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Earth System Dynamics
Discussions

Interactive comment on "Effect of changing ocean circulation on deep ocean temperature in the last millennium" *by* Jeemijn Scheen and Thomas F. Stocker

Anonymous Referee #2

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This paper analyzes the effect of ocean circulation changes on the transfer of surface temperature anomalies to the deep ocean on time scales of centuries to millennia. It is motivated by an earlier study of Gebbie and Huybers (GH19, see references), which was based on a model with constant ocean circulation as inferred from modern observations by inversion. This is an important question for understanding deep ocean climate evolution, but has also consequences beyond that, for example, how important is this history for the initialization of "historical" simulations.

Scheen and Stocker apply first a coupled model of intermediate complexity under idealized radiative forcing to derive surface conditions that mimic the transition to and from

the Little Ice Age towards modern global warming and beyond. Then they run ocean-only experiments driven by the surface conditions from the coupled model discriminating between simulations with fixed circulation and free currents. The experimental set-up is well designed and illustrates the long-term behavior of temperature trends at depth in the deep ocean. They find that circulation changes do play a role and may lead to quite different results from GH19. The authors provide some sensitivity studies to explore parameter uncertainty. Thus the tools are quite adequate and they are used in a clever and novel way.

The manuscript is written concisely and brings the message across. The abstract provides a good summary. The material and figures are illustrative to support the hypothesis. I find the paper quite convincing but suggest that the authors discuss a bit more the possible shortcomings of their approach.

In conclusion, I recommend to accept the manuscript after minor revisions.

General comments:

The authors describe that the coupled model is run to equilibrium and then the ocean only model is run "using steady state SST and SSS". Are there other drivers of the ocean model, e.g. momentum flux from the coupled model, or are winds and /or other fluxes prescribed externally?

If I understand correctly, the authors can in this set-up only study the effect of density changes on the circulation and the resulting feedback on temperature and salinity transfers. But in the "real" world of the last millennium, for example strong volcanic eruptions may have changed the dynamics of ocean and atmosphere for decades to centuries. It should be mentioned that such effects are not included here.

How different are the circulation and simulated features in the coupled simulation, compared to the ocean stand-alone run? Is the AMOC or meridional heat transport history similar? A large part of the finding depends on the history of the AMOC in the model.

The AMOC slightly strengthens during the LIA cooling and then weakens under modern warming. Does this mean that the cooling/warming drives the AMOC in this model? One could also assume that the cold surface conditions in the LIA North Atlantic were a result of weak AMOC and slow heat transports as has been put forward by many authors. Would the findings of this study still hold?

It is said that "simulations with fixed ocean circulation are implemented by using diagnosed values at every grid-point from the steady state". Which variables are used, only horizontal velocities, or also diffusion/mixing coefficients?

Minor issues:

Ln 73: :idealized forcing: was the forcing tuned in this way to get the desired SST time series to be similar to GH19 or is it based on estimates how the radiative forcing actually changed?

Ln 107: "at every grid cell are set to a latitude-longitude field": this is very unclear.

Ln 219: Was the Winton experiment a 1% CO_2 increase per year experiment?

Ln 221: should be: "column integrated heat content per unit area"

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