**Atmospheric
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Discussions**

Interactive comment on "Evaluating a 3-D transport model of atmospheric CO_2 using ground-based, aircraft, and space-borne data" *by* L. Feng et al.

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Evaluating a 3-D transport model of atmospheric CO_2 using ground-based, aircraft, and space-borne data

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We thank the referees for their constructive comments on our paper. We have addressed all the comments received in the revised manuscript, and believe the modifications will enhance our discussion of the work shown.

This paper is mainly focused on evaluating the GEOS-Chem CO_2 transport modeling by comparing model atmospheric CO_2 concentrations with observations at different altitudes. One obstacle of such a comparison is the lack of accurate information on surface CO_2 fluxes, in particular, the information on land biosphere CO_2 fluxes. As pointed out by the referees, current prior flux climatologies underestimate land sinks, resulting in an unrealistic annual increase of model atmospheric CO_2 concentrations. To ensure a meaningful comparison with observations, we have introduced corrections to the prior surface fluxes from 22 TransCom regions by fitting the model CO_2 concentrations to the ground-based observations at 66 GLOBALVIEW sites below 3 km, using an Ensemble Kalman filter.

One major concern from the referees' comments is about the accuracy of the fluxes estimated by our EnKF approach, which is similar to the common batch inversions used in

the TransCom 3 experiments but with a lag window of 8-months, (c.f. 3 years for batch inversions). We agree that changes in flux inversion configurations such as the flux spatial resolution, the selection of observations, and the assumptions on a priori fluxes can affect the a posteriori estimates. For example, a much longer time span in principle could result in more observation constraints on regional flux estimates. However, the nature of top-down approaches requires that the a posteriori should be inspected together with the associated uncertainty. When accompanied by the diluted signals of the monthly region fluxes, model errors associated with long-distance transport will limit the benefits from much longer time span in terms of both the uncertainty reduction, and bias corrections (considering that unevenly distributed constraints from the current observation network would not be dramatically improved from measurements on outflows far from their origins). Our results on the global annual net fluxes are in agreement with other long-term experiments, including Carbon-Tracker 2009, LSCE v1.0, and JENA S99 v3.2, usually well within the posterior uncertainties.

Uncertainties of the flux estimates, sparse existing observations, and the representation errors of the coarse spatial and temporal model resolution compromise our ability to evaluate model transport. This paper instead examines the main temporal and spatial structures of the model atmospheric CO_2 concentrations simulated by the GEOS-Chem transport model with two (GEOS-5 and GEOS-4) meteorological fields.

The following details our replies to the referee's comments (denoted by italics).

Review report 2

1 General comments

1.1 Paragraph 2, Page C8163

My major concern is about nature of the performed inverse modeling. The transport model with 22 geographical regions is rather crude, with a big numerical diffusion

The transport model itself has a horizontal resolution of $2° \times 2.5°$, with 30 (GEOS-4) or 47 (GEOS-5) vertical levels. However the corrections to the a priori fluxes are estimated over 22 geographical regions. We agree with the referee that there would be so-called aggregation errors for inversions at coarse spatial resolution, which implicitly imposes 'hard' constraints on the flux patterns. However, under the current observation network, inversions at higher spatial resolutions would still retain a lot of prior information (the so-called soft constraints), and the overall uncertainties for the regional fluxes will not be dramatically reduced.

The main aim of the paper is to evaluate the model transport. As mention above, our inversion is mainly employed to remove the exaggerated increment of CO_2 concentrations from a priori surface fluxes, by fitting model values with selected observations (majorly) at the boundary layers. Further comparison of the resulting a posteriori CO_2 concentrations with independent observations helps to evaluate performance of model transport at many important respects, such as the annual trends and seasonal cycles in the free and upper troposphere.

1.2 Paragraph 2, Page C8163

In a situation where a given transport and unknown sources, one can indeed inverse model the fluxes to match observation to any degree of precision. I am therefore not surprised by the good fit to the observations obtained in the paper. But how reliable

are these results, This is not clear.

In the inversion, we have adjusted monthly fluxes from 22 regions to fit weekly observations over 66 sites. The resulting a posteriori contains information from both the a priori and the observations. To some extent, we agree that like other optimal estimation procedures, the a posteriori fluxes are obtained under certain assumptions, and have some inherent uncertainties. Direct measurements of fluxes at large scale are difficult so that evaluation of the estimated surface fluxes is a challenge. But the assimilation of the ground-based observations result in much less net global emission than the a-priori estimates, which were confirmed by the observed annual increments of atmospheric CO_2 concentrations. Also, improved agreement of the model CO_2 simulations for the a posteriori fluxes with independent observations in the free and upper troposphere suggests the inherent coherence.

1.3 Paragraph 3, Page C8163

I suspect the obtained solution can be very sensitive to both the uncertainties in transport and imperfections

Impacts of errors in model transport on flux estimates are being investigated in recent studies. As found by Chevallier et al (GRL, 2010), such transport errors will usually downgrade the performance of the inversion system, but the a posteriori fluxes still represent an overall improved agreement with the (assumed) true values. As mentioned before, imperfections in the flux estimates prevent us examining model transport in great detail by comparison with independent observations, together with other problems such as the representation errors for sampling model at time and locations of observations. Here, we focus on the major features of the model simulations.

2 Minor issue

It seems that in the reference to Li et al.

The title for the reference is corrected following referee's suggestion.