On the resolution dependence in GFDL AM4 model: from 50km to 6km

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Summary

Many GCMs with horizontal resolution ranging from a few hundred kilometers to 25km tend to simulate an enhancement of the resolved precipitation and a reduction of the parameterized precipitation as resolution increases[1,2,3]. The increment of the resolved precipitation mainly comes from an intensification of the extreme precipitation[1,2,4,5]. It is not clear whether such resolution sensitivity holds as we increase resolution further. Here, we performed a series of aquaplanet simulation at progressively finer resolution from 50km to 6km using GFDL's global atmospheric model AM4 with the Morrison-Gettelman microphysics (MG2). Resolution dependence in the global mean resolved and paramterized precipitation (mostly deep plume) is consistent with earlier studies. The enhancement of the resolved precipitation with resolution seems to approach convergence for resolution finer than 13km. Surprisingly, we find little resolution sensitivity in the daily precipitation extremes in our model. The increment of the equatorial resolved precipitation with resolution mainly comes from precipitation of moderate intensity. We report a robust resolution sensitivity in the convective organization that has not been reported in earlier GCM studies. In simulations of finer resolution, the localized "popcorn" convection is suppressed, and the organized convective system associated with large-scale circulations becomes more prominent.

Model and Experiments

➤ Nonhydrostatic GFDL AM4-MG2 aquaplanet.
➤ Horizontal resolution:
$C192$ (50km), $C384$ (25km), $C768$ (13km), $C1536$ (6km)
➤ Same vertical resolution and tunining parameters.
➤ 1 year run, 3 months spin-up.

References

[1] Wehner et al., 2014, *JAMES*, 6, 980-997.
[2] Terai et al., 2018, *Clim. Dyn.*, 50, 3251-3279.
[3] Herrington and Reed., 2020, *QJRMS*, 146, 3789-3807.
[4] O'Brien et al., 2016, *JAMES*, 8, 976-990.
[5] Rios-Berrios et al., 2020, *JAMES*, 12, e2020MS 002102.

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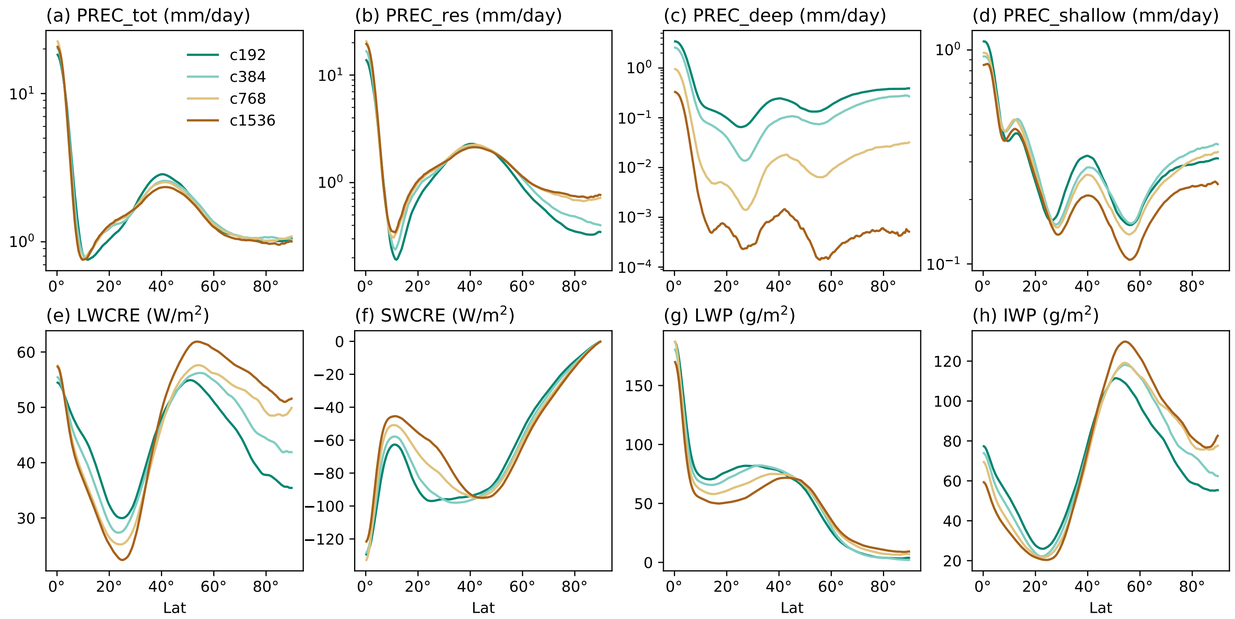
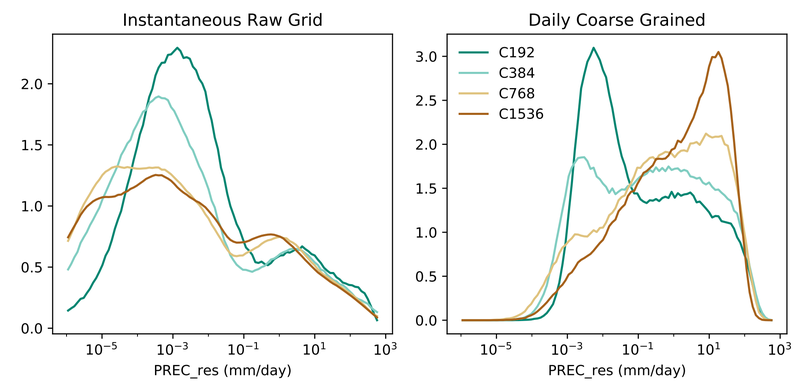
Resolution dependence in precipitation and cloud climatology



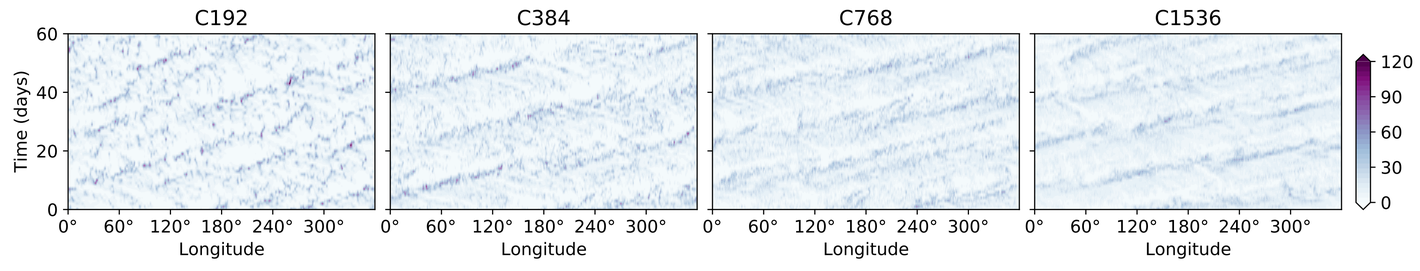
Zonal mean hemispherially-averaged climatology of total precipitation (PREC_tot), resolved precipitation (PREC_res), paramterized precipitation from the deep plume (PREC_deep), parameterized precipitation from the shallow plume (PREC_shallow), longwave cloud radiative effect (LWCRE), shortwave cloud radiative effect (SWCRE), cloud liquid water path (LWP) and cloud ice water path (IWP).

Probability distribution of the resolved precipitation intensity

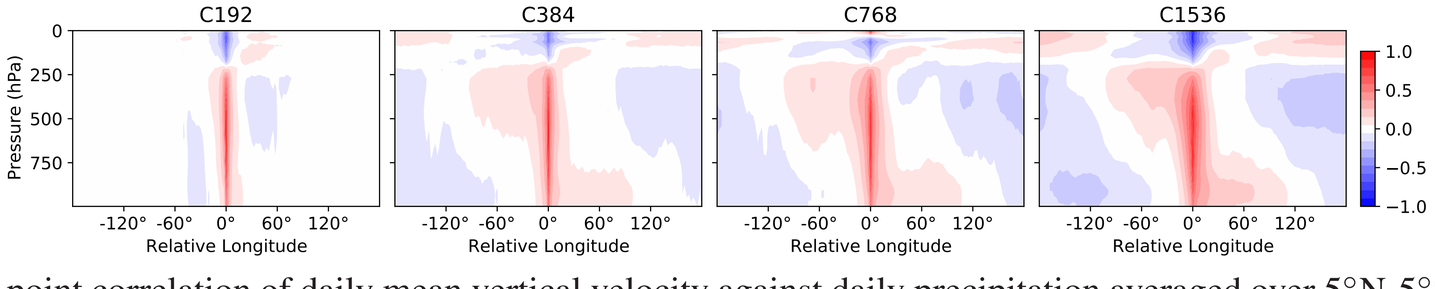


Probability distribution of resolved precipitation intensity between 5°N-5°S over 100 bins spaced evenly on logarithmic scale between 10^{-6} and 10^{3} mm/day. (Left) data are sampled instantaneously every 6 hour at the respective raw model grid. (Right) data are remapped to $0.5^\circ \times 0.5^\circ$ grid and averaged daily.
Finer resolution leads to an enhancement in the daily coarse-grained precipitation of moderate intensity but not in the extremes, which reflects a stronger role of the large-scale organization.

Resolution dependence in convective organization



↑ Hovmöller plot of daily coarse-grained precipitation averaged over 5°N-5°S. Kelvin wave dominates the variance here. Isolated "popcorn" precipitation is suppressed at finer resolution.



↑ One-point correlation of daily mean vertical velocity against daily precipitation averaged over 5°N-5°S. As resolution increases, the circulation associated with deep convection becomes stronger and wider.