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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.

Anonymous Referee #1

Received and published: 9 October 2015

Massart et al. describes the assimilation of column-air dry mole fractions of CO2 from the GOSAT-BESD retrieval using 4D-var in ECMWF's IFS atmospheric model. The assimilation product, termed the analysis, is evaluated by comparison with a free-running model of CO2 (does not use assimilation), observations of CO2 columns made from TCCON stations, and also GOSAT-BESD CO2 data. The authors conclude that the assimilation leads to a substantial improvement in the CO2 simulation of the analysis compared to the free-running model and to the GOSAT-BESD satellite observations. The analysis shows a reduction in the biases, increased precision, and improved accuracy compared to the free run. In addition, the analysis is able to better capture

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Interactive Discussion
Discussion Paper

synoptic scale variability in CO2 compared the the free run, and still shows improved synoptic scale skill up to 10 days into the future. The subject matter of the paper fits within the scope of the journal, and so ACP is a suitable venue for publication. I think the article should be accepted to ACP after having dealt with some minor revisions.

General comments

I am pleased to say that the authors have made a substantial improvement to the English in the paper. The sections that were confusing in the pre-ACPD version of the article have also been greatly improved and the article is consequently now much clearer and easier to read. 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. I have recommended some changes in the specific comments below. Further, there are still a few small grammatical errors, which are listed in the technical comments.

I have only three general scientific comments. 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 CO2. Ultimately, as the authors point out in the conclusions, 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.

Second, the authors have mentioned some of the sources of uncertainties on the GOSAT-BESD XCO2 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 XCO2 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

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with the typical errors estimated for the XCO2 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 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?

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?

Specific comments

Page 26276, line 25. I think it would be worth mentioning that aerosols can also affect the scattering of short wave radiation and therefore can affect the retrieval as well.

Page 26277, paragraph from line 4 onwards. There are several instances of the use of budget in reference to CO2 in the atmosphere. Given the context, I am not sure this is the correct technical term to use. Budget refers to the production and loss of something. However, the authors seem to be referring to CO2 in the atmosphere and how it might change over time. I therefore think something like “global concentrations” or “global distribution and abundance” might be more appropriate in this circumstance. Burden might be another option, but this is a single figure referring to the total mass of a gas in the atmosphere.

In Section 3.2:

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I think it would be better if c hat and c hat o are defined here as well as in the Appendix.

It might be better to define bias and scatter in equation 1 with notation rather than with words. Later in the text you refer to bias but use other similar terms, e.g., mean bias. The authors should use notation to remedy this problem.

The authors describe the bias as being calculated from the mean, which "is the simple average". However, we are not told if this is a temporal or spatial average. Linked to this, if a more formal notation was used in Eq 1., we could see how the average was being calculated.

Linked to the previous two points, I found that at some points in the paper the authors discussed a bias that is essentially a temporally averaged bias for each station. At other points, the authors use the term mean bias, which is essentially the spatial average of the temporally averaged biases. It would improve the clarity of the discussion if these terms were more distinct from one another and the authors need to do this.

I found the half paragraph (lines 9 to 16) and the following paragraph (lines 17-23) to be very confusing. Please can the authors try to improve these sections of text. To give some examples: the authors describe "the sum of", yet Eq 1 does not show any sum; as it stands, the description of offset sounds like bias in Eq 1 – can the authors make these terms more distinct with clearer text and equations; in the second paragraph, it is not clear what is meant by "each station individually" when compared to descriptions in the previous paragraph.

Please can the authors define offset, station to station bias deviation, and model precision with equations and also include notation for these terms.

I would recommend using another statistic: the mean absolute error. Later, when the authors compare the free run and analysis, the mean bias is used to compare both runs. However, the mean bias does not show very clearly that the analysis is greatly improved compared to the free run. The mean bias is still useful, but the mean absolute

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error shows more substantial improvement in the analysis.

Page 26279, line 1. I suggest maybe adding “on cloud and aerosols” prior to “. . .is mainly. . .”

Page 26283, Section 4. I think you can safely remove the first two sentences of Section 4 and begin the third sentence with “We. . .”.

Page 26285, lines 12-17. What about the CMDL surface CO2 measurements in Antarctica? ftp://aftp.cmdl.noaa.gov/data/trace_gases/ These data would make a useful comparison to the free run and analysis over this continent given the lack of satellite observations.

Technical comments

Page 26275, line 20, “. . .the atmospheric CO2. . .” – remove “the”.

Page 26275, line 21. Change “mean” to “means”. Means refers to the method and not the average.

Page 26275, line 21. I suggest changing “than the carbon of some other reservoirs.” to “than the other reservoirs of carbon.”

Page 26276, line 13. Remove “a” in front of “four-dimensional”.

Page 26276, line 14. Change “constraint” to “constrain” and remove “the” in front of “atmospheric CO2”.

Page 26276, line 19. Change “being the” to “are”.

Page 26276, line 20. Add “and therefore” in front of “AIRS measurements”.

Page 26280, line 10. Change “representativeness” to “representativity”.

Page 26281, line 14. Change “The ability of assimilating retrieval products from GOSAT was included in the IFS” to “The ability to assimilate retrieval products from GOSAT was included in IFS”.

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Page 26281, line 19. Change “are constant on each model” to “is constant for each model”.

Page 26282, line 9. Insert “the” between “where” and “mean”.

Page 26282, line 13. Misspelling of bias.

Page 26283, line 20. I suggest changing “station-to-station bias variations” to “the variation of the bias from station to station”.

Page 26284, line 23. Change “As for” to “Similarly to”.

Page 26284, line 27. Change “whereas” to “where”. Change “when” to “and”.

Page 26284, line 29. Insert “during” or “due to” in between “which is” and the “growing season”.

Page 26285, line 1. Insert “simulated” in between “of the” and “atmospheric”.

Page 26285, line 10. Move “has” to after “consequently”.

Page 26285, line 18. Change “Even if. . .” to “Despite the fact that. . .”.

Page 26285, lines 19-20. Move “only” from line 20 to between “the analysis” and “starts” on line 19.

Page 26285, line 25. Change “at” to “to”.

Page 26286, line 9. Insert “in the” between “cycle” and “bias”.

Page 26287, line 15. Remove “/” and replace with “minus”.

Page 26287, line 25. Change “3 times less” to “more precise”.

Page 26287, line 27. Insert “satellite” in between “in the” and “data”, and insert “to” before “0.5”.

Page 26288, line 8. Insert “at the“ between “occurred“ and “end“.

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Page 26288, line 9. Change “is coming” to “came”.

Page 26288, line 18. Change “is poorer in” to “has lower”.

Page 26292, line 7. Mispelling of “slightly”.

Page 26292, line 12. You can remove the “.” after the 1.

Page 26292, line 26. You can remove “allow to”.

Figure 4. Please can you increase the size of the axis labelling.

Figure 7. Please can you increase the size of the axis labelling for latitude and longitude.

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