Two-Tier MOM6 Regional Modelling Suite of the East Australian Current System

Point-by-point Author Response

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*RC refers to Reviewer Comment

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REVIEWER 1;

RC1.1 – Fair Comparison

1) Reviewer Comment
It is very difficult to make fair comparisons among three models: OM2-01(MOM5 0.1 degree global model), STHPAC10K(MOM6 0.1 degree large regional model), and EAC03K (MOM6 1/30 degree small regional model) because the model settings differ much among the three models. To properly assess the impact of a specific model setting, only the setting should be changed. Also, most results from EAC03K with the small domain appear to be largely

influenced by STHPAC10K. The comparisons between MOM5 and MOM6 by using OM2-01 with the global domain and STHPAC10K with the regional domain is also complicated. A large portion of the manuscript is devoted to the non-fair comparisons. If the authors would like to show how EAC03 simulated EAC region well, they should focus on the topic. Therefore, I recommend that the authors should rewrite the entire manuscript.

2) Author Response
We agree that isolating the impact of a specific model setting requires changing only one factor at a time. This principle is applied in the second half of the manuscript via controlled sensitivity tests within the 3km configuration. The first half, however, is not intended to as a "fair" attribution-style intercomparison; rather it provides contextual evaluation across two broad axes – *model framework* (MOM5 vs MOM6) and *resolution* within MOM6 – with observations used as an external reference. We will revise the Methods to make these objectives explicit. We also agree that dependence of EAC03K on the parent boundary forcing should be quantified; we have therefore completed an additional 3km simulation forced by OM2-01 boundaries and will include a targeted assessment of sensitivity to boundary forcing in the revised manuscript.

3) Author Changes
Part I – Fair Comparison:

We have added an introductory paragraph to the "Model Evaluation" subsection of the Methods (Line 215), clarifying the purpose of the intercomparison. The revised text now states explicitly that these comparisons are not intended as a controlled one-factor-at-a-time attribution of individual model settings, since the three configurations differ in multiple respects. Instead, the section is framed as a contextual evaluation as mentioned in the initial "Author Response" above. We also signpost the later sensitivity experiments as the part of the manuscript where individual parameter choices are isolated more directly.

Part II – Boundary Influence on Interior Solution

To assess Reviewer 1's concern regarding the influence of the parent model on EAC03K, we performed an additional 3 km simulation in which the open boundaries were taken directly from the global parent model (OM2-01), rather than from STHPAC10K as in the original configuration. In this short discussion, we refer to the original config as EAC03K-sthF, and the new config as EAC03K-om2F, reflecting the different boundary forcings. All other aspects of the 3 km setup were kept identical. This provides a targeted test of the sensitivity of EAC03K to its boundary forcing.

Figure 1 presents the results of this boundary-forcing comparison for sea surface temperature (SST) and sea surface height (SSH), showing the temporal mean, trend, and variance across the EAC domain. As in the manuscript, we show biases relative to observations rather than raw fields. Overall, the two 3 km simulations show very similar spatial patterns across all diagnostics, indicating that the principal structure of the EAC03K solution is not strongly altered by whether the boundaries are taken from STHPAC10K or OM2-01. Quantitative differences are present in some regions, particularly in the EAC Extension and off eastern Tasmania, where EAC03K-sthF exhibits a somewhat colder mean bias and stronger warming trend.

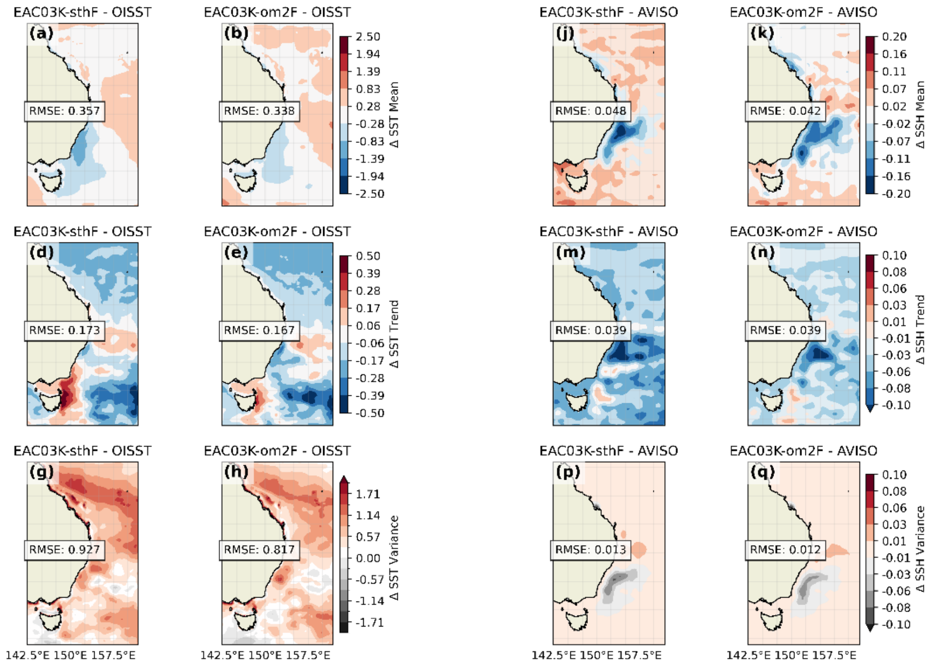

Figure 1. Surface biases relative to observations for SST (left) and SSH (right). First and third columns show biases from the STHPAC10K forced 3 km model (EAC03K-sthF), while second and fourth columns show biases from the OM2-01 forced 3 km model (EAC03K-om2F).

These differences are likely associated with differences in model adjustment associated with the initial state, rather than with a pervasive control of the EAC03K solution by the intermediate (STHPAC10K) model. This behaviour is also consistent with the slower adjustment noted in the manuscript (Fig. 10; around line 455).

The close similarity in the broader spatial bias structure between the two 3 km runs indicates that the main manuscript results are not simply inherited from STHPAC10K through the open boundaries, although the precise origin of these biases is beyond the scope of the present study. We therefore consider that this additional experiment does not support the suggestion made by Reviewer 1. Rather, it shows that while boundary forcing can affect the magnitude of some regional biases, the dominant spatial characteristics of the 3 km solution are robust to the choice of parent forcing.

RC1.2 – MLE Parameterisation

1) Reviewer Comment

I am not convinced that the parameterization of mixed layer eddies is implemented into 3km model. The model partially resolves submesoscales including mixed layer eddies as the author mentioned in the manuscript. The effect of the parameterization should be tested in the model at the coarser resolution that cannot resolve mixed layer eddies. Previous studies implemented the parameterization into the coarser models that do not resolve mixed layer eddies. Therefore, the authors should remove the sensitivity experiment of mixed layer eddy parameterization of 3km model.

2) Author Response
We would like to clarify that the MLE parameterisation is indeed active in the 3km configuration: when the parameterisation is switched off or its parameter value (frontal length scale) is varied, the model exhibits a clear change in behaviour, most notably in the long-term mean and variability of mixed-layer depth (consistent with the expected restratification effect). We agree that MLE parameterisations are typically evaluated in coarser, non-submesoscale-permitting models; however, the objective of this section is different – namely, to test whether the parameterisation remains necessary (or becomes largely redundant) at 3km resolution where submesoscale processes are partially resolved. We will revise the manuscript to make this objective explicit and to frame these experiments as a resolution-regime sensitivity test rather than a validation of MLE performance in a setting where its necessity is already established.

3) Author Changes
We have revised the manuscript in the MLE sensitivity subsection (~line 160) to clarify the purpose of these tests. In particular, we now state explicitly that the aim is not to evaluate the Fox-Kemper MLE parameterisation in the coarse-resolution regime for which it was originally developed, but rather to assess whether it remains influential in our 3km configuration, where submesoscale variability is becoming partially resolved. The revised text therefore reframes these experiments as a sensitivity test of the 3km solution to parameterised versus partially resolved mixed-layer restratification, and clarifies the motivation for varying $L_{f,\min}$ and disabling the scheme entirely.

REVIEWER 2;

RC2.1 – Mercator Grid specification

1) Reviewer Comment
All these models are on a Mercator grid, which is typical but should be made explicit. For example add:
Line 75: (Kiss et al., 2020), which is Mercator (i.e. the meridional spacing scales as the cosine of latitude) across the domain used here.

2) Author Response

Mercator Grid: We will revise the manuscript to explicitly state that all model configurations use a Mercator horizontal grid and add the suggested clarifying text in the methods section.

3) Author Changes
Authors have updated the phrasing around line 75 of the manuscript based on the Reviewer's recommendation.

RC2.2 – ALE Discussion

1) Reviewer Comment
The ALE discussion (line 100) overstates its advantages. The ALE scheme is accurate and robust to vertical motion and there is no need to compromise topography or resolution (unconditionally stable), but it does not necessarily reduce mixing across z-surfaces when configured for z-star coordinates. It does reduce spurious diapycnal mixing when using MOM6's HYCOM1 hybrid regridder, but that is no employed here.

2) Author Response
We agree that the current wording overstates the advantages of ALE in our z-star configurations. In the revised manuscript we will rephrase this section to more accurately reflect the use of ALE in our context.

3) Author Changes
We have removed the dedicated paragraph on the ALE method and incorporated a brief description of the generalised vertical coordinate framework into the preceding paragraph (around line 90). Since ALE is not a central focus of this paper, the original standalone discussion was unnecessary (as well as overstating it's importance). The revised text now more concisely emphasises the key distinction between the MOM5 and MOM6 vertical coordinate frameworks, while introducing the MOM6 target-grid approach relevant to our configuration.

Surface Momentum Flux + Wind Forcing (RC1.3 + RC2.3)

RC1.3 – Surface Momentum Flux (Note this has been combined with RC2.3 below)

1) Reviewer Comment
Please explain the surface momentum flux. The eddy variability (SSH variance) in the model is much influenced by how the surface momentum flux is estimated. The eddy killing (e.g., Zhai and Greatbatch, 2007; Renault et al., 2016) should be considered when the eddy

variability in the model is verified. If the surface ocean current is not considered, the eddy variability becomes relatively too strong.

2) Author Response
MOM6 computes the wind stress online using the relative winds ($U_{10} - u_s$) which explicitly includes wind-current interaction. We thank the reviewer for highlighting this ambiguity in the manuscript and will revise this to document the wind-stress formulation explicitly and briefly discuss its implications for interpreting SSH variance / EKE comparisons.

RC2.3 – Relative vs. direct wind forcing

1) Reviewer comment
A more serious issue is the use of relative wind forcing (i.e., $U_{10} - U_{ocean}$). This is the only available option in MOM6 and it is certainly the best choice when coupled to an active atmospheric model component as would be the case in a climate simulation. However, in "prescribed atmosphere" cases, as here, direct winds (i.e., U_{10} alone) are typically preferred because they give more realistic kinetic energies. Relative winds are not wrong, but their implications for the strength of fronts and eddies should be noted and the paper would be improved with the addition of simulations forced by direct winds. It is hard to tell if the conclusions would have been different had direct winds been used.

2) Author Response
We appreciate this important point. We will add a clear description of the wind-stress formulation used (relative winds) and include a dedicated discussion of its implications for mesoscale kinetic energy, frontal/eddy strength, and interpretation of SSH/EKE metrics in the data atmosphere context. We will note the lack of direct winds as a limitation in the present study.

RC1.3 + RC2.3 | Combined Author changes:

We have revised the manuscript in four places to clarify and contextualise the surface momentum flux formulation. First, in the forcing subsection of the methods (around line 140) we now explicitly state that MOM6 computes wind stress online using a relative-wind formulation, so that surface momentum flux depends on the difference between the prescribed 10 m wind and the model surface current. We then note in the SSH variance results section (around line 330) and eddy amplitude section (around line 430) that this formulation includes current feedback and is expected to damp mesoscale variability relative to direct-wind forcing. Finally, we add a short discussion paragraph identifying the use of relative winds in a prescribed-atmosphere framework as a limitation when interpreting absolute SSH/EKE amplitudes, while noting that the comparative conclusions across configurations remain informative because the same formulation is used consistently.