Secondary eyewalls in HWRF and HMON

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Secondary eyewalls are the most prominent structural feature of major hurricanes and they are associated with intensity changes and the horizontal expanse of storms, making them an even larger hazard. While in the past years mesoscale numerical models have struggled to generate secondary eyewalls, HWRF[1] and HMON both often generate secondary eyewalls in storms that also occur in nature. While in recent years there have been concerns that HWRF generates too few secondary eyewalls in its operational setting, the 2017 and 2018 versions of both models have secondary eyewalls as a common structure (and in some cases even generating secondary eyewalls with no corresponding structure in nature).

For the 2017 season, given an observation of a secondary eyewall (SE) at a specific moment in time, in principle there are 20 HWRF and HMON operational cycles that simulated a concurrent SE (since operational simulations are initialized every six hours and last for 5 days). The Atlantic major hurricanes Harvey, Irma and Maria of 2017 offer a unique opportunity to examine the realism of the numerical models since these storms underwent SE formation within the observable range of multiple ground based radars along their tracks over the Caribbean and Gulf of Mexico.

Hurricane Harvey (2017) generated an SE before it made landfall on the coast of Texas. 70% of the operational HWRF cycles of Harvey generated an SE, including 6 of the 7 cycles initialized in the Caribbean. In contrast with this abundance of SEs in the operational HWRF, the operational HMON only generated SE's in the last 7 cycles that included the time of an observed SE. The absence of SEs across a number of cycles is found to coincide with a weak intensity bias in the model. In these cases, absence of SEs does not point to an inability of the model to generate them but to the fact that the models are not generating them correctly when storms are weak (a feature also observed in nature[2]).

There is observational evidence of at least 3 SEs in Hurricane Irma (2017). Figure 1 shows evidence of SEs (a concentric structure in the wind magnitude field at 2 km height) in both the operational HWRF and HMON in simulations of Hurricane Irma. In the figure, one cycle for each model and two forecast hours with evidence of SEs at each time are presented. These two example cycles developed more than one SE. Overall, 93% of the 40 operational cycles that included the times when SEs were observed had at least one SE and 18% of them had more than one. Those figures are 95% and 58 cycles for the operational HMON. The 2018 version of HWRF has displayed an SE in 80% of the cycles analyzed and 30% of cycles have more than one SE. All of the HMON 2018 cycles analyzed have SEs and 30% of them exhibit more than one.

Hurricane Maria (2017) completed a canonical eyewall replacement cycle within about 15 hours. Both HWRF and HMON were able to capture this phenomenon in several of their cycles. Figure 2 shows a cycle of each model with an eyewall replacement cycle completed within 15 hours. All 2017 operational HWRF and HMON Maria cycles have SEs, and 82% and 85% of the 2018 HWRF and HMON cycles, respectively, have SEs. However, most of HMON cycles have more than one SE, which was a common occurrence in HWRF as well.

While the frequency of SE existence in HWRF and HMON is now high, as in nature, and while once actual SEs emerge they undergo a variety of different evolutions, there is a lot of inter-cycle variability in HWRF and HMON, both in their timing and whether or not a canonical eyewall replacement cycle occurs.

[1]Biswas et al., 2017: "HWRF Scientific Documentation" Developmental Testbed Center https://dtcenter.org/HurrWRF/users/docs/scientific_documents/HWRFv3.9a_ScientificDoc.pdf

[2]Yang, Y.-T., H.-C. Kuo, E. A. Hendricks, and M. S. Peng, 2013: Structural and intensity changes of concentric eyewall typhoons in the western North Pacific basin. Mon. Wea. Rev., 141, 2632– 2648, doi:10.1175/MWR-D-12-00251.1.

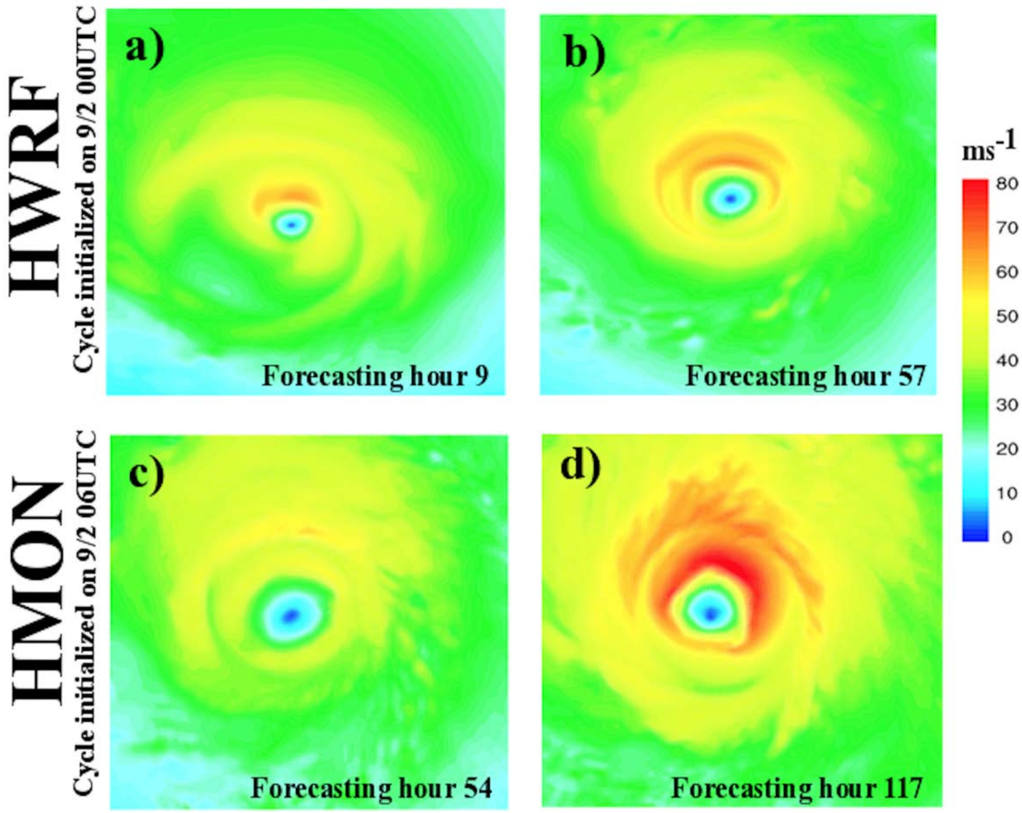

Figure 1. HWRF (upper panels) and HMON (lower panels) of horizontal wind magnitude at 2 km height [ms-1] for the cycles and forecast hours indicated in the image. The horizontal and vertical axis are 30 km long. The version of the models is 2018.

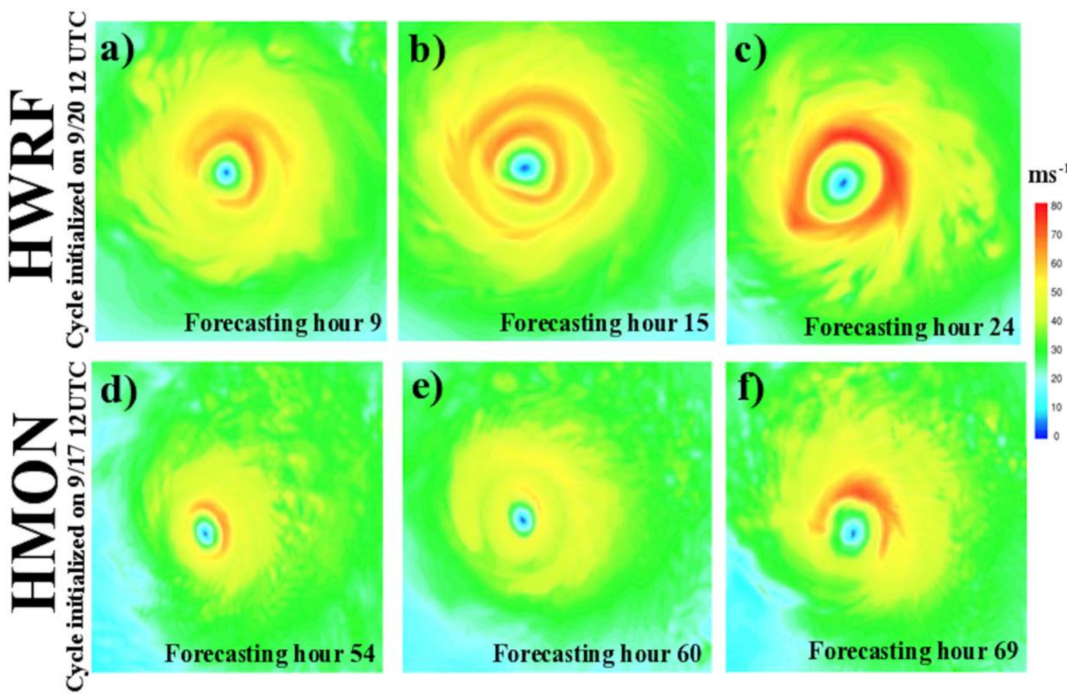

Figure 2. HWRF (upper panels) and HMON (lower panels) of horizontal wind magnitude at 2 km height [ms-1] for the cycles and forecast hours indicated in the image. The panels for each model span 15 hours in the evolution of the storm during which the integrations underwent a canonical eyewall replacement cycle. These results are from the 2017 operational models.