Testing a New Horizontal Mixing-length Formulation in HMON

Weiguo Wang[1], Lin Zhu[1], Hyun-Sook Kim[1], Dan Iredell[1], Keqin Wu[1], Bin Liu[1], Zhan Zhang[1], Avichal Mehra[2], Vijay Tallapragada[2]
[1]IMSG @ EMC/NCEP/NWS/NOAA, [2]EMC/NCEP/NWS/NOAA, College Park, MD 20740
Email: Weiguo.Wang@noaa.gov

1. Introduction

Recent studies indicate that the intensity of numerically-simulated tropical cyclones (TC) are sensitive to the horizontal mixing length (L_h) in the parameterization of horizontal diffusion. A fixed fraction of the model grid spacing or a constant value is usually used to approximate L_h in many current numerical models. This approximation is not in agreement with L_h derived from observational data and large eddy simulations. To improve the representation of horizontal diffusion in numerical models, we proposed a new formulation of L_h, which is a function of horizontal wind and its gradients. The new formulation has been used in HWRF to simulate Hurricane Harvey (2017) and showed very positive impacts (Wang et al, 2020). In one of the experiments supporting the upgrade of HMON model in 2020, we tested the new formulation in the latest HMON system. A brief description of the experiment and results are shown.

2. New formulation

Details of the new formulation are given in Wang et al. (2020). Here only a basic idea of the new formulation is given. The horizontal exchange coefficient K_h is calculated as, $K_h = L_h^2|D_h|$ where D_h is proportional to horizontal deformation. In many current numerical models, L_h is given as

$$L_h = Constant\ or\ \alpha\Delta,$$

where α is a constant, Δ is model horizontal grid spacing. The new formulation is flow-dependent,

$$L_h = 0.5(L_{h1} + L_{h2}),$$

where L_{h1} and L_{h2} are the length scales for shear and stretching, respectively.

3. HMON (**H**urricanes in a **M**ulti-scale **O**cean-coupled **N**on-hydrostatic) model in 2020

The operational deterministic HMON system contains two major components. The atmospheric component uses the Non-hydrostatic Multi-scale model on a B grid (NMMB) as its dynamic core. It is configured as triple-nested regional domains, with one parent domain and two movable nests. The ocean is simulated by HYCOM, coupled to NMMB through a coupler developed at NCEP. Large scale data are provided by the operational Global Forecast System (GFS) and Real-Time Ocean Forecast System (RTOFS). HMON is initialized every six hours, with a vortex relocation procedure. Compared with the 2019 version, major upgrades of the latest HMON system include: (1) the number of vertical levels increasing from 51 to 71; (2) using the original IGBP roughness length; (3) using the latest version of HYCOM, with a new version of mixed layer scheme, a C_d formula based on CORE v3, Newtonian relaxation employed in an implicit time step, and a corrected momentum reduction; (4) turning on the GWD option over the parent domain.

4. Results and discussion

As a control experiment (CNTL), the latest HMON 2020 was run to simulate 7 EPAC TCs in 2019, including Barbara 02E, Erick 06E, Flossie 07E, Juliette 11E, Kiko 13E, Mario 14E, and Lorena 15E. A fixed fraction of grid spacing is used in the CNTL as the horizontal mixing length over a given domain. They are 0.2, 0.2, and 0.3 for the parent and two nest domains, respectively. In the test run (EXPL), the new flow-dependent mixing length formulation is used in all domains. Figure 1 shows the track and intensity errors as well as mean bias for all verifiable cycles. Overall, the new formulation can improve the track forecast at almost all lead times. The intensity is improved before the 72nd hour but degraded by 4% after that. The EXPL produced TCs generally stronger than the CNTL did. Figures 2 and 3 show the verification plots for the runs (cycles) with intensity at initial time greater and less than 50 kt, respectively. For strong cycles, the new formulation improved both track and intensity slightly, but increased the positive bias. For weak cycles, the new formulation improved the track by as much as 12%, but it degraded the intensity by as much as 20%. The positive mean bias is slightly increased.

In summary, preliminary test results for EPAC TCs suggest that the new formulation in general produced larger positive mean biases in intensity. In terms of RMS errors, it can help improve tracks for weak cycles and give positive impacts on both track and intensity for strong cycles. For individual TCs, the improvement in track for Eric 06E is the largest, with slightly better intensity. Juliette (11E) has the largest intensity improvement. Flossie (07E) has the most degradation in intensity, with a moderately degraded track. Investigations of individual runs are warranted to further understand the impact of the new formulation.

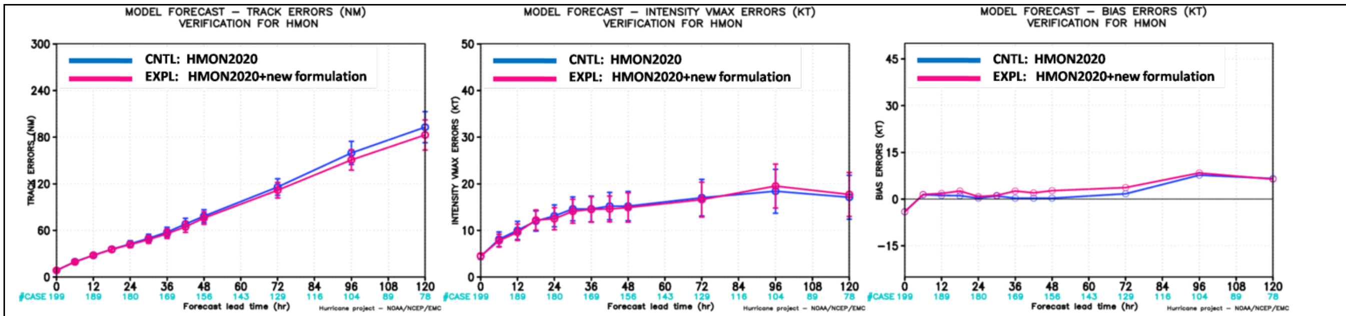

FIG. 1 Track errors (left). intensity errors (middle), and mean bias (right) of all verifiable cycles in two runs

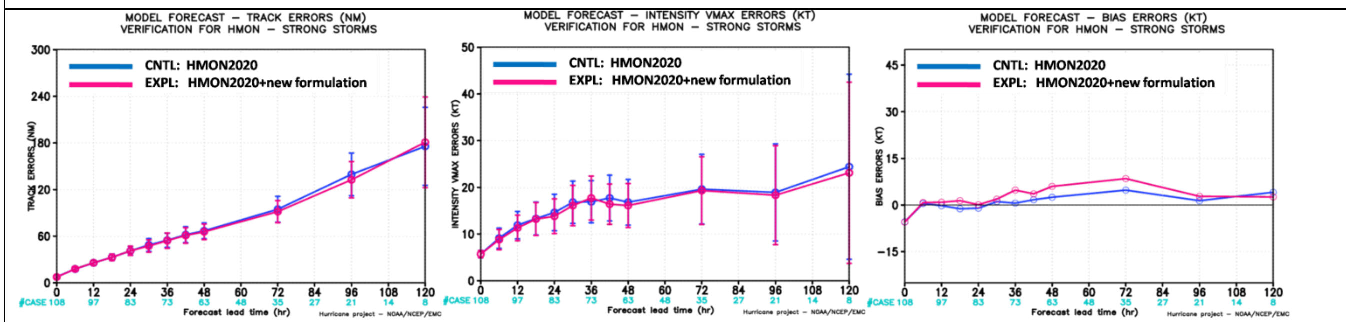

FIG 2. As FIG 1 except for cycles of initial intensity greater than 50kt.

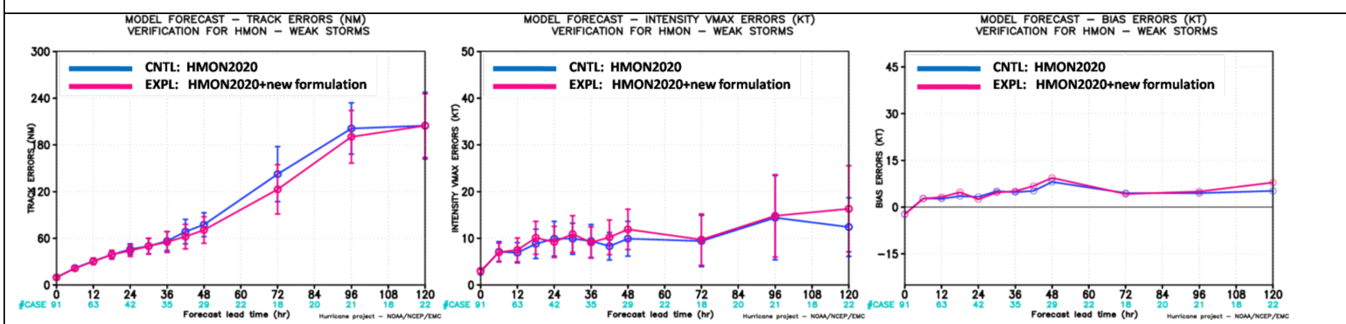

FIG 3. As FIG 1 except for cycles of initial intensity smaller than 50kt.

Reference:

(1) Weiguo Wang, Bin Liu, Lin Zhu, Zhan Zhang, Avichal Mehra, Vijay Tallapragada, 2020, A new horizontal mixing-length formulation for the simulations of tropical cyclones, to be submitted to ***MWR***

(2) Weiguo Wang, Bin Liu, Lin Zhu, Zhan Zhang, Avichal Mehra, Vijay Tallapragada, 2020, A flow-dependent horizontal mixing length scale and its impact on track simulations of Harvey (2017) in HWRF. AMS 2020 annual meeting. Boston, MA, Jan, 2020

(https://ams.confex.com/data/handoutams/2020Annual/ Paper_364510_handout_5057_0.pdf)