13D.3 TRANSITION IN ONSHORE HURRICANE BOUNDARY LAYER WINDS DURING THE LANDFALL OF HURRICANE LILI (2002)

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1. INTRODUCTION

Understanding the transition of the hurricane boundary layer near and at landfall is paramount to helping coastal society, with far-reaching impacts to forecast, emergency management, and disaster mitigation operations. Central to this are the changes in the wind field, which may undergo several modifications before reaching inland locations downwind of the coastline. In order to better understand these changes, observations from an array of portable and fixed meteorological surface stations and a portable Doppler radar located within the onshore winds during the landfall of Hurricane Lili (2002) are analyzed. This report will focus on analysis from four of the fixed stations, and attempt to account for some of the changes taking place within the onshore surface wind field. Lili made landfall on the central Louisiana coastline as a Category 1 hurricane with maximum sustained 1-min winds estimated at 41 m/s around 13:00 UTC, 3 October, about 150 km west of the four stations. Three of the stations (LUMAC, LUTAB, and LUTEB) are part of the Louisiana Universities Marine Consortium (LUMCON) network and the other (LAISH) is from the Louisiana Agriclimatic Information System (LAIS), a mesonet which collects data primarily for agricultural purposes.

2. METHODOLOGY

Data collected from the surface stations were synthesized according to available averaging times for a 48 hour period from 12:00 UTC 2 October - 12:00 UTC 4 October. Surface analyses of unadjusted basic-state and derived variables were generated in order to identify areas of focus. From the surface analyses, a 7.5 hour period of onshore wind (11:40 UTC – 19:10 UTC 3 October) was chosen for further analysis. During this time the wind direction vectors from each of the stations were nearly aligned. In accordance with Monin-Obukhov similarity theory, only 10-min mean wind data are employed. The LAIS records 3-sec peak gust data and wind speed standard deviation σ_u in addition to the mean 1-min wind, while each LUMCON station collects peak 2-sec gust and 1-min mean wind data.

In order to adjust the wind observations for exposure and height, some measure of surface roughness must be determined. An objective gust factor (GF) technique as outlined in Wieringa (1992) was employed to determine z_o. The wind data from the stations were stratified into 30^o sectors to obtain median gust factors for each sector, as prescribed by the technique. Sector roughness using this technique is determined by

$$z_0 = z\exp\left(\frac{-f_T A\left[1.42+0.3\ln\left(-4\times10^3\big/\overline{Ut}\right)\right]}{\left\langle u_{peak}\big/\overline{U}\right\rangle-1+A-f_T A}\right) \qquad (1),$$

where $\left\langle u_{peak}/\overline{U}\right\rangle$ is the median gust factor in a sector taken from at least 15 observations with $\overline{U} \geq 6$ m/s, f_T is a factor dependent upon averaging period and is unity for 10-min averages, and $\overline{Ut}$ is the mean gust wavelength.

$$A = \left[\left(1+\left[2\pi\lambda/\overline{U}\,t\right]^2\right)\left(1+\left[2\pi t_r/t\right]^2\right)\right]^{-1/2} \qquad (2)$$

is the attenuation of the gust amplitude by the anemometry/acquisition system, where λ is the anemometer distance constant and t_r is the response time of the data acquisition system. $\overline{Ut}$ is determined from a nomogram given in Wieringa (1976) and is dependent upon t_r, λ, and $\overline{U}$. Values of the parameters and relevant station information for this study are given in Table 1. It should be noted that A is extremely sensitive to the ratio of t_r to t and (2) becomes inapplicable when $t_r = t$. So, t_r was taken to be 0.2 s although it is likely that the response times of the systems are slower.

Table 1. Relevant station information

Parameter	*LAISH*	*LUMAC*	*LUTAB*	*LUTEB*
Location	Houma	LUMCON Marine Center	Tambour Bay	Terrebonne Bay
Anem, Height (m)	10	13.2	~12	13.9
λ (m)	2.7	2.7	2.7	2.7
Mean $\overline{Ut}$ (m)	55	60	60	60
Mean A	0.88	0.81	0.81	0.82

Roughness lengths, calculated using appropriate data collected from the 48-hour period, for the sectors applicable to this study are given in Table 2.

Table 2. Sector roughness information for onshore flow data

Wind Direction Sector	*z_o (m) by GF / by Photo / by TI / # obs used*			
	LAISH	*LUMAC*	*LUTAB*	*LUTEB*
5 ($105^o < \theta \leq 135^o$)	0.35/0.25 0.083/21	Not Applicable	Not Applicable	Not Applicable
6 ($135^o < \theta \leq 165^o$)	0.81/0.8 0.33/22	0.12/0.1 NA/23	0.032/0.008 NA/22	0.034/0.005 NA/22
7 ($165^o < \theta \leq 195^o$)	0.73/0.5 0.38/22	0.13/0.11 NA/78	0.01/0.003 NA/96	0.003/0.002 NA/115
8 ($195^o < \theta \leq 225^o$)	Not Applicable	0.039/0.02 NA/21	0.008/0.01 NA/35	0.004/0.003 NA/28

For each sector, a subjective roughness value determined from a GIS analysis of aerial photographs (Figure 1) is also given in the table. Furthermore, for LAISH, z_o was determined by turbulence intensity (TI) (Table 1) to further support the z_o values from GF used to adjust the data for exposure. This technique employs the log-law assuming the ratio of σ_u to the friction velocity u_* is a constant c ≈ 2.5. Some studies have

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**Corresponding author address*: Rob Howard, Texas Tech Univ., Atmospheric Science Group, Lubbock, TX 79409-2101; e-mail: rob.howard@ttu.edu shown that this assumption may not be valid except in regions well downwind of roughness changes where equilibrium with the new surface has been fully established. This technique has also been known to give lower values for z_o when compared to others. Thus, only the GF-determined z_o's were used for adjustment.

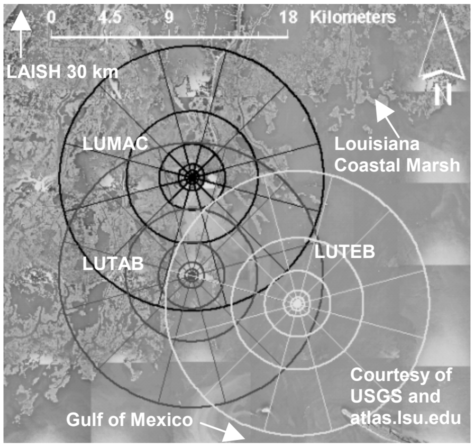

Figure 1. Aerial photographic map showing LUMCON stations (Range rings are 0.5 km, 1 km, 2.5 km, 5 km, and 10 km)

Although the elevation above mean sea level of all of the LUMCON anemometers used is several meters above standard 10 m height, no height adjustment appeared necessary due to the leveling effects of the storm tide. In order to factor out multiple roughness changes that exist between the land-water interface and the station, the over-land observations were adjusted to open terrain (z_o = 0.03 m) using an algorithm based upon the log-law and described in Wieringa (1976). For comparison purposes, the algorithm was also applied to adjust the land observations using the log-law with parabolic correction (not shown) (Deaves, 1981), which has been shown to yield more precise wind profiles. For each 10-minute period, the distance along the mean wind direction from each of the land stations to the coastline was determined, assuming that both of the over water stations are at distance zero. The adjusted and non-adjusted observations were then plotted against these data to determine the influence of distance from the interface on the mean wind speed (and GF, not shown).

3. ANALYSIS AND DISCUSSION

The roughness values generated by GF appear to vary in correspondence with the terrain located several kilometers upwind of each of the stations, although they appear high when compared with typical roughness classifications (Wieringa, 1992). This may be due to the GF technique applying to a longer upwind fetch than other methods of determining z_o. The z_o values from the offshore stations (LUTAB and LUTEB) are not as low as would be expected from open ocean conditions (z_o = 0.0002 m) for most of the fetch directions. Although determined from 10-min wind speeds < 22 m/s, these increased roughness values may be indicative of shorter, steeper, and younger waves in the shallow bay, consistent with previous modeling studies.

Buildings from the town of Cocodrie affected some of the LUMAC data, but these effects were minimized through adjustment to open exposure. Observations from LAISH were affected by roughness changes associated with a swamp located ~300 m upwind in sectors 6 and 7. Upwind of that swamp is a clearing and one more forested area, with open marshland extending 35-40 km south to the coast.

Figure 2 illustrates the slowing of the mean wind as a result of the surface change from water to land. The observations were normalized by those from LUTEB to develop the percentage decrease with respect to the coastline. For both the unadjusted and adjusted normalized observations, a best-fit curve analysis reveals an exponential decrease of mean wind with increased distance from the initial interface. This rate of decrease is ~10% within the first 10 km of the coastline and slows thereafter. Table 3 gives the best-fit statistics for both the unadjusted and adjusted normalized observations as well as correlation coefficients between the observations and distance from the coastline. Even when all of the land roughness changes are factored out through adjustment, modification of the mean wind appears to be dependent on the distance from the interface and the negative correlation between the two datasets is consistent with the decrease in mean wind with greater distance from the coast. Similar analysis of datasets from closer to Lili's landfall location will be shown at the conference.

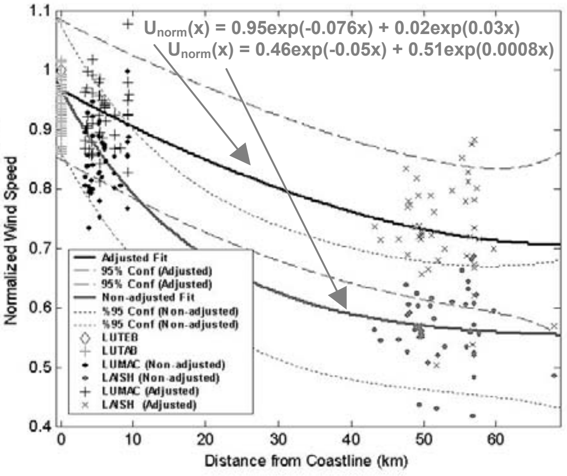

Figure 2. Normalized wind speed modification from coastline.

Table 3. Best fit and correlation statistics for mean wind values

	Best Fit Statistics			
Normalized Wind Observations	*Sum-Squared Error*	***Variance Explained***	*RMS Error*	*Correlation Coefficients*
Not Adjusted	0.52	0.91	0.05	-0.846
Adjusted Land Obs	0.63	0.74	0.06	-0.703

4. ACKNOWLEDGEMENTS

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5. REFERENCES

References are available upon request.