P1.39 Synoptic Patterns of Atlantic Hurricanes Categorized by Track Error and Forecast Confidence

Lindsey Day (LRD07@my.fsu.edu) and Robert Hart.
Department of Earth Oceanic and Atmospheric Sciences, The Florida State University

1. INTRODCUTION

There are documented instances where several numerical tropical storm track forecasts agree, yet the actual track is different (e.g. Hurricane Alberto, 2000). In such instances, lives and property are at risk when this situation occurs near land. Further, a track forecast with high confidence, yet eventual high error, has great potential to hinder hurricane preparedness actions including excessive evacuation orders and increased failure to order necessary evacuations. Yet, identifying commonalities in the synoptic situation among tropical cyclones (TCs) with high confidence yet high error could potentially alert forecasters when a highly confident track forecast may be misleading.

2. PREVIOUS STUDIES

Franklin et al. (1990) analyzed the steering currents present near Hurricane Josephine (1984). It was found that hurricane steering currents may be represented by the average flow over several vertical levels, or by gradients of absolute vorticity. Josephine's motion was parallel and to the left of the gradient.

Shapiro et al. (1999) studied factors impacting the steering of Atlantic storms. Findings suggested both synoptic scale ridges and troughs and upper-air potential vorticity anomalies can influence a hurricane's track forecast to varying degrees.

Hauke (2006) analyzed distributions of GFS ensemble mean total-track error conditioned upon ensemble spread (forecast confidence) for Atlantic storms. He found that "GFS ensemble spread did not provide statistically different [error] distributions" when categorized by forecast hour.

Brennan et al. (2011) did a case study analyzing Hurricane Ike (2008). The strong subtropical ridge located north of Hurricane Ike and the mid-level shortwaves located west of Ike in California were determined to have a significant impact on the accuracy of the track forecast. The initial conditions were perturbed before rerunning the GFS model. When the ridge was weakened and the shortwave was strengthened, the GFS track forecast produced a more accurate track forecast.

The following study builds on the above strong foundation and identifies synoptic patterns that may lead to higher track forecast error for several Atlantic storms.

3. METHODOLOGY

The NCEP Global Ensemble Forecast System (GEFS) is used to analyze 2004-2008 Atlantic TCs. The following method was used to calculate the forecasted track error. First, the GEFS ensemble mean forecast track was compared to the best track to calculate distance errors for forecast hours 6-120, and for each model initialization time. These results were used to calculate the average errors for each individual forecast hour 6-120. These errors were averaged and normalized by the number of initialization times for each forecast hour to calculate the total storm error.

To define forecast track confidence, the standard deviation of track position among all ensemble members for forecast hours 6-120 was calculated for each model initialization time. These results were used to calculate the average standard deviation for each forecast hour 6-120. These standard deviations for forecast hours 6-120 were averaged and normalized by the number of initialization times for each forecast hour to calculate the total standard deviation.

Error and confidence values were sorted into terciles and each TC's track forecast error and confidence was defined as high, medium, or low. As a result, there are nine possible bins of error-confidence combinations. The synoptic environments common to the following bins were examined: Bin 1) low confidence and high error, Bin 2) high confidence and low error, Bin 3) low confidence and low error, and Bin 4) high confidence and high error. The synoptic analysis was done three times for each storm: 25% (time 1), 50% (time 2), and 75% (time 3) of the way through the storm's life.

4. RESULTS

High confidence/low error and low confidence/high error storms are the most common types (Figure 1). Although rare, highly confident yet highly erroneous track forecasts exist for 2 of 81 cases.

CONFIDENCE	ERROR			
		Low	**Med**	**High**
	Low	4	5	18
	Med	5	15	7
	High	18	7	2

Fig. 1: Total number of storms and their breakdown into the nine described bins.

High error storms had longer lifespans (10 days) compared to low error storms (3 days). Note that Figures 2 and 5 compared to Figures 3 and 4, respectively. It should be noted that track forecasts for short-lived storms whose ensembles do not produce forecasts as far as 120 hours into the future are likely to have lower error and higher confidence.

Observations of the synoptic environment showed that all 18 storms with low confidence/ high error traveled into amplified flow in higher latitudes (poleward of 30°N; Figure 2).

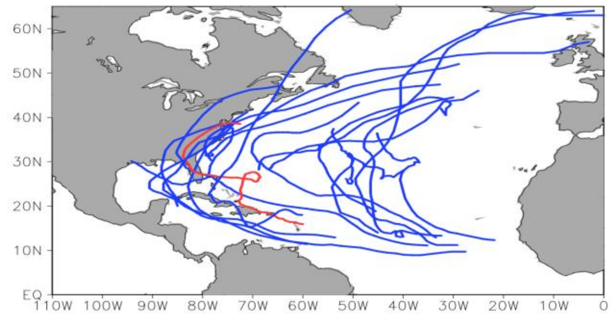

Fig. 2: Low confidence/ high error tracks.

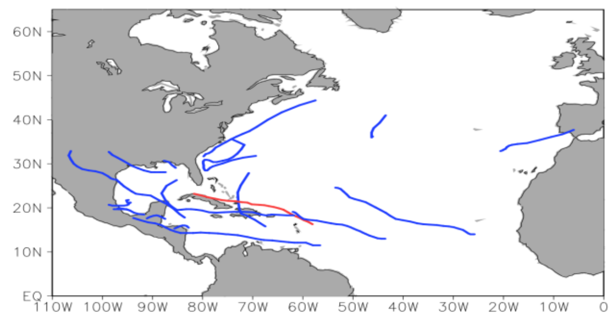

Fig. 3: High confidence/low error tracks.

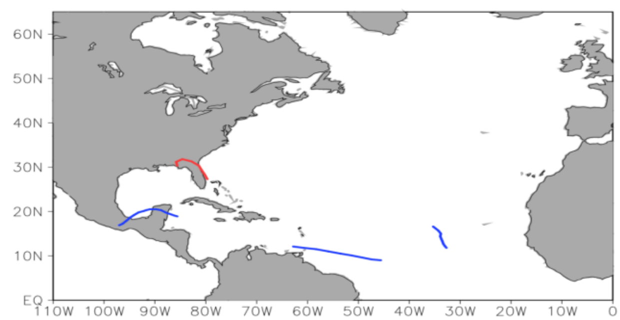

Fig. 4: Low confidence/high error tracks.

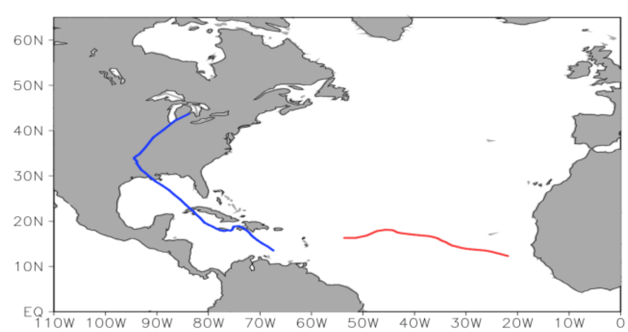

Fig. 5: High confidence/high error tracks.

A statistically significant negative correlation exists between total storm track forecast confidence and error (Figure 6).

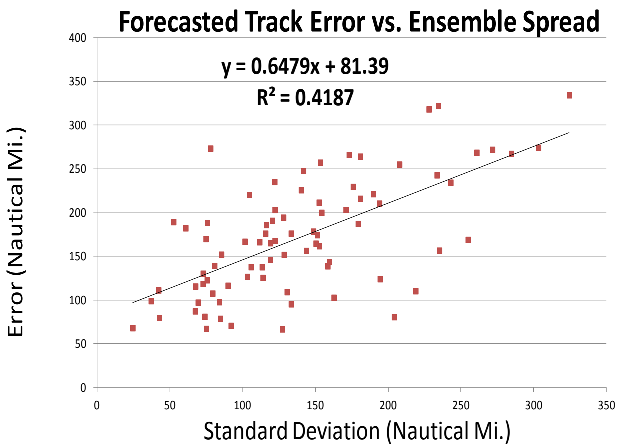

Fig. 6: Positive correlation between track error and standard deviation for all storms from 2004-2008.

Storms with low track error had lower intensities than storms with high track error (Figure 7).

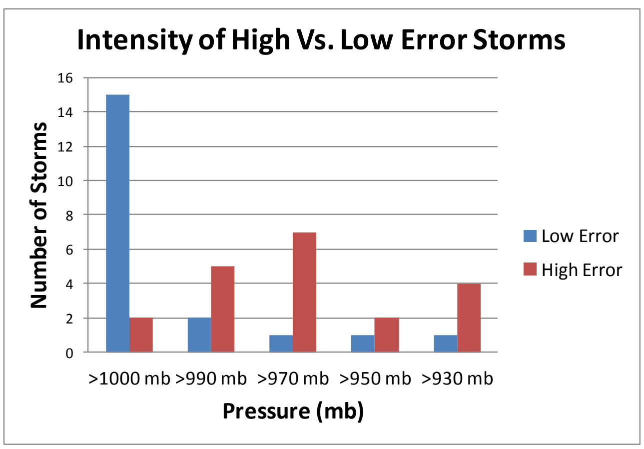

Fig. 7: A comparison of intensity and error of storms from 2004-2008.

An analysis of the synoptic environment of bin 4 storms (high confidence, high error) showed the storms were in close proximity to dominant ridges and/or troughs that had large shifts in position and changes in strength. They were also near other TCs. Both characteristics can be seen in Figures 8-10, which show the evolution of the synoptic environment of Tropical Storm Josephine (high confidence/high error storm) from 25% (time 1), 50% (time 2), and 75% (time 3) of the way through the storm's life.

The figures show: estimated TC size (green contour of the 925 mb 20 knot wind speed), 900, 700, 500, 250mb Geopotential height in meters (blue contours), and the storm track (black line).

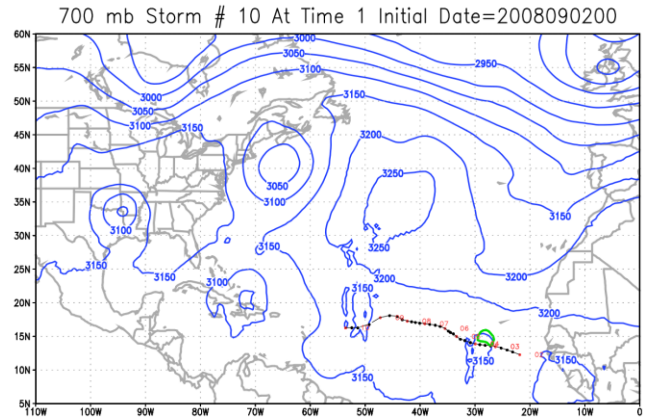

Fig. 8: 700 mb synoptic environment of high confidence/high error storm at time 1.

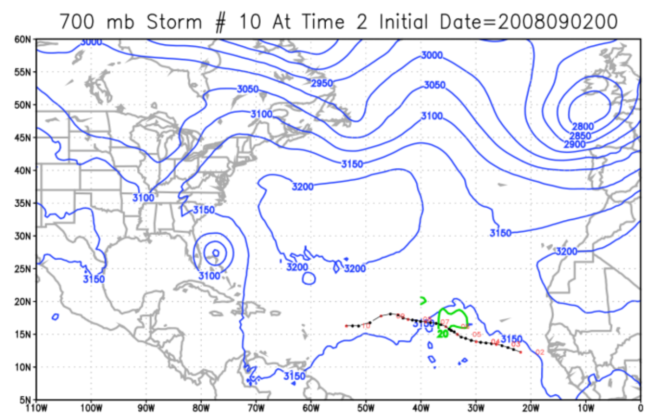

Fig. 9: 700 mb synoptic environment of high confidence /high error storm at time 2.

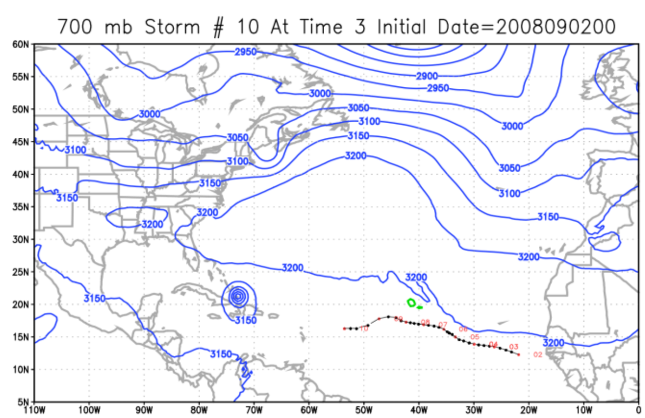

Fig. 10: 700 mb synoptic environment of high confidence /high error storm at time 3.

Both bin 1 and bin 4 storms, which are both high error cases, tend to be within the steering flow of a dominant synoptic scale ridge or trough that shifts position or changes strength over time. Bin 2 and 3 storms, however, which are both low error cases, tend to be within either weak steering flow and/or within steering flow of a synoptic scale ridge that is relatively stationary. This can be seen in Figures 11-13 below which show the same time evolution and synoptic environment as in Figures 8-11. This is an example of a low confidence/low error storm.

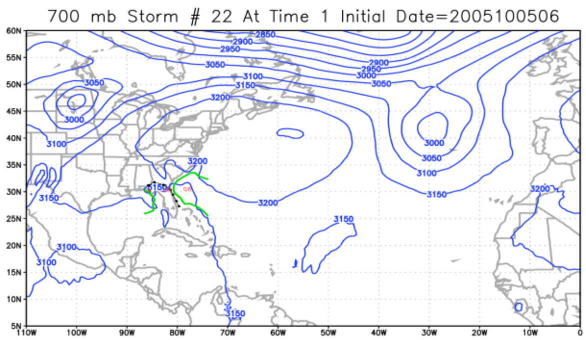

Fig. 11: 700 mb synoptic environment of low confidence /low error storm at time 1.

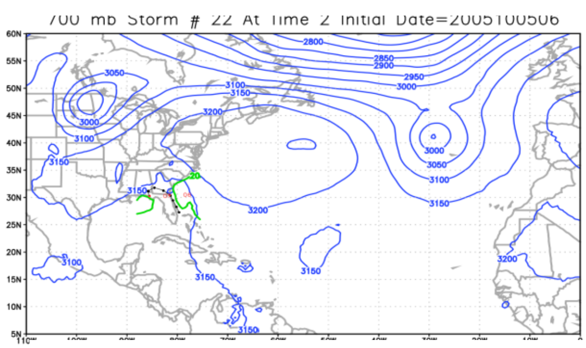

Fig. 12: 700 mb synoptic environment of low confidence /low error storm at time 2.

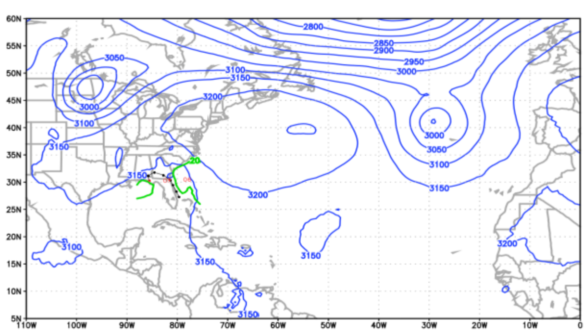

Fig. 13: 700 mb synoptic environment of low confidence /low error storm at time 3.

5. SUMMARY

High confidence/high error storms are the rarest of the nine types, occurring only in two of 81 cases. For both cases other TCs were present at some point during the life of the high confidence/high error storm. The track of high error storms tended to be primarily influenced by dominant troughs and/or ridges that shifted position or changed strength during the storm's life. Contrarily, low error storms tended to be within weak flow or near relatively stationary ridges. There is a statistically significant negative correlation between forecast track error and confidence. Ongoing work will refine the relationships found here for short-lived and long-lived storms, and may provide for warning flags within the models for situations where the guidance may be overly confident about a forecast scenario.

6. ACKNOWLEDGMENTS

This work was partially funded by a NASA Genesis and Rapid Intensification Processes (GRIP) Grant #NNX09AC43G.

7. REFERENCES

Brennan, M. J. and S. J. Majumdar, 2011: An Examination of Model Track Forecast Errors for Hurricane Ike (2008) in the Gulf of Mexico. *Wea. Forecasting*, 26, 848–867.

Franklin, J. L., 1990: Dropwindsonde Observations of the Environmental Flow of Hurricane Josephine (1984): Relationships to Vortex Motion. *Mon. Wea. Rev.*, **118**, 2732–2744.

Hauke, M. D., 2006: Evaluating Atlantic Tropical Cyclone Track Error Distributions Based on Forecast Confidence. M. S. Thesis, Naval Postgraduate School, 85 pp. [Available from http://handle.dtic.mil/100.2/ADA452140]

Shapiro, L J. and J. L. Franklin, 1999: Potential Vorticity Asymmetries and Tropical Cyclone Motion. *Mon. Wea. Rev.*, **127**, 124–131.