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Interactive comment on "Assimilating Compact Phase Space Retrievals (CPSRs): Comparison with Independent Observations (MOZAIC in situ and IASI Retrievals) and Extension to Assimilation of Truncated Retrieval Profiles" *by* Arthur P. Mizzi et al.

Anonymous Referee #1

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This study investigates the application of different methods for compressing the information content of satellite retrievals to the assimilation of CO from MOPITT. Results are compared to independent CO measurements from MOSAIC and IASI, overall showing a variable skill of the assimilation depending on elevation, pointing to a potential bias in the MOPITT data. A method is proposed to account for this bias, which is tested in the same framework and compared to results obtained without bias correction. The methods that are presented are interesting, although partially not new since this work

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Discussion paper

builds on earlier published work. The new part concerns a validation against independent data as well as the method to account for measurement biases. In my opinion, these two aspects are important to make a significant contribution beyond Mizzi et al (2016), which is needed for this work to be publishable. As explained further below, however, issues remain with both – as well as other conclusions that are drawn from this work, which remain to be addressed and call for significant revisions.

GENERAL COMMENTS

The assimilation period chosen for this work is only 9 days. Given the size of the domain, this is probably barely enough to move air from one side to the other side of the domain. This raises questions about the influence of the initial and boundary conditions that are applied. A large fraction of the RMS in Figure 1 is explained by a bias of the model relative to MOPITT. This is attributed to model errors in the first part but later to a MOPITT retrieval bias, which works rather confusing but more about that later. The trouble, which should be addressed in my opinion, is that parts of the domain are constrained by data whereas others or not (yet). The outcome of a validation comparison is then very dependent on whether the independent data are in the constrained or unconstrained parts of the domain. The Moziac comparisons include flights at June 3th and June 4th, i.e. the first part of the 9 days assimilation window. It should be made clear whether they are in data constrained regions of the domain of not, and whether the validity of the validation is compromised by the short spin up period. The same applies to IASI comparison. I was looking for information about co-location of IASI and MOPITT retrievals that were used but didn't find any. A more careful treatment of possible impacts of assimilation spin up is needed.

Looking at the validation results in Figure 1, 6, and 7, I'm not sure what to conclude since there are no error bars on the data nor the model estimates. Quite some discussion is spent on differences between the performance of MET, VMRR, and L10VMRR, in Figure 1. However, I doubt that any of that is significant. The same for the difference between CPSR and QOR. If I understand well, the MOZIAC profile is an average of

4 profiles. However, since the take-off and landing legs are in different cities, I suspect that the individual profiles could look rather different. In the case, I wonder how robust the altitude dependent under/overestimation really is (which is anyway hard to assess using only 4 profiles). To summarize, the statistics of the validation comparison requires more work.

On aspect of the retrieval compression I find very confusion, which is the information content before/after compression. I would think that you'd always loose information by filtering for dominant eigenvectors (whether in SVD or not). However, the text mentions several times that the uncompressed retrieval work less well because of larger observational uncertainty. I understand that the strategy is to select the most significant components of the averaging kernel, which are probably associated with the least uncertainty. However, those are contained in the unfiltered version of the assimilation also. Nevertheless, I also understand that if the poorly constrained directions introduce noise, this would deteriorate the assimilation performance. However, the evaluation has little to do with noise, but rather with bias. Somehow, the CSPR and QOR retrievals provide a stronger data constraint than their VMRR counterpart, pulling the solution stronger to the data reducing bias. However, it remains unclear to me how this happens, since preconditioning cannot add observational constraints. Could it be in the localization or some other part of the assimilation of the data?

A new element compared to Mizzi et al, 2016 is also the use of MOPITT super observations. However, it remains unclear how those observations are constructed. Issues are the averaging of data with different vertical sensitivities, averaging of averaging kernels and retrievals uncertainties. Given the importance of the averaging kernel and the retrieval error covariance for the method of compressing the data, further discussion is needed of how those are derived.

At first, I understood the validation in Figure 1 as the logical consequence of a bias in the model, explaining why both the assimilation and independent data statistics show similar improvements. However, the logic falls apart after a bias in the MOPITT retrieval

turns out to be the cause. In that case, you expect the assimilation methods that give the best agreement with MOPITT (in terms of bias) to give the worse agreement with IASI and vice versa. Why is the RJ3 experiment that is meant to account for the MOPITT bias performing poorer against IASI (Fig. 1, top right) than without this correction? What does it mean that CPSR-RJ3 performs better against MOPITT than L10VMRR-RJ3? (Fig. 1, top left) The suggestion is made that CPSR-RJ3 performs better, but you might as well argue that it performs worse because it ends up agreeing better with the biased MOPITT retrievals. It is concluded that the CPSR and QOR experiments perform better against MOZAIC than MET. However, looking at Figure 1 (bottom) I don't see this. QOR and CPSR are biased high because of the biased MOPITT retrievals. This is all fine, but how then can it be concluded that QOR and CPSR outperform MET in comparison to MOZIAC (page 19, line 22). All these points need thorough clarification.

SPECIFIC COMMENTS

Introduction: It reads like a duplication of the abstract. Yet, the introduction has a very different purpose, including how the current research fits into the work that is being done by other researchers. Currently, it mostly explains the relation between this work and Mizzi et al, 2016. A wider context is needed to provide the reader with a more general background of this research.

page 5, line 8-14: How many MOZAIC profiles have been used for validation?

Page 5, line 18: which state variables would otherwise be influenced by the CO data?

Section 4.1: the difference between regular and L10 retrievals is explained, but a more explicit link should be made to with is done in experiment VMRR and L10VMRR. The section about QOR and CPSR should return to this discussion since the equations that are shown there suggest L10VMRR are used although this is nowhere mentioned.

Page 6, line 20: 'Another reason is to include pre-processing methods that enable us

to not assimilate selected retrievals' I don't quite understand what is meant here.

Section 4.2: It remains unclear from the description if any filtering of dominant eigenvectors is applied to QOR, and, if so, based on what criterion.

Page 9, line 2: 'rank of A is greater ... i.e., n - k >= q' But this assumes that the elements that are removed are in the nul space of A, which need not be the case (for example, if the purpose of leaving out layers is bias correction).

page 10, line 4: The right order is VMRR -> MET -> L10VMRR ...

page 10, line 8: 'We have investigated our results and concluded that they are correct ...', What was done?

page 10, line 9-23: The two 'explanations' that are given discuss why CPSR and QOR result may be similar or different, but they don't explain what is referred to as 'the discrepancy' in line 9.

page 10, line 17: You mean that the observational error covariance is still singular when transformed to the SVD space?

page 11, line 13: A more quantitative discussion is needed here of the bias that is found, versus what has been reported MOPITT v5.

page 12, line 15: How about the opposite: MOPITT's lower tropospheric sensitivities influencing the upper troposphere through Ak smoothing?

page 13, line 15: 'Those results suggest ... most sensitive to CO in the lower troposphere' Why is that? The text above describes, but doesn't explain anything.

page 14, line 20 - 21: I don't really see this in the Figure.

page 16, line 8: L10VMRR-RJ3 does account for the observation error covariance, but you just don't diagonalize / reduce its rank, right?

page 17, line 12: 'The CPSR-RJ3 experiment skill improvement ...' How about the

significance of this?

page 17, line 21: ‘Reject Top Three’. Besides the point that this explanation of the meaning of the “RJ3” experiment comes rather late, it is also not clear what justifies this method of MOPITT bias correction – given earlier publications about the nature of the bias.

Figure 4 - 5: The discussion in the text is hard to follow, because it requires comparing figure 4 and 5. Why not show model – data differences, before / after assimilation in one Figure?

Figure 10: Why do these plots show results for all levels, whereas they represent experiments in which retrieval results for certain levels are not taken into account. How can these levels nevertheless show up?

TECHNICAL DETAILS

Title: misses a closing parenthesis (maybe better to remove the details enclosed in parenthesis anyway)

page 9, line 3: remove ’changes in’

page 9, line 4: ’retrieval’ i.o. ’observation’

page 12, line 15: ’artifact’ i.o. ’artifice’

page 12, line 25 and onwards: ’sensitivity’ io ’variability’

page 12. line 7: ’Fig. 3’ i.o. ’Fig. 2’

page 16, line 4: ’Section V.C.’

Figure 4, title of the lower left panel: CPSR – MET

Figure 8, 9, titles of panels in the bottom row: What is ‘Del-Fcst’?

2018.