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Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on "Ability of the 4-D-Var analysis of the GOSAT BESD XCO_2 retrievals to characterize atmospheric CO_2 at large and synoptic scales" *by* S. Massart et al.

S. Massart et al.

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We would like to thank the anonymous reviewer for his/her comments and remarks. We will try to account for all the comments in a revised version of the paper. Hereafter are the answers to the general comments of the reviewer.

Comment: *There are, however, some remaining issues regarding the clarity of the manuscript particularly in the description of the different statistics used in the methods section and then ongoing through the paper.*

To reply to the the first general comment, we will change the way we are describing

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the different statistics in the revised version of the paper. For example we will further develop Eq.(1) of the paper with the bias δ_k and the scatter σ_k for the TCCON station k

$$\delta_k = \frac{1}{N_k}\sum_{i=1}^{N_k}\left[\hat{c}_k\left(t_i\right) - \hat{c}_k^o\left(t_i\right)\right] ,$$
$$\sigma_k = \sqrt{\frac{1}{N_k}\sum_{i=1}^{N_k}\left[\hat{c}_k\left(t_i\right) - \hat{c}_k^o\left(t_i\right) - \delta_k\right]^2} . \quad (1)$$

The bias δ_k and the scatter σ_k for the TCCON station k are now temporal statistics on the difference between the observed time series $\hat{c}_k^o\left(t_i\right)$ and the model equivalent time series $\hat{c}_k\left(t_i\right)$ where t_i for $i \in [1, N_k]$ are the N_k times when we have a TCCON observation for the station k.

In this context, the model offset δ, the station-to-station bias deviation σ and the model precision π are for the N TCCON stations

$$\begin{aligned} \delta &= \frac{1}{N}\sum_{k=1}^{N}\delta_k , \\ \sigma &= \sqrt{\frac{1}{N}\sum_{k=1}^{N}\left[\delta_k - \delta\right]^2} , \\ \pi &= \frac{1}{N}\sum_{k=1}^{N}\sigma_k . \end{aligned} \quad (2)$$

Comment: *First, I think it would help to motivate the paper more generally if the authors included a brief description of the key scientific uncertainties relating to the surface emissions and sinks of* CO_2. *Ultimately, as the authors point out in the conclusions,*

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their work is a stepping stone towards performing source/sink inversion in the future and therefore towards resolving this uncertainties. As it is, the authors only weakly motivate on this subject by saying that monitoring may provide insight into surface fluxes.

One purpose of the study is to demonstrate the ability of the Copernicus Atmosphere Monitoring Service (CAMS) system to monitor atmospheric CO_2 by providing an analysis of the atmospheric CO_2 based on the assimilation of the GOSAT BESD XCO_2 data. The aim is also to assess the quality of the atmospheric CO_2 analysis.

If the quality of the analysis is judged to be good enough, one could use it instead of observations to infer surface fluxes using for instance a flux inversion system. This is not the focus of the analysis system developed at ECMWF within CAMS. For this reason, we do not think it is appropriate to describe in more details the uncertainties related to the surface emissions and sinks of CO_2.

We are nevertheless working on reducing the uncertainties on the modelled biogenic surface fluxes independently from the monitoring of the atmospheric CO_2. We have some ideas on how to merge the two approaches but this is very much work in progress so it is not mature enough to be detailed in the paper.

Comment: *Second, the authors have mentioned some of the sources of uncertainties on the GOSAT-BESD XCO_2 retrieval, but this was not done in much detail, nor did the authors discuss what the effects were of these uncertainties on the analysis. The authors explain to readers that filters are already applied during the GOSAT BESD algorithm and also that they include a 2 ppm uncertainty in the observation error covariance matrix for all of the XCO_2 observations used in the assimilation. Can the authors provide any insight into why the value of 2 ppm is chosen? For instance, is this consistent with the typical errors estimated for the XCO_2 retrieval? We are told that observations made under high SZA tend to be removed because these observations are more strongly affected by clouds and aerosols. We are also told that the BESD*

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algorithm explicitly accounts for both clouds and aerosols, when it has to do this, does this lead to higher uncertainties in the retrieval? Are these potential uncertainties fully taken into account with the 2 ppm uncertainty in the error covariance matrix? Can the authors explain what the potential effects are of the 2 ppm uncertainty are on the assimilation, and what the effects of unresolved errors might be?

We were not clear in the description of the GOSAT-BESD XCO_2 observation error. We provided in the paper the spatial and temporal mean value which is around 2 ppm. The observation error does vary in space and time as illustrated by Figs. 1 and 2 of this reply. The first figure shows for example that the observation error is lower in the Tropics than at higher latitudes north where the SZA is larger. The second figure shows that the observation error varies in time with a standard deviation that can be more than 0.5 ppm around the mean value.

We used diagnostics posterior to the analysis to verify if the specified observation error globally matches the expected one. We found that they agreed so we did not question the observation error provided by the BESD algorithm.

We will discuss further the GOSAT-BESD XCO_2 observation error in the revised version of the paper. In particular, we will explain that the observation error varies in space and time and that the variations account for the uncertainties of the retrievals.

Comment: *Finally, do the authors think that the remaining biases in the analysis could be reduced with even more observations and coverage? They have explained that the bias in the analysis likely exists because they do not attempt emission inversion. Is it possible though, that if one had a sufficiently large enough number of observations, could that bias be at least temporarily reduced in the analysis? Do the authors have any plans to try to further reduce the residual bias on the analysis through future work and developments?*

For the analysis, having a larger coverage from satellite observations would certainly help reducing the remaining biases. Another aspect that could help would be a short

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satellite revisit time. The surface flux error would not have time to accumulate too much if the revisit time would be small enough.

For the forecast, we would still have the accumulation of surface flux errors. In order to reduced these errors, we worked on a methodology we should document soon.

Interactive comment on Atmos. Chem. Phys. Discuss., 15, 26273, 2015.

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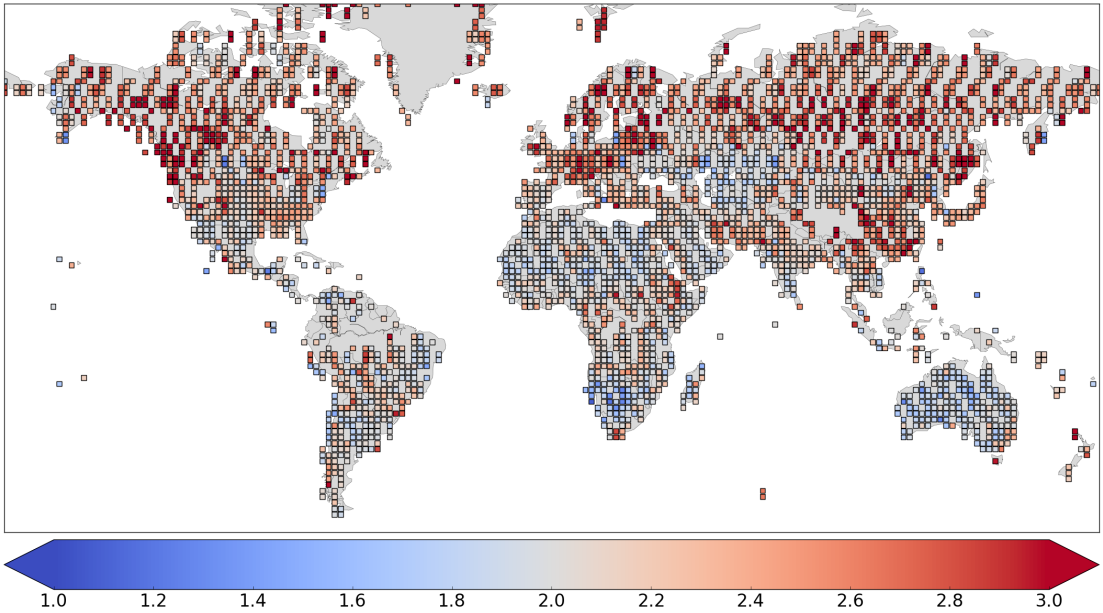

Fig. 1. Average value of the GOSAT BESD XCO2 observation error for the year 2013 on a 2x2 grid.

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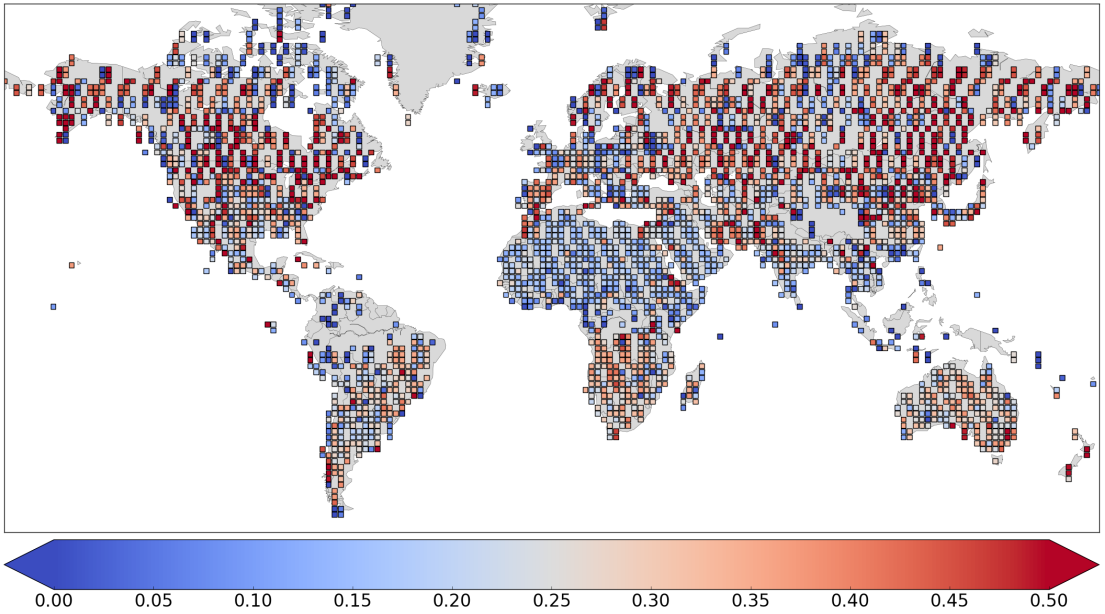

Fig. 2. Same as Fig. 1 but for the standard deviation of the observation error

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