Response to Reviewers - "The characteristics and structure of extra-tropical cyclones in a warmer climate"

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We thank the reviewer for their constructive comments on our submitted manuscript. We have copied the comments of reviewer 2 in black here and include our response to each individual comment in blue.

Reviewer 2

This is a very nice study looking at aquaplanet model simulations with a complex model. This provides a step in the model hierarchy between fully complex models (e.g. the CMIP models) and the very idealised models such as a baroclinic channel models. By using a Lagrangian feature tracking algorithm and looking at the lifecycles of extratropical cyclones, the authors have investigated the changing intensity and structure of the 200 most intense cyclones. The paper is well-written and the figures are very clear. I have a few minor comments and suggestions to make.

1. Line 208: The CMIP5 model projections are not shown here so it would be good to refer to a paper that shows these. We have added a reference here and also put the temperature change obtained in our experiments in context of predictions from CMIP5

2. Line 213: Is the poleward change of 2.2 degrees significant? This is much smaller than the shift in the jet. The maximum in the zonal mean precipitation moves 2.2 degrees polewards whereas the eddy driven jet (taken as the zonal mean zonal wind speed at 700 hPa) moves from 37.6N to 40.9N, a poleward shift of 3.3 degrees, therefore, we do not think the jet shift is much smaller than the shift in the maximum precipitation, especially given the model resolution this equates to one more grid point.

3. Line 219: Is there an explanation for the much lower average MSLP? Is this an issue with OpenIFS or something to do with the aquaplanet set up? This is an artefact of how we created the initial conditions for the aqua-planet which we explain in sections 2.2. We have revised this sentence to clarify this issue.

4. Lines 317-321: It would be good to see figures for the changes in the wind speeds. Both here and in the precipitation section, I think a useful addition would be some analysis of the footprints of the most intense winds and precipitation and how this changes. These footprints were considered in the Tierney et al 2018 and Pfahl et al 2015 papers. We now include a figure showing the

900-hPa wind speeds in CNTL and the response to warming which we previously discussed in section 6.2. The text about wind speeds has been expanded and moved to its own subsection.

5. Line 350: I think this sentence should be reworded slightly – it seems that what is consistent is that the condensation from the precipitation gives more latent heating and stronger PV anomaly (rather than the latent heating leading to more precipitation). We have revised this sentence.

6. Line 357: It would be good to make it clearer here and elsewhere in the paragraph when it is referring to changes in the SST4 experiment. Good point. We have revised this section to be clearer.

7. Line 376-377: I think it might be good to say the warm conveyor belts are further poleward relative to the propagation direction rather than the cyclone centre since the cyclones have been rotated for compositing. The rotation means that all cyclones in the composites are propagating due east which means that in the composite mean image the propagation vector is at the same point (in the meridional direction) as the cyclone centre. As we are discussing the rotated composite mean we have not changed this.

8. Line 416: I think the wrong figure panel is referenced here – it should be 10d.
Thank you, this was a mistake and we have now corrected it.

9. Section 7: It would be nice to see greater discussion of this study in the context of previous literature. For example, how do these results compare with, e.g. Pfahl etal 2015, Tierney et al 2018. Are there any other papers that analyse the structure of extratropical cyclones in the future? Two that I can think of are Yettella and Kay 2017 and Michaelis et al 2017. We have now expanded the conclusions section to include more discussion and comparison to previous studies and reference both of these suggested papers.

10. Section 7: Also, are there any caveats with the study – would the results change if you looked at the 500 most intense storms or the medium intensity storms? There are certainly caveats associated with this study, which we have added discussion about to the conclusions. We also now include the results of how the median cyclones change with warming in supplementary material.

References:

Yettella V, Kay JE. How will precipitation change in extratropical cyclonesas the planet warms? Insights from a large initial condition climate model ensemble.Clim Dyn. 2017;49(5–6):1765–81.

Michaelis AC, Willison J, Lackmann GM, Robinson WA. Changes in Winter North Atlantic Extratropical Cyclones in High-Resolution Regional Pseudo–Global Warming Simulations. J Clim. 2017 Jun 6;30(17):6905–25.