

Interactive comment on “The global ocean circulation on a retrograde rotating earth” by V. Kamphuis et al.

Anonymous Referee #2

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General Comments

This paper presents a study of some of the factors contributing to the present day asymmetry between the Atlantic and Pacific in the presence or absence of a meridional overturning circulation. This is done by means of an AOGCM simulation where the direction of rotation of the Earth is reversed; the stability of the resulting overturning pattern is further analysed by means of an implicit ocean model. The idea behind this paper is thought-provoking and unusual, and the general quality of the write-up is good, so I'm definitely in favour of its publication. There are some issues that I feel should be addressed in a little more depth, however, as detailed below.

Specific Comments

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My main concern is the degree to which the results are robustly applicable to the real climate, rather than just the model used here. Model-dependence is, of course, an issue with pretty much any climate experiment, but it is an important one and I think it should be carefully discussed, especially when dealing with such an unfamiliar application of the model, as here. I should admit to being one of the authors of the "Reverse World" poster generously cited on pg2460 - given that the authors have read our poster, I'd like to make two comments:

minor) our poster stated quite clearly that the purpose of our experiments was to investigate the Atlantic/Pacific asymmetry of the MOC - as such, the sentence on line 7, pg 2460 as to context of our work is quite incorrect. Sorry to be pedantic!

major) we found very different results to those shown here. Given the, shall we say, rather idealised nature of the experiment, I doubt that there is any mileage in a debate about whose overturnings are "right", but the differences underline the fact that the primary findings of extreme experiments such as these need to be discussed very carefully in terms of the performance of the basic processes and biases present in the model before claiming that they are robust. For instance, how do the changes in E-P surface flux they see from the change in rotation compare to the mean model error in these fields compared to observation-based climatologies? Are there salinity or temperature biases in the surface ocean (again with respect to observations) that might make the Pacific more or less likely to overturn given a buoyancy forcing of a certain magnitude in their model? I found drawing robust conclusions from our experiments very difficult - this is one of the primary reasons our work was not written up more formally - but I'd welcome someone else having a go at it.

Given the issues of model dependence, I think there must be a bit of a question mark over whether the results of section 2 really are mapping the bifurcation behaviour of either CCSM3 or a real retrograde Earth climate. Additionally here, why is PRO2 forced from climatology, not CCSM3 boundary conditions to match RETRO2?

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The other bigish issue I'd like to raise is that the forcing of the MOC is only really described in any detail in terms of the local E-P balance. There are, of course, a number of other influences on the density budgets of the ocean. Ocean transport of salinity - split into overturning and gyre components as both the overturning and wind forcing of the ocean change - may be highly relevant, and are barely mentioned. The transport of salt from the Indian ocean into the Atlantic has been suggested by a number of authors (eg Weijer) as being important in determining the state of Atlantic overturning - this transport is reversed on a retrograde Earth. And, to add further insight to the E-P analysis that the authors have done, we found an analysis of the atmospheric transport of water across certain sections, compared to the local evaporative fluxes from the ocean, very helpful in our work in determining why the surface E-P forcing changed as it did. Preliminary work by some of the authors of our poster even suggested that major changes in freshwater runoff from land might play a crucial role.

Generalising this point, I'd personally like to see more analysis of the general climate of the RETRO run with CCSM3, especially the oscillatory behaviour of the AMOC. It seems a shame to have gone to the trouble of running such a complex model for a thousand years in such an unusual configuration and to only present such a small subset of the results. I'm all for experiments like this, if only out of curiosity and to provoke out-of-the-box thinking, and papers like this are a good way to get some interesting, fun results out into the community. Having said that, I may be letting my enthusiasm run away with me in suggesting rather too many things that the authors could/should look at!

On page 2459, line 11, I'm not sure I really understand the definitions of i) and ii), used as shorthand later - maybe they could be clearer? Is it that i) says that the MOC asymmetry can *only* be as it is due to external forcings, whilst ii) says that the external forcings are weaker, implying a preferred state, but other states are possible too? In i), is the surface freshwater flux not partly a function of the ocean circulation? This experiment clearly doesn't reverse *all* the external forcing asymmetries between

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the Pacific and Atlantic - the basin widths, for example, remain constant. Have I misunderstood the authors' definition of "external forcing"?

as a final general point, I thought that the first three paragraphs of the intro were rather too sparingly referenced.

Technical Corrections

The statement, used in the abstract and repeated throughout, that the "North Atlantic is a basin with net evaporation" requires, I think, a clearer definition of the region the authors are referring to. Whilst its certainly true of the Atlantic as a whole, and that the E-P balance is more positive in the Atlantic than the Pacific, the Atlantic north of about 30N or so has net precipitation, I think.

page 2456, line 22: "extend" should be 'extent of'

page 2459, line 21: "to try falsify" should be 'to try to falsify'

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