Performance of MPAS for Tropical Cyclone Prediction in 2016, 2017 Seasons

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Introduction:

MPAS (The Model for Prediction Across Scales) is a global non-hydrostatic model developed for weather and climate applications. Its solver is based on C-staggering on unstructured centroidal Voronoi mesh that allows for both quasi-uniform and variable-resolution configurations. MPAS uses similar numerics as in WRF (Weather Research and Forecasting Model), and employs a subset of physics from WRF (Skamarock et al. 2012).

Some of the recent MPAS improvements include a split dynamics-transport integration scheme, revised three-dimensional divergence damping and making upper level gravity-wave absorbing layer scale-dependent, improved input fields for gravity-wave drag, and introducing an updated Tiedtke convection scheme (Zhang and Wang 2017).

In this presentation, we re-examine the performance of MPAS with its recent development in 10-day forecasts of tropical cyclones in 2016 and 2017 seasons and compare the results with those reported in Davis et al. (2016).

Model configurations:

- Meshes: 15 km (2017, MPAS), and 60-15 km (2016 and 2017, MPAS-WP)
- Initial condition: GFS analysis
- Forecast: once per day from 0000 UTC for 10 days
- Physics: similar to Davis et al. (2016) except for using a gravity-wave drag scheme and a newer Tiedtke convective parameterization with some improvement from 2016 to 2017.

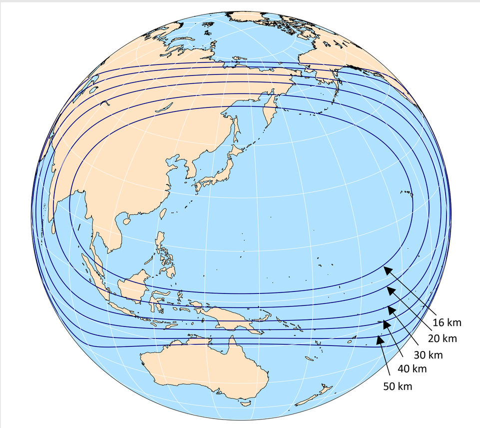

Figure 1: Mesh spacing for 60-15 km MPAS-WP mesh.

Results:

a. Verification of track prediction

Figure 2 shows the track forecast errors as computed with GFDL-tracker over Western Pacific Basin for 2016 and 2017 for MPAS-WP and GFS. The performance of MPAS-WP is comparable to that of GFS in both seasons.

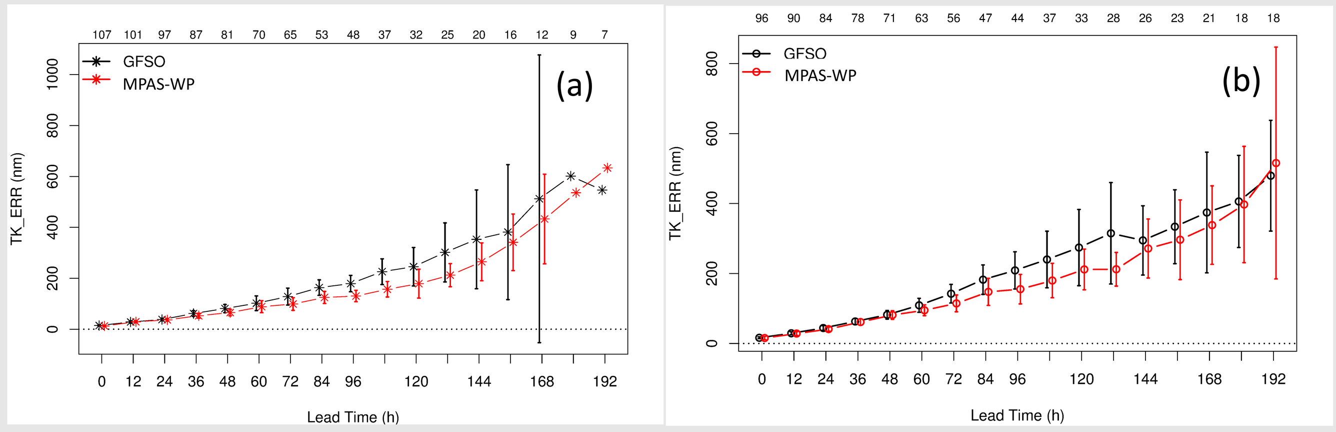

Figure 2: Mean track errors from July – October of 2016 (a), and 2017 (b) for MPAS-WP (red) and GFS (black) for each lead tune up to 192 hours. Bars indicates 95% confidence level.

To compare the forecasts over WP in the variable and quasi-uniform resolution runs, track errors from both meshes are plotted in Fig. 3. Similar performances are noted in both MPAS and MPAS-WP. This is consistent with Davis et al. (2016) and other studies using variable resolution models.

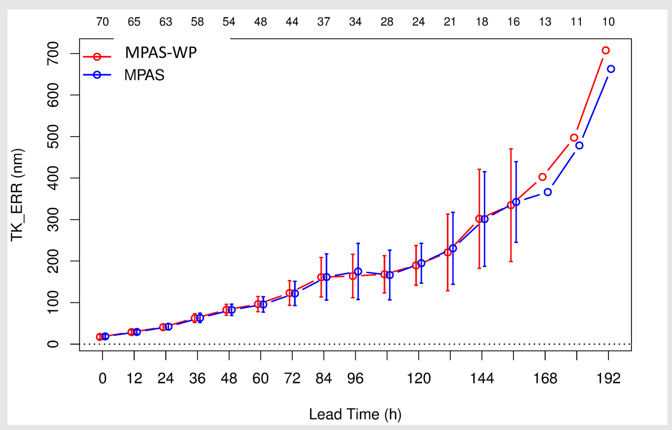

Figure 3: Mean track errors from August – October 2017 for MPAS (blue) and MPAS-WP (red).

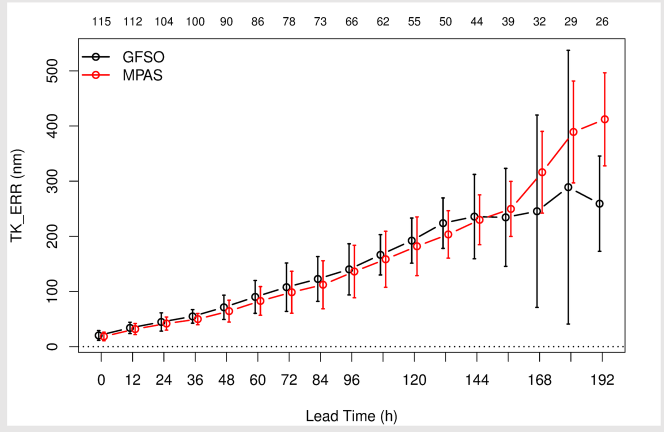

Figure 4: Same as Fig. 3, but for quasi-uniform MPAS and GFS forecasts for Atlantic Basin in 2017.

The track errors for Atlantic Basin (AL) is presented in Fig. 4 from the quasi-uniform 15 km MPAS forecasts. The performance of MPAS is comparable to that of GFS up to day 6 and the errors grew larger for some longer forecasts. Jose, Maria and Iram contributed most of the larger errors at the later forecast hours.

b. Intensity verification

Although the intensity forecast using ~15 km resolution from global models is limited, a plot of the mean errors from all three Northern Hemispheric basins is presented in Fig. 5 to show the wind biases are similar in MPAS and GFS. Most of the biases occur with wind speed greater than 60 knots.

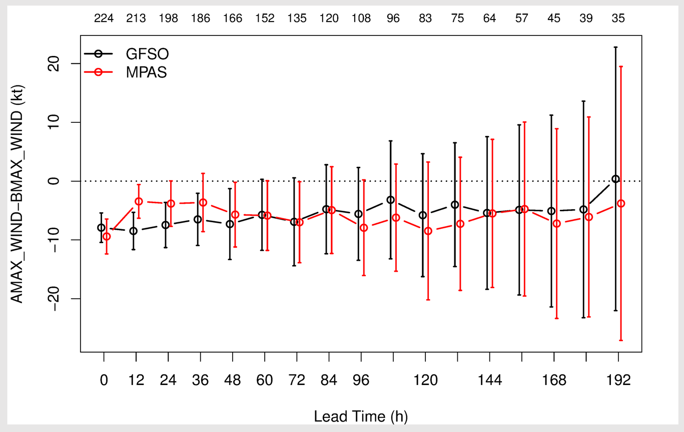

Figure 5: Mean max wind errors for NH for quasi-uniform MPAS and GFS forecasts from August to October in 2017.

c. Categorical verification

Both uniform and variable resolution MPAS forecasts produced too many false alarms in Davis et al. (2016). This problem has been alleviated in the version of MPAS used here. The counts of false alarms together with misses are plotted in Fig. 6 for MPAS-WP in 2016, with the false alarms reduced by an average of 12% for all forecast lead times and as much as 30% at 192 h. The number of false alarms was similar in 2017.

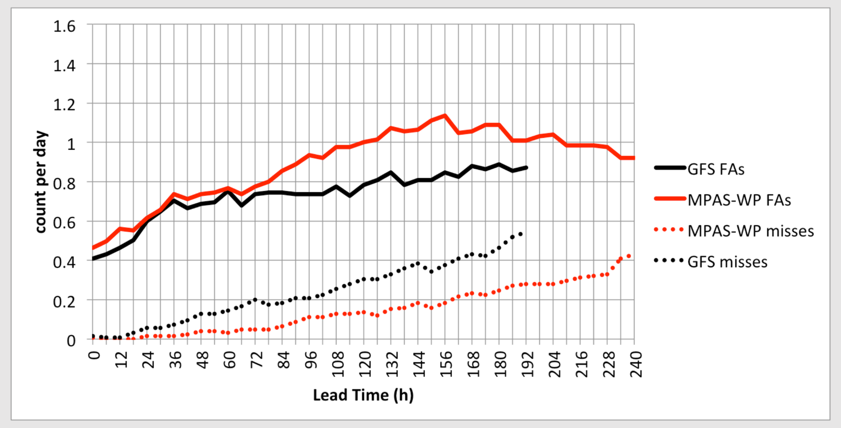

Figure 6: The counts of false alarms and misses per forecast lead time as estimated by GFDL-tracker for MPAS-WP 2016.

d. Rainfall prediction

Figure 7 shows the monthly mean day-5 predicted rainfall from quasi-uniform MPAS from Sept 2017 and CMORPH rainfall. Overall the MPAS simulated daily mean well over the tropics and the Northern Hemisphere. For the tropics, this represents a significant improvement over the previous version used in Davis et al. (2016). The September mean forecast for 2016 is similar (not shown).

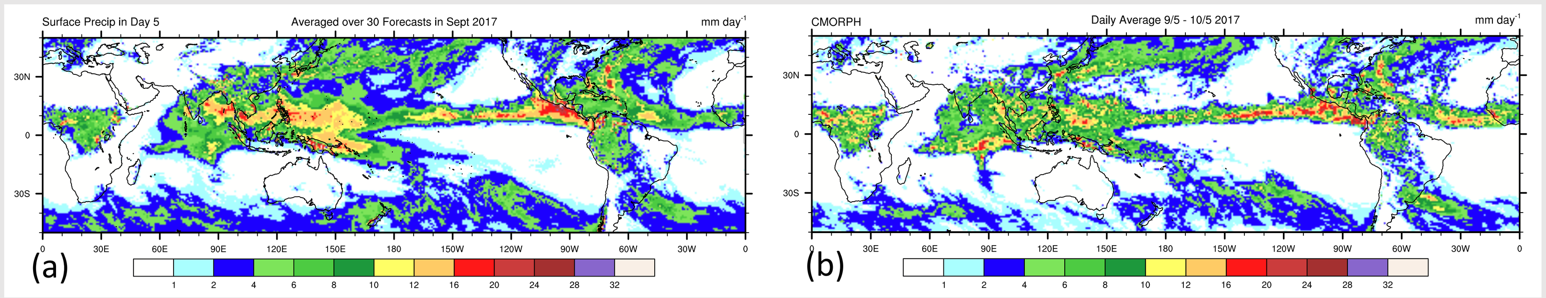

Figure 7: Monthly mean day-5 rainfall prediction from MPAS (a) and CMORPH (b) for Sept 2017.

f. Anormaly correlation coefficient for 500 hPa height

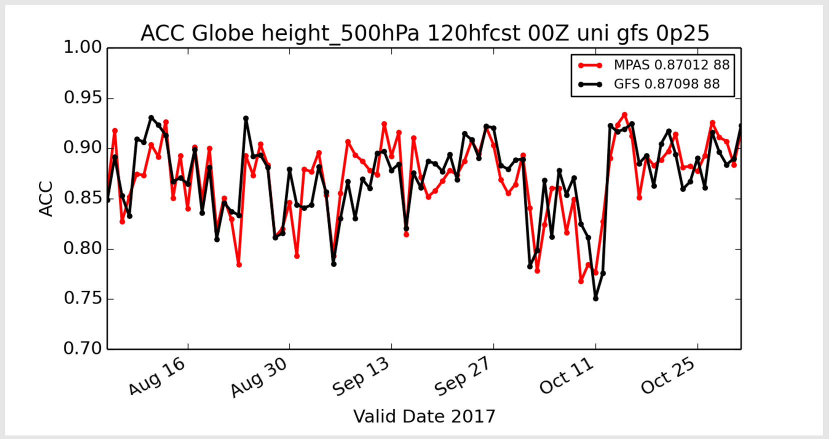

Figure 8: Daily anormaly correlation coefficient for 500 hPa geopotential height from MPAS (red) and GFS (black) for day-5 forecast from Aug 1 to Oct 31, 2017.

The anormaly correlation coefficient is a widely used measure to verify a model forecast at the operational centers. As shown in Fig. 8, the ACC from the 15 km quasi-uniform MPAS forecasts at day-5 is comparable to that of GFS over the globe.

Forecasts of Harvey and Irma:

Hurricane Harvey and Irma are two strongest storms to hit US mainland in 2017, and each produced huge damages. The 10-day forecast tracks from Aug 16 to 30 for Harvey is depicted in Fig. 9a. The earlier tracks turned to the left as the storm approached land. The tracks for Irma from Aug 29 through Sept 11 are shown in Fig. 9b. The earlier tracks turned right far too early. Fig. 9c and 9d show the forecasts from the same days but using European Center's analyses as initial conditions. These forecast tracks show improvement particularly in earlier forecasts for Irma.

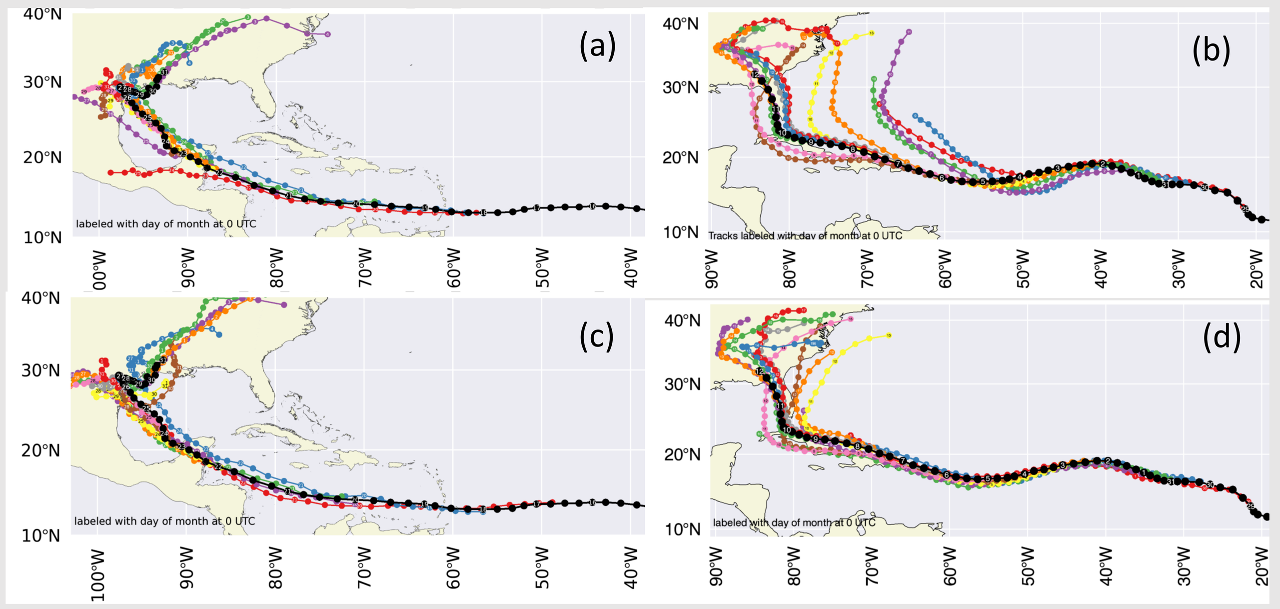

Figure 9: Forecast tracks for Harvey (a) and (c) and Irma (b) and (d). Forecasts (a) and (b) use GFS analyses, and forecasts (c) and (d) use ECMWF analyses.

Summary:

- The performance of MPAS in predicting tropical cyclones is evaluated and compared to that of GFS, and MPAS shows comparable skills.
- The tropical rainfall prediction as well as biases in the model (not shown) are also improved in 2016 and 2017 compared to Davis et al. (2016).
- The ACC scores are competitive to other global models on day 5.

For more information about MPAS, go to http://mpas-dev.github.io

References:

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Skamarock, W. C., J. B. Klemp, M. G. Duda, L. D. Fowler, S.-H. Park, and T. D. Ringler, 2012: A multiscale nonhydrostatic atmospheric model using Centroidal Voronoi tessellations and C-grid staggering. *Mon. Wea. Rev.*, 140, 3090–3105, doi:10.1175/ MWR-D-11-00215.1.

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