**Atmospheric
Chemistry
and Physics
Discussions**

Interactive comment on "Constraining the CO$_2$ budget of the corn belt: exploring uncertainties from the assumptions in a mesoscale inverse system" *by* T. Lauvaux et al.

T. Lauvaux et al.

tul5@meteo.psu.edu

Received and published: 8 November 2011

We thanks the reviewers for his/her comments. Our answers are listed below.

Major comments:

12 months of observations:

We agree with the reviewer that annual fluxes and interannual variability are of major importance in terrestrial ecosystems and the natural components of the carbon cycle. We present here the first available observations for the year 2007. A manuscript is in preparation for the years 2007 and 2008, comparing multiple inversions at different

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

scales and using different transport models and inversion systems (Schuh et al., in prep). We have focused here on 2007 for several reasons, and think that the results and conclusions will remain valid at the annual time scale.

Here, we present results over 4 months of winter and 3 months of growing season, September having a very low net uptake. Even if potential biases in winter are larger over longer periods, they would be present in our 7 month inversion. Our estimates here can be easily extrapolated to 12 months. Wintertime fluxes have a low net contribution at the weekly time scale compared to the growing season. Accumulated over 9 months, they represent half of the accumulated uptake during the three months of the growing season.

We compared our present results to agricultural inventory data. The inventory data are available for the year 2007 only (January to December). A paper has been submitted (comparison between inverse fluxes and inventories) using our prior fluxes for the first 5 months of the year 2007, and our posterior fluxes for the rest of the year. The present work has been limited to 2007 to make this comparison possible, without considering fluxes of 2008.

We are now working on the 3 years of available data but the computational time, the discontinuities in the concentration dataset, the absence of agricultural inventories for the two following years, the delay in the availability of eddy-flux tower data, are some of the issues when considering several recent years of our inversion flux product.

Prior flux errors and correlations:

In the present study, we defined several assumptions which are based on past literature, and we ensured that the balance of the system between observations and unknowns was consistent. We agree that the objectivity in the assumptions is harder to obtain. Now, this objectivity is limited by several factors and we think that additional information is missing in order to build objective prior errors and their related structures. For example, the use of eddy-flux data to estimate prior flux errors is informative

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

in time, but limited in space. Ecosystems such as grassland are highly variable, and only two towers are available in our domain in 2007. Variograms in this case will suffer from large representation errors. Instead of arguing about the veracity of our assumptions, we decided to use several assumptions which are all reasonable and potentially justified. For example, the correlation length used here varies from 100km (which is in fact 300km length scale limited by the ecosystem distribution) to 300km. In the recent literature, this length varies from 100 to 1000km at similar time scales. At similar time scales, several studies have provided very different spatial length scales as optimal solutions. We agree that the structure of the prior errors remains critical but even if we don't provide a quantitative answer to this problem, we quantify the range of plausible prior errors and structures that can be used and potentially justified using different criteria. We are now testing our assumptions with duality tests and cross-validation in a forthcoming study. Our results indicate that larger correlation lengths seem to improve the results (up to 300km length scales), but the introduction of biome dependent terms has a limited impact on the inverse fluxes. These results will be submitted soon for publication. In this article, we considered that the spatial structures in the prior flux errors and the variances will be treated with their uncertainties (in the sensitivity tests) due to the lack of a reliable estimate.

Boundary condition and flux biases:

We clarified this part of the paper. We proceed in two steps, independently, to distinguish boundary conditions from surface fluxes. First, we use aircraft data at the boundaries to remove major biases. Then we use these debiased boundary conditions as unknowns in the inversion, without trying to optimize the inflow. We simply affect some signals to the boundaries assuming that major biases have been removed previously. In other words, our present inversion system is considering the boundary conditions as an additional source of uncertainty, but cannot offer quantitative estimates of the inflow.

The temporal scales of the changes and the biases in fluxes and boundaries can be close, or even identical during weather related events as you noticed. We took two

assumptions here to estimate the uncertainty related to the choice of the frequency, because we actually don't know precisely how to define it best. Even in continuous observations, the contribution of the boundaries is mixed with the contribution of the local fluxes. Several studies aimed at separating these contributions, during synoptic events or front passages. But the combination of large scale signals, weather events, and local flux variability requires additional data to separate and quantify their magnitudes (vertical gradients, tropospheric contribution, continuous time series at the boundaries of the domain). We used here 4 aircraft profiles, which is limited, but still the densest network of vertical profiles of GHG concentrations in a regional experiment. We assumed here short term or synoptic scale variabilities, and found out that either case ends up with similar corrections over the period. From this study, it seems that the annual total inflow and the seasonal cycle of the inflow matters, but the attribution of shorter time scale events has a limited impact on the inverse 7 month fluxes. They do affect though the weekly flux estimates, and could potentially lead to weekly errors. Several products are currently tested as the Globalview product, but other sources of errors affect the results. Spaceborne instruments are the most promising observing systems to constrain the inflow in future regional inversions unless systematic errors remain.

The other major comments are discussed ore specifically in the detailed comments.

Detailed comments

Abstract: subjective comment, to be discussed

Introduction: look at the 4th paragraph?

p4, 1st paragraph: We consider here the importance of the seasonal cycle and the description of specific ecosystems such as corn. For this study, corn is really critical. Both its phenology and its large uptake in a very short period of time drive the spatial patterns of the 7-month fluxes, basically the 3 months of the growing season (June-July-August). Wintertime fluxes have little impact on the overall spatial patterns even

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

though they play an important role on the aggregated regional flux. The impact of the prior fluxes remains large despite the observational constraint. Even though the 7 month flux balance is similar using two different prior fluxes, the spatial distribution depends on the structures defined in the prior by the land cover and the vegetation classes. This study demonstrates the limited capacity of the inversion to constrain the entire area, and reinforces the need for refined terrestrial ecology models at the regional scale.

p5, 1st paragraph: We rephrased the corresponding sentence.

p6: We detailed the dimensions.

p7ff, p9-2nd paragraph, p10-2nd paragraph: We clarified the paragraph and detailed the standard deviation calculation. We also added the reference to the section of the paper describing the Ameriflux sites used here.

Several points were already presented in the paper. We have quantified the impact of the plausible range of standard deviations on the inversion (section 3.6), which corresponds to the uncertainty on the standard deviation. Because we performed the comparison at the weekly time scale, hourly and daily spikes are removed or very limited. The uncertainty assessment on the prior fluxes is limited because no observation provides a reasonable estimate of the fluxes at 10km resolution. In the present study, we based our initial standard deviations on eddy-flux towers. A large part of this mismatch is due to representation errors and should not be considered as prior uncertainty. In addition, the temporal variability observed in the corn ecosystems might be very different compared to grass or wheat seasonal cycles. In this context, affecting more specific temporal cycles to the flux errors or trying to evaluate precisely the model-data mismatch with observations at different spatial scales and over different ecosystems, might overconstrain the fluxes in some areas or relax prior fluxes in others. Instead, we evaluated the ratio between transport errors, boundary condition uncertainties, and prior flux uncertainties, using the reduced chi2 value. We also ensured the proportion

Full Screen / Esc

of the concentration mismatch attributed to flux signals versus the errors from transport and boundaries. Finally, our sensitivity analysis showed that the structures of the prior errors (temporal and spatial error correlations) are more critical than the standard deviations. We agree finally that no final answer was provided due to the lack of data at this scale, and the lack of model error assessment for the prior fluxes (ensemble methods or model-data comparison at the regional scale). We can only here define the range of solutions and consider it as an additional uncertainty source in our system.

p9, 1st paragraph: We described the CarbonTracker system in more details.

p11, section 2.4.1: We used meteorological data (analysis) at the boundaries and as initial conditions but the system was not run in a full assimilation mode. We performed overlapping runs in order to remove the spin-up of the simulations (24 hours).

p11f, section 2.4.2: The aggregation errors are implicitly estimated when comparing WRF at 10km to LPDM mixing ratios at 20km. We used WRF outputs to drive our LPD model. This point was added to the paragraph.

p12, section 2.4.3: We added the frequency and the number of flights available. The paragraph was slightly shorten.

p12, section 2.4.4: We modified the introduction to summarize the four steps (instead of three as previously stated) of our transport model error calculation. The section was also modified to clarify the different steps.

p13, last paragraph: We agree that the conclusions might appear inconsistent with the the different elements discussed in the paragraph. We corrected one mistake in the section first, clarifying the fact that we use no correlation in time in the reference setup but we compared the reference to another inversion using previously calculated correlation functions. We also added some explanations to justify our choice (i.e. no temporal correlation in our reference case).

Here, we define our reference setup without temporal correlation because the correla-

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

tion functions were computed using a different transport model, over a different region (Lauvaux et al., 2009a). Though, they were made at similar scales, and using a similar mesoscale model (non-hydrostatic) with similar performances compared to WRF. Other studies have found similar length scales. We think that even if temporal correlation should be computed for our case, which is computationally expensive, we can still use them as a reasonable estimate of temporal correlation. But they shouldn't be used as our reference case here.

p14, section 2.5.1: We moved the first lines to section 2.5.

p16, section 2.5.3: We clarified this section and explained our methodology.

p18, section 2.6: We used the three sites. This point was added to the paragraph.

p19, section 3.1: We used the 9 flights available (the entire database). These flights are both spatially and temporally relevant. Other datasets were considered such as radiosondes, but they provide little information in time (00z and 12z only) and space (3 radiosondes over the entire region). We agree that the aircraft dataset remains limited, but is the most useful and valuable we could use to compute PBL model errors.

The first sentence states clearly that we computed errors in vertical mixing in the lower troposphere.

We explained that we define the standard deviation with this comparison only (and not an addition to an initial error estimate), with the exact time windows detailed in the paragraph. No gradient nor interpolation was applied.

p19, section 3.2: This point was clarified after we modified previous sections. We used WRF to drive LPDM. The two models are coupled here and should produce similar results. This section details the computation of the adjoint model errors and aggregation errors. Whereas the advection is very similar because the particles are driven by WRF wind fields, the vertical mixing can be quite different between the two models. We compared here the impact of using LPDM as an adjoint compared to the

initial WRF results.

p22, section 3.4: we added several metrics (correlations and mismatch) for corn. Considering the large uncertainty in the observed eddy-flux measurements (due to site to site variability), we only provide qualitative comparisons.

In section 2.6, we explain that: "We represented eddy flux site errors by the variations across sites, assuming that representation errors are dominant in our context." At the weekly time scale, the site to site variability is larger than random errors. The data were filtered to avoid most of the systematic errors.

We removed the term 'homogeneous'.

p24, section 3.5: We included this short paragraph as an introduction to the network design concept. The main issue here is related to the complexity of the flux corrections. Showing differences or correlations between posterior and prior fluxes is function of the prior, the observations, and the prior flux errors. We just want to notice based on figure 7 that posterior fluxes are not over constrained by the present network.

section 3.6: We re-arranged the different scenarios following the table 1.

p30, section 4.3: As explained above, we used 3 months of summer and 4 months of winter. Our inversion is not biased toward summer fluxes.

More generally, biases are introduced even if errors are small (which is the case in winter with smaller weekly fluxes). The accumulation of small biases at the weekly time scale ends up with significant biases over the year. We show here that the potential of convergence is large, which does not imply that the inversion is correct, but just that, even if the regional balance of the prior fluxes is far from the posterior regional balance, the observational constraint is large enough. We also assumed correlation length in the prior flux errors which is the main factor of this convergence after the number of sites in the area. Our conclusions are limited to this conclusion.

Concerning the use of nighttime data and the transport model errors during stable con-

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

ditions, we are showing that even if most inversions are not using nighttime data, they are still affecting influence functions of daytime data. The impact of temporal correlations using hourly concentrations revealed the fact that simply removing observations under stable conditions is not sufficient.

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 20855, 2011.