Hurricane Isaac

August 21-30, 2012

Insurance Institute for Business & Home Safety®

Report Objectives

Despite the fact that Hurricane Isaac was upgraded to a Category 1 hurricane on the Saffir-Simpson Hurricane Wind Scale before landfall, its large wind field contributed to significant storm surge. As the area works to recover from the storm and damage is assessed, it is important to relate the damage to the storm conditions that actually occurred in the areas affected. The objective of this report is to provide IBHS member companies with a detailed summary of wind, storm surge and rainfall data collected as the storm struck the coast and to provide links to other publicly available analyses. IBHS hopes his report will help its member companies understand the storm effects in areas where they have experienced losses. Continued research to understand the complex relationship between peak winds, storm surge, and rainfall, and to investigate methods of disseminating severe weather information to decision-makers during pre-storm preparations will lead to a narrowing of the uncertainty gap in catastrophe modeling.

Introduction

Hurricane Isaac was the first hurricane to make landfall in the continental United States in 2012, and the first since Hurricane Irene in September 2011. Isaac became a Category 1 hurricane on the Saffir-Simpson Hurricane Wind Scale shortly before it made landfall near the mouth of the Mississippi River in southeastern Louisiana. This document summarizes the evolution of Isaac, the primary hazards, and their impacts at landfall along the northern Gulf Coast. Available data from various observation systems were compiled to provide a summary of wind including Texas Tech University Hurricane Research Team (TTUHRT) research platforms, storm surge, and rainfall measurements.

The Insurance Institute for Business & Home Safety (IBHS) provided staff to support TTUHRT landfall operations with IBHS research scientist Dr. Ian Giammanco participating in the deployment, and IBHS research engineer Dr. Tanya Brown providing logistical support from the IBHS Research Center; both are appointed as faculty research associates within the Wind Science and Engineering Research Center at Texas Tech. TTUHRT deployed 20 of 24 StickNet probes including 12 that provide real-time data transmission. These observations provided high spatial resolution mapping of Hurricane Isaac’s wind field with a research grade measurement approximately every 25 miles across the impacted region.

The landfall operations were conducted in coordination with the Digital Hurricane Consortium (DHC), an umbrella association created to coordinate the deployment of measurement assets from a number of universities and research laboratories including fixed meteorological towers, portable Doppler radars, and other wind and surge measurement instruments. As a result of the observational assets from the DHC and the research aircraft from the National Oceanic and Atmospheric Administration (NOAA), the landfall of Isaac became one of the most thoroughly documented in history. Many of the more complex data assets are still being analyzed and will no doubt offer new insights into the way wind characteristics change as a storm encounters different types of terrain.

1. Meteorological History

Hurricane Isaac developed from a westward moving tropical wave which emerged from the west coast of Africa on August 16. The system slowly intensified and was classified as a tropical depression (TD-9) on August 21 approximately 700 miles east of the Leeward Islands. Later in the day on August 21, Air Force reconnaissance aircraft confirmed that TD-9 had intensified into Tropical Storm Isaac. The system passed through the Leeward Islands on August 22 just south of Guadeloupe. Isaac's track took the cyclone across the western peninsula of Haiti and along the extreme northern coast of Cuba. TS Isaac intensified into a strong tropical storm prior to its crossing, with maximum sustained winds of 70 mph. Isaac's interaction with land effectively disrupted the cyclone and halted any intensification for nearly 12 hours after the system emerged over water. Isaac began to slowly intensify once entering the Florida Straits on August 26. Despite the impressive satellite appearance of Isaac, reconnaissance aircraft routinely reported that the inner-core eyewall structure was having difficulty becoming established despite a favorable environment for intensification.

Isaac moved northwestward across the eastern Gulf of Mexico around the periphery of a subtropical ridge of high pressure centered over the western Atlantic. Computer model forecasts struggled with an evolving gap between a ridge of high pressure across the southern great plains of the United States and the subtropical ridge to the east. As Isaac entered the Gulf of Mexico, the majority of the model guidance suite suggested that the system would eventually turn northward into the expected gap between the two areas of high pressure. This solution did not materialize, likely due to the underestimation of the strength of the southern plains ridge as a result of the persistent drought conditions in this region.

NOAA synoptic surveillance flights from its Gulfstream IV aircraft provided valuable observations to improve the model-depicted state of the atmosphere and aided in reducing the spread in the guidance envelope in the Days 4 and 5 forecasts prior to landfall. The Global Forecast System model (GFS) finally latched onto a consistent solution approximately four days prior to landfall and suggested that Isaac would continue slowly northwestward through landfall near the mouth of the Mississippi River. The remaining members of the computer model guidance followed suit 12 to 24 hours later. The persistent northwest motion of Isaac across the eastern Gulf of Mexico also was in disagreement with historical tropical cyclone tracks entering the Gulf of Mexico through the Florida Straits.

Isaac continued its slow northwest motion while gradually intensifying up to landfall along the Louisiana coast. During Isaac's approach, the central pressure of the cyclone steadily decreased. However, data from NOAA research and Air Force reconnaissance aircraft indicated that Isaac's strongest winds were significantly elevated and did not translate to the surface. Isaac, in fact, exhibited one of the lowest surface pressures recorded for a system of tropical storm intensity.

At 11:20 am CDT on August 28 Isaac was officially classified as a minimal Category 1 hurricane on the Saffir-Simpson Hurricane Wind Scale, only 75 miles south-southeast of the mouth of the Mississippi River. Isaac crawled northwestward and intensified to an 80 mph Category 1 hurricane before making an official landfall at 6:45 pm CDT on August 28 very near the southwest pass of the mouth of the Mississippi River. Isaac meandered slowly westward over the next eight hours moving back over water and making a second and final landfall near Port Fouchon, Louisiana at 2:18 am CDT on August 29. Isaac slowly moved northward taking nearly 12 hours to move only 75 miles inland. The system was officially downgraded to a tropical storm at 2:00 pm CDT on the 29th and to a tropical depression at 4:00 pm on the 30th over Northern Louisiana. The complete track of Isaac is provided in Figure 1.1.

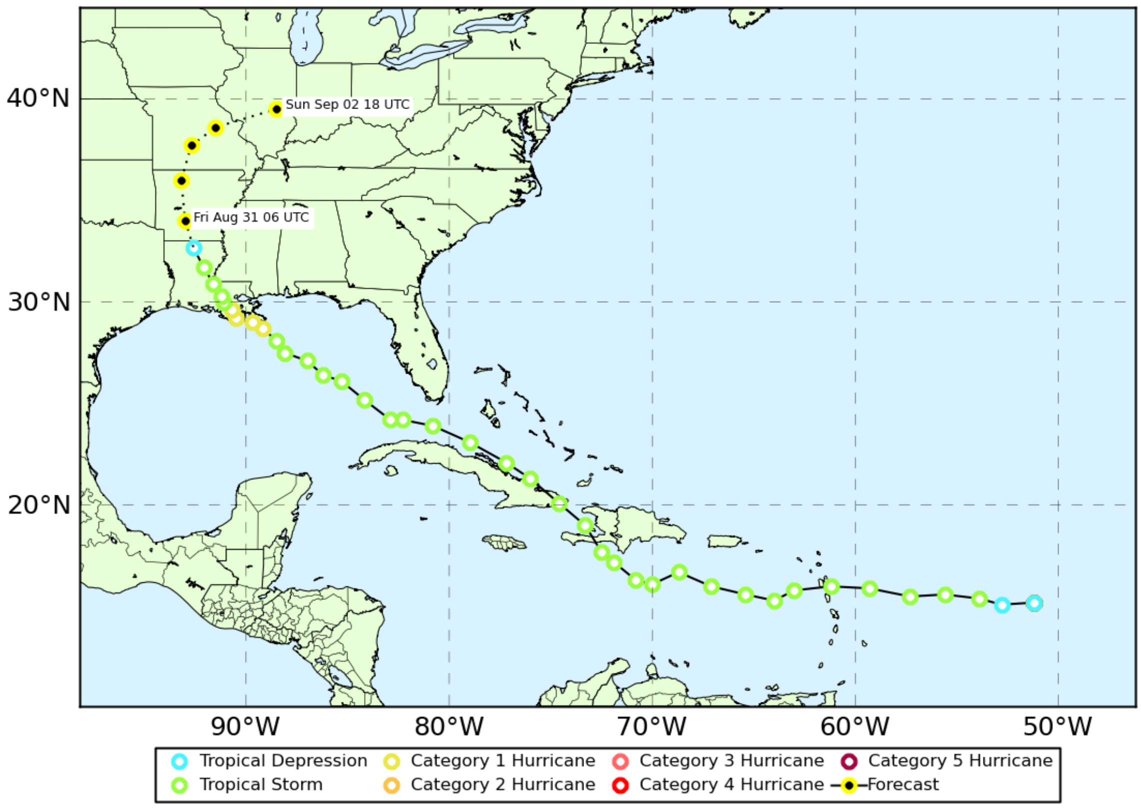

Figure 1.1. Track of Hurricane Isaac based on National Hurricane Center official advisory center positions. This track is subject to minor changes based on post-storm analysis by the National Hurricane Center.

2. Impact

Although Hurricane Isaac was only a Category 1 hurricane on the Saffir-Simpson Hurricane Wind Scale, it produced a significant storm surge which rivaled that of several past major hurricanes to strike the region including Betsy (1965), Georges (1998) and Ivan (2004). In addition to storm surge inundation, significant rainfall and a long duration of tropical storm winds added to the damage potential. Prior to landfall, surface wind field analysis by NOAA's Hurricane Research Division (HRD) indicated that Isaac had ratings of 2.0 for wind and 3.5 for storm surge/waves on the Powell-Reinhold Integrated Kinetic Energy (IKE) scale (continuous 0-6; Powell and Reinhold 2007). The H*Wind operational analysis at the time of Isaac's final landfall is provided in Figure 2.1. Although analyses suggest that hurricane winds were confined to a small region, most of southeast Louisiana and coastal Mississippi experienced tropical storm conditions for nearly 18 hours. Isaac produced very large rainfall amounts leading to significant runoff and flooding of local rivers and bayous. Rainfall amounts exceeding 10 inches were common across the impacted region with localized peak amounts over 20 inches.

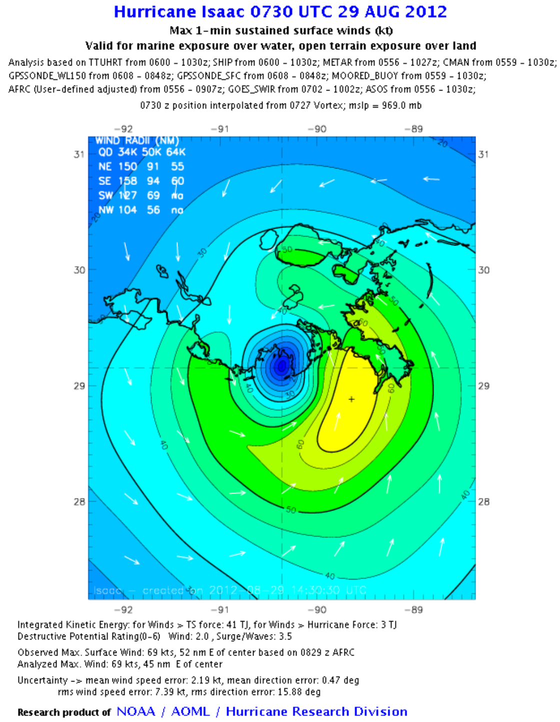

Figure 2.1. NOAA-HRD H*Wind operational analysis for Hurricane Isaac at 0730 UTC on August 29, 2012. TTU StickNet observations are included in this analysis.
Image Source: ftp://ftp.aoml.noaa.gov/hrd/pub/hwind/Operational/2012/AL092012/0829/0730/AL092012_0829_0730_contour04.png

2.1. Storm Surge Impacts

Hurricane Isaac was a very large tropical cyclone with an expansive wind field. Tropical storm force winds extended over 160 miles outward from the center in the northeastern quadrant of the storm, which allowed for a significant storm surge along the coastline of Mississippi and southeast Louisiana. Table 2.1 summarizes storm surge observations along the Louisiana and Mississippi coastlines. In Plaquemines Parish levee overtopping resulted in nearly 12 feet of inundation along the east bank of the Mississippi River near Pointe-a-la-Hache. Storm surge model guidance prior to landfall indicated the potential for 15 feet of storm surge flooding in the area. The eastern levee system in Plaquemines Parish was intentionally breeched on August 30 to drain water along the east bank of the Mississippi River into the surrounding marshland. It is noted that this region is located outside the New Orleans post-Katrina flood protection system.

Overtopping of the levee system along the coastal marsh on the west bank of the Mississippi River also occurred in Plaquemines Parish north of Port Sulphur, Louisiana, resulting in inundation of 3-4 feet. A significant surge moved up the Mississippi River late in the day on August 28 extending through August 29. The US Geological Survey (USGS) gauge on the Mississippi River at Belle Chasse, Louisiana, measured a flow rate northward that exceeded the average daily discharge rate of the river for nearly a 24-hour period, shown in Figure 2.2. Coastal flooding in Plaquemines, lower Jefferson, St. Bernard, and Lafourche parishes approached 8 feet. Along the Mississippi coast, storm surge tides of 7 to 10 feet were measured from Waveland eastward to Ocean Springs. Un-official observations made at research instrument deployment sites indicated localized storm surge levels of up to 12 feet west of Waveland and near Gulfport.

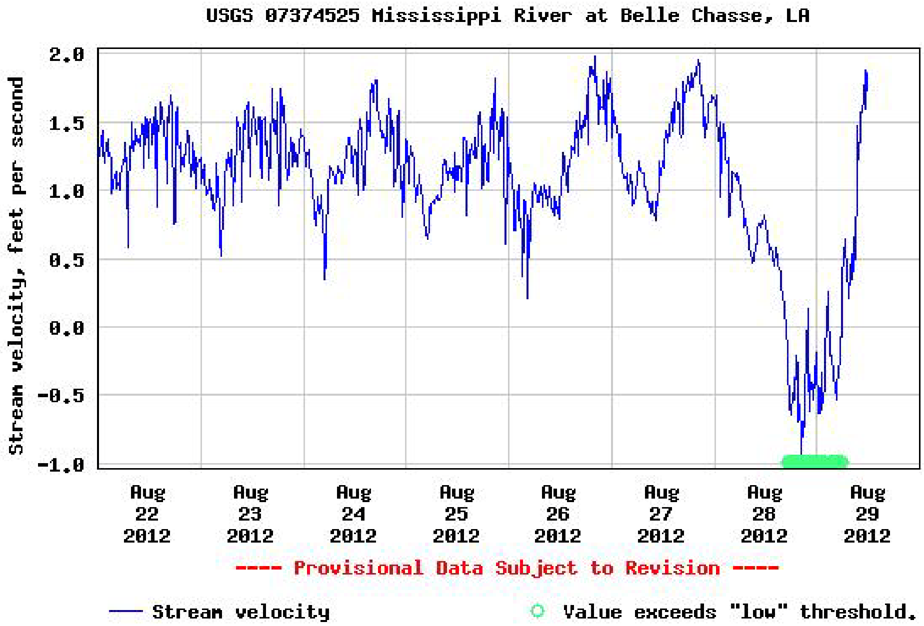

Figure 2.2. Stream velocity time history for the USGS Mississippi River Gauge at Belle Chasse, Louisiana. Note the peak upriver flow as a result of Hurricane Isaac. Plot courtesy of the USGS.

Within the New Orleans metropolitan area, the flood protection system performed well with no storm surge inundation observed within the levee system. Along the north shore of Lake Ponchartrain, significant flooding was observed as Isaac moved northward allowing for a southerly fetch to develop. The prolonged southerly flow pushed water from the tidal lakes onshore and into rivers and bayous. Storm surge flooding into bayous resulted in significant inundation in parts of Slidell south of Interstate 10 (I-10). This also occurred near LaPlace as a result of flooding along Lakes Ponchartrain and Maurepas. Storm surge flooding resulted in the complete closure of I-10 for more than 24 hours near the Interstate 55 (I-55) junction. The flooding left I-10 through Slidell and U.S. Highway 90 as the only routes into or out of the New Orleans metropolitan area. Debris from storm surge flooding briefly forced the closure of the I-10 bridge to New Orleans at Slidell.

Storm surge model guidance performed well in depicting the maximum water levels across much of the region. Sea Lake Overland Surges from Hurricanes (SLOSH) model runs, even 48 hours prior to landfall, indicated 6-12 feet of storm surge across the southeast Louisiana and Mississippi coastlines with maximum values approaching 15 feet near the mouth of the Mississippi River. Guidance indicated 11 feet of storm surge flooding along the north shore of Lake Ponchartrain. Storm surge forecast values from the research Advanced Circulation (ADCIRC) model also indicated very similar peak water levels.

Figure 2.3 provides a comparison between observed storm surge and forecast values prior to landfall by the SLOSH and ADCIRC model guidance. In general, observed storm surge values did not exceed the forecast levels and observations fell within the range of SLOSH predictions. The ADCIRC forecast at 18 UTC on the 28, although a higher resolution model than SLOSH, slightly overestimated water levels in some locations but in general performed very well.

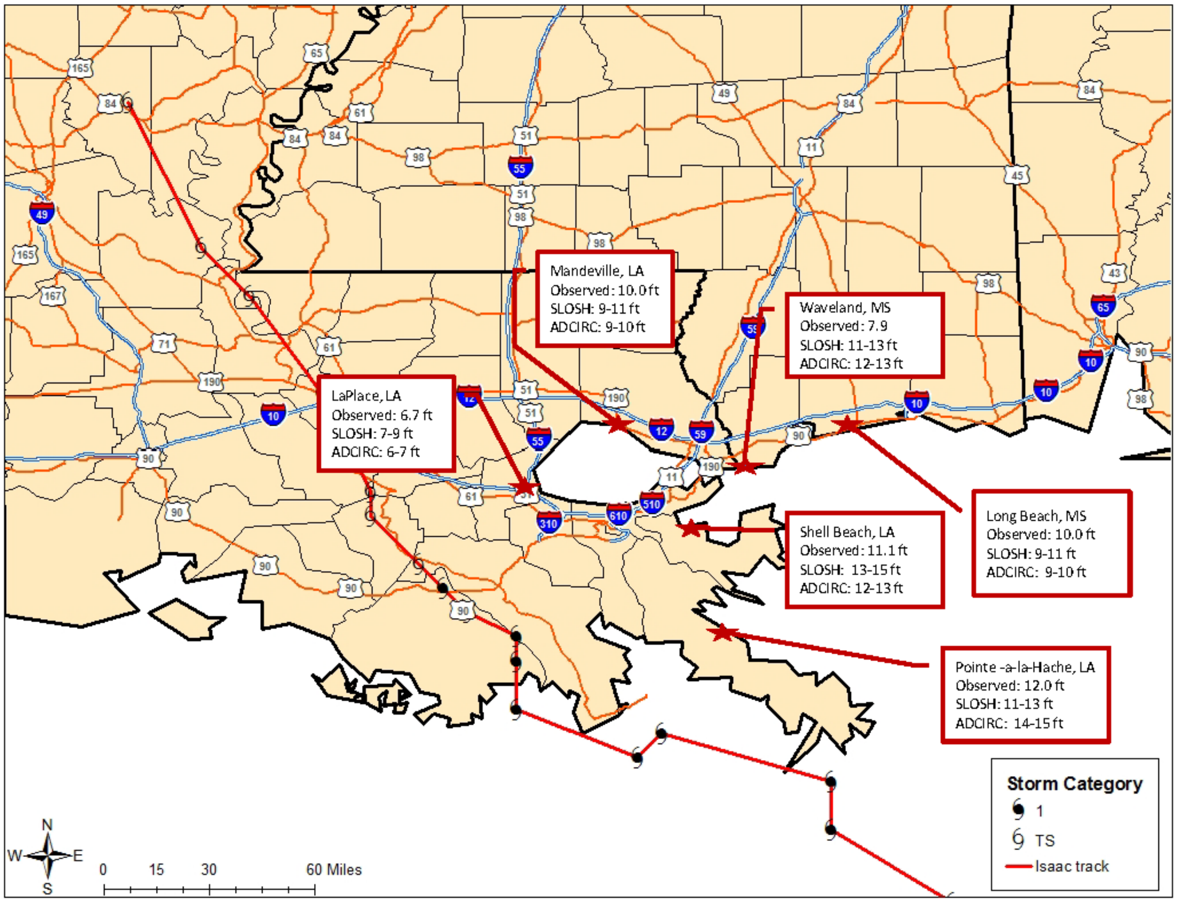

Figure 2.3. Comparison of SLOSH and ADCIRC model forecast for peak storm surge with select observing stations. Observational data courtesy of the USGS. SLOSH model forecast data courtesy of the National Weather Service based on 06 UTC 27 August 2012 model run, approximately 48 hours prior to landfall. ADCIRC data courtesy of Mississippi State University run at 18 UTC 28 August 2012. Track of Isaac is based on official advisory center positions and is subject to minor changes upon post-storm analysis by the National Hurricane Center.

Table 2.1. Storm surge observations for select stations. All stations are USGS.

Location	Parish/County	Date	Time (UTC)	Peak Storm Tide (ft)
LOUISIANA				
Rigolets –US 90	Orleans	8/30	0300	7.0
Grand Pass	St. Bernard	8/29	1530	7.5
Pilot Town	Plaquemines	8/29	0324	6.6
Grand Isle	Jefferson	8/29	1406	4.5
Shell Beach	St. Bernard	8/29	0536	11.1
Point-a-la-Hache	Plaquemines	8/30	0230	12.0
Irish Bayou	Orleans	8/30	0915	5.5
Lafitte	Jefferson	8/31	0900	8.5
Pass Manchac-LaPlace	St. John	8/30	1100	5.5
Bayou LaCombe	St. Tammany	8/30	0845	6.5
Bayou Liberty -Slidell	St. Tammany	8/30	0645	7.5
Mandeville – Bayou Chinchuba	St. Tammany	8/30	0843	10.0
Davis Pond - Boutte	St. Charles	8/30	1815	3.0
Bayou Gauche	St. Charles	8/31	0354	2.0
MISSISSIPPI				
Bay St. Louis	Hancock	8/29	1700	9.0
Pearl River – US 90	Hancock	8/29	1923	9.3
Waveland	Hancock	8/29	1642	7.9
Back Bay - Biloxi	Harrison	8/29	1845	7.7
Ocean Springs	Jackson	8/29	1815	6.9
Pascagoula	Jackson	8/29	1000	4.5
Long Beach – Mississippi Sound	Harrison	8/29	1734	10.1
Gulfport – Treasure Island Casino	Harrison	8/29	1830	9.2
Gautier	Jackson	8/29	2000	5.1
Moss Point	Jackson	8/29	1731	6.1
ALABAMA				
Coden – Bayou Labatre	Mobile	8/29	1439	5.3
Ft. Morgan – Dauphin Island	Baldwin	8/29	1436	4.9
Mobile – Downtown Airport	Mobile	8/29	1938	5.5
Fairhope – Mobile Bay	Baldwin	8/29	1729	4.9
Daphne Mobile Bay	Baldwin	8/29	1631	5.0

2.2. Wind Impact

Although at landfall Isaac officially had peak sustained winds of 80 mph, the slow motion of the system and relatively large wind field resulted in a wide area being exposed to tropical storm force winds for a long duration. The maximum gust wind speed observed by an official reporting site was at Bootheville-Venice with a 3-second gust wind speed of 84.0 mph. It is noted that the station record is incomplete due to a power failure. The peak sustained wind speed from official observing stations occurred at the New Orleans Lakefront Airport with a value of 59.8 mph. Table 2.2 provides a summary of official wind observations from the landfall of Isaac. Research platform observations are presented in a later section of this report.

H*Wind analyses from NOAA-HRD indicated that only portions of lower Plaquemines Parish experienced Category 1 sustained wind speeds, likely in a swath from near Buras northward to Carlisle, Louisiana along the Mississippi River. As Isaac moved inland, wind speeds decreased in association with the decay of the cyclone. Tropical storm force winds extended outward over 100 miles in all four quadrants of Isaac. The large size of the cyclone allowed much of southeast Louisiana and coastal Mississippi to be exposed to tropical storm force winds for a period of nearly 18 hours. The relatively low peak winds did not result in significant structural damage, however, widespread damage to trees and electrical infrastructure was observed. Minor loss of roof cover material also was observed. An example from Bay St. Louis, Mississippi is provided in Figure 2.3.

Figure 2.3. Photograph of roof covering loss on a dormer near Bay St. Louis, Mississippi. Photograph by Ian Giammanco, Ph.D.

Table 2.2. Official Automated Surface Observing Station (ASOS) peak wind speeds observed during Hurricane Isaac. Wind data are collected at 10 m height. For ASOS observations, sustained winds represent a 2-minute average and gust wind speeds represent a 3-second average. Table represents observations available at the time of this report.

Observing Station	Parish/County	Date	Time (UTC)	Peak Sustained Wind (mph)	Peak Gust Wind (mph)	Time (UTC)
LOUISIANA						
KNEW – Lakefront Airport	Orleans	8/29	0328	59.8	76.0	0507
KMSY – Armstrong Int'l Airport	Jefferson	8/29	0348	53.0	74.8	1007
*KBVE - Bootheville	Plaquemines	8/29	0302	54.1	84.0	0259
*KBTR – Baton Rouge	East Baton Rouge	8/30	1429	29.9	39.1	1428
KASD - Slidell	St. Tammany	8/30	0306	39.1	57.5	1239 (8/30)
MISSISSIPPI						
KGPT - Gulfport	Harrison	8/29	1719	52.9	70.2	1719
KPQL - Pascagoula	Jackson	8/30	0230	34.5	51.8	0136
C-MAN / NOAA BUOY STATIONS						
*BURL1 – SW Pass (30.5m)	N/A	8/29	0600	75.9	88.6	0500
GISL1 – Grand Isle CGS (9.4m)	Jefferson	8/29	0012	66.7	85.2	0012
SHBL1 – Shell Beach (10m)	St. Bernard	8/29	0324	64.4	78.2	0330
PILL1 – Pilot Town (24m)	Plaquemines	8/29	1506	64.4	79.4	0454
*42040 – NDBC Buoy (10m)	N/A	8/28	1950	62.1	82.9	1850
WYCM6 – Waveland (10m)	Hancock	8/29	1912	50.6	66.7	1536

**incomplete record*

2.3. Rainfall/Freshwater Flooding

The slow forward speed of Isaac contributed to a tremendous amount of rainfall across much of southeast Louisiana and southwest Mississippi. Table 2.3 provides a summary of rainfall totals for selected reporting stations across the impacted region. The copious amounts of rainfall also resulted in several rivers across the region exceeding their flood stage. However, given the prolonged drought across much of the Mississippi River flood plain, most area rivers were at record low-levels, including the Mississippi. Runoff into local watersheds resulted in the undermining of a dam at Lake Tangipahoa near McComb, Mississippi, resulting in several mandatory evacuations downstream along the Tangipahoa River near Kentwood and Robert, Louisiana. Freshwater flooding also occurred in southern Mississippi with the Wolf River near Gulfport setting a record level of 16.5 feet (flood stage of 8 feet). Major flooding was observed along the Tangipahoa, Tchefuncte, Amite, and Bogue Chitto rivers in Louisiana. Freshwater runoff combined with storm surge inundation did not allow for water to quickly recede following the Isaac's passage. As the storm moved further northward, regions in Arkansas, southern Missouri, and northern Mississippi received beneficial rainfall of 5-10 inches.

Table 2.3. Storm total rainfall measurements for selected sites.

Location	Parish/County	Station ID	Storm Total Rainfall (in.)
LOUISIANA			
Galliano	Lafourche	GALL1	10.89
Terrytown	Jefferson	TERL1	11.02
New Orleans -Carrollton	Orleans	NORL1	21.32
New Orleans – Armstrong Int'l Airport	Jefferson	KMSY	10.36
Livingston	Livingston	LVGL1	16.46
Talisheek	St. Tammany	TALL1	11.66
Robert	Tangipahoa	ROBL1	11.59
Gonzales	St. John	GZLL1	12.89
Slidell	St. Tammany	KASD	10.43
Abita Springs	St. Tammany	ABSL1	9.68
*Bootheville	Plaquemines	KBVE	9.47
Denham Springs	Livingston	DSPL1	9.39
Houma	Terrebonne	HUML1	8.26
Thibodeaux	Lafourche	THIL1	8.15
Baton Rouge	East Baton Rouge	SBRL1	9.21
Lutcher	St. James	LUTL1	10.38
MISSISSIPPI			
Pascagoula	Jackson	PGLM6	22.20
Biloxi	Harrison	BLXM6	17.72
Pascagoula - Airport	Jackson	KPQL	13.53
Waveland	Hancock	WVLM6	16.09
Bay St, Louis – Stennis Airport	Hancock	KHSA	12.21
Long Beach	Harrison	LNGM6	12.08
Ocean Springs	Jackson	OCSM6	11.25
Gulfport Airport	Harrison	KGPT	11.10
Biloxi – Keesler AFB	Harrison	KBIX	10.41
Kiln	Hancock	N/A	17.04
ALABAMA			
Mobile	Mobile	KMOB	9.67
Grand Bay	Mobile	N/A	11.07
Fairhope	Baldwin	N/A	6.42
Daphne	Baldwin	N/A	5.87
Foley	Baldwin	N/A	3.71
Mobile – U. of S. Alabama Campus	Mobile	N/A	9.0

**incomplete record*

3. Observational Research Assets

The Digital Hurricane Consortium (www.digitalhurricane.org) coordinated the deployment of instrumentation from several research institutions including Texas Tech University. These included mobile Doppler radar systems from the Center for Severe Weather Research, University of Alabama at Huntsville, and University of Oklahoma/National Severe Storms Laboratory. Surface observing stations were deployed by Texas Tech University (TTU) and the Florida Coastal Monitoring Program (FCMP). Figure 3.1 shows the entire deployment of all assets associated with the various institutions under the umbrella of the DHC. Although not shown in Figure 3.1, the USGS deployed nearly 120 storm surge measurement gauges stretching from Louisiana eastward to the Florida panhandle. The dataset obtained from Hurricane Isaac's landfall represents the most comprehensive ever collected from a hurricane at landfall.

Figure 3.1. Deployment map of all field instrumentation deployed by Digital Hurricane Consortium institutions for the landfall of Hurricane Isaac. The shaded green circles represent mobile Doppler radar coverage zones.

3.1. Texas Tech University StickNet Observing Stations

Texas Tech University maintains a fleet of 24 rapidly deployable, 2.25 m surface weather observing stations, known as StickNets (Weiss and Schroeder 2008). Each probe collects research grade measurements of wind speed and direction, temperature, relative humidity, and barometric pressure at sampling rates greater than 1 Hz. The fleet of instruments represents a fully mobile, self-sustaining, and adaptable observing network. A photograph of a deployed StickNet probe is provided in Figure 3.2. The need for such a network has arisen from the near

70 percent failure rate of National Weather Service Automated Surface Observing Stations (ASOS) once sustained winds reach 50 mph (Blessing and Masters 2005). Additionally, the coarse spatial resolution of official observing sites does not effectively capture the variability within a landfalling hurricane's wind field.

StickNet deployments are carried out by two teams, each responsible for a network of 12 probes. The set of probes are housed during transit within a covered trailer which is equipped with battery charging capability for all probes and a LAN network to provide rapid data download upon retrieval. Each team consists of two to three people and operates semi-autonomously, focusing deployments within a specified geographic area. Deployment sites are selected based on their surrounding terrain exposure (preference for coastal marine or open exposure) and their susceptibility to storm surge inundation. Specific experimental plans may also dictate deployment locations, such as within mobile radar coverage, near National Weather Service Doppler radars, or fine-scale arrays to investigate specific phenomena.

Twelve of the 24 probes have real-time data transmission capability. Each deployment team was responsible for the deployment of six real-time capable probes. The funding to develop and provide this capability was made possible through a grant from the State of Texas' Norman Hackerman Applied Research Program (ARP) and financial support from State Farm Insurance and the Office of the Vice President for Research at Texas Tech University. Real-time data are provided to the National Hurricane Center, local forecast offices of the National Weather Service, and private sector research collaborators. Data are also ingested into NOAA-HRD's H*Wind wind field model for near real-time analysis.

Figure 3.2. Photograph of StickNet probe 0213A being deployed by Team 1 near Luling, Louisiana in advance of Hurricane Isaac. Photograph by Ian Giammanco, Ph.D.

3.2. Deployment Chronology

The Texas Tech University Hurricane Research Team (TTUHRT) was activated during the day on August 25, along with the remainder of the Digital Hurricane Consortium, as it became clear that Isaac would become a threat to the northern Gulf Coast. The two StickNet deployment teams were on-site in south Louisiana late in the day on August 26. At this time, Isaac's forecasted landfall had accelerated from the previous day's forecast, which prompted the teams to forgo site scouting operations and begin deployments on August 27.

StickNet Team 1 was responsible for deploying six real-time telemetry capable probes in a coarse array stretching from St. Charles Parish, Louisiana to Hancock County, Mississippi. The remaining six probes were used to fill in gaps within the array to provide complete surveillance of the wind field of Hurricane Isaac as it made landfall, including the New Orleans metropolitan area. Team 2 was responsible for deployments in Terrebonne Parish stretching northward toward Baton Rouge. They also extended the eastern side of the StickNet array in Harrison and Jackson Counties in Mississippi. Figure 3.3 provides a map showing the locations of all TTUHRT StickNet probes. Deployments continued throughout the day on the 27th and into the 28th with StickNet Team 1 deploying their final probe late in the day on August 28 as Isaac was approaching the southwest pass of the mouth of the Mississippi River.

During this time IBHS research engineer Dr. Tanya Brown provided logistic support through identification and relay of suitable deployment locations. Dr. Brown had previously developed an extensive Google Earth and Microsoft Access database management system to provide information on previously used and scouted deployment sites. This information proved to be invaluable given the short deployment timeline prior to the onset of tropical storm force winds, and aided in efficiency given the difficulty maneuvering around the New Orleans metropolitan area.

The deployment featured five probes in pure coastal marine exposure with two unique deployments along flood-protection levees near Empire and Shell Beach, Louisiana. Another probe along the north shore of Lake Pontchartrain near I-10 was located in marine exposure as well. The data collected by these platforms will help researchers understand the roughness characteristics at the land-sea interface and how the structure of hurricane winds change as the flow transitions from breaking waves at the immediate coastline to a land surface. Six probes were located within mobile Doppler radar coverage.

An additional probe was deployed near the National Weather Service WSR-88D Doppler radar in Slidell, Louisiana, in support of an experiment examining the relationship between observed surface winds and radar derived vertical wind profiles. Deployment sites were relayed to NOAA-HRD who coordinated several flight legs by the NOAA P-3 research aircraft along the coastal array of StickNet probes. Several GPS dropwindsondes were released near instrument locations to aid in understanding the influence of the vertical wind profile on near-surface wind characteristics. It has been hypothesized that the wind speed maximum aloft may represent the upper bound of expected surface wind gusts.

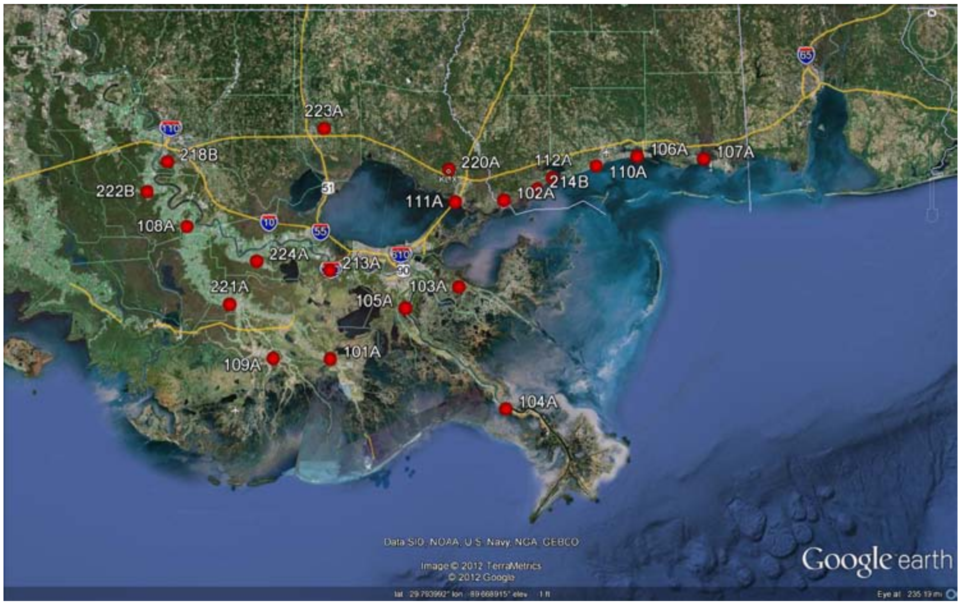

Figure 3.3. Map of TTUHRT StickNet deployments for the landfall of Hurricane Isaac.

As Isaac made landfall and began moving very slowly northward, the center of the system passed over several probes within the western portion of the StickNet array. The wind field of Isaac was effectively mapped by the array as well. Figure 3.4 provides a radar image from the Slidell WSR-88D Doppler radar (KLIX) showing Hurricane Isaac moving inland with StickNet probe 0109A near the exact center. Data records from Probes 0109A, 0221A, and 0108A show a wind speed minimum below 10 mph as the center of Isaac passed, an example of which is provided in Figure 3.5. The 12 stations with real-time data transmission performed flawlessly with more than 36 hours of uninterrupted dataflow. The real-time observations were used by the National Weather Service New Orleans/Baton Rouge Forecast Office, the Mississippi Emergency Management Agency's Emergency Operations Center, and were successfully included into NOAA HRD's H*Wind wind field model.

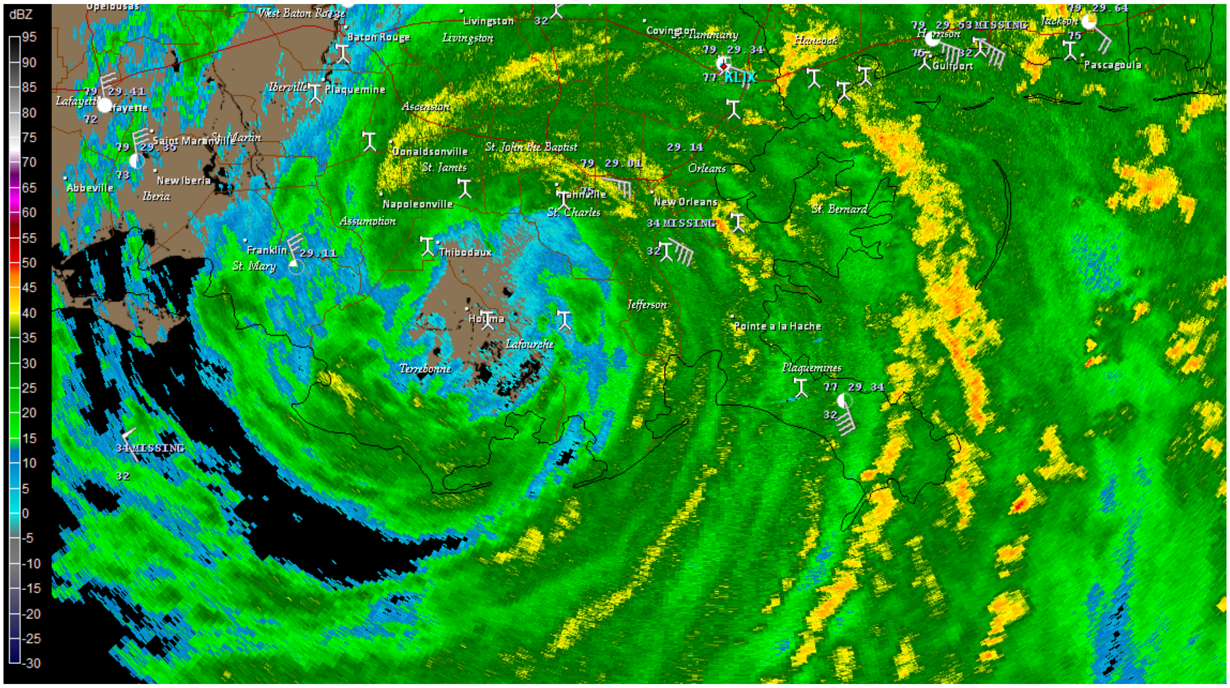

Figure 3.4. KLIX Doppler radar reflectivity image of Hurricane Isaac moving inland over Lafourche and Terrebonne Parishes. StickNet probes are shown as white symbols. Probe 0109A is near the exact center of Isaac. Official observing sites are shown by the wind barb symbols and their associated station plot (circles).

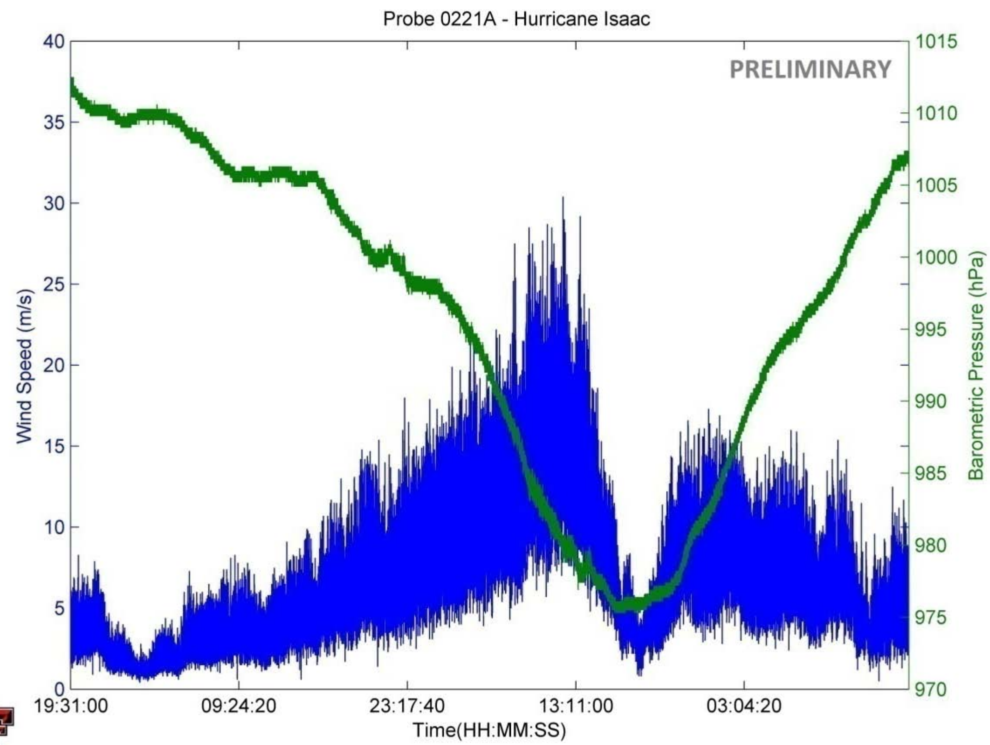

Figure 3.5. Time history of wind speed (blue) and barometric pressure (green) for StickNet probe 0221A. The probe reached a minimum pressure of 976 mb as the center of Isaac passed near the station.

The slow motion of Isaac prompted both teams to begin retrieving probes during the day on August 30 despite sustained winds over 30 mph and heavy rainfall across much of the region. Storm surge and freshwater flooding did not allow for retrieval of all probes. By August 31, all instrument platforms had been retrieved except for Probe 0104A near Empire, Louisiana. Levee overtopping near Port Sulphur had resulted in Louisiana Highway 23 becoming impassable due to high water and debris. The probe eventually was retrieved by members of the FCMP deployment team on September 5.

3.3. Data Summary

The StickNet array sampled both the center and the wind maximum of Hurricane Isaac with an average spatial resolution between probes of only 22 miles. Table 3.1 provides a summary of the wind observations collected by StickNet platforms. Peak winds are presented as a maximum 1-minute sustained wind speed and a peak 3-second gust. Wind data are measured at 2.25 m (7 feet) height. These data are not standardized to a uniform terrain exposure. Nearly all of the deployed probes collected a complete data record. Only Probe 0213A did not as a wind sensor issue did not allow for a complete record. The maximum 3-second gust wind speed measured within the StickNet array was by Probe 0104A near Empire, Louisiana with a value of 86.3 mph. The probe also measured 5-minute mean wind speeds above 50 mph for nearly 12 hours. Probe 0103A near Shell Beach measured a peak gust of 80.3 mph. At the time of their respective peak winds, both probes likely experienced marine exposure conditions as a result of storm surge inundation near their deployment sites. It is noted that these probes were deployed on levee structures and it is possible that topographic speed-up effects may have influenced the observations. The influence of the levee likely produced an over-estimate of the true 2.25 m wind speed by approximately ten percent. The influence of the specific deployment site characteristics will be investigated in later post-storm analyses.

Table 3.1. Peak wind speed summary for StickNet Probes. Observations presented in this table are considered preliminary and are subject to change upon further analysis. Wind data are measured at 2.25 m height and are NOT standardized for terrain exposure. Location references are given in miles.

Probe	Location	GPS Coordinates	Peak 1-minute wind speed (mph)	Peak 3-second wind speed (mph)
†0101A	1 S Larose, LA	29.56420˚N 90.38380˚W	49.9	70.5
†0102A	4 SE Pearlington, MS	30.30162˚N 89.50836˚W	33.6	49.7
†0103A	5 WNW Shell Beach, LA	29.86148˚N 89.77432˚W	63.1	80.3
†0104A	2 WNW Buras, LA	29.35773˚N 89.54670˚W	74.5	86.3
†0105A	1 S Oakdale, LA	29.77462˚N 90.02881˚W	49.2	65.5
†0106A	2W of Biloxi, MS	30.39449˚N 88.92348˚W	43.0	51.5
†0107A	1E of Gautier, MS	30.38178˚N 88.60455˚W	33.6	46.3
†0108A	5W of Donaldsonville, LA	30.10595˚N 91.07174˚W	50.1	62.0
†0109A	2SE of Houma, LA	29.56542˚N 90.65372˚W	38.7	59.1
†0110A	2W Gulfport, MS	30.35643˚N 89.11960˚W	46.1	60.6

†0111A	5S of Slidell, LA	30.20991˚N 89.79222˚W	47.0	62.2
†0112A	Bay St. Louis, MS	30.30745˚N 89.32741˚W	47.2	57.5
0214B	2SW of Waveland, MS	30.26280˚N 89.40210˚W	51.5	60.4
0218B	6WSW of Baton Rouge, LA	30.37210˚N 91.16940˚W	38.5	49.4
0220A	3NW of Slidell, LA	30.34320˚N 89.82230˚W	34.2	49.4
0221A	1WSW of Thibodeaux, LA	29.78630˚N 90.86360˚W	43.4	61.1
0222B	4 SW of Plaquemine, LA	30.24860˚N 91.26640˚W	46.5	56.6
0223A	3E of Hammond, LA	30.51210˚N 90.41970˚W	34.0	46.5
0224A	3 SW of Vacherie, LA	29.96480˚N 90.73590˚W	45.9	60.8

*†indicates real-time capability   *indicates incomplete record*

Probes 01XXA sample at 5 Hz, 01XXB sample at 1 Hz, 02XXA sample at 10 Hz, 02XXB sample at 1 Hz

4. Summary

Hurricane Isaac was the first hurricane to make landfall in the continental United States during the 2012 Atlantic basin hurricane season and the first to make landfall along the northern Gulf Coast since Hurricanes Gustav and Ike in 2008. Isaac came ashore initially at the southwest pass of the Mississippi River, emerged over water again, and made a final landfall near Port Fouchon, Louisiana. The primary cause of damage was storm surge and freshwater flooding. Category 1 hurricane winds were likely confined to a small swath along lower Plaquemines Parish. However, much of southeast Louisiana experienced tropical storm force winds for a prolonged period of time. The duration of winds over 35 mph likely contributed to minor roof cover loss on structures, damage to electrical infrastructure, and tree damage. Rainfall amounts were typically near 10 inches across much of the impacted region with maximum amounts exceeding 20 inches in some locations. Significant runoff led to major freshwater flooding along local rivers, creeks, and bayous.

Although Isaac was a Category 1 hurricane on the Saffir-Simpson Hurricane Wind Scale, its large size, slow forward speed, and the local coastal bathymetry led to a storm surge of up to 12 feet along the southeast Louisiana and western Mississippi coastlines. Storm surge flooding rivaled that of past major hurricanes that struck the area. The Powell-Reinhold IKE scale captured the storm surge threat very well with a Storm Surge/Wave impact rating of 3.5 at Isaac’s final landfall. Despite a very good storm-surge forecast from both the SLOSH and ADCIRC models, anecdotal evidence suggests that this information was not effectively communicated to the general public and emergency management officials. The official products from the National Hurricane Center clearly stated the significant storm surge and fresh water flooding potential, as shown in the example on the following page from the forecast advisory on the morning of August 28 while Isaac was still a tropical storm.

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BULLETIN
TROPICAL STORM ISAAC INTERMEDIATE ADVISORY NUMBER  29A
NWS NATIONAL HURRICANE CENTER MIAMI FL       AL092012
700 AM CDT TUE AUG 28 2012

...RECONNAISSANCE AIRCRAFT FIND ISAAC NEARLY A HURRICANE...
SIGNIFICANT STORM SURGE AND FRESHWATER FLOOD THREAT TO THE NORTHERN
GULF COAST...

SUMMARY OF 700 AM CDT...1200 UTC...INFORMATION
----------------------------------------------
LOCATION...27.8N 88.2W
ABOUT 105 MI...170 KM SSE OF THE MOUTH OF THE MISSISSIPPI RIVER
ABOUT 185 MI...295 KM SSE OF BILOXI MISSISSIPPI
MAXIMUM SUSTAINED WINDS...70 MPH...110 KM/H
PRESENT MOVEMENT...NW OR 305 DEGREES AT 7 MPH...11 KM/H
MINIMUM CENTRAL PRESSURE...976 MB...28.82 INCHES

HAZARDS AFFECTING LAND
----------------------
STORM SURGE...THE COMBINATION OF A STORM SURGE AND THE TIDE WILL
CAUSE NORMALLY DRY AREAS NEAR THE COAST TO BE FLOODED BY RISING
WATERS. THE WATER COULD REACH THE FOLLOWING DEPTHS ABOVE GROUND IF
THE PEAK SURGE OCCURS AT THE TIME OF HIGH TIDE...

* MISSISSIPPI AND SOUTHEASTERN LOUISIANA...6 TO 12 FT
* ALABAMA...3 TO 6 FT

* SOUTH-CENTRAL LOUISIANA...3 TO 6 FT
* FLORIDA PANHANDLE AND APALACHEE BAY...2 TO 4 FT
* REMAINDER OF FLORIDA WEST COAST...1 TO 3 FT

THE DEEPEST WATER WILL OCCUR ALONG THE IMMEDIATE COAST IN AREAS OF
ONSHORE WINDS.  SURGE-RELATED FLOODING DEPENDS ON THE RELATIVE
TIMING OF THE SURGE AND THE TIDAL CYCLE...AND CAN VARY GREATLY OVER
SHORT DISTANCES.  FOR INFORMATION SPECIFIC TO YOUR AREA...PLEASE
SEE PRODUCTS ISSUED BY YOUR LOCAL WEATHER SERVICE OFFICE.  NEAR THE
COAST...THE SURGE WILL BE ACCOMPANIED BY LARGE AND DANGEROUS WAVES.
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Despite these issues, the loss of life and reported injuries were extremely low given the very significant storm surge produced by Isaac. Although the five to seven day forecast of Isaac had considerable uncertainty, the three-day forecast prior to landfall was quite good with an error of only 75 miles in the forecast landfall position. While Hurricane Isaac represented another example of a quality meteorological and hydrological forecast, difficulties existed in conveying the associated risks to the general public and local decision-makers. It also highlights the complex relationship between peak winds, storm surge, and rainfall. The need continues for additional research on the sociological aspect of disseminating severe weather information to the general public and local government decision-makers.

Additional Notes

The data presented in this report are considered preliminary and are subject to change upon further post-event analysis. Additional data sources may become available. These data represent available observations as of 9 September 2012.

5. References

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