3B.1 THE INTENSITY OF WIND GUSTS UNDERNEATH AREAS OF DEEP EYEWALL CONVECTION IN HURRICANES KATRINA AND DENNIS AT LANDFALL

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1. INTRODUCTION

On 20 December, 2005, the National Hurricane Center (NHC) issued its report on Hurricane Katrina. Maximum sustained winds at landfall on both the Louisiana and Mississippi coasts were lowered from the values originally estimated within operational advisories issued on the morning of 29 August. This paper discusses whether the revision in the intensity of Katrina understated the overall wind damage potential of this storm and addresses the applicability of using the Saffir-Simpson Scale to convey this aspect of Katrina's destructive capability. The use of GPS dropsondes has revealed very strong vertical gradients of wind speeds exist in the boundary layer underneath the eyewall of hurricanes. The potential to mix some of these strongest winds down to the surface in areas of deep convection, in the form of localized gusts, will be discussed. Finally, the horizontal wind gradient that exists along the immediate beachfront will be examined along with a discussion of how these winds may have produced a considerable amount of the damage that was later masked by the extreme surge flooding event.

2. KATRINA / DENNIS RECON & SURFACE DATA

During the morning of 28 August, 2005, USAF Reserve reconnaissance aircraft AF302, flying Mission 1712A, and then later NOAA 43 flying mission 1812A, recorded some of the strongest winds ever measured in a tropical cyclone as Hurricane Katrina rapidly intensified from a MSLP of 935 millibars (mb), down to 902 mb, in less than 12 hours. One second averaged 700 mb wind values as high as 179 knots were measured in the northeast eyewall depicted in **Figure 1** (a photo of the WC-130J onboard radar taken at 1408 UTC from the southwest quadrant looking toward the northeast prior to this penetration). A dropsonde released into the inner edge of that northeast eyewall descended into a mesovortex that contained a boundary layer (BL) wind peak of 120 meters per second (m/s), or 234 knots, at the 866 mb level (approximately 600 meters above the Gulf surface). If valid, these would be the highest winds recorded to date in the eight years that GPS sondes have been sampling these BL maxima. Fourteen hours later, AF 305 released another sonde into the same eyewall that measured winds as strong as 78.2 m/s (152 knots) 421 m above the surface. After nine more hours, this portion of the eyewall swept over extreme southwest MS, after earlier moving across Plaquemines Parish, LA. **Figure 7** shows the profile of winds measured by a sonde that was released at 1422 UTC just off the MS coast that actually landed inland between Pass Christian and Henderson Point. It shows winds still as strong as 64.8 m/s (133 knots) only 350 meters above the beachfront. At that moment, intense convection had already rotated onshore through southwestern Harrison and southern Hancock Counties and passed further inland toward Diamondhead and the Stennis Space Center (see **Figure 3**, the Slidell, LA WSR-88D radar 1359 UTC image). The lack of surface winds stronger than 47 m/s (91 knots) suggest that by 1422 UTC, the convective conduit to the surface had already passed north of Pass Christian.

The importance of convection as a connective mechanism mixing wind maxima in the BL down to the surface was clearly evident during the landfall of Hurricane Dennis the previous month. Winds of up to 81 m/s (158 knots) were measured by a sonde from AF 308 at the 908 mb level (approximately 350 meters above the surface) during the early morning hours of 10 July. As Dennis approached landfall in the Florida Panhandle, it ingested a great deal of dry air from the southern Great Plains that had advected into the western Gulf of Mexico, considerably eroding the core convective structure. Even though very strong winds continued to be measured in the BL several hundred meters aloft, only in one small area were any of the strongest winds evident at the surface at landfall. Only the areas of Santa Rosa County, FL that were beneath an intense crescent-shaped remnant of the inner eyewall (see **Figure 4**, a radar image of Dennis at landfall) experienced major hurricane force winds. Eglin AFB, only 28 miles northeast of the center, never experienced sustained hurricane force winds (48 kt maximum sustained winds, 72 kt gusts). As the eye was coming ashore, only shallow, weak, rain bands were evident on radar over Okaloosa County, FL, so none of the strongest winds aloft were translated to the surface. Outside this convective crescent, only along the immediate beachfront of the barrier islands in Okaloosa County, where surface friction is minimized at the land-sea interface, did sustained winds reach hurricane force (72 knots at Eglin site A-5). On the A-13B tower (sensor elevation 70 meters) winds gusted to 90 knots.

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3. RITA 21 Sept: BOUNDAY LAYER WIND MAXIMA COUPLED TO SURFACE BY DEEP CONVECTION

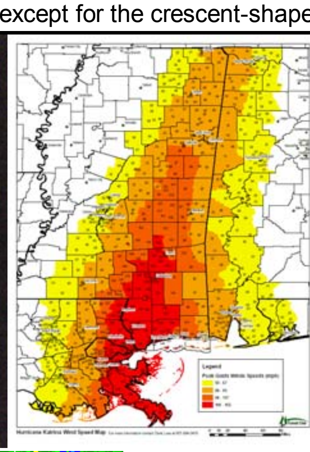
During the afternoon and evening of 21 September 2005, the MSLP of Hurricane Rita dropped an extraordinary 46 mb in nine hours. During this event, extremely deep and well organized convection in the eyewall (see **Figure 5**) was available to mix boundary layer winds all the way down to the surface. This was clearly evident in the dropsonde released into the north eyewall (that spiraled into the northwest eyewall as it fell) by AF 300 flying Mission 1418A at 2314 UTC. **Figure 8** shows near-surface winds stronger than the winds sampled with the sonde above 1500 meters (and even stronger than 700 mb flight level winds shown in **Figure 6**) with much of the 96.3 m/s (187 knot) wind maxima found at 349 meters translated down to the air-sea interface (the last quality controlled data point was at 46 meters) where winds of 81.7 m/s (159 knots) were measured.

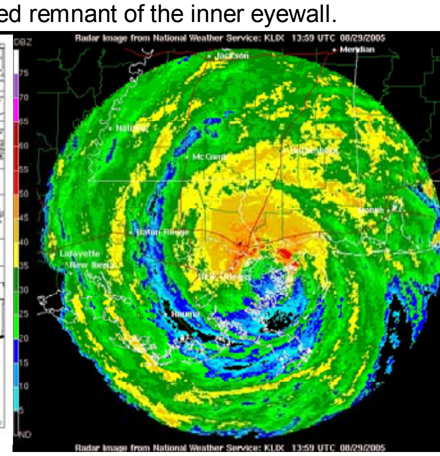
4. CONCLUSIONS

Eyewitness reports along the southwestern MS coast speak of very strong wind gusts causing considerable damage prior to the arrival of the massive storm surge that wiped out nearly every structure left standing by the winds (leaving it nearly impossible to examine debris for evidence of wind damage). Video taken by storm chasers Scott McPartland and David Lewison, from a parking garage in downtown Gulfport, when analyzed pixel by pixel, show gusts in excess of 130 knots. Estimates of maximum gusts complied by Clark Love of Forest One Inc. depict the “buzz saw” effect (similar to what was seen across the FL Peninsula with Charley (2004)) as the core of Katrina cut a swath of destruction from southwest to northeast inland across Mississippi. The darkest shading in **Figure 2** denotes wind gusts of 118-155 MPH and highlights the value of using maximum gusts (versus sustained winds).

The presence of convective-scale gusts, as well as the duration of wind stress placed on structures in the path of Katrina (with a 125 mile radius of hurricane force winds), contributed greatly to the extensive wind damage. Katrina, when contrasted with the lack of active eyewall convection in portions of the core of Dennis, highlights the utility of small scale analysis of convective features in estimating the wind damage potential of a landfalling hurricane. The results of such analyses are difficult to convey using the Saffir Simpson Scale, which seeks to quantify the overall destructive potential of a storm using a broad brush. This can be a handy tool in disseminating advisories to the public through the media, but one that also can be misleading in real-time as the storm event unfolds. Later, detailed post-storm studies to determine whether wind or water was responsible for damage to a particular location are hindered by capping the winds at levels set by Saffir-Simpson Category.

Figure 1 (upper left), the onboard radar of AF 302 at 1408 UTC 28 August looking toward the northeast just prior to eyewall penetration. **Figure 2** (upper center) Forest One plot of maximum wind gusts estimated for the landfall of Katrina (compiled by Clark Love) showing gusts of 118-155 MPH in the darkest red shaded areas. **Figure 3** (upper right) Slidell, LA radar at 1359 UTC showing intense eyewall convection rotating ashore into southwest Harrison and southern Hancock County, MS. **Figure 4** (lower left) Eglin AFB radar image of Dennis at landfall from 1429 UTC 10 July showing no deep convection remaining except for the crescent-shaped remnant of the inner eyewall.





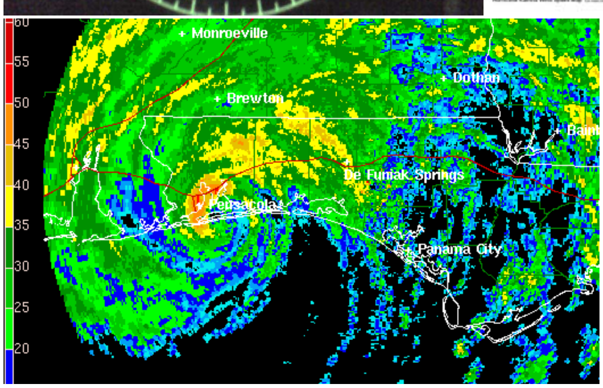
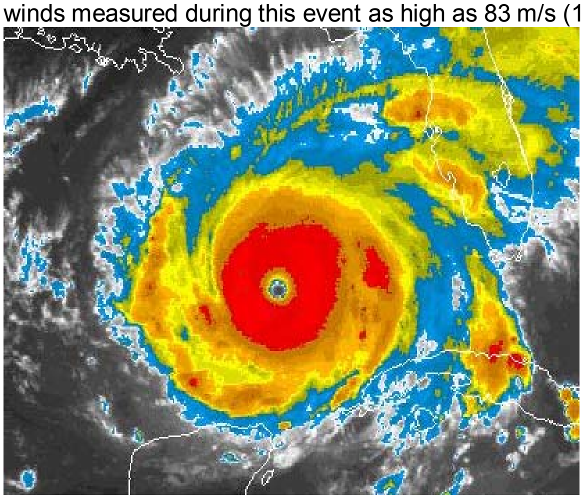


Figure 5 (left) GOES imagery of Rita during rapid intensification at 2145 UTC on the afternoon of 21 September showing extremely deep and well organized eyewall convection. **Figure 6** (right) One second averaged flight level winds measured during this event as high as 83 m/s (162 knots) at 2315 UTC in the northern eyewall at 700 mb.



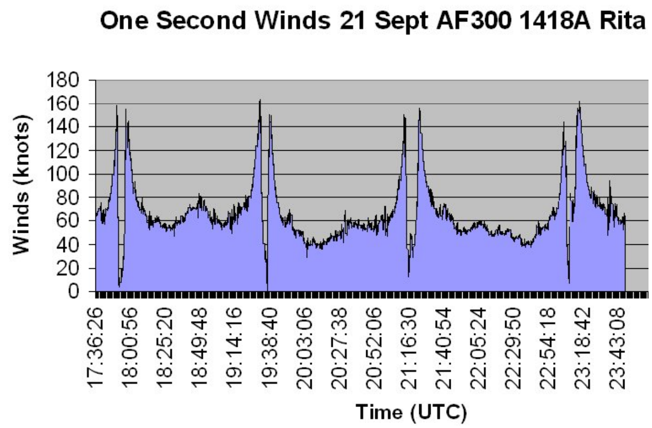


Figure 7 Dropsonde wind profile from AF 302 release at 1422 UTC 29 August into Hurricane Katrina, above the beach at Pass Christian, MS. The strongest eyewall convection had already rotated off the beach a few minutes earlier at this location and passed further inland, leaving weaker, more-shallow convection. As a result, winds measured at the near-surface (77 meters) dropped down to 47 m/s (only 91 knots, or 42 knots slower than just above at 350 meters). The sonde also fell onto land considerably inland from the beach, allowing for further reduction in wind speed due to friction with the terrain. Very large gradients in winds speed in the first 500 meters beyond the land-sea interface were noted in Katrina, adding greatly to the confusion as to whether damage was caused by wind or surge (since this matches nearly perfectly the trace of the inland extent of the storm surge).

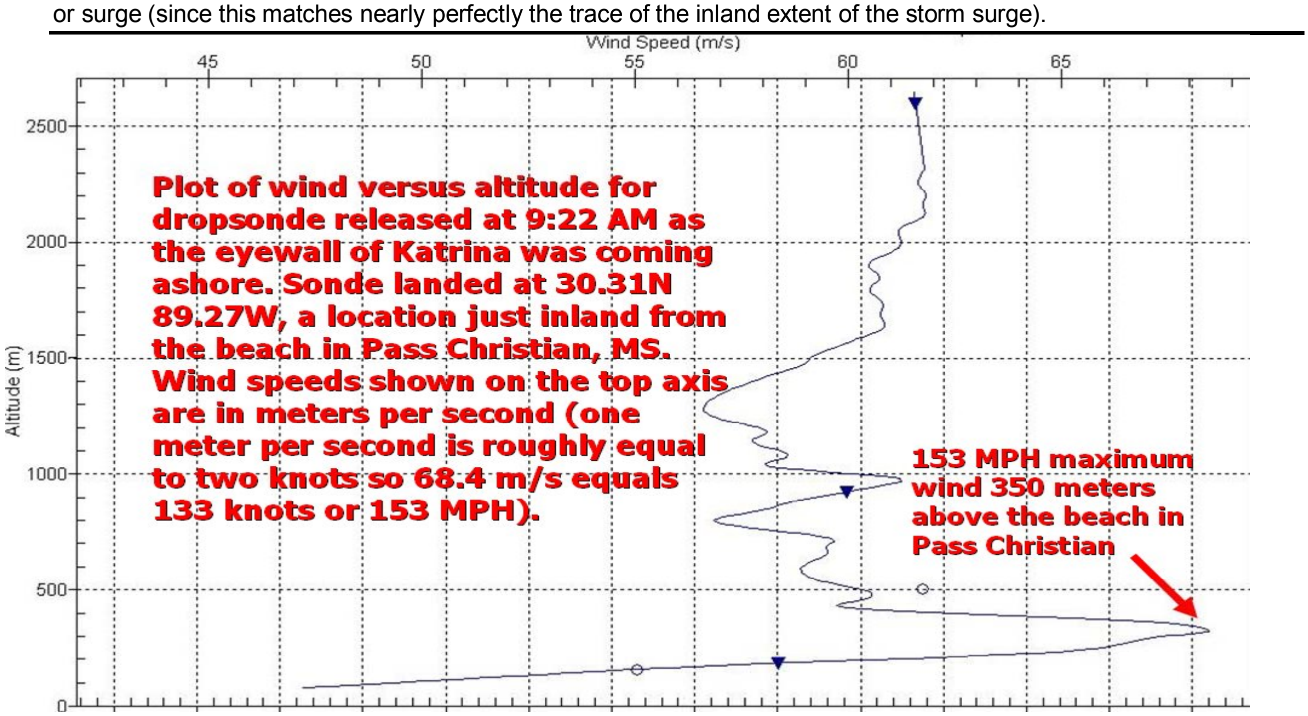


Figure 8 Dropsonde wind profile from AF 300 release at 2314 UTC 21 September into Hurricane Rita. The sonde fell into extremely intense eyewall convection which allowed much of the very strong winds in the boundary layer to be translated to the surface, at least in the form of localized gusts at this particular point and time.