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Interactive comment on "Global atmospheric carbon budget: results from an ensemble of atmospheric CO₂ inversions" *by* P. Peylin et al.

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Peylin Philippe,

Dear Reviewer,

We thank the reviewer for his/her positive comments and feedback on the paper. We have addressed all his/her concerns and we provide below detailed responses for each point.

As a general comment, we first need to mention that we decided to update the inversion results of five different groups for the final revision of the manuscript. We chose to do

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this for the following reasons: âĂć The initial submissions correspond to the beginning of 2011 and are thus relatively old, with several groups having significantly updated their system. For instance, JENA, NICAM, LSCEv, CarbonTracker US (CT2009), and CarbonTracker EU (CTE2008) have updated their set-up, changing the prior fluxes (i.e., the ocean fluxes for JENA), and/or changing the observation stations (i.e., NICAM), and/or correcting some optimization problems (i.e., CTracker). These changes led to changes in the estimated land and ocean surface fluxes. âĂć We need to provide the carbon cycle community a "state of the art" synthesis that compares up-to-date inversion results and that provides the current level of agreement and disagreement among the different surface fluxes. The reviewer has also mentioned this need. âĂć The changes with the new flux results for five inversions do not affect the main results of the paper and the main conclusions; they have just resulted in the removal of a few specific features resulting in an enhanced level of agreement between the different estimates, thereby providing a more coherent set of fluxes. âĂć We are aware that this paper will be part of a special issue and that the old inversion results were also used in other RECCAP papers of that issue. There is thus a need for "traceability" of the inverse results that were used in the other papers. âĂć In order to account for this (i.e., traceability), we propose to add in the revised manuscript i) a section that summarizes the differences between the new results and the old submissions used in the other RECCAP papers, and ii) a few sentences in the conclusion that reiterate these differences. We have also prepared two tar-files that gather the existing fluxes aggregated on the different regional domains discussed throughout the paper. These files will remain accessible under the "Transcom" web-site (http://transcom.lsce.ipsl.fr/).

We thus decided to update the inversion comparison with a more up to date set of inversion results for the final version of the paper. With this choice we thus claim to provide a state of the art synthesis of recent atmospheric inversions.

We have verified with the Editor that such a change was acceptable within the context of the RECCAP Biogeoscience special issue. All figures have thus slightly changed and

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the major changes in the surface carbon fluxes are: âĂć The JENA system changed with a mean ocean sink that increased by 1 PgC/yr due to a different prior flux. The corresponding land sink decreased by the same amount bringing the JENA estimates closer to the other inversions. The inter-annual flux variations, the seasonality and the long-term trends remain similar. âĂć The NICAM inversion changes lead to smaller land uptake in North America compensated by a larger land uptake in the tropics. Similar interannual flux variations (IAV) are found with slightly smaller amplitude in the Tropics and the North, especially in North America and North Asia. The new results are more coherent with the other inversions for North America. âĂć The LSCE variational system (LSCEv) became the MACC-II product. It is the reference simulation for MACC-II European project. Compared to LSCEv, the prior fluxes and errors in MACC-II have slightly changed. The new estimated fluxes have a larger ocean uptake (mainly in the south) and a smaller tropical land uptake and show few small changes in the IAV. The flux long-term trends also slightly changed with increased tropical land carbon uptake in the 2000s in MACC-II. âĂć The CarbonTracker US system went through several changes in the inversion set-up, especially with a correction of the atmospheric transport model (TM5) and the realisation of several sensitivity tests (the reported fluxes correspond to the mean of four different prior land/fossil fluxes). The new product "CT2011_oi" thus replaces the previous product "CT2009" with similar long-term mean fluxes (only a slight increase of the northern land uptake) and with slightly larger amplitude of the flux IAV. âĂć The CarbonTracker EU system also went through substantial changes (version "CTE2013" versus "CTE2009") with a two-way nested transport from the 3x2 degrees grid to highest 1x1 degree resolution over Europe as well as over North America and changes in the observation stations. The covered period is extended to 2010 in the new release (CTE2013) with similar long-term mean fluxes and a slightly larger amplitude of the flux IAV.

In order to keep track of the inversion results submitted initially and used in the other RECCAP papers, we added a section at the end of the Supplementary Material that: i) summarises the changes for the five inversions and ii) displays the key figures of the

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paper with the old flux results.

Specific comments:

» Page 5308, lines 6-7: I would rephrase this sentence to something like: "... descent algorithm using the gradient of J at each iteration. Such computation usually employs the adjoint technique..."

We have changed according to the suggestions.

»Page 5308, line 10: "Hessian" should be written with a capital H. Done

» Page 5309, line 2: please write "years" full, when used in a normal sentence. Done

» Page 5309, line 4: I would suggest to replace "rest upon" by "are based on" Done

» Page 5312, lines 1-4; This is true, but it should be reflected in the posterior error estimates. Observations are just one piece of information going into the problem. I think the real issue is to inform/educate users of the results how to properly interpret the values and their errors.

The reviewer is right and there are indeed several pieces of information that are combined through an inversion system. We have thus changed slightly the text including a new sentence that points the reader to the need to consider both the estimated fluxes and their uncertainties, with a reference to table 2. We added: "…. where there are few observing sites and it is directly reflected in the estimated flux uncertainties (see table 2)."

» Page 5319: My main comment on the whole paper is that I miss some information about the prior errors. This is a very important part of the inversion problem and it is needed to properly interpret the results. I would really like to encourage the authors to provide a map with some indication of the prior errors that have been used. I know different inversion systems use different prior errors, so it will be difficult to come up with one map, but if the authors can think of a way to do this, that would be very helpful.

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it would indicate where the prior constraint is strong and where the observations can influence the results significantly.

We agree with the reviewer that the prior flux errors are crucial to interpret the estimated fluxes. We could not come up with a map to summarize the different choices made by each group. We thus expanded table 2 in order to include the annual mean flux prior Bayesian error for the 22 Transcom regions and 9 larger aggregates. Table 2 now comprises for all inversions prior and posterior errors. Note that some groups were not able to provide the posterior Bayesian errors for some aggregates. Except for RIGC, all groups use a prior total land annual flux error that is at least three times larger than the prior total ocean annual flux error. Such choice partly influences the land versus ocean flux partition both for the long-term mean and the IAVs. Indeed most inversions remain relatively close to their prior ocean flux and with a relatively small IAV. Note conversely that RIGC, with similar global land and global ocean prior errors, provides the largest ocean flux IAV. We have thus slightly changed the text to refer to the prior error in Table 2.

»Page 5322, lines 7-9: What was done differently in the new JENA inversion? Does this provide a clue about the noted difference of JENA with the rest?

As explained in the introduction, we have revised the inversion submissions with updated results for a few systems, including the JENA system. The new JENA inversion (version 3.5) uses a different ocean flux prior with a larger long-term mean carbon uptake (but similar interannual variations) than in the old version 3.3, used initially. After optimization, the increased ocean uptake remains in the posterior fluxes, which leads to a land versus ocean flux partition that is more in line with the other estimates. The previous note on the JENA exception has thus been changed to a note stating i) that the old JENA release used in the other RECCAP papers provides a much smaller long-term mean ocean carbon uptake, and ii) that such feature is tightly linked to the prior ocean flux that is used.

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» Page 5327, lines 1-4: There is also a corresponding strong ocean sink in the NICAM results. Is this related?

We understand that the reviewer wanted to mention: “a corresponding strong ocean sink in the RIGC results” and not “in the NICAM results”. Indeed, we clearly see in figure 6 a strong ocean sink above 1 PgC/yr in the southern ocean in 1997. Such anomalous sink counterbalances the large tropical land source anomaly to meet the observed growth rate during that period. Whether such dipole is an artifact of the inversion not being able to partition the land versus ocean fluxes is difficult to assess and would require specific analyses that are beyond the scope of the paper. Nevertheless, we have completed the text to highlight this feature: “Note that such negative anomaly in 1997 is above 1 PgCy-1 in RIGC, compensating for the large positive tropical land anomaly.”

» Page 5329, lines 9-15: Did you test this trend for its significance level? It seems rather small, so it would be good to test it against the errors.

Given the revision of the inversion submissions (presented above with updated results for JENA, LSCEv, NICAM, CarbonTracker US and CarbonTracker EU), the results for the long term trend at continental scale have slightly changed: i) for the North American trend, LSCEv and NICAM results now present a trend that is similar to the other inversions with a slight increase in the land carbon uptake during the early 2000s; ii) for the North Asia trend we obtain the same tendency towards increasing land uptake during the years 2000s up to 2008 and a decrease of the carbon uptake afterward (2009 and 2010).

For North Asia, we agree with the reviewer that the trend noticed initially was rather small and that several sources of errors could potentially affect the result. First, the trend in fossil fuel emissions in China over the 2000s is still debated (Guan et al., “The gigatonne gap in China’s carbon dioxide inventories Âż, Nature climate change, 2012). Second, the emission may not be properly accounted for in the transport models

because all emissions are emitted at the surface, while a significant share corresponds to air traffic and should be emitted above the planetary boundary layer. Third, given the relatively low density of atmospheric measurement in North Asia, the inferred surface fluxes remain sensitive to the representation of each site in the transport model (i.e. data selection). These different sources of error may evolve through time and impact the inferred long-term trend. Ideally, we would need to test the observed trend in North Asia from 2000 to 2008 against the Bayesian uncertainties estimated by the inversion systems. However, in practice, a rigorous calculation of the uncertainty associated with the long-term trend for a given region requires the full posterior error covariance matrix (especially the temporal covariance). None of the systems were able to properly calculate this long-term trend error and we thus only compare the magnitude of the trend to the annual mean flux errors reported in Table 2 for North temperate Asia and boreal Asia. Although the Bayesian error significantly varies between the inversions, a typical value for North Asia would be around 0.4 PgC/yr, which is thus still relatively large compared to the observed flux trend of around 0.1 PgC/yr. We have thus revised the text to account for i) the new inverse results with a decrease of the carbon uptake in 2009 and 2010 and ii) the need for further investigations to properly assess the significance of the observed continental long-term trends (North Asia and Europe).

Interactive comment on Biogeosciences Discuss., 10, 5301, 2013.