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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Quantifying the constraint of biospheric process parameters by CO_2 concentration and flux measurement networks through a carbon cycle data assimilation system" *by* E. Koffi et al.

E. Koffi et al.

ernest.koffi@jrc.ec.europa.eu

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"Quantifying the constraint of biospheric process parameters by CO2 concentration and flux measurement system" by E. Koffi et al.

Our general comments on the reviews of the above mentioned manuscript:

There were three main criticisms by the reviewers, which we address below:

1) The use of BETHY generated fluxes as a proxy of flux measurements without validating them by observations

2) The use of few PFTs can give conclusions more specific to the CCDAS we are using

3) The description of the methodology is too long

We have addressed the item 1) by comparing BETHY hourly generated net flux (NEE) to those observed at some selected sites of FLUXNET network. Results show that at least for the selected sites, BETHY is doing a reasonably good job. Indeed, the simulated fluxes are in a fairly good agreement with the observations. Since the fluxes themselves are not a mandatory quantity in this study, we provide the results from this additional work as supplementary material for the paper. Indeed, the computation of the uncertainty in the process parameters of BETHY does require only the uncertainty in the observations.

For the point 2), we generally agree with the reviewer. In fact the impact of heterogeneity on the relative impact of flux and concentration measurements is the subject of Kaminski et al. 2012, a paper featuring most of the authors of the present study. The point is actually more general than a PFT-based formulation, it holds for any low-dimensional description. The point which surprised us in the current study was the confinement of information contained in high-frequency concentration observations to the vicinity of the underlying PFT. It remains true that atmospheric measurements sample larger footprints than flux measurements but the difference is smaller than we thought.

Regarding the point 3), we have added a flow chart (new Figure1) which is used throughout the text of the methodology to clarify some unclear parts. Since the methodology used in this paper has not been published elsewhere and because we think that the part that describes the concept is helpful for potential readers, we have then maintained the structure of the methodology as it was.

In what follows, our responses follow the comments of the reviewers and start by "Reply:"

Anonymous Referee #1 Received and published: 3 November 2012

Koffi et al present results from a well-executed application of the established CCDAS system to atmospheric CO2 concentration measurements and synthetic high frequency estimates of CO2 flux. The main aim is to quantify the relative information content of the two different data types, and assess data-acquisition network design, for constraining parameters of a terrestrial carbon cycle model. The manuscript is well written and the results clearly presented. There are some issues with how the experimental design was set up that should be addressed and potentially affect the interpretation of the results.

Major issues: The authors use the BETHY model to generate synthetic data at sites in either an exÂňisting or synthetic observation network. They then use that BETHY-generated data to constrain parameters in the BETHY model and compare constraint to that obtained when also using observed atmospheric concentration data. It is therefore not surÂňprising that the BETHY generated fluxes provide more constraint on BETHY than the concentration observations. If real flux observations were used, would the results be the same?

Reply:

The premise of this question reveals a misunderstanding of the procedure we followed. The comparison is based on the classical linear error propagation via the Jacobian of the model. This does not require the use of either real or synthetic data. This is described in section 3. There is an implicit assumption about our ability to model such data but we investigate this with various sensitivity studies. As described in section 3, the uncertainty in the BETHY parameters when using either the concentrations or the flux measurements depends on the uncertainties in both the underlying models and observations. Thus, when using flux measurements only, the uncertainties in BETHY simulations and the flux measurements are needed. For the concentrations, we must add the uncertainties in the transport model.

To ensure that the use of BETHY fluxes as a proxy of flux measurements is reason-

able, we have performed an additional work that focusses on the comparison of BETHY fluxes to those observed from the FLUXNET network. Results show that BETHY fluxes are in a fairly good agreement with these observations. For brevity sake and especially because the results of these comparisons do not bring anything new to the main conclusions of this study, we have summarized them in a supplementary material which is provided.

A potential problem here is that it is assumed that the BETHY generated fluxes are corÂňrect, and can be related to the observed concentrations. Many conclusions are based on this assumption. E.g., from the abstract: “Indeed, CO2 concentration sensitivities relevant for such high frequency fluxes are found to be largely confined in the vicinity of the corresponding fluxes, and are therefore not well observed by background moniÂňtoring stations.” The same result could be explained by the fact that BETHY does not reproduce the observed fluxes at the tower sites very well. The authors may argue that it does, or has been show to in previous publications, but I would argue that that needs to be shown here for these specific runs of BETHY for the sites used. I recognize that it is no minor task to do so, and the data is not necessarily freely available. Without showing that the BETHY model fluxes are comparable to observations, then significant reconsideration of the interpretation of results would be needed.

Reply:

Effectively, the conclusion from the abstract “Indeed, CO2 concentration sensitivities relevant for such high frequency fluxes are found to be largely confined in the vicinity of the corresponding fluxes, and are therefore not well observed by background moniÂňtoring stations” can be mitigated or reinforced according to how the modeled fluxes from BETHY used in the transport model to compute the concentrations compared to the observations. Following the reviewer’s comments, we have compared the BETHY net fluxes to the actual measurements from some FLUXNET stations selected evenly around the world (see supplementary material). Since BETHY simulates only a diurnal cycle of NEE per month, we have first calculated the mean diurnal cycle of

NEE for each month and for the selected observations. BETHY simulations by using its a priori parameters and those optimized by using only CO2 concentrations (Koffi et al., 2012) are compared to the corresponding observations. BETHY simulates pretty well the diurnal cycle of NEE for most of the selected sites, but in general it tends to overestimate their amplitude (See supplementary material). When using the optimized parameters of Koffi et al. (2012), the amplitudes of BETHY NEE decreases and the rate of decrease depends on the selected stations. This reduction in amplitude would probably serve to confine concentration variations even further.

Finally, since we have shown that BETHY generated fluxes are reasonable to represent flux observations, we do not amend the main conclusions of the paper.

Throughout the text, the BETHY-generated fluxes used in CCDAS are presented as 'flux measurements' or 'observations (BETHY-FLUXNET). This is misleading and needs to be addressed. The manner in which the FLUXNET locations are presented could lead the reader to understand that data from these sites are being used. E.g. in the footer of Fig. 2, 'The network of flux measurements we are using', could be understood to mean that flux measurements are being used, which is not the case.

Reply:

We have now stressed the fact that we use BETHY-generated fluxes and not actual flux measurements and this has been mentioned earlier in the abstract and throughout the text.

The authors argue that both fluxes and concentrations are needed to constrain the model, which of course makes sense. Does the story stop there though? Many studies have shown that flux data alone can constrain only a limited number of parameÂňters in carbon cycle models. Ancillary information on the distribution of carbon pool sizes within the system, and their turnover times, are essential for constraining paramÂňeters that govern fluxes over longer time scales. Quantifying the relative importance of such constraints is of course beyond the scope of the manuscript, but some disÂňcussion

should be included in order to avoid giving the impression that with flux and concentration we've got it all.

Reply:

We agree that data relevant to the parameters linked to the distribution of carbon pools would be helpful to constrain them. In BETHY, these parameters are those from the fast (τf) and slow (τs) pool turnover times at 25 oC, respectively. In addition, we assume in BETHY that the size of slow pool does not change over 21-years that leads a scaling factor β. These three parameters are optimized. With such a formulation of BETHY, both concentration and flux measurements constrain these parameters as shown by the large uncertainty reduction. Part of the reason for this is undoubtedly the length of the time series of the pseudo-data. Nevertheless, it would be worth considering observations relative to the pool turnover times as well as the time variations of the size of the pool to evaluate the optimized parameters first and if necessary to use these data to constrain them.

Minor Comments: Page 24132 Line 22-23: "a large suite of measurements ... is gathered". Consider rephrasing. The statement suggests that this suite of measurements has been consolÂňidated somewhere in a single database. If that's the case, give the reference.

Reply:

This is replaced by "A various source of measurements" . . .

P 24133 Line 12: It might be worth giving a bit of background information on CCDAS here. The authors say only that it can ingest many different data sets. But what is it?

Reply:

The CCDAS used here has two primary components: i) A deterministic dynamical model (here BEHY) that calculates the evolution of both the biosphere and soil fluxes given an initial condition, forcing and a set of process parameters of the model. ii)

An assimilation system that consists of an algorithm to adjust a subset of the state variables, initial conditions and/or process parameters to reduce the mismatch with observations. Usually any prior information on the variables which are adjusted are also taken into account (see Kaminski et al. [2002, 2003] and Rayner et al. [2005, and references therein] for the underlying methodology). These sentences have been added to the text

Line 25: 'A series of papers have shown'

Reply:

OK, corrected as follows: "Series of papers, ... This part of the sentence has been deleted

P 24134 Line 15-16: Please reiterate here that you are talking about atmospheric concentration data.

Reply:

. . . in assimilation system using atmospheric CO2 concentration so . . .

Line 25: A large impact on what? A large improvement in parameter constraint? Please specify.

Reply:

Yes. This has been replaced by " A large reduction in parameter uncertainty"

Line 21: See Kuppel et al., 2012 Biogeosciences for a more detailed analysis of beÂňtween site variability http://www.biogeosciences.net/9/3757/2012/bg-9-3757-2012.pdf

Reply:

This reference has been put in the list of the quoted papers there

P24135 Line 5: I agree with the authors and consider the evaluation of variability at

shorter time scales a very laudable goal. That said, I would question whether considering fluxes at the daily time scale is sufficient. Daily integrated flux incorporates two very different processes, respiration and photosynthesis. These can be effectively separated by conÂňsidering night-and day-time fluxes separately (e.g., Sacks et al 2007 showed the soluÂňtion of SipNET to be severely degraded if data were aggregated to the daily timestep because separate information about photosynthesis and respiration was lost). So, why use daily instead of hourly or at least a day-night separation?

Reply:

First, we have used daily fluxes because the observed CO2 concentrations are daily. Since we are doing sensibility study, it has been worth using these data. Results show that daily fluxes for the concentration do add little to what we have from monthly data. Hence, we agree with the reviewer that daily fluxes are not enough for photosynthetic parameters. Thus, when quantifying the uncertainty in BETHY parameters by using BETHY generated fluxes, we consider hourly data. Note that with these data, we also faced the problem of respiration since there is not any parameterization of such high temporal resolution in the model. We then assume constant the hourly respiration by dividing the daily respiration by 24.

Line 21: Constraint can not be provided by BETHY daily fluxes. I assume you mean daily flux integrals.

Reply:

OK. This corrected by "Daily averaged fluxes"

Line 21 (iii): As far as I can tell, no hourly flux measurements are being used in this study. Synthetic hourly flux estimates are being used, which is an entirely different thing. This presentation of synthetic flux estimates as actual measurements comes up a lot in the text, and needs to be addressed.

Reply:

We change “hourly flux measurements” by BETHY generated hourly fluxes as a proxy of flux measurements

P -24136 Line 6: Assumed or estimated? Uncertainty in measurements does not necessarily have to be assumed. In particular for eddy-covariance data it is well charÂňacterized.

Reply:

In this study, we assume the uncertainty in measurements since we do not use the actual flux measurements. The assumed values are in the same order of magnitudes even larger that of those estimated from measurements. Indeed, we compute the uncertainty reduction in BETHY parameters by assuming the uncertainties in the flux to be 25 and 75% of the computed fluxes. For very low fluxes, we also consider larger uncertainties.

Line 18: It would be good to state what the base temporal resolution of simulations is.

Reply:

This has been added as suggested. Note that the base temporal resolution of BETHY simulations is 1 hour, but one day is used for variables related to soil respiration

P-24139 Line 23. This is the first time the fact that the study uses only synthetic data is mentioned. This should be clarified throughout the manuscript.

Reply:

OK. This has been stated in the introduction (section 1) and considered throughout the paper

P-24141 Line 12:14. Actually, the uncertainty in flux measurements is well characÂňterized, and is known to be heteroskedastic. See work by Hollinger and Richardson, 2005; Richardson et al., 2008) This would seem to be quite important, as the level of measurement uncertainty will directly affect the magnitude of the retrieved parameter

uncertainties.

Reply:

Yes, random flux measurement uncertainty, expressed as a standard deviation was found to vary with the flux magnitude (Hollinger and Richardson, 2005; Richardson et al., 2008; Laslop et al., 2008). The authors showed that the error distribution in e.g., NEE is leptokurtic (i.e., the peaks result from the data being highly concentrated around the mean) and it is described by rather a double exponential (Laplace) than normal (Gaussian). However, when grouping the data according to the flux magnitude, Lasslop et al. (2008) found that high flux magnitudes follow a Gaussian distribution and then the leptokurtic error distribution found for all the data is largely due low flux magnitudes. In addition, the parameters in the error distributions are dependent on the observational sites. In this study, we also consider uncertainty in BETHY flux to be heteroskedastic, but not a leptokurtic distribution. Indeed, for large fluxes, we assumed the uncertainty in flux to be 25 and 75% of the flux magnitude. For near-zero or low fluxes, we consider a larger uncertainty based on the mean values of flux over the grid cell and for the whole period. With such an uncertainty characterization, we prevent any underestimation of flux uncertainty when computing the uncertainty reduction in the model parameters. We have added the references of Hollinger and Richardson (2005), Richardson et al. (2008), and Lasslop et al. (2008) in this section and clarified the text.

References

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Richardson, A.D. and Hollinger, D. Y : Statistical modeling of ecosystem respiration using eddy covariance data: Maximum likelihood parameter estimation, and Monte Carlo simulation of model and parameter uncertainty, applied to three simple models. Agricultural and Forest Meteorology 131: 191-208, 2005

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Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/12/C12593/2013/acpd-12-C12593-2013-supplement.pdf

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Interactive comment on Atmos. Chem. Phys. Discuss., 12, 24131, 2012.