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 prin-

ciple 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 reduc-

tion, 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 representa-
en errors of the coarse spatial and temporal model resolution compromise our ability
to evaluate model transport. This paper instead examines the main temporal and spa-
tial 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

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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 $2^\circ \times 2.5^\circ$, 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$_2$ concentra-
tions 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.