Impact of scale-aware deep convection on the cloud liquid and ice water paths and precipitation using the Model for Prediction Across Scales (MPAS-v5.2)

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Replies to Referee 1

Before replying to Referee 1, the authors wish to thank Referee 1 to read and provide a thorough review of our manuscript, including constructive critics and suggestions.

1. Replace "scale-aware" with "scale-adaptive": We understand that the Referre would want to replace "scale-aware" with "scale-adaptive". A few scientists have also argued "scale-insensitive" would be a better term as well. However, a lot of the publications related to GF and MSKF use the term "scale-aware" to describe how parameterizations of deep convection handles transitions between hydrostatic and nonhydrostatic. The authors would rather keep the "scale-aware" term in their manuscript.

2. Point out that for GF, the term $(1-\sigma)^2$ factor is very small for grid-spacings < 6 km while at 4-6 km we do not expect convection to be resolved: In order to reply to Referees 1 and 2, we rewrote the paragraph that discusses Fig.1. See lines 194-206.

3. Drop Figure 9: We removed Fig.9 showing the monthly-mean grid-scale (THOM) precipitation rate, as suggested by the Referee. We also revised the writing of Section 4, including that related to Tables 2 and 3.

4. In Figure 12, plot instead the difference in RH with the ERA5 reanalyses and rewrite discussion lines 582-598: As suggested by Referee 1, we plotted RH difference against ERA and ERA5 reanalyses (see Figs. 12-ERA and 12-ERA5 below).
   - First, the first author is reluctant to use ERA5 instead of ERA-Interim reanalyses since initialization of the four simulations was done using ERA-Interim data. Readers may wonder why the authors used ERA-Interim to initialize MPAS while they used ERA5 to analyze results. Figs. 12-ERA and 12-ERA5 show that the four simulations display biases of the same magnitude when compared against the "observed" relative humidity.
   - Second, the first author is reluctant to replace Fig 12 (updated to Fig. 11 since we removed Fig. 9) because RH depends on calculating saturation mixing ratios which are different in MPAS and ERA, particularly for the ice phase. This would imply further analyses on differences between simulated and ERA temperature longitude-pressure crosssections which is beyond the scope of this research.

5. Page 25, discussion of the upward moisture flux: In calculating of the upward moisture flux, convective drying/moistening is included in q_v. As discussed in Section 3.1 (starting lin 290), diabatic tendencies are added to the state moist variables in conjunction with horizontal and vertical advection during each Runge-Kutta timestep. Therefore, all state moist variables include the contribution from deep/shallow convection when grid-scale cloud microphysics is applied. The effect of water vapor and condensates are also included in the vertical momentum equation.

6. Page 27, lines 640ff rewrite and shorten: Done.

7. Figure 14: plot instead differences against you retrieved LWP: Done. The paragraph about Fig. 14 (now Fig. 13) has been rewritten accordingly.

8. Drop Figure 15: Done. The paragraph about Fig. 15 has been corrected accordingly.

9. <u>Put more emphasis on Figure 16</u>: The first author believes that she calculated correctly the precipitable water correctly by using the ERA specific humidity interpolated to fixed pressure levels, multiplied by the pressure thickness and divided by *g*. The pressure thickness was computed using the half-pressure levels above and below the fixed pressure levels. Specific humidties were first converted to water vapor mixing ratios. For the same reasons as in 4. above, the authors would prefer to use ERA-Interim instead of ERA5 monthly-mean reanalyses. The paragraph describing Fig. 16 (now Fig. 14) has been rewritten.

10. Is the overestimation of LWP in GF an error in the amount of condensate or only the phase (i.e. it doesn't glaciate correctly?: As I wrote in the manuscript, part of the overestimation in GF may be because of the shallow convection scheme. Additional short-term experiments could also be run varying the partitioning between detrained cloud liquid and water and ice. This could also be handled by improving the microphysics in the GF cloud model itself.

11. As for Fig. 14 (now Fig. 13), plotted differences between the simulated and SSF IWP (new Fig. 15) for consistency with the LWP.

12. Lines 699-702: you say that the partitioning between liquid and ice might be responsible, yes, but you can check this, also it could be the different mass flux profile, i.e. upper level condensate detrainment: See response in 10) above.

13. Lines 730-733: "the strong upscaling effect of the refined grid mesh": I tried to shortly address this issue in Section 4.2, following suggestions made by Referee 2. Further research is needed to understand the response of GF over the transition zone between the refined and coarse areas of the mesh.

14. Lines 738-740: Please note again the MSKF might give the right answer in LWP for wrong reason (too dry) and you need to check out why GF overestimates, at least apparently overestimates LWP. Noted. Thank you.

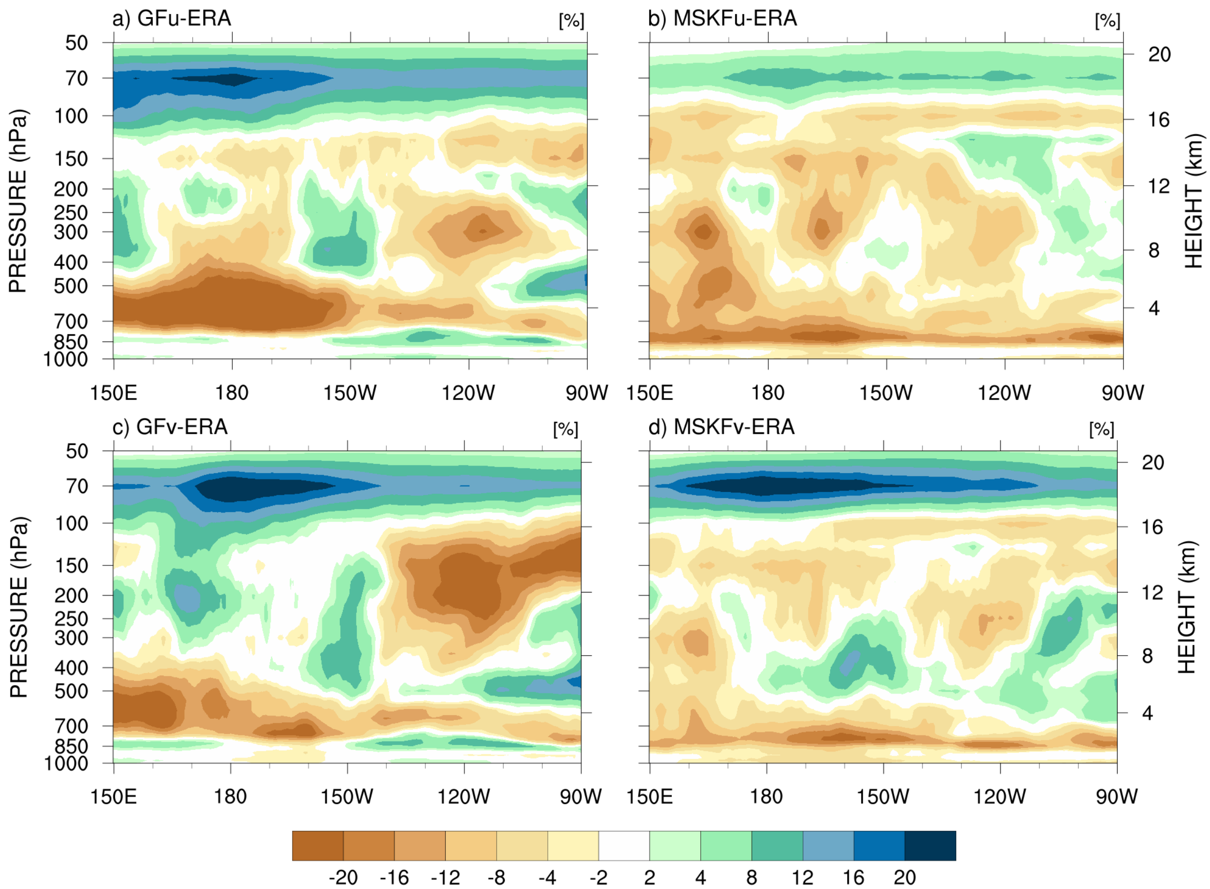

Figure 12-ERA: Longitude versus pressure cross-sections of latitudinally-averaged (between 5°S and 5°N) monthly-mean relative humidity (RH) difference across the Tropical Pacific Ocean for December 2015: a) GFu minus ERA-Interim RH; b) MSKFu minus ERA-Interim RH; c) GFv minus ERA-Interim RH; and d) MSKFv minus ERA-Interim RH.

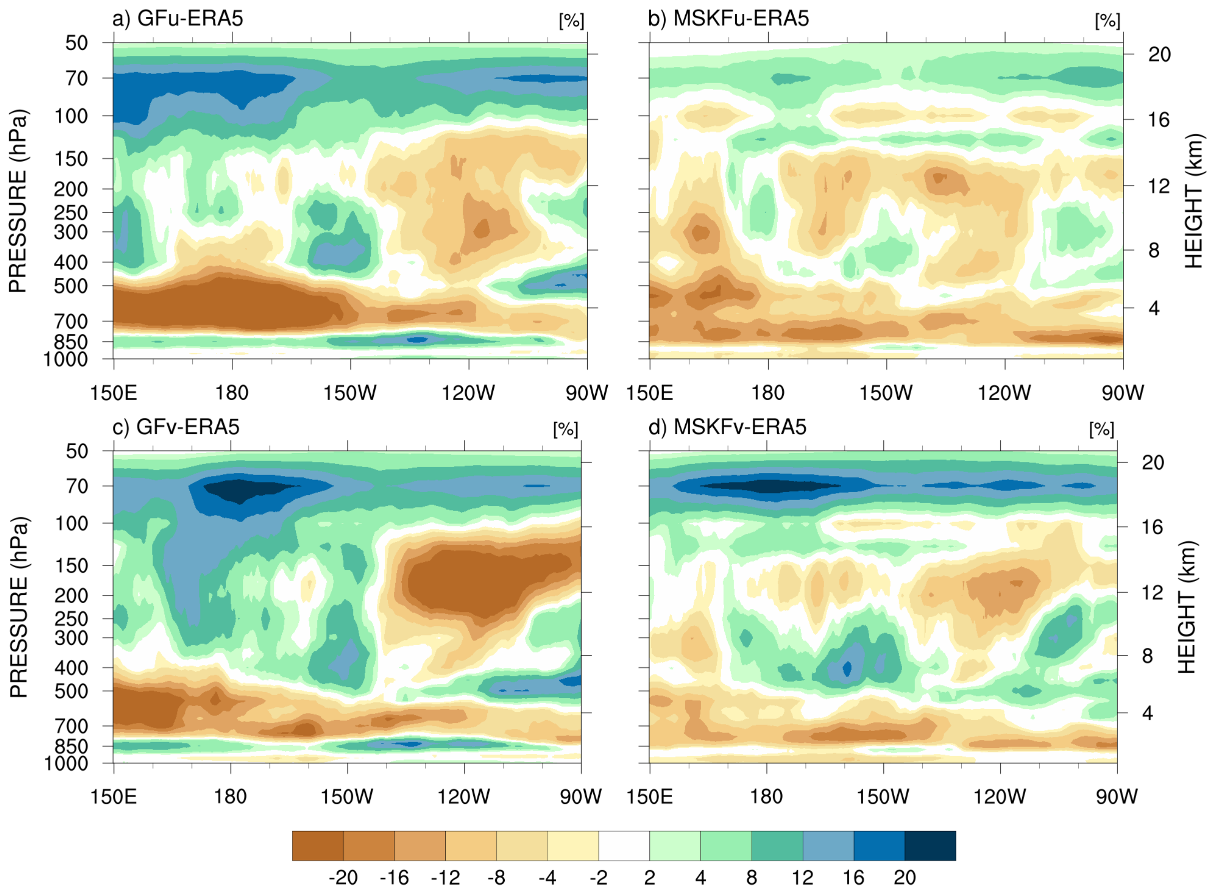

Figure 12-ERA5: Longitude versus pressure cross-sections of latitudinally-averaged (between 5°S and 5°N) monthly-mean relative humidity (RH) difference across the Tropical Pacific Ocean for December 2015: a) GFu minus ERA5 RH; b) MSKFu minus ERA5 RH; c) GFv minus ERA5 RH; and d) MSKFv minus ERA5 RH.