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Interactive comment on "The C4MIP experimental protocol for CMIP6" *by* C. D. Jones et al.

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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

General

It might be worth mentioning directly that this paper partially addresses a frustration by

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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 CO2 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 CO2 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?.

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 CO2?

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".

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 CO2

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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).

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? 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.

Small things

Some extra keywords might help. “Global Carbon Cycle”, “Climate Change”, “Nitrogen Cycle”. . .

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

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

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

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?\

Page 7, line 23. Typo: “provides”

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 CO2 fluxes? (MODIS I

think, for NPP?).

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

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

P21, line 23 – typo – extra white space

P23, line 15, type – "described".

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

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!

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?

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)

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.

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.

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.

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

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.

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