Dear reviewer, thank you for your review of our manuscript, and the comments below. In order to respond to your comments, we have kept your original comments in black non-italics. Our responses are in bold blue italics, and changes to the manuscript are in bold blue underlined italics.

Methane isotopologue detection is important for methane source detection. Measurements of isotopologues from satellite would be very important. The paper by Malina et al. is an interesting and informative paper on methane isotopologue detection capability, and is very relevant for GOSAT-2 and other future SWIR spectrometers. In general the story of the paper is well-written (although the text somewhat sloppy) and the figures are clear. The paper is suited for AMT. The paper can be accepted after the following comments are addressed.

Main comments:

- Sect. 2.1: A better description of the applicability of the limb sounding forward model ORFM for a nadir viewing instrument like GOSAT-2 is needed. There are missing processes in the ORFM model, like atmospheric scattering. Is surface reflection well included? Is surface elevation included?

Thank you for this point. We have expanded this section to give more details on how the ORFM can be applied to nadir viewing instruments, describing how surface reflectance and altitude is handled.

Manuscript adjusted in updated section 2.2, Page 6, lines 20-33 and Page 7 lines 1-3, 6,10-11.

- The term "solar inclination angle" is not used in nadir remote sensing. Therefore, this term should be converted to the term "solar zenith angle", which is 90 degrees – solar inclination angle. Please use the symbol \theta_0 for the solar zenith angle and \theta for the viewing zenith angle.

We have changed all references to solar inclination angle through the manuscript to solar zenith angle. Satellite inclination angle has been changed to viewing zenith angle.

Note that all values in the original discussion paper were solar zenith angles, we had just mislabeled them, therefore none of the calculations have changed.

- P. 8, l. 17: What is the basis of setting the scaling factor f to (10 %)2 variance ? This means that you needed a much larger deviating delta13C than can be anticipated. What is the basis of that assumption?

This is an important point, raised by reviewer 1 as well. The reason for this is based on the relationship between the a priori covariance and the DOFS from the assumed GOSAT retrieval. From experience we know that methane covariance is often set to (10%)² variance, in order to allow for some variation in the retrieved solution. At this level of variance we can expect between 1 and 2 DOFS (depending on the surface and solar zenith angle). Given that 13 CH₄ is roughly 1.1 % of the total methane signal, we deemed it very unlikely that setting a (10 %)² variance for 13 CH₄ would yield any total column information. We therefore decided to increase the magnitude of variance in order to establish the point when DOFS>1 can be achieved. We accept that such a method will drastically increase a priori and a posteriori errors, but we aim to reduce these through long term averaging.

We have included a discussion in the manuscript to this effect, Page.10, lines 26-31 and Page 11, lines 1-6.

Minor and Textual comments:

- P. 2, l. 6: acronym GHG was already explained on the previous page *Thank you for spotting this, we have removed the acronym definition.*

Text "Greenhouse Gases" removed, Page 2, line 6.

- P. 2, l. 28: please give a reference for VPDB *We have inserted a reference for VPDB.*

<u>Page 2, line 28.</u>

P. 3, l. 18: 6ppbv: please add a space between the number and the unit. This holds throughout the paper, at many places, for many quantities, including %.
 Thank you for pointing this out, we have changed this wherever it appears in the manuscript.

- Table 1: please give the spectral resolution of the bands. *This has been included. Page 8, Table 1*

- Eq. 7: DOFS: acronyms should not be in italics because they are not symbols – *Thank you, this has been changed. Page 9, line 20.*

- P. 11, l. 4: please give an example of such errors. *Examples given, Page 14, line 5*

P. 11, l. 18: channel > channels
 Thank you, this has been changed, Page 14, line 18

- P. 11, l. 30-32: this should be mentioned earlier. *We have removed this statement in this position, and included a similar statement into Section 2.2.*

Please see Page 7, lines 1-3

- P. 12, l. 17: why a comma after 2\nu3? *Removed, Page 15, line 17*

- P. 13, l. 8: phenomenon > phenomena *Thank you, updated, Page 16, line 8*

- P. 14, l. 1-2: All simulations ..: please add this information to the main text because it is important information.

These parts of the captions have been removed, and placed at the start of section 5. <u>Please see, Page 15, lines 5-7.</u>

P. 14, l. 10: spectral irradiance > solar irradiance
 Thank you, this has been changed. <u>Please see Page 17, line 10.</u>

- At the same line: please remove: "due to blackbody solar emissions" (which is a strange comment)
 Thank you, this has been changed. Please see Page 17, line 10.
- P. 14, l. 20-23: too long sentence please make shorter sentences. *Thank you, this has been changed. <u>Please see Page 17, lines 21,22.</u>*
- P. 15, l. 6: At which wavelength do these albedo values hold? Please give a reference for these surface albedo values.

We have included a link to the ADAM albedo database, which gives a comprehensive review of global surface albedos based on MODIS data (http://adam.noveltis.com/). <u>Please see Page 18, lines 6 and 7.</u>

- P. 15, l. 17: please refer to Eq. 11 for the definition of f *Thank you, this has been inserted. <u>Please see Page 18, line 19</u>*

- P. 16, l. 9: why does the inclination angle not matter? This is unexpected. The air mass is much larger at smaller inclination angles.

We were surprised by this result as well, for the reasons you mention. However given how low the optical depth of ¹³CH₄ is, it makes sense that varying the solar zenith angle will not make much difference. The optical depth of ¹³CH₄ in band 2 of TANSO-FTS-2 is highlighted for two narrow regions in the figure below.



Figure 5. Optical depth covering two narrow ${}^{13}CH_4$ spectral regions in band 2 of TANSO-FTS-2, the green line represents optical depth of all gases present in this portion of the spectrum (CH₄, CO₂ and H₂O), whilst the blue line shows optical depth of purely the methane isotopologue ${}^{13}CH_4$: (a) indicates optical depth in the wavelength range 1658-1659 nm; (b) shows optical depth in the wavelength range 1670-1671 nm.

We have included this Figure and detail in the manuscript, <u>please see, Page 19,</u> <u>lines 10-19.</u>

- P. 16, l. 10: The hotspot depends on the scattering angle, not on the

inclination angle; the sun glint depends on viewing and solar geometry. *We have removed this statement, please see Page 20, line 1.*

P. 16, l. 11: extreme angles > special geometries
 Thank you, we have changed this statement as suggested, please see Page 20, line 2.

- P. 16, l. 23: " ..., this is an ...": please start a new sentence *Thank you, this has been changed. Please see Page 20, line 15.*

- P. 17, l. 8: . . . therefore: please start a new sentence *Thank you, this has been changed. <u>Please see Page 20, line 31.</u>*

- P. 17, l. 13: remove: including *Thank you, this has been changed.* <u>*Please see Page 21, line 4.</u>*</u>

- P. 17, l. 33: manuscript > paper (also on next page) *Thank you, this has been changed.* <u>*Please see Page 1, line 17, Page 21, line 24,27.*</u>

- Caption fig. 4: Degrees of Freedom for Signal *Thank you, this has been changed. <u>Please see Page 22, line 2.</u>*

- Caption Table 4: Summarisation > Summary; and 6 surface albedos *Thank you, this has been changed. <u>Please see Page 22, Table 4 caption.</u>*

- Table 4: remove DOFS in the left-hand column since it is superfluous *Thank you, this has been changed. <u>Please see Page 22,23, Table 4.</u>*

- P. 19, l. 20: remove the points around below. *Thank you, this has been changed. <u>Please see Page 23, line 20.</u>*

- P. 20, l. 5: a priori should be in italics, and not in quotation marks (throughout the paper)

Thank you, this has been updated throughout this paper, along with any a posterioris showing similar properties.

- Caption Fig. 5: remove the second word retrieval *Thank you, this has been changed. <u>Please see Page 26, line 3.</u>*

- Caption Fig. A1: f should not be in quotation marks, since it is a normal symbol

All Figure captions which show 'f' have been updated.

- Figures: Fig. 1: please give the unit of the x-axis

Figure updated to include units on x-axis. <u>Please see Figure 2, Page 13.</u>

References:

- The references are very sloppy. First of all, the authors should replace the URLs by normal journal references. Please replace capital font for titles by normal font. Aydin et al.: the journal name is missing.

References have been tided up as requested. <u>Please see, Page 33 to end of Page</u> <u>37.</u>

Other changes not specified in the above comments: <u>With inclusion of a new Figure 1 and 5, all of the old figures have been renamed</u> <u>as appropriate, along with all references to the original figures.</u>

Based on the modification of the target ¹³CH₄ precision we have updated the results and conclusions shown in Section 7.1, 7.2 and 7.3, revising the target precisions, and the length of averaging times required. Please see, Page 24, lines 9-21, 28-33, Page 25, lines 1-6, 13-14.

Based on the inclusion of discussion points requested by reviewer 1 on the *Philips-Tikhonov method, and future validation methods, the conclusions and summary section is now section 10.*

Based on updates to the precision estimates, we have updates the metrics stated in the conclusions and summary section. Please see Page 27, lines 15-29 and Page 28, lines 1-6.

As above, we have updated all results stated in the abstract.