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Interactive comment on "MetUM-GOML: a near-globally coupled atmosphere–ocean-mixed-layer model" *by* L. C. Hirons et al.

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One aspect, in which the paper can be improved significantly, would be additional comparison with a simulation using the AGCM coupled to a slab mixed layer ocean model, in addition to the comparisons with the atmosphere only simulations. As the authors discussed in the introduction, the AGCM-slab ocean configuration is the most often used experimental design as the intermediate step between the AGCM-only and fully coupled configurations, and the most relevant one to the new MetUM-GOML. Therefore, it would be helpful for the future potential users to demonstrate the advantage of using MetUM-GOML over the AGCM-slab ocean.

It is true that the introduction in section 1.2 discusses slab ocean models as an intermediate step between fully coupled AOGCMs and AGCM-only models and that mixed-layer vs. slab comparisons could be potentially interesting.

Therefore, the discussion of slab ocean models in section 1.2 and the advantages of using the MetUM-GOML configuration over the AGCM-slab ocean model in section 1.3 have been modified and extended considerably. These sections now discuss the benefits of having a vertically resolved upper-ocean on the representation of variability (e.g., in the tropics for the MJO; Woolnough et al. (2007), Klingaman et al. (2011), Tseng et al. (2014)). They also discuss a further advantage of a mixed-layer over a slab ocean configuration: that within a mixed-layer configuration, temperature and salinity anomalies can be stored below the mixed layer and re-emerge in subsequent seasons as SST anomalies in the extra-tropics which can affect the atmospheric circulation (e.g., in the North Atlantic; Bhatt et al. (1998), Alexander et al. (2000), Cassou et al. (2007)). These advantages of the mixed-layer MetUM-GOML configuration over the intermediate AGCM-slab ocean experiment have been made clearer in the discussion.

These sections now also discuss the known sensitivities within a slab-coupled model configuration to the slab depth. For example, the representation of intraseasonal precipitation variability and propagation speed of the MJO have been shown to be very sensitive to the choice of slab depth (Maloney and Sobel (2004),Watterson(2002)). Given that the variability in the slab-coupled model can be tuned by varying its depth, it is not clear how to make a fair comparison between a slab and a vertically resolved ocean. This would certainly not be possible with a single slab configuration.

Therefore, because we already know that vertical resolution in the ocean is better than a slab and because it is non-trivial to fairly compare a slab and a vertically resolved ocean given the above-mentioned sensitivities to the slab depth, we believe further comparisons with AGCM-slab ocean configurations of the MetUM are beyond the scope of this particular study.

Overall, I recommend a minor revision of the manuscript. Additional comments are included below.

1. L.179-185, L6, L789: While the MetUM-GOML configuration is not one of the most commonly used types in climate modeling, it is not the first model with the full AGCM coupled to the 1-D multi-layer ocean mixed layer model. Please refer to the following papers for the similar previous experiments:

Bhatt, U.S., M.A. Alexander, D.S. Battisti, D.D. Houghton, and L.M. Keller, 1998: Atmosphere–Ocean Interaction in the North Atlantic: Near-Surface Climate Variability. J. Climate, 11, 1615–1632.

Alexander, M. A., J. D. Scott, and C. Deser, 2000: Processes that influence sea surface temperature and ocean mixed layer depth variability in a coupled model. J. Geophys. Res., 105, 16823–16842.

Alexander, M.A., I. Bladé, M. Newman, J.R. Lanzante, N.-C. Lau, and J.D. Scott, 2002: The Atmospheric Bridge: The Influence of ENSO Teleconnections on Air–Sea Interaction over the Global Oceans. J. Climate, 15, 2205–2231

Cassou, C., C. Deser, and M.A. Alexander, 2007: Investigating the Impact of Reemerging Sea Surface Temperature Anomalies on the Winter Atmospheric Circulation over the North Atlantic. J. Climate, 20, 3510–3526.

Kwon, Y.-O., C. Deser, and C. Cassou, 2011: Coupled atmosphere–mixed layer ocean response to ocean heat flux convergence along the Kuroshio Current Extension. Climate Dyn., 36:11-12, 2295-2312.

The authors acknowledge that this is not the first model using a full AGCM coupled to a 1-D mixed-layer ocean model. All of the above papers are configurations coupling the NCAR Community Atmosphere Model (CAM) version 2 to a one-dimensional ocean model developed by Gaspar (1988) and the authors are aware of them.

In the beginning of section 1.2 “widely used” has been added to the description of

current approaches to climate modelling to reflect the comment that there are others. At the start of section 1.3 the gap in modelling capability is referring to the “widely used” approaches outlined in section 1.2. This has been clarified in the text. Further to this, the CAM2 mixed-layer ocean configuration has been explicitly mentioned in section 1.3 with reference to the studies mentioned above. The point is made, however, that there are only a handful of such studies and that they do not typically use a contemporary AGCM. Until now, there is no existing mixed-layer (or slab) coupled model configuration of the MetUM.

Incidentally, current work by one of the authors, Nick Klingaman, has involved coupling the MC-KPP mixed-layer model to a more recent version of the NCAR CAM model. It will be interesting to compare these simulations with the existing studies which are highlighted here.

Additionally, a number of these references have been added to the discussion in sections 1.2 in relation to the advantage of a mixed-layer over a slab coupled model configuration. Specifically in the ability within a mixed-layer ocean model to store anomalies below the mixed-layer depth which can later re-emerge as SST anomalies in subsequent seasons and affect the atmospheric circulation.

2. Figure 1 caption: Please explain which observational dataset is used to calculate the model biases.

In Figure 1 in the caption and subtitles it has been made clear that the bias is calculated relative to the Met Office ocean analysis of Smith and Murphy 2007.

3. L388-391: Please discuss a bit more detail on the sensitivity of the model simulation to the choice of the relaxation time scale, e.g. how the results change from 5-day to 90-day time scale, or what objective measure is used to determine the time scale.

We tested 5-day, 15-day, 30-day and 90-day timescales. The 15-day timescale produced the smallest SST biases in the free-running coupled simulation, so we chose *that timescale for the simulations presented in this study. Longer timescales produced stronger SST biases since the relaxation was too weak to counter the SST drift in the forced simulation, which arises from the lack of ocean dynamics and biases in atmospheric surface fluxes. The 5-day relaxation timescale is analogous to forcing the atmospheric model with climatological SSTs. In the relaxation simulation, the atmospheric surface fluxes did not adequately adjust to the presence of coupling. This led to a substantial difference between the surface-flux climatologies of the free-running simulation and the relaxation simulation, for which the temperature and salinity tendencies could not correct, and hence larger SST biases than the simulation in which we used a 15-day relaxation.*

Text has been added to section 2.2 in the model description to give more detail about what objective measures were used to determine the preferred timescale.

4. L423-424: Please briefly explain why the 31-day smoothing is applied.

The A-K31 experiment is designed to mimic the AMIP-style setup of forcing the atmospheric model with monthly-mean SSTs. In this case a 31-day running mean was applied because it produces a smoother SST timeseries than interpolating monthly means to daily values. This has been clarified and added to the text in the description of the experimental setup in section 2.3.

5. Figures 3-5: It would be worth adding one more panel showing the MetUM-fully dynamical ocean (used in Fig. 1a) minus observation to compare with A-K31 minus observation, which will show the typical biases in a fully coupled model.

The authors partly accept the comment about showing the typical biases of the fully coupled version of the model, appropriate changes have been made to Figure 5 (see details below). However, the authors do not feel that adding such a comparison to Figures 3 and 4 would aid in the discussion presented here. The purpose of this manuscript is not to demonstrate that biases in the MetUM-GOML model configuration are larger or smaller than MetUM-NEMO - indeed some biases increase in magnitude

and some decrease, others are simply different – rather it is to investigate the role of air-sea interactions within a framework which has minimal effect on the mean state.

As suggested, a new panel has been added to Figure 5 to show the tropical precipitation bias of the MetUM-NEMO (MetUM coupled to a fully dynamical ocean model, as used in Fig.1a) compared with TRMM. A further panel has been added to show how the representation of tropical precipitation differs in A-K31 compared with MetUM-NEMO. In the case of tropical precipitation, the biases are of similar magnitude in A-K31 and MetUM-NEMO but exhibit different spatial structure. The different precipitation biases seen in Figure 5 are linked to the different SST biases between MetUM-GOML and MetUM-NEMO (Figure 1). Discussion has been added to the text to reflect this.

6. Figures 3-5, 7-9: Please test the statistical significance of the anomalies and discuss only when they are statistically significant.

The authors accept this comment and have tested the statistical significance of the anomalies shown in Figures 3-5 and 7-9 and made modifications to the figures and text accordingly, see details below.

In Figures 3 and 4 stippling indicates where the differences are significant at the 95% level. Figure 3a and 4a have also been changed such that the shading shows the bias following a comment by a separate reviewer.

Figure 5 has been modified such that only differences significant at the 95% level are shaded. Further panels have been added to Figure 5 to show the bias of the fully coupled MetUM-NEMO model compared with TRMM (Figure 5 (d)) and compared with the A-K31 (Figure 5 (b) ; following comment above). The relevant text has been changed accordingly. Additionally, a mistake in the JJA colour scales in Figure 5 panels (g) and (h) has also been corrected so that they are consistent with the colour scale shown on the multi-panel plot.

All changes in variance shown in Figures 7 and 9 and discussed in the manuscript are *significant at the 95% level.*

Stippling has been added to Figure 8 to show where the differences are significant at the 95% level.

7. Figure 6 caption: “interio-gravity” -> “inertio-gravity”

This change has been made to the figure caption.

8. Figure 8 caption: “130deg” -> “130degE”

This change has been made to the figure caption.

Interactive comment on Geosci. Model Dev. Discuss., 7, 6173, 2014.