16.7 EXTREME HORIZONTAL WINDS MEASURED BY DROPWINDSONDES IN HURRICANES

Sim D. Aberson* NOAA/AOML/Hurricane Research Division
Daniel P. Stern University of Miami/RSMAS/Meteorology and Physical Oceanography

1. Introduction

Since the use of Global Positioning System (GPS) Dropwindsondes in the hurricane eyewall was initiated in 1997, thousands of horizontal and vertical wind, temperature, and humidity profiles have been obtained. Franklin et al. (2003) used such profiles to look at the mean eyewall wind profile from the surface to about 700 hPa, where reconnaissance aircraft usually fly. They found that the mean profile has a broad maximum in wind speed centered about 500 m above the surface, below which the wind speed falls off exponentially toward the surface. They also found variations in the slope of this decrease with speed. However, in their sample, only five dropwindsondes reported wind faster than 90 ms^{-1} (in Hurricanes Georges and Mitch). Since that time, 53 dropwindsondes with wind speed exceeding 90ms^{-1} somewhere within the profile have been reported (Table 1). Neither Air Force Reconnaissance dropwindsonde data from the 2005 hurricane season nor the Hurricane Rita best track were available at the time of writing. The goal of the current study is to extend the Franklin et al. (2003) analysis to extremely high wind speeds.

2. Basic Statistics

Of the 53 dropwindsonde profiles with wind speed in excess of 90 ms^{-1} (Table 1), only two have wind speed greater than 100 ms^{-1}. Of these two, the Isabel profile has been previously investigated (Aberson et al. 2006); the second was obtained in Hurricane Ivan.

Not unexpectedly, the entire sample was obtained in storms with minimum central pressure less than or equal to 940 hPa. However, the dropwindsonde with the fastest wind measured was obtained in Isabel when the central pressure was at the sample high end. All the storms were category 5 on the Saffir-Simpson scale except the three with the highest minimum central pressure (Georges and Lili). All category 5 hurricanes which were sampled since 1997 have at least one dropwindsonde that meet the 90 ms^{-1} criterion.

All the data, except those in Hurricanes Georges and Isabel and Kenna, were obtained in the Gulf of Mexico or the Northwestern Caribbean Sea; interestingly, Georges and Isabel have high minimum central pressures compared to the remainder of the dataset. Until 2005, these extreme horizontal wind speeds were not sampled in the Gulf of Mexico.

The height of the maximum wind speed varies considerably. Two Isabel dropwindsonde profiles (one on 12 September and one on 14 September) have the maxima within the boundary layer (155 and 127 m above the surface, respectively), whereas the fastest wind measured was at 1375 m above the surface. The median height of the wind speed maxima is 550 m above the surface.

3. Mean flight-level to surface wind reduction

Franklin et al. (2003) found from their sample that the mean ratio between 700 hPa and surface wind speeds in the eyewall was 0.9. This ratio is important since operational aircraft reconnaissance missions generally fly at 700 hPa, and, in the absence of other measurements, surface wind speeds are estimated from wind speeds at that level.

Multiple dropwindsonde profiles from one eyewall penetration are here considered together. In this way, maximum 700 hPa and surface wind speeds from each dropwindsonde set are compared. In some instances, only one dropwindsonde is released during a penetration, but as many as 12 have been released at once. Aircraft flight level during some penetrations was below 700 hPa, so those dropwindsonde data are not included in this analysis. As in current operational practice, the wind speeds from the lowest 150 m of the profile are

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* *Corresponding Author Address:* Sim D. Aberson, NOAA/AOML/Hurricane Research Division, 4301 Rickenbacker Causeway, Miami, FL 33149; e-mail: sim.aberson@noaa.gov

Storm	Date	Time (UTC)	Aircraft	Dropwindsonde Maximum Wind Speed (ms^{-1})	Best-track Maximum Sustained Wind Speed (ms^{-1})	Best-track Minimum Surface Pressure (hPa)
George	19980920	000811	H	90.97	66.87	939
Mitch	19981026	191303	A	90.11	79.72	905
Mitch	19981027	065316	A	90.39	77.17	917
Mitch	19981027	224250	I	91.27	72.01	933
Mitch	19981027	224311	I	93.65	72.01	933
Lenny	19991117	165259	A	94.64	69.44	933
Kenna	20021024	185726	A	98.77	72.01	917
Lili	20021002	224703	H	90.16	64.29	940
Isabel	20030912	165924	I	90.53	72.01	920
Isabel	20030912	165945	I	94.56	72.01	920
Isabel	20030912	170913	A	94.33	72.01	920
Isabel	20030912	171926	A	91.99	72.01	920
Isabel	20030912	172258	H	91.88	72.01	920
Isabel	20030912	172311	H	92.46	72.01	920
Isabel	20030912	190346	H	90.28	72.01	920
Isabel	20030912	190353	H	91.56	72.01	920
Isabel	20030912	190405	H	93.17	72.01	920
Isabel	20030912	190414	H	94.64	72.01	920
Isabel	20030912	195406	I	92.97	72.01	920
Isabel	20030912	202833	H	90.32	72.01	920
Isabel	20030913	163624	H	93.62	72.01	920
Isabel	20030913	175248	H	107.00	72.01	932
Isabel	20030913	175422	I	93.26	72.01	932
Isabel	20030913	175427	H	91.82	72.01	932
Isabel	20030913	175436	I	91.41	72.01	932
Isabel	20030913	195012	I	91.43	72.01	932
Isabel	20030914	172103	I	90.45	72.01	933
Isabel	20030914	172146	I	93.12	72.01	933
Isabel	20030914	172158	H	90.11	72.01	933
Isabel	20030914	210318	H	92.75	72.01	933
Ivan	20040909	052637	A	91.52	72.01	925
Ivan	20040909	101320	A	92.27	72.01	919
Ivan	20040911	190936	A	99.68	74.58	920
Ivan	20040911	191000	A	93.36	74.58	920
Ivan	20040911	222231	A	90.63	74.58	910
Ivan	20040913	013658	A	92.88	72.01	916
Ivan	20040913	051007	A	93.45	72.01	920
Ivan	20040913	100755	A	102.71	72.01	915
Ivan	20040913	181720	H	98.37	72.01	912
Ivan	20040913	185206	H	95.69	72.01	912
Ivan	20040913	194319	H	91.05	72.01	912
Ivan	20040913	214655	I	92.18	72.01	914
Ivan	20040913	214710	I	95.47	72.01	914
Ivan	20040913	235423	I	91.26	72.01	914
Ivan	20040913	235439	I	91.96	72.01	914
Katrina	20050828	174412	I	93.36	77.15	902
Katrina	20050828	191915	I	94.42	77.15	902
Katrina	20050828	204124	I	95.20	77.15	902
Rita	20050921	191231	I	96.85		
Rita	20050921	191131	I	91.80		
Rita	20050921	193542	I	98.69		
Rita	20050921	194600	I	91.62		
Rita	20050921	194634	I	91.36		

Table 1. Dropwindsonde profiles used in this study.

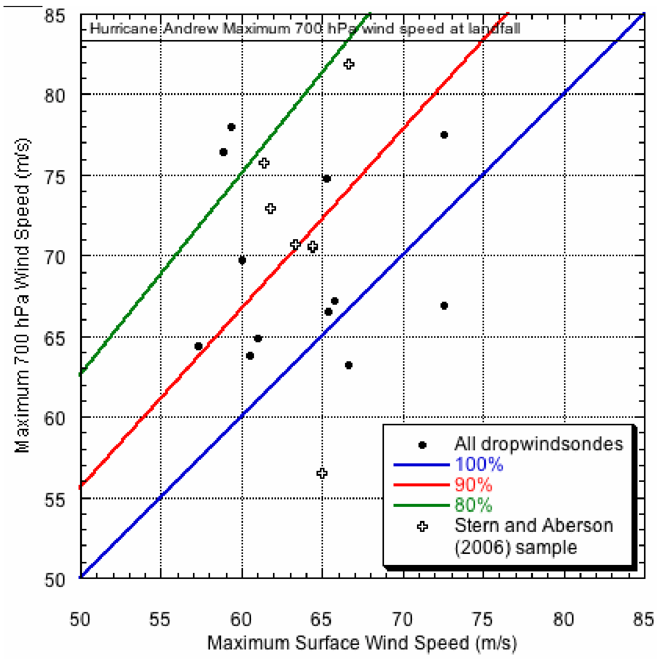

Figure 1. Ratio of maximum 700 hPa and surface wind speeds from dropwindsondes with at least 90 ms^{-1} wind speed measured somewhere within the profile. Dropwindsondes in this sample with extreme upward motions are shown separately. Representative ratios are also shown.

averaged and reduced to the surface to eliminate gustiness from the profiles. The average 90% reduction is confirmed for wind speeds greater than 90 ms^{-1} (Fig. 1), though there is quite a bit of scatter in the dataset. The small sample of dropwindsonde profiles with extreme upward motions do not show a bias.

4. Extreme horizontal wind speeds and superintensity

Persing and Montgomery (2003) reported that storm intensity in high resolution axisymmetric hurricane simulations can greatly exceed currently understood upper bounds for maximum potential intensity. They demonstrated that this “superintensity” was due to high entropy air at low levels in the hurricane eye being mixed into the eyewall by mesocyclones at the eye/eyewall interface. This provides extra power to the hurricane engine versus what is available directly from the ocean surface. Montgomery et al. (2006) and Aberson and Montgomery (2006) reported on data from aircraft in Hurricane Isabel (13 September 2004) within this context, and many dropwindsonde profiles used in that study are included herein.

The Isabel data were considered exceptional because the analyzed sea surface temperature (SST) was considered exceptionally low for a tropical cyclone at that intensity. At that time, the Reynolds SST analysis provided a temperature of 28.3°C at the storm location. However, because Isabel was moving over the track crossed by Hurricane Fabian a few weeks earlier, the SST was considerably lower. Of the current sample, only one dropwindsonde profile with extreme horizontal wind speeds was obtained in analyzed SST lower than this (Hurricane George in the central Atlantic – 27.6°C). The maximum SST was 30.5°C for the Hurricane Katrina dropwindsondes. Hurricane Georges is thus a prime candidate for further investigation of the superintensity hypothesis.

5. Implications

The current results show that the relationship between 700 hPa flight level wind speeds obtained by reconnaissance aircraft and surface wind speeds derived in Franklin et al. (2003) can safely be extended to wind speed higher than those reported in the original paper. This is important for operations in those cases in which surface wind speed measurements (such as from dropwindsondes or a stepped-frequency microwave radiometer) are not available. Further, for reanalysis of previous storms (Landsea et al. 2004), this can help in the deduction of maximum sustained wind speed for those cases in the past with 700 hPa flight level wind measurements. For example, Fig. 1 shows that the flight-level 700 hPa wind speed measurement during the landfall of Hurricane Andrew in South Florida was higher than the 700 hPa wind measured by any of the dropwindsondes in this dataset. This further confirms the Landsea et al. (2004) finding that Andrew had attained Category 5 status at landfall.

Implications of these data for theoretical upper bounds to hurricane intensity and to operational intensity forecasts have been provided in Montgomery et al. (2006) and Aberson et al. (2006). The inclusion of 2005 Air

Force reconnaissance dropwindsonde data in this dataset will hopefully provide more evidence for these findings.

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