Author's reply to Anonymous Referee #2

We would like to thank referee #2 for his/her comments that helped improve the quality of the paper. Below we addressed the comments one-by-one; comments from the referee are typeset in italic, our replies are in normal font, and our changes in manuscript are in blue. Line, page and figure numbers in the referee's comments refer to the original manuscript, whereas in our reply we give page and line numbers that refer to the revised manuscript.

General Comments

1. As the retrieval algorithm is firstly introduced in this paper, the authors need to explain the detailed description of the retrieval algorithm. For example, in Table 1, the authors should summarize the detailed a priori information, its structure and units as well as the state vector elements used in the algorithm.
Following the reviewer's suggestion, we have added the units and a priori information in Table 1. More detailed information on the algorithm is given by Butz et al., 2012 as stated in the text in section 2.1.

2. The authors should highlight the advantage of the retrieval algorithm, as compared with other algorithms for CH4 monitoring.
A discussion on the various CH4 retrieval approaches is given in the introduction. Also, mentioned there is that the proxy approach cannot be applied to TROPOMI because of the spectral range.The main advantage of our method compared to other physics-based methods is the computational speed which is an essential performance aspect for the operational data processing of TROPOMI measurements. We have added the following sentence on page 5, line 123:
To our knowledge, our algorithm is among the fastest in use for CH4 full-physics retrievals, with an average CPU time of ~7-0 seconds per retrieval (Hasekamp et al. 2016).

3. As described in Section 2.1.1, the aerosol type in this retrieval algorithm is characterized by the refractive index and size distribution, which are assumed and fixed parameters in the algorithm. However, aerosols information is the one of the most important factors on XCH4 retrievals and thus the authors should consider the effects of assumed aerosol information on XCH4 retrievals.
The refractive index is indeed assumed fixed, but this has no great influence on the retrievals as shown by Butz et al 2010. The size distribution is not fixed but retrieved through the size parameter alpha as described in Section 2.1.2. We have added the following sentence on page 6, line 154:
Butz et al. (2010) found that the exact choice of the fixed-value parameters, such as the refractive indices or the width of the height distribution, does not affect the retrievals significantly.

4. There is unclear description on the following point, A. In Section 2.3, authors describe the filtering criteria to remove the retrievals with bad quality. B. In line 233, authors applied the filtering criteria for the ratio of retrieved H2O column between at weak and strong band. Authors should describe the reason why the ratio is lower than 0.08.
The physical reason is that the water column retrieved from the strong absorption band is more affected by clouds than the water column retrieved from the weak absorption band as described by Taylor et al 2016 and Frankenberg et 2014. We have added references and explanation on page 10, line 243:
Here we make use of the fact that clouds and aerosols will modify the optical path length in the two bands differently due to the different absorption strengths (Taylor et al., 2016; Frankenberg, 2014). Thus there will be a difference between the H2O column retrieved from the strong band and the H2O column retrieved from

the weak band in the presence of clouds.
The exact value of the threshold has been found by varying the threshold and looking at the quality of the retrievals that pass the filter. Also, the same threshold was found by Scheepmaker et al 2016. We have rewritten the paragraph to clarify this, page 10, line 251:
Because the weak-band and the strong-band retrievals are differently affected by scattering, the ratio |H2O_weak – H2O_strong|/H2O_strong is strongly correlated with cloud contamination. Scenes in which this ratio exceeds a certain threshold can be flagged as cloudy and filtered out. Based on a realistic ensemble of synthetic measurements (see Sect. 4), we find that a threshold of 0.08 filters out most cloudy scenes and keeps most of the clear-sky scenes. However, a direct cloud filter based on VIIRS data is shown to be superior to this indirect two-band cloud approach. Therefore, the two-band cloud filter will only be used as backup when VIIRS data is unavailable.

5. In Section 3, the authors described the sensitivity of XCH4 retrievals to atmospheric input data and instrument errors. The authors would better describe about the sensitivity to assumed information in the algorithm. In addition, the authors would better show the sensitivity to aerosol information, such as aerosol column, aerosol size parameter and aerosol height parameter.
We would like to note that the XCH4 error caused by the assumptions in the aerosol parameterization is extensively discussed is the paper. Section 3.1 is almost exclusively dedicated to this topic. Other important a priori assumptions in the algorithm related to temperature, pressure, and vertical profiles of H2O and CH4 are also extensively discussed. In addition, instrument related error sources also form a very important contribution to the total error budget. So, we do not see here the necessity to adopt the manuscript.

6. In Section 4, cloud information derived from the MODIS products, such as cloud fraction, cloud optical thickness and cloud top height. The authors should briefly explain the method to obtain the cloud information.
We have added a paragraph on page 21, line 470:
Cloud fraction, cloud optical thickness and cloud top pressure are obtained from MODIS Aqua measurements at 5 x 5 km^2. Here, the cloud top height is derived from the cloud top pressure and the surface pressure, also provided by MODIS. The cloud properties are collocated in time and space to the TROPOMI orbit and used in the measurement simulation. For fractional clouds, the independent-pixel approximation is used to combine the cloudy and clear-sky parts of the scene

7. In Section 2.3, the authors described the method to filter out scenes including cloud screening. Moreover, in Section 4, the authors also described about cloud screening method and its performance in terms of comparison of two filtering method. The methods are mixed in these sections and is unclear. Please make sure the filtering criteria for post-screening and cloud screening in individual section if you want to simultaneously show its performance.
Section 2 describe the method while section 4 applies it to synthetic measurements. Following the reviewer's suggestion, we have put the description of a prori filtering and a posteriori filtering in subsections 2.3.1 and 2.3.2, respectively.

Minor Comments

1. In Fig. 3, please add a legend label.
We have added a legend and updated the caption:
The red shaded area represents the weak absorption band, while the blue area represents the strong absorption band of H2O.

2. In Fig. 4, is it monthly mean value of retrievals? Please show the period that you

have these results. Also, you can plot again with large legend.
It is explained in the text that we have simulations of one day per season, so it's not monthly mean. To clarify this, we added in the caption of Fig. 4:
The ensemble covers scenes for a day in January (JAN), April (APR), July (JUL), and October (OCT) as described in Sect. 3.1.

3. Table 2 shows the summarized the effect of instrument calibration errors on the XCH4 bias and precision. The authors would better summarize the effect of atmospheric input data and assumed scattering simultaneously.
The effect of the scattering forward model error is given in the Table as this is the baseline (first row). To clarify this, we added in the caption:
Note that all sensitivities include the baseline forward model error, caused mainly by aerosol and cirrus scattering.

For the atmospheric input data, we deliberately chose to represent these in a different way (in Fig. 6) as we studied many perturbations and we are convinced that this study would be more difficult to interpret from a tabular form. Therefore, we made no changes here.

4. In Fig. 9, authors describe the panel (c) and (d) give the valid retrievals after cloud filtering with MODIS and the backup cloud filters. The authors should revised that panel give the XCH4 biases of the valid retrievals after filtering.
This has been corrected:
Panel (c) and (d) give XCH4 bias of the valid retrievals after cloud filtering with…

5. In 471, please check spelling in the sentence
We rephrased the sentence, page 24, line 515:
To achieve this, it is needed to apply a priori filtering of cloud contaminated scenes and a posteriori filtering based on retrieved parameters