Interactive comment on “On the ability of a global atmospheric inversion to constrain variations of CO2 fluxes over Amazonia” by L. Molina et al.

Anonymous Referee #3
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Tropical South America is a geographical region where we know very little about the carbon balance on a large scale, with implications for quantifying the carbon balance over other regions. This paper examines the ability of using CO_2 mole fraction measurements from four additional sites on the eastern coast of South America, relative to a control calculation that has used all other available mole fraction data. I have a few comments but none of them are sufficiently negative to prevent this work being published – they can be addressed quickly.

A) We thank the reviewer for his analysis of our paper and for his very useful comments. The corrections that we will apply following this review should improve the manuscript.

To some extent this is (yet) another paper that highlights the many difficulties using measurements that represent constraints on spatial scales and temporal scales that are not described well by current models. In this experiment, the model resolution is very coarse that could easily compromise its ability to capture reliably observed variations on certain time scales. It would be good to learn a bit more about the model error that takes this into account because it plays an important role in determining the results.

A) Values of the configuration of the model errors in the inversion system will now be provided in the manuscript (see table A.1 at the end of this document) but they cannot fully reflect the actual values of these errors given the modest confidence in this configuration, due to limited experience acquired for the representation of ground based in situ measurements in this area using global transport models.

The new sites look great but there is precious little information to judge whether they are actual useful.

A) The new figure 8 provided below along with figures 6 and 9 will be used to better discuss in the new manuscript the fact that the impact of these new sites on the increments from the inversion is large and spread over a large area (at the transport grid scale, the increments from INVSAM to the annual fluxes generally exceed 150% of the prior estimate in terms of absolute values).. Still, the analysis of the increments will demonstrate that the reliability of this impact is quite low.

I assume they have been calibrated on a scale that is common to the data assimilated as part of the MACC project, but this point needs to be confirmed. More details would be helpful for this reader.

A) These details will now be provided in the manuscript.

I appreciate that these measurements are difficult to sustain over long periods but I am left concerned about the role of sampling frequency on the results. A simple simulation could be used to determine the ability of each site to constrain estimates of NEE and ocean fluxes. This would strengthen the ultimate message of the paper.

A) We are not sure about the kind of simulation that the reviewer had in mind. However, given the relatively short correlation length scales in B, and despite the long range corrections associated with the data in global inversions, we assume that corrections applied in response to data

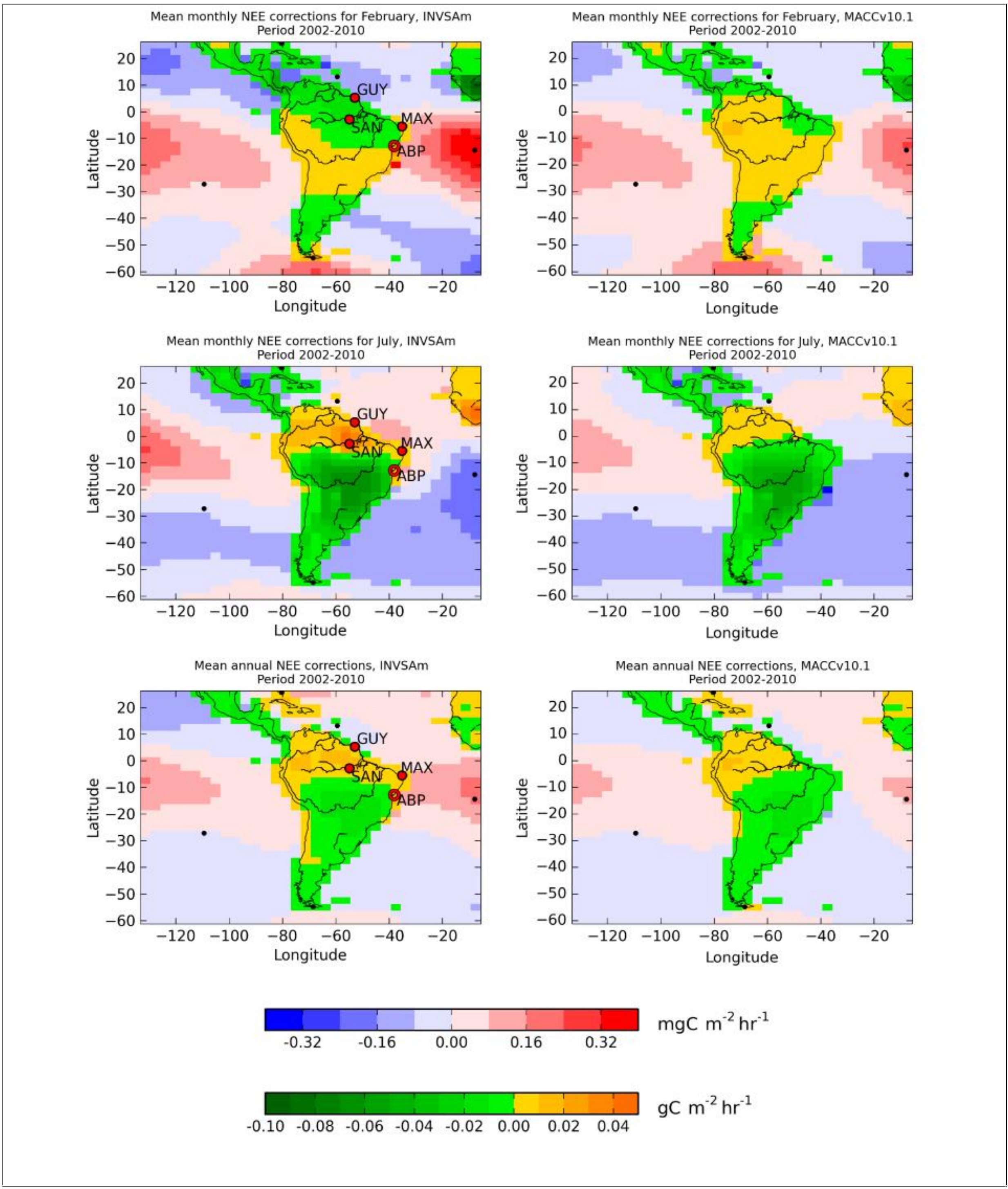
assimilation at a given site and over given years should not spread to the other years when there is no data available at this site. Therefore we do not think that we should verify it by conducting separate inversions on 2-3 year periods where one South American site only is available. Still, we now provide analysis of the results for 4-5 year periods in answer to one comment of the reviewer 1 (see the figure A.5 in the corresponding document) which demonstrates the influence of SAN and MAX in one hand, and of GUY and ABP on the other hand.

Incidentally, what about the ocean fluxes?

A) Thanks to the comments from the three reviewers, we will now provide an analysis of the increments to the ocean fluxes which brings new insights on the general patterns of the inversion over land, and in particular on the so-called dipole.However, we will still follow our objective to focus on the land fluxes and we will thus avoid a digression with a deeper analysis of corrections to the ocean fluxes.

Figure 8 will be replaced by the following figure below, which depicts corrections for both the ocean and land fluxes (with different color scales and units due to the different order of magnitude between increments over land and ocean) and over an area larger than that shown originally.

Based on this figure, the paper will explain that the increments from both the inversions have large patterns which are nearly zonal (or along the prevailing winds) and which overlap continuously the ocean and the land. The zonal positions and strength (i.e. the amplitude of the zonal gradient) of these zonal increments are modified by the inclusion in the inversion of the data from the new stations in the Tropical South America region. These effects are more visible when focusing on specific months, while the annual averages smoothens the patterns.



New Fig. 8. Spatial distribution of 2002–2010 mean flux corrections at the transport model resolution (3.75◦ × 2.50◦) to ORCHIDEE from (left) INVSAm and (right) MACCv10.1 over a larger area encompassing TSA: mean for February, July, and mean over the full period 2002–2010. Flux increments over land and ocean are represented with two distinct color scales and units: green—yellow for land, in gC m^{-2} hr^{-1}; blue—red for ocean, in mgC m^{-2} hr^{-1}. Filled circles indicate locations of sites with continuous measurements; and open circles indicate locations of sites with discrete air sampling.

Regarding the footprints that are shown for a day in February 2009. Are these representative of the season, year? Either a more comprehensive discussion of the site footprints or a climatology of wind fields would help to explain to the reader why these sites were chosen and potentially why that can add to what we know about NEE over the geographical region.

A) We will improve and clarify the discussion on this topic in the manuscript.

Theseasonal changes in the atmospheric circulation across region TSA is not critical in general. Figure S.1 below illustrates this with climatology(period 1981—2010) of wind fields from NCEP/NCAR reanalysis, averaged between the surface and a level of 600 hPa, during (a) the austral summer (February), (b) austral winter (July), and (c) annual mean. The dominant circulation patterns in the lower troposphere over TSA is that of winds entering Amazonia from the north-east, and as they reach the Andes they turn south back into the Atlantic ocean south of 20°S. We will better discuss it when commenting on figure 3. With the network configuration in TSA, coastal stations ABP and MAX receive information from background CO_2 incoming from the Atlantic Ocean. GUY and SAN, subject to the influence of vegetation,on the other hand, helpsestablish a gradient between the coast and north-eastern Amazonia; this information is used by the inversion system to constrain surface fluxes for the area between those stations.

But the analysis of the new figure 8 also reveals that the inversion relies on the long range extent of the station footprints to apply corrections at very large scale over South America. As previously explained, the inversion uses data from the South American sites and their long range gradients to other sites in the southern hemisphere to control the fluxes with large zonalpatterns of corrections (in the direction of the long range prevailing winds).

This will be better commented in the text. We will also include the figure below in the supplementary material.

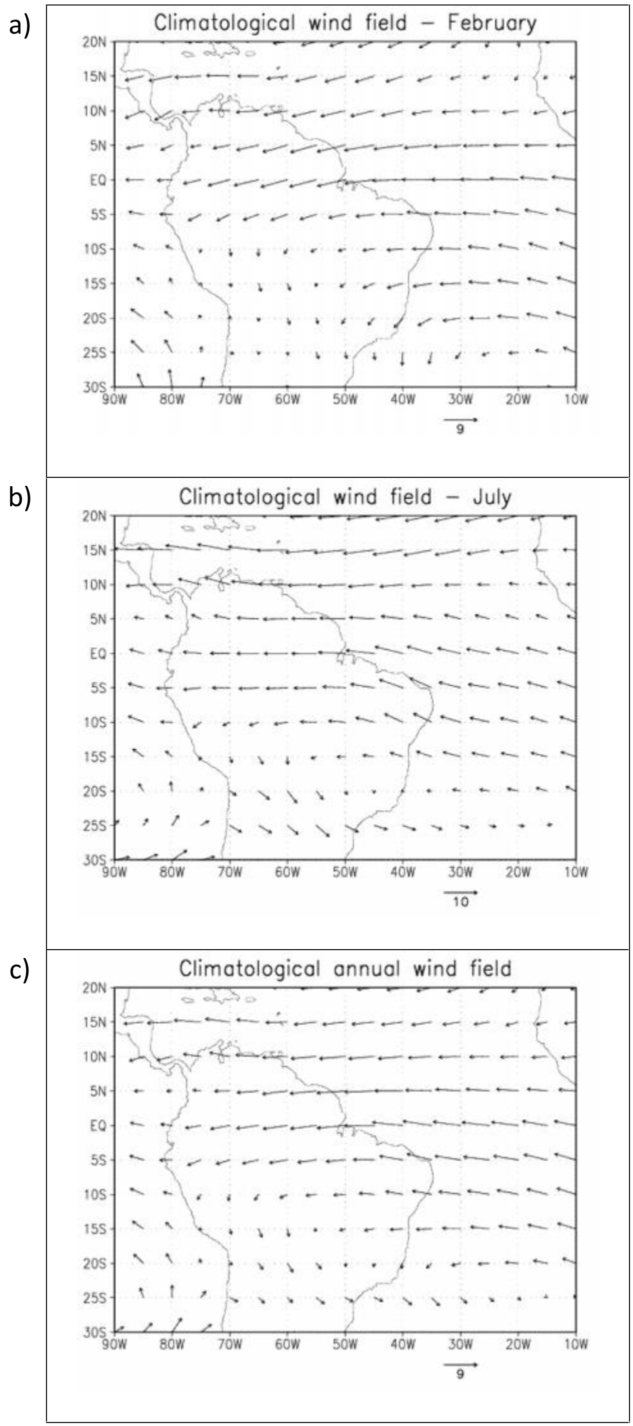


Fig.S.1. Long-term mean wind fields (1981—2010), averaged between the surface and a level of 600 hPa for (a) February, (b) July, and (c) annual mean. Data obtained from NCEP/NCAR Reanalysis.

The authors mention a comment on page 1928 line 20: "...results at ABP may reveal some local issues." What are they?

A) We will change this sentence. It was part of an analysis of a version of figures 4a and 5 where the results shown for ABP were wrong. We will update thesefigures and the analysis in the text will be modified accordingly. The true results are much more in line with what is expected from the inversion, with a decrease of the misfit to all sites when using INVSAm compared to MACC (see also the answers to reviewers 1 and 2 regarding this, and the new figures 4 and 5 in the document in answer to reviewer 1).

Perhaps my most serious concern is the absence of a discussion about uncertainties. How well did the model fit these new data? Can you give the reader a sense of the ratio of posterior and prior uncertainties associated with the NEE and ocean fluxes? What about the spatial correlated associated with the posterior NEE fluxes shown in Figure 8? For some of the estimates how does this reader know whether these new data have improved our knowledge of NEE? I expect the authors will respond by saying that the assimilation approach does not easily provide posterior uncertainties but I would argue that these results are difficult to interpret without this information.

A) We provide a detailed answer to such questions in answer to a series of similar comments from reviewer 2, which we summarize below. We will include several discussions regarding this topic in the new manuscript.

With our high space and time resolution inversion framework, the computation of the theoretical posterior uncertainties is highly expensive (it should be based on a Monte Carlo estimate with ensemble experiments that are not affordable in the framework of this study). Furthermore, due to their huge cost, such computations are generally made for typical years, while here, the reviewers ask for checking the impact of 4 specific sites and for the critical quantities analyzed in this study i.e. the mean seasonal cycle and the inter-annual variability, which would require the computation of uncertainty reduction for a large number of years.

Furthermore:

- We believe that the new figure 8 and figures 6 and 9 demonstrate the high impact on the inversion increments from the data in South America. If the inversion configuration is consistent with actual errors, large increments when using real data should demonstrate that the theoretical uncertainty reduction is high (for the inversion, statistically, corrections to the prior decrease the uncertainty). In answer to reviewer 2, we have also compared the prior and posterior misfits between hourly simulated and measured mole fractions, to the set-up of the observation errors in the inversion configuration. Such comparisons indicate a decrease of the misfits due to the inversion, and in particular when assimilating South American data, that is significant compared to the theoretical observation errors (Table A.1, below). These different results indicate that significant improvements of the fluxes in Amazonia could be, in principle, expected from the large increments from INVSAm, which are strongly driven by the South American sites. The theoretical computation of uncertainty reduction would thus quantify this qualitative indication.

Table A.1

	Standard deviation of the misfits Model - Observation			
Station	Prior	INVSAm	MACCv10.1	2 * (Standard deviation of the model error)
ABP	4.4	1.5	1.6	2.2
MAX	2.1	1.1	1.5	2.0
SAN	4.9	4.5	4.9	9.6
GUY	4.0	3.5	4.1	3.3

- The theoretical computation of uncertainty reduction and posterior uncertainties strongly relies on the configuration of the prior uncertainties and observation errors in the inversion system. However, as detailed in answer to the reviewer 2, this configuration has been derived and evaluated at very large scale using global datasets (eddy covariance flux measurements in Chevallier etal. 2012 and atmospheric mole fraction measurements in CH2010) that mainly sample the Northern hemisphere. There are reasons to think that it is not so robust at higher resolution and for a particular region, especially in the Amazon area, which is poorly sampled by these datasets. Actually, the results and discussion from this study question the inversion configuration for the Amazon region. This does not give confidence in the theoretical computation of posterior uncertainties and uncertainty reductions. Therefore, we do not really agree that, on the other way, such theoretical computation can give useful insights on the results in this study.

We hope that this clarifies why we do not perform the uncertainty analysis and we will detail it in the new manuscript.