Verification of Tropical Storm Track Prediction in SE Asia Using GFS Model

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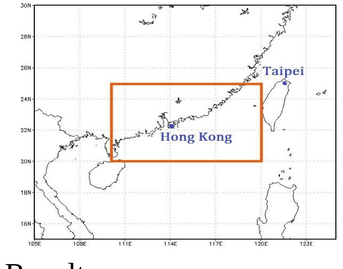
Introduction

The two major objectives of the research are (1) assess the statistical error and bias of the Global Forecast System's (GFS) Tropical Cyclone (TC) track forecast and (2) assess the reliability of the forecast initialization time of TC track forecasts by the GFS. This research would act as a reference for forecasters to forecast TCs in Southeast Asia and contribute in improving TC forecasts.

Methodology

Only TCs that passed through the grid box 20-25°N, 110-120°E during 2007 to 2011 were selected. A total of 14 out of 27 TCs were typhoons, and 4 of them had wave-like patterns (looping in the same region for days). The observed TC tracks, which were obtained from the best track data from the Joint Typhoon Warning Center (JTWC), and were compared to the forecast tracks from the GFS model output.

We used the GFS output initialized every 12 hours with 6-hour intervals between each plot of the TC locations, over a forecast period up to 8 days. Points of local lowest pressure represent the locations of TCs' centers in the target region. Errors between the actual TC tracks and the GFS forecast tracks in terms of total distance, north-south direction (latitude), west-east direction (longitude), and central pressure of every initialization are calculated. By averaging the errors in two categories (stronger or weaker than typhoon), absolute errors and biases are determined.



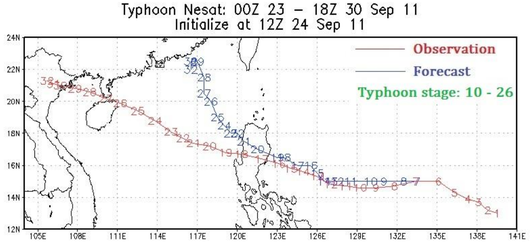
The orange box shows the study area; TCs that pass through the area are selected.

	TC number	GFS Initializations
All cases	27	385
Weaker than typhoon	27	385
Stronger than typhoon	14	192

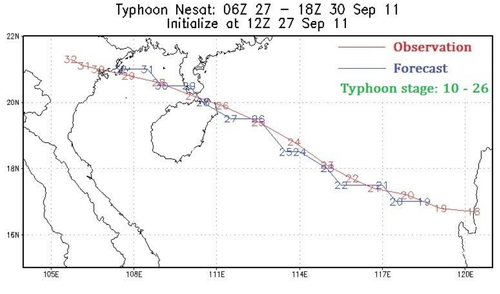
Results

Both categories of TC, weaker and stronger than typhoon, show similar absolute errors in distance, with larger errors in the east-west direction than in the north-south direction. The GFS forecasts have significantly greater errors in central pressure for TCs more intense than typhoon stage.

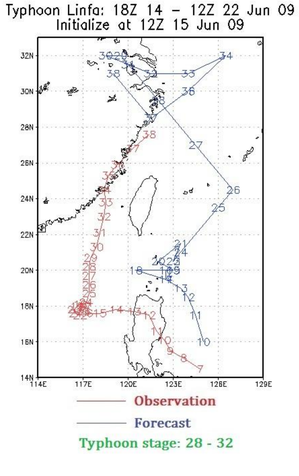
For all the TCs studied, the GFS forecasts demonstrate north and east biases on average, as well as an underestimation of TC strength. The errors in longitude are notably larger than the errors in latitude. Compared to TCs stronger than typhoons, the GFS forecasts exhibit smaller biases in latitude, longitude and central pressure for weaker TCs.



24 Sep 2011 12Z initialization: GFS forecast track shows north and east bias compared to the observation. Distance errors in the east-west direction are larger than distance errors in the north-south direction. Absolute distance errors are magnified over time. Typhoon Nesat from 00Z 23 to 18Z 30 Sep 2011.



27 Sep 2011 12Z initialization: GFS forecast track shows an excellent qualitative alignment with the observation. Distance errors of the typhoon stage and non-typhoon stage are similar. Absolute distance errors remain stable over time.



15 Jun 2009 12Z initialization: Typhoon Linfa, lasted from 06Z 13 to 12Z 22 Jun 2009, and exhibited a wave-like pattern. The GFS forecast track captured the wave-like pattern, however, absolute distance errors were greatly magnified after the looping period, which greatly reduced the quality of the GFS's forecast of Linfa. Excluding Linfa, the average absolute errors and biases are greatly improved (see tables).

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Absolute Error

	Lat error	N-S distance error	Lon error	E-W distance error	Absolute distance error	Pressure error
TC weaker than typhoon						
All TCs	1.42°	157.45 km	2.29°	236.85 km	311.36 km	7.639 hPa
Without typhoon Linfa	1.34°	148.59 km	2.22°	229.97 km	299.82 km	7.625 hPa
Without wave-like TCs	1.3°	144.07 km	2.16°	223.27 km	292.12 km	7.482 hPa
TC stronger than typhoon						
All TCs	1.4°	155.61 km	2.74°	286.04 km	347.37 km	35.106 hPa
Without typhoon Linfa	1.08°	119.96 km	2.45°	256.47 km	297.76 km	35.723 hPa
Without wave-like TCs	1.12°	124.09 km	2.56°	268.47 km	311.38 km	35.257 hPa

Bias

	Lat error	N-S distance error and bias		Lon error	E-W distance error and bias		Pressure error	Pressure bias
TC weaker than typhoon								
All TCs	-0.27°	-30.16 km		-1.51°	-156.72 km		-3.5 hPa	Under-estimate strength
Without typhoon Linfa	-0.15°	-16.71 km	North	-1.42°	-148.13 km	East	-3.429 hPa	
Without wave-like TCs	-0.11°	-12.74 km		-1.34°	-139.13 km		-3.252 hPa	
TC stronger than typhoon								
All TCs	-0.82°	-91.54 km		-2.33°	-244.08 km		-35.026 hPa	Under-estimate strength
Without typhoon Linfa	-0.46°	-51.14 km	North	-2.09°	-218.94 km	East	-35.636 hPa	
Without wave-like TCs	-0.47°	-52.15 km		-2.21°	-232.2 km		-35.155 hPa	

Excluding Typhoon Linfa in the analysis, the absolute errors and biases in distance of the GFS forecasts are remarkably improved. The GFS forecast errors for the other 3 TCs with wave-like pattern are similar to the forecast errors for rest of the selected TCs.

Conclusion

Forecasters should be aware that the GFS TC forecasts yields average distance errors of 300 to 350 km (in radius), which is less than half of the distance from Hong Kong to Taipei (808 km). Qualitatively speaking, the GFS model handles TC track forecasts better in normal cases (without looping) than in wave-like cases.

The JTWC might have overestimated the strength (understated the central pressure) of TCs, especially the more powerful ones, which leads to the substantial errors in pressure from the GFS forecasts.

Future work: determine the GFS TC forecast errors related to landfall locations and times; determine the confidence interval in terms of time for the GFS model to make an accurate TC track forecast.