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Interactive Comment

Interactive comment on "Assimilation of atmospheric methane products in the MACC-II system: from SCIAMACHY to TANSO and IASI" *by* S. Massart et al.

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We would like to thank the reviewers for their comments and remarks. They helped us to discover an issue concerning our usage of the data from the TCCON network looking closer at the experiment behaviour at the Darwin site. We assumed the modelled CH_4 molar fraction to be wet when it was dry. Therefore Fig. 10 and Table 3 of the paper have to be updated and the discussion Sec. 3.5.2 will be changed (see Table 1 and Fig. 6 of this reply).

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1 Main comments

• *But the study as is focuses on technical aspects and includes little scientific value. As such I do not see it suited for a journal like ACP, but suggest it would be better suited for GMD. There are also a number of issues I think shoud be addressed before publication.*

We prefer to let the decision where to better publish this paper to the editor.

2 Major Comments

• *The results demonstrate no clear improvement with the assimilation compared to the free run. Overall the free run actually seems to show the best performance. There are also large differences when assimilating the different products or different retrieval versions of the same product in case of TANSO. Yet the authors do not provide an analysis on the cause of these differences except for a general statement on possible biases in the different satellite products. Such a bias should anyways be addressed in advance of assimilating the products, specifically when jointly assimilating two products (TANSO+IASI). The results as shown give very little confidence in using any of the products for methane assimilation.*

Our paper describes the first results of the assimilation of xCH_4 satellite products to constrain the atmospheric methane. It aims to serve as a starting point from where we have to improve the system. The improvements will come from the assimilated observations as well as from the assimilation system. Even if these improvements will be necessary in the near future, we do think the whole system is now good enough to provide satisfactory results and we do not think that the FREE run seems to show the best performance.

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Our experiments suffer from global biases that cannot be removed in near real time (see the answer below about this subject). The assimilation is nevertheless doing a good job reducing the CH_4 concentration in the northern hemisphere during the summer (Fig. 5 of the paper). And when the bias is removed, the distribution (both vertical and horizontal) of CH_4 is much better after assimilation as proved by the comparison with the data from the HIPPO campaigns (Fig. 9 of the paper). For the second period (after October 2011), the new version of Tab. 3 (see above) proves for example that the TANSO+IASI experiment has a better agreement with the TCCON data (global bias of about -0.8 ppb) than the FREE run (global bias of about 4.6 ppb). In order to have an overview of the differences between the experiments and the TCCON data, we computed the optimal quadratic function of latitude for each month that fits the monthly mean difference between the experiment and the TCCON data at each available TCCON site, following Bergamaschi at al. (2009). We then plotted the time series of these quadratic functions (Fig. 6). We would like to include this figure in the new version of the article as it allows to have a better idea of the time and latitudinal variation of the bias of each experiment. It also shows that for the second period (after October 2011) the bias of the TANSO+IASI experiment is lower than for the TANSO experiment and they are both low compared to the bias of the FREE experiment. Finally it shows that the bias of the SCIA experiment does not vary much with the latitude as found by Bergamaschi at al. (2009) for the SCIAMACHY data.

Concerning the differences between the two versions of the TANSO product, please see appendix A. In summary, the difference comes much more from the a priori information provided with the data than from a bias between the data themselves.

The bias of the assimilated data is indeed an issue. We are running the system about 6 months behind real time as soon as the satellite products are ready to be assimilated. These products are already biased-corrected by the data providers but it is a difficult task as unfortunately they do not have independent data in near real-time to properly bias-correct the products. As we want to run the system as close as possible to the real time, we cannot wait for these independent data. If such independent data were available in near real time, another solution would have been to bias correct the assimilated data directly in the assimilation process following Dee and Uppala (2009).

Moreover, before assimilating together IASI and TANSO data, we verified the consistency between them. It's a tricky thing to do as they are sensitive to different regions of the atmosphere (lower troposphere for TANSO, middle troposphere for IASI). Therefore they should not be directly compared. We did compare the IASI data with the columns from the TANSO experiment (using the IASI weighting functions) before assimilating the IASI data. It was not a completely fair comparison but this comparison did not show inconsistencies between the IASI product and the experiment. We thus simply added IASI without any specific treatment. Assessing its impact in the analysis as we did in the paper can be viewed as a way to identify bias in the product.

- *The observation error is taken from those reported in the data products, but for most satellite products these have been shown to not well represent the actual error established from product evaluations. Can the authors comment on this and have they tested the sensitivity of the results to these assumptions?*

Before running the full experiments, we ran several tests to be sure that the setting of the assimilation system was appropriate. Concerning the observation errors, we did look at some a posteriori diagnostics as described in Desroziers et al. (2005). These diagnostics showed that we should inflate the given TANSO observation errors by a factor of 1.3 for the version v.1 of the data (Fig. 2) and by a factor of 1.2 for the version v.2.0 (Fig. 3). For SCIAMACHY, the factor was found to be about 1 (Fig. 4). For IASI, the factor was found to be 0.3 (Fig. 5). We choose nevertheless not to inflate the TANSO observation errors as we were not able to see much difference in the analysis between a factor 1 and 1.3. For IASI, we didn't want to apply a coefficient lower than 1 which would means that the provided errors are too large.

- *Can they authors provide estimates for biases and errors associated with the different*

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satellite product from the evaluation with independent data? How do these depend on assumptions taken in the assimilation system (observation error, correlation length, background error covariance, etc.)? How do they compared to reported errors?

To have broad estimates of the biases and errors of the satellite products, we can first compare one experiment with the satellite products that were not assimilated. For example we can compare the TANSO experiment with the SCIAMACHY product. In June 2011, the difference between the analysis from the TANSO experiment and the TANSO (version v.1) data is 0.5±8.3 ppb for the northern hemisphere. The comparison between the same analysis and the SCIMAMACHY data give a difference of 11.8±37.6 ppb. One can therefore assume that the bias between TANSO and SCIAMACHY is 11.3 ppb.

If we perform the opposite computation, the SCIAMACHY experiment compared to the SCIAMACHY data gives an difference of 0.3±33.5 ppb. And compared to the TANSO data the difference is -9.7±14.6 ppb. One can therefore now assume that the bias between TANSO and SCIAMACHY is 10 ppb.

Let's use another data set as a reference. If we choose the data from the HIPPO campaigns, Tab. 1 of the paper would suggest that the bias between the TANSO and SCIAMACHY data for the northern hemisphere is 8.83 ppm (-36.38 ppb - (-27.55 ppb)) in average between June and November 2011. In conclusion, the bias between the TANSO and SCIAMACHY data for the northern hemisphere in summer could be between 8.8 and 11.3 ppm. The uncertainty in the value comes in particular from the fact that the assimilated data are not exactly at the same place as the validation data, their coverage differ, their vertical sensitivity to the atmosphere is not the same. For example it does not make sense to compare the TANSO+IASI experiment with the SCIAMACHY data in the northern hemisphere above 30°N as the constrain in the analysis from the IASI data is low.

For estimating the errors, it is even more tricky. One can make the assumption that

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the analysis error is low compared to the observation error. Therefore, if we refer to the numbers given previously, the error of the TANSO data should be between 8.3 and 14.6 ppb while the error of the SCIAMACHY data should be between 33.5 and 37.6 ppb. There is again some uncertainty in the values of the estimated errors.

• *Does the evaluation with HIPPO and TTCON give consistent results? The information is hidden in the results, but should be brought out more clearly.*

Looking at the Tabs. 1 and 3 (middle) we can see consistent results between the evaluation with HIPPO and TCCON data. For example the north-south gradient in the FREE experiment. The bias is positive in the northern hemisphere and negative in the southern hemisphere for both comparisons with a north-south offset of about 15 ppb for the comparison with HIPPO and of about 9 ppb for the comparison with TCCON.

We can also see inconsistent results. For instance, the value of the bias with respect to the HIPPO data of the TANSO and TANSO+IASI experiments in the tropics is between the values of the bias in the northern and the southern hemispheres. When compared to the TCCON data, the value is always larger than the values of the bias in the two hemispheres. These differences could be the result of the significance of the value of the bias when compared to the TCCON data as we do not have a lot of stations in the tropics. This could also be due to the sensitivity of the TCCON measurements that are columns with averaging kernel while the comparison with the HIPPO data gives the same weight to the whole troposphere.

3 Other Comments

• *More information on the details of the assimilation technique, error assumptions etc. are needed*

We already introduced the assimilation technique page 2559 line 25 (12 h 4-D-Var

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window). Next page, page 2560, from line 19 to 26 we detailed the assumption on the background and observation errors. And when each satellite product was introduced, we provided information on its error.

• *Line 20, page 2560: what is the background error estimate based on?*

The background error covariances were estimated using the NMC method.

• *Line 25, page 2574: shouldn't the assimilation diagnostics be checked to see if the data assimilation system makes proper use of the IASI data?*

As described below, the CH_4 background error covariances were estimated using the NMC method based on an experiment assimilating the SCIAMACHY data. The assimilated data have an impact on the estimation resulting from the NMC method. As the TANSO data have similar characteristics as the SCIAMACHY ones, using the estimated background error for the assimilation of the TANSO products is pertinent. But one can argue that this background error is not pertinent for the assimilation of IASI products. Work is in progress to asses the impact of the IASI data on the estimation of the background error.

• *Line 19, page 2580: more discussion should be given on why IASI assimilation deteriorates the results.*

This is not the case anymore with the comparison with the data from the TCCON network. The conclusion will be reshaped.

• *Figure 9: The figure caption is not in line with the text in the manuscript and the figure itself.*

We do not understand this comment

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Table 1. New version of Table 3.

	NH	Trop	SH	Global
FREE	1.19	−6.61	−7.60	−1.22
SCIA	−26.53	−28.88	−30.34	−27.50
TANSO	−8.34	−3.11	−3.90	−7.04
TANSO+IASI	−11.05	2.28	−3.92	−8.61
Before Oct. 2011				
FREE	−2.79	−16.04	−12.67	−5.52
SCIA	−27.50	−30.43	−30.35	−28.24
TANSO v.1	−16.67	−10.97	−8.65	−14.71
TANSO v.1+IASI	−17.74	1.49	−6.07	−14.33
After Oct. 2011				
FREE	7.03	0.12	−1.00	4.62
SCIA	−25.09	−27.76	−30.33	−26.49
TANSO v.2.0	3.91	2.42	2.26	3.41
TANSO v.2.0+IASI	−1.19	2.85	−1.09	−0.79

4 Tables

5 List of figures

Fig. 1: New version of Fig. 10.

Fig. 2: Time series of the mean observation error (in ppb) on the TANSO data per 12-hour assimilation window for June 2010. The observation error as given by the data provider is in black. The observation error as computed by posteriori diagnostics is in red. The dashed lines and the title of the plot provides the monthly average values for the observation errors (Diag. for the diagnosed value and spec. for the specified value) as well as the ratio between them.

Fig. 3: Same as Fig. 2 but for December 2011.

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Fig. 4: Same as Fig. 2 but for SCIAMACHY.

Fig. 5: Same as Fig. 2 but for IASI.

Fig. 6: Time series of the monthly average smooth xCH_4 difference (in ppb) between the experiments and the measurements from the TCCON network: (a) FREE, (b) SCIA, (c) TANSO and (d) TANSO + IASI experiments.

6 References

[1] Bergamaschi, P., Frankenberg, C., Meirink, J. F., Krol, M., Villani, M. G., Houweling, S., Dentener, F., Dlugokencky, E. J., Miller, J. B., Gatti, L. V., Engel, A., and Levin, I.: Inverse modeling of global and regional CH4 emissions using SCIAMACHY satellite retrievals, J. Geophys. Res., 114, doi:10.1029/2009JD012287, 2009.

[2] Desroziers, G., L. Berre, B. Chapnik, and P. Poli. Diagnosis of observation, background and analysis-error statistics in observation space. Q.J.R. Meteorol. Soc., 131:33853396, 2005.

[3] Dee D. P. and S. Uppala. Variational bias correction of satellite radiance data in the era- interim reanalysis. Q.J.R. Meteorol. Soc., 135:18301841, 2009.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/14/C1066/2014/acpd-14-C1066-2014-supplement.pdf

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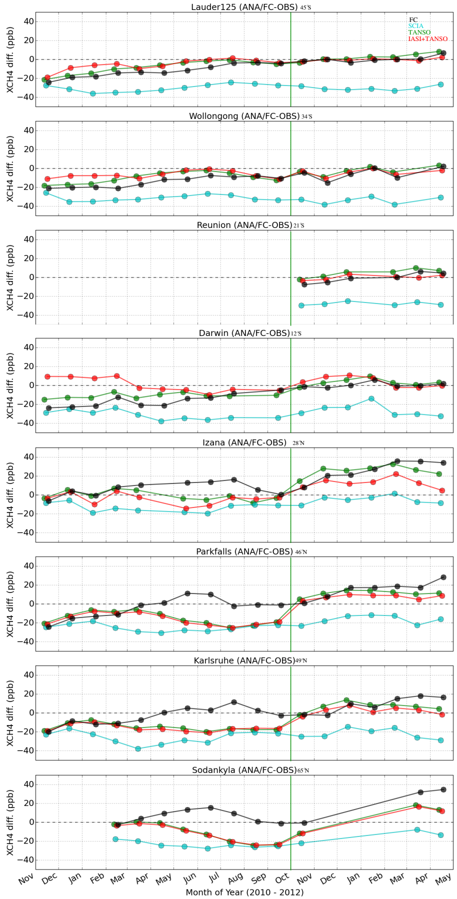

Fig. 1.

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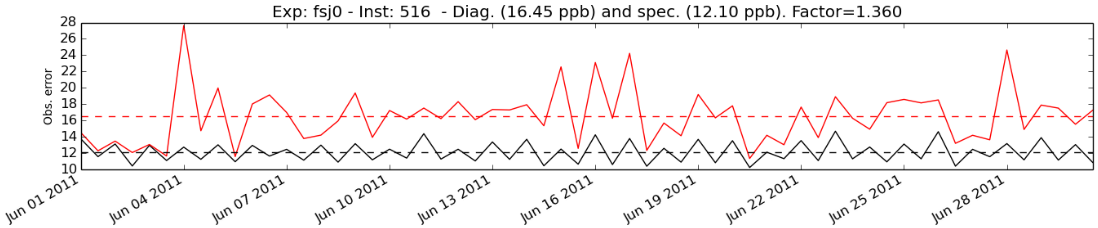

Fig. 2.

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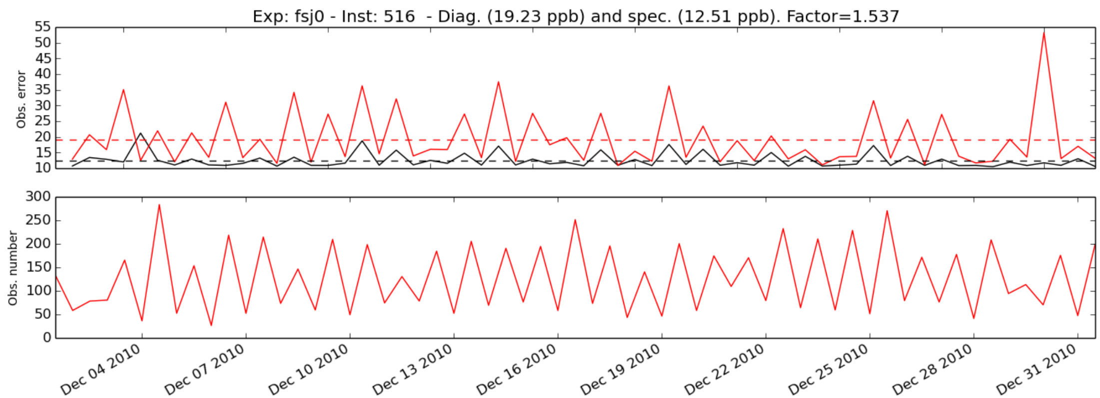

Fig. 3.

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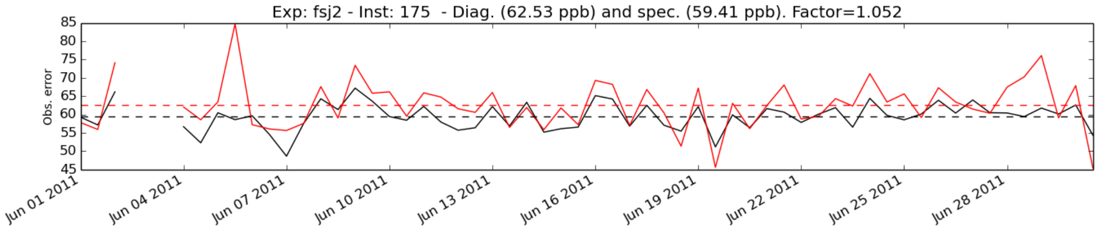
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Obs. error
85
80
75
70
65
60
55
50
45
Jun 01 2011
Jun 04 2011
Jun 07 2011
Jun 10 2011
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Jun 28 2011

Fig. 4.

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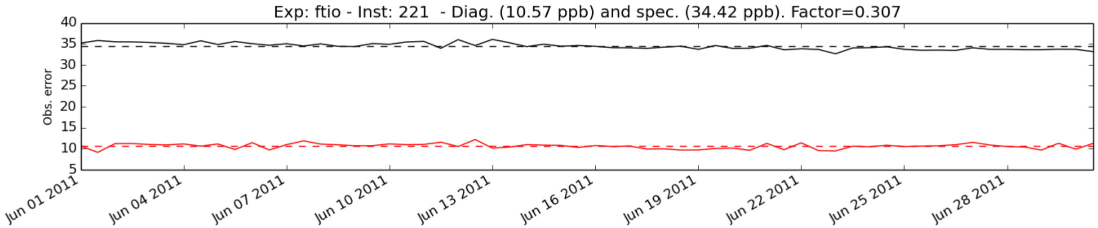

Fig. 5.

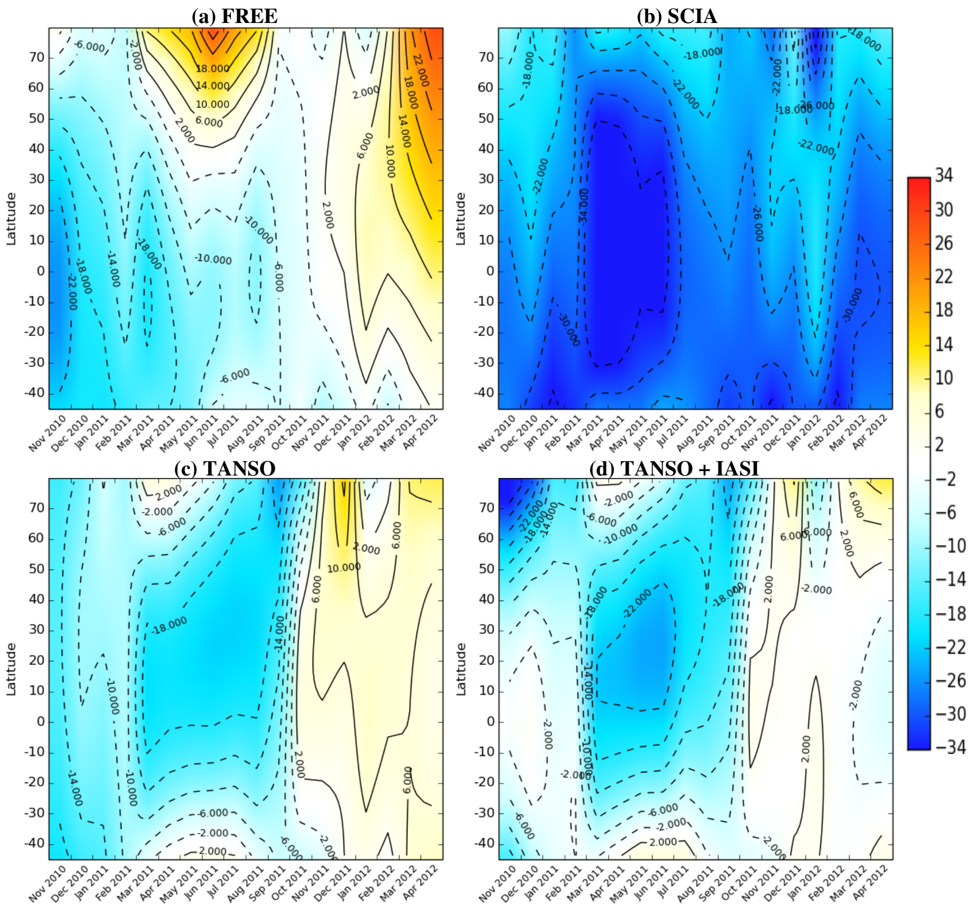

Fig. 6.