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# *Interactive comment on* "A new step-wise Carbon Cycle Data Assimilation System using multiple data streams to constrain the simulated land surface carbon cycle" *by* P. Peylin et al.

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General comments : The manuscript reports development and application of a data assimilation system which is used to produce a version of ORCHIDEE model optimized to reproduce NDVI, net ecosystem exchange and latent heat flux at land validation/flux tower sites and CO2 seasonality at background CO2 monitoring sites. The stepwise optimization approach is proposed as a simplified alternative to optimizing model to fit NDVI, flux tower data and atmospheric CO2 data simultaneously. Despite splitting the process in several stages authors succeeded to find a set of parameters allowing the model to fit all types of constraints.

The manuscript is well written, and presents an original and valuable contribution. It



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Discussion paper

can be published after minor revision, hopefully addressing the comments listed below.

We thank the reviewer for his positive review and we describe below how we have address his comments.

General comment 1. In the optimization framework adopted by authors, model parameters optimized at the set of flux tower sites are later extrapolated to whole land surface using available spatial data on vegetation type, weather and soil type information as drivers. The flux tower site optimization is made by combining several sites within same vegetation type in one group, and average flux seasonality is shown to be improved by the optimization. The variability of the fluxes due to soil quality and slope/drainage within same vegetation type is not directly captured by this approach, while some studies (Ise an Sato, 2008) suggest there is a way to address site level differences in productivity potential (edaphic variability) based on remote sensing data. It would be relevant to mention this factor in discussing reasons for remaining spread in the degree of success that can be achieved using one set of model parameters for optimizing fluxes at several sites of same vegetation type.

We agree that the optimization approach is not able to account for all sources of variability for the carbon and water fluxes measured at FluxNet sites and in particular those linked to edaphic conditions (soil quality, slope and drainage,...). This is indeed a potentially important limitation of current global LSM. The study of Ise and Sato (2008) brings an interesting perspective to include part of the edaphic variability although it relies on strong hypothesis: i.e., the impact of edaphic variability directly controls the vegetation distribution at high spatial resolution and the GLC2000 land cover product is able to capture the differences between high, medium and low productivity ecosystems. The authors have shown that taking into account the spatial variability of the land cover from GLC2000 could significantly improve the model simulation of Leaf Area Index at high latitude in North America, but not really over Siberia. We thus believe that it is an interesting direction of research, worth to be mentioned in the discussion, but not specific to data assimilation as it concerns the global LSM performance in general.

We thus only added in section 4 the following sentence: “Finally, one can mention new approaches based on remote sensing data to account for site level differences in productivity potential due to edaphic variability (soil quality and slope/drainage) within the same vegetation type (Ise an Sato, 2008).”

Detailed comments Page 01 – Line 03. In addition to “incorrect model parameter values” one should mention uncertainty in spatial distribution of the parameters coming from the maps of soil properties, topographic features, vegetation types.

We agree and have added: “poor description of land surface heterogeneity (soil and vegetation properties),. . .”

Page 04 – Line 05. Randerson et al (1996) paper can be mentioned among influential studies that use air concentration as constraint

We agree that Randerson et al. (1996) was a key paper that used atmospheric CO2 concentration as a constraint to evaluate the impact of specific processes linked to organic matter decomposition. However, this study only used the data to evaluate the model output but not to constraint some parameters with a formal optimization procedure. Given that the introduction is focusing on studies that have used an optimization procedure, we prefer not include Randerson et al. (1996); else we would need to include several other studies that have similarly used atmospheric observations to validate specific ecosystem processes.

Page 04 – Line 26 To extend a list studies using multiple input streams and C stock data in assimilation (Saito et al 2014) can be added.

We agree that this study was missing from the list of data assimilation studies and we thus added it.

Page 20 Line 13. In many transport models it appears difficult to match CO2 seasonal cycles in PBL and free troposphere at the same time, which can be attributed to simulated PBL height biases and biases in other processes. The problem can lead to finding a set of model parameters that are optimized well for LMDz model with its PBL height and PBL ventilation rate, but not performing that well when model is different. It would be useful to add figure showing match with free tropospheric data for model validation. Aircraft data and TCCON data can be used for validation, especially high latitude sites know for high seasonal amplitude such as Poker Flats Alaska, or TCCON at Sodankula (Lindqvist et al., 2015). A useful check would include use of vertically integrated profile data at airborne observation sites (Nakatsuka and Maksyutov, 2009), as it is more stable against the PBL height biases.

We agree with the reviewer that the representation of the PBL spatial and temporal dynamic is crucial when using atmospheric CO2 data to optimize ecosystem model parameters or surface fluxes. However, using few scarce free tropospheric data to evaluate the performance of the optimization will not bring significant information as the dynamic of the PBL varies substantially between regions; we thus would need to have a large set of free tropospheric data to provide a comprehensive validation. The second suggestion of the reviewer concerns vertically integrated data, such as TCCON. Indeed they depend less on PBL height biases, but they however depend crucially on other large-scale uncertain model features, such as the north – south overall mixing. Finally a technical constraint complicated the evaluation of the model output with these new observations. We indeed used pre-calculated transport fields (model Jacobian) that were calculated at a selected set of surface stations (computationally intensive process) with an older version of LMDz: version 3. It would thus require us to run again the LMDz transport model version 3, which was not feasible in a reasonable time frame period.

Given this technical constraint and the relatively small-expected gain from the evaluation at free tropospheric sites or at TCCON sites, we propose instead to use additional surface stations not used during the optimization (but where the Jacobian are available). We have used 17 sites that are more representative of continental fluxes than the stations that were assimilated and 7 sites that correspond to Pacific Ocean cruises that were left aside in order not to overweight that particular region in the optimization. This independent atmospheric CO2 evaluation illustrates that the improvement is not only valid at the optimization sites. On average the mean RMSE for the 27 additional sites is 10.5 ppm for the prior of step 1 (prior of ORCHIDEE), 2.8 ppm for the prior or step 3 and 2.1 ppm for the posterior of step 3. The corresponding values for the 53 sites used for the optimization are: 10.5, 2.45, 1.8 ppm, respectively. The error reduction during step 3 is thus similar for both the assimilated and the validation data sets. We added this additional evaluation in the paper (section 3.1.3) as an independent validation of the optimization with selected atmospheric CO2 observations.

Technical corrections

Fig 1. Correct spell: “Carbone fluxes” to “Carbon fluxes”

Corrected

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