Evaluation of Rapid Intensification in NCEP's Hurricane Weather Research and Forecasting (HWRF) Model: Idealized Studies and Real-Time Forecasts in the Northwestern Pacific Basin

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Introduction

The Environmental Modeling Center's Hurricane Weather Research and Forecasting (HWRF) model is an updated version of the WRF model programed specifically for hurricane forecasting. In the northwestern Pacific basin, it has been outperforming many regional models even though it has only recently been implemented for providing real-time forecasts for this basin. Upgrades to the modeling system are made on an annual basis through focused research and development based on the model performance in real-time, and this research hopes to discuss areas of improvement for the model for future implementations.

This study will focus on the analysis of multiple idealized experiments conducted with the HWRF model in an effort to analyze its capability in predicting rapid intensification of typhoons, and identify discrepancies in the model to tackle for future upgrades.

Objectives

- Conduct idealized experiments to understand the behavior of rapid intensification (RI) in the HWRF model, defined as a 30-knot wind increase in 24 hours, in an effort to identify sensitivity of the model's RI to specification of various parameters such as vortex size, intensity and structure of the initial vortex, and to examine the processes responsible for RI.
- Stress the importance of continued model upgrades by discussing real-time performance of the HWRF model in the northwestern Pacific basin and the social impacts of particularly devastating storms in the region

Methods

- Triple nested domains 27/9/3 km configuration
- Use an HWRF idealized configuration in moist (Jordan 1965 tropical profile) environment (Constant SST, quiescent environment, and constant boundary condition)
- Model physics include Ferrier microphysics scheme, GFDL radiation for short/long wave; GFS PBL scheme; no SAS cumulus convection for 3km domain. (Gopalakrishnan et al. [2011, 2013] and Bao et al. [2012], Kieu et al. [2014])
- Model physics modified by Chanh Kieu at EMC to include capability for changing the radius of maximum wind and maximum tangential wind for the initial vortex

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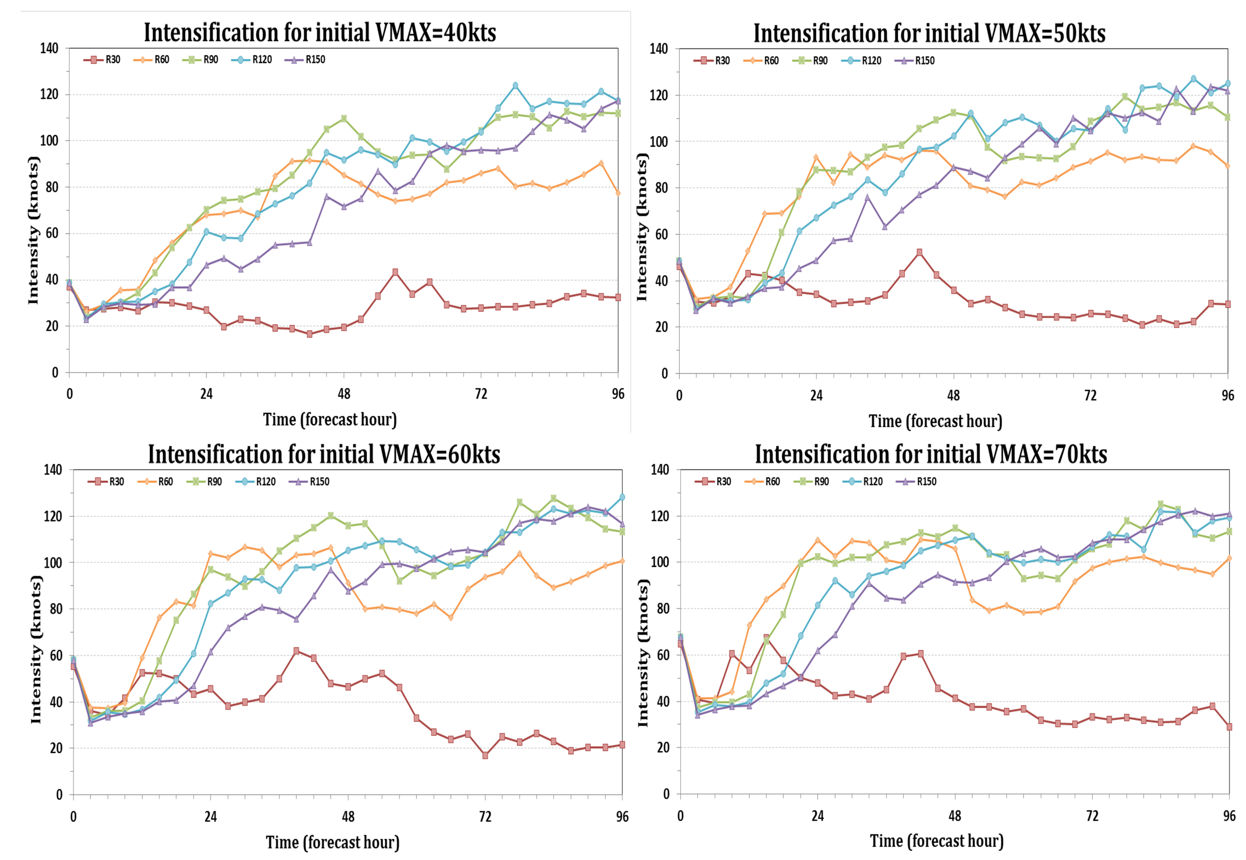
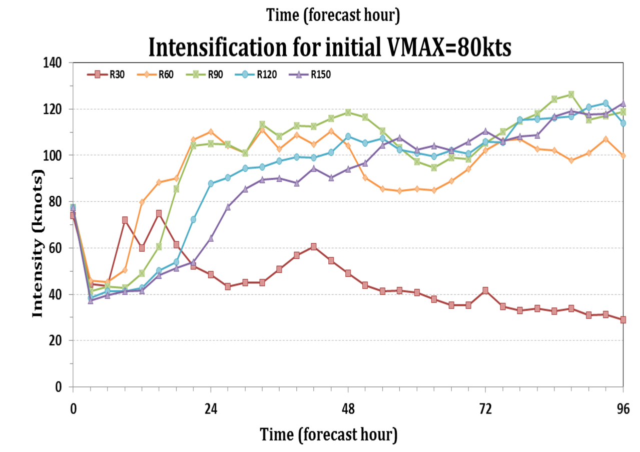
Results

Sensitivity to specification of RMAX (radius of maximum wind):
R30 (30 km), R60 (60 km), R90 (90 km), R120 (120 km), R150 (150 km)

Sensitivity to specification of VMAX (maximum tangential wind):
V40 (40 kts), V50 (50 kts), V60 (60 kts), V70 (70 kts), V80 (80 kts)

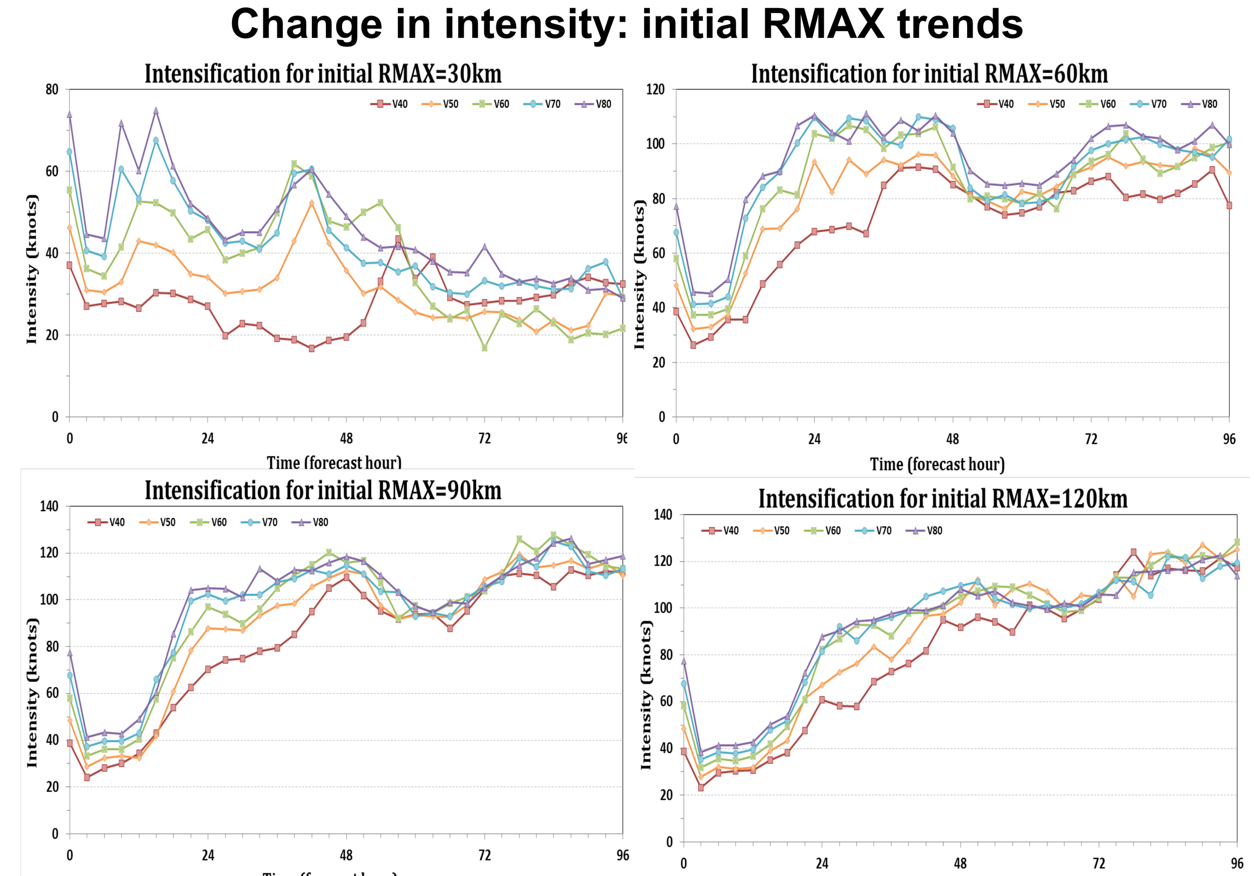
Change in intensity: initial VMAX trends

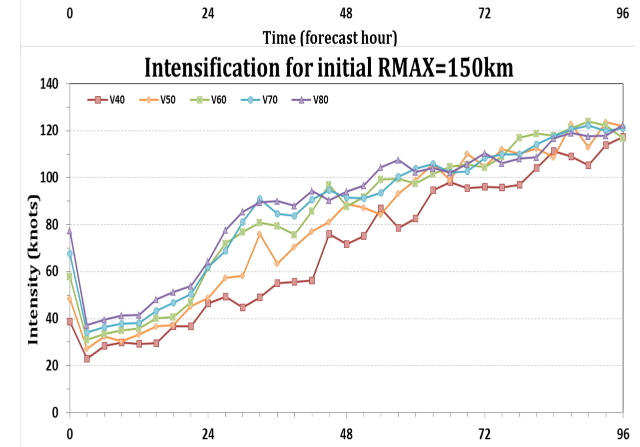




- Smaller storms have the largest intensification rate, however they level off faster than the larger storms
- Given the same VMAX, if the storm is too small, HWRF fails to forecast intensification (as seen with red line in all experiments)

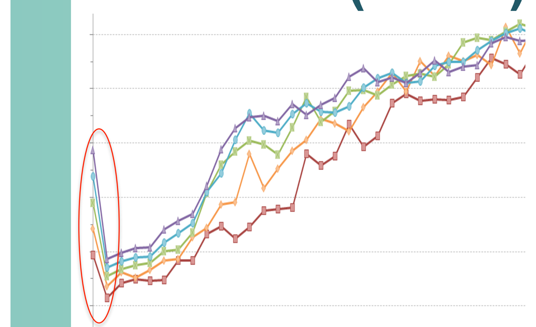
Change in intensity: initial RMAX trends





- As the initial RMAX increases, HWRF becomes more consistent in its runs at later times
- HWRF has a harder time intensifying initially smaller storms overall
- Can again see all R30 storms spin down

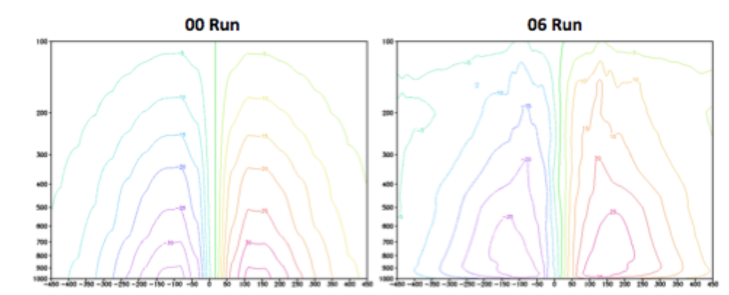
Results (cont.)



Initial spin-down effect

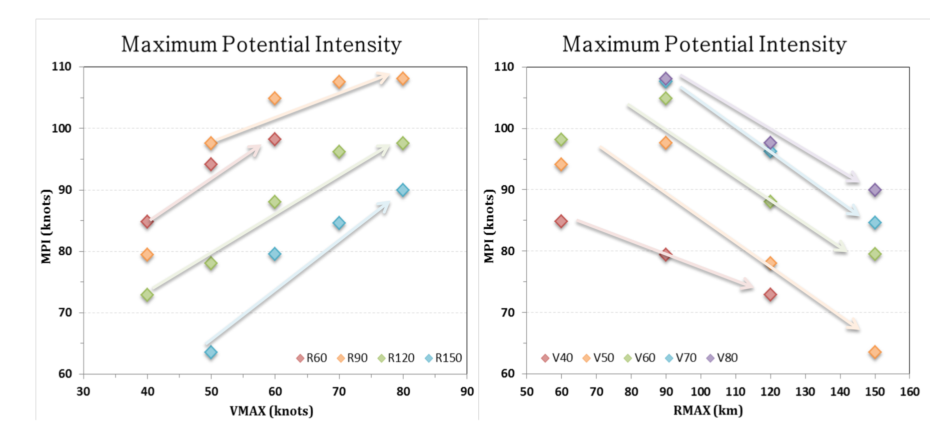
The reason for the consistent initial spin-down in each model run is due to the initial conditions. Initially, the maximum wind is positioned at the surface, which is not true of actual storms.

The model attempts to correct back to actual storm structure from run to run and forecasts a drastic initial spin-down of the vortex due to friction.



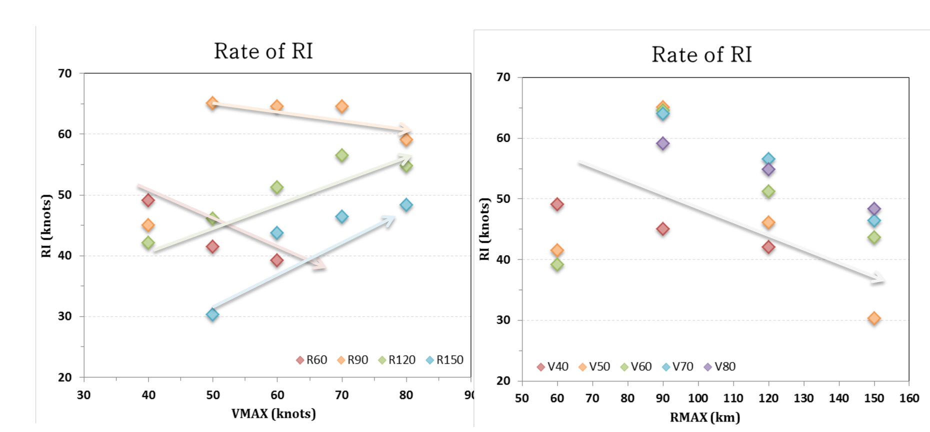
Taking this into consideration, all data before the 12-hour run were not used in the following calculations.

Trends for Maximum Potential Intensity (MPI)



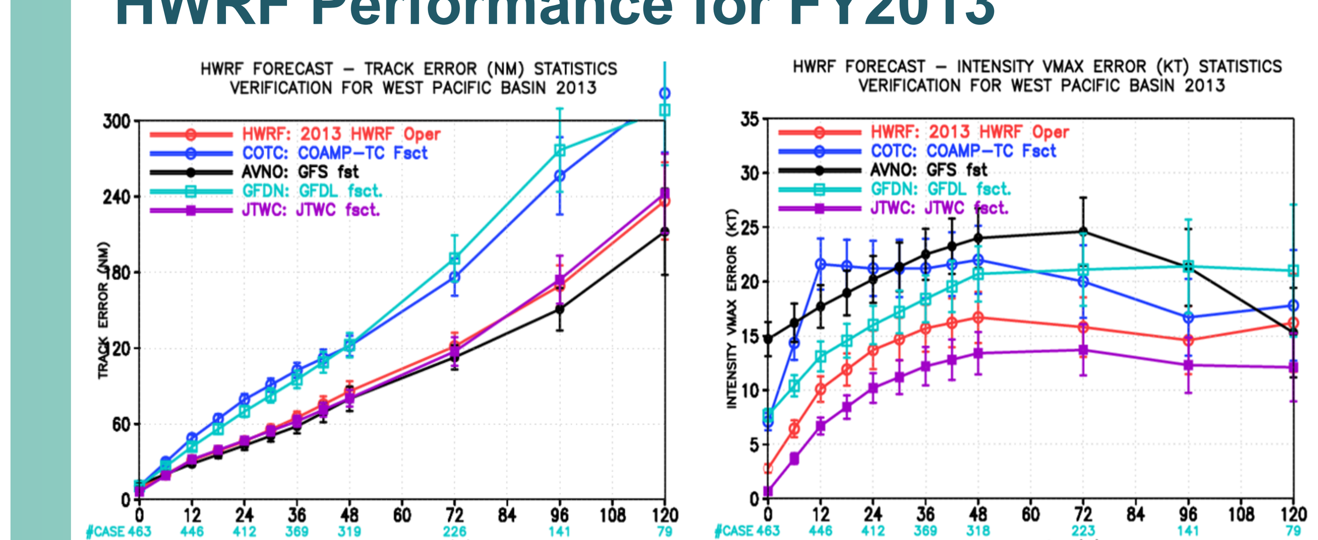
As the initial VMAX increases, MPI increases.
As the initial RMAX decreases, MPI increases.

Trends for Rate of RI



For larger storms with initially stronger VMAX, RI rate is larger. There is an overall downward trend for RMAX, however more data is needed to confidently state this due to the outliers.

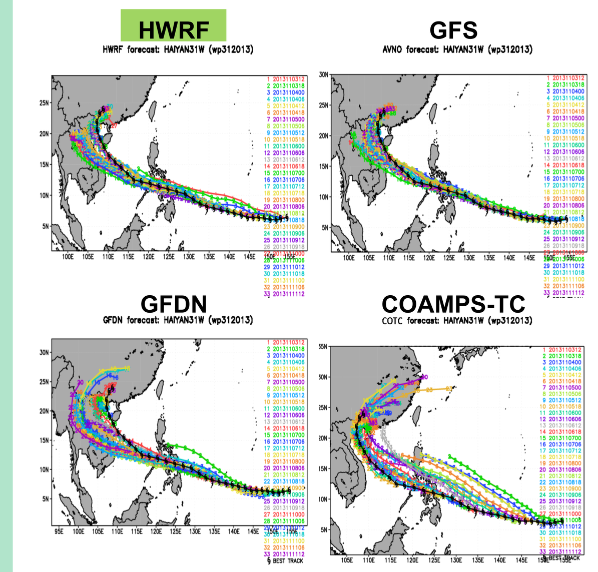
HWRF Performance for FY2013



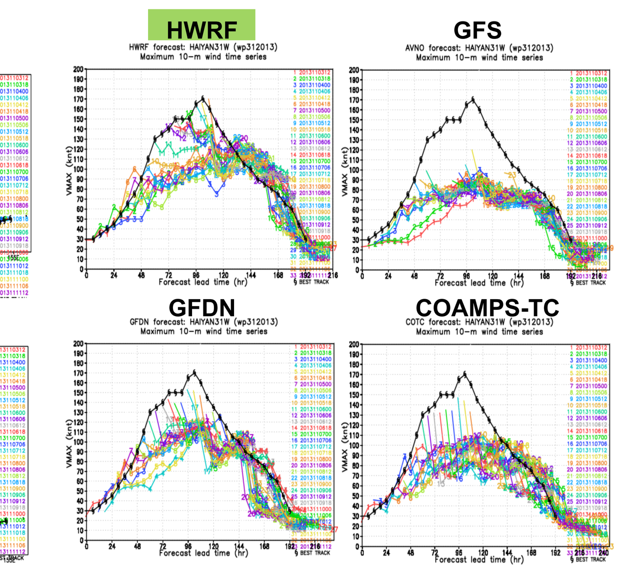
HWRF superior to regional models and close to GFS in track forecasts.

HWRF superior to all other models in forecasting VMAX intensity.

Case Study: Super Typhoon Haiyan (2013)



GFS forecasted the most consistently and accurately, however HWRF was a close second.



Although HWRF did not fully capture RI, it captured Haiyan's raw intensity better than other models with considerably less spin-down.

Conclusions

Through the idealized experiments, this analysis found that smaller storms tend to have the largest intensification rate, however they also tend to level off faster than R120 and R150 storms. As the initial RMAX increases in value, HWRF becomes more consistent in its runs at later lead-times. Given any value of VMAX, if storm is too small (R30), HWRF fails to intensify in all experiments (further investigation is currently being conducted on this issue).

There is an upward VMAX and downward RMAX trend for MPI. For a larger initial storm with initially stronger VMAX, RI rate is larger, and there appears to be an overall downward trend for RMAX and RI rate, however there must be more analysis to make this statement conclusively.

In the northwestern Pacific, HWRF was superior to regional models and close to GFS in track forecasts for FY2013. HWRF was superior to all other models in forecasting storm intensity for FY2013. This was consistent for its performance for the specific case study of Super Typhoon Haiyan (2013), where HWRF came close to GFS in best track forecasts. HWRF did fail to capture Haiyan's raw intensity, however HWRF did comparatively better than all other models with significantly less model spin-down effect.

References

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