Comparisons of high-resolution simulations of tropical cyclones with a single domain and nested domains

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1. Introduction

Currently global (regional) numerical weather prediction (NWP) models can be run in real time on a 10^4 (10^3)-meter scale at operational centers. However, such resolutions are still not high enough for simulations of tropical cyclones (TCs) which are characterized by multi-scale interactions on the order of 10^2 to 10^6 meters. Even with advances in computer technology, it is not yet practical to run NWP models with a very high resolution on all scales. To this end, the widely-used grid nesting technology will continue to play an important role. In the literature, there are reports regarding the impact of resolution and domain configurations on TC simulations. But there are few studies on direct comparisons of TC structures simulated over a single domain and nested domain. We designed an experiment using the Hurricane Weather and Research Forecast (HWRF) model to illustrate TC simulations using a triple nested domain configuration (TRIDOM) can be very close to those using a single domain configuration (ONEDOM) with the same resolution as the innermost nest domain, given proper feedback between domains. The former configuration uses significantly fewer resources and is hence more practical.

2. HWRF configurations

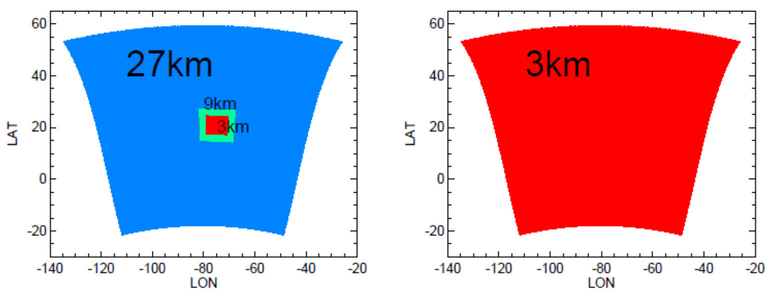

FIG. 1 Schematics of (left) 27-9-3km domains (TRIDOM) and (right) a single 3-km domain (ONEDOM).

In the TRIDOM simulations, HWRF was configured with three domains, a parent grid and two telescopic and movable 2-way nested grids that follow the storm. The parent domain covers approximately 80º x 80º with 27-km grid spacing, and the two nested grids cover 12º x 12º and 7º x 7º with 9-km and 3-km horizontal grid spacing, respectively. The model top is 50hPa, with 61 levels in the vertical and approximately 18 levels below 1000 m. Physics options include a GFDL surface layer coupled with a slab land surface model, Ferrier microphysics scheme, GFDL radiation schemes, simplified Arakawa-Schubert convective scheme (only for the parent and intermediate domains), and GFS PBL scheme. Lateral boundary conditions are derived from GFS forecasts. Initial conditions are derived from the GFS analysis and enhanced through a data assimilation system and vortex relocation technique. The configuration, boundary and initial conditions of the ONEDOM run are the same as TRIDOM, except that HWRF was run only over the TRIDOM parent domain with 3-km resolution (a full cloud resolving mode). In addition, in order to evaluate the impact of feedback between nest grids, TRIDOM was run using different values of feedback percentage.

3. Results and discussions

As a case study, the results of simulations of Hurricane Isaac (2012) initialized at 2012082518 are compared. For the TRIDOM simulations, HWRF with full two-way nesting (100% feedback) produced hurricane track and intensity forecasts which are better than those with one-way nesting (0% feedback) (Fig. 2). This implies the importance of multi-scale interactions of dynamic and physical processes in hurricane simulations. Track forecasts from TRIDOM runs are closer to observations than from the ONEDOM run. Large-scale fields on the 27-km grid are closer to observations than those from the 3-km grid in the ONEDOM run. It is likely due to the performance of physics schemes with different resolutions, given that the use of a higher resolution should reduce the errors in numerical approximations. Many schemes were developed originally for simulations over coarse grids and may not work well for higher resolutions. The TRIDOM run with full feedback yields an intensity close to the ONEDOM run, suggesting that main TC features simulated in ONEDOM can be reproduced by the smaller nested domains in TRIDOM. Figure 3 shows that the size and depth of simulated TCs from the TRIDOM run with full 2-way feedback are very close to those from the run using a single large domain with 3-km resolution. So are the distributions of temperature perturbation and relative humidity (RH). The one-way feedback run of TRIDOM generated a deeper, smaller, and stronger TC than the single large domain.

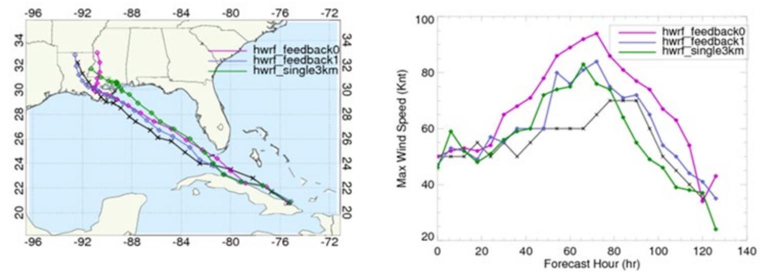

FIG. 2 Hurricane tracks and intensity. Black lines: best track data.

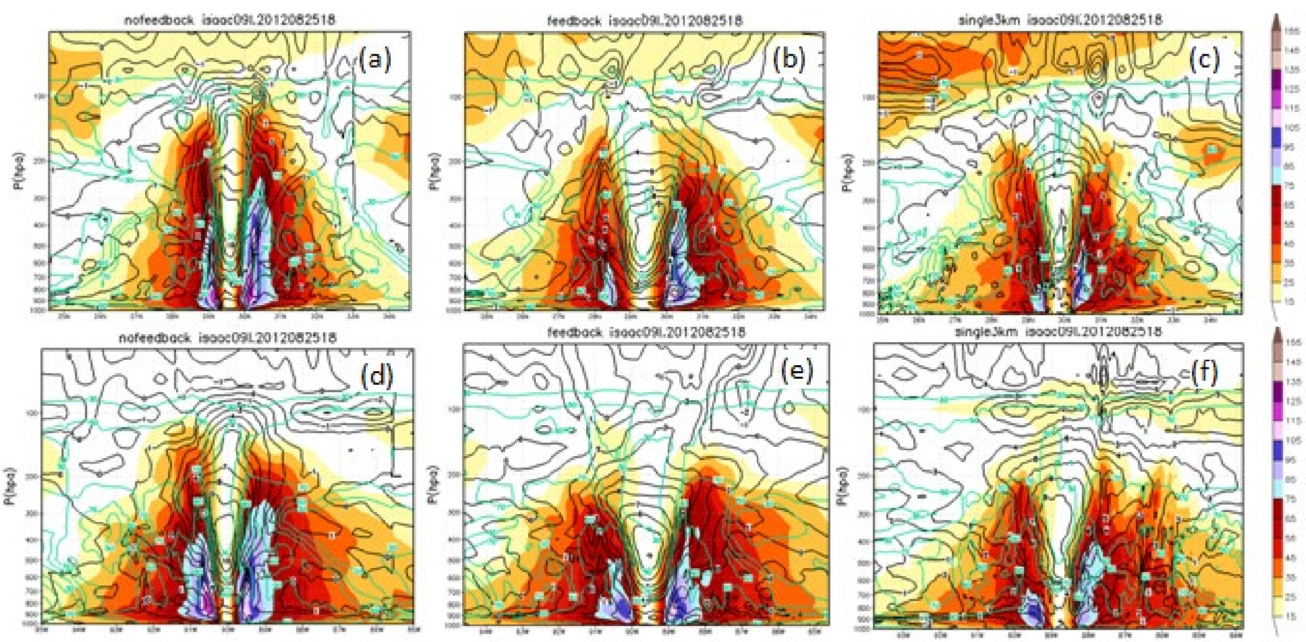

FIG. 3 North-South vertical cross-sections of wind speed (shaded), RH(green), and temperature perturbation (black) from runs of (a) one-way nesting, (b) two-way nesting, and (c) single 3-km at 72 hr. Same for (d), (e), and (f) except for West-East cross-sections.

4. Conclusions

Preliminary analyses suggest that the HWRF using moving nested grids with full two-way feedback can give comparable results to a single high-resolution domain run in terms of TC track, intensity, and structure. Many physics schemes are not yet fully scale/resolution-aware and, therefore, could account for the performance of runs using different resolutions. Improving the scale awareness of physics parameterizations is a priority for multi-scale high-resolution simulations. Given limited resourses, especially in operations, a nesting technique is still a useful and effective way to simulate multi-scale weather events.