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Atmospheric Measurement Techniques Discussions

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Interactive comment on "Atmospheric CO_2 retrieval from ground based FTIR spectrometer over Shadnagar, India" *by* P. Mahesh et al.

P. Mahesh et al.

mahi952@gmail.com

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Referee #1 Dear Referee, Thank you very much for your valuable suggestions and comments. This certainly helped us to understand the importance of FTIR community. We are very sorry for not acknowledging the TCCON group and we admit our mistake. Presently due to some internal limitations, we were not able to be part of TCCON group and in near future, we shall ensure to be part of this group from India. This will certainly give mutual benefit to the scientific community. In the present study, we have implemented basic line-by-line radiative transfer algorithm (LBLRTA) based on the TCCON and NDACC literatures such as Rodgers (2000); Warneke et al., (2005); Wunch et al., (2010); Petri et al., 2012 and Messerschmidt et al., (2012). We agree that our retrievals are not meeting the TCCON standards. The reasons are assumed for the poor accuracy could be due to impact of clouds, varied instrumental line shape (ILS) and

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solar zenith angle (SZA). Warneke et al. (2005) showed sensitivity of variable SZA on the precision and accuracy of the retrievals. FTIR 125M is using at our study site, due to AC coupling of the system, some of the spectra might impacted by passing clouds which probably introduce uncertainty in the retrievals. Since DC coupling method measures the variable transmission. These are our certain limitation for not achieving the high accuracy, which would be mostly negotiated with the support of TCCON in the near future.

1. The demonstrated precision and daily variation of XCO2 is $\sim$ 4ppm, 5-10 times worse than that achieved in TCCON. The total column amounts around 390 ppm appear to be biased 5-10 ppm low based on the calibrated TCCON network results. To be of value for current satellite validation and model applications, the accuracy and precision needs to be improved by an order of magnitude.

Ans: Thank you very much for your observations. We agree that the bias is at higher end when compared to TCCON sites where accuracy is below 0.2-0.5 % ($\sim$ 2 ppm). Retrievals of columnar observations up to 4 ppm (1.0 %) accuracy have been accomplished with IFS 125M FTIR in the present study while previous studies have reported the necessity for an accuracy of 1-2 ppm (0.2%). Due to aforementioned limitations, we could achieve an accuracy of 1 % ($\sim$4 ppm). This accuracy partly influenced by the less stable instrumental line shape (Hase et al., 2004; Warneke et al., 2010), an imperfect a priori information and clouds. Since the focus of the study is retrieve the columnar concentration of trace gases at best possible accuracy using LBLRTA which was implemented based on the information available from the TCCON literature.

2. The poor accuracy and precision appear to be due to both the actual collected spectra and the retrieval method used. The spectra shown in Fig 1 show very bad saturation, especially in the MIR region. It is well known in TCCON that the InSb detector used here also saturates unless bandpass filters are used to restrict the photon flux. InSb is inferior to InGaAs detectors. Saturation will directly affect the accuracy of retrieved total column amounts. These aspects of the measurements are all described in

the available published TCCON and NDACC literature but appear to have been ignored by the authors.

Ans: Kiel et al. (2016) showed clear difference between InSb and InGaAs detector recorded solar spectra. At our site in India, we used InSb detector and CaF2 beam splitter for NIR measurements and MCT and KBr beam splitter for MIR region. We agree that, without band pass filters detector gets saturated and reduce incoming photon flux. Our attempt to retrieve columnar concentration of CO2 was in NIR region. Due to uncorrected source brightness fluctuations and solar zenith angle influence, retrieval of XCO2 is not confirming to the TCCON standards. These impacts on retrievals accuracy and precision explained by many TCCON observations, which have been cited in the revised manuscript.

3. The retrieval method based on FASCODE3 is inadequately described - there is the perception that it is used as a "black box". The residuals displayed in Figure 2 show clearly that the forward model is not adequately fitting the measured spectra. The residuals are several times larger than those achieved with GFIT in the TCCON network or with other codes such as SFIT2/SFIT4 or PROFITT and indicate poor lineshape and position matching. However no details of the model are provided in the paper. No mention is made of how the solar spectrum is included in the forward model. Line 119 implies that only an average solar zenith angle around 75 degrees is used for all spectra - if true this is a major source of potential error and inadequate for the accuracy required for these measurements to be useful. Finally, the method for profile retrieval is not explained at all

Ans: We agree that the retrievals from SFIT2/SFIT4 or PROFITT and GFIT achieve TCCON standards, which can be able to incorporate DC-interferogram and correct the instrumental line shapes. In the present study also, we attempted basic LBLRTA which is a heart of those models. Figure 2 shows particularly in the case of O2, fitting was not adequate due to source brightness fluctuation and imperfect inputs to the standard model. These are some of the reasons for unexpected deviations. Below flow chart shows the how column retrieval have been obtained from the measured solar spectra. In FASCODE3, we have modified (P,T) profile information obtained from GSFC, science@hyperion.gsfc.nasa.gov. Details of the FASCODE3 model and its applications are given by Smith et al., (1978); Notholt et al., (1994) and Wang et al., (1996). I am sorry for misrepresentation of SZA instead SZA are 75°-90° (11:30 LT-12:30 LT). Sensitivity of precision and accuracy of retrieved columnar CO_2 also dominated by solar zenith angle. Attached figure shows the retrieval method which we implemented based TCCON literature.

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/amt-2016-177/amt-2016-177-AC1-supplement.zip

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- L-by-L radiative transfer algorithms accommodates various inputs such as standard atmospheric (P, T) profiles and volume mixing ratio (vmr)/a priori information of different gases.
- (P, T) profiles obtained from NCAR model simulated outputs
- NCAR/Whole Atmosphere Community Climate Model (WACCM) simulated Volume mixing ratios (vmr) profiles were utilized as a initial guess to LBLRTM
- Spectral line list information about each gas obtained from HITRAN spectroscopy data base
- Using HITRAN data base, we have calculated molecular absorption cross section which is proportional (Beer's law) to columnar density of a gas in the atmosphere.
- Solar absorption spectra and solar zenith angle information from IFS 125M spectrometer
- To minimize the retrieval uncertainty due to observational constraints, dry mole fraction was computed by taking atmospheric columnar concentration of O_2 molecule.

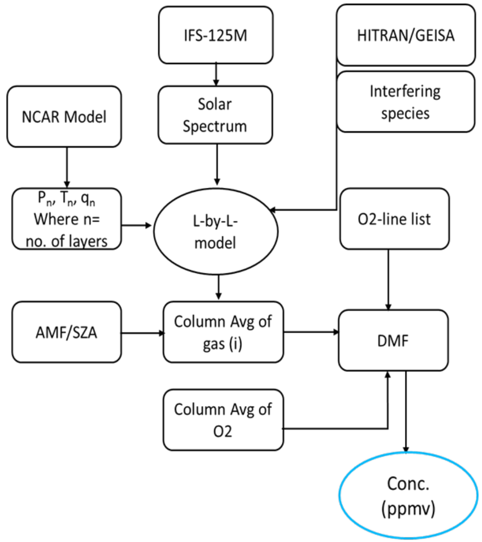

Fig. 1.

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