P2H.17 LANDFALL FORECAST BIASES FOR GULF OF MEXICO TROPICAL CYCLONES

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1. INTRODUCTION

When a tropical cyclone is forecast to make landfall along the Gulf coast, it is inevitable that many critical decisions will have to be made. The goal of this study is to provide guidance to meteorologists and decision makers concerning landfall forecast errors and biases for different categories of tropical cyclones. The results are expected to aid decision makers with important pre-storm activities such as evacuation, resource/aid pre-placement, and petrochemical plant shutdowns. Recently, based on the experience from major hurricanes Katrina and Dean, decisions are being made much earlier than with previous expected landfalls. For example, during the threat of Hurricane Dean (2007), evacuation timelines and resource/aid pre-placement decisions were made by the state of Texas based on the National Hurricane Center's 120 hour forecast of tropical storm force winds reaching the coastline. Meteorologists who are briefing these decision makers need to be aware of any substantial forecast biases to help provide guidance to decision makers who are often acting on very low probability landfall events at extended timeframes.

2. DATA AND METHODS

Landfalling Gulf of Mexico (GOM) tropical cyclones occurring during the ten year period of 1998-2007 are analyzed in this study. The resulting dataset consists of 48 tropical cyclones. Tropical depressions are included provided that they became a named storm at some point in the Gulf of Mexico. Since the goal of this study is to provide guidance to coastal decision makers, only landfall forecasts are evaluated, with landfall occurring between the forecast hours of 12 and 120. Only one inland forecast hour point from a landfall forecast is included. The result is 443 landfall forecasts available for evaluation.

Forecast track error is determined by calculating the great circle distance between the forecast location and the observed location (Powell and Aberson, 2001). Forecasts evaluated are those issued every 6 hours by the National Hurricane Center (NHC). Actual tropical cyclone positions and landfall timing and locations are determined by using the "best track" dataset from the NHC, which is available after post analysis of all available data. Landfall forecast times are obtained by utilizing the Hurrevac tracking software which is available to emergency managers and NWS forecasters.

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3. RESULTS

3.1 Organization

Table 1 summarizes the results from this study. The table is organized into three sections (a, b, c) based on the initial intensity of the tropical cyclone (hurricane (>=65 KTS), tropical storm (35-60 KTS), tropical depression (<= 30 KTS)). Each intensity category is further subdivided based on the initial speed of movement and landfall forecast period. Intensity and speed of movement were found to be the primary factors correlating to future track error in a related GOM landfall forecast study (Wood et al., 2004), and these initial condition variables are utilized here to organize and best categorize the results of this study.

3.2 Along Coast and Timing Errors/Biases

The majority of forecasts depicting landfall within 72 hours for tropical storms and hurricanes are left (along the coast) of the actual landfall location and exhibit a late bias (Table 1). Interestingly, a significant right bias is present beyond 72 hours from landfall (73 to 120 hour period) for hurricanes and for <12 mph tropical storms. This reversal of directional error is important for decision makers to realize as the error trend is likely to shift from right to left as tropical cyclones near the coast. Note that fast moving tropical storms (> 12 mph) are the exception to this observation as a significant left bias is present in the 73 to 120 hour period. The standard deviation (STD) of time error indicates that appropriate timing errors for planning purposes, for hurricanes, range from 3 to 5 hours for in the 12 to 36 hour period to 15 to 19 hours in the 73 to 120 hour period. Given that large timing errors are common beyond 72 hours from landfall, and that an early forecast bias ranging from 6 to 13 hours exists for hurricanes, decision makers should be careful not to rush to action as they will often have more available time than is being forecast.

3.3 Intensity Errors/Biases

In most categories, the STD of intensity error ranges between 10 and 20 KTS (Table 1). This result indicates that planning for at least one Saffir-Simpson category increase in hurricane intensity greater than forecast at landfall is an appropriate action. However, it should be noted that the largest STD of intensity error (22.8 KTS) for hurricanes occurs for >12 mph hurricanes in the 12 to 36 hour period. Within this group are Hurricanes Charley (2004) and Lili (2002), both of which exhibited rapid intensity changes just prior to landfall with individual landfall forecast errors of +/- 40 KTS. They are a reminder that rapid intensity changes close to landfall are a significant forecast challenge, and

often result in large intensity forecast errors. Large intensity biases are not present for hurricanes; however, intensity forecasts for tropical storms (at forecast initiation) tend to under-forecast (-) landfall intensity, especially beyond 36 hours from the forecast landfall.

REFERENCES

Powell, M. D. and S. D. Aberson, 2001: Accuracy of United States tropical cyclone landfall forecasts in the Atlantic basin (1976-2000). *Bull. Amer. Meteor. Soc.*, **82,** 2749-2767.

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(a)

Category	Hurricanes					
Movement (mph)	> 12			<= 12		
Forecast Period (hrs)	12-36	37-72	73-120	12-36	37-72	73-120
Number of Forecasts	26	30	29	32	35	33
ABS Time Error (hrs)	2.3	5.7	13.1	4.1	5.1	15.8
Time Bias (hrs)	0.1	-2.3	-6.2	3.5	2.3	-12.8
STD Time Error (hrs)	3.4	7.8	19	4.9	7.6	15.7
Left-/Right+Bias (km)	-39.3	-19.4	147.2	-54.2	-73.2	150
ABS Intensity Error (kt)	18.5	12.7	10.7	13	14	12.9
Intensity Bias (kt)	-0.8	-2.3	4.1	7	6	-4.1
STD Intensity Error (kt)	22.8	18.5	13	14.5	16.8	14.8

(b)

Category	Tropical Storms								
Movement (mph)	> 12			7 to 12			< 7		
Forecast Period (hrs)	12-36	37-72	73-120	12-36	37-72	73-120	12-36	37-72	73-120
Number of Forecasts	27	6	14	35	37	6	30	27	5
ABS Time Error (hrs)	2.3	5.8	8	4.9	7.9	9.8	6	11	25.2
Time Bias (hrs)	1.4	0.8	2.7	1.1	5.8	5.2	4.3	9.2	9.2
STD Time Error (hrs)	2.7	7.7	10.4	6.4	10.2	17.1	7.4	10.7	31.8
Left-/Right+Bias (km)	-25.6	3.4	-215.9	-82.6	-14.9	95.9	-23.6	-237.6	188.6
ABS Intensity Error (kt)	11.1	25.8	13.6	13.3	13.8	34.2	7.5	11.7	18
Intensity Bias (kt)	3.5	-19.2	-12.1	6.7	3.2	-10.8	1.8	-3.5	-14
STD Intensity Error (kt)	12.3	31.5	15.3	14.8	16.7	40	9.4	16.1	18.5

Category	Tropical Depressions					
Movement (mph)	>= 7			< 7		
Forecast Period (hrs)	12-36	37-72	73-120	12-36	37-72	73-120
Number of Forecasts	11	18	*	12	24	6
ABS Time Error (hrs)	5.4	12.6	*	9.5	10.5	19.8
Time Bias (hrs)	-2.8	5.9	*	-5	1	19.8
STD Time Error (hrs)	10.6	7.7	*	10.2	13.4	5.3
Left-/Right+Bias (km)	-80.3	17.4	*	8.6	-42	234.5
ABS Intensity Error (kt)	11.4	10.8	*	9.2	9.8	11
Intensity Bias (kt)	1.4	-0.8	*	-9.2	3.1	-11
STD Intensity Error (kt)	13.2	13.5	*	11.6	11.2	2.2

(c)

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Table 1. Landfall forecast statistics for (a) Hurricanes, (b) Tropical Storms, and (c) Tropical Depressions (at forecast initiation). Left/right landfall bias calculated along the coastline and time and intensity errors at landfall by cyclone category and forecast period. Negative numbers indicate a left of track, early arrival, or weaker than actual intensity bias. ABS = absolute value and STD = standard deviation.