Impact of Nest Domain Size on the Track Forecast of TC Sarai (2019) by HWRF Model

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1. Introduction

Tropical Cyclone Sarai 04P (2019) was a moderately strong storm that impacted several island nations in the South Pacific in late December 2019. The storm traveled generally from west to east for most of its lifecycle. The operational HWRF model struggled to make accurate forecasts of the storm track. In many cycles, the storm was forecasted to move slowly from west to east at the early lead hours, then abruptly change its direction to the north and northwest, which significantly deviated from the observed track. To investigate this issue, a number of experiments have been designed including the sensitivities of HWRF simulations to the PBL scheme, surface drag parameterization, horizontal diffusion parameterization, wave coupling, and domain size. Analyses suggested that while the intensity prediction is not sensitive, the storm track forecast by HWRF is very sensitive to the sizes of the horizontal domains, as summarized below.

2. HWRF configuration for the South Pacific basin experiment

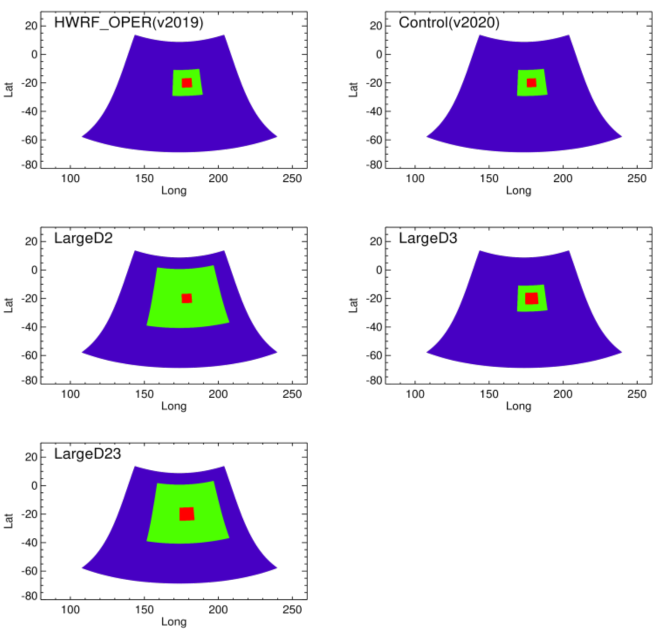

Figure 1. Parent (in blue), two nested domains (in green, red) of operational HWRF and experimental runs.

These experiments use the 2020 HWRF model, which is the same as the 2019 operational version except for more frequently (3h vs 6h) updated BCs, higher-resolution land-sea mask data, and some tunings of the initialization process and physics parameters. The operational HWRF configuration includes three telescopic domains, with one parent grid (D1, ~80^{o}x80^o) and two movable 2-way nested grids (D2, 18^{o}x18^o and D3, 6^{o}x6^o). Horizontal resolutions are 13.5, 4.5, and 1.5 km, respectively. 75 levels are used in the vertical, with a top of 1000 Pa. Boundary conditions are derived from NCEP GFS forecast data. Initial conditions are derived from GFS analysis data, enhanced by a vortex initialization process. Figure 1 shows the experimental domain configurations of each run. The control run uses the same domains as those in the operational HWRF. Other runs use larger nested domains, as indicated by their names (Table 1).

Table 1. Number of grid points in rotated *x* and *y* directions of three domains in different runs

Domain#	HWRF_oper	Control(2020)	Large D2	Large D3	LargeD23
D1	390x780	390x780	390x780	390x780	390x780
D2	268x538	268x538	668x1238	268x538	668x1238
D3	268x538	268x538	268x538	348x690	400x780

4. Results and discussion

For each experiment, HWRF model was initialized every 6h from 2019122600 to 2019123118, producing 23 verifiable cycles. The forecasted 5-day track and intensity are compared with the NHC's best track data using NHC's verification package (Figure 2). The track error of the control run is close to that of the 2019 operational version, except for the degradation during early lead hours and improvement after 72h, which is statistically insignificant. Compared with the control run (green line), the larger individual nest D3 (LargeD3) shows mixed improvement for the track forecast for lead times before 48h, but reduces the track error persistently for lead times beyond 48h (yellow line), with the maximum reduction being 10%. Increasing the size of domain 2 (LargeD2) exhibits more improvement than the LargeD3 run, with the track error reduced by 16% persistently for lead times beyond 24h. The experiment expanding both nested domains (LargeD23) exhibits even more improvement in the track forecast. Compared with the control run, the track error is reduced by 10% to 32% for all lead times (cyan color). Also of note is that LargeD23 outperforms the GFS for all lead times except beyond 96h.

Figure 3 shows the tracks of all runs for the forecast initialized at 2019122818. It is seen that the tracks of all runs are very close before 48h. After that, the tracks become more visibly different. The storm simulated by the operational HWRF (2019) turns abruptly to the north, significantly deviating from the observed track (in black) and other simulations. The 2020 HWRF, LargeD2, and LargeD3 predict that the storm moves to the northeast, giving a better track forecast but still significantly different from the observed. In contrast, LargeD23 predicts a track very close to the observed.

The motion direction of the storm is generally consistent with the environmental wind streamlines at the 500-hp level. As an example, Figure 4 shows the 500-hp streamlines at 48h from the control (Left) and LargeD23 (Right) forecasts. The general patterns of large-scale wind are similar, but it is seen that the storm in LargeD23 is located a little further east or moving faster than the control at this hour (see TC symbols in red). Such a small difference makes the storm impacted by the southwesterly flow in the control run but by westerly flow in LargeD23, resulting in a larger track difference over time. This suggests that storm translation speed may be an important factor affecting the storm track in complex flow. Larger nest domains might help the model to produce better simulations of both storm structure (e.g., size, depth) and large-scale flow. Another run using a larger parent domain (D1) does not show track improvement. Higher horizontal resolution over a large domain can help the track forecast; this is also shown by HAFS with a 3-km single large domain. More investigations are warranted.

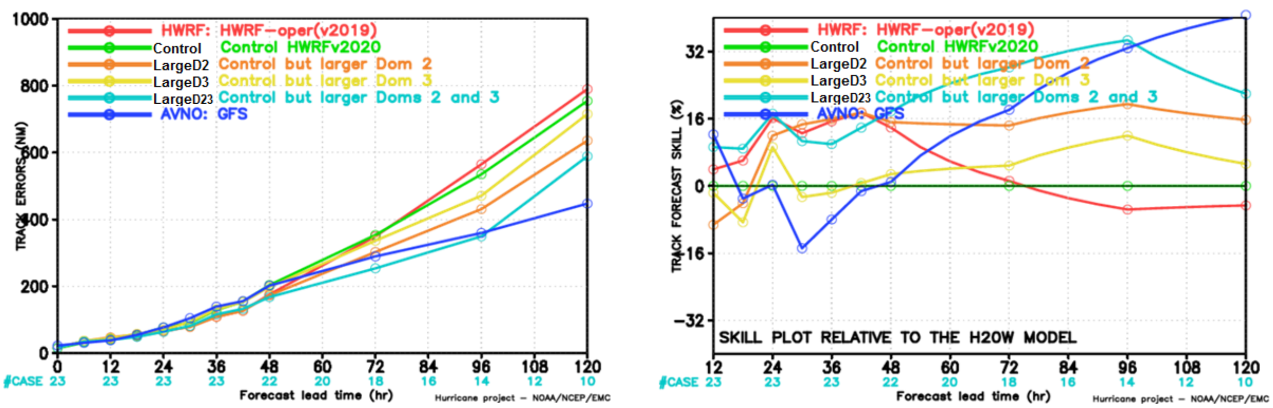

Figure 2. Mean absolute errors of track (Left). Track errors relative to the control run (Right).

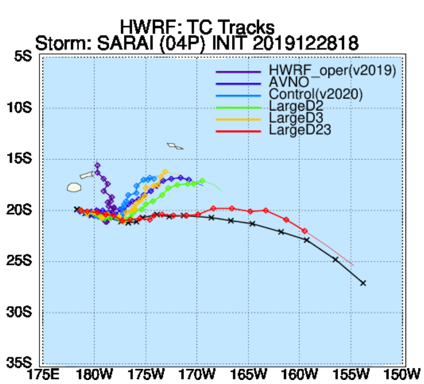

Figure 3. 5-day tracks of 2019122818.

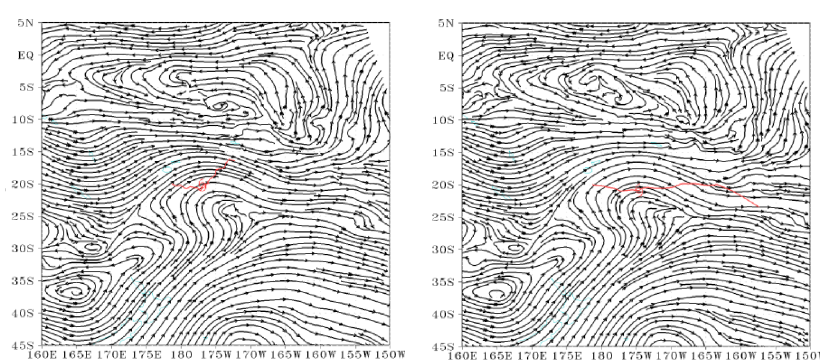
Figure 4. 500-hp streamlines at 48h (L) Control, (R) LargeD23. Track is in red.