Review: "A fully automated FTIR system for remote sensing of greenhouse gases in the tropics" M. C. Geibel et al., MS No.: amt-2010-91

General comments

In their paper "A fully automated FTIR system for remote sensing of greenhouse gases in the tropics", the authors describe a fully automated FTS system and show first results taken at Jena (Germany). This paper is suited for publication after addressing the comments below.

The paper is clearly structured and easy to read. Nevertheless some changes have to be made to improve the focus and to supply missing information. To be useful for others the automation should be explained in more detail, e.g. the used hardware. Further it should be clearly described which parts of their automation are specific for the tropics. All existing solar absorption activities in the tropics should be mentioned (e.g. Warneke et al, ACP 2010, Petersen et al, ACP 2008, ACPD 2010, Deutscher et al, AMT 2010, Senten et al., ACP 2008). In the result section a model comparison would be interesting.

In an overview the questions provided by AMT will be answered in this section. Specific aspects will be deepened in the following section:

1.Does the paper address relevant scientific questions within the scope of AMT?

Yes, FTIR measurements are an important measurement system as they measure precisely the total column of trace gases. For example FTIR spectrometry is therefore the only suitable technique to calibrate/validate greenhouse gas abundances from space-borne instruments. The automation of such an instrument reduces significantly maintenance cost and increase measurement hours and number of taken spectra. Overall 18 FTS stations have been constructed in the last years only in the scope of TCCON. The groups that have not developed their own automation concepts will benefit from this paper.

2.Does the paper present novel concepts, ideas, tools, or data?

Several automated FTIR systems are already constructed within TCCON at the sites Darwin, Park Falls, Lamont, Bialystok, and Orleans. The first automation of a FTIR system was briefly described in Washenfelder et al. 2006. Therefore the idea is not new, but the concept for the automation is unique and therefore interesting.

3.Are substantial conclusions reached?

The automation concept is unique and clearly presented. Therefore groups starting to develop their own automation concept will benefit from this paper. Nevertheless the authors should work more on their first results. For example the results shown in Figure 13 should be interpreted and e.g. compared with results of a model.

4.Are the scientific methods and assumptions valid and clearly outlined?

The concept of the automation is clearly presented. They should work on the section about the results.

5.Are the results sufficient to support the interpretations and conclusions?

Yes, the results show that the automation concept is working. However, as mentioned before the discussion of the results has to be improved.

6.Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)?

The author should focus more on the description of their devices used in the automation. Then the reproduction is possible.

7.Do the authors give proper credit to related work and clearly indicate their own new/original contribution?

The author should definitely mention some missing but important publication made on automations of FTIR systems. It should be made clear, that there are several similar automated FTS systems, which can "be deployed nearly anywhere in the world" (page 4, 1.paragraph of section 2) as well.

8.Does the title clearly reflect the contents of the paper?

It isn't clear to me why they focus on the tropics in the title. The authors describe an automation concept and the first results. The automation concept even point out that they can measure anywhere in the world. Therefore I would either focus on the future plans (it is intended to bring the system to the tropics), describing the site, …., or to focus on the automation concept and to skip the "in the tropics" in the title.

9. Does the abstract provide a concise and complete summary? Yes

10. Is the overall presentation well structured and clear? The presentation is remarkable clear!

11.**Is the language fluent and precise?** yes

12.**Are mathematical formulae, symbols, abbreviations, and units correctly defined and used?** yes

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13.**Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated?** In more detail in next section
14.**Are the number and quality of references appropriate?** In next section
15.**Is the amount and quality of supplementary material appropriate?** In next section
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Specific comments

Title

A fully automated FTIR system for remote sensing of greenhouse gases ~~in the tropics~~ (or focus more on the site in Ascension Island)

Abstract

This article introduces a new fully automated FTIR system that ~~is~~ will be part of the Total Carbon Column Observing Network. It will provide continuous ground-based measurements
of column-averaged volume mixing ratios for CO_2, CH_4 and several other greenhouse gases in the tropics.
[…]

1 Introduction

[…]

Recent analyses of solar spectra obtained by near-infrared Fourier Transform Spectrometers (FTIR) demonstrate that xCO_2 can be retrieved with high precision (Washenfelder et al., 2006; Warneke et al., 2005; Dufour et al., 2004; Yang et al., 2002, Messerschmidt et al. 2010).
[…]

To obtain the column-averaged volume mixing ratio, these values have to be related [what does "to be related" mean?] either to surface pressure or measured O_2 total column.
[…]

The Atmospheric Remote Sensing group (ARS) of the Max Planck Institute for Biogeochemistry (MPI-BGC) in Jena, Germany, is currently making the final preparations for installing such an FTIR instrument in the tropics, where such measurements have only been taken within short campaigns (~~Petersen et al., 2010~~ Petersen et al. 2008, Warneke et al, 2010) (statement is wrong: FTS site in Darwin is in the tropics, NDACC site in Reunion as well, even though they do not measure in the NIR range). The instrument will be part of the Total Carbon Column Observation Network (TCCON) (Toon et al., 2009, Wunch et al. 2010) that ~~will~~ provide ground-~~truth~~based data for satellite validation (it is not clear if the network or the new FTS system is meant).
[…]

2 The MPI-BGC FTIR System

~~Most of the existing FTIR systems are operated either by a person physically sitting next to the instrument or controlled remotely through a data connection. Furthermore, those systems were usually built for one special location and designed to cope with that location's typical special environmental conditions. In contrast to this the main goal of the MPI-BGC's FTIR project was to build an instrument that could be deployed nearly~~
~~anywhere in the world (Fig. 1).~~ (this statement is wrong. There are several sites around the world which are fully automated: Park Falls, Darwin, Lamont, Bialystok, Orleans [Washenfelder et al. 2010, Deutscher et al. 2010, Messerschmidt et al 2011 in preparation])
(better: explanation what is the basic work (measurement of xGases), basic challenge (weather detection, different tasks, error handling, …), then explanation how the concept deals with theses challenges and how the implementation work). The author can point out their individual focus in the automation concept, but they can't forget mentioning the other existing automated systems, which are dedicated for global usage as well.
[…]

2.1 The Container

[…]

2.2 Fourier Transform Infrared Spectrometer (FTIR)

The atmospheric measurements are performed by a Bruker 125HR FTIR instrument. The instrument provides high resolution solar absorption spectra over a large spectral range. The resolution of the instrument is 0.0035 cm^{-1} ~~and it covers a bandwidth from 3800 cm^{-1} to 15800 cm^{-1}.~~ Similar to the Park Falls instrument (Washenfelder et al., 2006) it is equipped with two detectors measuring simultaneously in different spectral areas. A silicon diode detector covers the spectral ~~area~~ range from 15800 cm^{-1} to 9000

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cm^{-1}. A Indium-Gallium-Arsenide (InGaAs) detector (.) covers the spectral area range from 12000 cm^{-1} to 3800 cm^{-1}
To enhance the temperature stability of the system all measurements are performed under vacuum. Therefore the system is equipped with a multi-stage oil-free scroll pump. To avoid vibrations of the pump influencing the measurements, the pump only runs during night time. For accurate measurements the monitoring of the instrumental line shape is necessary. This is realized as described by Hase et al. (1999) by integrating an HCl gas cell in the beam path inside the FTIR instrument. First results of this procedure are described (in) section 3.1. The atmospheric measurements are performed with a 0.014 cm^{-1} resolution and two scans (one forward, one backward) per measurement (is this true?, if the measurement are proceeded with slice-ipp, the normal procedure is that one Forward scan leads to one measurement and one backward scan to a second measurement. They are not averaged). (I would restructure this section explicitly after hardware restriction (res, max bandwidth, max …) and then settings of the instrument for the NIR)

2.3 Solar Tracker and Protective Devices

[…]

2.3.1 The Solar Tracker Dome

[…]

2.3.2 The Shutter

[…]

2.4 Automation

For the automation the system was divided in three autonomous modules. Each of these modules is designed to be as reliable as possible. In case of a malfunction or a complete failure of a component, the modules bring the system to a defined standby or sleeping status. ~~This way it is very unlikely that the system ends up in an undefined state.~~

2.4.1 Weather Station

The weather station (Fig. 5) is equipped with a number of different sensors to monitor outdoor and indoor conditions (Table 4). Most of the sensors are redundant since their data are either crucial for the measurement process or for the protection of the system against bad weather conditions[…]

2.4.2 Programmable Logic Controller (PLC)

[…]

In case of a power failure the PLC ensures that all components are properly shut down and the dome is closed before the UPS battery runs out. It is also the first ~~system~~ mode? that automatically restarts after such a shutdown. All the other components are afterwards restarted in a defined cascade until the whole system is fully operational again.

2.4.3 Dual PC (in section 2 the authors wrote "These modules are the weather station, the Programmable Logic Controller (PLC) and the Master PC". Here the first time "Dual PC" is used. The relationship of the Dual PC, Master PC and the Tracker PC, which is mentioned later, should be clarified.)

For high availability (it isn't clear to me what high availability means) the container is equipped with an industrial 19-inch rack-mount computer system. […]

Master PC

[…]

2.5 Communication, Data Storage and Transfer

The container can be accessed remotely in two ways. First, it has a wireless link that can cover up to 2 km to the next available internet access. It also is equipped with a BGAN satellite receiver that provides internet connection almost anywhere in the world. However, the transfer of large amounts of data over the satellite link is very expensive, so this link is intended mostly for remote control. If there is no alternative internet connection, data can also be saved to 72-GB DDS (DAT) tapes which can be mailed easily.

(Experiences show that you can get up to 5GB data per day, therefore 72GB doesn't last to long ~ 20days. This limitation doesn't fit to the statement in section 2 that the container can run "even for years". I would expect more clarification on this point, especially because the focus of the paper lies on the "fully automated concept over years everywhere in the world")

3 First Results

(I would think about dividing this section in a retrieval part and a measurement part)

3.1 Instrument Line Shape (maybe "Alignment" would be better as title?)

For the accurate retrieval of total column values, a good alignment of the FTIR is crucial.

[…]

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The long term stability is not a specific issue of the Jena instrument, but of all Bruker instruments around the world. Therefore I am not sure if this section is necessary, or if they could just state in the introduction part that FTS systems are quite stable and refer to some publication within TCCON ?!

3.2 Column measurements at Jena

[…] Also GFIT has been used for the analysis of spectra from several ground-based FTIR spectrometers (Notholt et al., 1997). In recent years GFIT and has become the standard data analysis tool for TCCON. (mention Wunch et al. 2010, and publication of Geoffrey Toon)

[…]

As ~~mentioned~~ (shown) by Washenfelder et al. (2006), there are two methods for calculating the total dry column □dry air.

[…]

In general the approach of calculating the total dry column via surface pressure with Eq. (2) is more precise since Ps can be measured very accurately (see Section 2.4.1). Using the more noisy retrievals of the O_2 column for the calculation in Eq. (3) will increase the random scatter. But non-perfect measurement conditions (like pointing errors and variation of intensity during the measurement) and systematic errors will affect the O_2 and CO_2 retrievals similarly. Those are eliminated when □dry air;O_2 is used in Eq. (1)

~~Figure 12 shows the change with the solar elevation angle of the GFIT averaging kernel for xCO_2 over Jena. These kernels have been determined for the CO_2 6220 cm□1 band. The averaging kernel represents the change in the retrieved total column abundance with respect to a perturbation of the true profile at a particular level/altitude.~~ (I would delete this paragraph, because the averaging kernel has nothing to do with the automation and is not specific for the site in Jena. It would fit in a general paper about FTS and GFIT retrieval -> Wunch et al. 2010)

The diurnal variation of total column xCO_2 over Jena (Fig. 13) illustrates the decrease in atmospheric xCO_2 over the covered period in more detail. It shows also that the decrease of xCO_2 over the day is relatively constant.

(This paragraph is rather short. If the authors would like to present these results, they should investigate more into the details, e.g. comparing with models TM3, describing what they would expect and what they got.)

[…]

(The same comment can be applied for the next paragraph. The comparisons are quite interesting, but to show their value the authors should investigate more. Are there measurements of the Zeilometer to derive the boundary layer?, …)

4 Conclusions and outlook

This article describes the principal components and the design concept of the MPIBGC FTIR system. The main design goals were reliability and low maintenance effort for operation at remote sites (70GB tapes you would need to exchange at least once a month). This was realized through the interaction of independent subsystems that were kept as simple as possible. Critical components are redundant as much as possible.

(Moved paragraph from lower part:

The instrumental line shape of the FTIR was determined from HCl cell measurements. During a period of six months this ILS changed only slightly. From these results one can expect that – once aligned – the instrument will be very stable over long time persiods.)

[…]

~~The instrumental line shape of the FTIR was determined from HCl cell measurements. During a period of six months this ILS changed only slightly. From these results one can expect that – once aligned – the instrument will be very stable over long time persiods.~~

[…]

After the campaign, the instrument will be shipped to Ascension Island (7.93_ S, 14.37_ W) […] This paragraph is rather short. If the author would like to keep the title I would add some more information up to the site in Ascension Island. What would they expect ? , Why is it important to have such a site, …)