Preliminary Investigation of Selected Radar Patterns Associated with Local Maximum Wind Gusts in Rainbands of Landfalling Tropical Cyclones

Keith G. Blackwell

Coastal Weather Research Center
Department of Earth Sciences
University of South Alabama, Mobile Alabama

1. INTRODUCTION

Outer rainbands associated with landfalling tropical cyclones often bring the first initial tropical storm or hurricane-force gusts prior to the arrival of the storm core. Also, for locations on the periphery of the storm, outer rainbands may produce the strongest winds observed there during the storm landfall event.

In operations, Doppler radar data is used by local National Weather Service offices to issue warnings for initial tropical storm-force winds associated with these outer squalls. Are there preferred locations within these rainbands where localized maximum wind gusts are often found?

2. Data

In this preliminary investigation, maximum wind measurements from selected C-MAN (Coastal Marine Automated Network) were temporally and spatially matched with nearby WSR-88D reflectivity and velocity patterns within rainbands associated with four nearby tropical cyclones. The C-MAN *continuous wind* product contains the maximum 5 second wind gust to the nearest minute of occurrence for each hour. Table 1 lists the four hurricanes used in this study along with the C-MAN stations selected for providing the maximum surface wind speeds.

The Level II WSR-88D data used in this study was obtained from the National Climatic Data Center and was evaluated using the Gibson Ridge “GRAnalyst” radar software. C-MAN information was obtained from the National Data Buoy Center.

Storm Name	C-MAN Observation Identifier and Location	WSR-88D Doppler Radar Identifier and Location	Distance and Direction of C-MAN from WSR-88D	Radar Base Beam Elevation at C-MAN Location
Ivan (2004)	DPIA1 (Dauphin Island, AL)	KMOB (Mobile, AL)	50 km to the Southeast	563 meters
Katrina (2005)	DPIA1 (Dauphin Island, AL)	KMOB (Mobile, AL)	50 km to the Southeast	563 meters
Rita (2005)	SMKF1 (Sombrero Key)	KBYX (Key West, FL)	59 km to the East	712 meters
Ike (2008)	SRST2 (Sabine Pass, TX)	KLCH (Lake Charles, LA)	93 km to the Southwest	1274 meters

Table 1. A list of tropical cyclones and respective C-MAN stations.

3. General Observations and Discussion

For purposes of this study, the tropical cyclone domain at radii greater than eyewalls is sub-divided into 2 different regimes: 1) peripheral precipitation outside the central dense overcast (CDO) and 2) other precipitation at shorter radii, often embedded within the CDO.

a. Peripheral Convection Outside the CDO

If convection was present in the outer bands or as isolated cells near the periphery of the storm, the strongest C-MAN wind gusts were generally occurred prior to the heavy rain reaching the station. This indicates that the most likely location for the maximum gust for this type of situation is observed along the gust front preceding the convective squall and not within the heavier precipitation areas of the squall itself. This was especially the case when the convection was situated outside of the stratiform CDO area. For instance Figure 1 depicts the leading edge of initial squalls approaching SMKF1 in the Florida Keys ahead of westward-moving Hurricane Rita.

The fact that many maximum local wind gusts in peripheral tropical cyclone convection were found to occur in close proximity to the gust front suggests that the cold pool beneath the squall was likely being strengthened by mid-level dry air being entrained into the convection. The best location for dry environmental air would probably be near the edges of the storm where large-scale ascent associated with the storm has not yet moistened the mid-troposphere. The sounding from Key West approximately 7 hours prior to the image above is shown in Figure 2 and displays a moist lower troposphere, but dry air is found at mid-levels and is likely a source for the enhancement of gust fronts.

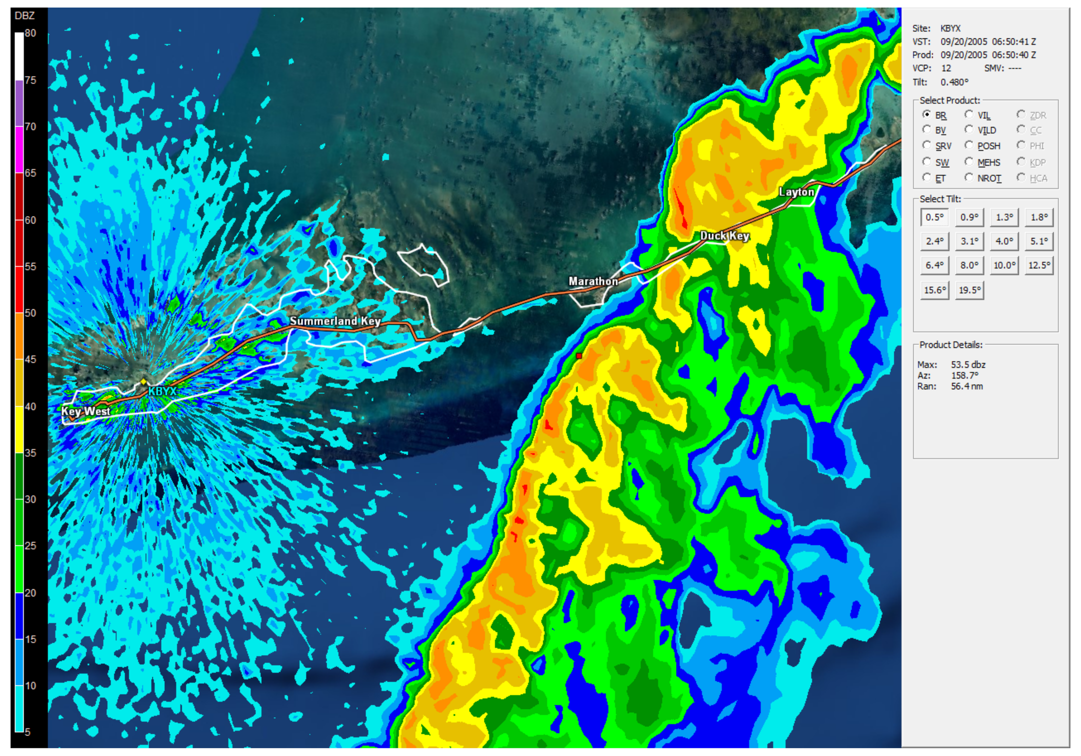
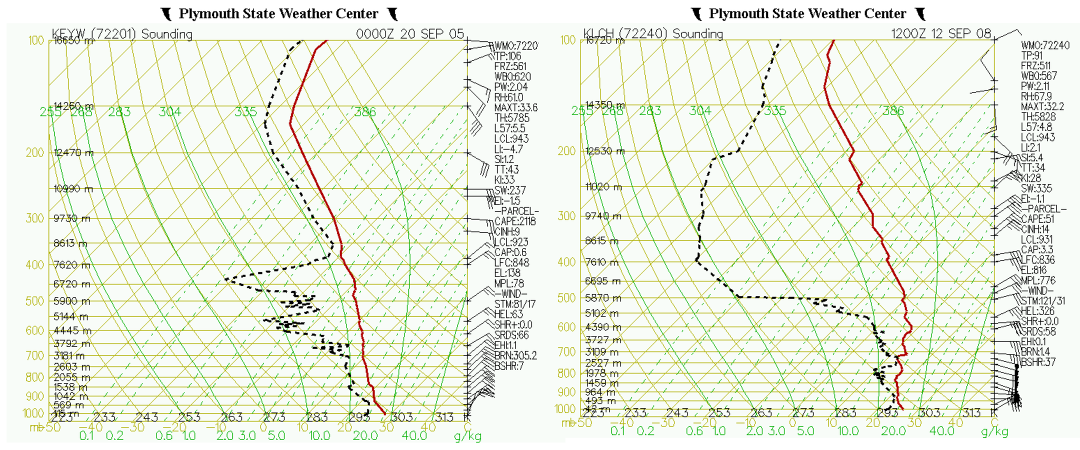


Figure 1. *Base reflectivity from the KBYX WSR-88D Doppler radar in Key West, FL at 0651 UTC, 20 September 2005. The leading rainband from Hurricane Rita is rapidly approaching SMKF1 (red dot) from the east. The maximum hourly wind gust of 20 m/s (39 kts) was recorded at SMKF1 at this time immediately prior to the heavy rain reaching the station. This likely means that the maximum hourly wind gust at SMKF1 occurred in association with the gust front. (Note: Gust fronts were often poorly depicted or completely absent in radar imagery near the remote C-MAN locations due in part to radar beam elevation.)*

A similar type of environment (except for a shallow nocturnal radiation inversion at the surface) is indicated in Katrina’s outer northwest quadrant in the Slidell, LA sounding (KLIX) at 1200 UTC, 28 August 2005 (not shown), and indeed, the strongest local wind gusts in Katrina’s initial outer convection at DPIA1 appeared to occur in the gust front area.



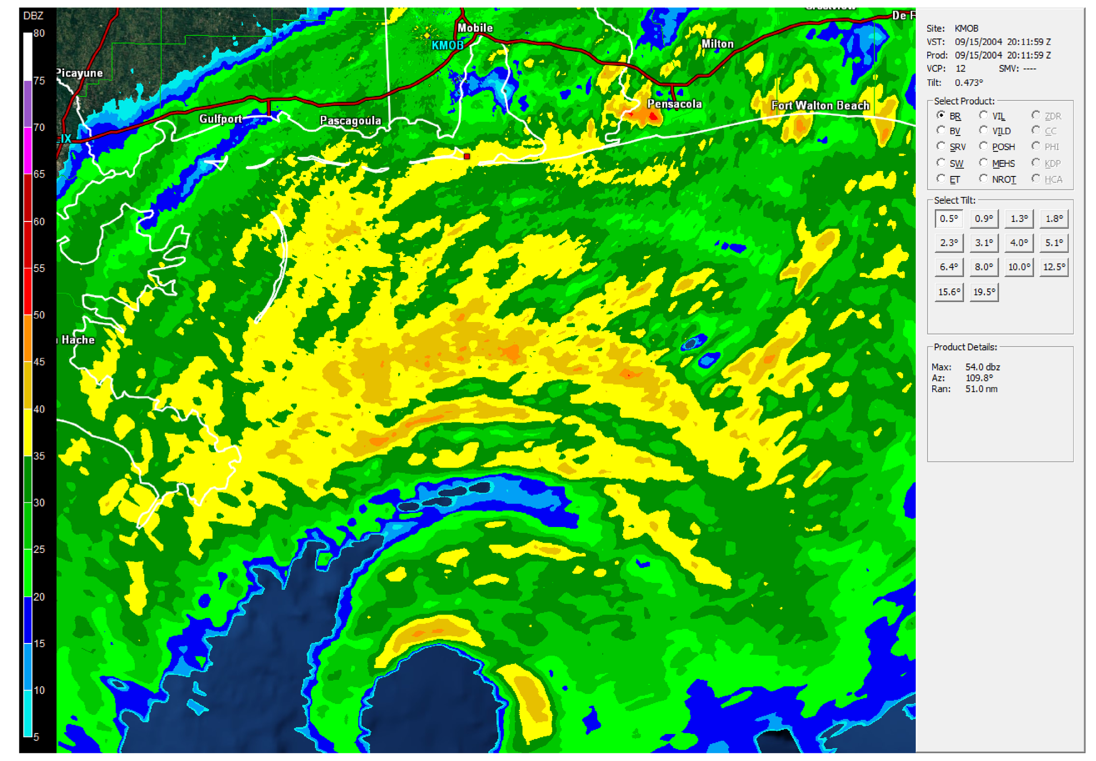
a b

Figure 2. Rawinsonde balloon soundings for a) Key West, FL (KEYW) at 0000 UTC, 20 September 2005 and b) Lake Charles, LA (KLCH) at 1200 UTC, 12 September 2008. Dry air is found in the middle troposphere in a) which could enhance winds near gust fronts with initial outer squalls of Hurricane Rita. A much more stable lower troposphere is evident in b) within the outer reaches of Ike’s northwest quadrant, limiting initial outer-edge precipitation development to isolated patches of weak low-altitude stratiform precipitation. (Figures courtesy of Plymouth State University).

b. Other Precipitation at Shorter Radii often within CDO

Once away from the outer edges of the storm, convection near and inside rainbands generally exhibited the strongest local wind gusts within the heavy precipitation cores themselves rather than with a gust front. This was particularly the case in situations where convection was already embedded within the general CDO stratiform precipitation region, such as in Figure 3.

Some of the strongest hourly wind gusts occurred near vortex activity associated with heavy convective squalls. This was particularly the case in Ivan and Katrina. For instance, Figure 4a shows a close-up of the squalls near DPIA1 earlier depicted in Figure 3b; significant vortex activity is depicted within three of the heavy squalls, including one which passed very close to DPIA1 (see Figure 4b).



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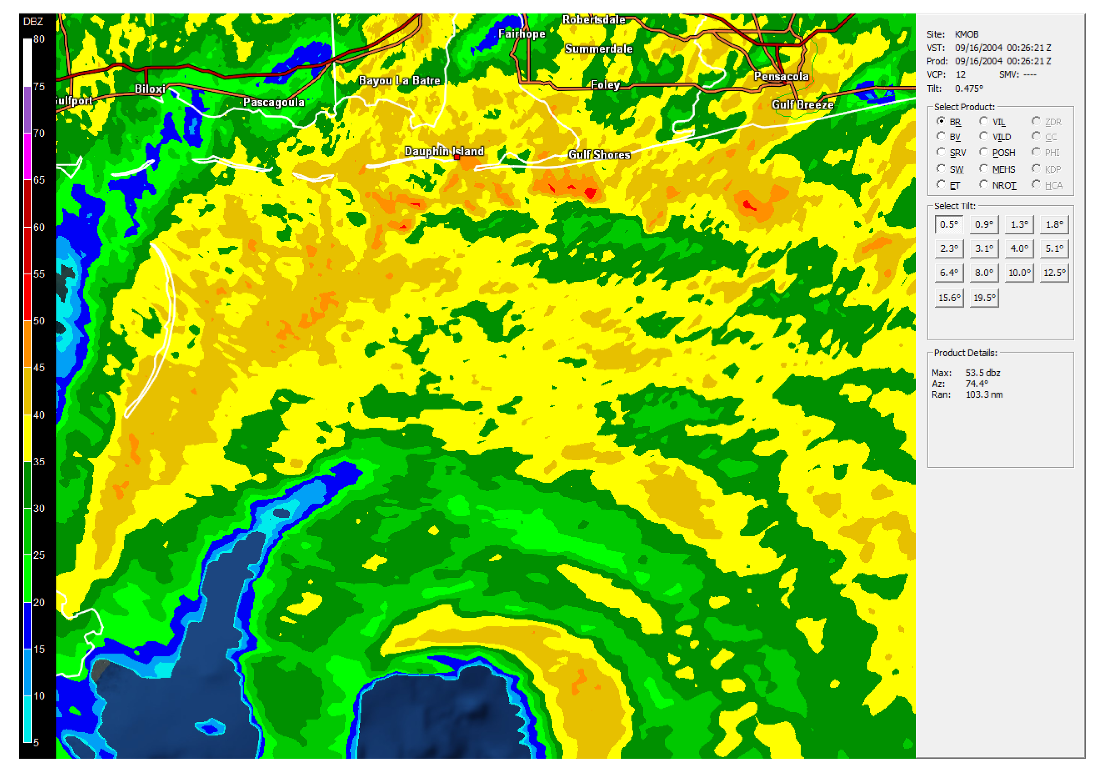

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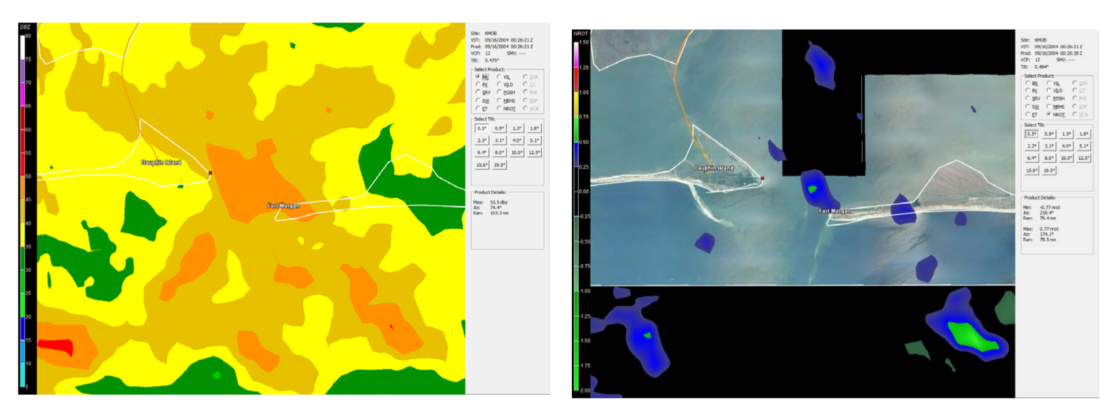
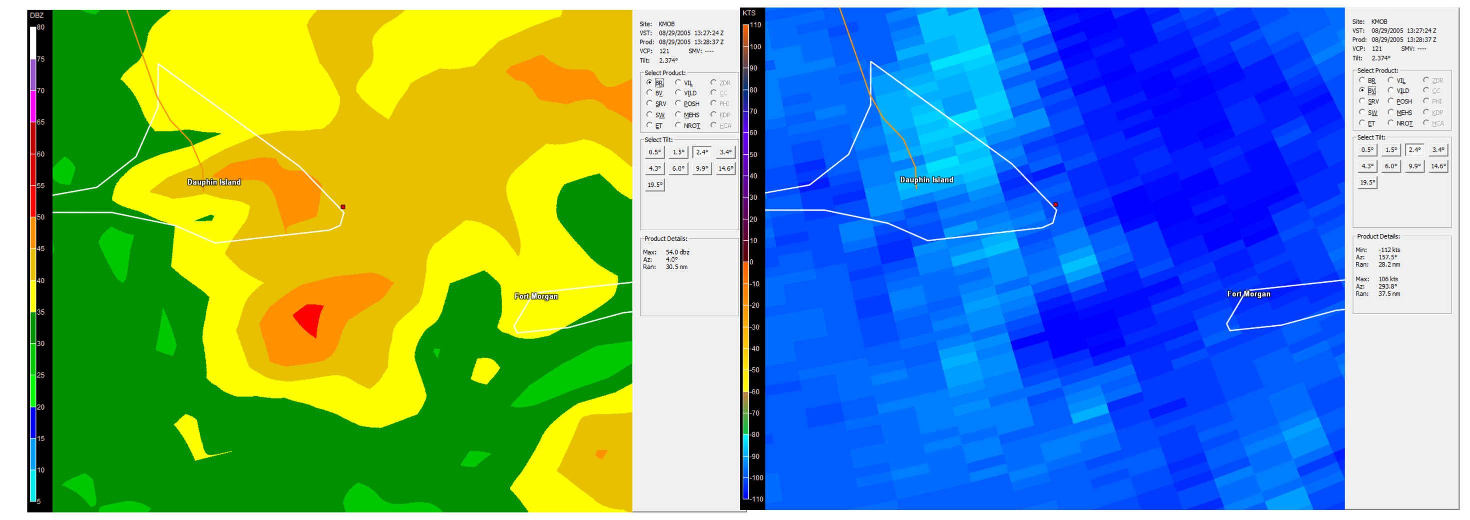
Figure 3. *Base reflectivity from the KMOB WSR-88D Doppler radar in Mobile, AL at* ***a)*** *2012 UTC and* ***b)*** *0026 UTC, 15 September 2004. Hurricane Ivan’s outer bands are moving onshore along the northern Gulf coast. Rainbands with* ***a)*** *weak convection and* ***b)*** *vigorous strong convection are moving across DPIA1 (red dot) on the Alabama coast; coincident strongest respective local hourly gusts of 27 m/s (52 kts) and 36 m/s (70 kts) occurred at DPIA1 within the heavy precipitation deep within these bands. Note that both of these bands are embedded within a large region of stratiform precipitation, likely associated with Ivan’s CDO.*



a b

Figure 4. **a)** Base reflectivity and **b)** normalized rotation (blue-purple often with embedded green represents cyclonic vortex-like features) at approximately 0026 UTC on 16 September 2004 from the National Weather Service WSR-88D Doppler radar in Mobile, AL (KMOB). A vortex-like feature is associated with a heavy squall moving across the mouth of Mobile Bay. Two other vortex-like features are also depicted farther offshore with associated heavy convective cells.

Some of the squalls associated with Hurricane Katrina also contained associated vortex-like activity, including those shown in Figure 5.



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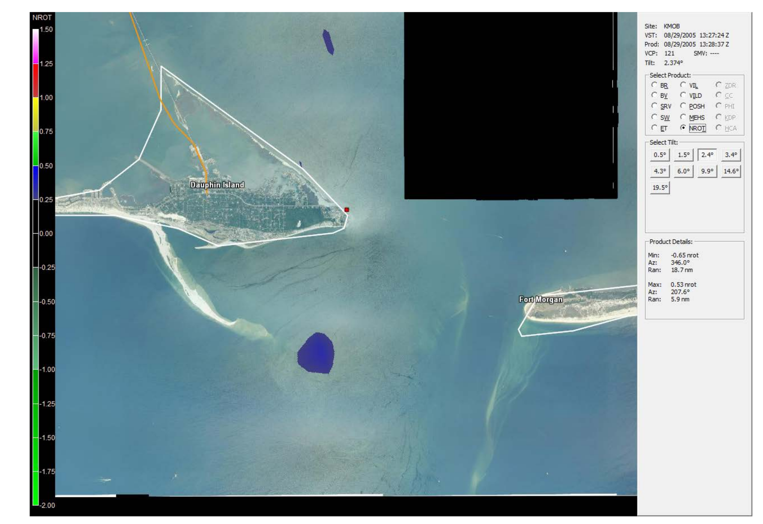
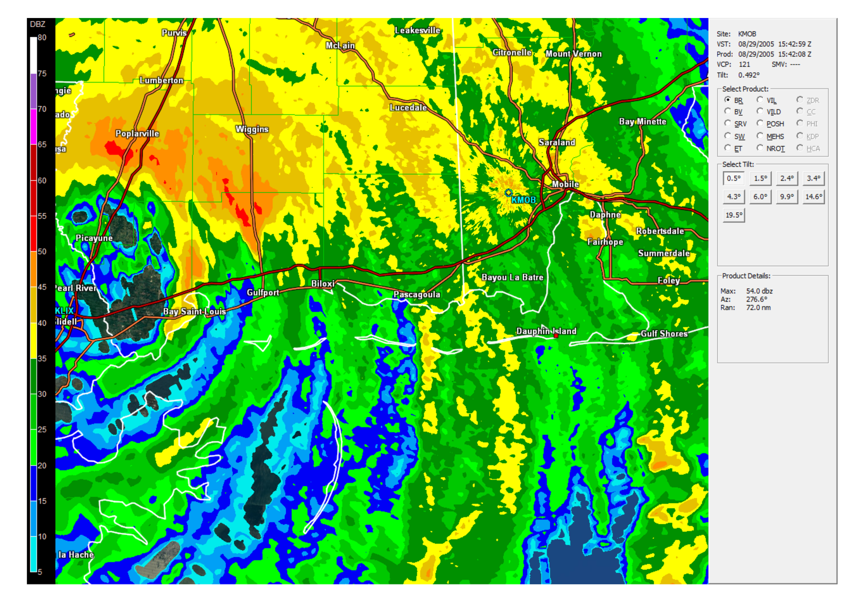


c

Figure 5. **a)** Reflectivity (2.4º), **b)** radial velocity (2.4º) and **c)** normalized rotation (blue-purple represents cyclonic vortex-like features) at approximately 1329 UTC on 29 September 2005 from the National Weather Service WSR-88D Doppler radar in Mobile, AL (KMOB). Vortex-like feature within a heavy squall is rapidly approaching Dauphin Island from the SSE within a heavy squall. Winds gusted to 44 m/s (85 kts) at DPIA1 within the next couple of minutes as the vortex-like feature passed to the west. Radial velocities >56 m/s (108 kts) were observed at multiple levels to the east of the vortex down to the base beam elevation (726 m).

The winds at DPIA1 gusted to 44 m/s (85 kts) as the center of the vortex-like feature passed approximately 2.4 km to the west. Figure 5b shows the large expanse of strong winds (circled area) extending outward to the east of the vortex-like feature (purple shading in Figure 5c).

Finally, some of the strongest C-MAN measured winds occurred with bands that did not contain significant convection. Some of these winds actually occurred within stratiform band-like features, such as in Figure 6.



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4. Conclusions

A preliminary limited study was accomplished of radar precipitation patterns and peak local hourly wind gusts measured at four C-MAN locations within convection at radii outside the eyewall within four separate hurricanes. These peak hourly gusts were observed to occur under a variety of precipitation patterns, but some preliminary general characteristics were observed.

The strongest local hourly gusts often occurred 1) in association with the gust front for convection at large radii near the outer edge of the storm; 2) within heavy convective precipitation cores (generally in bands embedded within stratiform CDO precipitation) at shorter radii, 3) in association with convectively-induced vortex-like features, and at times 4) within stratiform rainbands generally embedded within the CDO and often associated with nearby convection (winds not measured at the C-MAN location may be locally stronger in nearby convection).

More study with a larger group of storms and surface observations is necessary to further refine and categorize the above situations.

5. REFERENCES

References will be provided in the extended abstract.