Author response to: RC3: review from Chris Huntingford

Review comments in BLACK

Author responses in Blue/Italics

Review of paper: "The C4MIP experimental protocol for CMIP6" by Chris Jones et al.

The paper is a well thought-out plan for understanding and modelling the land and ocean roles in the carbon cycle that is being perturbed by human burning of fossil-fuels. It is an important paper, not just setting out a scientific research agenda, but also by informing future modelling protocols for climate-carbon cycle simulations. GMD is the appropriate journal for this manuscript. The diagrams help focus attention on what are the main issues still being developed in parameterised in the global carbon cycle.

The paper should be published and in its current form. Below are just a few small points that the authors might like to consider.

Happy to sign the review. Chris Huntingford

We thank Chris for his thoughtful comments and review

General

It might be worth mentioning directly that this paper partially addresses a frustration by those who had built GCMs with a full interactive carbon cycle, and hence the logical approach was to force with different emissions scenarios. However to keep in GCM modelling groups who only describe the physical climate, then instead the CMIP5 protocol was to use prescribed forward profiles in atmospheric CO_2 concentrations. There has been relatively little attempts to then find compatible emissions with those concentration trajectories. This CMIP6 protocol paper goes a long way to addressing that concern. Although concentration pathways will still be prescribed, the methodology in this paper submission explicitly states the need to back out land-atmosphere and ocean-atmosphere CO_2 fluxes. From this, "permissible" emissions can be calculated. …Ah, reading on…. OK, can see p10, line 13 - and bullet point 5, page 11, that there will be emissions-driven simulations. Is this worth stating explicitly, point (3), line 8, page 2, up in the Abstract/Introduction, that the rcp-approach frustration is in part removed?.

We have added mention of E-driven runs in the introduction:

"...by quantifying the role of carbon cycle feedbacks in the evolution of atmospheric CO_2 due to anthropogenic carbon emissions"

P5. I always think the sentence (that appears, similarly, elsewhere too): "All models agreed qualitatively that the sign of the carbon-climate feedback was positive" should be given more context to those not so familiar with this area of work. This is not saying that the land and oceans automatically put more CO2 back in to the atmosphere under climate change, and the Introduction makes this clear. Would it be an idea to say something like: the direct effect of climate offsets some of the fertilisation-induced ability to draw-down atmospheric CO_2?

Yes we agree this is important to get clear. This is actually already explained in the second half of that sentence:

"All models agreed qualitatively that the sign of the carbon-climate feedback was positive – i.e. the interaction of the carbon cycle with climate led to reduced carbon uptake..."

Section 2.2 sets out three main expected scientific advances. This makes the paper very interesting beyond just protocol description. Maybe highlight these three paragraphs better, with either subheadings or short introductory sentences. E.g. "Terrestrial Nitrogen Modelling", "Enhanced Soil Modelling" or "Better Ocean Circulation Modelling".

This is a nice idea, but when we discussed this we decided not to make this look like a prioritised research agenda, as these are only some example and cannot be exhaustive.

Sorry if I've missed this somewhere tucked in the paper, but how is the emissions timeseries determined for the SSP5-8.5 scenario? The name hints this will be a scenario that gets an atmospheric concentration profile similar to the rcp85 prescription of CO_2 concentration. Are "harmonised" emissions taken from Malte Meinhausen's rcp page? Here:

http://www.pik-potsdam.de/~mmalte/rcps/

(OK, there is a brief mention line 29, page 19, but no reference given).

Yes, this was mentioned briefly in the data section right at the end, but we will add a clearer explicit mention (in our section 3.3) of the forcing data, and references to the CMIP6 and forcing GMD papers and CMIP forcing web link:

Added to section 3.3: "The CMIP6 paper (Eyring et al., 2016) and a range of papers in the GMD CMIP6 special issue will document the forcings in more detail. The data will be made available from the CMIP6 webpage (http://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6)."

P21. N-deposition. I had to run through this a couple of times to understand how the future scenarios of N deposition for SSP5-8.5 will be determined. Line 13, p 22 says: "The provided N-deposition data will cover both land and ocean". This looks like the preferred option – is there a reference to the model that will produce these fields, and the scenario used for the future?

We have made this more explicit that the forcing for the CMIP6 scenarios will be provided elsewhere (and linked via the forcings web page as above). For C4MIP we only create our own idealised profile based on these spatial patterns.

I wouldn't want to slow this paper down, so only if the authors have the time. But it would be helpful – especially for people coming to parts of the Earth System they are unfamiliar with – if all variables could have their units specified (e.g. myself, more familiar with the land surface, so units would help me better understand Figure 13). It could also avoid confusion when the CMIP5 .nc files are built – e.g. are flux units best saved as: /sec, /day or /hour.

Thanks we will mention units where appropriate, but more importantly will cite the CMIP data request where all details (such as CF-NetCDF names, definitions and units) can be found:

the WGCM Infrastructure Panel; https://www.earthsystemcog.org/projects/wip/

Small things

Some extra keywords might help. "Global Carbon Cycle", "Climate Change", "Nitrogen Cycle"…

OK. We added "Global Carbon Cycle", "Climate Change". We felt that the paper was not explicitly about the global nitrogen cycle (any more than it is ocean ecosystems, permafrost, tropical forests etc etc) so we just added these two which apply generally to the whole of C4MIP.

P6, top line – give the webaddress as a reference to the COP21 meeting.

https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf

OK. Done.

Page 7, line 14. What is the difference between B and beta - and similarly between the two gammas.

These refer to either FLUX or STORE definitions of the feedback terms (the former from Friedlingstein et al. and the latter from Arora et al.). In fact the symbols are not required for the text and we have removed them to avoid this confusion.

Page 7. Is there a reference to the 1pctCO2 experiment. Or state that this is a cumulative increase – i.e. 1% per annum, year on year. Correct?

Correct, yes. We now cite Eyring et al CMIP6 paper

Page 7, line 23. Typo: "provides"

Thanks - corrected

P8, line 25. Is there any merit in mentioning that there are now a few Earth Observing datasets that can help constraint terrestrial land-atmospheric CO_2 fluxes? (MODIS I think, for NPP?).

We provide some example of datasets (both EO and ground-based), but can't list them all. This specific product is itself a numerical model to transform satellite radiances into an estimate of NPP, so we choose not to mention it explicitly.

Page 9, line 12. If we knew the fluxes well, and the residence times, then wouldn't that also give us the stores?

Yes, that's absolutely true, and is what we were trying to express – models have been evaluated well for fluxes but not residence times and hence the stocks are not constrained, so we need to step up and do both. The text has been clarified in this regard:

"In addition, consideration of residence times is crucial, which together with carbon fluxes jointly determine the stores."

Page 9, paragraph on carbon-14 from nuclear weapons testing. I guess we know the magnitude and timing of the drivers of these well enough to make the simulations, given the secrecy of the cold war? Otherwise, we could suggest a detection-attribution style study is needed. So a bit like inclusion of volcanic eruptions in and D&A analysis.

We have clarified that we are only requesting carbon isotopes be simulated in land and ocean model components. We are not requesting that models run carbon-14 or carbon-13 in emission-driven mode to simulate atmospheric D14C and d13C. We will provide atmospheric D14C and d13C forcing, which is well constrained by observations including tree rings, ice cores and direct measurements for 1850-2014. For future scenarios, we will provide atmospheric D14C and d13C forcing using a simple carbon cycle model following Graven, PNAS, 2015. Thus, the isotopes will primarily serve to provide tracers for the land and ocean components of the ESMs.

The reviewer is correct that one of the inputs needed for carbon cycle models to simulate atmospheric D14C is the production of carbon-14 from nuclear weapons testing. Bomb carbon-14 production has been estimated by Naegler, T., and I. Levin (2006), Closing the global radiocarbon budget 1945–2005, J. Geophys. Res.

We have revised the text on p9 to avoid confusion, and clarified the type of forcing for carbon-14 later in the document the specifications for isotopes.

P10. Is there a land surface MIP, that might mirror OMIP?

Good point – yes there is a land surface MIP called LS3MIP and an activity of the Global Carbon Project called TRENDY. Both focus on offline land-surface models, and the latter specifically on carbon. We cite them both here.

P21, line 23 – typo – extra white space

thanks. removed

P23, line 15, type – "described".

Thanks. Corrected

Figure 5. What is the top-left box "(co2)"?

This refers to atmospheric CO2 concentration. Whilst not a land-carbon pool, it is relevant here because we require it to be reported from the emissions-driven runs. The caption is updated to explain this.

Figure 5. The line from the main box to "cProduct" (for products, e.g. "furniture") comes from cLitter. Shouldn't that box be linked to cVeg? The IKEA bookcases in my flat, they look like they were built from trees ("cVeg"), rather than their litterfall!

Thanks. The figure is re-drawn to improve clarity. We were disappointed to hear that the reviewer has IKEA bookcases and not an antique Chippendale writing desk.

Page 26, line12. Is there a reason why the fast, medium and slow definitions were not used by the community, if this is actually the way carbon passes through separate pools?

We don't know why these were not well used, but now we request a finer breakdown of carbon pools from soil carbon models to avoid any ambiguities of re-classing them. See response to reviewer #2.

Could be problems with the toner in my printer, but for Figure 6, the brown, yellow and orange colours are difficult to differentiate between. Maybe use red, yellow, green (and blue) colours? (Similarly Fig 8)

Thanks. We agree it's important that these figures are clear both on screen and in print. We have darkened the brown arrows (now with white text) to improve the distinction. We have also passed these figures through a colour-blindness synthesiser to ensure they are accessible to anyone who may have difficulty with similar colours.

Maybe it's obvious, but "c" in variable names is for carbon pools and "f" for fluxes (e.g. Eqns on page 29). Might be worth just stating that.

Whilst not true of every variable (especially well known existing ones such as gpp) we have tried to do this for new ones. We have added mention of this:

"For ease of understanding we have adopted a convention for newly defined variables that a carbon pool is prefixed by a "c" (as in cVeg or cSoil) and a flux by an "f" (as in fLandToOcean). Some existing variables (e.g. gpp and npp) do not conform to this but are considered to be well known and do not need to be changed."

More importantly on notation, are all the names in the Equations – e.g. on page 25, 26, 28, 29 – these are the specific names that will be used on the CMIP6 database. This might be worth stressing if it is correct (so like "tas" is near-surface temperature in the CMIP5 database). That will aid 1-1 correspondence between the database and this manuscript.

Yes, this is the intention and we have checked through that this is the case.

As the quantities from this paper will be cited heavily, please use equation numbers at each point. I realise paper etiquette is to only number equations if they are explicitly cited in the main text, but here an exception could be made given the documentation implications of this paper.

Yes, this is a good idea and we have done so.

The paper style change slightly around p33, where the physical state variables are presented more in bullet-point format. OK?

These non-carbon variables are likely to be of more interest to other MIPs (notably LS3MIP) so we list them here for completeness but do not feel the same need for the detail given to the carbon cycle variables.

Conclusions. Although this is about the CMIP6 model setup and protocols, the paper is still also important in general terms, as it expresses current thinking in modelling climate and associated global geo-chemical cycles. Would it be appropriate to have a couple of sentences that outline what is still missing? So hinting at CMIP7. One key example might be the lack of a fully interactive methane cycle.

A fully interactive methane cycle would indeed be interesting, although this cuts across activities including C4MIP but also atmospheric chemistry (AerchemMIP). We have chosen to restrict discussion to CMIP6 advances – as CMIP7 is a very long way into the future. One MIP at a time!