Earth Syst. Dynam. Discuss.,
https://doi.org/10.5194/esd-2020-83-RC2, 2021

Earth System Dynamics
Discussions
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Interactive comment on "Labrador Sea sub-surface density as a precursor of multi-decadal variability in the North Atlantic: a multi-model study" *by* Pablo Ortega et al.

Anonymous Referee #2

Received and published: 4 January 2021

Variations of the Atlantic Meridional Overturning Circulation (AMOC) and the associated meridional heat and fresh water transports are an important driver of climate variability in the North Atlantic region and beyond. They are also thought to provide a source of predictability on decadal time scales. Previous studies have described mechanisms behind this variability often focusing on the source regions of North Atlantic Deep Waters. The authors describe the AMOC characteristics of about 20 CMIP5 models, most of them at resolutions in the ocean models of 0.5 to 1 degree, and two coupled models using an eddy-permitting ocean grid. They relate AMOC variability in the sub-polar and sub-tropical Atlantic to density changes in the Labrador Sea (LS). Such a connection has been invoked in several earlier studies, but the merit of this

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Discussion paper

manuscript is that they provide an investigation in a multi-model context. They concentrate on the buoyancy-driven part of the overturning circulation and use long pre-industrial control simulations to provide statistically sound results. A striking result is that there is a high degree of coherence in the models (at least in this specific class of models) regarding the relation between the LS density structure and the sub-polar North Atlantic circulation. Even the corresponding relation to the lower latitudes is still quite robust, even though model differences lead to different strengths of the correlations. The study itself and the individual analyses are well thought-through and the text describes adequately the results presented in the figures. Apart for sharing the critique of the first reviewer on missing discussions of some important previous papers (I would also include, for example, Delworth and Zeng (2016) where the mechanisms are nicely described), I feel that the authors overstate a bit the robustness of the "observational constraints". For example, given the results of Jackson et al. (2019), I don't think that the numbers of AMOC strength from DePreSys (used in figure 8) are any better than the zoo of results provided in that paper. Other than that, I have only some more minor issues that I would like to see corrected or commented (see below). Therefore, I recommend publication after minor revisions.

Specific comments: Abstract, ln 27: Given all the uncertainties that the authors discuss themselves, I recommend not to end the abstract with this statement.

Experiments: Ln 134 ff: I suggest to discuss already here why you have chosen the piControl runs and not the historical simulations (I assume to have better statistic in the long runs). This needs to be justified as several studies have pointed to the forced component of the AMOC and AMV in the 20th century.

ln 140: which of the MPI models? Ln 141: there is no IPSL model in table 1

Ln 155 ff: EN4 should be introduced here and not in a half sentence when it is first used.

Labrador sea density: Ln 196 ff (Figure 1 b): it is interesting that some models show

very cold temperatures near the bottom. Is this originating from the overflows? Are these models specifically good in representing the overflows or include a parameterisations (CESM)? Do these differences matter in the later analyses?

Figure 1 a: I suggest to use a more intuitive and color-blind friendlier color map.

Figure 2b: it is not immediately clear that the orange and red curves belong together (one might think they are from MRI as in the previous figure), the thick green looks more like black in my print-out.

Figure 3: why is the 10 year time scale highlighted?

Figure 4d: what is the difference between this and figure 6 a?

Ln 340ff: if you want to explain cooling or warming, shouldn't one look at heat transport divergence/convergence?

Ln 351: could it also be related to a dynamical spin-up or down due to variations in the horizontal density structure (e.g. Born et al, 2013).

Figure 8: If the DePreSys AMOC is so far off from RAPID, why should it give a good observational estimate at 45N?

The symbols here and in fig 9 are very hard to decipher, e.g. I can't see GC2 in 8b

Figure 9: caption: it is hard to see any green line. Is there an "and" missing between "assimilation run" and "EN4"?

Ln 410ff: could the DePreSys run help to define which depth level of the DWBC is most consistent with observations?

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