

## ***Interactive comment on “Variability of the ocean heat content during the last millennium – an assessment with the ECHO-g Model” by P. Ortega et al.***

**Anonymous Referee #3**

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This paper addresses an important topic in the broader arena of global climate change: namely ocean heat content and particularly through the past 1000 yrs. It is an area that we need more contributions, and to this end this work can make a contribution.

However, I found the paper to be lacking in a couple of areas that need to be revised (some major and then also some more minor) before being suitable for publication.

My primary concern with this paper lies in using a model (ECHO-G) that has applied heat and freshwater flux adjustments based on current observations (Levitus) and on a very short time scale (30 days) – at least according to Ortega et al, 2012 (OR12 in the paper) to 1100 yr runs that simulate the Last Millennium and 100 yrs in the

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future. The flux adjustments to late-20th Century and on short time scales suggest that changes and variability in ocean heat content due to forcings of the past 1000 yrs will be strongly constrained by this rather than sufficiently allowed to vary in a manner that can truly increase our understanding of ocean heat content during this time frame. Without discussion, explanation (or a clearer one than is presented?) and analysis of the effects of the constraints on ocean heat and ocean heat variability (and substantial drifts!) from the heat and freshwater flux adjustments to modern times (which appear to be SST and salinity relaxations?) on longer simulations, it is not possible to adequately evaluate the scientific results of this paper.

Another, albeit smaller, concern are inconsistencies w.r.t. choices of which simulations to use for comparison, which ones to extend, how long to extend, etc. For example, observations from the 20th century from 1955-2010 are used, but both runs over the historical period only go to 1990 whereupon “future scenarios” are used. Then FOR1 is extended to 2000 (why not 2010?) – and yet it is FOR2 that is used for analysis of the Last Millennium (so why not extend FOR2 for historical time frame too)? And what indeed do the scenarios A2 and B2 represent? These are relatively minor (compared to above issue), however they are confusing and an explanation of why the choices were made (and of the scenarios A2 and B2 so that one doesn’t have to go to references to find out what they represent) would help.

## Specific comments:

p. 4227 Line 7: does the HOPE-G ocean model include an ice model? How is sea ice simulated? Or is it? Lines 7-14: What effects do the model resolutions have on heat and freshwater fluxes as well as heat content (or mixing and sub-grid scale parameterizations)?

pp. 4227-4228, Lines 25-Lines 7: The forcings over the Last Millennium and the next century are sufficiently important to this paper to put in a figure so that the reader can refer to them immediately rather than look them up in another paper. If, due to

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constraints on space, etc. require that a figure on the forcings is not included, referring to them as shown in Figures 8-9 as well as a sentence or two describing the basic premise of the scenarios (A2 and B2) will help (e.g. “high emissions” or “low emissions” or some description giving at least an idea of what these scenarios represent). This is particularly important as the simulations using current conditions stop at 1990 (21 yrs ago) and it’s not at all clear which scenario (A2 or B2) most closely resemble a continuation at least of historical conditions.

p. 4230 Lines 17-20: How exactly where the % of variance explained by forcings calculated? Perhaps easily explained in a “methods” section?

p. 4231 Lines 2-15: Linear trends in OCH estimated from observations (discussed here and shown in Figure 2) have stronger zonal gradients than simulations. Any ideas why? Likewise, there appear to be large discrepancies between obs and simulated OCH trends in the North Atlantic in regions of deep water formation – add a bit of discussion here (why, etc.) – not just AMO.. The 1990s, in particular, have a large increase in AMOC in observations, decreases in temperature in the subpolar gyre, and corresponding changes in circulation (e.g. Levitus, 1990; M. K. Flatau, L. Talley and P. N. Niiler, 2003, J. Climate 16; Hakkinen and Rhines, 2004, Science 23). These may be part of natural variability rather than trends...so some discussion please.

p. 4235, line 24: Figure 6 shows insignificant cooling in Weddell Sea but large and significant warming(cooling) in Amundsen (Ross) seas (respectively).

p. 4237, lines 1-3: largest values in the Southern Ocean are in the Ross Sea region, NOT the Weddell Sea (generally thought of as an area of deep water formation). Where in the ECHO-G model in the Southern Ocean is deep water formed/ convection? Also, only net surface ocean cooling that appears to be significant (from the figures) in the Southern Ocean is in very small geographic areas near the Ross sea. . .

p. 4239, lines 19-24: Is the AMO detrended but not the PDO? Do you apply a linear detrending to the AMO after removing global signal (and thus really detrend 2x – which

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doesn't make sense particularly over a short – 55 yr – time frame)

There is no discussion about teleconnections between ENSO and Southern Hemisphere surface temperatures, sea ice, etc. (and the classic dipole pattern is partly observed in Figure 11 a but either not present or obscured by the "obs" label in the bottom right of the plot) suggested in obs. OHC (and suggested by Figure 11a) but either not reproduced in simulations (Fig 11b) or possibly suggested but a bit too far north (Figure 12a). These teleconnections between ENSO and Southern Ocean appear robust in obs – some discussion is merited here, including an overview of the models ENSO performance. p. 4241-4242, line 29-line3: This is an important result and should be supported by a Figure in which one can actually tell which way the arrows are pointing, or another way of showing this (see comment below on Figures 8, 9, 14).

Technical comments:

p. 4224: Line 7: "later" not "latter" and delete "on" Line 19: remove "Besides" (doesn't make sense)

p. 4229 line 19: verb tense – "concern" not "concerning"

p. 4237, line 17: "Besides" doesn't make sense... "In addition" or remove

p. 4240, line 24: Eliminate "besides"

Figures: Fig. 8 What "horizontal dotted line"? I can't see one or find one... Figures 8, 9, 14: The "arrows" are very difficult to see and in some regions impossible to tell the direction they point. I suggest either eliminating them entirely (they do not clearly support conclusions as they are not visible or understandable).

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Interactive comment on Clim. Past Discuss., 8, 4223, 2012.

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8, C2014–C2017, 2012

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