P2.37 **EXTREME WINDS ASSOCIATED WITH A COLLAPSING CORE ON THE MOBILE WATERFRONT DURING THE LANDFALL OF HURRICANE KATRINA**

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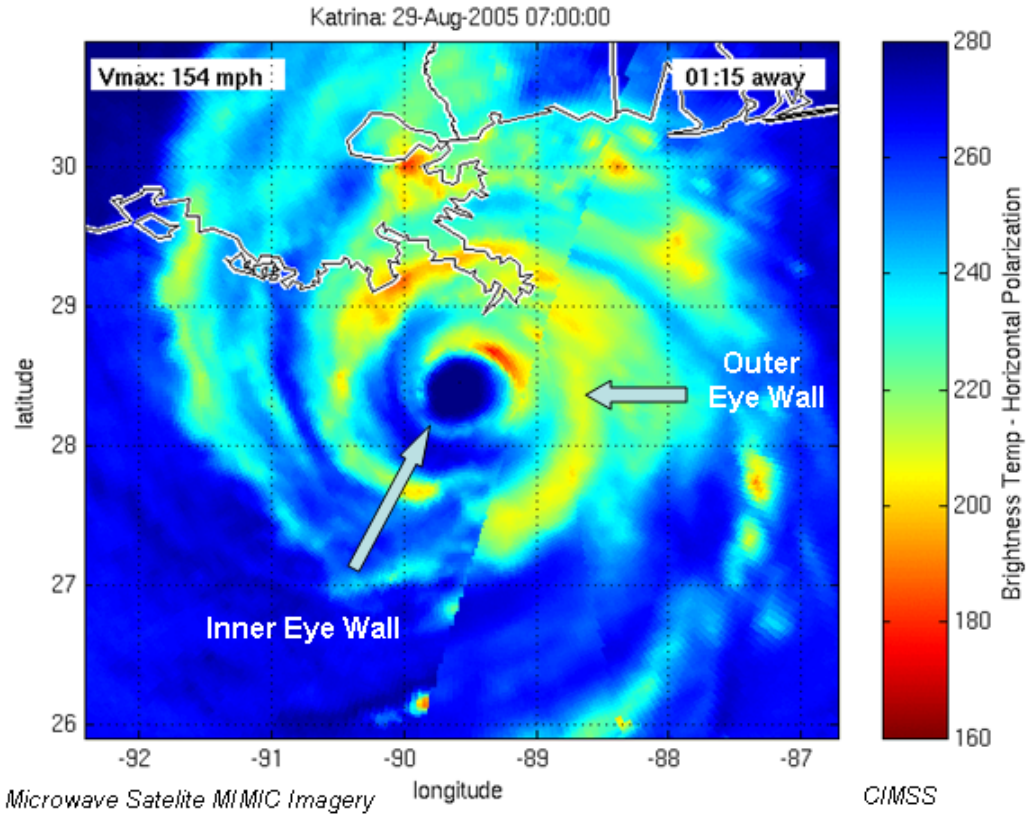
1. INTRODUCTION

Hurricane Katrina struck the northern Gulf Coast on 29 August 2005 with the third lowest pressure on record for a landfalling U.S. hurricane. The core of the storm moved inland over southeast Louisiana and southern Mississippi, producing catastrophic damage in these areas. However, very strong squalls in the northeastern quadrant of the storm also moved inland across coastal Alabama. One of these squalls dislodged a large vessel along the Alabama coast in the Mobile River.

2. OVERVIEW

As the storm approached the northern Gulf coast, the structure of Katrina changed dramatically when the storm began an eyewall replacement cycle. During this cycle, a developing outer eyewall began to encircle the inner eyewall (Figures 1a, 1b, and 1c) and Katrina became a concentric eyewall storm. This multiple eyewall configuration in Katrina is documented by, Hawkins et al. (2006), Blackwell et al. (2007, 2008a), Wimmers and Velden (2007) and Powell et al., 2010.



1a.

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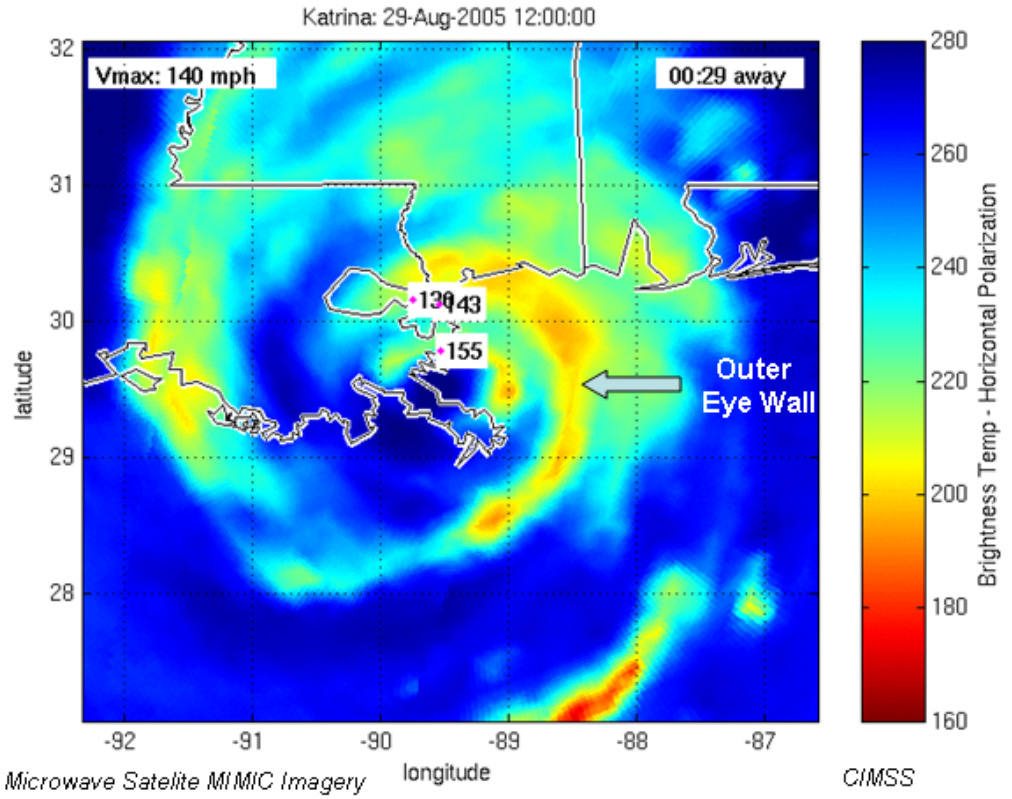
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Vmax: 140 mph
00:29 away
143
155
Outer
Eye Wall
32
31
30
29
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latitude
-92
-91
-90
-89
-88
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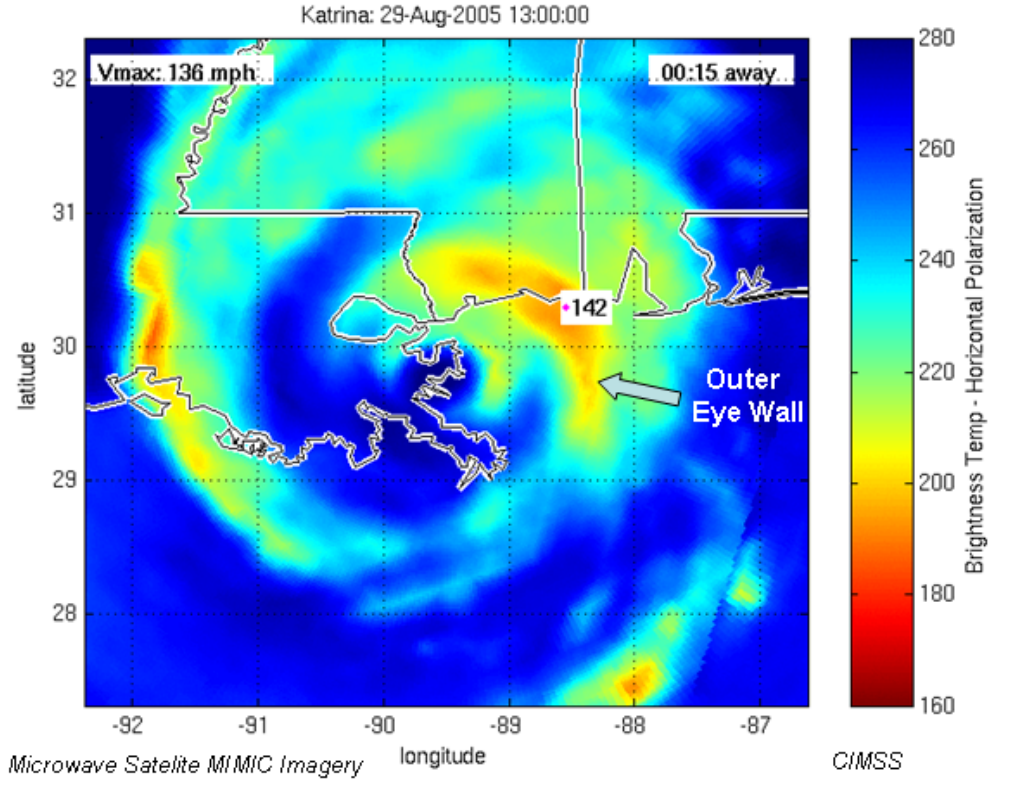
Brightness Temp - Horizontal Polarization
Microwave Satelite MIMIC Imagery
CIMSS

1b.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Vmax: 136 mph
00:15 away
142
Outer
Eye Wall
32
31
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latitude
-92
-91
-90
-89
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-87
longitude
280
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Brightness Temp - Horizontal Polarization
Microwave Satelite MIMIC Imagery
CIMSS

1c

Figure 1. Color morphed microwave imagery of Hurricane Katrina at a) 0700, b) 1200, and c) 1300 UTC 29 August 2005 from the MIMIC (Morphed Integrated Microwave Imagery at CIMSS) system (Wimmers and Velden, 2007) showing Katrina's double eyewall structure as the storm approaches the Louisiana and Mississippi coasts. Maximum dropsonde-measured winds (mph) between the surface and 610 m observed within a few minutes of each of these images are posted at various locations. Winds in excess of 60 m s^{-1} are depicted in the outer eyewall near the Mississippi Coast, and winds in excess of 65 m s^{-1} are indicated in the inner eyewall near the coast of southeastern Louisiana. Image courtesy of the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison.

Figure 1c shows heavy squalls moving across the Mobile Bay region of Alabama (yellow enhancement) at 1300 UTC as Katrina's eyewall passed a short distance to the west across the Mississippi coast.

3. METHODOLOGY

Doppler radar Level II archive data for the KMOB location were acquired from the National Climatic Data Center for the time period encompassing Hurricane Katrina's Landfall. This digital Level II data were displayed and analyzed with Gibson Ridge Software's GRLevel2 Analyst Edition radar software.

Base reflectivity patterns were scrutinized for possible collapsing core activity over the Mobile, AL waterfront around 1300 UTC on 29 August 2005. When deep convection was observed, 3-dimensional cross sections were used to further investigate the feature. Base velocity patterns were also examined in the vicinity of the convection.

4. RESULTS

A very heavy squall moved across the Mobile AL waterfront at the head of Mobile Bay shortly after 1300 UTC on 29 August 2005. This squall was within one of Katrina's spiral bands and produced extremely strong winds which dislodged a large semi-submersible oil drilling platform (*PSS Chemul*) from its 20 mooring lines on the east side of the Mobile River. This floating platform was then blown across the river where it collided with another ship (*M / V Fornarun Naree*) and later with additional dock facilities along the river before eventually becoming lodged against a large suspension bridge over the Mobile River (Figure 2). Eyewitnesses indicate that the platform broke free during the squall. Captain Mike Donovan, aboard a nearby U.S. Navy ship (USNS 1st Lt Harry L. Martin) (Figure 3) located directly across the river, reported an unconfirmed wind gust of 55 m s^{-1} (122 mph) measured on the ship's standard U.S. Navy anemometer about the time the platform broke loose.

Figure 2. Semi-submersible oil drilling platform “PSS Chemul” lodged against the Cochran Bridge north of Mobile Alabama. The platform broke away from its 20 mooring lines at Bender Shipyard #9 on the eastern shore of the Mobile River. (Picture courtesy of Mike Kittrell/Mobile Press-Register.)

Figure 3. U.S. Navy Ship (USNS) *1st Lt Harry L. Martin* measured winds to 122 mph while situated across the river from Shipyard #9 during the passage of a heavy squall in one of Katrina’s spiral bands. The semi-submersible drilling platform *PSS Chemul* broke free from its 20 mooring lines during the same heavy squall which produced the extreme wind gust.

Landfalling tropical cyclones often contain collapsing cores of heavy precipitation within their eyewalls (Holmes et al., 2006 and Blackwell, 2008a). Numerous authors, including Parrish et al., (1982), Powell et al., (1991), Wakimoto and Black (1994), Powell and Houston (1996), Willoughby and Black (1996) and Blackwell (2009) indicate the likely linkage between downburst-like features and strong wind gusts in hurricane eyewalls; however, very few surface-based measurements of winds associated with these features actually exist. In addition, collapsing core-type features are also observed in heavy convection within tropical cyclone rainbands.

Doppler radar analysis indicates the squall along the Mobile waterfront was moving rapidly toward the northwest at 42-44 m s^{-1} (94-98 mph). Figure 4 shows a >50 dBZ reflectivity core collapsing to the surface as the squall rapidly approaches the *PSS Chemul* platform from the southeast. Notice the large elevated core of reflectivity (**4c**) which is not evident near the surface (**4a**) at 1306 UTC. Five minutes later at 1311 UTC, the >50 dBZ region has collapsed to near the surface (**4b**) near the *PSS Chemul* about the time the platform broke free and the nearby Navy ship measured the extreme winds.

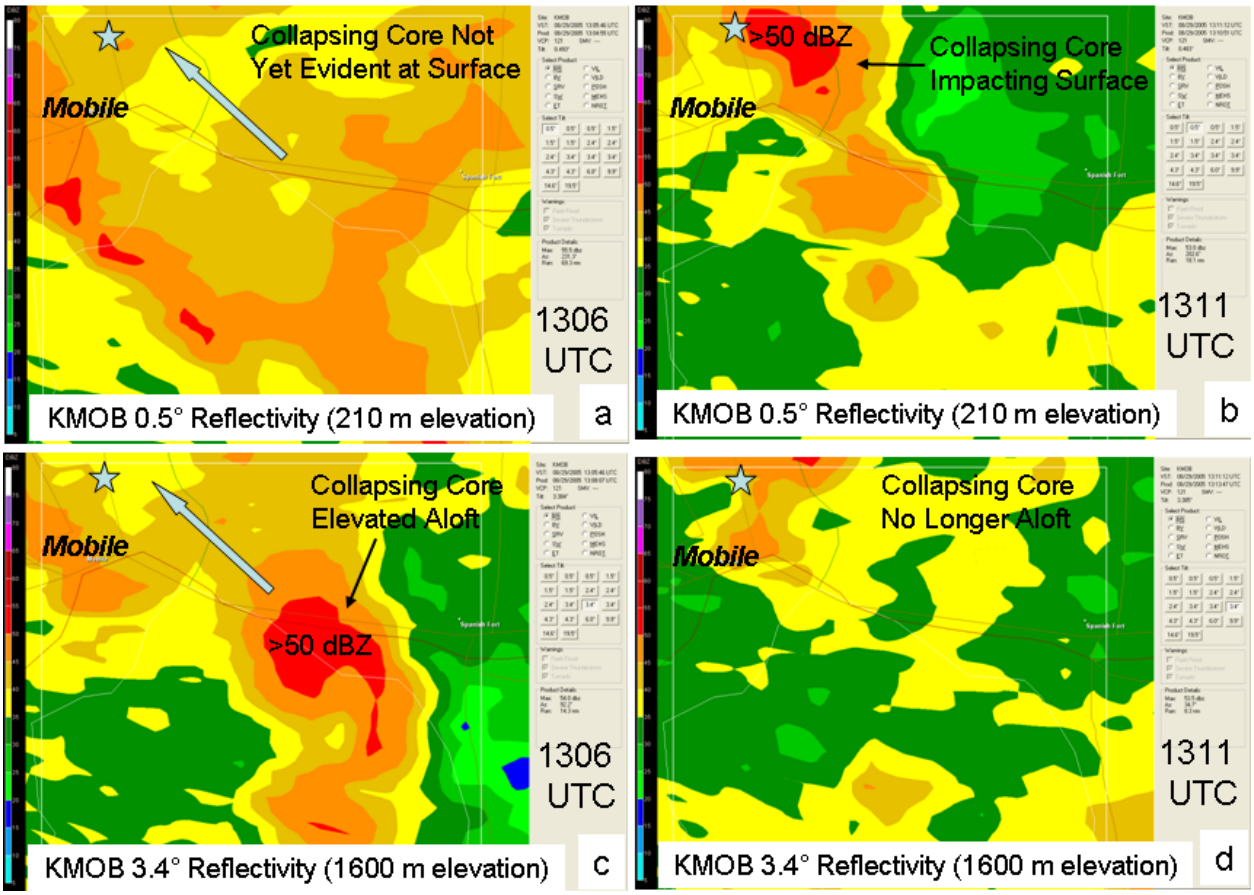


Figure 4. Reflectivity from the 0.5˚ and 3.4˚ scan angles as detected by the National Weather Service WSR-88D Doppler radar in Mobile, AL (KMOB) for 1306 UTC (**3a** and **3c**) and 1311 UTC (**3b** and **3d**) respectively, on 29 August 2005. The star in the upper left corner of each image represents the location of the *PSS Chemul* drilling platform at Bender Shipyard #9. The blue arrow in the two left-most figures indicate the direction of motion of the storm as it approaches the shipyard. This image sequence depicts a core of very heavy precipitation collapsing toward the surface, associated with extremely strong wind gusts near the Mobile, AL waterfront. Elevations listed in **a** and **b** are relative to the *PSS Chemul* position, whereas elevations listed in c and d are relative the >50 dBZ reflectivity region shown in **c**.

Reflectivity cross sections indicate that the squall contained a >50 dBZ collapsing core which reached the surface about the time the squall moved across the moored *PSS Chemul* drilling platform's location (Figure 5).

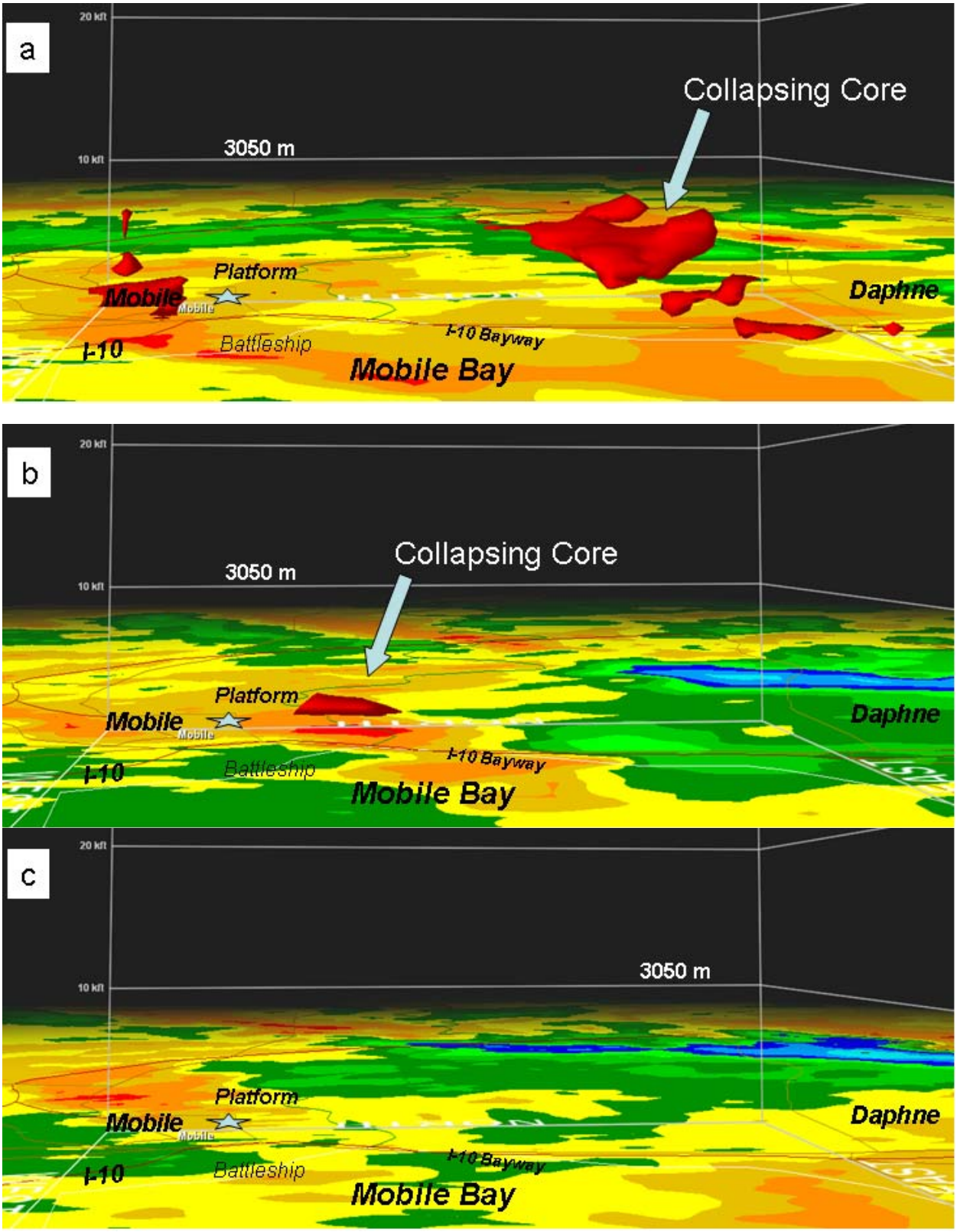
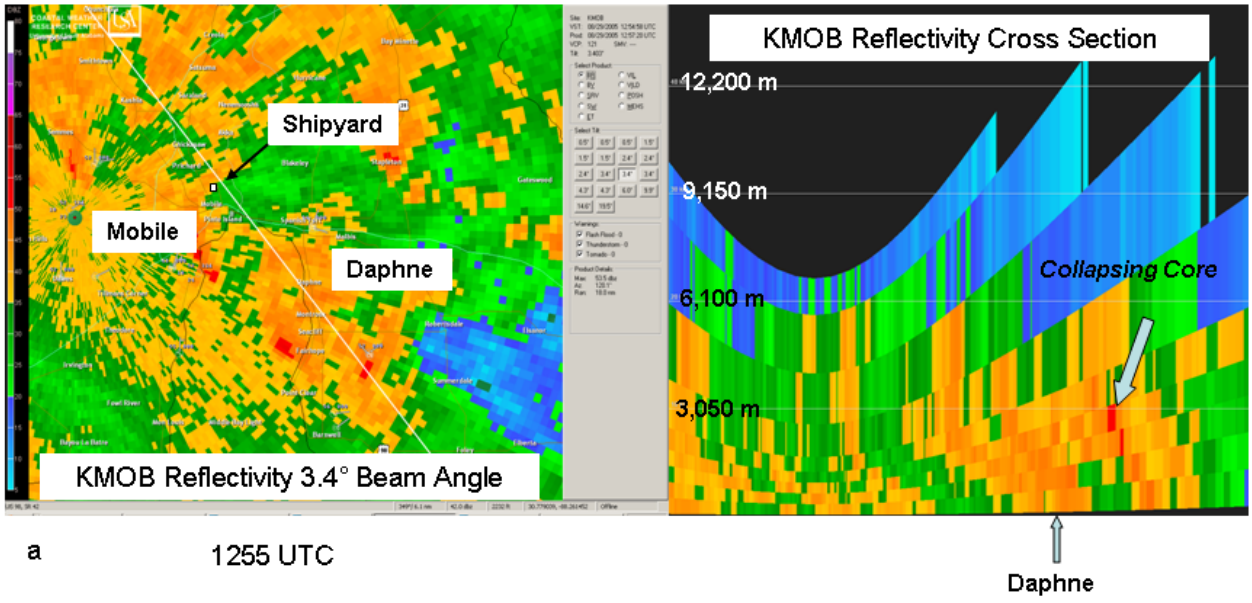


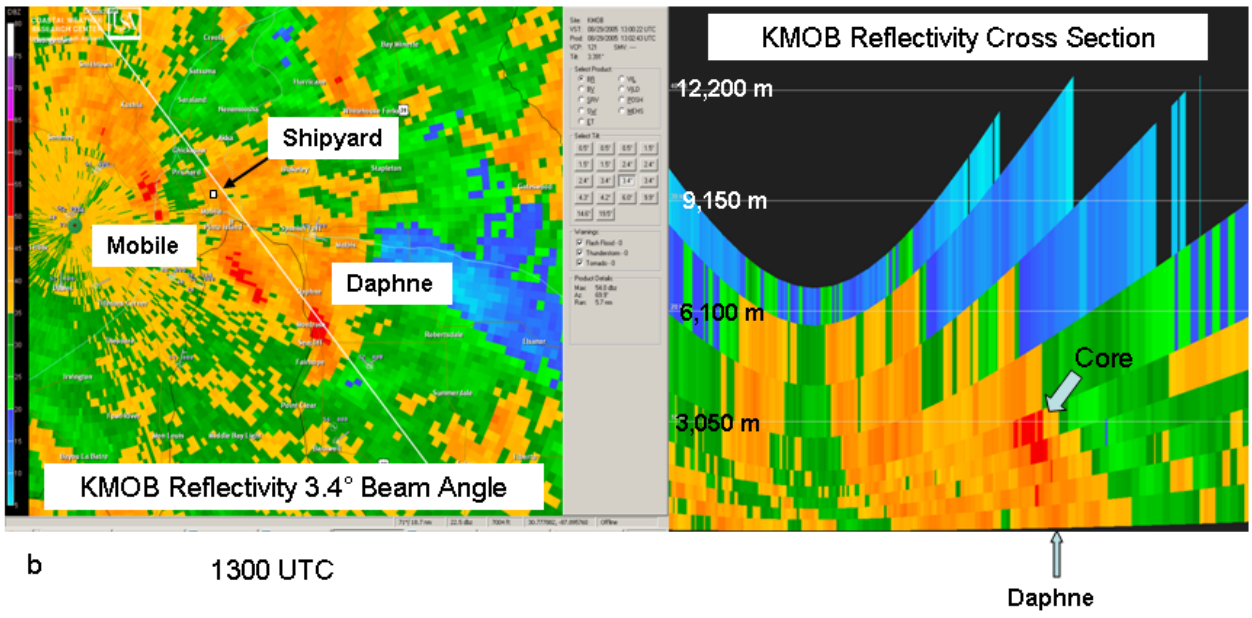
Figure 5. Three-dimensional reflectivity cross sections at a) 1306 UTC b) 1311 UTC and c) 1316 UTC, respectively, on 29 August 2005 as detected by the National Weather Service WSR-88D Doppler radar in Mobile, AL (KMOB). The star in each image represents the location of the *PSS Chemul* drilling platform at Bender Shipyard #9. This

image sequence depicts a core of very heavy precipitation collapsing toward the surface, likely producing a downburst-type event associated with extremely strong wind gusts near the Mobile AL waterfront.

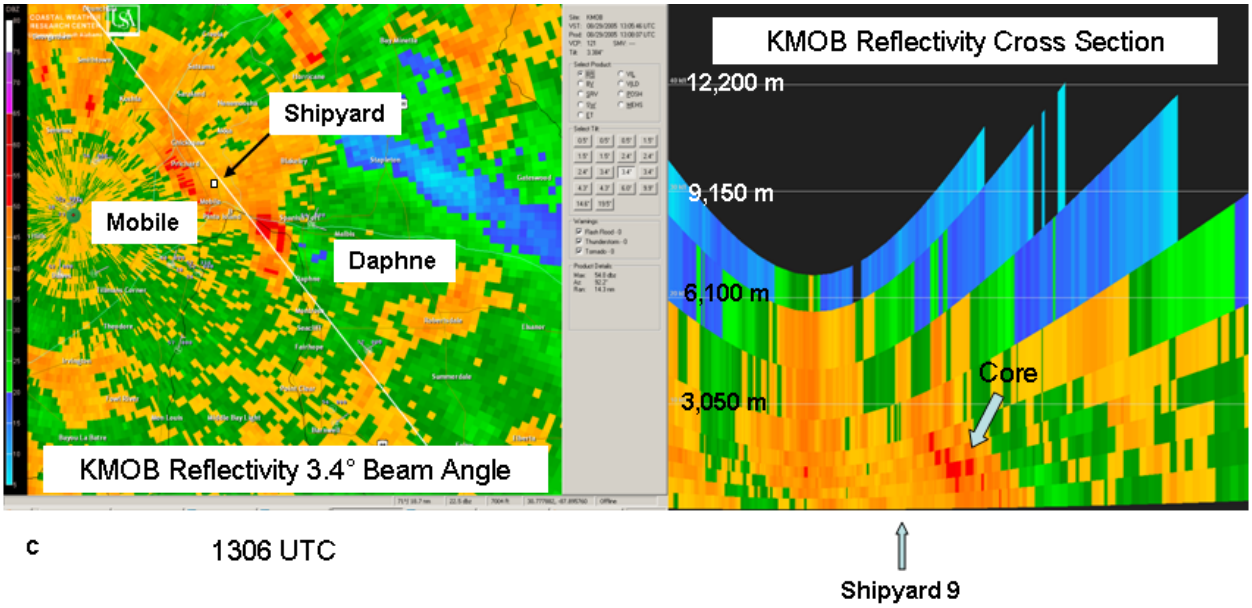
A sequence of reflectivity cross sections (Figure 6) depict the core's collapse toward the surface as it approaches the Chemul at Shipyard #9. The cell originated over Fairhope and Daphne in Baldwin County near the eastern shore of Mobile Bay. The storm moved rapidly toward the northwest as a large precipitation core collapsed to the surface near the Mobile waterfront.



a 1255 UTC



b 1300 UTC



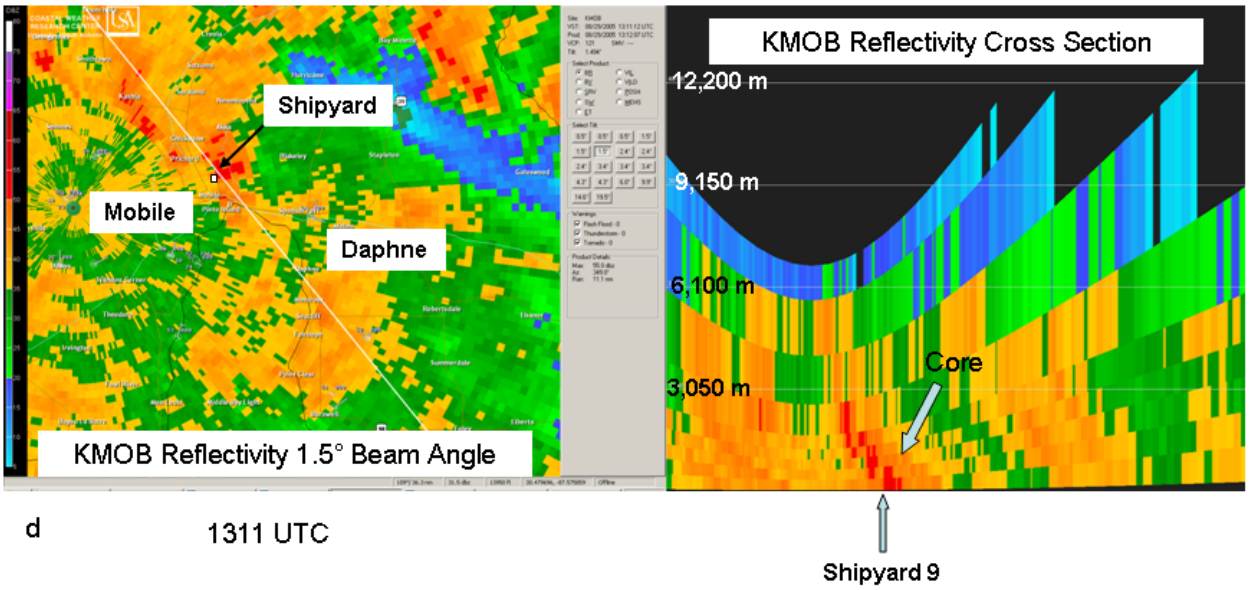


Figure 6. Reflectivity (left) and reflectivity cross sections (right) at **a)** 1255, **b)** 1300, **c)** 1306, and **d)** 1311 UTC, 29 August 2005 as detected by the National Weather Service WSR-88D Doppler radar in Mobile, AL (KMOB). The white dot in each image on the left represents the location of the *PSS Chemul* drilling platform at Bender Shipyard #9. This image sequence depicts a core of very heavy precipitation collapsing toward the surface, likely producing a downburst-type event associated with extremely strong wind gusts near the Mobile AL waterfront.

Stronger momentum from the top of the boundary layer was likely advected toward the surface as the very heavy collapsing precipitation core approached the shipyard, thus providing a favorable situation for very strong near-surface wind gusts at the time the platform broke loose.

Doppler radar base velocity values (Figure 7), when corrected for beam azimuth-wind direction differences via a technique by Lee et al. (1999), indicate that winds were estimated to exceed 54 m s^{-1} (120 mph) at an elevation as low as 240 m (790 ft) in the vicinity of the *PSS Chemul* drilling platform with the passage of this squall. Though not explicitly shown in this image, it is also possible that a shallow vortex-like feature may have developed along the lateral edge of the collapsing core's downdraft as it swept across the shipyard, similar to the type of event stated by Powell and Houston (1996).

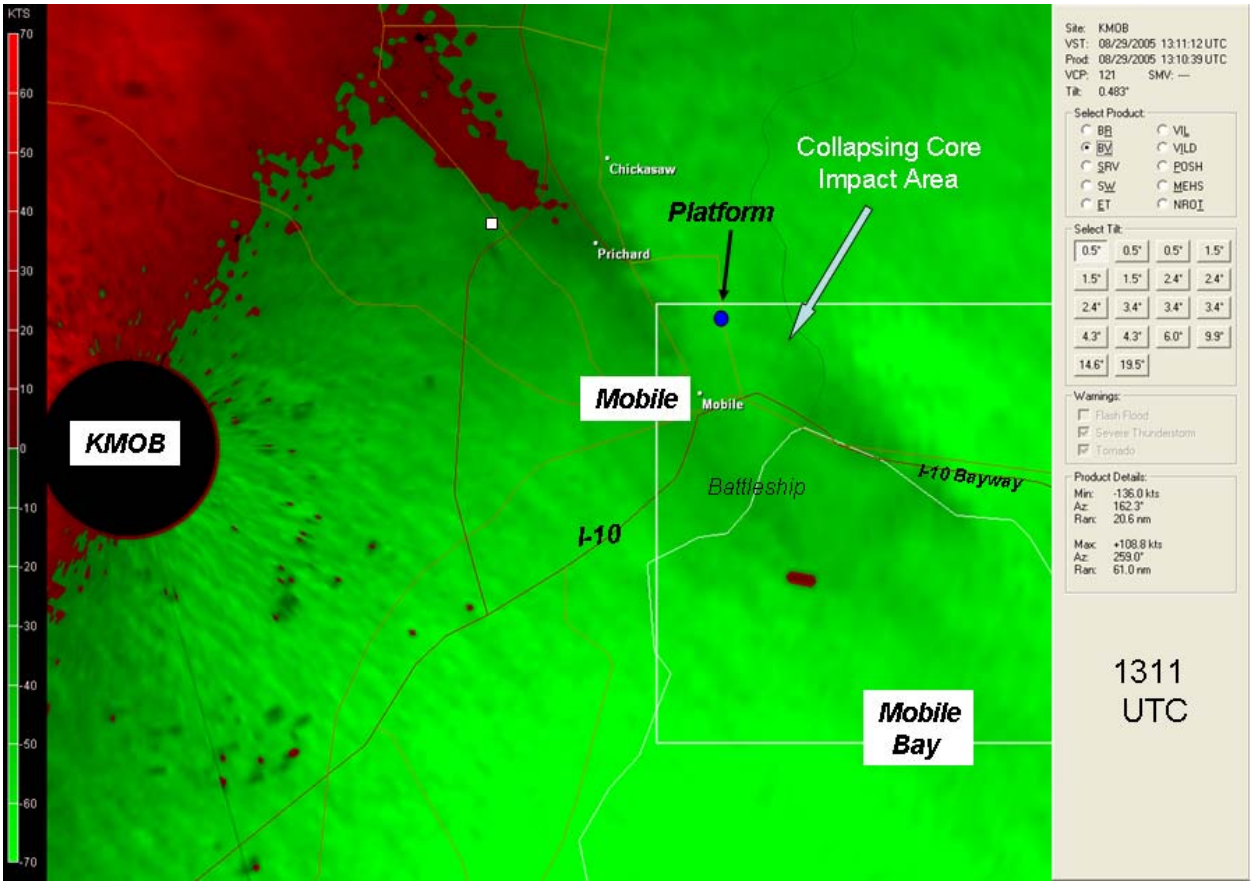


Figure 7. Doppler base velocity image at 1311 UTC on 29 August 2005 as depicted by the National Weather Service WSR-88D Doppler radar in Mobile, AL (KMOB). The blue dot in the image represents the location of the *PSS Chemul* drilling platform at Bender Shipyard #9. This image depicts a somewhat divergent wind pattern near the collapsing core's impact area, a pattern expected in the vicinity of a rapidly-moving downburst. The white box outline represents the domain encompassing the 3-D cross-section depicted in Figure 5.

Although a record high tide of approximately 3.7 m (12 ft) occurred along the Mobile waterfront during Hurricane Katrina's landfall, the platform broke loose several hours before the highest water arrived. In addition, large accommodation modules, removed from the *PSS Chemul* drilling platform during renovation, tightly stacked weighing several tons each and situated above the level of peak water, were moved around within the shipyard where the platform was originally moored, a further testament to the extreme winds which affected this location.

5. SUMMARY

As Hurricane Katrina was making landfall in Louisiana and Mississippi, a heavy squall developed in Katrina's northeast quadrant within a spiral band over Baldwin County AL just east of Mobile Bay. As this squall raced rapidly toward the northwest, a very intense elevated region of rainfall developed around 3000 m above the surface. This elevated core of precipitation then collapsed downward and reached the surface about the time the squall passed across Bender Shipyard #9 where the *PSS Chemul* drilling platform was moored with approximately 20 lines. The PSS Chemul broke its moorings, drifted across the river and collided with the *M / V Fornarun Naree* vessel before becoming lodged beneath the Cochrane Bridge over the Mobile River. The Navy vessel *USNS 1st Lt Harry L. Martin* unofficially reported a wind gust to 55 m s^{-1} (122 mph) measured on the ship's standard U.S. Navy anemometer about the time the platform broke loose.

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7. ACKNOWLEDGEMENTS

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