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Atmospheric Measurement Techniques Discussions

Interactive comment on "Characteristics of the Greenhouse Gas Concentration Derived from the Ground-based FTS Spectra at Anmyeondo, Korea" *by* Young-Suk Oh et al.

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General comments: First of all, we would like to strongly appreciate referee's very constructive and valuable comments, suggestions, and feedbacks on the manuscript. On the basis of this, we have tried to address all the issues raised on this manuscript. We have discussed the feature of OASIS system and its performance in a detail manner in the revised manuscript. We have included other TCCON site data for comparison purpose, and also added some species such as CO, and CH4 derived from Anmyeondo FTS instrument. Comments: Section 2.2: What exactly does "operation is semi-automated" mean and how does it affect e.g. the number of measurements as

opposed to fully automated like many other TCCON instruments?

Response: The FTS instrument is operated in semi-automated, which mean that some systems are operated by manual (someone should be there for controlling certain systems). However, this mode of operation does not affect the measurements.

Section 2.3: OASIS I think this is the most interesting technical part of this TCCON site but the description and analysis is not thorough enough. Especially, I miss a detailed discussion of the pros and cons of a system like OASIS. For example: what is the dynamic range of OASIS?

Response: We tried to elaborate regarding Operational Automatic System for the Intensity of Sunray (OASIS) system to some extent in section 2.3, which may not be sufficient to get in-depth information about it. We planned to address all issues like the pros and cons of this system on the measurements, as well as other technical details based on sufficient experiments on a special issue. (*The OASIS part was decided to write a separate paper on TCCON.)

How large is the quality difference of clear-sky spectra with OASIS compared to without? - In the example in Fig. 5, why is the signal with OASIS lower than without?

Response: In this particular example, the spectra were taken with and without OASIS April 04, 2015 (starting time in the case of without OASIS was 06:12:03 and ending time 08:46:40 while the starting time in the case of OASIS was 04:31:00 and approximately ending time 05:40:00). The solar intensity differences are occurred due to measurement time differences. Unfortunately, we did not conduct experiment in assessment of the quality of spectra measured with and without OASIS during clear sky condition. In next work, this will be examined. (*The OASIS part was decided to write a separate paper on TCCON.)

Does the better stability with OASIS compensate the loss in intensity and hence in signal-to noise?

Response: Yes, it would improve well the stability and signal-to-noise ratio of the spectra. (*The OASIS part was decided to write a separate paper on TCCON.)

do you log what OASIS is doing? Can you still distinguish between observations with truly clear sky and such with thin clouds or other intensity fluctuations? May be some would better be dropped rather than compensated. Is a system like OASIS worth the effort? How many more spectra do you get compared to the TCCON approach of dropping ones with SIV>5%?

Response: Yes, this OASIS system controls the aperture size based on the external sun light intensity. In the meantime, we do not have clear idea to distinguish observations with truly clear sky and such with thin clouds since we did not perform experiments. We obtained around 1230 number of spectra more as compared to TCCON approach of dropping ones with SIV > 5%. It is required further effort to briefly explain the impact of the OASIS system on the measurements. (*The OASIS part was decided to write a separate paper on TCCON.)

In Fig. 5, it looks like there were only a few events with strong drops in intensity. And I wonder if they could actually be corrected by OASIS. Certainly, a thick cloud moving in from of the sun cannot be compensated. How does OASIS affect the pointing accuracy of your solar tracker?

Response: Yes surely, a thick cloud moving in from of the sun cannot be compensated. (*The OASIS part was decided to write a separate paper on TCCON.)

Section 2.4: This whole subsection only describes standard TCCON retrieval procedure without any obvious site-specific adaptions. I think the whole subsection can be left out and be replaced by a single sentence and a reference to Wunch et al. 2015.

Response: We have removed the unnecessary part of Section 2.4 retrieval methodology, and modified this section; please see section 2.5 Data processing in revised manuscript. Section 3.1: - you should explain a little better what Xair is and how it can

be used as an indicator of stability. what are the plots in Fig. 8 showing? Obviously not single retrievals! Are these daily means or medians or something else?

Response: The Xair would be unity for an ideal retrieval, however, due to spectroscopic limitations there is a TCCON wide bias and solar zenith angle (SZA) dependence. The Xair is a useful indicator of the quality of measurements, with retrievals deviating more than 1% from the nominal value of 0.98 demonstrating systematic error. Initially, Fig. 8 showed the time series of Xair, surface pressure, and column amounts of O2 and CO2 in daily means in the period between February 2014 and December 2015, but we have re-plotted this figure again, where we considered only Xair and others are excluded.

- Plotting and discussing CO2 and O2 separately here is a poor choice. The whole idea behind TCCON is to remove airmass-related effects to produce high-precision observations. What we see here is simply the change in airmass probably due to the seasonal change of the sun's position in the sky (and a small part from ground pressure changes). All carbon-cycle related effects are completely hidden by this effect.

Response: We appreciate this very nice comment. We understood that discussing CO2 and O2 separately is not relevant so that we removed this discussion part.

Section 3.2: - I don't understand the argument about the comparison between g-b FTS and OCO-2. A priori profiles and averaging kernels are available for both observations. What CO2 profile do you mean with "... since we do not have the CO2 profile that reflects the actual variability over the measurement site."?

Response: We have improved the arguments about the comparison between g-b FTS and OCO-2. Please see the discussion in section 3.4 in revised manuscript.

Section 3.3: - Is this really all you can see: XCO2 variability because of photosynthesis? Are there no in-situ observations nearby so one could separate CO2 in the Planetary Boundary Layer (PBL) from CO2 in the free troposphere or at least look for differences in PBL and total column?

Response: We strongly appreciate the comment. We included the in-situ tower observation data and compared the seasonal cycle of CO2 with g-b FTS XCO2. The seasonal cycle of FTS XCO2 followed nearly same pattern as that of in-situ observations, this would suggest that seasonal cycle of CO2 is most likely controlled by the imbalance of terrestrial ecosystem exchange, even though it is required further work to examine other effect like the role of transport. Please see section 3.1 in revised manuscript.

- Especially in this section, the other observed species like CH4, CO, and N2O might have been really useful. I doubt that all you can see at your site are local effects and maybe some seasonal background variation. There must be transport from other regions which would probably show up in CH4 or CO.

Response: In addition of XCO2, we have also considered other species such as XCO and XCH4. The XCO2 along with the retrievals of XCO and XCH4 obtained from g-b FTS spectra are presented in Figure 8 (panel a-c), in the time period of February 2014–December 2016. (Please see section 3.1). Furthermore, we have discussed the relation between XCO and XCO2 at our site, which is presented in section 3.2 in revised manuscript.

Minor corrections: - please make sure that all acronyms and abbreviations (liek "g-b") are defined in the main text, even if they have been defined in the abstract already.

Response: We corrected and checked all acronyms and abbreviations throughout the text in the manuscript.

- p. 1, l. 31: "G-b FTS" is not a very good choice for a keyword. Neither is "OASIS" as it is not a unique term and also not a well-established acronym (yet).

Response: We have removed “G-b FTS” and “OASIS” as key words. (*The OASIS part was decided to write a separate paper on TCCON.)

- p. 2, l. 15: "TCCON achieves the accuracy and precision in measuring the total col-

umn of CO2 ..." -> TCON achieves this precision and accuracy for the column averaged dry air mole fraction of CO2 (XCO2), not for the total column!

Response: We have corrected as “TCCON achieves the accuracy and precision in measuring the column averaged dry air mole fraction of CO2 about 0.25 %.....”

- p. 2, l. 12: you mention "several atmospheric GHGs" but you neither say which nor discuss them in any way in this manuscript. Why?

Response: It is very nice comment. We described the GHGs that have been measured with our instruments at Anmyeondo site. Those prominent GHGs are CO2, CH4, CO, N2O, and H2O. We included CH4 and CO results obtained from g-b FTS and discussed.

- p. 2, l. 25: "a new home made OASIS system" sounds as if "OASIS" was an established acronym. It is not, it is just your internal name for your device. It might also be better to define the acronym OASIS in the main text rather than in the abstract. My suggestion for the sentence would be "One of the interesting issues in this work is a new home made addition to our g-b FTS instrument (see Sect. 2.3) that reduces the solar intensity variations from the 5% maximum allowed in TCCON to less than 2%."

Response: Thanks to the comment. We have defined the acronym OASIS in the main text as well. We have replaced the previous sentence written in Sect. 2.3 by "One of the interesting issues in this work is a new home made addition to our g-b FTS instrument (see Sect. 2.3) that reduces the solar intensity variations from the 5% maximum allowed in TCCON to less than 2%." (*The OASIS part was decided to write a separate paper on TCCON.)

- p. 2, l. 25: "SIV" instead of "SVI"! In fact, you don’t need this acronym at all. It is TCCON jargon and only used three times in the whole manuscript (and you spelled it out each time!).

Response: We made correction “SVI” by “SIV”.

- p. 2, l. 27-28: there is no need to provide an outline of the sections and numbers. Scientific papers typically don't have a table of contents. Just drop these two lines.

Response: We improved it. Please see the last paragraph of the introduction section in revised manuscript.

- p. 3, l- 3: Please replace "G-b" with "g-b" throughout the text unless it starts a sentence.

Response: We corrected it.

- p. 3, l. 5: "... Seoul, the capital city of Korea." -> I don't want get into politics here but isn't the country officially named "Republic of Korea"? "South Korea" would probably also be clear, maybe even clearer to the general reader.

Response: Thanks for the comment. The country official name is "Republic of Korea". We corrected the sentence ". . . Seoul, the capital city of Republic of Korea."

- p. 3, l. 22-23: avoid the line break for "A 547". In fact, I believe the tracker model number is "A547" (w/o space).

Response: Replaced "A 547" by "A547".

- p. 3, l. 23: "... are about 0_ to 315_ and 10_ to 85_ degrees ..." -> (1) "_" and "degrees" are redundant, (2) is the elevation range really only 10 to 85 degrees? Does that mean the tracker cannot point to the horizon or zenith at all?

Response: We removed the redundant of "_" and "degrees" from the text. The tracker can point to the horizon and zenith as well.

- p. 4, l. 3: "oil-free" -> "vacuum pump" is missing. Is the pump running continuously?

Response: The vacuum pump is running continuously.

- p. 5, l. 9: "... voltage ranges of approximately 0 to 219 mV." This information is hardly useful for anyone outside your department. Especially since you claim that "... the

detail characteristic of the operation is beyond the scope of this paper."

Response: We omitted ". . .voltage ranges of approximately 0 to 219 mV. . .." from the text, since the detail characteristic of the operation is beyond the scope of this paper.

- p. 5, l. 13-14: "the intensity of the incoming light occurred due to changes in thin clouds and aerosols loads or interceptions by any other objects along the line of sight over the measurement site." -> thin clouds is clear but aerosol load should not really change during a 2-minute measurement. And what objects could be passing the line of sight often enough to justify such a system?

Response: We understood that this sentence ". . .interceptions by any other objects along the line of. . .." is irrelevant so that we omitted the sentence ". . .interceptions by any other objects . . .." in the text.

- p. 6, l. 13: GGG is not developed "by JPL" even though the main developer works there. But there are also other main developers who work at different institutions even outside Caltec/JPL. It would be correct to say that GGG is developed by the TCCON community.

Response: We thank the referee's comments. We corrected it accordingly.

- p. 8, l. 9: "LINFIT" -> "LINEFIT"! Response: Corrected "LINFIT" by "LINEFIT"

Figures Response: All figures have been replaced. Data analysis period and quality improved.

- Fig. 1: (1) picture quality is not very good, (2) country borders and maybe the location of Seoul would be helpful, (3) For the insets: the upper one is clear but what is the lower one? The labels are Korean only.

- Fig. 2: (1) "server" instead of "sever", (2) you used "solar tracker" throughout the text, so you should not use "sun tracker" in the figure, (3) "Photographs of the automated FTS laboratory."

- Fig. 3: how is signal-to-noise defined here?

- Fig. 4: low quality/resolution

- Fig. 5: (1) low quality/resolution, (2) is this the same day for both plots? (3) why does signal drop off to the right with OASIS even though start time is earlier? (3) better plot this over solar zenith angle than over time!

- Fig. 6: very low quality with obvious JPEG compression artifacts. This should be redone in a lossless compression format like PNG or a vector format like PDF!

- Fig. 7: (1) not referenced in the text at all! (2) Should probably belong to Sec. 2.4 which means it should appear before (!) Fig. 6. (3) I don't know why this Figure is even part of the manuscript. Is this an original figure created by the authors or taken from somewhere else? (4) similar quality problem as with the other figures. The box labels are basically unreadable.

- Fig. 8: (1) low quality/resolution (2) why not just plot XCO2? The variations in column are mostly due to seasonal airmass variation (as can be seen in O2 column). XCO2 would tell you something about carbon-cycle related effects at your site!

- Fig. 9: unlike the other figures, this one has acceptable quality. I would still suggest to plot daily medians instead of means.

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2017-88/amt-2017-88-AC2-supplement.pdf

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Fig. 1. Anmyeodo (AMY) g-b FTS station

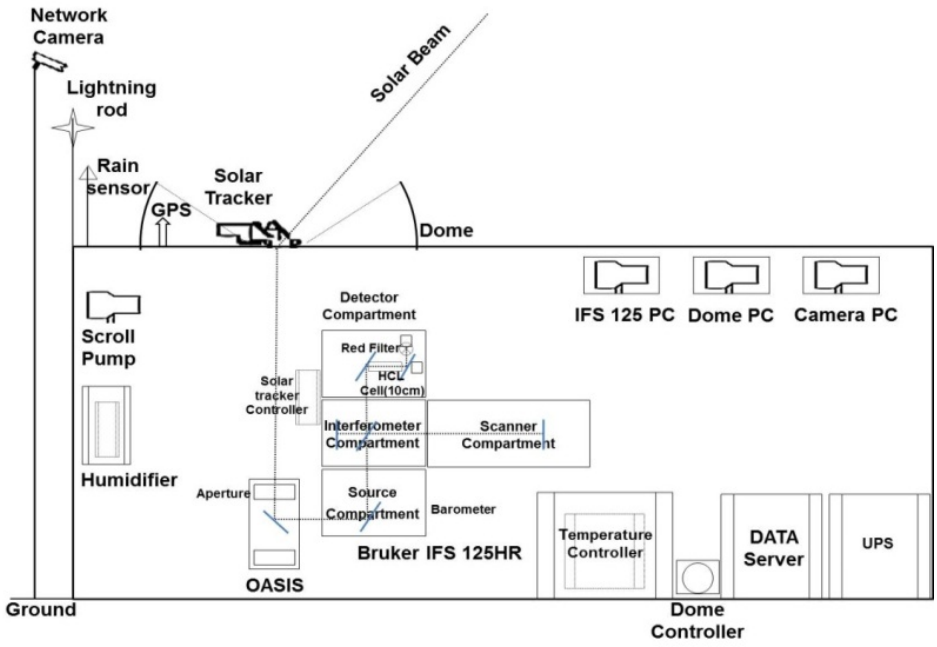

Fig. 2. Photographs of the automated FTS laboratory

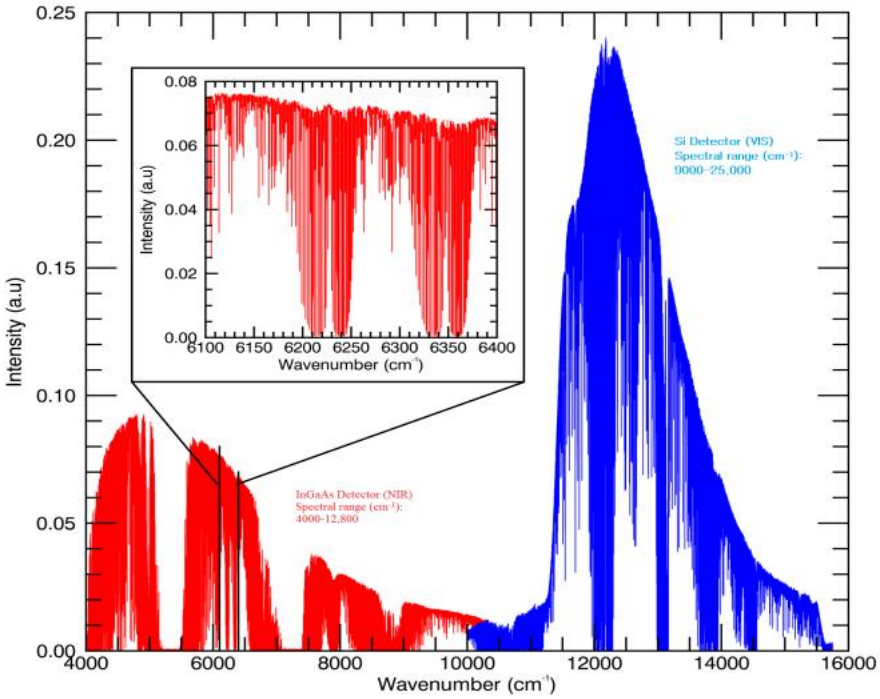

Fig. 3. Single spectrum

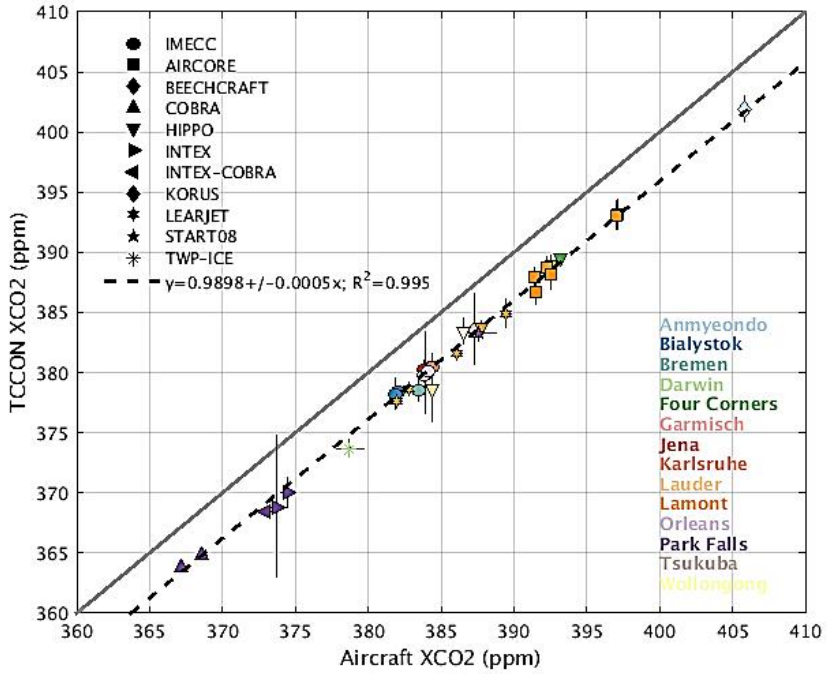

Fig. 4. The result of comparison between aircraft observation and TCCON concentration

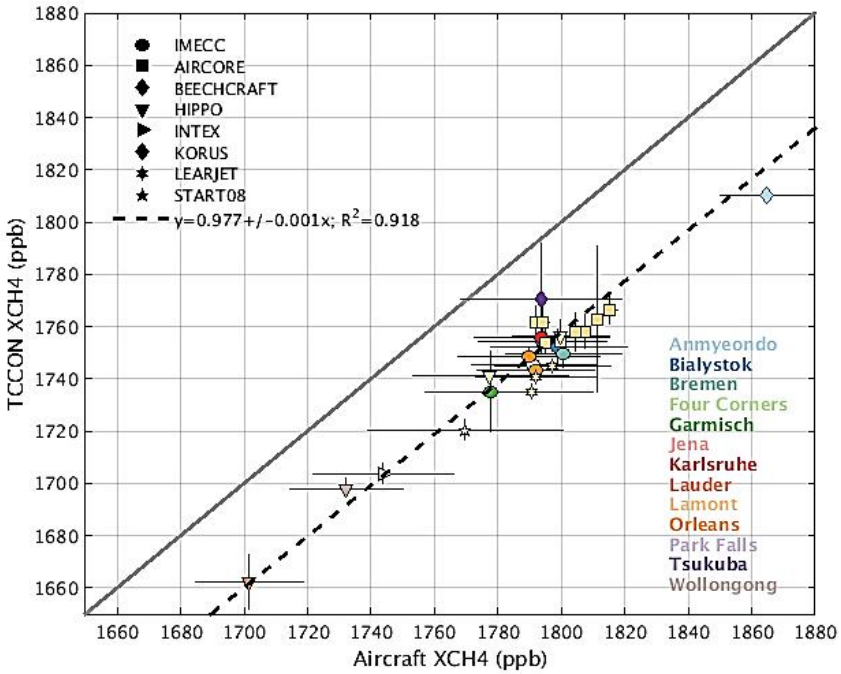

Fig. 5. The result of comparison between aircraft observation and TCCON concentration

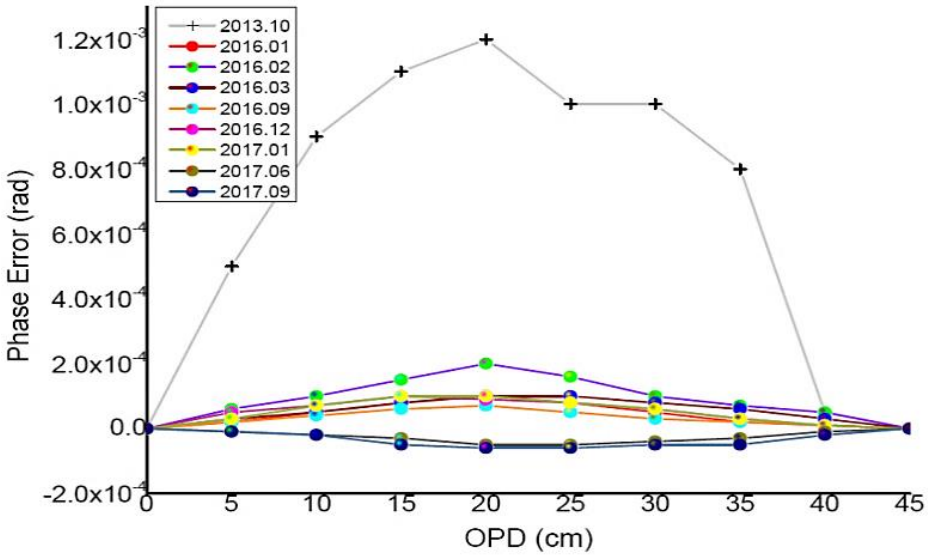

Fig. 6. Phase error

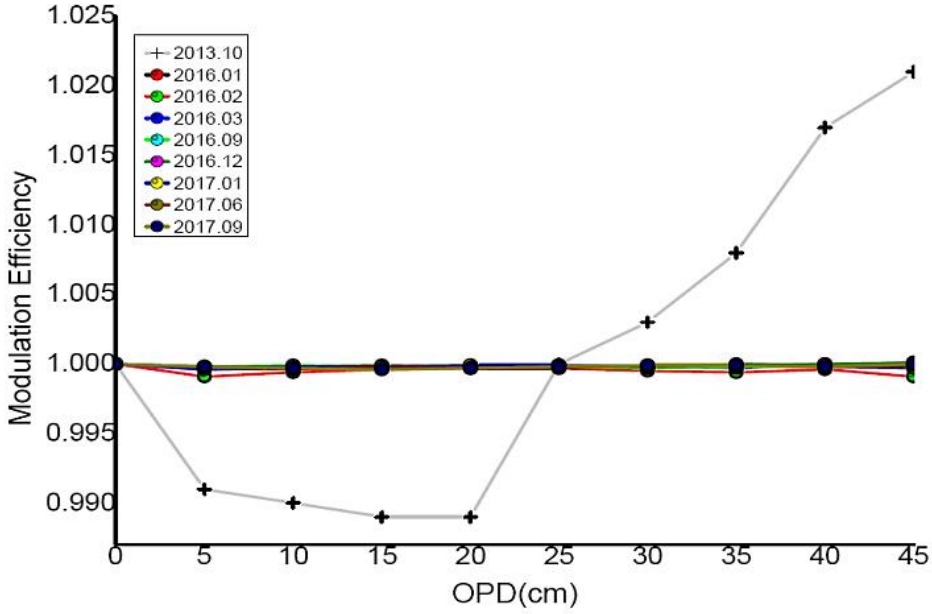

Fig. 7. Modulation efficiency

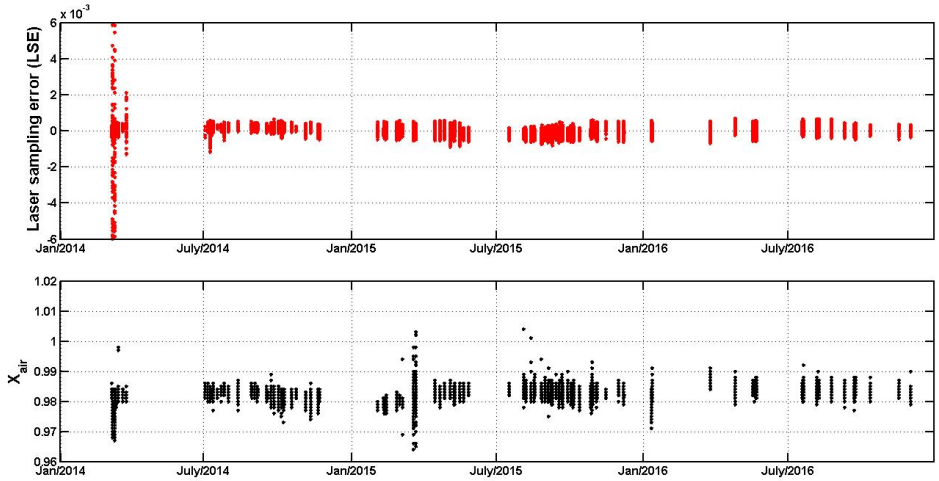

Fig. 8. Time series of LSE (top panel) and Xair (bottom panel) from the g-b FTS during 2014-2016

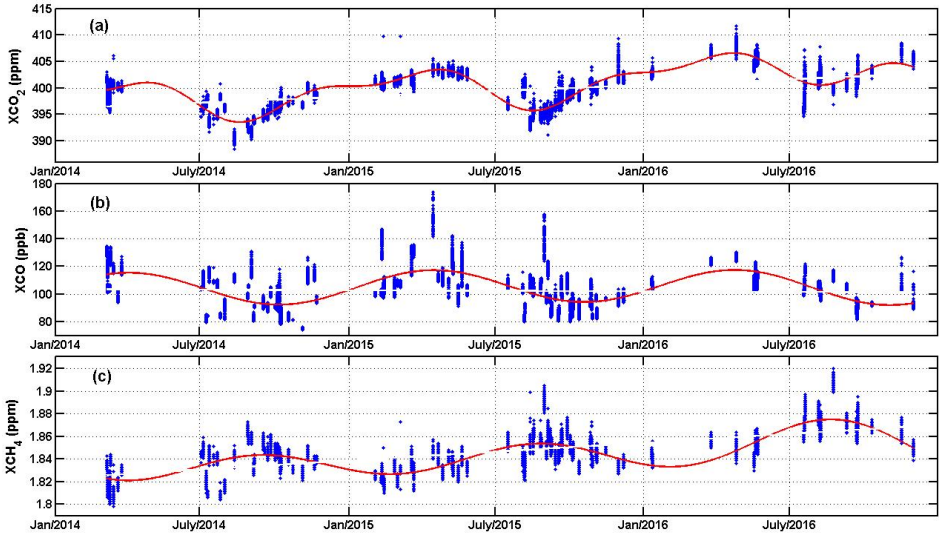

Fig. 9. Time series of XCO2, XCO, and XCH4 from top to bottom panels (a-c), respectively in the period between February 2014 to December 2016.

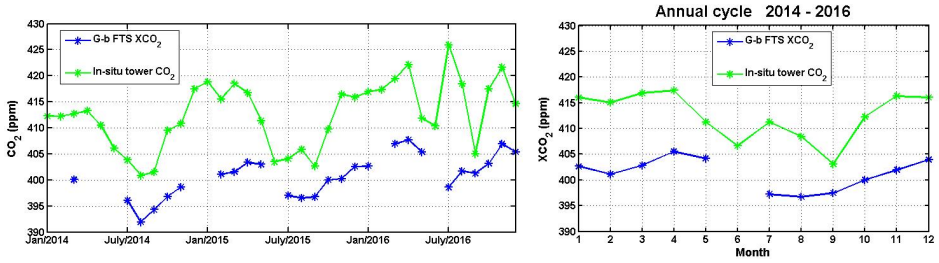

Fig. 10. Left panel shows the time series of FTS XCO2 and in-situ tower CO2 on monthly mean basis, whereas right panel depicts annual cycle

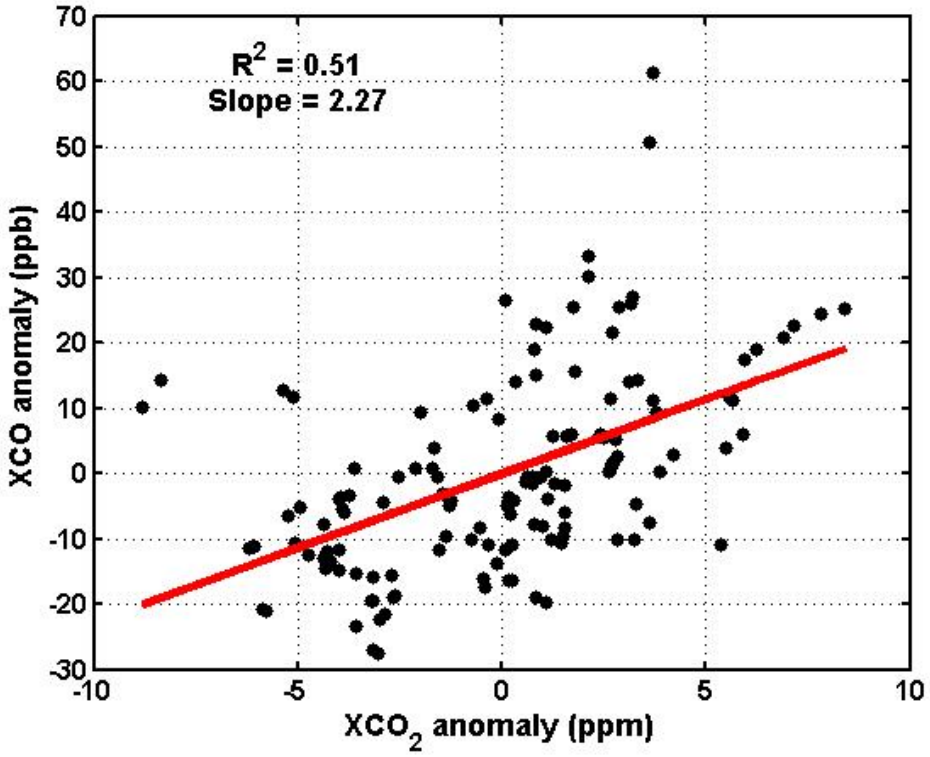

Fig. 11. Correlation between XCO2 versus XCO anomalies at Anmyeondo FTS site between February 2014 to December 2016, excluding summer data

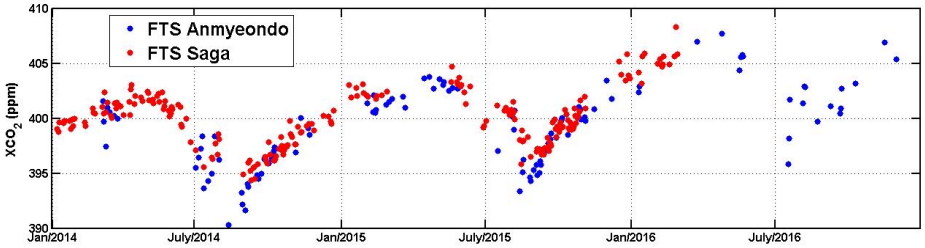

Fig. 12. Time series of XCO2 retrieval from Anmyeondo FTS and Saga FTS in the period of February 2014 to December 2016 .

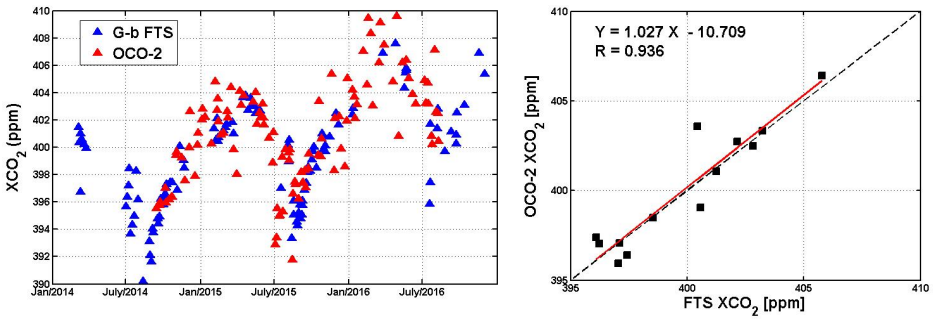

Fig. 13. Left panel: The time series of XCO2 from the g-b FTS (blue triangle) and OCO-2 (red triangle) over the Anmyeondo station from February 2014 to December 2016. Right panel: The linear regression curve b