Impact of CRM-GCM Coupling on Tropical Cyclone Simulations using the Superparameterization Framework

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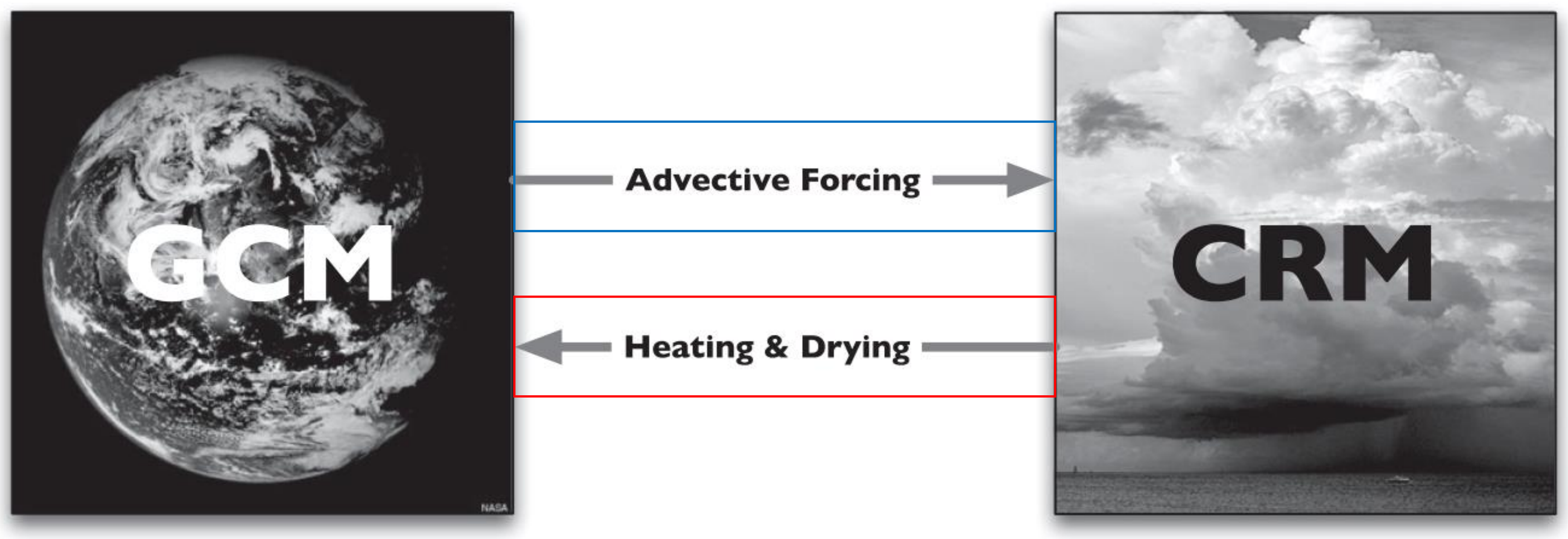
What is Superparameterization (SP)?



(Randall et al. 2016)

"Super-Parameterization"

$$\widetilde{q_G^{n+1}} \equiv q_G^n + B_G \Delta t_G$$

$$\frac{q_G^{n+1}-q_G^n}{\Delta t_G} = B_G + \frac{\langle q_C\rangle^{n+1} - \widetilde{q_G^{n+1}}}{\Delta t_G}$$

$$q_G^{n+1} = \langle q_C\rangle^{n+1}$$

$$\frac{q_C^{m+1}-q_C^m}{\Delta t_C} = B_C + \left(\frac{\widetilde{q_G^{n+1}} - \langle q_C\rangle^n}{\Delta t_G}\right) + S_C$$

$$\frac{\langle q_C\rangle^{m+1}-\langle q_C\rangle^m}{\Delta t_C} = \langle B_C\rangle + B_G + \langle S_C\rangle$$

How Does Convective Representation in CRMs Affect TC Numbers in SPCAM? (Kuo et al. 2023)

Our previous study demonstrated that a smaller CRM domain size resulted in the generation of numerous and intense tropical cyclones (TCs). This can be attributed to the fact that larger CRM domain sizes exhibited stronger mass fluxes and more realistic removal of CWV. In contrast, a more noticeable moisture bias was observed in the smaller CRM domain experiment. This discrepancy may be linked to the frequent occurrence of regions with high convective instability, which subsequently contributed to the heightened frequency of TC genesis and development.

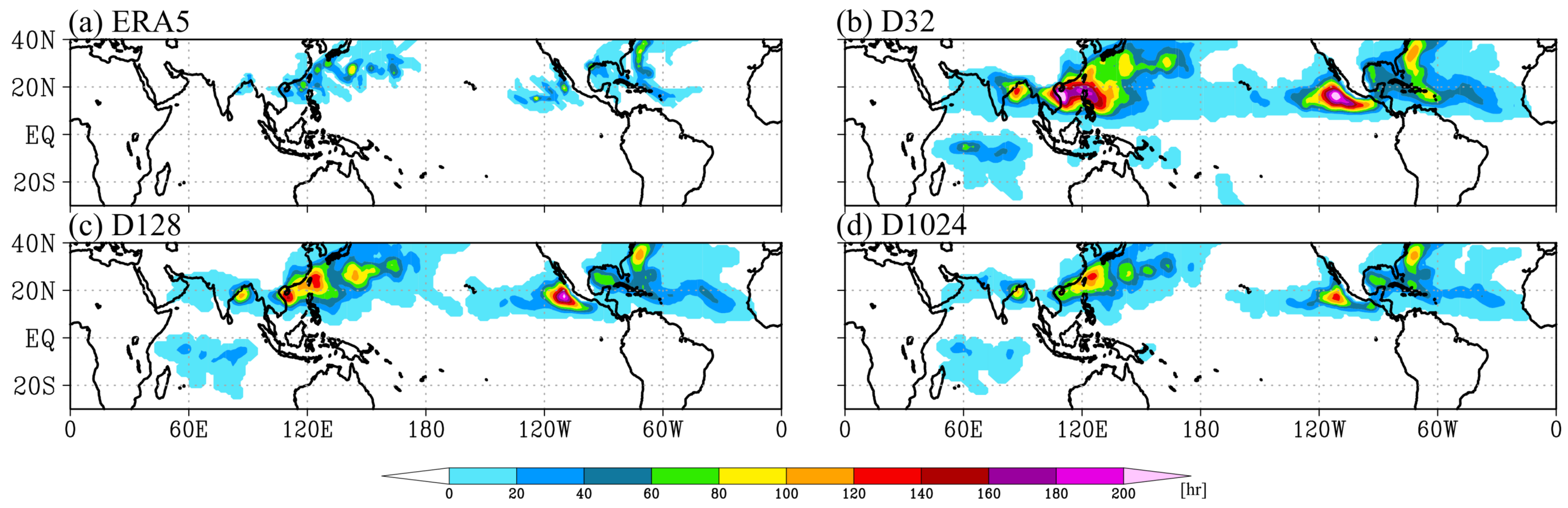


Figure 1. The ensemble average TC track density on the TC areas for (a) ERA5, (b) D32, (c) D128, and (d) 1,024. The unit is hours per summer (June–September).

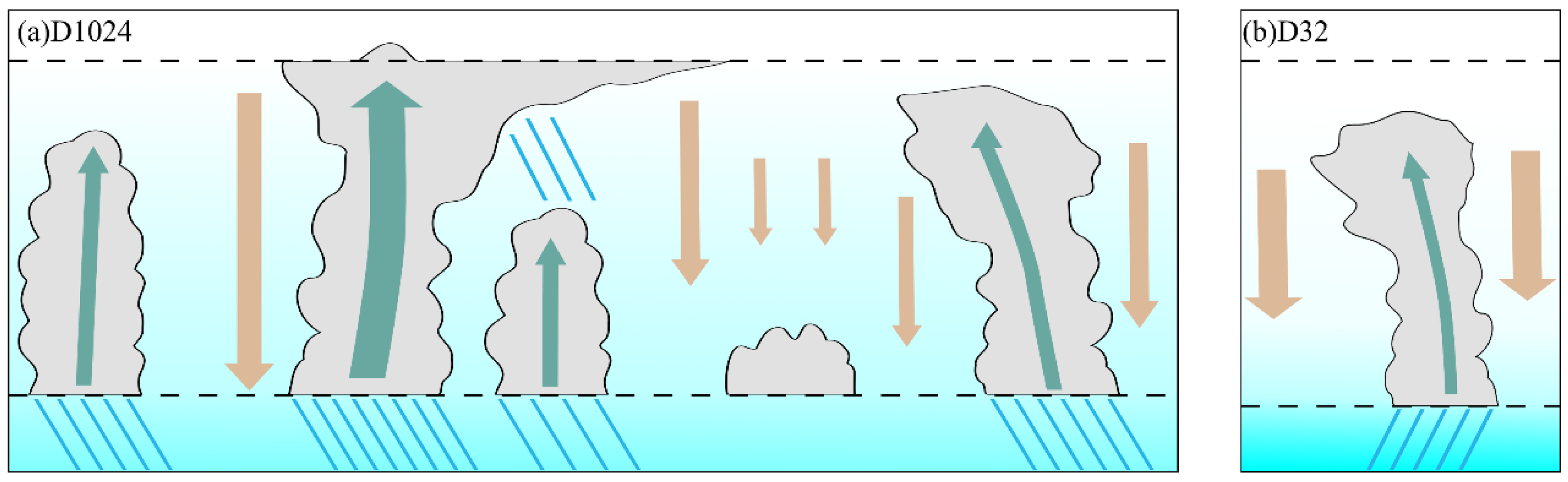
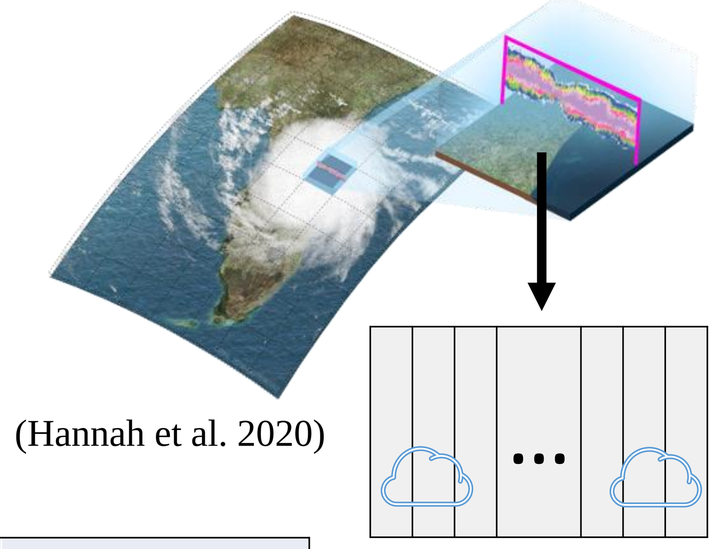


Figure 2. A schematic diagram adapted from a snapshot of the experiments (a) D1024 and (b) D32. The blue shading represents the water vapor mixing ratio. The green arrows represent the updraft of convection. The yellow arrows represent the compensating subsidence to convection. The bottom and top dashed lines represent the boundary layer and the tropopause, respectively.

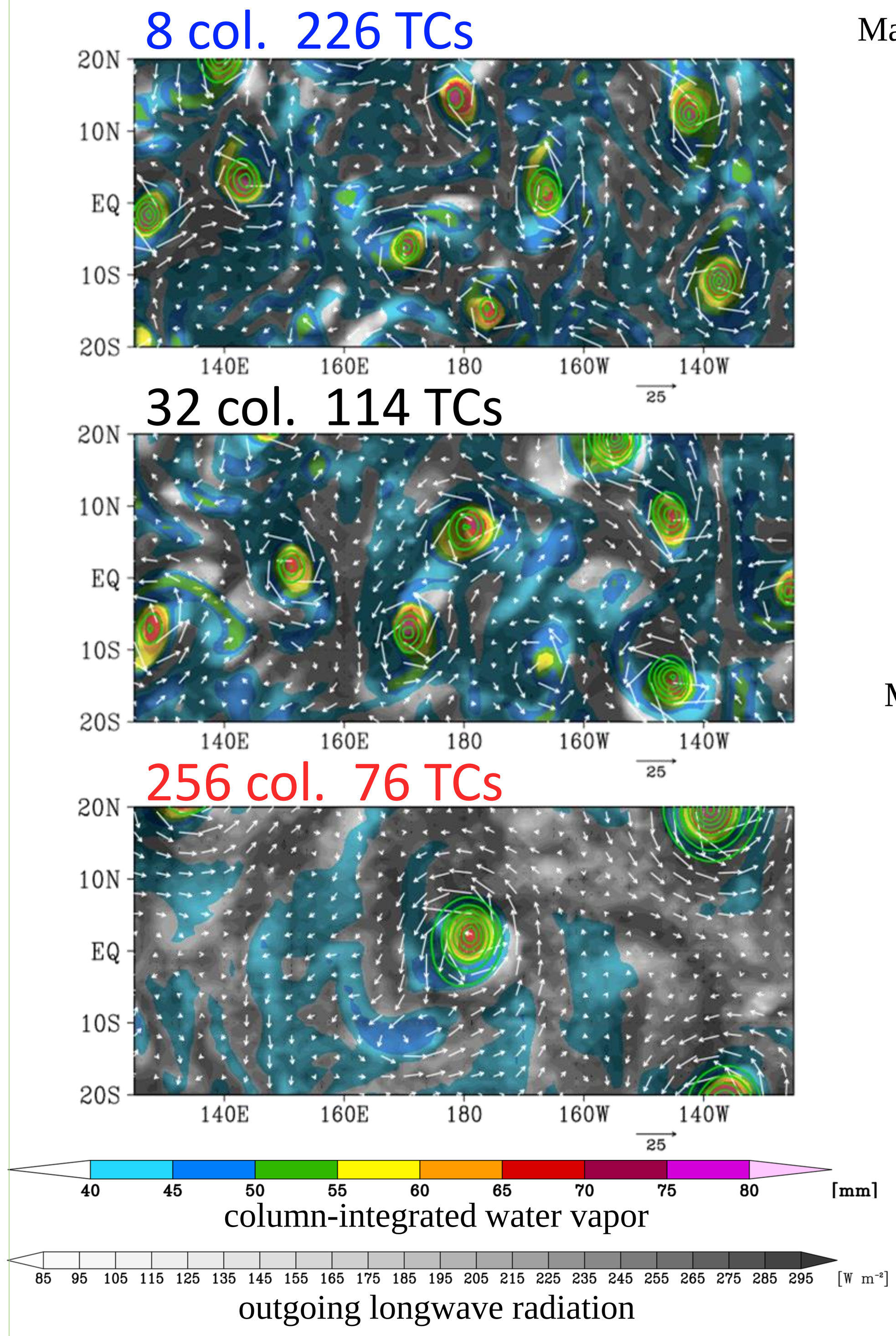
RRCE experiments reveal TC genesis via spontaneous convective processes

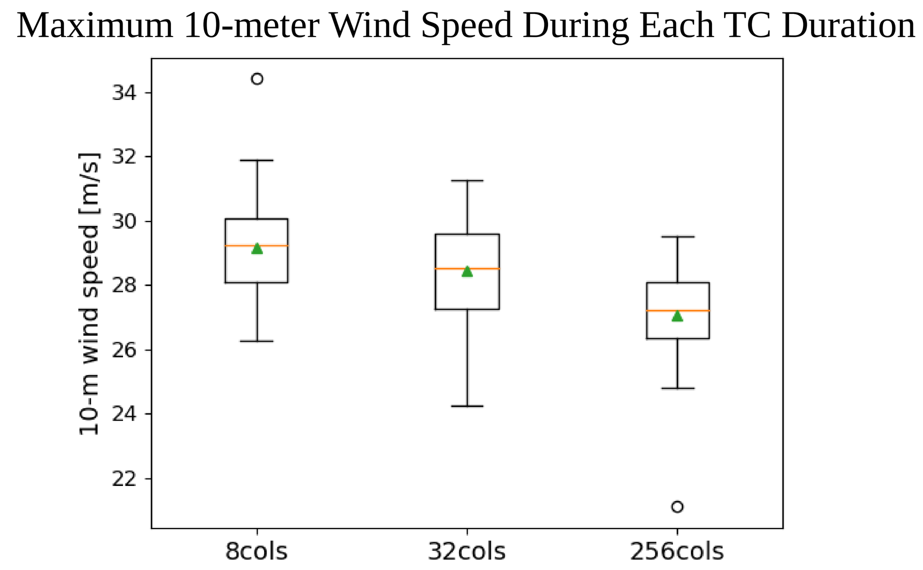
- Model: CESM2.2.1
- GCM Resolution: 0.9°x1.25°, 32 levels
- CRM Resolution: 4 km, 30 levels
- Duration: 5 months (151 days)
- Prescribed SST: 300 K
- Coriolis parameter: $f = 1{\times}10^{-4}\ s^{-1}$
- RCEMIP settings (Wing et al. 2018)

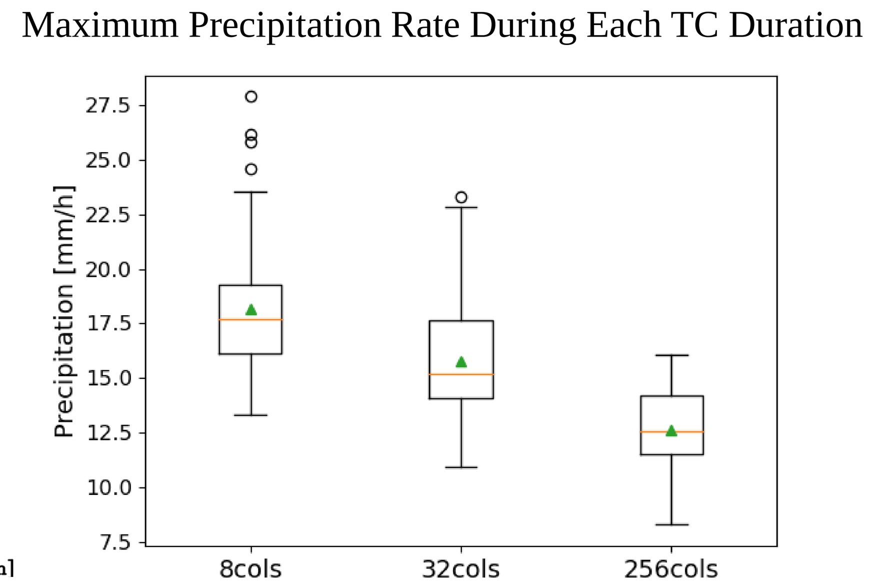


(Hannah et al. 2020)

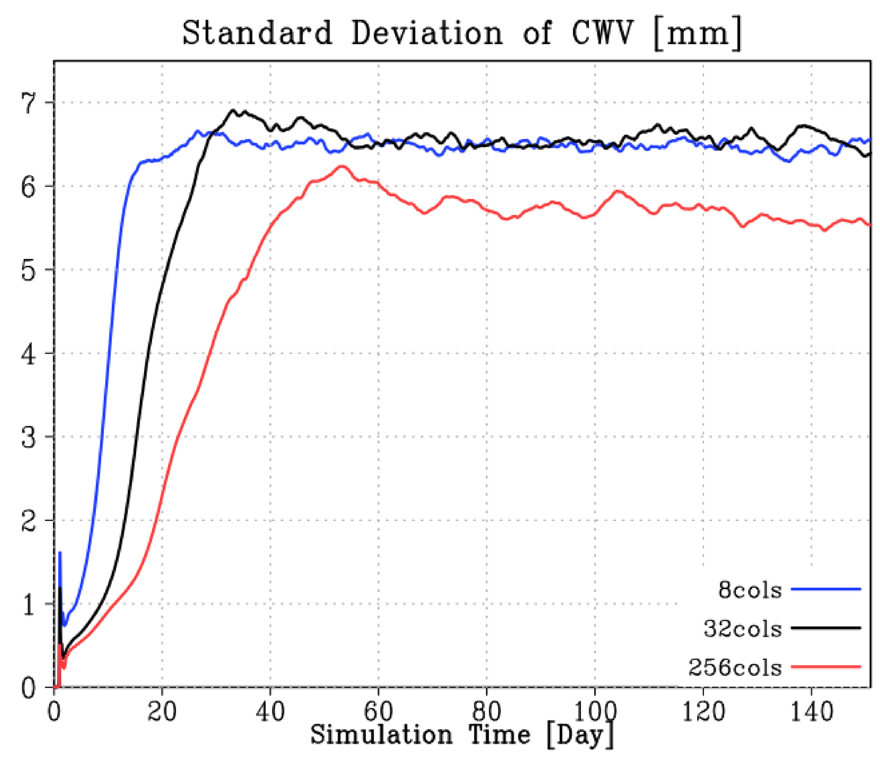
2D CRM columns	8 columns	32 columns	256 columns

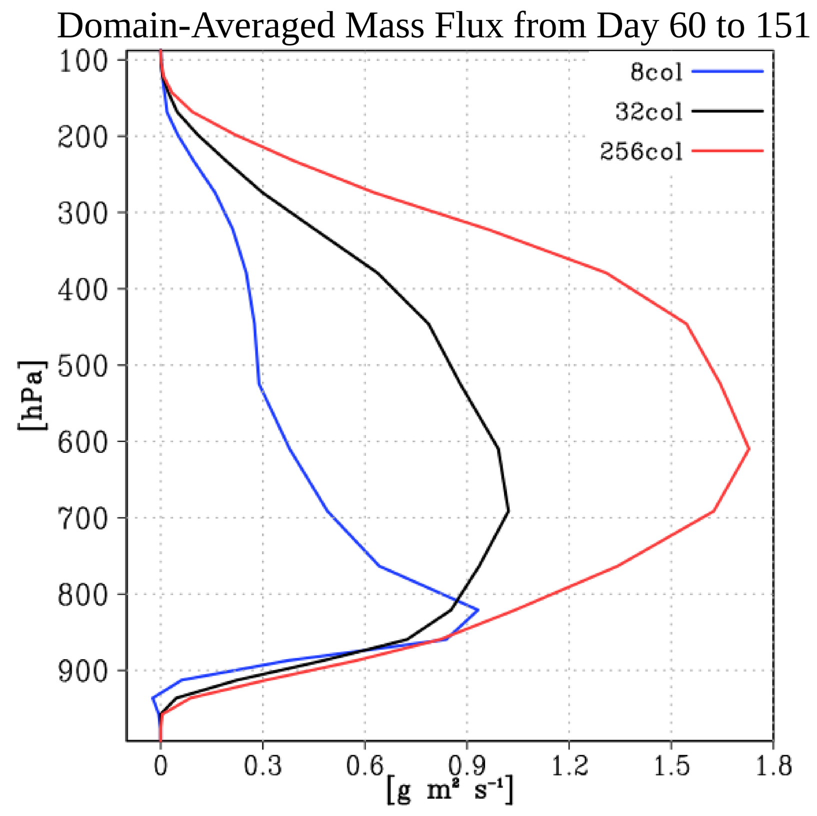






The experiments with a reduced number of CRM columns exhibit a quicker attainment of rotational RCE. This configuration also leads to a greater occurrence of TCs. Furthermore, the experiment with fewer CRM columns yields stronger TCs. This result is consistent with the findings of Kuo et al. (2023). The mass fluxes demonstrate that the configuration with more columns shows higher efficiency of vertical mixing, which results in greater consumption of moisture and convective instability.





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