Response to Reviewer 2

The authors would like to thank Reviewer 2 for the helpful comments. We have addressed the issues raised by the reviewer in the following. The review comments are copied in red and our responses are in black normal font and our changes in the manuscript in black bold font below. The references and figures which have been added/modified in the manuscript are attached at the end of the response to reviewer 1.

Major Comments

1) It is unclear how much the GOSAT data itself contributes to this work and whether it is really capturing the signals that are claimed. For example, there are very large discrepancies between GOSAT and TCCON throughout the time period, with GOSAT seemingly having a large amount of variability (noise?). Some quantification of the uncertainty on the GOSAT would make it more convincing that the observed anomalous high values can be trusted.

The main objective of this study is to show how well the GOSAT data capture synaptic-scale variations. For this, we verified the observed enhancement of XCH_4 in the summer of 2013 through the ground-based observations and examined the mechanism using model analysis. As the reviewer commented, GOSAT XCH_4 data have large variability compared with TCCON ground-based observations. That is partially due to larger uncertainty in the retrievals due to many bias factors than the ground-based measurements. This large variability in GOSAT data is a challenge to fully utilize the GOSAT data for flux estimation, even though the GOSAT dramatically expand the spatial coverage of the observation compared with the ground-based measurements. The capability to capture synoptic-scale variations of atmospheric CH_4 is important to improve regional flux estimates because the synoptic-scale variations of atmospheric CH_4 can carry the information on regional surface fluxes. Beside surface fluxes, the atmospheric CH_4 concentrations are highly changeable with the atmospheric transport. Toward improving regional flux estimation, it is essential to observe a synoptic-scale variation of the atmospheric CH_4 and quantify the attribution of such variations. Therefore, in this study, we demonstrate how the GOSAT is capable of detecting a synoptic-scale variation.

Reply to reviewer 2

We modified the introduction in the manuscript to make our objective clear. To verify the GOSAT-observed anomalous high XCH_4, we have added more information on GOSAT observation and analysis results on GOSAT XCH_4, including the back trajectory analysis.

P25001L15/Fig 4. – What is the error on these data points? The GOSAT data seems highly variable and it is difficult to see a correlation until the latter time period. Statements like "data agree overall" need to be quantified.

In Fig. 4 (**now Fig. 5(a)**), both of GOSAT and TCCON values are daily means. The number of GOSAT data per day over the Japan region ranges from 1 to 20, and the average is 3.5 retrievals per day. The mean deviation to daily mean is 9.53 ppb (for >=3 retrievals per day) For TCCON, the average number of retrievals per day is 101.1 per day at Saga and 145 per day at Tsukuba. Moreover, the mean deviation to daily mean is 4.04 ppb at Saga and 5.97 ppb at Tsukuba. To compare the synoptic variations between GOSAT and TCCON, we have included the figure of the time-series removed the mean seasonal cycles from individual de-trended XCH_4 datasets and those monthly means (**Fig. 5(b)**). The correlation coefficients (r) of the monthly means between GOSAT and TCCON Saga, and between GOSAT and TCCON Tsukuba, are 0.81 and 0.61, respectively. These correlation coefficient values exceed the 95% significance level.

2) The use of wind fields in Fig. 8 to argue that this observed enhancement is due to atmospheric transport do not appear to be very convincing. If anything, they would seem to suggest that Saga would primarily be observing clean ocean air. Further analysis/quantification is needed here to make the argument more convincing.

We conducted back trajectory analysis for Saga and Tsukuba. The back trajectory results have been included in Sec. 4.1 in Discussion of the manuscript**. Figure 12** visualizes the air mass reached Saga was traveling inland over East China in August 2013. This supports that the high CH_4 air was transported from China to Saga in August 2013 while the trajectory result for August 2012 is almost climatological; the dominant wind to Saga was from the Pacific, bringing the clean air. In September 2013, most of the air masses to Saga were still from the continent (China), while the air masses in 2012 were mainly from the Pacific.

3) It is unclear what exactly is shown in Figure 7. If it is the enhancement above the South Pole values as it seems, that does not seem to be a useful quantity. It would be of interest to see the actual modelled data here, rather than this enhancement (or have the enhancement calculated in a more meaningful way).

The presentation with respective to the South Pole is one of conventional ways to look at a relative spatial distribution. Responding to the comments from both reviewers and to avoiding further confusion, we have replaced the original Figure 7 with the spatial distribution of actual model output **(Fig. 8).** Also we have included the time-series of modeled XCH_4 for GOSAT and TCOON (**Figs. 9 and 10).**

All the model simulations agree with the observations with the correlation coefficients, r = 0.50-0.72, which exceed the 95% significance level. Furthermore, the modeled XCH_4 capture the observed enhancement of XCH_4 in the summer of 2013.

4) Figure 2 shows a significant increase in the number of GOSAT soundings over Japan in 2013/2014. Presumably this is due to the change in the GOSAT sampling strategy. This should be discussed in more detail, especially regarding any implications this may have that lead to a sampling bias for these latter years. A spatial map of the GOSAT soundings for each year would be of interest and help to indicate whether the enhancement seen in GOSAT is related to the increase in spatial sampling.

As the reviewer noticed, the number of GOSAT soundings over Japan was increased in 2013. We have added the paragraph to explain the change in GOSAT observation over Japan in Sec. 2.1:

The number of GOSAT retrievals over Japan increased in 2013 and 2014, compared with those in the previous years. This increase is due to the change of the observation strategy to increase available GOSAT retrievals over Japan. The initial regular schedule, there were fewer soundings over lands, but most soundings were over oceans or land-ocean mixed locations. The soundings over ocean or mixed locations are difficult to be retrieved. As a result, a few retrievals remained over Japan after screening. Aiming at increasing the retrievals over Japan, the observation locations were moved inland from ocean and mixed

locations as much as possible. The observation strategy change was made as a concerted decision by GOSAT Project terms among the three agencies NIES, JAXA, and MOE. The observation change was implemented on May 6, 2013.

The spatial maps of GOSAT retrievals we used in this study have been included in the manuscript (**Fig. 3**). As seen in **Fig. 3a**, most of the soundings were taken at lower surface elevation; ~80% is below 100m for the entire period. The locations of GOSAT retrievals in August/September, 2012 and 2013 are shown in **Figs. 3b and 3c**. The highest elevation is ~850m in both 2012 and 2013. The number of retrieval over Japan increased in the summer of 2013, around by five-times as the one in the summer of 2012. As far as the China-Korea, there is no significant difference between 2012 and 2013.

5) This manuscript, while generally well-written, would benefit from proof reading by a native English speaker as some sentence structure is grammatically poor and/or confusing. There are too many instances to list each individually but some examples include:
Since 2009, Greenhouse gases Observing SATellite (GOSAT) has been provided column-averaged dry-air mole fractions of atmospheric CH4 (XCH4).
As charactering the observed extreme event
The GOSAT orbiting with three-day recurrence successfully observed the synopticscale XCH4 enhancement in the comparable accuracy to the TCCON data.

The reviewer's comment is helpful to improve our English text. We have rephrased some of the sentences which may confuse the readers, including those listed above.

6) The manuscript would benefit from further explanation on where this work sits in the context of other recent GOSAT/CH4 studies. As mentioned by the other reviewer, the literature review here is sorely lacking and would add important context to this work.

As mentioned in our response earlier, our objective is to examine the high XCH_4 anomaly and to demonstrate the capability of GOSAT to capture synoptic-scale events, which is required to improve the regional flux estimates. We have added the sentences below in introduction of the manuscript to explain the background and the implication

of this study:

The capability to capture synoptic-scale variations of atmospheric CH_4 leads to better regional flux estimation because the synoptic-scale variations of atmospheric CH_4 can carry the information on regional surface fluxes. On the other hand, the atmospheric CH_4 concentrations are highly changeable with the atmospheric transport as well as surface fluxes. Toward improving regional flux estimation, it is essential to observe better a synoptic-scale variation of the atmospheric CH_4 and quantify the attribution of such variations.

As both reviewers pointed out, our original manuscript is in a lack of relevant references, especially to the satellite-based inversion. We have added the references to the inversion studies using satellite data in the introduction section, mentioning the recent satellite studies focusing on a regional- and local-scale at the high spatial resolution.

Minor Comments/Technical Corrections
P25001L4 – Please include the version number for the TCCON data. TCCON data now also has a DOI and should be cited accordingly.

TCCON data started having DOI from GGG2014. We used GGG2012. This case we understand the references for the data is sufficient.

P25008L19 - CCON data -> TCCON data

We have corrected.