Interactive comment on “Retrieval algorithm for CO₂ and CH₄ column abundances from short-wavelength infrared spectral observations by the Greenhouse Gases Observing Satellite” by Y. Yoshida et al.

Anonymous Referee #2

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The comment was uploaded in the form of a supplement:

http://www.atmos-meas-tech-discuss.net/3/C2345/2010/amtd-3-C2345-2010-supplement.pdf

Interactive comment on Atmos. Meas. Tech. Discuss., 3, 4791, 2010.

The manuscript entitled “Retrieval algorithm for CO2 and CH4 column abundances from short-wavelength infrared spectral observations by the Greenhouse Gases Observing Satellite” by Yoshida et al. described the recent version (V01) of GOSAT retrieval algorithm for space-borne measurement of greenhouse gases CO2 and CH4. GOSAT was the first satellite designed and successfully launched to measure the two major greenhouse gases from space. The manuscript covers an important and hot topic. It will benefit the carbon cycle study community and will be highly cited. The manuscript is clearly outlined and the retrieval algorithm is well described. I recommend it to be published in AMT after the following comments are addressed.

=> Thank you for your careful reading of our paper. The followings are our reply to your comments. The words with "double line (═)" were removed and those with "under bar (___)" were added.

Section 2.1 in the 2nd paragraph about cloud and aerosol effects, an earlier paper by Mao and Kawa (2004 in Applied Optics) may be cited as the first publication showing full radiative transfer calculation results for aerosol and cirrus cloud scattering effects on CO2 measurement path length using the surface reflected SWIR.

=> Done.

<Reference>

"Mao, J., and Kawa, R.: Sensitivity studies for space-based measurement of atmospheric total column carbon dioxide by reflected sunlight, Appl. Optics, 43, 914-927, 2004."

Section 4.1, a reference may be cited for the Levenberg-Marquardt method. And what are the typical

value of λ and number of iterations needed for most retrievals?

=> The typical range for final lambda is 10^{-3} to 10^{-6}. The value of lambda just determines the direction for next step (between the Gauss-Newton direction and the gradient-descent direction) and doesn't relate to the retrieved value, therefore we don't add the information of the final lambda. The typical range for iterations is 3 to 6. As for the iteration number, we add following information. Also, references for Levenberg-Marquardt method are added.

<p.4803, line 4>

"The iteration continues until changes in the normalized chi-square $\chi^2 = J(\mathbf{x})/m$ and $\mathbf{x}$ between iterations become sufficiently small, where m indicates the number of channels used in the retrieval analysis, or the number of iteration reaches the pre-determined maximum number (currently 20 iterations)."

<p.4813, line 18>

"**6.3 Retrieval results**

Before the discussion of the retrieval results, we briefly mentioned about the MAP iteration. The solution converges in less than six iterations for more than half of the measurement scenes. About 1.5 % of the measurement scenes can not converge."

<Reference>

"Levenberg, K.: A method for the solution of certain nonlinear problems in least squares, Quart. Appl. Math., 2, 164-168, 1944."

"Marquardt, D. W.: An algorithm for least squares estimation of nonlinear parameters, J. Soc. Ind. Appl. Math., 11, 431-441, 1963."

Section 4.2, the relationship between the "surface albedo" and the "target reflectance" in the retrieval should be clarified. It seems the Lambertian surface is assumed here.

=> If the target scene is over the land, the Lambertian surface is assumed, but if that over the ocean, the bidirectional reflectance based on the Cox-Munk slope probability density function is assumed. That is why we retrieve a surface wind speed for ocean case. The explanation for ocean case was insufficient, therefore, we revised as follows.

<p. 4806, line 2>

"~~Over ocean, the wavenumber dependency of water reflectance is related to that of the refractive index of water, and the surface wind speed can determine the reflectance magnitude over the whole spectral range.~~ The assumption of the Lambertian surface is not adequate for water surface. The bidirectional reflectance distribution function for water

surface is calculated based on the slope probability distribution function proposed by Cox and Munk (1954). The Cox-Munk assumption can determine the reflectance of water surface over the whole spectral range with single parameter of a surface wind speed."

<Reference>

"Cox, C., and Munk, W.: Measurement of the roughness of the sea surface from photographs of the Sun's glitter, J. Opt. Soc. Am., 44, 838-850, 1954."

P. 4804, line 20, what the weighting function ***h*** is? Please provide its formula or definition.

=> The formula of ***h*** is given in eq. (14).

Section 5, line 20, the AOD threshold value of 0.5 is for every band or just for CO2/CH4 band at 1.6 μm? since AOD of aerosols is a function of wavelength.

=> AOD at 1.6 μm is used here. We add this information as follows.

<p.4810, line 19>

"Therefore, the retrieval results of VCO_2 and VCH_4 are dismissed when the retrieved AOD defined at the wavelength of 1.6-μm is larger than 0.5."

P. 4806, line 1, it seems that TANSO-FTS band 3 at 2 μm is used in this paper to screen cirrus clouds in the retrievals.

=> At p.4806, line 1, we focus on the surface albedo database prepared as the a priori values in the forward model calculation. The TANSO-FTS 2-μm test (section 3.1) judges the possibility of cloud existence only from the measured spectrum and does not use any a priori information. As for the retrievals of XCO_2 and XCH_4, current algorithm does not use the TANSO-FTS Band 3 spectrum. As a result, the surface albedo database for TANSO-FTS Band 3 is not used in the current algorithm.

Section 6.2 about information from measurement, the GOSAST measurement capability for both CO2 and CH4 changes may be described and illustrated in this section. It could be the simulated sensitivity to both CO2 and CH4 variability for single measurement.

=> At p.4814, line 14, the retrieval precisions for XCO_2 and XCH_4 are given. These values are not the simulated value, however, almost same values are expected to be obtained by a numerical simulation.

Section 6.3, 1st paragraph about Xco2 and Xch4 retrievals results, are these general seasonal variations from a priori or from radiance responses? This question is relevant to the previous question and should be addressed somehow and somewhere in this paper.

=> These variations come from radiance responses. As written in the section 5, we apply the DFS test for the quality control of the retrieval results. This test removes data which constrained to the a priori value. In other words, the quality controlled retrieval results reflect the radiance responses rather than the a priori. We think that no revision is needed.

Section 6.3 about the retrieval results needs to be extended to include how the retrieval errors are estimated and both retrieval precision and accuracy as two components of data uncertainty need to be presented and discussed, even though the reasons for the large bias in current GOSAT retrievals are still inconclusive. As addressed in the first paragraph of introduction, CO2 measurement is about carbon flux and bias in the measurement is even more critical than radon errors in estimating carbon flux.

=> As written at the end of section 6.3, the retrieval accuracy is discussed in another paper (Morino et al., AMTD, 3, 5613-5643, 2010). Although the retrieval precision and accuracy are important, this paper focused on the description of the retrieval algorithm itself.