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Interactive comment

Interactive comment on "Evaluation of terrestrial pan-Arctic carbon cycling using a data-assimilation system" *by* Efrén López-Blanco et al.

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Review of "Evaluation of terrestrial pan-Arctic carbon cycling using a data-assimilation system"

Matthias Forkel, Wien, 2018-06-20

1 Summary

López-Blanco et al. apply a land carbon data assimilation system to assess carbon fluxes, stocks, and turnover times in arctic and boreal regions. Within the CARDAMON system, parameters of the DALEC2 model are optimized per 1° grid cell against observational datasets of LAI, biomass, and soil organic carbon. From the optimized model, carbon stocks, fluxes and turnover times are computed and then compared against results from global vegetation models (GVMs). The approach is very valuable because the carbon turnover in land ecosystem is a main uncertain feature of the global carbon cycle. I really appreciate this work; however, the paper needs substantial revisions before I can recommend publication in ESD (see major comments).

Also the structure of many chapters needs to be revised because information are either repeated often at several places or is not given at the appropriate places (see specific comments).

2 Major comments

2.1 Tundra-taiga transition and Mongolian grasslands

The grassland region in Mongolia is rather a "steppe" than a tundra (lines 110-112, Fig. S1). Please separate steppe and tundra by either using a latitude threshold, temperature conditions, or a biome map.

2.2 Computation of transit times

Based on our theoretical assumptions on carbon turnover times (Carvalhais et al., 2014) [supplement], your computations of transit times are partly wrong. The turnover (or transit) time is defined by the C stock of a carbon pool and its outgoing flux. For example the transit time of vegetation is TT_vegetation = biomass / T whereby T includes all processes that remove C from vegetation (litter fall, disturbance, mortality, etc.). Under the steady state assumption (i.e. T = NPP), the transit time of the entire vegetation can be defined as TT_veg = biomass / NPP. Accordingly for the entire ecosystem, the transit time can be defined under the steady state assumption as TT_eco = (biomass + SOC) / Reco = (biomass + SOC) / GPP.

In your calculations, all transit time are computed based on NPP However, only a fraction of NPP goes into the different C pools which is in DELC well defined based on

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the allocation parameters. Hence the correct computation of a transit time for a certain carbon pool should be based on a fraction of NPP:

NPP_photo = a_foliage * NPP + a_labile * NPP [I assume that C_photo contains the foliar and labile C pools of DALEC2 but this is not described in the paper.]

TT_photo = C_photo / NPP_photo

TT_veg = C_veg / (NPP – NPP_photo) [should this rather be named TT_wood?]

TT_soil = C_soil / litterfall [?] = C_soil / Rh [Why you name this TT_dom?]

2.3 GVMs with GCM climate forcing

What is the reason for using GVM results that are based on climate forcing from GCMs (lines 176-182)? ISIMIP provides also historical forcing that is based on observed climate data and at least LPJmL provides also model output based on historical data (ISIMIP2A). I assume that the historical climate data better represents climate conditions than the (even though bias-corrected) GCM outputs. Differences in climate forcing can have huge impacts in GVMs. Hence, the comparison between CARDAMON (forced with reanalysis data) and GVM outputs is per se unfair and not comparable.

I request that the comparison between CARDAMON and GVMs should be made comparable by either taking GVM outputs from the historical forcing with ERA-Interim data or by running the optimized CARDAMON with the same GCM forcing.

2.4 Biases with biomass and GPP – wrong use of data and parameter uncertainties?

CARDAMON underestimates the biomass and FLUXCOM GPP. The overestimation of FLUXNET GPP is contradictory but the source of the mismatch is almost impossible to assess given the scale mismatch between FLUXNET sites and 1° grid cells. However, if we would assume that both biomass and FLUXCOM GPP are consistent; this could tell us that CARDAMON only needs a higher GPP to gain higher biomass. I'm wondering if it was actually possible to constrain both biomass and GPP within the assimilation framework. Were there any prior parameters used that constrain GPP? As far as I can understand the setup of the approach, there were no data and no parameters included that would constrain GPP (apart from LAI that, however, likely only constrains the seasonality of GPP). To better understand the assimilation results, it is necessary to show maps of reduction of uncertainty of each DALEC2 model parameter. Which parameters were mostly reduced (phenology, allocation, C pools, turnover rates)?

Please also note that the biomass map by Thurner et al. (2014) is largely in agreement with in situ observations of forest carbon density in Russia and slightly underestimates in the USA. If CARDAMON underestimates the biomass, this implies that it would even stronger underestimate the in situ observations than the biomass map. From the results, I get the feeling that the assimilation is over-confident in the SOC data and degrades the performance with the biomass map. Hence the key question is how data uncertainties were used as weights in the assimilation? The uncertainties in SOC are much larger than in biomass (Carvalhais et al., 2014); so I expect that CARDAMON should rather fit the biomass map than the SOC map if these data uncertainties were correctly used.

In summary, please report:

1. Which data uncertainties were used and how they were included in the assimilation;
2. How parameter prior uncertainties were included in the assimilation;
3. How the cost function was designed and the different datasets weighted;
4. What are the changes between prior and posterior parameter uncertainties.

2.5 Benchmarking ISIMIP with CARDAMON

At this point, I will not further comment on chapter 3.3. given the inconsistencies in climate forcing between CARDAMON and GVMs and given the fact that it is not clear how data uncertainties were treated in the assimilation and hence affect the CARDAMON results.

3 Specific comments

1 Introduction: I suggest to slightly restructure the Introduction to make things a bit more clear. For example, several topics are mentioned twice: “transit times” (around lines 48 and 76), the available data (lines 46-59 and 83-86), and the specific features of the arctic carbon cycle (1. Paragraph, lines 55-59). In addition , the meaning of “transit times” is never explained. I suggest to :

- keep the first paragraph as it is,

- to rewrite the second paragraph: define “transit” and/or “turnover” and /or “residence” time and why it is important,

- to write in the third paragraph about the available in situ and satellite-based data to assess “turnover” times and the associated uncertainties,

- to write in the fourth paragraph about the inabilities and uncertainties of GVMs with respect to turnover times,

- and finally to present model-data integration and CARDAMON as the potential “solution” in the last paragraph including the definition of your objectives.

Line 37: Use either “warming” or “temperature increase” but not “warming increase” because this would be an acceleration in temperature increase.

Line 40-41: In addition to Lucht et al. and Myneni et al., you could also cite more recent related publications (Forkel et al., 2016; Graven et al., 2013; Zhu et al., 2016) [I don’t request to include my paper!]

Line 48 and lines 75-82: “transit times” – Carvalhais et al. use “turnover” time, Friend et al. “residence” time, and Thurner et al. (2016) “turnover rate”. Is there a reason why you use “transit time” and why you are not using one of the other terms? Please provide a short definition of these terms or the term that you are using and how they differ.

Line 61: “PFT or spin-up”: The “or” should be replaced by “and”.

Line 74: Relevant is also the work by Thurner et al. (2016)

Lines 84-85: Please provide references.

Line 87: A reference to a general overview paper on model-data integration might be useful.

Line 95-96: It is not clear to me how your analysis will provide further insight into GVMs that goes beyond the work of Friend et al. (2014), Carvalhais et al. (2014), and Thurner et al. (2017). Please make clear what kind of additional knowledge you are expecting from your analysis on the problems of GVMs.

Lines 106-107: Please define which classes you used to separate forest and non-forest.

Section 2.2: The description of CARDAMON refers mostly to previous work. However, to understand _this_ paper, I suggest to provide some more details or equations with respect to the following questions:

- LAI, biomass, and SOC are used as data sets in a cost function for parameter estimation and not as forcing data. Is this correct?

- What is the cost function? How are the differences in the number of data points weighted (LAI is a time series, SOC and biomass only single values per grid cell)?

- Why is the MHMCMC algorithm used three times? Does it not explore the full parameter space if it is applied only once? Or are there difference in initial values?

- Can you make a conceptual figure that shows which data sets go into the assimilation and which are only used as independent evaluation data?

Line 147: What is the difference between “photosynthetic” and “vegetation” C stocks? Is photosynthesis not vegetation?

Line 159: Did you directly compare the 1° grid cell with the FLUXNET site? If yes, how are the FLUXNET sites representative for the 1° grid cell? If no, did you run CARDAMON with the site meteorological data? Add: Only from the discussion (lines 318-238), I now learn that you did a grid cell to point comparison. This should be already mentioned in the methods and be recalled at the appropriate place in the results section.

Lines 166-168: This is a repetition from lines 123-125. Please merge the two sentences.

Line 171: TT_veg was already mentioned at line 148. I suggest to remove both occurrence of TT_veg and to already define TT_veg in the new second paragraph of the introduction.

Line 171: At the end CARDAMON is also just only a GVM but with grid cell-specific parameters. I don't see how CARDAMON then serve as a benchmark for the other GVMs. Would it be not enough to directly benchmark the GVMs against the reference data? You should try to better motivate already in the Introduction why you can use CARDAMON as a benchmark for GVMs.

Line 173: LPJmL (capital L). Please indicate which version of LPJmL was used. Is it the most recent version (LPJmL4) (Schaphoff et al., 2018a)? LPJmL4 includes also a new permafrost module (Schaphoff et al., 2013) and a data-constrained phenology module (Forkel et al., 2014) and hence better reproduces boreal and arctic carbon stocks and carbon cycling than the previous versions (Forkel et al., 2016; Schaphoff et al., 2018b).

Lines 184-194: I got really confused by this paragraph because initially I got the impression that you "jump" across all results without explanation. Please make clear that this paragraph is a summary of all results by either using a heading or a suitable topic sentence.

Line 202: Which of the used data sets constrain the separation between GPP and NPP?

Line 216: Do you find spatial pattern in TT_photo that would resample the distribution of evergreen and deciduous trees?

Line 219: “Interestingly” – Please tell me why this is “interestingly”.

Line 257: “as noted “ – Please check.

Lines 330-331: This sentence should be merged with the numbers given at lines 349-352.

Line 341: Are you sure to use the right reference for LPJ-GUESS-WhyMe?

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