Geosci. Model Dev. Discuss., 6, C2178–C2181, 2013
www.geosci-model-dev-discuss.net/6/C2178/2013/

Geoscientific Model Development Discussions
Open Access

Interactive comment on "Can sparse proxy data constrain the strength of the Atlantic meridional overturning circulation?" *by* T. Kurahashi-Nakamura et al.

T. Kurahashi-Nakamura et al.

tkurahashi@marum.de

Received and published: 13 December 2013

We appreciate the reviewer's constructive review and insightful comments.

Q) One is left wondering whether the issues with the reconstructions arise from proxy data uncertainties, the assimilation method, the sampling locations, or with using the AMOC as the goal metric.

A) In the revised manuscript we will add some analyses and explanation to give a more consistent interpretation and more insight to the experiments. The outline will be:

- In all experiments for both Target 1 and 2, very strong vertical mixing occurs in the

N-ATL at the beginning of the optimization runs, because there is an adjustment of the model SST to the much colder target SST (i.e., denser water).

- For Target 1 the point is how to recover from the "initial shock". Without deep-ocean data the lighter (warmer) deep water of the reference ocean tends to remain, causing continued mixing.

- For Target 2 the warmer deep water of the reference helps to maintain the strong mixing. However, without any salinity constraints, the surface water becomes too light (too fresh) because the colder SST there leads to less evaporation.

This analysis suggests that the sampling locations would matter irrespective of the data uncertainty with respect to predicting (at least) the direction of AMOC change. Also we will add one column to Table 1 (also see below) to present the mean cost (i.e., cost function divided by the number of model-data comparisons), which shows that the data-fitting itself is successful.

Q) I would recommend trying to better explain the results from knowledge of the AMOC dynamical sensitivity

A) We appreciate the reviewer's suggestion. Along with a new interpretation above, we will add a discussion based on the AMOC dynamical sensitivity, which will be also useful for the next question below.

Q) One thing that the manuscript would definitely benefit from is a clarification as to why the addition of data sometimes makes the fit worse, even if that data has small uncertainty (e.g. comparing E1-7 with E1-8).

A) The difference between E1-7 and E1-8 comes from the difference of T, S, and MLD in the ocean at depths shallower than 500 m that has almost no data points (see Fig.3 of the manuscript). This result implies the importance of data at such depths, even though the convection of the target can be roughly reconstructed from surface information.

GMDD

6, C2178–C2181, 2013

We will add some explanations to the revised manuscript.

Q) the fact that deriving the target from the same model as is used for the reconstruction neglects model error. (could go at the end of the introduction section)

A) Because we used physical configurations or parameters for the targets different from those used for the initial guess, and because they are not included in the control factors or variables, the model (in the context of the state estimate) is imperfect and in this sense we in fact include model error. We report an identical twin experiment, where only the only control parameters are the varied parameters for targets, ie. viscosity. This experiment just gives confidence that the system works in the case of a perfect model. We deliberately changed the model physics, albeit slightly, in order to mimic the more difficult but realistic problem of an imperfect model. It is true that the method of strong constraints implies that we do not allow for a formal error of the model, ie. the model equations are taken as exact: $Ax = b$, as opposed to a weak constraint model $Ax-b = n$, where there is room for model uncertainty. Our system is "mixed" in the sense that the internal model dynamics are strong constraints and there is no residual error n, but surface and initial conditions are enforced in a weak sense. One important aspect of our experiments is how good the state estimation works in spite of this imperfectness.

We will modify the manuscript to clarify and emphasise these points.

Q) the fact that the resolution is very coarse, especially in the vertical. How does this effect the problem, especially given the fact that the authors highlight the sensitivity to MLD?

A) First, we should emphasise that the coarse resolution has the great advantage of low computational cost and relatively few degrees of freedom (especially given the apparently scarce data). Besides, the low resolution should not be a serious problem as long as we use artificial targets from the same model with the same resolution. However, when we try to fit real proxy data, this may not be so straightforward, neither

GMDD
6, C2178–C2181, 2013

for the MLD reconstruction nor for the correspondence between the model depth and the data depth. It will be a trade-off between the advantages.

We will add some description about this problem to the manuscript.

Q) the timing intervals chosen (i.e. a 20 year run with the objective function assessing the mean over the last 10 years). Is this an appropriate interval for the time-scales of the AMOC?

A) Although we have to admit that the 20-year interval is not long enough to ensure a steady state as already discussed in the manuscript, in our experiments the adjustment of the AMOC strength is very fast; it typically occurs in the first 10 years of a 20-year experiment. This is plausible also from the time scale of sensitivity propagation of the AMOC shown by Heimbach et al. (2011). Therefore, we believe that the time interval is sufficient for estimating the change of the AMOC strength.

We will add some sentences about this to the Conclusions section.

Q) Section 4.2 line 28 and 29. I disagree that it was difficult to pull the model as the optimized AMOC varied in strength from 14 to 44Sv.

A) We rephrase this sentence and replaced "pull" with "guide the model properly"

Interactive comment on Geosci. Model Dev. Discuss., 6, 4417, 2013.