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Atmospheric Chemistry and Physics Discussions

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 mole 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 on the reply to the first review).

1 General comments

• *There is some information missing about how the satellite data products, SCIAMACHY, TANSO, and IASI were assimilated, i.e. what were the resolutions of the products and how were they used in the data assimilation system. For example, the data assimilation system has a resolution of circa 80 km (T255), while SCIAMACHY has a pixel size of 30 x 60 km, TANSO has a field of view of 10.5 km diameter, and IASI 12 km. The only information, I could find was in the caption of Fig. 2, where it states that the observations are at a resolution of 0.7 x 0.7 degrees, but further information should be given in the text in section 2.2. Furthermore, it is not mentioned whether or not data errors were correlated in time and/or space. Even if the data were assimilated assuming no error correlations, this should be stated.*

We are using all the available pixels of the instrument that are quality flagged. Because the pixel size of the instrument is smaller than the size of the model grid cell, as commented by the reviewer, we could of several observations per model grid cell. To avoid this, we chose to thin the observations on a $1^\circ \times 1^\circ$ grid. We will add this information at the end of the first paragraph of Sec. 2.2.

Concerning the observation error covariances, the information could be find in Sec. 2.1, page 2560, lines 24 to 26.

• *I think the authors should include (even if only briefly) a discussion of previous studies on the comparison of satellite data products of CH4 with ground-based observations (especially TCCON) in section 3.5.2. For example, for SCIAMACHY, the work of Houweling et al. and Bergamaschi et al., which also include a discussion of the latitudinal and seasonal dependence of errors.*

We will try to link our study with previous ones on similar topics, as suggested. To start with, we decided to fit the monthly difference between the experiment and the TCCON data with a quadratic function following Bergamaschi et al. (2009). We would

like to add the time series of the quadratic functions for each experiment (Fig. 6 on the reply to review 1). For the SCIA experiment our mean difference with the TCCON data is -27 ppb which is between the values found by Bergamaschi et al. (2009) for the SCIAMACHY bias (between -10 and -20 ppb for 2004) and the value of -37 ppb found by Houweling et al. (2013). In Bergamaschi et al. (2009) the bias seems to be more latitudinally dependent during the winter months, as in our evaluation (Fig. 6 of the reply to reviewer 1).

2 Specific comments

• *P2555, L12: Suggest that the authors update the reference to the latest version of the IPCC report, i.e. AR5.*

We will update the reference with Myhre et al. (2013). According to Table 8.2 in this report, the radiative forcing of the well-mixed Greenhouse Gases is 2.83 $\mathrm{W\,m^{-2}}$ in total. The methane contribution is $0.48 \pm 0.05\,\mathrm{W\,m^{-2}}$, that represents 17 ± 1.8 %. We will thus update the sentence with: "accounting for 17 ± 1.8 % of the enhanced greenhouse effect (Myhre et al., 2013)."

• *P2555, L13: "hydroxide" refers the anion (OH-), whereas, what is meant here is the "hydroxyl" radical.*

We will change hydroxide by hydroxyl.

• *P2555, L14: From this sentence, it is not clear what is meant by "Its", do the authors refer to the impact of the concentration of CH4 or to the oxidation by the hydroxyl radical. I suspect it is the former but it is not obvious.*

We will change the sentence with: "Methane impact is nowadays of great concern as CH_4 atmospheric fraction has increased substantially since the pre-industrial period."

• *P2558, L25: How is "good enough" precision defined? Could the authors please explain?*

We will change the sentence with: "Currently the product can be used in the tropics only". More details on the precision are provided later on in the paper (page 2565, lines 7 to 13).

• *P2562, L14-15: The resolution of the CarbonTracker CO2 mole fractions is not stated, however, the TM5 model used in CarbonTracker is at lower resolution than the that of the SCIAMACHY data and the MACC-II analysis system (T255). Therefore, using the CarbonTracker CO2 to calculate xCH4 requires either smoothing the SCIAMACHY data or interpolating the CO2 mole fractions. It should be stated, which is used.*

The CarbonTracker CO_2 fields are $1^\circ \times 1^\circ$ degrees over North America and $3^\circ \times 2^\circ$ elsewhere. For each SCIAMACHY pixel, the CO_2 value in the nearest neighbour cell of the CarbonTracker grid is used to calculate xCH_4. This information will be added in the paper.

• *P2563, L22-23: The authors should state the resolution of the TANSO xCH4 product that was used in the assimilation.*

See the answer to the general comments.

• *P2565, L5-6: The authors should state the resolution of the IASI product that was used in the assimilation.*

See the answer to the general comments.

• *P2567, L20-24: I am confused by these sentences. The meteorological parameters were only replaced in the FREE experiment, was this also the case in the analyses? In the FREE experiment, were the meteorological parameters taken from a separate assimilation in which these parameters were optimized? Why was it not possible to have the same meteorological forcing in all experiments, and what are the possible implications of having different forcing?*

In the analysis experiments (SCIA, TANSO and TANSO+IASI), the meteorological parameters are analysed by the assimilation of all the operational meteorological data. At the beginning of each assimilation window (12 hours each) they are updated by the assimilation and then forecasted for the next 12 hours, and so on.

The FREE experiment consists of consecutive 12 hour forecasts in which the meteorological parameters are initialised at the beginning of the forecast with those from the SCIA analysis. On the other hand, the methane mole fraction is cycled from the previous forecast. This process generates small unavoidable differences in the meteorological parameters between the FREE experiment and the other experiments due to the computer precision in the input/ouput. The differences have nevertheless no impact on average. We will change the sentences to clarify this.

• *P2569, L13-15: It seems fairly logical that the SCIA experiment would still have lower xCH4 compared to the FREE experiment in winter, even when there are fewer observations to assimilate due to the time needed to re-adjust to equilibrium. Also it is clear that any difference with respect to the FREE experiment will be propagated with atmospheric transport. Therefore, these two hypotheses are equally valid and not independent from one another.*

We will change the sentence with: "This is due to both the transport that spreads the observation information in space and time, and the model adjustment to its equilibrium state."

• *P2570, L28: I am not sure how this statement supports the previous one. Could the authors please explain.*

The SCIA experiment has differences with the FREE experiment in the stratosphere. However, the sensitivity of the SCIAMACHY data is in the lower troposphere and the assimilation of these data should not impact directly the stratosphere. The differences found in the stratosphere could come from the transport, the background error vertical correlation or the fact that the meteorological parameters are not exactly the same in

the two experiments.

A closer investigation leads us to conclude that the differences in the stratospheric methane are likely due to the transport. In average, the assimilation of SCIAMACHY or TANSO has for effect to add some methane in the tropics, in the troposphere up to 50 hPa. The tropospheric CH_4 increase is moreover advected to higher levels by deep convection that adds more CH_4 in the stratosphere. The stratospheric CH_4 increase is then advected at high latitudes by the meridional circulation in the stratosphere.

We will remove "the previous" in the sentence as this statement was not issued previously. We will also better explain from where the differences are coming from.

• *P2571, L8: The authors should emphasize that this is compared to the TANSO only assimilation (if that is indeed the case).*

We will change the sentence with:" The IASI+TANSO experiment has between 5 and 15 ppb less methane in total column after October 2011 than for the TANSO experiment".

• *P2572, L18: Do the authors mean that the global bias between each experiment and the observations was subtracted? If so, then this also removes the global offsets between each experiment. Therefore, it can only be the spatial gradients or relative differences that can be compared between experiments.*

We will change the sentence with: "We removed for each experiment the global average difference between the model and the measurements to better compare the spatial gradient errors between the experiments". In the following discussion only the differences between the gradients and the regional differences between the experiments are discussed.

• *P2573, L13: This is approximately the same bias as found by Houweling et al., for SCIAMACHY (-37 ppb) and should be referred to here.*

Houweling et al. (2013) are using the TCCON data to get this value of -37 ppb. We

already referred to this study Sec. 3.5.2 when we compared the SCIA experiment with TCCON data. We believe it is the right place to provide the reference and we will not add it here.

• *P2573, L21: I suggest specifying that this is an underestimate of 7 ppb in FREE and 3 ppb in the assimilation.*

We will do it.

• *P2576, L15: This is not sufficient to say that there is not a latitudinal bias in SCIAMACHY, in fact previous studies have found a latitudinal bias (e.g. Bergamaschi et al. 2009)*

We will change this sentence, especially regarding Fig. 6 of the reply to review 1.

3 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] Houweling, S., Krol, M., Bergamaschi, P., Frankenberg, C., Dlugokencky, E. J., Morino, I., Notholt, J., Sherlock, V., Wunch, D., Beck, V., Gerbig, C., Chen, H., Kort, E. A., Röckmann, T., and Aben, I.: A multi-year methane inversion using SCIAMACHY, accounting for systematic errors using TCCON measurements, Atmos. Chem. Phys. Discuss., 13, 28 117–28 171, doi:10.5194/acpd-13-28117-2013, 2013.

[3] Myhre, G., D. Shindell, F.-M. Bréon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J.-F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura, and H. Zhang. Anthropogenic and Natural Radiative Forcing in: Climate Change 2013:

The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2013.

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 2553, 2014.