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Interactive comment on "Atmospheric inversion of the surface carbon flux with consideration of the spatial distributions of US crop production and consumption" *by* J. M. Chen et al.

Anonymous Referee #3

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The paper entitled "atmospheric inversion of the surface carbon flux with consideration of the spatial distributions of US crop production and consumption" presents inverse flux estimates from 2000 to 2007 using a global atmospheric inversion system assimilating the GLOBALVIEW-CO2 data. Agricultural statistics were used to modify the spatial distribution of the prior fluxes from the BEPS vegetation model including the crop production and consumption spatial patterns. Results show that the posterior fluxes were re-adjusted with the displacement of a large sink in the South East of the US in the original inversion to a large sink in the US Midwest.

Overall, the introduction of agricultural data from inventories into prior fluxes is an interesting and potentially helpful constraint in the inverse system. Several papers have

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already considered this problem and followed a somehow different approach, by including the statistics into the vegetation models, which then could be used to generate prior fluxes for the inversion (e.g. Lokupitiya et al., 2009 for crops; Williams et al., 2012 for forest). The approach presented here is a simplified modification of the original prior fluxes, forced to fit the spatial distribution from the inventory data, without considering the underlying processes or modifying the original vegetation characteristics. However, in an ill-conditioned inversion system (210 stations over the globe) primarily driven by the prior spatial distribution, the impact on the posterior fluxes is more than expected, if not absolutely certain: the posterior spatial distribution will resemble the spatial distribution of the agricultural data.

Several major concerns listed hereafter were not addressed in this paper. In addition, the methodology used for the introduction of the statistical data was not evaluated nor discussed. The main conclusion, i.e. "sink increase in production areas and sink decrease in crop consumption areas", is nothing more than the direct consequence of the changes in the prior flux spatial distribution. Whether or not these changes are correct and not entirely driven by the prior is another question that has not been addressed here. The attempt to compare the results to other studies is rather limited and overall incomplete. The following concerns should be carefully addressed before this study can even be considered for publication.

1. Sensitivity tests: the authors need to perform additional experiments to evaluate the sensitivity of the system to the modifications in the prior, evaluate the observational constraint and see if the signals are atmospheric or prior-based, and finally evaluate their results with other inverse flux estimates, or other inventories available over the US. Several inverse estimates are available for the same time period. Here, the results were compared to two other studies, with one being performed on a smaller domain. Also, many questions related to the real impact of the adjustment remain. If the prior flux resolution is increased, can the system retrieve the US Midwest sink as in CarbonTracker? If not, is the lack of data or the presence of errors in the transport the main

problem? Several recent papers have shown the large uncertainties among inverse estimates (e.g. Peylin et al., 2013). Therefore, it is unlikely that one inverse system, which does not present any improvements in the transport or in the amount of data, can provide reliable results. The production/consumption adjustment cannot solve the other issues such as transport biases and the lack of atmospheric data. Additional tests need to be performed in order to quantify the total uncertainties. Finally, the prior are not indicated in any tables, but only on maps (with a poor color scale which makes the figure hard to read). The ecoregion total prior fluxes should be presented to evaluate the influence of the prior on the posterior. As presented here, the inverse results are compared to inverse results, which makes it impossible to evaluate the sensitivity to the prior fluxes.

2. Evaluation of the inversion results: The evaluation of the US Midwest flux is incomplete, and represents a very small limited evaluation for a global inversion. In addition, some shortcomings need to be explained. When saying that the posterior averaged flux is 220gC/m2/year over the US midwest, doubled compared to the prior, and compare well to 150gC/m2/year in other studies, it also means that the prior of about 110gC/m2/year was even in better agreement. In this case, the inversion degraded the prior fluxes. In addition, the comparison to CarbonTracker results for 2001-2005 over the Midwest is also interesting because CarbonTracker system does not include a “crop correction”. Can your system detect the crop “signals” if you use a smaller ecoregion similar to CarbonTraker? Is the introduction of agricultural statistics needed or would a better definition of the ecoregions suffice? One can also wonder if there were enough data and if the resolution of the model was high enough over the US to adjust the fluxes. In this case, using a decent prior and a limited atmospheric correction will guarantee the posterior fluxes to be reasonable, i.e. not far from the prior flux estimate.

3. Introduction of the agricultural statistics in the system: the method used to modify the prior is inaccurate. The adjustment is based on the surface area covered by crops. Whereas crops represent a limited fraction of the US Midwest (less than half, at best,

depending on how the US Midwest was defined), their contribution to the annual sink represents most of the US Midwest regional sink. Except the Corn Belt, the area is rather dry and covered with grassland, which have a very limited contribution to the carbon sink. Using the crop surface as a proxy is incorrect and highly underestimates the net flux. The NEE needs to be adjusted based on the regional sink rather than the crop surface over the region. Once again, the method presented here to introduce the crop production and consumption into the prior shows satisfactory results but it remains totally unclear if this is thanks to the lack of atmospheric data, or the poor resolution of the system to assess a regional flux, or the prior flux errors being too generous, or the fact that the prior fluxes are already reasonable by construction, or a combination of all. For sure, assuming that the NEE can be scaled with the crop surface is unrealistic and inappropriate for highly productive ecosystems such as corn, a plant able to store a large amount of carbon over a very limited area.

Technical comments:

L18-21 on page 6073: The authors claim that Midwest croplands should not be a regional sink. Because of agricultural export out of the Midwest region, corn is a net loss and is indeed creating an apparent regional sink. Accumulation of carbon is not the only way to generate a net sink. It seems that the authors contradict themselves later on, at lines 12-13 on page 6081. This may be a poor construction of the sentence leading to a false statement in the introduction.

L7-P6073: you cannot use a flux per surface unit (110-140gC/m2/year) to illustrate a large regional sink. What is the size of the area corresponding to this flux?

L24-28–P6073: The discrepancy is not only due to the lack of lateral transport. Vegetation models simply do not simulate crops correctly, and are usually parameterized as a forest or a natural ecosystem.

L9-P6073 to L2-P6074: The top-down approach does not need to add the lateral exchanges of carbon, as they are present in the atmospheric observations. Using better prior fluxes can help, but they are already present in the data. Only bottom-up estimates do not include them.

L22-P6076: The resolution of 1x1 degree is different than TM5 resolution (L1-P6077: 3x2). Which one is correct?

L11-P6080: R is diagonal whereas the system is using data at multiple levels for several sites. For daytime data, this assumption is unphysical. Using weights is not sufficient as this method allows for independent corrections whereas model errors are highly correlated in the vertical within the Planetary Boundary Layer) (Gerbig et al., 2003; Lauvaux et al., 2009).

L4-P6082: The fact that the crop consumption does not balance the crop production is not considered later on. What is the impact of a difference of 0.3% to 6% on the US carbon balance? Consumption and production are large numbers and the errors may be even larger compared to the net annual flux over the continent.

L4-P6082: What happens to the export? Are they included somewhere else on the globe? This study only considers the US crop statistics and it seems that the US export is not added to another region (wherever the crops are exported).

L7-P6088: Comparing the impact of the adjustment to the control inversion is not sufficient. The prior fluxes should also be added, to see if the innovation is simply in agreement with the prior or if the signals are based on atmospheric data. If the changes are mainly due to the prior, one can wonder what role has the inversion in constraining regional signals across the continent. A second SNR could also be added, replacing the term "mu_control" by the prior, which will show if the innovation is significant compared to the information contained in the prior flxues.

L14-P6088: . . . with an asterisk (*).

Figure 4: The color scale is not adapted for the prior. The inherited structures from the prior are hidden by the lack of contrast. Use a different color scale to highlight the

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spatial patterns in the prior.

L22-P6091: Canada remains local for the US, as most towers do measure signals from the northern part of North America. This comment should be supported by the results presented in Table 5.

L26-P6091: If the adjustments were included assuming a balance annually, why would the annual balance be affected? This comment is confusing.

L16-18-P6092: The atmospheric inversion is designed to correct for biases in the prior fluxes. This comment is confusing, Please re-phrase.

4.2: What are the conclusions from this analysis? It remains unclear what is the impact of the adjustment at the global scale. If the same experiment was made using European or Chinese agricultural data, should we expect the same, i.e. a larger sink in Europe/China and no other impact elsewhere?

L14-15-P6096: The discrepancy over the South East is similar to the US Midwest, with a lot of export for wood production. Have you included the forest statistics in the prior?

L3-9-P6097: The paragraph starts with "there is also a significant portion of the crop being exported", and ends with a difference of 0.03PgC/year, which is not a significant difference. Reconcile the statement with the estimate.

Conclusions: 1. If your changes are significant, then the inversion will produce significant changes. Because the prior fluxes were modified significantly, the posterior fluxes show significant changes directly related to the changes in the prior. To illustrate the point, the prior errors should be compared to the changes in the prior. If the changes are larger, the impact will be large in the posterior fluxes. 2. The neutralization does not happen at the same place. There is no reason to neutralize the regional sinks by neutralizing the fluxes at the continental scale. Re-phrase your conclusion.

Figure 1: Add a zoomed map showing the region codes for North America. The regions are hard to read if not zoomed in. Table 3: add the prior flux results.

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