MARINE FORECAST AND HINDCAST FOR HURRICANE IKE 2008 The CCM as a Marine and Tropical Meteorologist

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1. INTRODUCTION

The 2008 Hurricane Season was very costly for the Gulf of Mexico offshore oil and gas industry. Gulf of Mexico exploration and production companies have lost 175 structures since 2004 due to the impacts of Hurricane Ivan 2004, Hurricane Katrina 2005, Hurricane Rita 2005, Hurricane Gustav 2008, and Hurricane Ike 2008. Prior to Ivan, the most significant hurricane impact to the Gulf of Mexico exploration and production infrastructure was from Hurricane Andrew in 1992, during which 22 offshore structures were destroyed or damaged. Most of the offshore damage from hurricanes is caused by waves.

Figure 1 is a plot of the tracks of Hurricane Ivan, Katrina, Rita and Ike across the Gulf of Mexico oil leases. The black dots indicate the 3,800 oil and gas platforms. Approximately 2,127 oil and gas platforms were exposed to hurricane conditions from Hurricane Gustav and Ike in 2008. According to MMS, sixty platforms were destroyed as a result of Hurricanes Gustav and Ike. These destroyed platforms produced 13,657 barrels of oil and 96,490,000 cubic feet of gas daily or 1.05% of the oil and 1.3% of the gas produced daily in the Gulf of Mexico. Another 31 platforms were extensively damaged and 93 platforms were moderately damaged.



Figure 1: Plot of Recent Gulf of Mexico Hurricanes

The offshore industry spent a great deal of money to understand what happened during Ivan, Katrina and Rita. Hurricane Ivan caused the first 100 ft wave to ever be measured during a Gulf of Mexico hurricane. Special committees met and operation and design requirements were updated as a result of what was learned from these hurricanes. By the beginning of the 2008 hurricane season, industry operators felt they had a better understanding of Gulf of Mexico hurricanes. But, then in September 2008 came Ike.

There are only a few private sector companies that provide daily marine and tropical forecasts to the Gulf of Mexico Offshore Oil Industry. There are even fewer Certified Consulting Meteorologists [CCM] providing these forecasts.

Hurricane Ike was a Category 2 hurricane on the Saffir/Simpson Scale but it was also a very large storm, creating a challenging job for the CCM to communicate the significant threat Ike posed to the offshore oil and gas industry. Using GIS as a tool, the CCM was able to depict the number of offshore properties that would be exposed to high waves and would possibly experience damage or be destroyed by the hurricane.

The CCM's job is not over after a hurricane passes. Almost immediately, the forensics start with gathering and archiving data that will be used to hindcast the storm to better understand its impacts. Hurricane Ike left the offshore industry confused and frustrated. How could a Category 2 hurricane cause so much devastation? The CCM was asked to investigate this. Hurricane Ike was compared to other significant past Gulf of Mexico hurricanes by hindcasting the hurricane wind and wave fields and plotting them using GIS. The result was a finding that SIZE MATTERS when it comes to a storm's ability to generate large offshore waves.

The CCM not only provides real-time marine and tropical weather forecasts but also designs and develops marine and tropical wind and wave models, hindcasts past hurricanes, and provides expert testimony related to the hurricane's impacts.

2. HURRICANE IKE 2008

The wind and wave fields during Hurricane Ike 2008 were hindcast and these hindcast demonstrated that <u>Size Matters</u> when it comes to the impacts of hurricanes on offshore structures and coastal regions. The Saffir/Simpson Damage-Potential Scale is currently what is used to give an estimate of the potential for damage. Based on wind, Ike was classified as a Category 2 hurricane on the Saffir/Simpson Scale.

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However, the hurricane force winds extended out 110 nautical miles from Ike's center, making it a very large hurricane and allowing the waves to increase significantly as Ike moved across the Gulf of Mexico.

Ike formed in the eastern Atlantic and tracked across the central Atlantic before moving over Cuba as a Category 3 hurricane. Ike then moved into the Gulf of Mexico, grew in size and headed for the Upper Texas Coast, causing tides to rise the day before landfall. Hurricane Ike moved over the east end of Galveston Island, Texas in the early morning hours of September 13. Ike caused fatalities in Haiti, the Dominican Republic, Cuba and across the United States. Storm surge from Ike destroyed parts of Galveston Island and the Bolivar Peninsula along the Upper Texas Coast. The remnants of Ike even produced wind gusts to hurricane force in the Ohio Valley.

When comparing the size of Ike to recent Gulf of Mexico hurricanes, the area of maximum sustained winds of hurricane force was one of the largest since Hurricane Gilbert 1988 [See Table 1]. The largest known hurricane to move through the Gulf of Mexico was Hurricane Carla in 1961, which had tropical storm force winds extending out 300 nautical miles from the center and hurricane force winds extending out 120 nautical miles.

Table 1: Recent Gulf of Mexico Hurricanes

		Max	Radius of	Radius of	
		Sus	Tropical	Hurricane	
		Winds	Storm	Winds	
		[Knots]	Winds	[n. mi]	
			[n. mi]		
2008	lke	95	240	110	
2008	Gustav	130	150	60	
2005	Rita	150	180	75	
2005	Katrina	150	200	90	
2004	Ivan	140	225	90	
2002	Lili	125	170	45	
1998	Georges	95	130	80	
1992	Andrew	125	120	40	

Hurricane Ike was a very large storm which generated very high waves over the Gulf of Mexico oil and gas leases. Weather Research Center [WRC] meteorologists used WRC's Hurricane Wind and Wave Model in real time to forecast Hurricane Ike as it moved through the Gulf of Mexico leases. During the 2008 hurricane season, the CCM noticed the significant difference in the hurricane wind field size between Hurricane Gustav and Hurricane Ike. Using ARCGIS, the CCM was able to graph the results for the hurricane wind and wave model to communicate the threat of Hurricane Ike.

Figure 2 shows the comparison of the maximum sustained wind fields for Hurricane Gustav and Hurricane Ike. The yellow wind barbs indicate the

hurricane force winds greater than 63 knots [Category 1 on the Saffir/Simpson Scale], the light orange wind barbs indicate winds greater than 83 knots [Category 2], and the dark orange wind barbs indicate winds greater than 96 knots [Category 3]. The radius of hurricane force winds for Hurricane Gustav extended out to the right of the hurricane track 60 nautical miles compared with Hurricane Ike which had hurricane force winds extending out 110 nautical miles. Ike was so large that waves were crashing into the Galveston sea wall two days prior to landfall. [See Figure 3]



Figure 2: Hurricane Wind Fields of Hurricane Gustav [right] and Hurricane Ike [left]



Figure 3: Waves Crashing into the Galveston Sea Wall

WRC's Hurricane Wind and Wave Model also computes the significant waves that are generated by the hurricane wind field. So the CCM was also able to plot the significant waves generated by Hurricane Ike using the ARCGIS software. A composite plot of the regions with significant waves greater than 30 feet, 34 feet, 40 feet, etc. were made using GIS. GIS also lets the user to overlay other fields such as the location of the Gulf of Mexico offshore platforms and pipelines. The damaged and destroyed properties can also be overlaid on the wave fields, see Figure 4. The green and yellow stars indicate the damaged and destroyed properties as a result of Hurricane Ike and Hurricane Gustav. Sixty platforms were destroyed by Gustav and Ike in 2008. Over 2,000 offshore properties experienced hurricane force winds and significant waves greater than 30 feet.



Figure 4: Significant Wave Height Bands for Hurricane Ike 2008. Green and yellow stars and circles indicate the damaged and destroyed offshore platforms.

Hurricane Ike was classified as a Category 2 hurricane on the Saffir/Simpson Scale which usually means the significant waves generated cause little damage offshore. However, the size of Ike allowed for a very long fetch of the hurricane force winds which in turn generated very high significant waves and storm surges for this hurricane intensity. This led the CCM to review the different hurricanes that have influenced the Gulf of Mexico oil leases to determine if an improved damage potential scale could be generated.

3. SIGNIFICANT GULF OF MEXICO HURRICANES

In order to demonstrate that size matters and should be used to create a new Hurricane Damage Potential Scale, the CCM used the Center's Hurricane Wind and Wave Model and plotted the results using GIS. The winds and waves were computed not only for Hurricane Ike but also for Rita 2005, Katrina 2005, Ivan 2004, Lili 2002, Georges 1998, Andrew 1992, Camille 1969, Betsy 1965, Hilda 1964 and Carla 1961.

Figure 5 is a GIS plot of the various hurricane winds fields from Hurricanes Audrey 1957, Carla 1961, Hilda 1964, Betsy 1965, Beulah 1967, Camille 1969, Celia 1970, Carmen 1974, Lili 2002, Ivan 2004, Katrina 2005, Rita 2005, Gustav 2008 and Ike 2008. Notice that hurricanes based on the size of their hurricane wind fields come in all sizes. The yellow wind barbs are Category 1, orange wind barbs are Category 2, dark orange wind barbs are Category 3, red wind barbs are Category 4 and purple wind barbs are Category 5.



Figure 5: Hurricane Wind Fields for past Gulf of Mexico Hurricanes.

Figure 5 demonstrates that size that SIZE MATTERS!

Figure 6 is a plot of the cross section of the maximum sustained winds for each hurricane as it was over the Gulf of Mexico Oil Leases. The graph shows how the wind fields of each hurricane were unique and different sizes. The bold black horizontal line in the graph indicates sustained winds of 64 knots. The distance is along the bottom with the middle being the center of the storm. This graph shows how many nautical miles to the right and left of the hurricane track the hurricane force and tropical storm force winds extended. The graph also depicts how far from the center the maximum winds in the hurricane occurred. When you compare Hurricane Ike's wind profile with Hurricane Andrew 1992, depicted in the brown line, you can see that the area exposed to hurricane force winds is much larger. Notice that Hurricane Andrew's hurricane force winds extended out about 50 to 60 nautical miles compared to Hurricane Ike which extended out 110 nautical miles.

Figure 7 is a cross section of the significant waves generated by the hurricane winds for the various hurricanes. The bold black horizontal line on the graph indicates the significant waves of 34 feet. Thirty-four feet was chosen because it results in a wave crest of 45 feet, which is a critical value for some of the older platforms in the Gulf. These older platforms tend to have air gaps of 40 to 45 feet. Usually the damage results from waves crashing into the decks of the platform.



Figure 6: Past Gulf of Mexico Hurricane Wind Profiles. The orange line represents Hurricane Ike 2008.





4. FREEMAN/HASLING HURRICANE DAMAGE POTENTIAL SCALE

The CCM used GIS to determine how many offshore properties were exposed to hurricane sustained winds and significant waves greater than 33 feet. Figure 8 shows how the different size winds fields can be plotted along various hurricane tracks. GIS can then compare the number of platforms exposed to the hurricane winds and significant waves of various heights. Table 2 gives a summary of the exposed offshore platforms versus how many offshore platforms were actually damaged and destroyed from Hurricanes Andrew, Katrina, Rita and Ike. Hurricane Ike 2008 and Hurricane Rita 2005 exposed the most offshore properties.



Figure 8: Swaths of Hurricane Force Winds for Various Gulf of Mexico Hurricanes

Table 2: Past Storm Exposure

Past Storm	Offshore platforms Exposed to >33 feet	Actual Offshore Platforms Damaged or Destroyed	
Andrew 1992	970	87	
Katrina 2005	697	67	
Rita 2005	1055	98	
lke 2008	1135	91	

The CCM used this information to develop the Freeman/Hasling Hurricane Damage Potential Scale. The Freeman HDP Scale is not only based on the maximum sustained winds in the storm but also the central pressure, storm speed, storm heading, radius of 34 and 64 knot winds, the area of significant wave heights and the duration of the winds greater than 64 knots.

The Freeman/Hasling HDP Scale uses the Saffir/Simpson Scale and the radius of hurricane force winds to determine the Freeman/Hasling HDP number. The Freeman/Hasling HDP number is then used to calculate the HDP percent that can be used to estimate the number of exposed offshore properties that could be damaged or destroyed by a particular hurricane.

Table 3 illustrates the Freeman/Hasling Hurricane Damage Potential Scale. You enter this table with the Saffir/Simpson Category assigned to the hurricane based on the maximum sustained winds and then enter the radius to hurricane force winds. This will give you the Freeman/Hasling HDP number which is then used to determine the percentage of the number of damage or destroyed properties from the number properties exposed.

Radius of Hurricane force Winds [R64] in nautical Miles	<=30	>30	>=45	>=60	>=80
Saffir/Simpson					
1	0	0	0	4	5
2	0	0	0	5	5
3	0	0	1	5	5
4	0	1	2	5	5
5	1	2	3	5	5
Freeman/Hasling HDP Scale	1	2	3	4	5
HDP Percent	2%	4%	6%	8%	10%

Table 3: Freeman/Hasling Hurricane Damage Potential Scale

5. CONCLUSION - HURRICANE SIZE MATTERS

The Saffir/Simpson Damage-Potential Scale does not take into account the size of the hurricane wind field. Tropical storm force winds and high waves can impact an area 24 to 30 hours prior to hurricane impact. This is the main reason the CCM has developed the Freeman/Hasling Hurricane Damage Potential Scale. This scale uses the Saffir/Simpson Scale as input and takes into account the size of the hurricane wind field to determine the damage potential. The history of the Saffir/Simpson Damage-Potential Scale is given below.

The Saffir/Simpson Damage-Potential Scale was developed in 1975 in order to describe the type of observed damage a storm produced on a particular coast. It was then used to describe the type of damage a storm would cause to a coastal area if it were to strike a particular coast with its current parameters of size, winds, pressure and expected storm surge. The scale was derived by looking at past hurricanes and categorizing the damage into 5 groups.

The Saffir/Simpson Scale is currently being implemented just using the observed maximum sustained winds in a hurricane, which is only one of the parameters of the cyclone. The scale does not take into account the size of the hurricane wind field. The return of large storms to the Gulf of Mexico, similar to the storms of the 60's, has demonstrated how devastating a large hurricane can be both offshore and onshore.

This research demonstrates one of the roles of a CCM in marine and tropical meteorology.

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