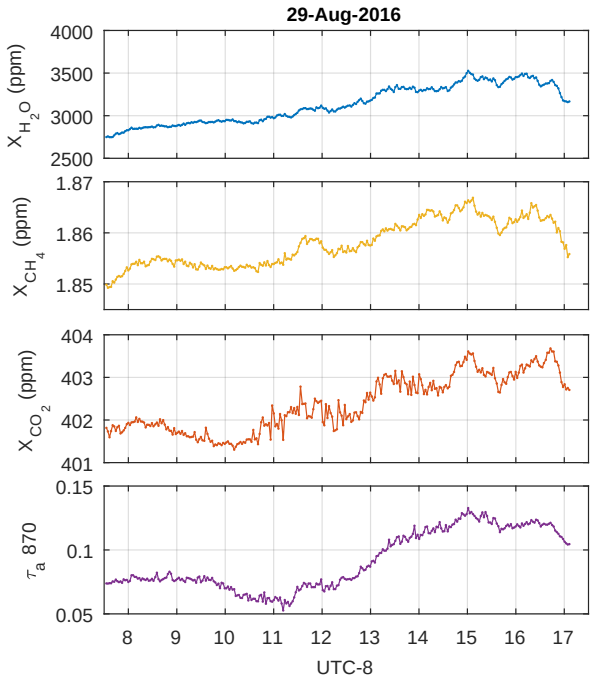

Figure 1: Example diurnal profiles for different species. Plotted are 2 min averages. Broad structure is common among all species, with a general increase. Finer scale co-variation may be present for a few peaks, but is not common for all peaks.

Validation of GOSAT Products in the Southern Hemisphere: Alice Springs Desert M-Gain Comparisons

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Abstract

In addition to ongoing TCCON measurements, this past year we deployed a portable spectrometer system (Bruker EM-27/SUN) to Alice Springs in desert Australia in order to understand the differences in GOSAT M-gain and H-gain retrievals; M-gain retrievals are used over bright surfaces such as deserts and semi-arid regions. The world's deserts and semi-arid regions encompass large areas that are mostly undisturbed by anthropogenic emissions and are important for understanding the carbon cycle, however, there are no TCCON stations that are ideally located in a desert or semi-arid region that is not influenced by city emissions. Because of this, there has been no direct comparison and/or validation of GOSAT M-Gain retrievals with TCCON. Results from the measurement campaign in Alice Springs, Australia are shown here. A follow-up campaign with the EM27/SUN and an AirCore to provide vertically resolved profiles is planned in 2017.

Keywords: GOSAT validation; GOSAT M-Gain; EM-27/SUN

Evaluating Canada's air quality forecasting model with FTIR data from NDACC and TCCON

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Abstract

GEM-MACH is an air quality forecasting model that is used operationally at Environment and Climate Change Canada. Several research versions of GEM-MACH exist for atmospheric research. The model has been well-validated using surface in situ observations, and some satellite observations. However, this is the first time we evaluate the model's 3D output with ground-based FTIR measurements. Different GEM-MACH configurations and how well they agree with the archived NDACC-IRWG and TCCON FTIR measurements will be presented. A case study whereby sea bird ammonia emissions are added to the Arctic model will also be presented. The overall goal of this project is to use the model and FTIR measurements to study different atmospheric processes, with a focus on trace gases relevant to air quality and climate change.

Keywords: FTIR; air quality modelling; GEM-MACH

1 Introduction

GEM-MACH is an air quality forecasting model that is used operationally at Environment and Climate Change Canada to issue twice daily Air Quality Health Index forecasts for the country [1,2,3]. Several research versions of GEM-MACH exist for atmospheric research, such as GEM-MACH-Arctic for testing the effects of increased marine shipping in the Arctic [4], GEM-MACH-global for transport policy scenarios and future data assimilation [5], and GEM-MACH-PAH for simulating toxic compounds at high spatial resolution [6]. The operational model has been well-validated using surface in situ measurements, and some satellite observations [6], however, this is the first time we evaluate the model's 3D output with archived ground-based FTIR measurements. The unique NDACC and TCCON datasets should provide added valuable information on the model's performance, especially for developing model improvements.

2 Results

Four different GEM-MACH configurations were evaluated: Global at 0.9^{o} resolution, Arctic at 15-km resolution, operational (Canada & U.S.) at 10-km resolution, and "Pan Am Games" (Ontario and NE U.S.) at 2.5-km resolution. These are compared to NDACC-IRWG and TCCON FTIR measurements of CO, O_3, H_2CO, NH_3, NO, NO_2, and HNO_3. A case study whereby sea bird NH_3 emissions are added to the Arctic model was also compared to measurements [7], and it was found that the added bird emissions greatly improve the results compared to FTIR measurements.

3 Conclusions and future work

The NDACC-IRWG and TCCON data provide valuable datasets for model evaluation. These initial comparisons have shown a good agreement between model and measurements, therefore, the model may also be useful to the NDACC and TCCON communities for future collaborative atmospheric studies, both globally and at higher resolution in North America. In addition, we expect the new East Trout Lake TCCON site to be useful in evaluating a future oil sands emissions study to be performed with the high-resolution Oil Sands model.

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Ground based remote sensing activities at Hefei, China

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Abstract:

In this presentation, we present ground based remote sensing activities at Hefei, China. It includes site report for both TCCON and NDACC-IRWG observations and some research activities based on these observations.

MicroCarb : A small-size satellite mission for the monitoring of CO_2 fluxes

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MicroCarb is a space mission under development at CNES (the French Space Agency) for a launch around 2020. The scientific objective is the monitoring of CO_2 fluxes through the observation of spatio-temporal gradients of atmospheric concentrations. These objectives are thus similar to those of the GOSAT, OCO-2 or Tansat missions launched in the past years. One goal of MicroCarb is to acquire high quality measurements with a compact instrument, which opens the way for a long term monitoring of the Carbon cycle from a series of small satellites, or satellites of opportunities. In addition, the MicroCarb instrument shall acquire spectra over a band that is not sampled by the other sensors listed above and that may permit a more accurate correction for the atmospheric scattering.

The presentation shall detail the scientific objectives of the mission and describe the main features of the MicroCarb instrument.

Progress in GOSAT-2

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We present on the GOSAT-2 update in the GOSAT-2 project team in NIES since the last TCCON meeting in Jeju.

Sentinel-5 Precursor – Status of First Copernicus Atmospheric Mission

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Sentinel-5 Precursor (S-5P) is the chemistry mission to be launched within the European Commission's Copernicus Programme. With the current launch window of summer 2017 and a nominal lifetime of 7 years, S-5P is expected to provide continuity in the availability of global atmospheric data products between its predecessor missions SCIAMACHY (Envisat) and OMI (AURA) and the future Sentinel-4 and -5 series. S-5P will deliver unique data regarding the sources and sinks of trace gases with a focus on the lower troposphere including the planet boundary layer due to its enhanced spatial, temporal and spectral sampling capabilities ascompared to its predecessors. The S-5P satellite carries a single payload, namely TROPOMI (TROPOspheric Monitoring Instrument) that was jointly developed by the Netherlands and ESA. Covering spectral channels in the UV, visible, near- and shortwave infrared, it measures various key species including tropospheric/stratospheric ozone, NO_2, SO_2, CO, CH_4, CH_2O as well as cloud and aerosol parameters. These data sets will be extended by the Sentinel-4 (S-4) and Sentinel-5 (S-5) missions, which are hosted instruments on EUMETSAT geostationary and polar orbiting platforms to be launched during 2021.This paper presents the status of the S-5P mission, focusing on spacecraft and ground segment preparation and the Cal/Val activities.

A proposal to calibrate FTIR OCS with AirCore profile measuremenrs

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1 Abstract

Carbonyl sulfide (OCS) has the potential to be used for the separation of photosynthesis and respiration fluxes of CO_2, because it is taken up by plants during photosynthesis through a similar pathway to CO_2, but is not emitted by respiration; however, there are large uncertainties in the OCS sources and sinks, which makes this application challenging. Current available OCS in-situ measurements are too sparse to constrain the OCS fluxes, and therefore more measurements are needed for improving the OCS flux estimation.

The NDACC FTIR network has obtained solar spectra at numerous sites around the globe for up to two decades. These spectra are available and OCS columns and coarse profiles can be retrieved from them. A limitation for the use of the FTIR OCS retrievals is the lack of calibration. We propose to "calibrate" the FTIR OCS measurements against the in situ OCS standards using AirCore profile measurements. This approach has been successfully used for the "calibration" of CO_2 and CH_4 within the TCCON global network. After the calibration, we will perform an OCS flux inversion using both in-situ and FTIR measurements. Hence the expected outcomes of this proposal are a) a calibration for OCS data from the NDACC FTIR network and b) an improvement of the OCS flux estimation.

Keywords: FTIR AirCore, OCS

2 Introduction

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4 Conclusions

5 References

In situ measurements of greenhouse gases at TCCON sites

David Griffith (1), Nicholas Deutscher (1), Voltaire Velazco (1), Dan Smale (2), Dave Pollard (2), Sebastien Biraud (3), Debra Wunch (4)

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Global Atmosphere Watch (GAW) is the WMO network which provides oversight and coordination of global greenhouse and other gas in situ measurements. In situ measurements of GHGs are routinely made at some TCCON sites– these measurements are tied to the WMO calibration scales to which TCCON is compared through overflights. At Darwin, Wollongong, Lauder, and Lamont, continuous, automated measurements of CO_2, CH_4, N_2O, CO and $d^{13}C$ in CO_2 are made using the Wollongong-developed FTIR analyser now commercially available as "Spectronus" from Ecotech, Australia. Anmyeondo is a GAW site and measures a wider suite of species.

With this talk I would like to describe in situ measurements relevant to TCCON partners, including:

- Intro to GAW and the in situ networks
- The Wollongong/Spectronus FTIR trace gas analyser
- Illustrative TCCON and in situ data from Darwin, Wollongong, Lauder and Lamont
- Discuss value of in situ measurements to TCCON data at the same site.

Operational CAMS model validation using TCCON data

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During the last year TCCON rapid delivery data from Orleans, Bialystok and Reunion have been used to validate high resolution global CAMS model data http://atmosphere.copernicus.eu. During this talk we present the main results obtained this far and discuss some difficulties encountered when applying the TCCON averaging kernels at high solar zenith angles.

COCCON news

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Instrumental calibration and long term stability of COCCON spectrometers

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Quantification of CO_2 and CH_4 Tokyo megacity emissions using solar absorption spectrometers

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Overview of the IASI-NG satellite mission

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MERLIN : a Franco-German active space mission dedicated to atmospheric methane

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The Methane Remote Sensing Lidar Mission (MERLIN) is a joint cooperation between France (CNES) and Germany (DLR) on the development, launch and operation of a space LIDAR dedicated to the retrieval of total methane (CH_4) atmospheric columns. Atmospheric methane is the second most anthropogenic gas, contributing 20% to climate radiative forcing but also plying an important role in atmospheric chemistry and a precursor of tropospheric ozone and low-stratosphere water vapour.

For the first time, measurements of atmospheric composition will be performed from space thanks to an IPDA (Integrated Path Differential Absorption) LIDAR (Light Detecting And Ranging), with a precision (target 20 ppb for a 50 km aggregation along the trace) and accuracy (target 3 ppb) sufficient to improve the constraints on methane fluxes compared to current observation networks. The very low systematic error target is ambitious compared to current methane space mission, but achievable because of the differential active measurements of MERLIN, which guarantees almost no contamination by aerosols or water vapour cross-sensitivity. As an active mission, MERLIN will deliver data for all seasons and all altitudes, day and night.

Here, we present the MERLIN mission and its objectives. A focus is put on the reduction of uncertainties on methane surface emissions. To do so, we propose an OSSE analysis (observing system simulation experiment) to estimate the uncertainty reduction brought by MERLIN. To do so, a precise analysis of causes of errors has been done for the MERLIN mission and is also presented. The originality of our system is to transfer both random and systematic errors from the observation space to the flux space, thus providing more realistic error reductions than currently provided in OSSE only using the random part of errors.

Zugspitze and Garmisch Site News

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Site report of the BIRA-IASB FTIR sites

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Abstract

The Royal Belgian Institute for Space Aeronomy (BIRA-IASB) is, in collaboration with local partners, conducting continuous long-term measurements of climate-relevant gases at three of its remote sites. Two of the three sites are located on Ile de La Réunion (21° S, 55° E); the first site, at about 85 m a.s.l., in St. Denis conducts measurements of greenhouse gases within the framework of the TCCON network. The TCCON measurements at this site have been performed since September 2011. The second site is located on the mountain at about 2155 m a.s.l. at the Maïdo observatory. These measurements are performed within the framework of the NDACC network. The site is operational since March 2013. The third site is located at Porto Velho, Brazil (-8.774° N, 296.128° E, 87 m a.s.l.).The site is operated since July 2016 in the framework of the NDACC network. This talk will focus on the current status of the above mentioned BIRA-IASB sites and will show some of the recent results.

Keywords: Climate; Greenhouse Gases; Remote Sensing; NDACC-IRWG; TCCON

Site report on Rikubetsu and Moshiri as an NDACC site

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We report on the status of Rikubetsu and Moshiri FTIRs since the last NDACC/IRWG meeting in Jeju.

Jungfraujoch site report

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We provide a brief overview of the activities of the Liège group over the last 12 months: observational program at the Jungfraujoch station, exploitation of the spectra and current target gases, ongoing projects and funding status, archiving at the NDACC-DHF.

Toronto Site Report

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Abstract

This site report for Toronto gives a brief overview of the atmospheric measurements being conducted at the University of Toronto Atmospheric Observatory (TAO), in Toronto, Ontario, Canada (43.66N, 79.60W). The primary instrument at TAO is the Bomem DA8 FTIR spectrometer, which is coupled together with an active solar tracker. Currently measured species are O_3, CO, CH_4, N_2O, C_2H_2, CH_3OH, H_2CO, HCl, HCN, HCOOH, HF, HNO_3 and NH_3. The data until the end of 2016 have been analyzed using SFIT4 and archived in the HDF format on the NDACC server. This site report will summarize the current status of the instrument and data analysis.

Keywords: Toronto; Site report; TAO; FTIR

Xinglong and Xianghe sites introduction

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East Trout Lake TCCON Station

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This poster will introduce the new East Trout Lake station for which we are applying for provisional TCCON status.

FTS measurements of CO_2 and CH_4 at Sodankylä, Finland

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Fourier Transform Spectrometer (FTS) measurements of CO_2, CH_4 and other gases were established by FMI in Sodankylä (67.4° N, 26.6° E) during early 2009 (*Kivi and Heikkinen, 2016*). Our Bruker IFS 125HR instrument is equipped with two room temperature detectors, which are used for the TCCON measurements: an indium gallium arsenide (InGaAs, covers 4000-11000 cm^{-1}) and a silicon diode (Si, covers 9000-15000cm^{-1}). The measurements are performed in vacuum to improve stability and to reduce water vapor in the system. The optical path difference for the TCCON measurements is 45 cm and the spectral resolution is 0.02 cm^{-1}, collection time for a single scan is 78 seconds. Column abundances of CO_2, O_2, CH_4, H_2O, HDO, HF, CO and N_2O are retrieved from the spectra. The retrieval is based on the TCCON GFIT algorithm (*Wunch et al., 2011*). In addition to the TCCON measurements, also longer wavelength measurements are taken, using a liquid nitrogen cooled indium antimonide detector (InSb, covers 1800 –6000cm^{-1}). The sequence of measurements is such that after two InGaAs/Si scans, one InSb scan is taken. To be able to make the solar intensity variation correction, the interferograms are recorded in the DC mode. The solar tracker is of type A547N, manufactured by Bruker Optics. The cover of the tracker and related software was made locally. The FTS can be operated from a remote system. On average, there have been 146 measurement days per year. A single measurement is graded as acceptable if the solar intensity variation during the measurement is less than 5% and the solar zenith angle is less than 82°. Due to the zenith angle constraint, good measurements at the site are possible from 8 February to 11 November each year (268 days).

Here we present results of the long term TCCON measurements and comparisons with the satellite based observations, including the Greenhouse gases Observing SATellite (GOSAT) and the Orbiting Carbon Observatory-2 (OCO-2). In the future the FTS data will be used for validation purposes of also other satellite missions, such as TROPOMI on board ESA Sentinel-5P satellite. Regarding the long term measurements we find statistically significant increase of column amounts of carbon dioxide by 2.2 +/- 0.2 ppm per year and methane increase by 7.1 +/- 0.8 ppb per year. The lowest monthly XCO_2 values within the seasonal cycle are found in August and the highest in February–May. Year-to-year variability is lowest in March–May and highest during the growing season in June–September. Monthly XCH_4 values are the lowest in April and March, while the XCH_4 values increase towards October-November. The year-to-year variability of XCH_4 is largest in March-April. During the years 2009-2016 we find a good agreement between the GOSAT and ground based observations. In case of CO_2 the relative difference between the two instruments has been 0.04 +/- 0.02 % and in case of CH_4 the relative difference has been -0.07 +/- 0.02 %. We have also performed year around AirCore measurements at Sodankylä. AirCore data is directly related to the WMO trace gas scales and can be used to validate retrievals based on remote sensing measurements (e.g., *Tukiainen et al., 2016).*

References

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