Reply to Anonymous Referee #2

Thank you for these constructive comments and suggestions that have enabled us to improve the manuscript. We have addressed all your comments and suggestions (repeated in boldface), as detailed below.

The term "Earth System Model" is currently being used to describe a wide range of models (e.g. EMICS). As defined for the CMIP5 experimental design, Earth System Models (ESMs) are defined as having a closed carbon cycle (Taylor et al., 2012). It may be worth noting this distinction in the title (e.g. Part 1 - Description and basic evaluation of the physical climate).

We agree to this suggested clarification of the title and will change it accordingly.

The authors note that NorESM1-M differs from CCSM4 by inclusion of advanced schemes for chemistry/aerosol/cloud/radiation interactions, as well as using an isopycnal ocean. In a comparison of two ESMs which are identical except for the ocean component (depth-based versus isopycnal), Dunne et al., (2012) found that the ESM with an isopycnal ocean has a shallower and less-ventilated thermocline, weaker ENSO, and shallower mixing and mode water formation. While detailed analysis/comparison to CCSM4 may not be possible here, consider adding a few comments on the strengths and weakness of using an isopycnal ocean versus a depth-based ocean model, and what aspects of physical climate were improved as a result.

We do not at the moment have twin experiments available where we can properly diagnose the impact of replacing the NorESM isopycnic ocean component with POP2, the CCSM4 *z*-coordinate ocean component. NCAR's CMIP5 experiments are run with a higher resolution atmosphere component without indirect effect of aerosols and are therefore not suitable for direct comparisons with NorESM. In the first paragraph of section 2.4, describing the ocean component, there are some general remarks about generally accepted advantages of using an isopycnal model: "The main motivation is to exploit the fact that isopycnic surfaces are a good approximation to neutral surfaces in regions of the ocean. Thus, there is a potential to formulate a numerical model with accurate transport and mixing along isopycnals and complete control of the diapycnal mixing applied". As a follow-up to this statement, we certainly think it is useful to discuss aspect of the NorESM results in relation to the findings of Dunne et al. (2012). Thus, we propose to add a paragraph at the end of section 5.5 discussing the apparent shallow thermocline depth in NorESM:

"The cold bias in the depth range 200-1000 m seen in Fig. 14a,b indicates that the thermocline depth in NorESM is shallower than in observations. According to Munk (1966) this would on the global scale indicate either too strong upwelling, balanced by excessive deep water formation, or too week diapycnal mixing. Both Megann et al. (2010) and Dunne et al. (2012) compare climate model experiments that only differ in the choice of ocean components, which is either a *z*-coordinate model or a model with interior isopycnic layers, the latter of similar type of that used in NorESM. Both comparisons indicate a shallower than observed thermocline depth with isopynal models and deeper than observed depth with *z*-coordinate models. This is attributed to less diapycnal mixing in the isopycnic models compared to the *z*-coordinate models. Although NorESM share this thermocline depth bias with other climate models featuring isopycnic ocean components, it is not clear that unrealistic week diapycnal mixing is causing the shallow thermocline depth in NorESM since in particular the strong AMOC might contribute to excessive deep water formation."

The added references are:

Dunne, J. P., John, J. G., Adcroft, A. J., Griffies, S. M., Hallberg, R. W., Shevliakova, E., Stouffer, R. J., Cooke, W., Dunne, K. A., Harrison, M. J., Krasting, J. P., Malyshev, S. L., Milly, P. C. D., Phillipps, P. J., Sentman, L. T., Samuels, B. L., Spelman, M. J., Winton, M., Wittenberg, A. T., and Zadeh, N.: GFDLs ESM2 Global Coupled Climate Carbon Earth System Models. Part I: Physical Formulation and Baseline Simulation Characteristics, J. Climate, 25, 6646–6665, doi:10.1175/JCLI-D-11-00560.1, 2012.

Megann, A. P., New, A. L., Blaker, A. T., and Sinha, B.: The Sensitivity of a Coupled Climate Model to Its Ocean Component, J. Climate, 23, 5126–5150, doi:10.1175/2010JCLI3394.1, 2010.

Munk, W. H.: Abyssal recipes, Deep-Sea Res., 13, 707–730, 1966.

Page 2848, lines 1-2: suggest changing "which both were also used" to "which were both also used".

We will follow this suggestion.

Page 2848, line 7: insert "of" between "resolution" and "1.9o" and change "times" to "by".

These suggestions will be taken into account.

Page 2848, line 10: insert "that" between "double" and "of".

This suggestion will be followed.

Page 2848, line 25: consider citing IPCC AR4 estimate of change in indirect radiative forcing.

We suggest to replace the sentence that mention the AR4 estimate by: "These values are closer to the estimate by the IPCC fourth assessment report (AR4) of −0.7 [−1.1,+0.4] W m^{-2} (only cloud albedo effect; Forster et al., 2007) than the previous estimate in CAM-Oslo of −1.9 W m^{-2} by Hoose et al. (2009)."

Page 2848, line 26: consider changing "Much thanks" to "Due".

We will follow this suggestion.

Page 2887, line 17: change "refereed" to "referred".

This will be corrected.

Some of the figures (e.g. Figs 3, 4, 5, 6, 7, 8, 9, 13, 14, 15, 19, 25, 26) could benefit from the addition of short labels/titles at the top of the panels to visually aid the reader without reference to figure caption.

We will add short labels/titles on figures with more than 2 panels.

Figures 5 and 6: As noted by referee #1, these figures could be merged. Additionally, since all the figures use the same vertical scale, consider using only once color bar e.g. at

the bottom of the figures.

As noted in the reply to the comments of referee #1 we will combine Figs. 5 and 6. With the introduction of a difference map, another color bar is now present in the figure. Thus, vertical color bars will be combined between side-by-side panels (see the figure in the reply to referee #1).

Figure 7: consider shifting so that longitudes start at 180W.

We will shift the longitudes so that the displayed range is [180W,180E].

Figure 19: consider using one color bar as vertical scale is the same for both panels.

We will use one common color bar in Fig. 19.