3.1 STANDARDIZING HURRICANE SIZE DESCRIPTORS FOR BROADCAST TO THE PUBLIC

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1. INTRODUCTION

The effects of Hurricanes Katrina and Ike in 2005 and 2008, respectively, have highlighted the importance of the size attribute of the tropical cyclone (TC), together with track and intensity, in constituting the threat to the public. These two large storms, bearing Saffir-Simpson (SS) intensity designations of SS3 and SS2, respectively, presented dangers greater than their SS categories would have indicated to some, in part, because of the additional dimension of threat posed by their size.

Size, a storm attribute, is analogous to track and intensity; all three are characteristics of the storm itself. Storm attributes as a class are distinct from storm effects, defined as the physical phenomena the TC produces at a location, e.g., storm surge, rainfall, high winds. The National Hurricane Center (NHC) and local National Weather Service (NWS) advisories include estimates and forecasts for the track, intensity, and size attributes of storms, as well as projections of likely storm effects at various locations.

During the approach of a TC, broadcast media routinely convey operational forecasters' knowledge about track and intensity, and about likely storm effects, to general audiences. The communication of storm size is significantly more complex. The relevant concepts, e.g., wind radii, are technical and require detailed and lengthy explanation to be properly understood by nonspecialists. In addition, the numerical size descriptors pertaining to the radii may not by themselves be particularly meaningful to general audiences without some preexisting sense of scale as it pertains to Atlantic hurricanes.

Nontechnical size descriptors, both scalable and nonscalable, e.g., "large" and "growth", respectively, are also utilized, but their usages and meanings are not standardized. Although these terms have definitions pertaining to the size attribute that are standard in the research sector, they are sometimes employed colloquially outside that sector to describe storm intensity. Thereby, the size and intensity attributes of storms are linguistically conflated in the common usage. A consequence is that the natural descriptors of storm size have become, through informal practice, unavailable for the purpose of clearly and exclusively describing size.

2. RATIONALE

Elevating the profile of the size attribute, a significant component of the hurricane threat, to the same level as track and intensity is warranted by the direct implications of hurricane size for public safety. Size contributes to surge heights (Powell and Reinhold 2007, Irish et al. 2008, Dean, Emanuel, and Chavas 2009) and to the duration and extent of storm effects more generally. In addition, by virtue of the 34 kt wind threshold, it is intricately connected to evacuation timing and deadlines (Powell and Houston 1998, Knaff 2006).

Describing the size of a TC to general audiences contains a number of inherent difficulties. The wind radius, the quantity captured by the numerical size descriptor, is a technical construct, mathematical in nature. The asymmetry of the wind field necessitates the division of the storm into its quadrants, also a technical notion, which results in four numerical values (NE, SE, SW, NW) for each forecast time instead of only one. Estimates and projections are issued for three different wind thresholds, 34 kt, 50 kt, and 64 kt, yielding a 3 x 4 numerical table rather than a single row of four values. Although an efficient framework for recording and transmitting data within the scientific disciplines, the tabular format is not necessarily familiar or meaningful to those outside those disciplines. The size data, which appear in this format, would have to be fully deconstructed and “uncompressed” by the broadcaster in order for the knowledge behind the data to be meaningfully conveyed to the public.

A further difficulty emerges because, although forecasters always describe and quantify size in terms of radius, the logic of which derives from the physical structure of hurricanes, broadcasters sometimes follow suit, but other times they describe and quantify storm size in terms of diameter. This lack of standardization in the reported quantity renders more

difficult the gradual emergence among the public of an intuitive sense of scale from repeated exposure to familiar ranges of numerical values. Finally, the discrepancy surrounding the units of measurement, specifically, the use of nautical units by forecasters and English units by the general public, presents an additional barrier to conveying knowledge about storm size to nonspecialists.

As the size attribute of hurricanes is operationally difficult to estimate and forecast, the resulting wind radii values as they appear in the advisories are subject to large errors and difficult to verify (Knaff 2006, Knaff et al. 2007, NHC 2012b). The detailed technical explanations of the raw data must also therefore include discussions about the large degree of uncertainty, itself an abstract, technical concept the successful communication of which has long eluded hurricane forecasters and broadcasters alike.

Instead of the complex technical explanations, it might be more beneficial to build the uncertainty into the size descriptors by constructing them to incorporate a range of numerical values, and to tag them with nontechnical labels capable of conveying a sense of scale to nonspecialist audiences. Scalable size descriptors would thus be employed to convey to members of the public whether the hurricane or tropical storm approaching their coastline, given its estimated and forecast size, is or is forecast to be particularly small or large as storms go.

3. METHODOLOGY AND DATA

This research involved an analysis of nonnumerical forecaster size characterizations (e.g., “small”, “medium”, “large”, “very large”) of past hurricanes and tropical storms as recorded in the NHC archives, in the context of the then-current estimates of the radii of the 34 kt winds (hereafter R34, the same as the gale- or tropical storm-force winds) of those storms. For those TCs whose size characterizations were found in NHC advisories, the R34 estimates in the forecast advisory text products were taken as representative of the objective size knowledge forecasters had available at the time on which to base their characterizations. For those storms whose size characterizations were found in the NHC poststorm Tropical Cyclone/Preliminary Reports or other official sources rather than in real-time advisories, the R34 estimates came from the Extended Best Track (EBT) database (Colo. State Univ. 2012), which contains these data going back to 1988. In the case of two historical hurricanes that predate the EBT coverage period, Hurricanes Carla (1961) and Camille (1969), the objective size estimates came from the Hurricane Research Division's H-Wind analyses. It was hypothesized that the set of operational forecasters’ characterizations would be more or less internally consistent. If so, whatever forecaster characterizations were found could, in their aggregate, form the underlying basis of a set of standardized nontechnical relative size descriptors for use in conveying forecasters’ knowledge about storm size to North American audiences.

The EBT dataset was additionally consulted for the radius of the outer closed isobar (ROCI), another measure of size, for each TC coinciding with the dates and times of the forecaster size characterizations. For those storms whose characterizations were found in the Tropical Cyclone/Preliminary Reports or other official sources rather than in real-time advisories, the estimated ROCI at landfall were taken instead. The characterizations and the estimated ROCI were analyzed together against the classification provided by Merrill (1982), which scaled Atlantic TC size according to the ROCI in a multi-ocean basin climatological study. It was hypothesized that the size characterizations of the forecasters would be roughly consistent with the size ranges presented in that study. If so, standardized size descriptors for use with Atlantic basin populations could be anchored in both the operational and research sectors, thus achieving a degree of consistency across the research to operations threshold.

4. RESULTS

Storm size, or the spatial extent of the wind field, is alternatively defined as either the R34 or the ROCI (Holland and Merrill 1984, Kimball and Mueller 2004, Knaff and Zehr 2007). Other definitions have been proposed (e.g., Liu and Chan 1999), and a variety of customized size parameters has been utilized for specialized research purposes.

Neither the R34 nor the ROCI is a perfect measure of storm size. The R34 does not include the entire wind field, and by definition it cannot be used to describe the size of tropical depressions, while the ROCI, as discussed in Dean, Emanuel, and Chavas (2009), underestimates the outer wind radius. Most importantly for practical purposes, operational

forecasters in the Atlantic basin estimate and forecast values of R34 and include them in the advisory packages, which is not the case for the ROCI or any of the alternate size parameters.

a. The global size scale

The global TC size classification employs nontechnical relative size descriptors (Table 1), but it cannot be meaningfully used to convey forecasters' knowledge about hurricane size to North American audiences. Merrill (1984) found Atlantic TCs to be, on average, approximately 1.5 degrees of latitude smaller than their Pacific counterparts. Given that Atlantic hurricanes and tropical storms are relatively small by global standards, it follows that a hurricane considered large by Atlantic basin standards might fall closer to the middle part of the range on the global scale (Table 2). In addition, the global scale defines size according to the ROCI, while the NHC advisories, the operational forecasting products released to the public, contain estimates and projections of values of R34.

Global Tropical Cyclone Size Scale

ROCI (°LAT.)	ROCI (NM)	SIZE
< 2	< 120	Very small/midget
2 - 3	120 - 180	Small
3 - 6	180 - 360	Medium/average
6 - 8	360 - 480	Large
> 8	> 480	Very large

Table 1. The global tropical cyclone size scale, which utilizes the ROCI as the definition of storm size (JTWC 2012).

Global Size of Selected Atlantic Hurricanes

STORM	ROCI (NM)	ROCI (° LAT.)	GLOBAL SIZE
1999 Floyd	300	5	Medium/avg
2003 Isabel	300	5	Medium/avg
2008 Ike	300	5	Medium/avg
2005 Katrina	350	6	Medium/large
2010 Igor	400	7	Large

Table 2. Several Atlantic hurricanes during their approach, large by Atlantic standards, as they would be described according to the global size scale. The estimated ROCI (nm) for these hurricanes are from the EBT archive (Colo. State 2012).

Meaningful conveyance of size-related knowledge to North American audiences thus necessitates that the basis of comparison for a current storm should be other Atlantic hurricanes and tropical storms and not tropical cyclones globally. A coastal resident in a hurricane-prone region in North America might legitimately inquire: 'Is this storm small or large within the range of storms we get?' Since the R34 is an accepted definition of TC size, and since there is no forecast for the ROCI and the NHC estimate is not included in the advisories, archived estimates and forecasts of R34 in the Atlantic basin are taken as the primary reference point. The resulting standardized size descriptors, with R34 as the definition of size, should be suitable for broadcast to North American audiences for both tropical storms and hurricanes.

b. Constructing the standardized size descriptors

A sample of North American landfalling hurricanes and tropical storms during the period 1995-2010 for which size characterizations by NHC forecasters were found in the archived advisories, Tropical Cyclone/Preliminary Reports, or other official sources, are listed in Table 4, together with the estimated outermost R34 for those TCs at the corresponding dates and times. The outermost R34 in any quadrant is taken instead of the average of all four quadrants for a variety of operational, practical, and public safety reasons. Several well-known historical hurricanes for which forecaster size characterizations and R34 estimates were found are also included.

It was hypothesized that the forecasters' size characterizations of Atlantic TCs would be more or less internally consistent, which they are, and that the characterizations would be roughly aligned with the Atlantic size ranges in Merrill (1982), which they generally are, with the major exception of a gap in forecaster characterizations describing the middle of the size range. Examination of the NHC advisories revealed a tendency of the forecaster size characterizations to move directly from "small" to "large" (Table 4), with no term indicative of the middle of the range. Further, a number of the TCs characterized as "large" were not estimated numerically to be much larger than those characterized as "small."

It is possible to make some space for the middle of the range and attach the label "medium" to those storms, using Merrill's Atlantic size (Merrill 1982) as guidance (Table 5). In his study, Merrill introduced a procedure for measuring storm size according to the

ROCI, and by this definition, he estimated the average size of an Atlantic TC to be on the order of 3 degrees latitude (180 nm). Table 3 lists his size ranges for small, medium, and large tropical cyclones specifically for the Atlantic basin.

Merrill's Atlantic Tropical Cyclone Size

ROCI (° LAT.)	SIZE
1-2	Small
= 3	Medium
> 3	Large

Table 3. Atlantic tropical cyclone size defined according to the ROCI and expressed in degrees latitude (Merrill 1982).

Forecaster Size Characterizations for a Sample of Atlantic Tropical Cyclones, 1995-2010

STORM	DESCRIPTION	DESCRIPTION SOURCE	R34 (OUTERMOST, NM)	DATA SOURCE
SMALL				
2007 Gabrielle	"very small"	Forecast Discussion 8	40	Forecast Advisory 8
2007 Humberto	"small"	TC Report	50	Extended Best Track
2007 Lorenzo	"very small"	Forecast Discussion 11	60	Forecast Advisory 11
1999 Bret	"small"	Forecast Discussion 7	90	Forecast Advisory 7
2004 Charley	"small"	TC Report	100	Extended Best Track
2007 Felix	"relatively small"	Forecast Discussion 16	100	Forecast Advisory 16
2008 Cristobal	"small"	NASA	110	Forecast Advisory 11
1992 Andrew	"relatively small"	TC Report	120	Extended Best Track
1969 Camille	"small"	Preliminary Report	125	HRD H-Wind
2001 Iris	"small"	TC Report	125	Extended Best Track
LARGE				
1999 Dennis	"larger than average"	TC Report	140	Extended Best Track
1998 Earl	"fairly large"	Forecast Discussion 6	150	Forecast Advisory 6
2004 Frances	"large"	Forecast Discussion 35	160	Forecast Advisory 35
2008 Gustav	"large"	Public Advisory 27	175	Forecast Advisory 27
2005 Rita	"large"	TC Report	180	Extended Best Track
2007 Dean	"large"	Forecast Discussion 25	180	Forecast Advisory 25
1995 Opal	"large"	Forecast Discussion 20	200	Forecast Advisory 20
1998 Bonnie	"large"	Public Advisory 28	200	Forecast Advisory 28
2004 Ivan	"large"	Public Advisory 52	225	Forecast Advisory 52
2005 Wilma	"large"	Public Advisory 37	225	Forecast Advisory 37
2009 Bill	"large"	Public Advisory 21	225	Forecast Advisory 21
1996 Fran	"large"	TC Report	250	Extended Best Track
1999 Floyd	"large"	Forecast Discussion 30	250	Forecast Advisory 30
1961 Carla	"large"	Hydromet. Prediction Ctr.	300	Preliminary Report
2003 Isabel	"large"	TC Report	300	Extended Best Track
VERY LARGE				
2005 Katrina	"very large"	Public Advisory 25	200	Forecast Advisory 25
2008 Ike	"unusually large"	Forecast Discussion 46	240	Forecast Advisory 46
2010 Igor	"particularly large"	Public Advisory 40	300	Forecast Advisory 40

Table 4. Operational forecaster size characterizations of a sample of North American landfalling hurricanes and tropical storms occurring between 1995 and 2010, from the NHC archives (NHC 2012a) and other official sources, and estimated R34 (Colo. State 2012, NHC 2012a).

Derivation of Standardized Atlantic TC Size Descriptors from NHC Characterizations and Merrill's Atlantic Size

STORM	R34 (OUTERMOST, NM)	NHC SIZE CHARACTERIZATION	ROCI (NM)	MERRILL'S ATLANTIC SIZE ROCI (° LAT., ROUNDED)
SMALL				
2001 Iris	125	"small"	100	small 2°
2004 Charley	100	"small"	100	small 2°
2007 Lorenzo	60	"very small"	100	small 2°
1999 Bret	90	"small"	120	small 2°
2007 Gabrielle	40	"very small"	120	small 2°
2007 Humberto	50	"small"	120	small 2°
1992 Andrew	120	"relatively small"	125	small 2°
1969 Camille	125	"small"	140	small 2°
2008 Cristobal	110	"small"	140	small 2°
2007 Felix	100	"relatively small"	150	medium 3°
MEDIUM				
1999 Dennis	140	"larger than average"	175	medium 3°
1998 Earl	150	"fairly large"	200	medium 3°
2004 Frances	160	"large"	200	medium 3°
LARGE				
2004 Ivan	225	"large"	200	medium 3°
2007 Dean	180	"large"	200	medium 3°
2009 Bill	225	"large"	240	large 4°
1998 Bonnie	200	"large"	250	large 4°
2008 Gustav	175	"large"	275	large 5°
2005 Rita	180	"large"	300	large 5°
2005 Wilma	225	"large"	300	large 5°
2005 Katrina	200	"very large"	350	large 6°
2005 Opal	200	"large"	360	large 6°
VERY LARGE				
1996 Fran	250	"large"	250	large 4°
1999 Floyd	250	"large"	300	large 5°
2008 Ike	240	"unusually large"	300	large 5°
1961 Carla	300	"large"	n/d	large > 4°
2003 Isabel	300	"large"	300	large 5°
2010 Igor	300	"particularly large"	400	large 7°

Table 5. Standardized size descriptors (underlined categorizations), derived from NHC characterizations of past TCs and Merrill's Atlantic size. The R34 estimates (Colo. State 2012, NHC 2012a) and operational forecasters' size characterizations (NHC 2012a) are juxtaposed with the labels these TCs would bear at the corresponding time according to the Atlantic size chart appearing in Merrill (1982) based on their estimated ROCI (Colo. State 2012).

Standardized Atlantic basin storm size descriptors, thus derived, are defined in Table 6. A number of past hurricanes are listed in the adjacent column as examples; it was considered important that any standardized size descriptors for conveying size knowledge to North American audiences be consistent with well-established understandings and official descriptions of historical Atlantic basin hurricanes with respect to their size.

Standardized Size Descriptors (R34) for Atlantic Hurricanes and Tropical Storms

SIZE	R34 (OUTERMOST, NM)	EXAMPLES
SMALL	≤ 125	Camille, Andrew, Charley
MEDIUM	126 – 174	Emily, Dolly, Fay
LARGE	175 – 225	Frances, Katrina, Rita
VERY LARGE	> 225	Carla, Isabel, Ike

Table 6. Standardized size descriptors, taking R34 as the operative definition, to convey the size of approaching Atlantic hurricanes and tropical storms to North American audiences, and the application of these descriptors to several recent and well-known historical hurricanes.

c. Disentangling size and intensity descriptors

Some of the meanings of both scalable and nonscalable TC size terminologies are not well delineated in the casual discourse surrounding hurricanes; the most important of these is "growth." Growth is a size descriptor, “an expansion of the cyclone circulation” (Merrill 1984), but just as the term "large" is sometimes used colloquially in broadcast media to describe an intense hurricane, "growth" is sometimes used as a synonym for intensification. The opposite of growth is contraction, and the opposite of intensification is deintensification. Growth and intensification cannot be used interchangeably because they describe two separate TC attributes.

Carving out some logical space in which storm size can be discussed alongside track and intensity, with clear boundaries as to where one ends and the other begins, necessitates the disentanglement of the size descriptors, specifically, the terms "large" and "growth", from intensity, in which the problem emerges through the informal use of size descriptors to denote intensity.

5. CONCLUSION

The American public would benefit from easy to understand, nontechnical comparative size descriptors specifically for hurricanes and tropical storms occurring in their ocean basin. The standardized descriptors of small, medium, large, and very large to denote relative size for Atlantic TCs, grounded both in operational forecast products and poststorm reports, as well as in the research sector, and taking R34 as the definition of storm size, may be employed for this purpose.

The reinforcement of the existing standard definition of the nonscalable size descriptor “growth,” already defined in the research sector as an increase in TC size, and freeing both it and the scalable size descriptor “large” from their colloquial intensity-related usages would make it possible for broadcasters to report unambiguously what forecasters know about the size of an approaching hurricane, in much the same way as they already do with track and intensity.

The disentanglement of size from intensity, a precursor to the elevation of size among the general public as a storm attribute of recognized importance in its own right is also an important step in addressing the public confusion surrounding the meaning and significance of the SS categories, highlighted by the large-scale public underestimation of the dangers posed by Hurricanes Katrina and Ike.

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