Author response to: Interactive comment on “The C4MIP experimental protocol for CMIP6” by C. D. Jones et al., Anonymous Referee #2

Review comments in BLACK

Author responses in Blue/Italics

The past C4MIPs (e.g., that within CMIP5) have greatly stimulated research on carbon cycle-climate change feedbacks. The next C4MIP in association of CMIP6 is expected to continue such a great influence in the community.

Overall, this manuscript is well written and clearly describes C4MIP experiments and output requirements. If all participating modelling groups can follow the protocol, out- puts of this MIP will be extremely useful for the community to learn more about the carbon cycle models in particular and consequently improve carbon cycle science in general.

Thank you for these supportive words

I have no major criticisms on the manuscript but strongly suggest the protocol may consider require the modelling group to generate a pool-flux diagram for each model such as in Xia et al. 2013 with CABLE. Figs 5 and 6 already outline the pools and fluxes. The pool-flux diagram is a representation of Figs 5 and 6 for individual models and supposed to be corresponding to the matrix form of pools and fluxes. This protocol may require modeling groups to report the pool-flux diagram and deposit their model codes in the Earth System Grid Federation (ESGF) or GitHUB. In this way, C4MIP will make the C4MIP modeling totally transparent for the community to learn about modelstructures, parameters, and output variables.

We agree that such a documentation of each model is extremely useful. We don't feel able to require all groups to follow the Xia reporting protocol exactly, but have suggested this as a way that could be used. We have added a request in the land-diagnostic section that all models document and report their structure and also report more detail of soil carbon pools above and below 1m.

The protocol that is currently specified as tier-1 in the manuscript allows analysis to compute the results as a 2x2 matrix (where the two members are live vegetation and dead CWD/litter/soil) as in Koven et al Biogeosciences 2015. Anything beyond that level of complexity requires assumptions that may not be shared universally (such as different structures/numbers of veg/CWD/litter/soil pools? is each PFT a separate matrix element? how to handle size-structured wood pools? how to handle vertically-resolved soil C? how to handle nonlinear soil C models? etc). We agree that this is a useful way of framing the issue, but do not feel the approach is yet ready to be mandated universally for all models.

***Added text: “*For CMIP5 the soil carbon pool was requested to be divided into components with fast, medium and slow turnover timescales. However, this distinction was not found useful by the community and as a result was not used in many analyses. For CMIP6, we are requesting a**

breakdown in two different ways. Firstly based on the vertical distribution of soil carbon: total soil carbon should be split into above and below 1m depth (cSoil and cSoilBelow1m, respectively). Models which do not explicitly represent ~~a~~ vertical distribution of soil carbon should report all of their soil carbon in cSoil. The rationale for requesting this is the availability of several observation-based datasets that report soil organic matter content to 1 m depth. A second level of vertical reporting is then requested for tier 2. We ask that models with a vertical structure to their soil carbon report total soil carbon for each soil layer. As the structure for this may vary between models it is essential that the model is thoroughly documented.

In order to be able to diagnose and evaluate the turnover rates of carbon within the terrestrial system we make a second tier 2 request to report individual soil carbon pools. In order for this to be useful it is also required to report the turnover rate (defined as 1/residence time) for each pool. For models with a vertical structure we recognise that this could become an unmanageable number of pools reported, so we request that the individual pools are aggregated above and below 1m. To ensure such output is used correctly in analyses it is also essential that the pool-flux structure of each model is fully documented in its model description paper. This output will enable reduced complexity approaches (e.g. Xia et al., 2013) to recreate and analyse the soil carbon dynamics within each model."

The description of outputs of modeled land carbon pools and fluxes is quite comprehensive but becomes quite lengthy. It will become much easier and clearer if the pools and fluxes are expressed in a matrix form as in Xia et al. 2013. Then all the elements in the matrix equation should be reported to allow accurate analysis of model outputs.

As above (and as commented by review 1) we feel the length and comprehensiveness of documentation here is important and appropriate.

The sentence on page 26 "However, this distinction was not found useful by the community and as a result was not used in many analyses" may not be accurate. Distinguishing different soil pools is essential as repeatedly shown by many empirical and modeling studies. When you lump soil C together from many pools, it is almost impossible to understand how each model simulates soil carbon dynamics. I strongly recommend your protocol to require the report of outputs of individual soil carbon pools.

We believe the sentence to be true that very little use was made of these distinctions from the previous set of outputs (CMIP5). We do agree though that individual soil carbon pools should be reported and have updated the manuscript and our data request to reflect this (as per response to your point above).

The same requirement should be make clear to report outputs of soil pools in different depths.

We agree – we have now requested models to output all their pools individually above and below 1m.

Other minor comments:

P. 6, L4-5, in addition to those differences in model structures, you may also set a goal to understand sciences behind model development, evaluation and improvement.

We agree – it is very much our intention to stimulate such advances – especially with evaluation. This is explicit in our stated goals for C4MIP in the introduction

P.6, third para, we may bear in mind that most of the nitrogen models may not well reflect N processes in the real-world ecosystems as shown in some model intercomparison and model-data intercomparison studies. It requires transparency of models if we want to advance our field.

We agree that nitrogen, as well as many other ecosystem processes, are not always well represented. Again we have set evaluation of the models as a research priority.

P.8, L1, should the subtitle 2.2.2 be "evaluation of global carbon cycle" or "evaluation of global carbon cycle models"?

Thanks. We have corrected this to say "models"

P.9 second para, you may separately discuss evaluation techniques vs. datasets

We agree, but feel they are sufficiently linked that we have kept this paragraph as it is.

P.9 third para, it appears that the idea on isotope modeling is not very well developed.

It is true that coupled (GCM) modelling of isotopes is certainly not well developed. We hope that having an explicit request for groups to simulate carbon isotopes where possible and report the outputs will stimulate research in this area. Our analysis plans will evolve depending on how many ESMs are able to do so for CMIP6. This paragraph was revised for clarification.

P. 11, C4MIP: How do you distinguish this C4MIP from other C4MIPs?

This is the 3rd generation of C4MIP having evolved from the single publication of Friedlingstein et al (2006) that documented the first C4MIP intercomparison to the J. Climate special issue from CMIP5 carbon cycle analyses. We decided against applying a "vn3" label to this, but link it instead simply to CMIP6. This is now discussed in the introduction

P. 14 L. 11-12, The sentence “A model cannot be conformant to the C4MIP protocol unless it can be run in both these configurations” is not very clear and needs more explanation.

We have rephrased this for clarity – a model needs to be able to perform both emissions-driven and concentration-driven simulations in order to fulfil the C4MIP required set of simulations:

“A model must be able to run in both these configurations in order to perform the C4MIP simulations”.

P.16, L10. Land carbon cycle spin-up may use the semi-analytic method developed by Xia et al. 2012, which provides much more accurate estimates of steady states after spin-up. At least this protocol should recommend it.

Thank you. We have added this to the list of possible techniques groups may choose from

P26. L11-17, Should report how soil carbon module is structured and all pools should be reported.

As above - We agree and request this now

P28 L19, this is a great point to ensure mass conservation of C.

thank you

P28, L21, If all modeling groups use matrices to represent pools and fluxes, we will have a uniform way of reporting.

As above we mention this approach as an option

P27, l23-24 “Some models may also simulate this flux directly from vegetation to soil carbon, for instance, in the case of root exudates.” In a matrix form, all those become straightforward.

As above we mention this approach as an option

P29, L9, for “in order to close the nitrogen budget”, can you use the same language (i.e., mass conservation) as in the carbon cycle?

We explicitly added mention of conservation

Page 30, L6 “to close nitrogen cycle budget over land” means the mass conservation but uses different terms.

We explicitly added mention of conservation

P31, section 4.1.3. where in the paper did you specify the required outputs of the forcing variables?

We do not request outputs of the forcing data