Reviewer 2

Review for the manuscript "Interactions between trade-wind clouds and local forcings over the Great Barrier Reef: A case study using convection-permitting simulations" by Zhao et al.

This study examines how trade-wind clouds and precipitation over the Great Barrier Reef (GBR) from a particular case study respond to three local forcings: orographic lifting, aerosol concentration, and sea surface temperature (SST). The authors employed the Weather Research and Forecasting (WRF) model, with three-level nested domains. The finest horizontal resolution in the smallest domain is 1 km. The simulations were driven with large-scale forcings from ERA5. During the period of this case study, April 2016, trade-wind cumulus was present northeast of Queensland, Australia, upwind of the mountains. The author performed sensitivity studies to three local forcings: the orography, aerosols, and sea surface temperatures. They compared how the cloud fraction and precipitation in the upwind and downwind regions of the mountain ranges respond to these three factors and discussed relevant explanations to the changes they found.

I really enjoyed reading about the orographic effects on trade-wind clouds over the GBR. The authors clearly demonstrated how the orography drives low-level flows which then affect the cloud-top boundary layer. However, for the aerosol and SST sensitivity tests, I find that some analysis and discussion are still missing - a reason for why I think this manuscript needs some major revisions. I believe that after these changes, especially those mentioned in major comments #2 and #3, this manuscript will be a valuable contribution to the literature on shallow cumulus clouds.

Major comments:

1. **Simulation setups:** More information on the simulation setups is necessary. Are the simulations nudged to ERA5 large-scale forcings, and if so, what is the time scale? What is the vertical resolution in the smallest domain of your simulations? And with the finest resolution, 1 km, this is still quite coarse for marine shallow cumulus and stratocumulus especially if you are using the convection-permitting mode / turning off the cloud parameterization. I recommend you discuss other modeling studies of marine shallow clouds that compare their results when using coarse (~O(1 km)) vs. finer (~O(100 m)) resolutions. Based on their findings, that may help justify your choice of resolution and the robustness of your model output. You could look at these studies and the reference therein for example: Saffin et al. (2023, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2022MS003295). It should also be noted that in their studies, Saffin et al. (2023) found that a longer spin-up time helps them reproduce a better agreement with the observations.

   Thank you for your comments. We have now included more information regarding the model set-up in sector 3 of the revised manuscript.

   - In this study, both CTRL and sensitivity simulations are initialized with ERA5, and then run freely, with no nudging applied, allowing the meteorology to fully develop throughout the simulation. This information has been added to the revised manuscript (line 164-166).
   - Regards to the vertical resolution, 65 vertical levels configuration has been applied to all domains, with the finest resolution of ~30m (at lower level below 750m), and coarsest resolution of ~600m (upper level above 10km). Details about the vertical resolution have also been added to the supplementary (new Figure S2) as suggested.
   - We agree that a higher-resolution modelling such as large-eddy simulation (LES) could better resolve the details of the complex cloud and precipitation processes. While our simulations are at a lower resolution than needed to resolve detailed cloud processes such as entrainment and convective aggregation, they are at a high enough resolution to explicitly represent convection while allowing for a considerably larger domain size at an affordable computational cost. The significance of a large domain size has been demonstrated in accurately representing the mesoscale organization of trade-wind cumulus (Vogel et al., 2020; Bretherton and Blossey, 2017). High-resolution LES is not currently possible at much larger domain sizes and therefore it is difficult to use it to study detailed interactions between orography, cloud organisation and variation, and large-scale

forgings. We have added a note to comment this issue in the revised manuscript (Line 748-761).

- We recognize that the optimal spin-up time may vary from case to case, depending on the specific atmospheric conditions and dynamics settings. For this reason, we have tested multiple spin-up times as part of our initial evaluation. As noted in the manuscript (line 175), our results indicate that a relatively shorter spin-up time, specifically 12 hours, performs best in this case based on our evaluation against the available observations. Thank you for highlighting this important aspect, we have also included a note to comment on the spin-up time selection (Line 167-172) as follows:

  "It is worth noting that sensitivity to different spin-up times (e.g. 12h, 18h, and 24h) has been tested as the optimal spin-up time configuration may vary across different case studies, reflecting the unique atmospheric conditions and dynamics inherent to each scenario. The results indicate that the simulation with a shorter spin-up time (12h) produces a better agreement with observations for this case (not shown)."

2. **Aerosols:** Your sensitivity studies showing how the shallow clouds over the GBR respond to the aerosols emitted off the coast. But for a complete story, I find that some discussion is still missing. For example, why do you consider "water friendly" and "ice friendly" aerosol categories? Are you assuming all aerosols are hygroscopic? Are your aerosols size-dependent? What is the PDF of the aerosol size distribution, and does it change uniformly when you increase the aerosol concentrations? The sizes of the aerosols will play an important role when you consider the cloud fraction and precipitation changes. For example, if you increase finer particles, you may have more clouds but not rain, but if you increase coarser particles, you may have more rain but not clouds. Therefore, more information on the aerosol type and size distribution is needed for you to justify your aerosol sensitivity tests. For references, see Hoffmann and Feingold (2021, https://doi.org/10.1175/JAS-D-21-0077.1) for example. Furthermore, aerosols do not only interact with clouds via microphysical processes but also change the turbulence through radiation. The latter has been shown to affect marine shallow cumulus clouds in a recent study, i.e., the second half of Narenpitak et al. (2023, https://doi.org/10.1029/2022MS003228).

   The Thompson Aerosol Aware microphysical scheme is updated from the previous version (Thompson et al., 2008) to incorporate the activation of aerosols as cloud condensation (CCN) and ice nuclei (IN). Rather than determining the specific aerosol types and chemical composition of multiple aerosol categories, a priori, this scheme simply refer to the hygroscopic aerosol (a combination of sulfates, sea salts, and organic matter) as a 'water friendly' aerosol and the nonhygroscopic ice-nucleating aerosol (primarily considered to be dust) as 'ice friendly' aerosol. To get the final number concentrations from mass mixing ration data, it assumes lognormal distributions with characteristic diameters and geometric standard deviations taken from Chin et al. (2002). Samples of the climatological aerosol dataset applied in this study can be found in Thompson and Eidhammer (2014, Fig 1). The water-friendly aerosol in this study, therefore, is changed uniformly as a combination of the hygroscopic aerosol regardless of size distribution.

   While using a more comprehensive representation of aerosol sources in the model is desirable for a more complete understanding of the complex interactions between aerosols and atmospheric processes, these aerosol-resolving models commonly come at a significant computational cost and are simply unaffordable at a cloud-resolving resolution over a large domain. The primary aim of our study is to better understand the first-order impacts of local forcings on the clouds and precipitation over the GBR, which is the first step towards a more comprehensive investigation of aerosol-cloud-climate interactions. This research requires a large domain at reasonably high resolution to properly capture the complex interactions between the large-scale meteorology and local forcings, which are critical for trade-wind cloud formation (e.g. Vogel et al., 2020; Bretherton and Blossey, 2017). Although far from perfect, the use of the (simplified) aerosol-aware Thompson and Eidhammer (2014) scheme in a convection-permitting configuration is a reasonable middle ground to address these two critical needs. Note that a combination of sulfates, sea salts, and organic matter is found to represent a significant fraction of known CCN and are found in abundance in clouds worldwide (Thompson and Eidhammer, 2014). Therefore, while it would be an interesting (and important) topic for a different project, a precise understanding of aerosol sources, amounts and composition is beyond the scope of the present study. In our revised manuscript, we have included further detailed information and discussion regarding the microphysical scheme and aerosol behaviours in the sector 3 of the revised manuscript.

At present, the sulfates, sea salt, organic carbon, and dust aerosols used by the microphysics scheme to activate water droplets and ice crystals do not scatter or absorb radiation directly, and only the typical background amounts of gases and aerosols present within the RRTMG scheme were considered for scattering– absorption–emission of direct radiation in this study. Thank you for pointing this out, a note has been added to comment this issue (Line 216-219).

3. **Local SST:** Typically, reduced SST leads to more shallow clouds or higher cloud fraction. There are some studies that have found otherwise, just like in your simulations. In this section, I recommend you add more analysis as to why the clouds in your simulations reduce with lower SST. In general, warmer SST increases surface latent heat flux, sensible heat flux, and moisture flux (consistent with what you showed in Fig. 14). More is needed from there.

   (1) **How does the inversion strength change?** If the TWI is weakened, your clouds will deepen, and more dry-air entrainment will dry out your clouds with warmer SST. But if the TWI is stronger, this may prevent entrainment of dry air from the free troposphere, and this may still help retain the clouds. Precipitation also affects these processes further.
   (2) **How does the temperature lapse rate change when the SST is changed in your simulations?** More stable lapse rates may prevent formation of shallow clouds.
   (3) **Does the humidity in the free troposphere in your simulations change?** If the free troposphere is drier and the TWI is weaker, more dry air can be entrained into the clouds, depleting the cloud liquid water with warmer SST.

For more processes linking changes in SST to cloud amount and precipitation, you can read Bretherton and Blossey (2014, http://dx.doi.org/10.1002/2013MS000250) and Vial et al. (2017, https://doi.org/10.1007/s10712-017-9418-2). A study that finds warmer SST increasing cloud fraction (similar to your simulations) is Narenpitak and Bretherton (2019, http://dx.doi.org/10.1029/2018MS001572); their reasoning might also be helpful in your analysis and discussion.

Thank you for your insightful suggestions. We have now added analysis of TWI strength, EIS, LTS, and humidity for the SST experiments.

The SST-cooler simulations reveal a less stable lower troposphere compared to CTRL, which inhibits the formation of trade wind clouds. A slight unstable condition is seen in the SST-climatology experiment, which is likely contributed to the warmer pool at the upwind ocean, driving a more variable changes in cloud and precipitation. Two measures of the inversion strength are showing less response to the SST modification. As discussed in the manuscript, the inversion strength is more likely to be influenced by synoptic to larger-scale atmospheric processes (Milionis and Davies, 2008), which have the potential to override the impact of local forcings.

Looking at the atmospheric humidity, slightly drier condition is seen at the lower level below 1km in the SST-cooler, however, there is no significant difference near the free troposphere (2.5km). Considering the magnitude of adjustment in surface temperature, the changes may not be felt by the upper atmospheric levels. This limited impact could be further diminished by large-scale atmospheric dynamics. Nevertheless, drier condition at lower level is likely contributing to the stabilized boundary layer simulated in the SST-cooler experiment. Combined with the results shown in the original manuscript, overall, our simulations suggest that the lower troposphere stability and surface flux likely explain most of the response of trade cumulus over the GBR to changes in SST. Discussion has also been included in the revised manuscript (Line 639-659) as follows:

“It is also suggested that with a warmer SST, the boundary layer becomes more humid, which becomes destabilized by increased clear-sky radiative cooling, driving more cumulus convection

(Narenpitak and Bretherton, 2019; Wyant et al., 2009; Narenpitak et al., 2017). In this study, the SST-cooler experiment reveals a less stable lower troposphere (Figure 15a) compared to CTRL, which inhibits the formation of trade wind clouds. A slight unstable condition is seen in the SST-climatology experiment, which is likely contributed to the warmer pool at the upwind ocean, driving a more variable changes in cloud and precipitation (Figure 7f and 9f). Another factor that controls the cloud amount is the free tropospheric humidity (Bretherton et al., 2013; Eastman & Wood, 2018). It is suggested that drier air at the level of free troposphere causes more entrainment drying, depleting the boundary layer cloud water. As shown in Figure 15b, slightly drier condition is seen at the lower level below 1km in the SST-cooler, however, there is no significant difference near the free troposphere (2.5km). Large-scale circulation as well as local processes play important role in driving the thermodynamic profiles (Nygård et al., 2021). Considering the magnitude of adjustment in surface temperature, the changes may not be felt by the upper atmospheric levels. This limited impact could be further diminished by large-scale atmospheric dynamics. Nevertheless, drier condition at lower level is likely contributing to the stabilized boundary layer simulated in the SST-cooler experiment. Finally, two measures of the inversion strength, specifically TWI strength and EIS, have been examined with SST experiment. The results show that inversion strength is not a predominant factor impacting the interactions of trade clouds and local SST forcing. As discussed above, the inversion strength is more likely to be influenced by synoptic to larger-scale atmospheric processes (Milionis and Davies, 2008), which have the potential to eclipse the impact of local forcings."

4. **Inversion strength:** It is great you are computing the trade wind inversion (TWI) and the inversion strength derived from the inversion base and top from the TWI. However, there are other indices to measure the inversion strength, which are commonly used in the literature of marine shallow clouds. Those are the "estimated inversion strength" (EIS, Wood and Bretherton, 2006, https://doi.org/10.1175/JCLI3988.1) and the "estimated cloud-top entrainment index" (ECTEI, Kawai et al., 2017, https://doi.org/10.1175/JCLI-D-16-0825.1). I suggest adding a calculation of either one of these indices, so the results from your study can be easily compared with other studies in the shallow cloud literature.

   The EIS is also a common index used in the literature when discussing about the SST's effect on shallow cumulus and stratocumulus clouds. It might be helpful for other readers to compare your manuscript with the others if you decide to use it, but this change is not necessary.

   We have now added the analysis of both EIS and LTS in the revised manuscript as suggested. In the Topo300 simulation, which incorporates a lower orographic setting, there is a notable increase in the stability of the lower troposphere over mountainous regions, which is largely attributed to the reduced elevation in these areas. A less stable lower troposphere suggested in the CTRL is conducive to the enhanced development of trade cumulus clouds. The comparison of LTS between the CTRL and Topo300 scenarios over the upwind, however, reveals minimal differences, suggesting that the impact of orography on atmospheric stability is predominantly localized. Additionally, EIS and TWI strength do not show significant responses to the changes in topography over both downwind and upwind. It is possible that atmospheric inversion strength is often influenced by synoptic to larger-scale atmospheric processes (Milionis and Davies, 2008) which may override the local topographic effects. In contrast, the height of inversion layer might be more strongly influenced by factors such as local topography. Relevant discussion has been included (Line 467-480 and 491-496) as follows:

   "There is a notable increase in the stability of the lower troposphere over mountainous regions (Figure 10d), which is largely attributed to the reduced elevation in these areas. A less stable lower troposphere suggested in the CTRL is conducive to the enhanced development of trade cumulus clouds. The comparison of LTS between the CTRL and Topo300 scenarios over the upwind, however, reveals minimal differences, suggesting that the impact of orography on atmospheric stability is predominantly localized."

And "Interestingly, measures of inversion strength, specifically TWI strength and EIS, exhibit no substantial variation in response to the changes in topography, over both downwind and upwind domain (Figure 10f and h). It is considered that atmospheric inversions strength is often influenced by synoptic to larger-scale atmospheric processes (Milionis and Davies, 2008) which can override the local topographic effects. In contract, the height of inversion layer might be more influenced by factors such as local topography."

As mentioned earlier, we have also included analysis of EIS for SST experiments. Thank you for your suggestion.

Minor comments:

Line 106: "Figure S2" – should be "Figure S1" since it is first mentioned.

Thank you for pointing this out - it has now been corrected.

Figure 2: I suggest using a different colormap that is not diverging, since you are showing something that ranges from 0 to 100. Having blue color representing zero precipitation is counterintuitive to me. It's also hard to see the black topography contours on the blue (zero precipitation) color!

Thank you for your suggestion. We have now changed the colormap for Figure 2.

Line 144: Does this mean the vertical resolution is roughly 100 m? It would be nice if the vertical resolution can be shown along with the vertical profiles in Fig. 4 or in the supplementary information.

In the model, 65 vertical levels are distributed unevenly (as shown below) with the finest resolution of ~30m (at lower level below 750m), and coarsest resolution of ~600m (upper level above 10km). It is important to note the different vertical distributions over the ocean points and the topography points, especially for the lowest eta levels. Figure S2 has been added to the supplementary for reference. Thank you for your suggestion.

Section 3.1: In general, do you nudge the simulations to ERA5? Or do you simply initialize the simulations and let them run? Please specify.

As mentioned earlier, in this study, both CTRL and sensitivity simulations are initialized with ERA5, and then run freely, with no nudging applied, allowing the meteorology to fully develop throughout the simulation.

The manuscript has now been revised to include this information (Line 164-166) as follows:

"Following initialization, model is allowed to freely run with no nudging applied, which enables the meteorology to fully develop throughout the simulation."

Lines 168-169: What is the "auxiliary aerosol climatology" and what is the aerosol concentration of the "multiyear (2001-2007) global model simulations"? What are the aerosol size distributions of the aerosols prescribed in your simulations? The latter is important for interpreting the aerosol sensitivity study.

Following the suggestion, we have now included more information of the aerosol climatology used in this study (Line 197-209) as follows.

"The aerosol input data are derived from multiyear (2001-2007) global model simulations (Calarco et al. 2010) in which particles and their precursors are emitted by natural and anthropogenic sources. Multiple species of aerosols, including sulfates, sea salts, organic carbon, dust and black carbon, are explicitly modelled with multiple size bins by the Goddard Chemistry Aerosol Radiation and Transport model with 0.5° longitude by 1.25° latitude spacing. The microphysical scheme then transformed these data into simplified aerosol treatment by accumulating dust mass larger than 0.5 μm into the IN (ice-friendly) mode and combining all other species besides black carbon as an internally mixed CCN (water-friendly) mode. To get the final number concentrations from mass mixing ratio data, it is assuming lognormal distributions with characteristic diameters and geometric standard deviations taken from Chin et al. (2002). Samples of the climatological aerosol dataset can be found in Thompson and Eidhammer (2014, Fig 1). Note that black carbon is ignored for this version but might be incorporated into future versions (Thompson and Eidhammer, 2014). However, it is not expected that the absence of black carbon aerosol will have a significant effect for pristine maritime trade cumulus clouds."

Lines 173-175: What exactly are the "water friendly" and "ice friendly" aerosol scheme? As in, what do the "hygroscopic aerosols" and the "nonhygroscopic ice nucleating aerosols" do in the cloud microphysics / aerosol scheme? More information about the process, rather than the "water friendly" and "ice friendly" description is needed. Also, how will your results change if you use a different aerosol scheme that has different assumptions about the aerosol types?

Thank you for your comment. As mentioned earlier, we have now added further description of the microphysics scheme including how it treats aerosols in the revised manuscript.

We agree that, as you pointed out earlier, distinct cloud-aerosol interactions can be observed across different aerosol species. A more comprehensive representation of aerosol sources in the model would allow for a more detailed response (e.g. aerosol category dependent) of warm cloud and precipitation to aerosol perturbation (Ghan et al., 2012; Wang et al., 2013). However, when considering the broader picture, we anticipate that the results will demonstrate consistency. This expectation is based on the understanding that a combination of sulfates, sea salts, and organic matter constitutes a significant fraction of known cloud condensation nuclei (CCN). These components are widely prevalent in cloud formations across the globe (Thompson and Eidhammer, 2014). Therefore, employing a different aerosol scheme is expected to yield more detailed and nuanced results, rather than simply altering the existing findings.

Line 188: Figure S1 should be Figure S2 (swapped with the other figure in line 106, based on the order they are first introduced.

The manuscript has now been corrected.

Line 193: Maybe show the result of a 500 m threshold in the supplementary information? It would be interesting to see.

Detailed analysis of topography sensitivity experiments, including both 300m and 500m thresholds, are presented in the PhD thesis Zhao (2022), which is publicly available. Results can be found here: https://bridges.monash.edu/articles/thesis/Cloud_properties_over_the_Great_Barrier_Reef_and_its_interaction_with_local_conditions/22117343

Lines 195-196: I was confused when I first read the descriptions of the simulation names. The CTRL simulation has the warmest SST, followed by the SST-climatology simulation, and then the SST-cool is the coolest. Is that right? If so, that is worth mentioning here too since you show the SSTs only in the supplementary information. Additionally, it's good to note that between CTRL and SST-climatology, the temperature different is not spatially uniform and it is cooler in CTRL between 18-19S, 149-151E. Is this where the clouds are observed or upstream of the air trajectory flowing to the shallow cumulus clouds?

SST-cool has a spatially uniformed 1°C cooler than control SST distribution. SST-climatology represents the climatological condition, with a non-uniformed SST anomaly distribution (the maximum SST anomaly could reach to 1°C, with some area showing warmer than control) when compared to control.

Yes, the clouds are moving from the upstream area, where the SST in SST-climatology is warmer than control, under the south-easterly trade wind condition.

A further note has now been added to the manuscript (253-256) as follows:

"It is important to note that, unlike the SST alteration in the SST-cooler experiment, part of the ocean area in the SST-climatology is warmer than the actual SST (Figure S1). Nevertheless, the sea surface temperature over the majority of the GBR is reduced in the SST-climatology experiment."

Lines 199-202: Why do you only consider the "water-friendly" / hygroscopic aerosols? Aerosols that do not get activated as cloud condensation nuclei can also affect shallow cumulus cloud processes by changing the radiative heating profiles, which then alters the stability of the cloud layer and cloud fraction. This is different from the Twomey effect and the Albrecht effect, which you discussed earlier. See major comment #2 for details.

Thank you for your comment. As mentioned earlier, we have included a note to comment this aerosol direct effect in the revised manuscript.

Line 243 and Fig. 5b: Based on the sounding profiles, the simulated temperature profile does not really show a temperature inversion layer. In a case like this, how do you compute the TWI?

Good point! Thank you for this comment.

In this case, the sample will not be included. We've checked the available samples after the calculation, where around 19% of the total samples are excluded. We believe the remaining 81% samples still make the result statistically significant.

A note has now been added to the manuscript to clarify this (310-311) as follows.

"It should be noted that grid points with no TWI identified (around 19% of total samples) are excluded from the TWI analysis."

Line 250: Do you mean Figure 6?

This was a typo, the manuscript has been corrected.

Line 258: Do you mean green contours, not black? Honestly the green contours are hard to see with the black background. I suggest trying a different colormap for the brightness temperature (maybe white-blue, rather than white-black) and use black contours instead of green.

We've revised the colormap for cloud field to a white-blue colormap, which indeed looks better. In terms of topographical representation, we experimented with three color schemes: green, grey, and black. The grey color scheme was found to be the most distinguishable against the blue background.

Figure 6 in the manuscript has now been updated to white-blue colormap with grey contours showing topography.

Lines 262-264: There is a bias / discrepancy in observed and simulated precipitation, south of 17.5S, 146E, where the mountains are only 250 m tall. Maybe it's worth discussing about this discrepancy, especially how this may or may not affect your sensitivity test.

This discrepancy is considered as a bias in the spatial distribution of major precipitation events, with the simulated precipitation indicating a northward shift relative to the observation. However, the simulated accumulated precipitation amounts agree reasonably well with the rain gauge observations and the precipitation distribution remains predominantly over the mountainous region, which lies within our domain of interest. It is, therefore, suggesting that the simulation is skilful in representing the precipitation patterns, despite some spatial discrepancies. We should also note that there is considerable natural variability in precipitation that is not expected to be precisely captured by one single simulation.

We have revised the manuscript to address this comment (348-352) as follows.

"Although a bias is noted in the location of the peak precipitation, with the simulated precipitation indicating a northward shift relative to the observation, the simulated accumulated precipitation amounts agree reasonably well with the rain gauge observations. This suggests a considerable ability of the model in predicting precipitation patterns and magnitude, despite some spatial discrepancies."

Figure 4: There is also a disagreement in the wind speed east of Townsville on 30 April 2016 (bottom row). Might this be a cause for the precipitation discrepancy?

The disagreement in the wind speed on 00UTC 30 April is not considered to contribute to the precipitation discrepancy shown in Figure 2, as the precipitation covers the time period of 2016-04-27 23:00UTC to 2016-04-29 23:00 UTC. It is also worth noting that the major precipitation event is produced on 29th April.

We have included a note on the disagreement shown in Figure 4 in the revised manuscript (322-323).

Lines 280-283: It would be good to see whether the subdomains (red boxes) in Fig. 3c and 3d overlap with each other. Please consider combining Fig. 3c and 3d, and show both of your subdomains in the same plot.

Figure 3 in the manuscript has now been revised, with Figure 3c showing both the upwind and downwind subdomains. Labels have also been added to Figure 3c. Thank you for your suggestion!

Line 286: Since you already compute mid and low cloud fraction, it will be helpful to show a spatial map of mid- and low-cloud fraction, similar to Fig. 9, but for both the upwind and downwind subdomains. It will be helpful to see where the clouds are before seeing the precipitation. This will also help your discussion (Lines 300-304) and Fig. 7-8. Right now it's rather hard to follow that discussion.

The spatial distribution of low-level cloud fields at various timestamps both before and after precipitation have been added to the supplementary. The simulated cloud fields are shown by grid point that indicating either cloudy (blue color) or clear (white). Note that an altitude of 3 km, where most of trade-wind cloud reside, is applied when defining the low-level cloud. A cloudy grid point (note that 'cloudy' is indicated by a binary number '1' in the model output) in this analysis for low-level cloud is defined when the column has at least one cloudy layer within the lowest 3km. It can be seen that low cloud moves from the upwind ocean area (Figure R1a) towards the topography region (Figure R1b), generates precipitation around 00UTC 29th April before starting to dissipate (Figure R1d). A note has also been added to the revised manuscript accordingly.

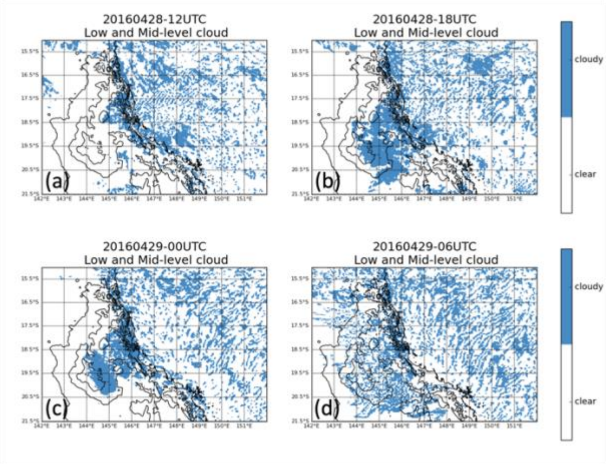

Figure R1: Examples of simulated cloud field from CTRL at (a) 12UTC 28, (b) 18UTC 28, (c) 00UTC 29, and (d) 06UTC 29 April 2016.

Figures 7-8: Firstly, it's counterintuitive to have red colors represent "more clouds" and blue "less clouds". Please consider reversing your colormap. (The same goes for Fig. 9.) Secondly, it might be helpful if you can show the average height of the TWI base along with the PDF of the cloud fraction. This will help the audience see if the cloud changes are, at all, connected with the TWI, which is an important constraint for shallow clouds.

Figure 7, 8 and 9 have now been revised with a reversed colormap applied. Additionally, the averaged base height of the TWI has also been added to Figure 7 and 8.

Figure 9: Is a colorbar for CTRL missing?

Figure 9 in the manuscript has now been revised.

Line 330: I suggest introducing CAPE, w_diff, and 10-m wind convergence in the order you show in Figure 10.

The Figure 10 has now been revised to be consistent with the context.

Lines 341-344: This is a nice discussion. I'm curious to see the surface temperature differences between the CTRL and TOPO300 runs. A comparison figure could be added to the supplementary information. This will build up a nice discussion for your SST sensitivity part too.

Thank you for this good idea. We have included the surface temperature difference into supplementary. The manuscript has been revised accordingly.

It can be seen that the simulated thermal patterns in the mountainous region, as indicated in the CTRL scenario, reveal a distinct variation in surface temperatures relative to the Topo300. Notably, the mountain areas exhibit cooler temperatures compared to the Topo300 surface temperature. This cooling effect is primarily attributed to the higher altitude. In contrast, the leeward side of the mountains demonstrates a notable warming trend. This is explicable in terms of adiabatic warming processes, where air, upon descending along the mountain slope, undergoes compression and consequently heats up over an extended trajectory.

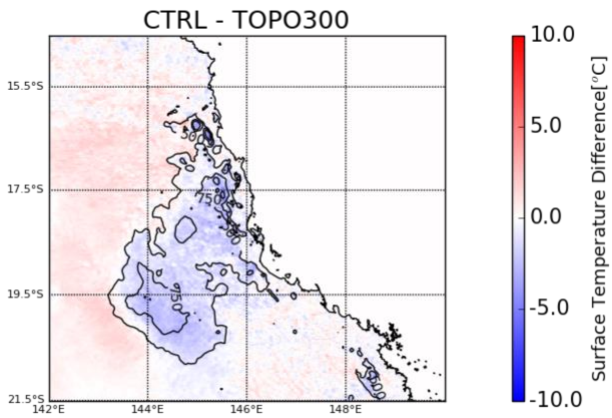

Figure R2: Differences of simulated surface temperature between CTRL and Topo300. Black contours show the topography from 500 to 1500 m with 250 m interval.

Line 356: There's an extra "that" in your sentence.

This typo has now been corrected.

Lines 451-452: I suggest including an analysis of the TWI or EIS, and other relevant factors that might affect the cloud fraction when you perturb the SST. See the main comment for details.

Thank you for your comment. As mentioned earlier, analysis of TWI and EIS has now been added.

Line 522 / Conclusions: Other forcings that might be relevant: There are other local forcings that affect cloud and precipitation in trade-wind cumuli, such as wind shear and surface wind speed. The mesoscale organization of these clouds may also matter. Will you be looking at other relevant forcings? Or why not?

We have expanded the discussion to include other local forcings (767-773).

"Subsequent research endeavours should indeed consider the influence of additional local forcings, such as wind shear (Yamaguchi et al., 2019), in the modulation of cloud and precipitation dynamics within trade wind regimes. Li et al. (2014) also suggests that downdrafts at the cold pool boundary play an important role in the development of trade wind cumuli. These studies highlight the complex nature of atmospheric dynamics in trade wind cumuli and emphasize the need for comprehensive investigations to enhance our understanding of cloud and precipitation in the GBR region."

References:

Bretherton, C. S., & Blossey, P. N.: Understanding mesoscale aggregation of shallow cumulus convection using large-eddy simulation. Journal of Advances in Modeling Earth Systems, 9(8), 2798–2821. https://doi.org/10.1002/2017MS000981. 2017.

Chin, M., and Coauthors: Tropospheric aerosol optical thick- ness from the GOCART model and comparisons with satellite and sun photometer measurements. J. Atmos. Sci., 59, 461–483, doi:10.1175/1520-0469(2002)059,0461:TAOTFT.2.0.CO;2. 2002.

Colarco, P., A. da Silva, M. Chin, and T. Diehl: Online simulations of global aerosol distributions in the NASA GEOS-4 model and comparisons to satellite and ground-based aerosol optical depth. J. Geophys. Res., 115, D14207, doi:10.1029/2009JD012820, 2010.

Ghan, S. J., X. Liu, R. C. Easter, R. Zaveri, P. J. Rasch, J. Yoon, and B. Eaton: Toward a Minimal Representation of Aerosols in Climate Models: Comparative Decomposition of Aerosol Direct, Semidirect, and Indirect Radiative Forcing. J. Climate, 25, 6461–6476, https://doi.org/10.1175/JCLI-D-11-00650.1. 2012.

H. Wang, Easter, R. C., Rasch, P. J., M. Wang, X. Liu, Ghan, J., Y. Qian, J.-H. Yoon, Ma, P.-L., & Velu, V.: Sensitivity of remote aerosol distributions to representation of cloud-aerosol interactions in a global climate model. Geoscientific Model Development Discussions, 6(1), 331–378. https://doi.org/10.5194/gmdd-6-331-2013. 2013.

Li, Z., Zuidema, P., & Zhu, P.: Simulated Convective Invigoration Processes at Trade Wind Cumulus Cold Pool Boundaries. Journal of the Atmospheric Sciences, 71(8), 2823–2841. https://doi.org/10.1175/JAS-D-13-0184.1. 2014.

Milionis A. E. & Davies, T. D.: The effect of the prevailing weather on the statistics of atmospheric temperature inversions. International Journal of Climatology, 28(10), 1385–1397. https://doi.org/10.1002/joc.1613. 2008.

Thompson, P. R. Field, R. M. Rasmussen, and W. D. Hall: Explicit forecasts of winter precipitation using an improved bulk mi- crophysics scheme. Part II: Implementation of a new snow parameterization. Mon. Wea. Rev., 136, 5095–5115, doi:10.1175/ 2008MWR2387.1. 2008.

Thompson, G., and Eidhammer, T.: A study of aerosol impacts on clouds and precipitation development in a large winter cyclone. Journal of the atmospheric sciences, 71(10), 3636-3658, https://doi.org/10.1175/JAS-D-13-0305.1, 2014.

Vogel, R., Nuijens, L., & Stevens, B.: Influence of deepening and mesoscale organization of shallow convection on stratiform cloudiness in the downstream trades. Quarterly Journal of the Royal Meteorological Society, 146(726), 174–185. https://doi.org/10.1002/qj.3664. 2020.

Yamaguchi, T., Feingold, G., & Kazil, J.: Aerosol-Cloud Interactions in Trade Wind Cumulus Clouds and the Role of Vertical Wind Shear. Journal of Geophysical Research. Atmospheres, 124(22), 12244–12261. https://doi.org/10.1029/2019JD031073. 2019.