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Short Communication

Classification of hurricanes: Lessons from Katrina, Ike, Irene, Isaac and Sandy

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ABSTRACT

Lessons learned from disastrous hurricanes in recent years, especially Katrina, Ike, Irene, Isaac and Sandy are discussed, and improved ways to inform the public about the potential impact of tropical cyclones are presented. An alternative classification system is shown to be more informative than the Saffir–Simpson scale currently in use, and should prove beneficial to the general public and the coastal engineering community. *The most important lesson is that the size of the hurricane matters, not just its intensity*.

1. Introduction

In a special issue of this journal (Demirbilek, 2010), experts in various fields discussed the lessons learned from the most devastating hurricane in the history of this country, Katrina. They also addressed many issues related to hurricanes, including their anatomy, associated winds and waves, and resulting storm surges. One of the papers in the special issue (Irish and Resio, 2010a) took on the task of better estimation of an index for storm surges generated by land-falling hurricanes, with subsequent improvements by Kantha (2010) and Irish and Resio (2010b). However, the important task of improving the overall classification of hurricanes, with the goal of better informing the public and coastal engineering community, was not addressed.

An article in New York Times (August 29, 2011) by Henry Fountain, immediately after hurricane Irene hit New York city, titled “Hurricane lost steam as experts misjudged structure and next move” is an excellent example of non-experts being confused by the continued use of the Saffir–Simpson hurricane scale (SSHS, see Table 1) by the National Hurricane Center (NHC) to convey the severity of a tropical cyclone to the general public. The article states that “What hurricane specialists had forecast to be a Category 2 or possibly Category 3 storm when it hit eastern North Carolina early Saturday, with maximum sustained winds of 49.2 m/s (110 miles per hour, mph) or higher, roared across the Outer Banks as a Category 1, with winds that were more than 10% slower.” If the winds slow down by 10%, the intensity of the hurricane decreases by only about 19%. That is not a significant decrease. The damage sustained in North Carolina was because the “weak” Irene was also enormous in size.

The potential damage due to a hurricane depends not just on its intensity, but also on its size. SSHS does not account for the hurricane size. This brief note is an attempt to bring to the attention of the coastal engineering community, the shortcomings of SSHS, and suggest ways to improve the overall classification of hurricanes.

2. Hurricane classification

Hurricanes, more appropriately tropical cyclones, have the potential to be highly destructive to coastal structures, habitats and communities (see Pielke et al., 2008). Hurricane Irene has once again brought to the forefront the shortcomings of SSHS in extensive use since the 1970s. Improved measures of hurricane intensity and damage potential (e.g. Kantha, 2008, Irish and Resio, 2010a, b) are therefore needed. For more details, the reader is referred to Kantha (2012) and the references cited therein.

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Table 1
Saffir–Simpson hurricane scale (SSHS).

Type	p_c (mb)	V_{max} in m/s (mph)	Surge in m (ft)
TD	1007	< 17 (< 39)	
TS	< 1000	17–33 (39–73)	
Cat 1	980	33–42 (74–95)	1.2–1.5 (4–5)
Cat 2	979–965	43–49 (96–110)	1.8–2.4 (6–8)
Cat 3	964–945	50–58 (111–130)	2.7–3.7 (9–12)
Cat 4	944–920	59–69 (131–155)	4.0–5.5 (13–18)
Cat 5	< 920	> 70 (> 156)	> 5.5 (> 19)

SSHS was originally designed by Herebert Saffir to be an index of the potential *intensity* of wind damage. Thus it is neither an indication of the true *intensity* of the hurricane nor the potential *extent* of wind damage. The then director of NHC, Mr. Simpson added rough estimates of potential storm surge and the resulting SSHS has been used by NHC until recently. In 2009, after Katrina demonstrated unequivocally that storm surge potential based simply on SSHS is misleading, NHC removed the storm surge estimates from SSHS. But the basic scale is still retained.

A peculiar aspect of the SSHS is that, unlike the Richter earthquake scale, the resulting values are quantized. Each category hurricane has a range of properties assigned to it. This means that a change of just a m/s (few mph) in maximum speed near the transition value can make a unit change in the category, which can be highly misleading to the general public (see Table 1). On this scale, if the maximum sustained wind speed is between 49.6 and 58.1 m/s (111 and 130 mph), the hurricane is classified as Category 3; if between 42.9 and 49.2 m/s (96 and 110 mph), as Category 2, and if between 33.1 and 42.5 m/s (74 and 95 mph), as Category 1. If the maximum speed falls to or below 32.6 m/s (73 mph), it becomes just a tropical storm. Irene was initially designated as a Category 3 hurricane, but was downgraded to Category 2 as it neared North Carolina because the maximum wind speeds had dropped a mere 5 mph from 51.4 m/s (115 mph) to 49.2 m/s (110 mph). However, the intensity of the hurricane, which depends on the square of the wind speed, had decreased by only 8.6%. The hurricane was later downgraded to Category 1. These incorrect and ill-advised downgrades dictated by the inherent discrete nature of SSHS are not just confusing to the public and the decision-makers such as local public officials, but might lead to complacency among some and increase public risk.

SSHS also saturates at its higher end because no matter how much higher the maximum speed goes above 69.7 m/s (156 mph), the hurricane is characterized as Category 5. Granted that once the hurricane reaches Category 5, it is sufficiently destructive that further increases may not make much difference, it is still desirable to devise a scale that does not saturate at the higher end, especially since global warming could very likely spawn much stronger hurricanes in the coming decades. Because of ongoing climate change, it is quite possible that some cyclones in the future could exceed Category 5. As clearly demonstrated by hurricanes Katrina, Wilma and Ike, the SSHS is also a grossly misleading index of the *extent* of hurricane impact to be expected. One needs to know not just the hurricane intensity and hence the *intensity* of expected damage in localized domains but also the *extent* of expected damage so that adequate relief measures can be organized.

Judging by the economic cost, the Category 3 hurricane Katrina of the 2005 hurricane season did far more damage (even ignoring the damage done to the city of New Orleans by widely-predicted but unanticipated levee breaks and concentrating merely on the physical damage in Louisiana, Mississippi and Alabama) than the Category 5 Hurricane Andrew did in 1992. For details, see Demirbilek (2010) and fourteen papers included in that Special Issue dedicated to the Hurricane Katrina. This anomaly can be explained by noting that Katrina was almost three times the size of Andrew, with hurricane winds extending to 217 km (135 miles) in radius. The result was that the damage extended along a larger stretch of the coastline. The enormous size of Irene (with hurricane-strength winds extending 140 to 205 km (87 to 128 miles) from the center and tropical-strength winds extending roughly three times as much) is one reason for the extensive wind damage in North Carolina, and of course the wide-spread rainfall and flooding in the northeast US. Storm size matters as much as storm intensity.

Table 2 (adapted from Kantha (2010)) shows prominent Atlantic cyclones that have made landfall in the US. R_{33} is the radius of the hurricane winds (in km), p_c is the central pressure (in mb), L_{30} is the distance to 30 m isobath (in km), SSHS is the Saffir–Simpson scale, SS is the Irish and Resio (2010a, 2010b) surge index, and $Y_{2\ m}$ is the lateral extent of inundation over 2 m (in km). Maximum velocity (V_{max} in m/s) values are from NHC database and so are values of the forward speed at landfall (V_{sp} in m/s). HII and HHI are hurricane intensity, and wind impact indices from Kantha (2006, 2008). Surge index SSI and surge impact index HSI are from Table 1 of Kantha (2010), but values have been corrected for a mistake that made the values slightly higher than the correct values shown in Fig. 1 of Kantha (2010). Note that hurricanes Irene, Isaac and Sandy have been added to the table.

The three catastrophic tropical cyclones in recent years (Katrina in 2005, Ike in 2008 and Sandy in 2012) have demonstrated conclusively that the damage inflicted by a land-falling tropical cyclone does not depend merely on its category on the Saffir–Simpson hurricane scale. Katrina, only a Category 3 hurricane at landfall, caused more physical surge and wind damage than the Category 5 hurricane Camille did in 1969, along the same US Gulf coast. A similar situation occurred again in 2008, when the weak Category 2 hurricane Ike hit the Texas coast and caused extensive storm surge damage there and surprisingly, along the distant southeast Louisiana coast as well. This naturally raises the question in people's minds: how is it that relatively weak hurricanes can wreak so much havoc? The answer to this question necessarily involves the storm size. The relatively large sizes of both Katrina and Ike indicate that the impact potential of a tropical cyclone is also a function of its size. The larger the hurricane, the higher its impact potential, even if its intensity is the same. Since only the SSHS is widely disseminated, the lay public (and local officials not privy to sophisticated models and other data at the federal level) is generally unaware of the true destructive potential of a tropical cyclone. Consequently, there was widespread puzzlement in 2008 as to how a mere Category 2 hurricane Ike could cause so much devastation. Based on the fact that Katrina was *only* a Category 3 at landfall, many people on the Gulf Coast expected it to be far less destructive than the 1969 Category 5 hurricane Camille, and this might have led to complacency among some and compounded the Katrina tragedy.

3. Alternative indices

Alternative indices have been proposed recently to overcome the above-mentioned deficiencies but have not been adopted by NHC. The delineations of hurricane intensity in the SSHS are not based on flow dynamics. The basic tenet of fluid dynamics is that the forces exerted by the fluid must be proportional to the dynamic pressure, the product of the fluid density and the square of the fluid velocity. Whether it is a hurricane, a tornado, a winter storm or a katabatic wind *does not matter*. The storm strength must be proportional to the square of the maximum wind speed,