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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Constraining terrestrial ecosystem CO2 fluxes by integrating models of biogeochemistry and atmospheric transport and data of surface carbon fluxes and atmospheric CO2 concentrations" *by* Q. Zhu et al.

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1. Why was AIRS chosen, rather than a NIR sensor (GOSAT, SCIAMACHY) with greater sensitivity to the lower troposphere?

Response: We chose AIRS CO2 data over GOSAT or SCIAMACHY due to the consideration of (1) spatial coverage and (2) data accuracy. SCIAMACHY CO2 products have the smallest spatial coverage, roughly 8-20% of the global surface. The measurements over ocean are filtered out due to low surface reflectance. GOSAT CO2

products roughly have 32-44% spatial coverage, because that the areas with aerosol optical depth less than 0.5 are eliminated. In comparison with these two products, AIRS CO2 products have much higher spatial coverage (about 95%). We used satellite CO2 retrievals aiming to compensate the low spatial coverage of GLOBALVIEW-CO2 network. Therefore, AIRS CO2 is the most appropriate product for our purpose. Validated against a global network of ground-based high-resolution CO2 measurements (TCCON network), SCIAMACHY data are systematically lower; GOSAT CO2 retrievals have large random errors due to instrumental noise; the mean difference between AIRS and TCCON is small. Collectively, compared with surface CO2 measurements, the relative accuracy of GOSAT, SCIAMACHY and AIRS CO2 are 0.38%, 0.87%, and 0.25%, respectively (Miao et al., 2013).

2. What measurement and model/representativity uncertainties were assumed for the GLOBALVIEW and AIRS measurements used to constrain the fluxes?

Response: GLOBALVIEW-CO2 observation errors are from data product (GLOBALVIEW-CO2 2013). The errors are roughly 0.5 ppm including the instrumental error and errors from the GLOBALVIEW data fitting procedure. The representation error (inability of transport model to represent the observed site location) is not considered. A previous study implied that the representation error is about 0.3 ppm (Baker et al., 2006). AIRS CO2 errors are from AIRS CO2 level-2 dataset version 5 (Susskind et al., 2011). A two (two adjacent FOVs) by two (two adjacent scan lines) array of AIRS CO2 retrieval is used to determine the final retrieval of CO2 concentration. The error represents the spatial coherence over the 2 by 2 array. We only used the level 2 "standard product", in which the errors are less than 2 ppm. The CO2 retrievals with errors larger than 2 ppm are placed in level 2 "support product", which was not used. However, the representation error is not considered in the AIRS CO2 level 2 products.

3. Are the prior and posterior fluxes only at monthly time scales? If so, why, and what effect might this have on the evaluation in concentration space? What time step was

the model running at?

Response: The model used to estimate the prior surface CO2 fluxes has a monthly time step. And our prior and posterior fluxes are also at monthly time scale. The low temporal resolution of surface CO2 flux is one of the potential limitations of our study. It limited our ability to capture the fine-scale (e.g. daily, diurnal) variation of CO2 concentration. Therefore, we were only able to compare and validate our posterior CO2 concentrations against monthly averaged CO2 concentration data (both GLOBALVIEW-CO2 and CONTRAIL).

4. Why only 2003? This makes it difficult to compare to other flux estimates, in many cases, as the inter-annual variability can be quite substantial. Also, was there a spin-up or spin-down time with the atmospheric inversion? Or is this not an issue with the specific 4D-Var method used here? I would strongly recommend expanding the analysis to a longer time period, even just a few years, in order to provide a better basis for analysis and comparison.

Response: We limited our study period in 2003 mainly because we aimed to illustrate the methodology and effectiveness of combining transport inversion and ecosystem model parameter inversion in estimating global NEP. The research question is whether or not an improved NEP prior (based on TEM model data assimilation) would benefit the estimate of posterior NEP. And whether or not the sequential data assimilation approach is a good way to carry out CO2 inversion study? Therefore, it doesn't really matter which year we are conducting for our inversion and analysis. We agree with the reviewer's concern that limiting our study period in 2003 made us difficult to compare our inversion results with others. In this revision, we have applied the CO2 inversion to a longer period to analyze the long-term trend and inter-annual variability of global NEP. However we decide not to show the results in this study, because it conflicts to our future publication plan regarding to the long-term trend and interannual variability of global NEP. Therefore, we only provided some results of our posterior NEP for 2004 and 2005 in this response letter, but not in the manuscript. Figure 1 shows the posterior

NEP over eleven TRANSCOM 3 land regions for 2004 and 2005. The annual total terrestrial ecosystem carbon sinks are -2.6 Pg C yr-1 and -2.7 Pg C yr-1. In both 2004 and 2005, North American temperate is the largest carbon sink followed. North American Boreal, Europe, Eurasian Boreal, and South American Tropical regions are secondary largest carbon sinks. It is interesting to see that the South American tropical region is a much stronger carbon sink in 2005 compared with that in 2003 and 2004. It coincides with the Amazonia green-up during 2005 (Saleska et al., 2007). It implied that the atmospheric CO2 concentration signals were able to reflect the enhanced land carbon sink for this region.

5. The approach holds a great deal of promise, but this attempt is rather heavily weighted towards the bottom-up side of things. The analysis does little to inform me of the added value of using the surface stations and satellite measurements. Perhaps it would be worthwhile to compare inversions using only the surface network with those using AIRS as well, to see what value the mid-tropospheric information brings to surface processes.

Response: In this revision, we conducted an additional CO2 inversion using only GLOBALVIEW-CO2 dataset. Comparing the differences of NEP among (1) prior; (2) posterior NEP using only GLOBALVIEW-CO2; and (3) posterior NEP using both GLOBALVIEW-CO2 and ARIS CO2, we are able to show the added values of assimilating GLOBALVIEW-CO2 and AIRS CO2 datasets (Figure 2). We find that regional NEP is more effectively constrained over North America and Europe, where in situ measurements are abundant. GLOBALVIEW-CO2 data generally provide more added values to posterior NEP, compared with AIRS CO2 data. AIRS CO2 data are most beneficial for European regional NEP, they provide almost equal added value to prior NEP, compared with GLOBALVIEW-CO2 data. We added a paragraph and Figure 2 to the manuscript in this revision.

7. Here you're adding the land-use change flux to surface fluxes constrained by atmospheric measurements to argue that there's good agreement. But in both cases

(Peylin et al., 2013 and the current study) the atmospheric measurements have "seen" the land-use change signal, and this should be reflected (however erroneously) in the optimized fluxes, provided the prior uncertainty isn't too tight. Or am I missing something?

Response: We agree that the observed atmospheric CO_2 signals contain information about all the land surface CO_2 activities including the land-use induce CO_2 emissions. The definitions of natural land CO_2 flux are different in our study and Peylin 2013. Our inversed natural land fluxes only contain Net Ecosystem Production (NEP). The land-use induced CO_2 emission was considered as a part of fire emission, which had been subtracted before we inversed the NEP. Peylin et al. (2013)'s study defined that the natural land fluxes are the summation of NEP and land-use related fluxes (usually fires emission). Therefore, we need to add the land-use induced CO_2 emission back into our posterior NEP, in order to be comparable with the posterior natural land fluxes reported by Peylin et al. (2013).

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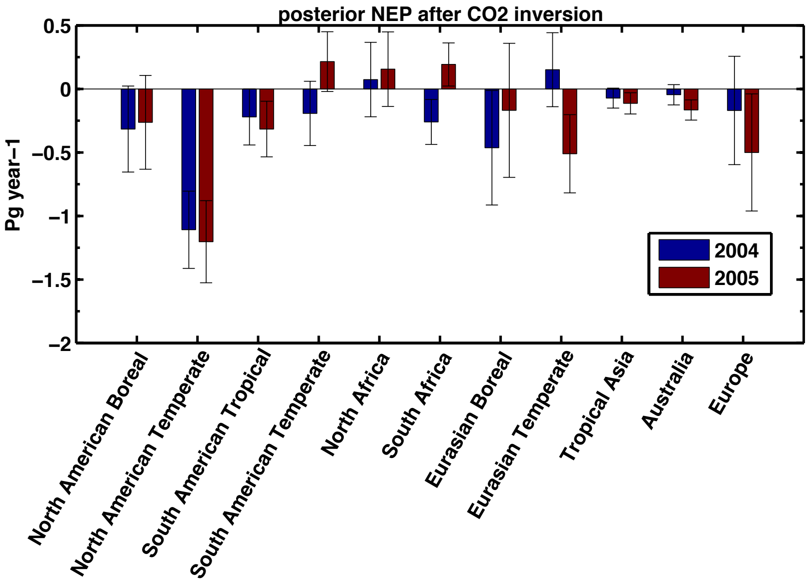

Fig. 1. 2004 and 2005 posterior NEP after CO2 inversions over 11 TRANSCOM3 defined land regions.

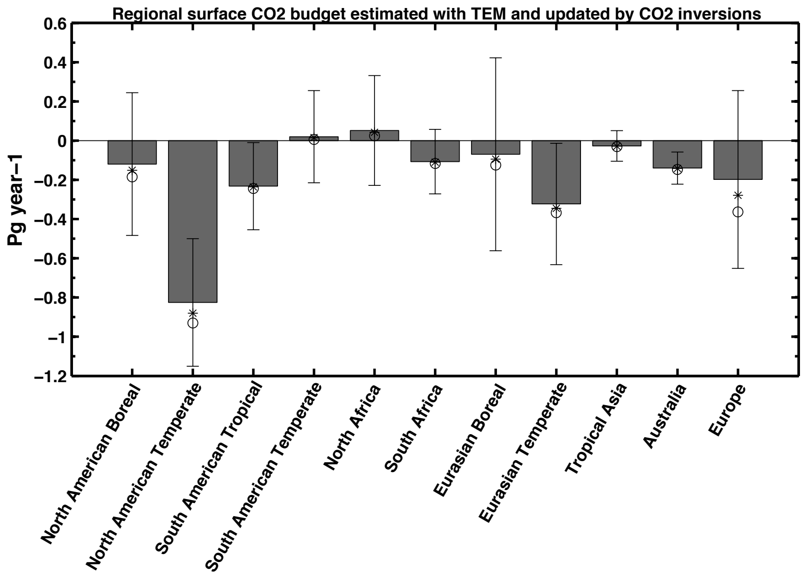

Fig. 2. Bars are prior. Stars (*), circles (o) represent the posterior mean of NEP updated by CO2 inversion after assimilating only GLOBALVIEW-CO2 dataset and GLOBALVIEW-CO2 + AIRS CO2 datasets, respectively.