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HYBRID MASS FLUX CUMULUS SCHEME (HYMACS) AS A STEP TO UNIFIED CUMULUS PARAMETERIZATION AND ITS APPLICATION TO TROPICAL CYCLONE INTENSITY PREDICTION

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1. INTRODUCTION

In this study, a hybrid mass flux cumulus scheme (HYMACS) adapted from the Kain-Fritsch scheme (KFS) is investigated with the weather research and forecasting model (WRF) in terms of the dependence on horizontal grid resolution and the effect on simulated tropical cyclone intensity. The aim is to reduce the resolution dependence of cumulus parameterization (CP) schemes between 3 km and 20 km, the so called gray zone (e.g., Arakawa and Wu, 2013), and to lessen the tendency of the KFS to overestimate the intensity of tropical cyclones in the gray zone (e.g., Singh and Mandal, 2014).

2. METHOD AND RESULTS

The HYMACS solve convective drafts implicitly but compensating motions explicitly by introducing a subgrid-scale mass source/sink term to the grid-scale continuity equation in a fully compressible model (e.g., Kuell et al., 2007). In contrast, the KFS assume local compensation of convective mass fluxes (e.g., Kain and Fritsch, 1993). The HYMACS is compared with the KFS in mass lifting experiments with prescribed mass and heat source/sink of a subgrid-scale convective draft in a horizontal resolution of 3, 9 and 27 km. Of the simulations with different resolution, the column air mass decrease is 6 times on average more significant with the KFS than the HYMACS. On the other hand, the column air mass decrease difference between 3 km and 27 km resolution is 7 times larger with the KFS than the HYMACS.

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To analyze the effect of the HYMACS on tropical cyclone intensity, simulations of an idealized tropical cyclone on an f-plane with constant sea surface temperature are conducted in those horizontal resolution settings with the HYMACS, the KFS and an explicit scheme without any CP. With the explicit scheme in 3 km resolution as reference, the results (Fig. 1.) in 9 km resolution after 2-day spin-up suggest that the KFS overestimates the intensity in terms of central sea level pressure by 30 hPa in 3 days, and the HYMACS reduces the overestimation by 10 hPa with large variation, suspected to be originated from the interaction between grid and sub-grid scale process.

To look into the direct effect of local compensation of convective mass fluxes, the results with the KFS in 9 km resolution are used as initial conditions to restart simulations with the HYMACS every 30 minutes so that the influence of grid scale process on sub-grid scale one is controlled. The results (Fig. 2.) in the tropical storm stage show that local compensation of convective mass fluxes leads to sea level pressure change, -7 hPa/day at most, with significant variability near the center, implying sensitivity of convective trigger to initial condition here.

3. SUMMARY

The HYMACS reduces the difference between 3 km and 27 km by 1/7 in the mass lifting experiments, and lessens the overestimation of intensity of the KFS by 10 hPa in 3 days in the tropical cyclone simulations. Last but not least, local compensation of convective mass fluxes in the KFS could lead to a sea level pressure change of -7 hPa/day.

4. ACKNOWLEDGEMENT

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5. REFERENCES

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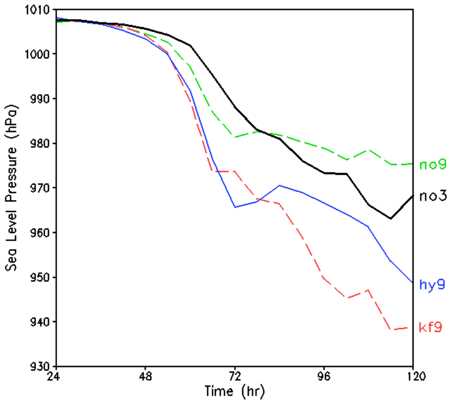

Fig. 1. Temporal evolution of central sea level pressure in the tropical cyclone simulations. The control experiment, no3, uses an explicit scheme without any CP in 3 km resolution. The sensitivity experiments, no9, hy9 and kf9 use the explicit scheme, HYMACS and KFS in 9 km resolution respectively.

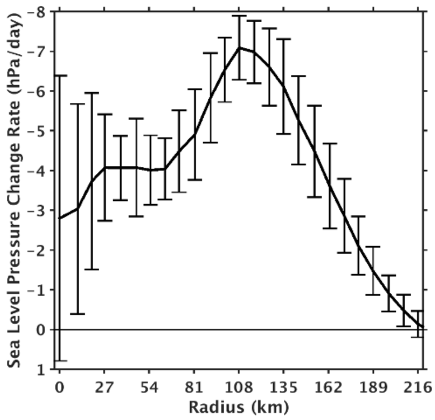

Fig. 2. Ensemble mean and standard deviation of axisymmetric mean sea level pressure change rate difference (subtract HYMACS from KFS, hPa/day), representing the direct effect of local compensation in the KFS on sea level pressure.