

Interactive comment on “Information-based mid-upper tropospheric methane derived from Atmospheric Infrared Sounder (AIRS) and its validation” by X. Xiong et al.

Anonymous Referee #1

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SUMMARY This paper considers the use of a reference level referred to the tropopause for simplifying the use of methane measurements from the AIRS instrument. Comparisons with aircraft measurements are used to confirm that this is a valid way of interpreting the data.

It is difficult to look at the utility of this approach without some comparison to other approaches. The use of the methane field, which is generally extremely uniform, is biased towards producing a good result for any method. The paper requires significant attention to the question: “How much better is this approach than others?”

Overall this paper leaves the reviewer only half-convinced. The two major issues; that

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the use of the 50-250hPa layer below the tropopause is a significant step forward and that the validations with the aircraft measurements are robust are not argued persuasively.

There are also a much larger number of errors in language than there should be and several places where the discussion is not clear.

DETAILED COMMENTS The measurement of CH₄ from satellites is complicated by the fact that no satellite instrument makes a simple measurement. No satellite instrument measures the mixing ratio at a single level and no satellite instrument (indeed no instrument that this reviewer is aware of using any technique or platform) measures the total column amount. All satellite instruments have some weighting function or averaging kernel associated with the measurements and this is an integral part of the result. Thus the statement that SCIAMACHY is sensitive to total column amount (16336) is incorrect – SCIAMACHY has an averaging kernel as every other instrument. That averaging kernel may be nearer a vertical line than other instruments, but it is not a vertical line from the surface to the edge of space and therefore it does not measure a true column amount.

Retrievals can be further complicated by additional assumptions about the profile, whether these are contained in a priori information or in the details of the constraints in retrieval.

A major issue therefore is the statement on page 16338 that the averaging kernel for this AIRS product is not distributed with the data. If this is true, then it is a major defect of the data and should be rectified. These kinds of measurements without the corresponding AKs are very hard – almost impossible – to understand. However in the next paragraph the authors produce these averaging kernels in Fig. 1. The reviewer assumes that this is a result from a more specialized retrieval code. The lines in Fig. 1 should be defined. Reference is made to 11 trapezoidal functions and a 100 level grid, but it is not clear how these work together.

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It seems that the fundamental point of this paper is that referring the problem to the tropopause level makes things more consistent than referring them to the surface. Fig. 2 is the key figure in this respect, but it is confusing. The last statement of section 3.1 is that “we can see that the maximum sensitive layers are mostly located between 50 and 250hPa below the tropopause”. The figure lower panel certainly indicates that the level is below the tropopause, but the results at higher latitudes seem to be grouped into two: 0-130hPa and 150-300hPa with an interesting minimum between them. There is also some confusion as to whether the discussion refers only to the NH or to both hemispheres.

16340 The statement is made that comparisons are limited to data above 500-600hPa – the reviewer would have expected a value and not a range here.

16341 The simultaneity condition for the AIRS profiles is stated here as within 800km and 24hr. The authors should specify whether that is $\pm 800\text{km}$ and $\pm 24\text{hrs}$ and also clarify the statement on page 16339 where the time criterion is specified as “the same day”.

16341 Comparison is made with a previous paper by Xiong et al.. Although that paper is available, the reviewer would advise including the relevant figure in this paper so that the improvement can be directly judged. There is a further problem when doing the comparison in that Figure 9b does not appear to be the correct figure number. The comparison with the 22 sites is in Figure 6b and in that case the correlations indicated are 0.79 for 459-596 and 0.77 for 358-459, significantly higher than the 0.64(0.57) in this study in contradiction with the text.

16341 There is a statement made about extending the profile above 350hPa, but no reference to how often this is a significant issue. If the reference is to the tropopause, perhaps the upper limit of the profile should also be specified wrt the tropopause.

16342 Reference made to a number of aircraft measurements and then to a specific in situ measurement system. Was this used in INTEX A? B? Which aircraft? Are these

the only results being compared in the following discussion?

16342 The reviewer considers that the use of the term “truth” is inappropriate. A number of measurements by different techniques that are being compared. None of these is “truth” – each has its errors and biases to consider.

16343 The discussion of “tuning” of the absorption coefficients is disquieting. What effect does this have on the results? If the retrieval is tuned to a particular dataset, how does it behave with other datasets?

16344 The the measurements in Fig 6 lack error bars. There is no explanation of the figure. As far as the reviewer can determine the vertical lines are the # of cases for the NOAA data, but this is not explained and they look like error bars.

16345 “Due to the large difference in the sampling time and location..” It is not clear whether this is the 800km/24hr criterion or something else. One alternative would be to tighten the criterion to produce fewer matches, but more relevant ones.

16346 There actually little in the paper to show that the tropopause correlates “well” with the maximum sensitive layer. Figure 2 is not convincing. Some simple histograms showing the pressure level of the maximum sensitivity and the delta pressure from the tropopause would be useful. Presumably the latter would show a much tighter distribution than the former. The improvements cited in the correlations and biases are there, but are not outstanding. The comparisons show that the AIRS data are consistent with the aircraft measurements – but as to showing “valuable information” – there has to be an application where this is significant – can AIRS measurements help with diffuse sources such as the wetlands/permafrost? These large-area diffuse sources are the hardest to determine by any method.

16347 The discussion of the possible errors and biases in the measurements should not be made in the summary and conclusions section. The discussion is unfocussed and confusing. A much better assessment of how (for example) the sampling bias

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of the aircraft measurements might influence the results should be made. What are the relevant error sources and what can be done to reduce them? The correlations recorded in Figs. 3-5 are not large – the best is 0.72 – and some explanation of the reasons for the variance and how this might be reduced would be appropriate.

16348 An attempt has been made for the case for the use of the tropopause as the reference layer in this paper. This method might well be appropriate to well-mixed gases such as CO₂ and N₂O, but is unlikely to be successful for CO where the changes in the shape of the vertical profile are very significant. In that case, the averaging kernels, that should be used in any case, are going to be absolutely necessary for the interpretation.

FIGURES Many of the figures are of poor quality in my copy and should be re-drawn. In fig 1 the colored lines are not defined.

In figures 3-5 the dashed line is the line of 1:1 correspondence ($x=y$) not a fit to the data. The reviewer could not find that explained anywhere in the text. The fit line is not shown.

In these same figures the definition of the symbols is not well-separated from the use of the symbols themselves – particularly in fig. 3 – and the symbols are for some reason repeated in the definition which confused the reviewer.

In Fig.4 the rms value overlaps the points.

In Fig. 6 as mentioned above, the vertical lines are not explained.

MINOR CORRECTIONS 16332:2 either “...contain about one degree of freedom...” or “...contain about 1.0 degrees of freedom...” the first is preferable since “about” and “1.0” are incompatible.

16332:5 “Thus interpretation and/or analysis...”

16332:10 “..CH₄ in mid-high-latitude regions.”

16332:16 “...~0.6-0.7, and the bias and...”

16332:19 “..to use thermal infrared sounder data...”

16332:21 “..without the AK.”

16332:25 “The rate of increase was observed...”

16333:4 “For example a large CH₄ emission...”

16333:7 “...large emissions from plants...” It is not clear what the adjective “terrestrial” adds to the noun “plants” in the context.

16333:10 “..they provide large spatial...”

16333:12 “..with space-borne observations...”

16333:14 “..out the existence of some....”

16333:16 “... with model simulations...”

16333:19 “... the observations from near the tropopause...”

16333:22 “..using the near infrared...”

16333:25 “ al., 2008), the Halogen...”

16333:28 “..therein), and the Michelson...”

16333:30 “the observations of CH₄ in the middle troposphere using the thermal...”

16334:2 “., 2003), the Tropospheric...”

16334:3 “..therein), the AIRS instrument on NASA/Aqua.... and the Infrared...”

16334:6 “...2009). The measurements of...”

16334:7 “... 2008), and the Greenhouse..... which carries the ...(TANSO) instrument.. was launched by the Japan...”

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16334:11 :However, due to the limited information content of the thermal infrared sounder measurements,..”

16334:13 “..which strongly depends on the..”

16334:18 “..mixing ratio in the real atmosphere..”

16334:21 “..mixing ratios..”

16335:2 “..information of the retrieval..”

16335:4 “. . .sensitive layer of the AIRS retrieval and uses the retrieval in its. . .”

16335:9 “in the free troposphere.”

16335:21 “..used are presented in Sect. 3.”

16335:23 “. . .comparison of the seasonal cycle..”

16335:26 “AIRS was launched into a sun synchronous polar orbit. . . . on the National. . .”

16336:5 “..and AIRS nominally..”

16336:10 “..sounding retrievals with a spatial..”

16336:10 “The version 5 of the AIRS. . .”

16336:14 “..of the AIRS product is produced at the NOAA. . .”

16336:24 “In contrast to SCIAMACHY which uses the. . .”

16337:2 “..(SVD) of the. . .”

16337:5 “..of the solution on the. . .”

16337:8 “altitude, and does not vary with. . .”

16337:16 “..CH4 mixing ratios in different layers. . .”

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16337:18 “An appropriate validation of the retrieval. . .”

16337:19 “However, there is no doubt that the. . .”

16337:20 “..than any other layers.”

16338:17 “. . .where the maximum of the averaging kernels’ area is located in the 100 level. . .”

16338:19-21 The reviewer did not understand this sentence

16338:21 “. . .computed using the temperature profile. . .”

16338:25 “..tropopause can be found in Reichler et. . .”

16338:26-27 These figures seem to have more significant digits than is warranted.

16339:2 “. . .using one day of global. . .”

16339:3 “. . .~120hPa in the tropics to ~300hPa in the Northern Hemisphere at latitudes >45oN.

16339:5 “From the difference between the maximum sensitive layer and the tropopause (. . .) we can see that the maximum. . .”

16339:14 “. . .below the tropopause. . .”

16339:19 “..we refer to CH4 in this layer as. . .”

16339:22 “. . .requires enough profiles from AIRS. . . so the ARIS profiles are selected if that are within the same day and. . .”

16339:25 “The mean of these profiles. . .”

16340:1 “. . .CH4 from the NOAA. . .”

16340:5 “These campaign data are of more use to validate AIRS CH4 at the level where AIRS has the largest sensitivity. To. . .”

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16340:9 “...data from TM3...”

16340:11 “..aircraft measurements are use for comparison with data from AIRS.”

16340:17 “...routinely collecting air samples...”

16340:19 “Air samples are...”

16340:21 “Measurements are made...”

16340:24 “..resolution of up to...”

16340:26 “..profiles for the 22 sites used can be found in Xiong et al. ...”

16341:1 “However, data from Rarotonga...”

16341:2 “For the other 20 sites the...”

16341:7 “...data in the layer 50-250hPa...”

16341:12 “..using the convolved values, 0.64,.... than using the aircraft...”

16341:18 “..using the convolved values are...”

16341:19 “This is unexpected but ...”

16341:20 “When applying the AK to convolve...”

16342: 3 “An air sample is collected in a...”

16342:10 “A comparison...CH4 derived from AIRS with aircraft measurements from..”

16342:11 “78 aircraft profiles were used.”

16342:13 – use “result”, not “truth”

16342:27 “..are near the tropics.. 26 profiles with latitude >25oN are used.

16343:8 “..aircraft measurements..”

16343:13 “If we select...2006, and the retrieval bias.”

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16343:22 “In Fig. 6 we plot the...-B at the time...”

16343:29 “..AIRS retrievals are from a large area within 800km of the aircraft measurements...”

16344:1 “We note that there was a... INTEX-A. This event...”

16344:7 “..consistent with the aircraft...”

16344:8 “..Alaska are plotted...”

16344:10 ..in the layer from... AIRS profiles. The solid line is the 30-day running mean for the AIRS-derived tropospheric CH₄.

16344: 20 “...2005, the ones with the largest...occur on 10 July...”

16344:22 “..aircraft measurements...more significant in the aircraft measurements.”

16344:24 “..with the occurrence of the minimum of CH₄ in the marine...”

16344:25 “An increase of...”

16345:3 “..has been plotted...”

16345:4 “aircraft samples has...seasonal cycle as a 30-day running mean (..). Two years of AIRS...”

16345:7” is the magnitude of the CH₄... decrease in August which is larger in the aircraft measurements than from AIRS

1645:9 “..aircraft measurements among different years is large,...

16345:12 “Another way to combine the aircraft measurements is to consider measurements... This can be done by taking all... in North America.”

16345:27 “Since the first guess of CH₄ in the retrieval from AIRS is a smooth function of...seasonal variation (Xiong et al., 2008),...information on CH₄ in the...”

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16346:6 “As the most sensitive level is. . .”

16346:9 “..only applicable in mid-high latitudes.”

16346:13 “Validation of this product. . .”

16346:15 “..depending upon the season.”

16346:21 “. . .were used, and in. . .”

16346:25 “. . .information on CH4. . .”

16347:8 “..and are hard to estimate. . .”

16347:10 “. . .CH4 in clear cases. . .”

16347:13 “. . .the error due to the tropopause height for this. . .

16347:15 “However changing the. . .”

16347:17 “Differences in the. . .”

16347:20 “There will be a larger uncertainty from the aircraft. . .”

16347:30 “However none of these aircraft measurements were carried out for the purpose of validating. . . so we have no other choice.”

16348:3 “As a new product. . .without referring to the averaging kernels.”

16348:7 “..AIRS products into models to. . .”

16353 (Fig 1) “. . .the tropopause averaged over 3 days from. . .”

13654 (Fig 2) “. . .pressure between the maximum sensitive later and the tropopause..”

13655 (Fig 3) “AIRS data is gridded at 3x3 degrees in. . .”

13658 (Fig. 6) “. . .and a comparison with. . .”

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