Unique Meteorological Data During Hurricane Ike’s Passage Over Houston

PAGE 215

Hurricane Ike passed over the Houston, Tex., metropolitan area during the early morning of 13 September 2008. Although Ike had been rated only a category 2 on the Saffir-Simpson scale at landfall near Galveston, Tex., the storm’s widespread damage to urban trees, many lacking proper trimming, knocked out the area’s power distribution system; for some customers, power was only restored a month later.

The hurricane’s path after landfall (Figure 1a) went north through Galveston Bay and Baytown. The city of Houston—with its economically important ship channel—experienced the less severe western eye wall, the tight circulation with maximum wind speeds around the hurricane’s center. The eye’s passage was recorded between 3:00 and 4:30 A.M. Central Standard Time (CST; Figures 1a and 1c). It had maintained its unusually large diameter of 35–40 kilometers in its first hours after landfall.

Characteristics of land-falling hurricanes have been recorded previously [e.g., Lorsolo et al., 2008; Shriver et al., 2005] but not over urban terrain. Data recorded at two elevated meteorological stations in Houston may be able to shed light on why Ike’s winds were so devastating.

Hurricane Ike in Urban Houston

Urban surfaces are aerodynamically rougher than most natural surfaces [Roth, 2000], creating increased friction and shear, including many small-scale wakes from individual structures [Kipp, 2007]. To demonstrate the hurricane’s force in the urban environment, meteorological data were used from a Texas A&M University project located at a commercial, lattice-structure communications tower owned by the Houston Yellow Cab company (HYC; 29.789º N, 95.345º W, 14 meters above sea level (asl); Figure 1b), with sensors up to 60 meters above ground level (agl); and from a University of Houston (UH) project located atop the university’s northern Moody Towers building (29.718º N, 95.341º W, 11 meters asl, 76 meters agl). At the HYC tower, data were recorded in 10-second intervals and were stored as 1-minute averages and standard deviations; atmospheric pressure data were recorded every 15 minutes. While some sensors were lost, wind data from the top level, installed north of the tower structure, were unaffected. The four lower-level cup anemometers, installed south of the tower, recorded reduced speeds during northerly winds. Rainfall and pressure were recorded at 12 and 2 meters agl.

The UH measurements included 10-second samples of pressure, temperature, humidity, wind speed, and direction. Figure 1c shows pressures and accumulated rainfall, and Figures 1d and 1e show 1-minute mean winds (sustained winds) and 10-minute mean winds at the 60-meter level on the HYC tower (Figure 1d) and at 76 meters agl on the UH tower mast, respectively. Maximum sustained wind speeds exceeded 30 meters per second (67 miles per hour (mph)) when the eye of the hurricane was located east of the HYC site. Peak 10-second gusts were estimated to have ranged from 34 to 36 meters per second (80 mph). Maximum rain rates in the hurricane’s inner rainbands were 40 millimeters per hour, with peak values of 1.25 millimeters per minute. The lowest pressure, 960 millibars, was recorded slightly later at the HYC than at the UH site, as expected from the hurricane’s northerly path (Figure 1a). Maximum sustained wind speeds of 32 meters per second (72 mph) were recorded at the UH site, with peak 10-second gusts exceeding 58 meters per second (85 mph), on the southwest side of the eye with winds advecting relatively flat terrain toward the building.

Wind Damage and Turbulence

Wind damage to structures arises from static and dynamic, or gust, wind loads [Plate and Kiefer, 2001]. Because of friction-induced gustiness, the wind damage potential is likely larger to trees in an urban environment than to those in undisturbed forests. Measurements and modeling of wind damage potential to remaining trees in logged forests [e.g., Ancelin et al., 2004; Panferov and Sogachev, 2008; Zeng et al., 2009] have shown that aside from the static wind load (proportional to the sustained wind speed squared), dynamic wind load due to turbulence can be critical. Turbulent kinetic energy (TKE) in hurricanes is dominated by shear production, proportional to the square of the friction velocity ($u_{*}^{2}$). The effect of TKE on wind loads grows much more rapidly with wind speed than with static load [Panferov and Sogachev, 2008].

Presented at the Second Swarm International Science Meeting, to be held at the German Research Centre for Geosciences (Deutsches GeoForschungsZentrum (GFZ)), in Potsdam, Germany, from 24 to 26 June 2009. For more information on geomagnetic research and its applications, please visit http://www.esa.int/esaLP/LPswarm.html.

Acknowledgments

We would like to acknowledge Richard Blakely, Eric Donovan, and two anonymous reviewers for very helpful suggestions.

References


Blakely, R. J., T. M. Brocher, and R. E. Wells (2005), Subduction-zone magnetic anomalies and implications for hydrated forearc mantle, Geology, 33, 445–448.


Author Information

Eigil Friis-Christensen, National Space Institute, Technical University of Denmark, Copenhagen, Denmark; Email: ef@space.dtu.dk; Hermann Lühr, German Research Centre for Geosciences (Deutsches GeoForschungsZentrum (GFZ)), Potsdam, Germany; Gauthier Hulot, Institut de Physique du Globe de Paris, Paris, France; Roger Haagmans, European Space Agency, Noordwijk, Netherlands; and Michael Purucker, Raytheon at NASA Goddard Space Flight Center, Greenbelt, Md.
Figures 1f–1h show along-wind and cross-wind turbulence intensities at both sites, as well as $u^2$ and TKE from wind gradient and sonic anemometer data at the HYC tower. The observed turbulence intensities increased only slightly during the hurricane. Yet large increases occurred at both the UH and HYC sites when major buildings upstream of the sites affected the flow: at the UH site for south winds due to the wake from the southern Moody Tower (Figures 1f and 1g), and at the HYC site for north-northwesterly winds (Figure 1g) due to a change in surface roughness caused by several large warehouses. Note also that cross-wind turbulence plunged at both sites when the edge of the eye came closest.

The TKE-$u^2$ development during the hurricane’s approach (Figure 1h) suggests maximum friction velocities between 2.5 and 3 meters per second in the eye wall. It appears likely that the dynamic wind loads under these extreme turbulence conditions—especially as affected by building wakes—produced most of the widespread damage, including the highly publicized damage to windows at the downtown JPMorgan Chase tower between 2:00 and 3:00 A.M. CST. The impact of future hurricanes may be reduced if tree trimming ordinances are enforced and new tree-planting sites are carefully chosen.

Acknowledgments

The authors gratefully acknowledge partial funding for their projects from the Texas Air Research Center. Bernhard Rappenglück thanks UH Residential Life and Housing. Gunnar Schade is indebted to Houston Yellow Cab.

References


