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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Elevated uptake of CO_2 over Europe inferred from GOSAT X_{CO_2} retrievals: a real phenomenon or an artefact of the analysis?" *by* L. Feng et al.

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We thank the anonymous reviewer's comments, which help us improve our manuscript. We have carefully read the reviewer's comments, and make changes in the revision accordingly. Below we address all comments (marked by italics) raised by the reviewer.

After Reuter et al. (2014), Feng at al. specifically address the current inconsistency between satellite-based atmospheric inversions and other sources of information about Europe's carbon sink. Both studies present a series of sensitivity tests (some tests being rather similar between the two), but they come to a different conclusion. The

reason for the divergence is not made explicit, which is all the more surprising that four scientists (half of the current team) co-author both papers.

In this paper, we propose a different hypothesis on the elevated European uptake inferred from GOSAT XCO2. We have investigated the relationships between flux estimates and possible observation biases within and outside European region. Our global (and quasi-regional) inversion experiments shows that a large portion of the enlarged European uptake is related to elevated CO2 inflow caused by assimilating GOSAT XCO2 retrievals outside the immediate European region. A varying sub-regional bias of 0.5 ppm can explain much of the remaining extra uptake. Currently there are no sufficient data to rule out that GOSAT XCO2 retrievals are indeed biased.

There are many differences between the regional flux inversions used by Reuter et al., and our global inversion approach. Several previous reports of elevated Europe uptake (such as Deng et al., (2014); Basu et al., (2014), and Chevallier et al., 2014) are also based on global flux inversion systems. Using our global inversion system, we are able to show that GOSAT XCO2 data outside Europe can have significant impact on the European flux estimate. Another important difference is how to use regional bias correction. As discussed in our revised Appendix A, applying on-line bias correction is helpful, particularly for limiting the adverse effect from inaccurate boundary conditions around Europe. However, characterizing and correcting for systematic bias is non-trivial. Mis-characterization tends to weaken observational constraints and compromise a posteriori flux estimates.

Finally, this paper is not intended to invalidate the work by Reuter et al. Instead, it highlights that without extra measurements, we cannot reach a robust conclusion about whether the elevated uptake was a true phenomenon or an artefact caused by uncharacterized systematic bias of the data or associated with issues of inversion approach. That is the reason all the co-authors are supporting for further investigation on this topics.

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The heart of the present study seems to lie in the short fourth section ("Bias estimation") that clearly contradicts Reuter et al.: it would deserve more substance. For instance, can the authors demonstrate the superiority of INV_ACOS_INS and INV_UOL_INS compared to the others are the inferred retrieval biases consistent with misfits to TCCON; can the inferred biases be linked to physical variables? I note that the correction to the West-East retrieval gradient reaches nearly 1 ppm during some months, which is considerable.

The joint data assimilations INV_ACOS_INS and INV_UOL_INS are part of our experiment set to show that flux inversions are sensitive to small regional biases, which, currently, cannot be properly characterized by independent observation network. INV_ACOS_INS and INV_UOL_INS are able to explore larger constraints from both in-situ and space-based observations, which coverages are often complementary to each other. Including an online bias correction also helps to (partially) remove possible biases in XCO2 retrievals, provided they are consistent with the assumed spatial and temporal patterns. INV_ACOS_INS and INV_UOL_INS have much (about 60%) less European uptake than GOSAT only inversions. Also, a posteriori model concentrations for INV_ACOS_INS and INV_UOL_INS agree better with independent aircraft observations than the GOSAT-only inversions. But we agree that there are no sufficient observations to fully prove (or disprove) the results, including the bias estimates as well as the small European uptake around 0.6 GtC/a. So they are indeed part of our main argument that whether the elevated European uptake is an artefact or a real result is a question that demands further investigation.

In summary, I would therefore only recommend publication if an extra depth of analysis is provided that clearly shows the added value of the new sensitivity tests and justifies the change of conclusion.

As stated in above responses, the emphasis of our paper is that observation biases can result in an apparent elevated estimate of European uptake, and as shown in the revised Appendix, we have no robust approach to remove adverse effects of the un-

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characterised observation biases. So we believe this manuscript raises a valid question on whether the elevated European uptake inferred from GOSAT data is real or an artefact due to the high sensitivity of flux estimates to small regional biases, which cannot be ruled out without further dedicated measurements.

Detailed comment:

1) Abstract and introduction: the text suggests that current knowledge about re- gional carbon fluxes comes from atmospheric inversions, but actually most of it comes from process models, flux measurements and inventories.

We agree with the reviewer. To avoid such impression, we have changed the sentence in introduction to 'the top-down flux estimates have not improved. . .'

2) As shown throughout the text, the inversion uncertainties are unrealistically small. Does this come from a flaw in their computation or from a flaw in the inversion configuration? Less striking, the prior global uncertainty seems to be quite small (p.1994, l.13) given the type of prior fluxes used. Last, as it is presented, the sensitivity test about the prior uncertainty suggests that the uncertainty about the prior error covariance matrix drives the satellite-based inversion, leaving not much value to the other sensitivity tests, hence to a large part of the paper.

We thank the reviewer spotting this mistake. We mistakenly replaced the unit convert factor of 144 (=12x12) with 199 the number of geographical regions. We have corrected this error, and also increase the apriori uncertainty by 20We also add one sentence to point out that a posteriori uncertainty can be underestimated by the inversion system itself:
'However considering the limited spatial resolution (only 12 sub regions for the whole TransCom European region), and unquantified model transport and representation errors, we anticipate that the complete a posteriori uncertainty is larger than the value estimated by the inversion system itself, as suggested by large inter-model variations found for in situ inversions [e.g., Peylin et al., 2013]. '

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3) p.1994, l.15: this is minor, but the reader may wonder why in situ (continuous) measurements are discarded.

We indeed have used some continuous measurements as well. To avoid confusion, we have changed it to 'conventional surface observation'.

4) p.1994, l.16: GGG2012 had known problems that can be damped at least with the recommended bias correction (https://tccon–wiki.caltech.edu/Network_Policy/Data_Use_Policy/Data_Description_GGG2012 #Laser_Sampling_Errors) but the authors seem not to have used it.

When our major calculations were made, bias corrections for several European TCCON sites were not available, so we chose to use GGG2012 to avoid possible inconsistency. We have now re-calculated our results using the GGG2014 data.

5) The comparison to HIPPO would deserve more details, or it should be removed.

A revised Figure 2 shows that GOSAT-only inversions generate higher concentrations over low latitudes.

6) p.1998, l.9-11: it is not clear how the authors come to this conclusion.

What we mean is that: although in the combined inversions INV_ACOS_INS and INV_UOL_INS we have assimilated the GOSAT XCO2 over east Europe, the annual net European uptake is close to the in-situ only inversions. But we agree that the impact of observations over East Europe needs further investigation, so we drop this sentence.

7) p.1998, l.19-21: the role of this sentence in the logic is not clear.

We change the sentence as:
'The effect of bias correction is much smaller for INV_UOL (0.07 GtC/a), because of the different bias patterns.'

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