

“Sometimes da #beachlife ain't always da wave”: Understanding People’s Evolving Hurricane Risk Communication, Risk Assessments, and Responses Using Twitter Narratives

JULIE L. DEMUTH AND REBECCA E. MORSS

National Center for Atmospheric Research, Boulder, Colorado

LEYSIA PALEN, KENNETH M. ANDERSON, JENNINGS ANDERSON, MARINA KOGAN,
KEVIN STOWE, AND MELISSA BICA

University of Colorado Boulder, Boulder, Colorado

HEATHER LAZRUS AND OLGA WILHELMI

National Center for Atmospheric Research, Boulder, Colorado

JEN HENDERSON

Cooperative Institute for Research in Environmental Sciences, Boulder, Colorado

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ABSTRACT

This article investigates the dynamic ways that people communicate, assess, and respond as a weather threat evolves. It uses social media data, which offer unique records of what people convey about their real-world risk contexts. Twitter narratives from 53 people who were in a mandatory evacuation zone in a New York City neighborhood during Hurricane Sandy in 2012 were qualitatively analyzed. The study provides rich insight into the complex, dynamic information behaviors and risk assessments of people at risk, and it illustrates how social media data can be collected, sampled, and analyzed to help provide this understanding. Results show that this sample of people at significant risk attended to forecast information and evacuation orders as well as multiple types of social and environmental cues. Although many tweeted explicitly about the mandatory evacuation order, forecast information was usually referenced only implicitly. Social and environmental cues grew more important as the threat approached and often triggered heightened risk perceptions or protective actions. The results also reveal the importance of different aspects of people’s cognitive and affective risk perceptions as well as specific emotions (e.g., fear, anger) for understanding risk assessments. People discussed a variety of preparatory and protective behavioral responses and exhibited multiple types of coping responses (e.g., humor) as the threat evolved. People’s risk assessments and responses were closely intertwined, and their risk perceptions were not continuously elevated as the hurricane approached; they exhibited different ways of interpreting, coping, and responding as they accessed and processed evolving information about the threat.

1. Introduction

The risks posed by many natural hazards are dynamic in that the threat and information available about it evolve. When a hurricane threatens a coastline, for example, its position and intensity changes, and forecast and preparedness information is refined as the storm approaches. People’s assessments of and responses

to natural hazard risks are also dynamic, as individuals process information and interact with each other to communicate about, interpret, and respond to the changing threat. These dynamic individual and social processes are fundamental aspects of how people perceive and respond to natural hazards (Morss et al. 2017). Thus, it is essential to understand them in order to develop effective risk communication and emergency response policies that help protect people from harm.

Corresponding author: Julie L. Demuth, jdemuth@ucar.edu

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Although previous research notes that people may iteratively assess and respond to a threat (Lindell and Perry 2012; Mileti and Sorensen 1990), there is little empirically based understanding of how this actually occurs for an evolving risk, such as that posed by an approaching hurricane. This lack of knowledge derives partly from the difficulty in gathering data from people about what they know, perceive, feel, and do at multiple times as a threat is occurring. These challenges are exacerbated by the inherent uncertainties associated with whether, where, and when hazardous weather events will occur, which make it difficult to know in advance who will be affected and thus to design and implement real-time data collection with those populations throughout a threat.

The prevalence of social media use offers new opportunities for studying the dynamic risk information ecosystem that emerges when hazards threaten (Morss et al. 2017). Although in the weather community social media is often discussed in terms of its potential for authorities to distribute risk information, it can offer much more. Social media offers intrinsically participatory platforms where users actively access, discuss, create, and share information about many topics, including information about their situations, attitudes, and behaviors related to risks (Palen et al. 2010; Neeley 2014). Moreover, when people post on social media more than once during the course of a threat, their posts offer a chronological record of how they are assessing and responding to a real-world, evolving risk from their context and perspective.

Here, we utilize social media data as a lens for examining individuals' risk information behaviors, risk perceptions, and responses as a hazardous weather threat unfolded over several days. We investigate these processes by qualitatively analyzing Twitter narratives created by people at risk from Hurricane Sandy¹ during the time period leading up to and during the storm's landfall. The Twitterers analyzed were located in the Far Rockaway neighborhood of New York City, which was in a mandatory evacuation zone during Sandy. Complementing recent work that utilizes Twitter data for macrolevel analyses of what hazard information is shared, how much, and by whom across broader populations (see section 2), we perform an in-depth analysis that aims to build a rich understanding about how individuals experience evolving risks.

¹ The day that Hurricane Sandy made landfall, it transitioned to a posttropical storm, and thus was no longer referred to as a hurricane by the National Weather Service (NOAA 2013a,b). However, for simplicity, we refer to it as Hurricane Sandy throughout the article.

Our study addresses three research questions:

- 1) How do people interact with different types of information related to the hurricane threat?
- 2) How do they perceive and respond to the risks posed by the hurricane?
- 3) How do these processes evolve and interact as the threat unfolds?

We focus on the time period leading up to landfall because we are interested in investigating evolving forecast and preparedness information as a form of risk communication that can influence people's risk assessments and responses. Moreover, the dynamics of this time period is understudied compared to the response and recovery phases of a hazard, even as studied through social media (Shelton et al. 2014; Morss et al. 2017).

The goal of this analysis is to gain a deeper understanding of the complex and evolving ways that people assess and respond to their risk from the dynamic threat of an approaching hurricane by analyzing social media narratives from a sample of individuals who were at high risk leading up to Sandy. In doing so, we aim to augment knowledge gained from other studies that utilize complementary methods, samples, and theories to investigate behavioral responses to risks. We further aim to provide a foundation for additional research investigating similar questions using social media data, including broader Twitter datasets.

This study adds to the weather risk, natural hazards, and social media literatures in several ways. First, it reveals what is salient to people who are at risk from an approaching hurricane as they process the ubiquitous pieces of risk-related information available to them, evaluate the risk, and decide how to respond. Because the Twitter narratives we investigate provide a new type of data for understanding how people assess and respond to risks, the analysis reveals aspects of these processes that have not previously been well described in the theoretical and empirical literatures. It also develops new knowledge about the dynamics of these processes, for example, what factors are important at different times and how these intersect and change as a threat evolves. Finally, the analysis illustrates the potential value not only of social media data, but also of social media narratives, for building understanding about how people interact with information and perceive and respond to evolving threats.

2. Background and study scope

A number of previous studies have investigated how people assess and respond to hurricane risks [see, e.g., reviews by Baker (1991), Dash and Gladwin (2007),

Lindell (2012), Lazo et al. (2015), and Huang et al. (2016)]. This body of work provides important knowledge about how people's perceptions of hurricane risks and their protective decisions are influenced by a variety of factors, ranging from sociodemographic characteristics to situational factors to risk messages. Much of this research utilizes data gathered through surveys, survey-based experiments, or interviews to understand how people perceive risks and make decisions at a specific point in time or integrated across a hurricane threat. Fewer studies have focused on understanding how people's decision processes evolve over the lifetime of a hurricane using, for example, retrospective interviews (Gladwin et al. 2001; Taylor et al. 2009; Morss and Hayden 2010), simulations (Christensen and Ruch 1980; Meyer et al. 2013; Wu et al. 2015a,b) or multiple phone surveys conducted during the same hurricane threat (Meyer et al. 2014). Because hurricane threats and responses are dynamic, as Meyer et al. (2014, p. 1402) note, "additional attempts to conduct real-time measurements of responses to natural hazards" are needed—particularly multiple measurements from the same sample of people. Social media data provide one means for potentially filling this gap, whereby an individual's postings and shares over time constitute "multiple measurements" for analysis.

Social media is a useful resource for studying hazards and disasters because it is a participatory platform that users actively and creatively leverage during disruptive, uncertain situations (Palen et al. 2010; Neeley 2014; Houston et al. 2015). As such, social media helps make visible the individual and social processes that have long been thought to contribute to how people assess and respond to risks. The information that people share on social media is quasi real time, in that it can reveal what they observe, think, or feel at that moment, or it can be summative and reflective. In the context of hazards, this information may be about the threat, situations, attitudes, perceptions, and behaviors pertaining to one's own or others' risk.

Much of the research noted above collects data about how people assess and respond to hurricane risks using questions structured by the researcher. Social media provides a different type of data, with its content determined by what a person chooses to convey in quasi real time from their perspective. The collection of information from a social media user over a period of time constitutes a narrative, that is, a "written text giving an account of an event/action or series of events/actions, chronologically connected" (Creswell 2007, p. 70). These narratives can be analyzed to investigate timing, changes, and causal connections in what people share. In short, social media leave "digital traces" of individuals'

perspectives when faced with real-world, changing risks, providing researchers a window into people's evolving risk assessments and decision-making (Palen et al. 2010; Morss et al. 2017).

Twitter is one social media platform that is particularly conducive to research because the data are publicly available (Twitter 2016). Tweets are limited to 140 characters (as of November 2017, tweets may now contain up to 280 characters), but they nevertheless can provide a rich source of information, including the tweet text itself and embedded emoticons or emojis along with Internet links to websites, photos, Facebook posts, and so forth. Thus, researchers are leveraging Twitter to investigate different hazard and crisis events. Twitter research of weather hazards includes studies of winter weather, floods, tornadoes, and hurricanes, including Hurricane Sandy. One area of emphasis within this body of research is the temporal and geospatial patterns in hazard-related Twitter data and their covariation with other factors, such as National Weather Service watches and warnings or economic damages (Lachlan et al. 2014a; Ripberger et al. 2014; Shelton et al. 2014; Kryvasheyev et al. 2016). Scholars also have studied Twitter activity by public safety organizations and news media, including their tweet content and citizen engagement (Cates et al. 2013; Hughes and Palen 2014; Lachlan et al. 2014b; St. Denis et al. 2014; Sutton et al. 2015; Rice and Spence 2016). Other areas of research include classifying "useful information"² or expressions of emotion in citizen's tweets (Brynielsson et al. 2013; Lachlan et al. 2014a,b; Spence et al. 2015) and investigating local versus nonlocal information sources and behaviors (Shelton et al. 2014; Kogan et al. 2015).

These Twitter-focused research studies provide valuable knowledge about the Twitter information ecosystem during weather hazards. In most studies, however, the units of observation and analysis are the individual tweet (or a subset of the individual tweet), and thus the tweet datasets are derived accordingly (e.g., by using only certain keywords or hashtags, by only gathering a set number of most recent tweets at a point in time). Consequently, other tweet content that may be relevant goes uncollected and unanalyzed. Moreover, individual and social evolutions in and connections among risk information, perceptions, responses, and

² These authors operationally define useful informational tweets as "those whose primary intent was to provide information concerning the technical aspects of the storm or specific mitigation efforts" (Lachlan et al. 2014b), and that such information "included risk, loss of assets, food/shelter, evacuation, the whereabouts of others, financial assistance, cancellations, and care for the sick and elderly" (Spence et al. 2015).

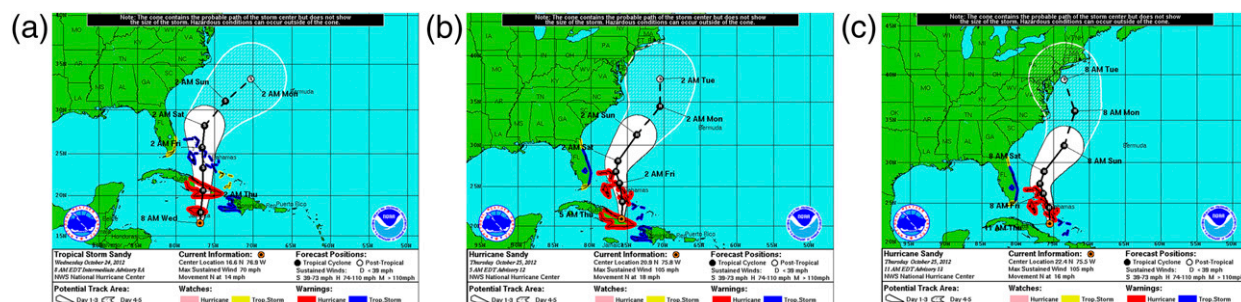


FIG. 1. The National Hurricane Center's 5-day forecast track and cone of uncertainty for Sandy, issued (a) Wednesday, 1200 UTC 24 Oct 2012; (b) Thursday, 0900 UTC 25 Oct 2012; and (c) Thursday, 1500 UTC 25 Oct 2012.

other factors—which are key topics of interest in our research questions—are less able to be investigated.

Here, we add to the extant research by studying a sample of people who were at risk from a dynamic weather threat and examining how they evaluated and managed this evolving risk. As discussed in detail in section 3b, we identified users who were at high risk of Sandy and collected all of the tweets in their narratives (and associated images and other content) over a multiday period as the storm approached and made landfall. This approach allows us to acquire and analyze tweets in which users discuss the risk of Sandy but that do not necessarily use any researcher-defined keyword. This approach also allows us to analyze the context of, associative and causal connections among, and evolutions in a user's tweets.

We analyze these narratives qualitatively to address the three research questions presented in the introduction. Our analysis draws empirically on knowledge from previous research on hurricane risk communication and evacuation decision-making, including the studies noted above. We also draw on concepts and theories from the risk communication and hazards literatures, including Lindell and Perry's (2012) Protective Action Decision Model (PADM), which is a multistage, iterative framework that models people's responses to environmental hazards. More specifically, the analysis draws on representations of information sources (forecast and warning messages, social cues, environmental cues), threat perceptions (cognitive and affective), and responses (communication, protective, and emotion focused) from the PADM and other literature (e.g., Mileti and Sorensen 1990; Peacock et al. 2005; Trumbo et al. 2016; Demuth et al. 2016). However, the analysis ultimately is based on the content of the Twitter narratives. Thus, in addition to elucidating how people discuss these concepts in ways that are consistent with what is characterized in the existing literature, our analysis reveals new aspects of how people experience hazard threats.

3. Methods

a. Hurricane Sandy: Summary of the event

Hurricane Sandy formed as a tropical depression in the Caribbean Sea on 22 October 2012. Over the next two days, the five-day hurricane track and cone-of-uncertainty forecasts from the U.S. National Hurricane Center projected Sandy moving north and making landfall in Jamaica, Cuba, and the Bahamas, and then curving northeast out to the Atlantic Ocean (Fig. 1a). Subsequent forecasts showed the hurricane recurving to the north, with indications that the northeastern U.S. coast could be affected (Fig. 1b). By late morning on 25 October, Sandy was projected to make landfall near New Jersey (Fig. 1c), and the forecast track and landfall location remained consistent over the subsequent days. On 28 October just before 1530 UTC, New York City's Mayor Bloomberg announced a mandatory evacuation order for zone A of New York City, which included Far Rockaway (see section 3b). Sandy made landfall on 29 October at approximately 2330 UTC along the New Jersey coast, approximately 140 km south-southwest of Far Rockaway. Far Rockaway experienced sustained winds of approximately 50 kt (25.7 m s^{-1}) and a storm surge of approximately 1.5–1.8 m (5–6 ft.) above ground level (NOAA 2013a,b).

b. Hurricane Sandy Twitter data collection, sampling, and analysis

As Palen and Anderson (2016, p. 225) articulate, “a tempting myth is that large volumes of social media data alone will reveal patterns of behaviors.” Yet, in order to develop robust, meaningful findings, data from social media (like other forms of research data) must be extracted and sampled in ways that match the research questions. To develop such a dataset for this study, we used a multistep process (Palen and Anderson 2016).

First, beginning on 24 October 2012, we used Twitter's public streaming application program interface (API)

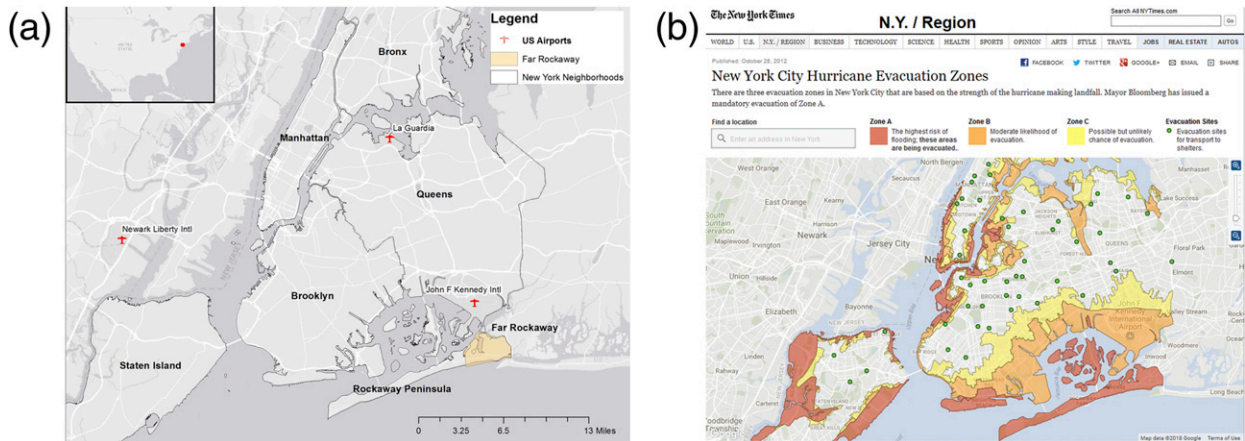


FIG. 2. (a) Study location of Far Rockaway, located in the Queens neighborhood of New York City, New York, and (b) map showing the issuance and location of the mandatory evacuation of zone A for Hurricane Sandy along with the location of the other nonevacuated zones (*New York Times* 2012).

to collect, in real time, all tweets³ that included any of the following Sandy-related keywords: frankenstorm, hurricane, hurricanesandy, perfectstorm, sandy, sandycam, stormporn, and superstorm (Kogan et al. 2015; Morss et al. 2017). This collection yielded 15.9 million tweets worldwide through 16 November 2012.

Initial exploration of this Twitter dataset suggested that there were indications of information use, risk perceptions, and decision-making related to Sandy, but that mentions of these constructs were rare and difficult to extract from the global keyword dataset. After exploring several ways of sampling the Twitter data to support analysis of people's risk assessments, we focused our analysis on tweet streams provided by Twitterers who resided in geographic areas that were at high risk of strong winds and storm surge from Sandy and thus were asked to evacuate. In other words, we focused on people who were sufficiently exposed to Sandy that they might be deciding whether to take protective action—and thus utilizing Twitter in assessing their risk—prior to landfall. After exploring multiple ways to identify such a population in the dataset (Morss et al. 2017), we utilized a geographically based sampling strategy by selecting Twitterers who (leading up to Sandy) resided in an area that was at high risk from the hurricane and that experienced significant impacts. This approach is similar to that often used in posthurricane interview and survey studies, in which people are sampled from selected

geographic areas that were at risk and/or significantly affected by the storm.

We selected Far Rockaway, New York, to investigate our research questions for several reasons. Far Rockaway is a neighborhood on the Rockaway Peninsula of New York City, and thus it is at significant risk from storm surge flooding from coastal storms. Consequently, Far Rockaway is fully within New York City's evacuation zone A, and thus the entire neighborhood was under a mandatory evacuation order for Sandy (Fig. 2), and it experienced significant impacts from Sandy (Shelton et al. 2014; Superstorm Research Lab 2013). Far Rockaway also is a sufficiently distinct geographic "place" that Twitterers made reference to it, which we determined empirically by exploring its mention within the Sandy keyword-based dataset (described in the next paragraph) relative to other New York City neighborhoods that were under a mandatory evacuation order. The neighborhood distinction allowed us to subsample from the Sandy-keyword dataset using localized, place-based terms (Palen and Anderson 2016) without obtaining an overwhelming number of nonlocal Twitterers.

Identifying the set of Far Rockaway Twitterers was informed and refined by our exploration of the Twitter data; we searched the Sandy-keyword-based dataset for mentions of "farrockaway," "far rockaway," "far rock," and "farrock"⁴ in either the users' tweet content or their metadata during the period from 24 October through

³ Full details on the infrastructure supporting the data collection and analytics are in Anderson and Schram (2011), Schram and Anderson (2012), and Anderson et al. (2013).

⁴ We added "far rock" and "farrock" to our search after observing in the dataset with mentions of "farrockaway" and "far rockaway" that the neighborhood is often referred to in this way.

7 November. Next, using the full-archive, historical search from the Gnip API, we pulled *every* tweet authored by each of these Twitterers during the same time period. These “contextual” tweet streams provide a Twitterer’s narrative, which is important for interpreting tweets in context rather than in isolation and for finding tweets that are relevant to Sandy but that do not explicitly mention the Sandy keyword search terms used (Palen and Anderson 2016; Morss et al. 2017). This place-based, contextual dataset yielded 307 Twitterers with approximately 144 000 tweets [see Anderson et al. (2016) for more details].

The first two authors then read through the contextual tweet streams for the 307 Twitterers to identify those who were located in the Far Rockaway area leading up to Sandy’s landfall (rather than tweeting about it from afar). Users also were required to be tweeting primarily in English (for readability by the analysts), to have some original tweet content [versus all retweets (RTs)], and to have at least one original-content tweet pertaining to Sandy before or during landfall to allow for analysis of their risk assessments during this period. This process of pulling contextual tweet streams to identify a relevant Twitter user sample is what Palen and Anderson (2016, p. 225) refer to as “mak[ing] ‘Big’ data bigger, then smaller.” The resulting dataset for this article consists of 53 Far Rockaway–area Twitterers who generated 8660 tweets from 24 October through 7 November. The number of tweets per user during this period ranges from 6 to 1040 and the overall distribution is right skewed (median = 78.0, mean = 163.4, std dev = 228.0).

Per our research questions, we qualitatively analyzed these Twitter narratives, focusing on the Sandy-related information that the Twitterers attended to and shared, their perceptions of the risk to themselves and to others, their responses to the threat, and evolutions in these processes as Sandy approached and made landfall. Each tweet was analyzed in the context of the user’s full tweet narrative and in the context of the Sandy threat. When analyzing the data, we examined the tweet text itself as well as emoticons/emojis and linked content (images, Facebook posts, etc.), when publicly available. Our data analytic approach is iteratively deductive, drawing on theories of behavioral responses to risks and knowledge from previous empirical studies (section 2), and inductive, guided by what the 53 Far Rockaway users chose to tweet about, when, and how.

Per Twitter’s terms of service, unless individuals choose to protect their tweets, all tweets are visible to anyone with or without a Twitter account. Twitter’s privacy policy further explains that the company shares data with universities (Twitter 2016). The Twitter data analyzed here thus are publicly available. However, this

does not absolve researchers from responsibly treating Twitterers (Boyd and Crawford 2012; Zimmer and Proferes 2014; Bica and Anderson 2016). We have therefore taken several steps in our data presentation in accordance with our ethical considerations to respect and minimize risk of harm to the Twitterers. For all tweets presented, tweet authors were anonymized, web links were removed, profanity in tweets was redacted, and user names of other Twitterers who were explicitly named (i.e., @mentions) were anonymized except for Twitterers who clearly maintain a public profile (e.g., media professionals). Also, to make it more difficult to search for the Twitterers presented in section 4c, the tweet text in the narratives was modified in minor ways that do not alter the meaning. The tweet content was not otherwise modified (e.g., punctuation, capitalization, and misspellings were not corrected). Last, we have taken care to avoid presenting tweet content with identifying or sensitive information, and we focus on presenting tweets that illustrate points that are central to the research purpose.

4. Results

This section examines how people interacted with information and perceived and responded to risks leading up to and during Sandy’s landfall, as revealed by our analysis of the Far Rockaway Twitter narratives. The findings illustrate what was most salient to these high-risk individuals as Sandy threatened, as indicated by what they chose to tweet about.

The main informational, perceptual, and response-related themes in the data are depicted in Fig. 3. The information themes are discussed in section 4a, and the perception and response themes are discussed in section 4b. Exemplar tweets illustrating key points for these two sections are presented in Tables 1–9 and are referenced with alphanumeric identifiers. Although we use individual tweets as examples, these were interpreted in the context of the individuals’ narratives.

The primary emphasis in sections 4a and 4b is on characterizing the main concepts in Fig. 3, although aspects of their evolution and interactions are discussed. In section 4c, we discuss how these concepts evolve and interact in greater depth by examining four example Twitter narratives, presented in Tables 10–13 and again referenced with alphanumeric identifiers.

a. Risk information

Analysis of the Twitter narratives reveals that people attended to four major types of risk information as the hurricane threatened: weather forecast information, evacuation orders, social cues, and environmental cues (Fig. 3).

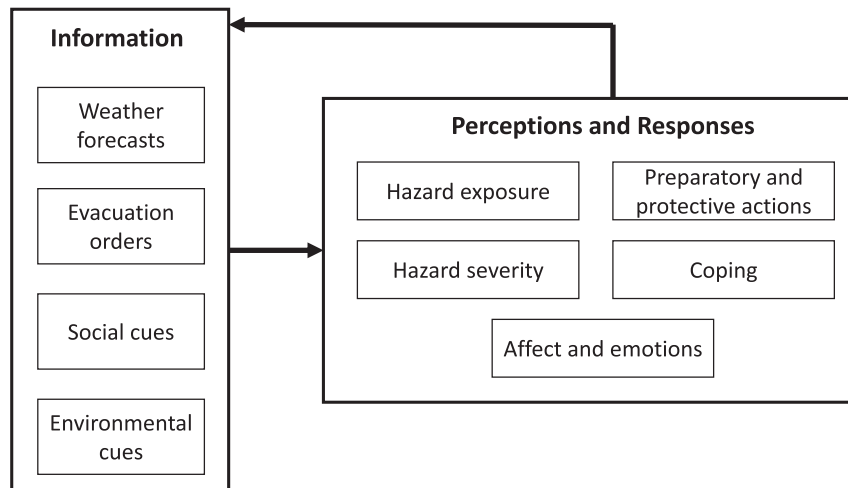


FIG. 3. Model of key types of hurricane risk information, perceptions, and responses and their interactions that emerged from analysis of Twitter data from Hurricane Sandy.

Many Twitterers made reference to information regarding the weather forecast for Sandy (Table 1). Most of these mentions were *implicit*, in that no specific forecast products or sources were named, yet the tweets indicate that the Twitterers had obtained some type of forecast information. Examples include references to the hurricane's forecasted timing of landfall and impacts (A1–A3), track (e.g., “a hurricane coming towards my crib again” in A4), and severity of impacts (A5). These examples illustrate how Twitter narratives can reveal the influence of forecasts even when people do not specifically mention them in the language typically used by forecasters.

Fewer Twitterers made *explicit* references to forecast information from formal sources or products. Those who did shared information about Sandy's forecasted timing of landfall (A6) and physical impacts, including storm surge (A7, A8) and wind gusts along the coast (A9, A10). Most of the explicit forecast mentions were RTs, such as those shown in A7 and A10 from private weather providers and in A8 from a public official. Some, however, tweeted in their own words about explicit forecast information that they obtained, for instance, from the National Weather Service (A6) or from television meteorologists (A9, Twitterer34's reference to being “in the 60–80 [mph] part” of the forecast map shown in Fig. 4).

The mandatory evacuation order was a salient piece of information for many of the Twitterers (Table 2). Mayor Bloomberg held a press conference to notify people about New York City's evacuation order, which included all of Far Rockaway, shortly before 1530 UTC on 28 October. Four people in our sample

tweeted about the evacuation order within one minute of the announcement (B1–B4), and over one-fifth tweeted about it within three hours; many others followed suit in the subsequent hours. Most of these Twitterers also conveyed that they were considering what the evacuation order meant for them personally, for instance, through indications of being displeased about needing to leave (B3–B7) as well as barriers they face in doing so (B3, B6). Although some, including those who tweeted about the mandatory evacuation order, ultimately decided not to evacuate for various reasons (see section 4b), expressions of defiance of the evacuation order (B8) were rare.

Social cues, that is, observations of others' behavior and other information from the social environment, have long been recognized to play an important role in people's risk assessments (Mileti and Sorensen 1990; Krimsky and Golding 1992; Renn 2008; Lindell and Perry 2012). Indeed, they are a central tenet of the social amplification of risk framework, which theorizes that risk assessments are amplified or attenuated through, among other things, social “stations” (e.g., opinion leaders, personal networks, organizations), which can affect the salience of a risk through the volume of information and interpretations about it (Kasperson et al. 1988, 2005). However, it is not well understood what social cues people find most significant when hazards threaten and how these cues influence risk assessments. This is true in general, and especially in the social media context, which expands and adds complexity to this dynamic social space.

Three key types of social cues emerged as prevalent in our data analysis (Table 3). The first type of social cue,

TABLE 1. Example tweets about weather forecast information.

Identifier	Example tweet [anonymized Twitterer (date, time in UTC) tweet text]
Implicit forecast information	
A1	Twitterer34 (25 Oct, 1756) @Z Yeah, I'm on the coast in the rockaways in NY, so we're looking to get pretty wet on Monday... ^a
A2	Twitterer12 (27 Oct, 2159) This hurricane stuff just ruined all of my plans for the first three days of the week -_-
A3	Twitterer40 (29 Oct, 0632) Hold up.....Sandy aint 'gon be here till Tuesday at 2 a.m., Im going to bed smh
A4	Twitterer7 (26 Oct, 2059) Why da **** is a hurricane coming toward my crib again. Its nov. Da season should be done. The Govt playing with that weather machine I see
A5	Twitterer35 (29 Oct, 0935) @Z yuppp still here last yr i stood for irene but now im thinkin to leave to bk cus its gonna be worst den Irene
Explicit forecast information	
A6	Twitterer21 (26 Oct, 1407) @Z landfall is expected Monday night, 6 p.m. last I checked with National Weather Service
A7	Twitterer34 (28 Oct, 1516) RT @nymetrowx ^b : From NHC ^c : "Sandy expected to bring life-threatening storm surge flooding to Long Island Sound and NY Harbor."
A8	Twitterer2 (27 Oct, 1532) RT @NYCMayorsOffice: Mayor: Latest forecasts are for an even greater storm surge hitting the coastal areas of the city. #Sandy
A9	Twitterer34 (28 Oct, 1507) We're on the coast in the 60-80 part. #Sandy [link to photo shown in Fig. 4]
A10	Twitterer4 (29 Oct, 1855) RT @TWCBreaking ^d : BREAKING: TWC's experts now expect localized wind gusts of 90 + mph near the coast of NJ, NYC, and Long Island later today.

^a In Tables 1–9, all user names in @mentions are anonymized (excepting users who clearly maintain a public profile) with the letter “Z.” Tweets with more than one @mention also are denoted by a number.

^b The abbreviation “wx” stands for “weather.”

^c NHC is the acronym for the National Hurricane Center.

^d TWC is the acronym for The Weather Channel.

and that perhaps most commonly described in the literature, is *cues from peers* (family, friends, neighbors, and others). These cues comprise protective and preparatory actions others are taking, such as boarding up one's home (C1), purchasing supplies (C2), or more general behaviors (e.g., “evrybdy is goin krzy” in C3). These cues also include information about others' perceptions, such as the lack of concern conveyed to Twitterer34 by his neighbor who “rode out” Hurricane Irene the previous year (C4). Although most tweets about peer cues are mentions of what others are thinking and doing (descriptive norms), some are messages from the tweet authors that aim to cue others

about what they should be thinking and doing (injunctive norms). For instance, on the morning of landfall, Twitterer38 directs people to “Get out of #farrockaway before it's too late!” along with a photo (not shown) of flooded roads (C5).

A second type of social cue is *cues from businesses*, such as the closing of coffee shops, stores, and restaurants for Sandy (C6–C8). These types of cues often were important amplifiers of the risk, as indicated by comments like “You know Rockaway's in trouble when Pickles and Pies is closed” (C7), especially if the Twitterers experienced that business staying open a year prior during Hurricane Irene (C8).

TABLE 2. Example tweets about evacuation information.

Identifier	Example tweet [anonymized Twitterer (date, time in UTC) tweet text]
B1	Twitterer33 (28 Oct, 1528) And there is the mayor's evacuation order for us. #sandy
B2	Twitterer34 (28 Oct, 1529) Mandatory evac of #ZoneA for hurricane #Sandy. About time, @MikeBloomberg-why'd you wait so damn long?
B3	Twitterer15 (28 Oct, 1529) Dammit!! Mandatory evacuation of Zone A. Hazards of living on the beach. Been there, done that. But this time we have to pack up a baby. UGGGGHHH!
B4	Twitterer45 (28 Oct, 1529) Soooo I might have to evacuate -_-
B5	Twitterer12 (28 Oct, 1549) Mandated evacuation for all of the Rockaways 😊
B6	Twitterer53 (28 Oct, 1558) Farrock has to be evacuated 😊 where da hell ima go?? Cause da island ain't so safer my dad lives right by the water too
B7	Twitterer36 (28 Oct, 1816) I'm on my way out of my house for mandatory evacuation. #sandy. my house is 2 blocks away from Atlantic Ocean and 3 blocks from Jamaica Bay
B8	Twitterer40 (28 Oct, 1600) @Z I aint evacuating ****...I'll be right here !

TABLE 3. Example tweets about social cues.

Identifier	Example tweet [anonymized Twitterer (date, time in UTC) tweet text]
Cues from peers (family, friends, neighbors, others)	
C1	Twitterer34 (27 Oct, 1534) From my office I hear the "tap tap tapping" of people boarding up their windows. #ZoneA #Sandy
C2	Twitterer1 (28 Oct, 1857) Water line is crazy #Costco
C3	Twitterer46 (28 Oct, 1818) Evrybdy is goin krzy for this hurricane/tropical storm. Lik rly. We wnt thru worsr conditions n survived wth minimal damage
C4	Twitterer34 (27 Oct, 1532) Just talked to our neighbor who rode out Irene—he does not seem too concerned, though #Sandy is supposed to be a monster in comparison.
C5	Twitterer38 (29 Oct, 1951) Get out of #farrockaway as before it's too late! #Sandy #Sandy #Sandy is on the way [link to photo of flooded residential streets, not shown]
Cues from businesses	
C6	Twitterer5 (28 Oct, 1953) RT @DavidMuir: You know it's bad when Starbucks says they're closing at 4 p.m. across NYC. Got our preshow coffee run in just in time #Superstorm #Sandy
C7	Twitterer15 (29 Oct, 2327) You know Rockaway's in trouble when Pickles and Pies is closed. The bay meets the ocean on 116th. Wow. Hoping everyone is safe and business do not suffer too much damage.
C8	Twitterer40 (29 Oct, 0332) Ok Im a lil scared now....the arab store stayed open during Irene, that ***** is closed (-_-)
Cues from government	
C9	Twitterer34 (28 Oct, 2039) The boardwalk is closed.:(#Sandy #Rockawaybeach [link to photo of authority figure taping off access to the boardwalk, not shown]
C10	Twitterer36 (28 Oct, 1451) In NYC train will be suspended at 7:00 p.m. tonight and bus will be suspended at 9:00 p.m. Be home tonight
C11	Twitterer48 (28 Oct, 1501) RT @MTAInsider: .@NYGovCuomo has announced all #MTA service will be suspended as of 7 p.m. tonight: NYC Subway, NYC Buses, LIRR and Metro-North all included.
C12	Twitterer19 (29 Oct, 2204) All bridges will be closed within next hour. That's unheard of! #NYC #Sandy
C13	Twitterer39 (28 Oct, 2155) BLOOMBURG SAID "**** THE PROJECTS".... HE DEADING LIGHTS N WATER IN THE PROJECTS, IN CERTAIN ZONES. (JUST STORM TRUTH)
C14	Twitterer43 (28 Oct, 2302) Well its 7 there supposed to shut off the elevators an the lights and water, but there still on so looks like N.Y.C.H.A ^a lied once again

^a N.Y.C.H.A. is the acronym for New York City Housing Authority.

Third, protective steps taken by local jurisdictions served as *cues from government* for many. Examples include closing public areas such as the boardwalk (C9), suspending public transportation (C10, C11), closing

bridges (C12), and shutting off utilities (C13, C14). As the latter tweets indicate, such governmental actions spurred feelings of anger and distrust for some (see also [section 4b](#); [Anderson et al. 2016](#); [Lazrus et al. 2017](#)).

TABLE 4. Example tweets about natural and built environmental cues.

Identifier	Example tweet [anonymized Twitterer (date, time in UTC) tweet text]
D1	Twitterer19 (28 Oct, 1011) I hear those Sandy winds creeping through the air. Already... #NYC
D2	Twitterer14 (29 Oct, 1430) Di breeze tunup out deh
D3	Twitterer3 (29 Oct, 1418) Wow #Sandy whipping up Atlantic Ocean in Far Rockaway Queens already [link to photo of rough ocean, not shown]
D4	Twitterer5 (29 Oct, 2252) I can literally smell the saltwater from my house. #FarRock #sandy
D5	Twitterer5 (29 Oct, 2202) Oh God the tree down the street is about to fall D: #sandy
D6	Twitterer12 (29 Oct, 2259) This wind is scary. My dog is going crazy over here _.. #hurricanesandy
D7	Twitterer 34 (29 Oct, 1837) Rain and wind pounding the windows up here—totally intense. #Sandy #frankenstom *****this [link to video showing rain and wind out the window]
D8	Twitterer19 (29 Oct, 2159) @Z And it's already dark as night. Wind consistently picking up over the last 10 min.
D9	Twitterer6 (29 Oct, 0042) ***? It hasn't even started to rain yet and there's flooding in the street already. Water is coming up thru the sewer drains O_O
D10	Twitterer30 (29 Oct, 1846) Dis how sandy has got farrock lookin sometimes da #beachlife ain't always da wave [link to photo shown in Fig. 5]
D11	Twitterer31 (29 Oct, 2221) Lights flickering...Now im scared:/
D12	Twitterer44 (Oct 30, 0021) Power just went out!!!!!!! Om*g I thought I was gonna be all good...

TABLE 5. Example tweets about perceived exposure.

Identifier	Example tweet [anonymized Twitterer (date, time in UTC) tweet text]
E1	Twitterer23 (27 Oct, 2322) @Z1 @Z2 easier said when you don't live at or below sea level #Rockaways
E2	Twitterer35 (29 Oct, 1030) #hurricanesandy #FarRockAway #rockawaybeach i live across from the beach 🤔🤔🤔🤔🤔
E3	Twitterer40 (29 Oct,1628) @Z My block is one of the few blocks in far rock that never floods, now if nothing comes through my window I should be good LOL
E4	Twitterer52 (29 Oct, 1245) @Z it does not flood.... Where I'm at... Stop watching the news Twitterer52 (29 Oct, 1248) @Z it never does... Did not with Irene either
E5	Twitterer6 (29 Oct, 2352) I live on the second floor so I should be good. Have food and water. I'll update in a couple of hours #sandy
E6	Twitterer13 (29 Oct, 1450) God Is Good, hopefully things Pan out, I live on the Second Floor of my home, (I Pray for My Neighbor's and Family home on the First flr, but I'm on the job protecting their's too), I Hope this Crackhead house hold up but hey it's been here since the 1950s it's seen more *** than me and still here, God and My Mom have put a Force Field around the House so far and My Faith is on Super Hero for Family and Friends. ^a
E7	Twitterer53 (28 Oct, 1601) @Z atleast your in a building lol my house is gonna blow away
E8	Twitterer48 (29 Oct, 1512) @Z thanks Mel we at my grandmas house. Good ol projects building gonna keep us safe lol
E9	Twitterer12 (29 Oct, 1632) We are staying in far rockaway. We do have a plan B if things go wrong. I do live in a building so my worries are less of those who do not

^a Tweet linked to Facebook post, allowing the content to be longer than 140 characters.

As with social cues, environmental cues are recognized to play important roles in people's assessments of environmental risks (Taylor et al. 2009; Lindell and Perry 2012; Lazrus et al. 2016; Demuth 2018). However, less is known about which environmental cues are important, when, and how. This perhaps is because environmental cues do not manifest regularly or clearly for all types of risks. Weather hazards, however, intrinsically present such cues, and more than half of the Far Rockaway users tweet about them. Thus, the social media data analyzed here offer insight into the salience of such cues to people as they assess a threat (Table 4).

Many people tweeted about *natural environment cues* related to Sandy, most commonly the strong or strengthening winds (D1–D8). Often they mentioned wind along with related cues, such as the rough ocean (D3), the smell of ocean spray (D4), falling trees (D5), and animal behavior (D6). Others mentioned different

natural cues, like rain (D7) and darkness (D8). *Built environment cues* also were important indicators to some, as water poured from street drains (D9), roads were flooded (D10; Fig. 5), and especially as power flickered or went out (D11, D12). Most environmental cues mentioned in these data were observed by the person tweeting, although some were from information relayed by others. Mentions of environmental cues often were associated with negative emotions, which are further discussed in section 4b.

As might be expected given the different types of risk information available at different times leading up to Sandy (section 3a), the information that people tended to tweet about evolved with the threat. Mentions of weather forecast information began on 25 October, were common on 26–27 October, and continued until landfall as people tweeted about where Sandy was and when it would make landfall with increasing specificity. Mentions of evacuation orders primarily clustered on

TABLE 6. Example tweets about perceived severity.

Identifier	Example tweet [anonymized Twitterer (date, time in UTC) tweet text]
F1	Twitterer16 (26 Oct, 2227) Ago #hurricanesandy you are ****... Straight *****. You pack no punch. Ya lil *** 75mph winds aint sayin nothin. Just ask what happened to to you sister Irene last year. I surfed her wit my channel 7 dude NJ Burkett. [. .] Get ya weight up to like a buck 10 and then maybe you sayin somethin. ^a
F2	Twitterer28 (28 Oct, 1748) Hopefully my house is not underwater by tomorrow #Sandy
F3	Twitterer34 (28 Oct, 1436) @RockawayBeachNY Hey, I live on you. Ready to get rocked by #Sandy?
F4	Twitterer10 (28 Oct, 2328) Yooo what if Rockaway look like new orleans after Katrina ???
F5	Twitterer24 (28 Oct, 1747) Wow guess #Sandy real this wind already crazy out on Long Island
F6	Twitterer53 (28 Oct, 2056) Smh it's getting real out In farrockaway ! Omw out 🤔
F7	Twitterer34 (28 Oct, 2147) RT @Z: We are now about 24 h from landfall along the Jersey coast. This time tomorrow will be crazy.
F8	Twitterer14 (29 Oct, 2233) Hope everyone is safe.. this hurricane is not a joking matter..

^a Tweet linked to Instagram photo and caption, allowing the content to be longer than 140 characters.

TABLE 7. Example tweets about affective and emotional perceptions and responses.

Identifier	Example tweet [anonymized Twitterer (date, time in UTC) tweet text]
G1	Twitterer12 (28 Oct, 1907) This hurricane stuff is stressing me out
G2	Twitterer14 (28 Oct, 2013) Feeling ah Lil worried n sad now...
G3	Twitterer15 (29 Oct, 2356) Ok Sandy. You got our attention. Now please, do no harm. Damn.
G4	Twitterer34 (29 Oct, 2329) **** [link to photo shown in Fig. 6] Twitterer34 (29 Oct, 2344) **** **** omg Twitterer34 (29 Oct, 2344) **** **** omg
G5	Twitterer40 (29 Oct, 1813) The tree outside my house is scaring the **** outta me...
G6	Twitterer12 (Oct 30, 0018) To Evelin. We just lost power right when I was making something:(lol. Nilo was hiding under the table. **** is scary
G7	Twitterer24 (Oct 30, 0100) This wind is cray. I sleep right by the window too. Scared to go to sleep now *****
G8	Twitterer34 (28 Oct, 0153) .@MikeBloomberg Hey Mike if #Sandy's NO BIG DEAL like you claim, how about you come stay with us in Far Rockaway, you chump joke of a mayor?
G9	Twitterer40 (29 Oct, 0106) The Far Rockaway hurricane jokes tho #****Yall
G10	Twitterer7 (29 Oct, 1928) **** hurricane sandy I had to leave my crib in far rockaway cuz of u. U dum *****!
G11	Twitterer34 (26 Oct, 1450) Off "aware" and on "alert" for #Sandy. I'll be live-tweeting photos and video if this #frankenstorm hits us. Watch me drown in real time!
G12	Twitterer33 (28 Oct, 1539) Bloomberg speaks just the funniest Spanish.
G13	Twitterer28 (29 Oct, 1942) Lmao RT @Z1: RT @Z2: what if gangnam style is a big rain dance and we brought this upon ourselves..
G14	Twitterer53 (29 Oct, 2349) 🙏🙏 RT @Z: Dear God please let my chocolate chip cookies bake before the madness begins

28 October, the day the mandatory order was issued for Far Rockaway. Mentions of social cues were most common around the time of the evacuation order, as the risk became more certain, and as more people considered and engaged in preparatory and protective actions; social cue mentions also extended into 29 October, the day of landfall. Environmental cues were mentioned

by a few Twitterers on 28 October, but most tweets about environmental cues were on the day of landfall, and they increased in frequency as Sandy approached.

b. Risk perceptions and responses

Although risk perception and response typically are parsed theoretically, we found that these processes often

TABLE 8. Example tweets about preparatory and protective actions.

Identifier	Example tweet [anonymized Twitterer (date, time in UTC) tweet text]
H1	Twitterer34 (28 Oct, 2029) My house says "No Thanx #Sandy" - #ZoneA [link to photo of boarded up window with "No Thanx #Sandy" spray-painted on it, not shown]
H2	Twitterer23 (29 Oct, 0153) Batteries,water,ducttape,paracord,food,and a brand new axe #prepper.
H3	Twitterer53 (28 Oct, 1622) Aight so my championship ring, laptop, phone and their chargers, important papers and some clothes = my bag to take w/me
H4	Twitterer15 (28 Oct, 1624) We were actually able to book hotel rooms. It's gonna be and Edge/Rachell mini vacation.:)
H5	Twitterer33 (28 Oct, 1819) And with that, I evacuate my home for some higher ground. See you on the other side, Rockaway. #sandy [link to photo of his home, not shown]
H6	Twitterer53 (28 Oct, 2130) Leaving far rock ! 🙏🙏
H7	Twitterer49 (29 Oct, 1048) Into Inwood. Rolling deep with minivans right now. #escapefromrockaway
H8	Twitterer4 (28 Oct, 1710) My family is staying here in the rockaway's #wishusluck
H9	Twitterer43 (28 Oct, 2043) I live in zone A but im not gunna evacuate because I did last time and regretted that choice.
H10	Twitterer37 (28 Oct, 1942) #SandyABC7 They're no evacuation plan here at Rockaway Manor (Adult Home). At least not as of yet... Twitterer37 (29 Oct, 0628) #SandyABC7 Looks like were staying at Rockaway Manor. The Front Door is locked tight. And the wind is slowly gaining strength.
H11	Twitterer34 (26 Oct, 1813) I trimmed my "Alan Moore" in preparation of dying and/or not having power for weeks.
H12	Twitterer6 (29 Oct, 1300) Let me go take this shower before I don't have hot water for 2 weeks #sandy
H13	Twitterer34 (Oct 30, 0219) Temporary dog bed gets Dara out of room with lots of windows [link to photo of dog in the bathtub with several blankets, not shown]
H14	Twitterer6 (29 Oct, 1832) Already had to pump water outta the basement. Fortunately I started just before it reached the boiler. Crisis averted (so far) #sandy
H15	Twitterer12 (Oct 30, 0106) Turning off my phone to preserve battery. Hope everyone in rockaway and every other zone A area is safe. #hurricanesandy

TABLE 9. Example tweets about coping responses.

Identifier	Example tweet [anonymized Twitterer (date, time in UTC) tweet text]
I1	Twitterer13 (27 Oct, 1408) FAMILY and FRIENDS, Well today is the CALM before the STORM literally, Mon-Thurs SANDY will be whooping on Our ***, So tonight were going to PARTY like it's 1999 (in my Prince voice) . . .
I2	Twitterer15 (28 Oct, 1735) So I'm wondering why my husband isn't packing. I inquired. He announced that he's not evacuating until the Giants game is over. And their game starts at 4. Really? We're about to battle. #footballwidow
I3	Twitterer43 (28 Oct, 2042) watching the Giants game waiting on the storm
I4	Twitterer16 (28 Oct, 1914) 🌬️🌿 Enjoying the calm before the storm 🌧️🌿... I had to get out and enjoy the #foliage 🌿 before it gets bare out here. I still think #sandy #hurricanesandy is straight buns. #nature
I5	Twitterer21 (29 Oct, 0210) Rum and coke and a movie marathon is in my near future. Might even fry up some whiting later on...already have fresh kale on deck...
I6	Twitterer35 (29 Oct, 1539) We got this #hurricaneSandy #farrock #RockawayBeach 🙏🙏
I7	Twitterer47 (29 Oct, 2116) @Z #sandy ..I live in Far Rockaway and I think its gonna get real but I'm prayed up and sitting back. Everyone be safe
I8	Twitterer4 (29 Oct, 2351) Fun in the dorms, keeping our minds off sandy 🛹 lol me and my other half #boredomstrikes #scooters #lilkids [link to photo of the twitterer and her friend riding scooters, not shown]

are indistinguishable in the Twitter narratives, especially as the hazard approaches. Thus, we combine discussion of them into this section. The data analysis reveals that, as people gathered information about and assessed the evolving threat, several aspects of their cognitive and affective risk perceptions emerged as important, along with their emotional, preparatory and protective, and coping responses (Fig. 3).

One aspect of people's cognitive risk perceptions that emerged was their perceived exposure to hurricanes (Table 5), that is, their beliefs about the natural and built characteristics of the environment that influence how they could be affected by a hurricane (Zhang et al. 2004; Wilhelmi and Hayden 2010; Lazo et al. 2015; Morss et al. 2016). Many Twitterers referenced their perceived *geographical exposure*. Some indicated that they thought their location's elevation (E1) or proximity to the ocean (E2) put them at greater risk. Others thought that their location was at lower risk, for example, because it "never floods" (E3) or has not in previous storms (E4). Some Twitterers discussed their perceived *vertical exposure*, based on what floor in a building they reside on (e.g., perceived lower risk above the first floor; E5, E6). And, some discussed their perceived *structural exposure* based on the type of building they reside in. In the Far Rockaway Twitter data, this was often expressed through the notion that being in a "building" (E7–E9), meaning public housing provided by the New York City Housing Authority, was safer than a single-family home or other smaller structure (Lazrus et al. 2017).

Our analysis of the Twitter narratives also revealed a second type of cognitive judgment: people's perceived severity of Sandy and its impacts (Table 6). These perceptions were expressed through many of the forecast information tweets discussed in the previous section, such as A1 ("we're looking to get pretty wet on Monday") and A7 ("Sandy expected to bring life-threatening storm

surge flooding"). Another example is F1 (which includes Instagram text associated with the tweet) downplaying the intensity of Sandy and suggesting that the hurricane might pose more harm if it were stronger ("a buck 10", i.e., with 110 mile-per-hour winds). Others referred to perceptions of Sandy's severity in terms of potential impacts to their home (F2) and to Far Rockaway (F3), including concern that the area might "look like new orleans after Katrina" (F4). Some described the potential for specific negative impacts, such as their home being "underwater" (F2), but most people's expressions of the possible severity were vague, holistic, and idiomatic, such as through comments about Sandy getting "real" (F5, F6), "crazy" (F7), or being no joke (F8). These tweets and those in the previous paragraph reveal the range of ways that people think about and express their views about how likely they are to experience a risk and how bad it could be.

In addition to cognitive risk perceptions, our analysis revealed several important aspects of people's affective responses to the hurricane threat, as well as specific emotion states (Table 7). The majority of expressions of affect and emotion were negative, including worry, fear, anger, and other unspecified negative emotions. Worry often emerged a day or more prior to landfall, which the context of the Tweet narratives indicate is due to the prospect of the negative effects from Sandy (G1, G2). As Sandy approached and made landfall, many people indicated fear, either implicitly (G3, G4) or explicitly (G5–G7). Fear was often spurred by environmental cues, including strong winds, power loss, and flooding (G4–G7). For instance, Twitterer34 sends, in rapid succession, a series of tweets expressing surprise and negative emotions along with a photo as floodwaters reach his home (G4, Fig. 6). Another commonly expressed emotion was anger, prompted, for example, by perceived poor decision-making by officials (G8; see

TABLE 10. Tweet narrative from Twitterer33. Tweets that are emphasized in the text are shown in boldface. (n/a = not applicable)

Identifier	Tweet stream [(date, time in UTC) tweet text]
J1	(25 Oct, 1820) RT @clusterstock: Mayor Bloomberg Tells NYC Residents: 'Be Prepared To Evacuate' by @DinaSpector http://t.co/lSsLmJEA
J2	(26 Oct, 1407) Way too into weather blogs rite now.
J3	(26 Oct, 1938) RT @ElBloombito: Get off el twittero! Packo su Vamos Bag! Andale!
J4	(27 Oct, 1355) Waiting For Sandy. Hurricane preparations out on Rockaway Beach [broken link]
J5	(27 Oct, 1400) This is how we prepare for hurricanes in Rockaway Beach. @ Rockaway Boardwalk [link to photo of sand being hauled to the beach, not shown]
	1 n/a tweet
J6	(27 Oct, 1520) Saturday Morning Surfing. Before the weather hits Rockaway. [broken link]
J7	(27 Oct, 1807) In case I need to swim on out... @ Arverne By The Sea [link to photo of swim fins, not shown]
	1 n/a tweet
J8	(28 Oct, 1343) (Pre) hurricane surfing. @ Rockaway Beach - 74th Street [link to photo of solo surfer, not shown]
J9	(28 Oct, 1454) @A Sounds like the rest of Long Island barrier islands are evacuating, so probably a matter of time for us, too.^a
J10	(28 Oct, 1455) A lot of Rockaway residents are buying water and groceries, but does not look like many are prepping to leave. #Frankenstorm
J11	(28 Oct, 1528) And there is the mayor's evacuation order for us. #sandy
J12	(28 Oct, 1539) Bloomberg speaks just the funniest Spanish.
J13	(28 Oct, 1559) @B Yeah, we're packing a couple bags and are heading for Jersey.
J14	(28 Oct, 1727) There are more people going to the beach right now than going away from it. #sandy
J15	(28 Oct, 1729) Eyewitness News is out on the scene. Ooh. #sandy @ Rockaway Beach-74th Street [link to photo of local ABC news van on site, not shown]
J16	(28 Oct, 1733) The beach is pretty much deserted at this point. . .no more surfers. #sandy @ Far Rockaway Beach [link to photo of empty beach and ocean, not shown]
J17	(28 Oct, 1739) JFK still is open. @ Rockaway Beach, NY [link to a photo of an airplane, not shown]
J18	(28 Oct, 1747) I found out where all the surfers went. @ Rockaway Beach-84th Street [link to a photo of several surfers in the ocean, not shown]
J19	(28 Oct, 1803) A lot of sirens are going off. Emergency services really working for their paychecks today. #sandy
J20	(28 Oct, 1813) A local blogger informed me that my photo made it onto @gothamist. Nice. [link to photo of solo surfer from tweet J8, not shown] #sandy #surfing
J21	(28 Oct, 1819) And with that, I evacuate my home for some higher ground. See you on the other side, Rockaway. #sandy [link to photo of street with homes, presumably including the Twitterer's home, not shown]
J22	(28 Oct, 1819) @C Heading out right now.
J23	(28 Oct, 1819) @D Quite true.
J24	(28 Oct, 1823) @E Heading out now. Thank you again for selling me that car last week
J25	(28 Oct, 1938) Mostly it just looks like autumn in New Jersey. #sandy @ Trader Joe's [link to photo of street, cars, and buildings, not shown]
J26	(28 Oct, 2042) A case of Dale's to help me thru the storm. @ [town name] [link photo of a case of beer, not shown]
J27	(28 Oct, 2150) We now are on high ground. #sandy @ [town name] [link to photo of residential area from up high, presumably on a hill, not shown]
J28	(28 Oct, 2211) Watching my neighborhood on TV from 65 miles away. #sandy @ [town name] [link to photo shown in Fig. 7]

^a All handles in @mentions are anonymized (excepting users with a public profile) with different letters representing different people.

also section 4a), jokes from others (G9), and having to evacuate (G10).

The Twitter narratives also included expressions of nonnegative affect and emotion, such as excitement about the hurricane and humor (G11–G14). As discussed in Parkhill et al. (2011), humor is one way that people cope when faced with risks. Thus, while humorous comments about Sandy may seem to be dismissive of the risk (Knox et al. 2016), they may also be an indication of risk perceptions and help reveal important aspects of “the

ways in which people experience and live with risk” (Parkhill et al. 2011, p. 352). Other ways of coping are discussed below.

As discussed in section 2, dozens of studies have examined people's behavioral responses to hurricane risks. Many of the actions to prepare and protect life and property that are well known from the literature were seen in the Far Rockaway Twitter data (Table 8). These include references to actions taken, such as boarding up one's home (H1), gathering supplies (H2), preparing to leave

TABLE 11. Tweet narrative from Twitterer53. Tweets that are emphasized in the text are shown in boldface. (n/a = not applicable)

Identifier	Tweet stream [(date, time in UTC) tweet text]
K1	(28 Oct, 1552) Last year when Irene hit I was on the 10th floor in my dorm building nice and safe. This time around I'm in farrock -- it's over for me lol smh
K2	(28 Oct, 1558) Farrock has to be evacuated 😞 where da hell ima go?? Cause da island ain't so safer my dad lives right by the water too
K3	(28 Oct, 1601) @A atleast your in a building lol my house is gonna blow away
K4	(28 Oct, 1605) I would live by the beach and my dad would live right by the ferry on da island 😞
K5	(28 Oct, 1614) @B I'm going to my brothers dorm
K6	(28 Oct, 1614) @A it's over for us lol
K7	(28 Oct, 1616) Mommy said pack a bag cause we out 🙌 idk what to pack all my stuff's important 🤔😞 lol smh help me please ?! 1 n/a tweet
K8	(28 Oct, 1622) Aight so my laptop, championship ring, phone and their chargers, important papers and some clothes = my bag to take w/me
K9	(28 Oct, 1623) @A lmao I can't swim ... I'm tall for nothing
K10	(28 Oct, 1624) I will be just a tad bit upset if I am evacuating for nothing. But rather be safe than sorry 🙏 1 n/a tweet
K11	(28 Oct, 1641) but why [college] still aint cancel classes lmaoo they better stop playing . but *** it atleast my philosophy midterm is pushed back
K12	(28 Oct, 1705) No school or practice tmrw cuz [college] gym is used as an evacuation center 🙌👏👏
K13	(28 Oct, 1705) My ankle gets an extra day to rest 🙏 and my groin will be 100% healed . I'll be refreshed Whoohoo
K14	(28 Oct, 1714) They need to cancel practice and class on Tuesday too . 1 n/a tweet
K15	(28 Oct, 1801) RT @cunynewswire: ALL scheduled Day and Evening classes at [college] campuses are canceled for Monday 29 October 2012.
K16	(28 Oct, 1801) @C yea same here . You be safe wherever you go 2 n/a tweets
K17	(28 Oct, 1809) Packing . Will be back in a few
K18	(28 Oct, 1853) Really do not feel good ughhhh 😞 but tryna pack and to get ready to leave the rockaways .
K19	(28 Oct, 1854) The thing about this hurricane is that you don't know what to expect. Last year was supposed to be big but it wasn't so ppl are confused
K20	(28 Oct, 1854) I say be safe rather than be sorry .
K21	(28 Oct, 2039) My mom is blowing mine. It's your idea to evacuate and yet you stay later at work like the trains do not stop running at a certain time smh
K22	(28 Oct, 2040) Smt I just do not get it man
K23	(28 Oct, 2046) Smh it's getting real out In farrockaway ! Omw out 🙌
K24	(28 Oct, 2130) Leaving far rock ! 🙌👏 1 n/a tweet
K25	(28 Oct, 2209) This wind is serious . My skinny *** can't walk in this . It be holding me back smh 3 n/a tweets
K26	(29 Oct, 0136) Brothers dorm with da fam and my other half

^a All handles in @mentions are anonymized (excepting users with a public profile) with different letters representing different people.

(H3, H4), and evacuating (H5–H7), as well as actions *not* taken, such as decisions not to evacuate (H8–H10). Although some Twitterers explicitly say that they are or are not evacuating, other mentions of evacuation decisions are less apparent and require the user's narrative to accurately determine the meaning. For example, “Rolling deep with minivans right now. #escapefromrockaway” (H5), is the way that Twitterer49 conveys he is evacuating, but his other tweets, including those after Sandy makes landfall, are needed

to ascertain this. The value of having a user's narrative is further shown in [section 4c](#).

In addition to these protective actions commonly discussed in the literature, additional types of preparatory and protective behaviors emerged, especially among nonevacuees. For instance, to prepare to be without utilities, Twitterer34 trimmed his beard (i.e., “trimmed my ‘Alan Moore,’” H11), and Twitterer6 showered while hot water was still available (H12). As Sandy approached and conditions worsened, these same

TABLE 12. Tweet narrative from Twitterer48. Tweets that are emphasized in the text are shown in boldface. (n/a = not applicable)

Identifier	Tweet stream [(date, time in UTC) tweet text]
L1	(26 Oct, 1913) Hurricane sandy 😊 1 n/a tweet
L2	(26 Oct, 1917) @A yea they said Monday. U know farrock the first to go >60 n/a tweets and 1 tweet about the number of people killed by Sandy in the Caribbean
L3	(28 Oct, 1128) @A idk. Fell asleep woke up and can't go back ^a
L4	(28 Oct, 1130) @A prob worried bout this hurricane
L5	(28 Oct, 1134) @A wish I was on a beach sipping on mimosas and eating breakfast right now 😊
L6	(28 Oct, 1501) RT @MTAInsider: .@NYGovCuomo has announced all #MTA service will be suspended as of 7 p.m. tonight: NYC Subway, NYC Buses, LIRR and Metro-North all included.
L7	(28 Oct, 1502) RT @RevRunWisdom: Dont worry ..Trust God with your life.. After All He gave it to you..
L8	(28 Oct, 2232) The beach is one block away from me and I'm staying home. Pray for me y'all
L9	(28 Oct, 2237) 🙏 RT @B: God can't help u lmfao RT @Twitterer48: The beach is one block away from me and I'm staying home. Pray for me y'all 8 n/a tweets
L10	(29 Oct, 1335) The water really looks like 🌊🌊🌊🌊🌊
L11	(29 Oct, 1350) #hurricanesandy I am out here 🙏🙏🙏🙏🙏 [link to photo of twitterer standing on the beach, not shown]
L12	(29 Oct, 1507) Floods are everywhere #farrock #hurricanesandy [link to photo shown in Fig. 8] 1 n/a tweet
L13	(29 Oct, 1512) @C thanks Mel we at my grandmas house. Good ol projects building gonna keep us safe lol 4 n/a tweets
L14	(29 Oct, 1531) So do not wanna stay at my grandmas house
L15	(29 Oct, 1557) **** I left my cash home and gotta go back
L16	(29 Oct, 1631) RT @D: #SANDYONFOX I'm in zone A and I'm not going nowhere
L17	(29 Oct, 1645) RT @E: "Refrigerator food only lasts 4 h after outage.." - HLN Survival tip 1 n/a tweet
L18	(29 Oct, 2143) Finally settled in at the house.
L19	(29 Oct, 2145) My aunt about to make us her famous fried chicken with some French fries 🍗🍟
L20	(29 Oct, 2228) These winds are crazy!!!!
L21	(29 Oct, 2228) I just pray farrock does not go under

^a All handles in @mentions are anonymized (excepting users with a public profile) with different letters representing different people.

two people took additional protective actions by moving the family dog into a bathroom away from windows (H13) and by pumping flood waters out of the basement (H14). After losing power due to the storm, others tweeted about preserving computer and mobile phone communication capabilities by powering off devices (H15).

Although coping in the aftermath of a disaster is well chronicled, it is less frequently studied in the predisaster phase. Our analysis revealed several ways in which people coped with Sandy's evolving threat before and during landfall (Table 9). In the days leading up to Sandy's landfall, some people engaged in leisure activities, such as having a party (I1), watching sports (I2, I3), and enjoying the outdoors (I4). As the storm approached and made landfall, some mentioned spending the time stuck indoors by cooking, eating, drinking, or

binge watching television or movies (I5). Others coped through prayer (I6, I7) or found ways to have fun or distract themselves (I8). As discussed above, people also used humor to cope with Sandy's threat, from a few days before up to landfall (G11–G14).

c. Individuals' evolving information use, risk assessments, and responses

The analysis presented in sections 4a and 4b illustrates the different, nuanced ways that people interacted with risk information, perceived their risk, and responded as Sandy approached and arrived. In this section, we explore in greater depth the complex, interwoven nature of those processes and their evolution by presenting and discussing segments of four of the Twitter narratives. These four narratives were selected to illustrate the dynamic ways in which different people attended to

TABLE 13. Tweet narrative from Twitterer6. Tweets that are emphasized in the text are shown in boldface.

Identifier	Tweet stream [(date, time in UTC) tweet text]
M1	(28 Oct, 1709) @A @B I'm tempted to stay . . . I dunno yet.
M2	(28 Oct, 1729) @B @A @C last time it wasn't as bad as they said. If I stayed I could've pumped out the water and prevented damage.
	2 n/a tweets
M3	(29 Oct, 0042) ***? It hasn't even started to rain yet and there's flooding in the street already. Water is coming up thru the sewer drains O_O
	1 n/a tweet
M4	(29 Oct, 1300) Let me go take this shower before I do not have hot water for 2 weeks #sandy
M5	(29 Oct, 1351) @D thanks man. Hasn't even started to rain yet but we're having some flooding due to high tide.
M6	(29 Oct, 1832) Already had to pump water outta the basement. Fortunately I started just before it reached the boiler. Crisis averted (so far) #sandy
M7	(29 Oct, 1834) @E thanks man.
M8	(29 Oct, 2204) Tide rising. Lights flickerin. Wind whipping. #thuglife
M9	(29 Oct, 2230) Welp, my power's out. So time to conserve this phone battery.
M10	(29 Oct, 2350) Pitch black outside aside from car alarms/lights going off from being submerged in water. Water was waist high n rising at last check.
M11	(29 Oct, 2352) I live on the second floor so I should be good. Have food and water. I'll update in a couple of hours #sandy
M12	(Oct 30, 0741) Water in the streets has receded all the way. At its peak during high tide last night there was about 5.5 to 6 feet of water.
M13	(Oct 30, 0746) Streets looked like a river. Lots of damage. Backyard fence was completely swept away. Still dark so I can't fully assess everything #sandy
M14	(Oct 30, 0748) We're all okay for now. Have to go thru another high tide though. We'll see what happens w/ that. I'll try to report back later #sandy
M15	(Oct 30, 0751) @F @G @A @H doing okay for now. thanks for the concern.
M16	(Oct 30, 1202) @I no electricity. lots of damage to the 1st floor. everyone is safe though.
M17	(Oct 30, 1331) No electricity or hot water. Car is destroyed and no trains or buses running. Stores are closed. Don't know what I'm gonna do but I'm surviving

^a All handles in @mentions are anonymized (excepting users with a public profile) with different letters representing different people.

different risk information, interpreted and responded to the risk, and made decisions, including how these processes interacted with the unique context of people's lives. Each sequence of tweets discussed is only a subset of that person's full tweet narrative; all tweets are shown for the period of time selected unless otherwise indicated.

Twitterer33 is an example of someone who indicates early awareness about the risk of Sandy; as the threat evolves, he attends closely to weather information, evacuation orders, and social and environmental cues, and then evacuates (Table 10). His Sandy-relevant tweets begin four days before landfall, with a retweet of information from Mayor Bloomberg about potential evacuation (J1). The next day, he indicates that he has been actively seeking and obtaining weather information (J2). Over the next few days, he tweets almost exclusively about Sandy, with increasing frequency, sharing photos that document his experience. The morning of 28 October, he anticipates an impending evacuation order based on the evacuation of nearby areas (J9), and then he tweets about the mayor's evacuation order for his area during the press conference

(J11). Twenty minutes later, in conversation with another Twitterer, he tweets about packing and his plans to evacuate (J13). After several tweets about social cues (J14–18), he then tweets that he is evacuating, less than three hours after Bloomberg announced the evacuation order (J21, J22, J24), using a car that he purchased the week prior (J24). His tweets also reveal coping behaviors through humor (J12) and purchasing beer (J26). After evacuating, he continues to seek information about Sandy by watching news coverage (J28, Fig. 7).

Twitterer53 is a young adult who is less focused on risk information than Twitterer33 and has different concerns and constraints, but who also evacuates (Table 11). The segment of her narrative shown begins shortly after the mayor announces the evacuation order for her area. Although she does not mention forecast information and makes only a vague reference to the evacuation order, her Twitter narratives reveal that she recognizes her risk from Sandy. For example, she tweets four times in 13 minutes about her perceived exposure, including the exposure of different locations relative to the ocean and different types of structures (K1–K4). The risk



FIG. 4. Photo shared by Twitterer34 of a television meteorologist showing the forecast wind gusts from Sandy (see tweet A9 in Table 1).

perception content in these tweets is interspersed with consideration about where she should evacuate to, at times expressing humor and at times frustration. She then tweets that she is evacuating to her brother's dormitory (K5) with her mother (K7). Over the next few hours, she tweets about packing to evacuate (K8, K17) and social cues in the form of class cancellations (K12), interwoven with tweets about past hurricane experience, evacuation decision-making, hurricane risks, and associated uncertainty (K10, K19). Although she expresses

concern about potentially evacuating unnecessarily (K10), she twice says that she would rather be safe than sorry (K10, K20). After a short delay waiting for her mother to leave work (K21), she tweets that they evacuate Far Rockaway that evening, noting the environmental cues that indicate worsening conditions (K23–K26).

Twitterer48 is aware of and worried about the risk of Sandy several days before landfall, although she does not explicitly reference forecasts or other official risk information. Initially she decides not to evacuate, but she then changes her mind and moves somewhere safer hours before landfall (Table 12). She first tweets about Sandy on 26 October, revealing that she is aware of Sandy's threat and expressing (through an emoji) negative affect (L1). A few minutes later, another tweet reveals her awareness that Sandy is forecast to make landfall on "Monday," 29 October and her associated risk perceptions in the form of Far Rockaway's exposure (L2). She then tweets almost exclusively about topics other than Sandy, until 28 October. That morning begins with her tweeting in conversation with someone about having difficulty sleeping, which she says is probably due to worry about Sandy (L3, L4). Several hours later, she retweets information about a governmental social cue (suspension of local public transportation, L6), and then tweets about her decision not to evacuate (L8). After several tweets unrelated to Sandy, on 29 October (the

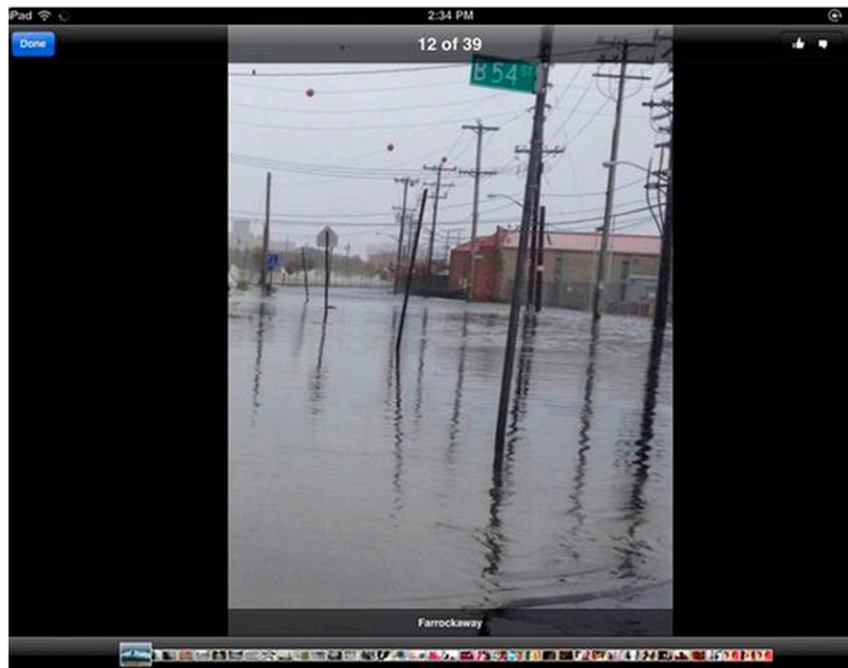


FIG. 5. Photo shared by Twitterer30 of flooding as an environment cue (see tweet D10 in Table 4).



FIG. 6. Photo shared by Twitterer34 of flooding outside his front gate as Sandy made landfall (see tweet G4 in Table 7).

morning of landfall), she tweets about environmental and social cues: the large ocean waves (L10), a photo of herself on the beach (L11, photo not shown), and a photo of a boarded-up gas station surrounded by flooded streets (L12, Fig. 8). Within a few minutes, her Twitter narrative reveals that she has moved to a relative's home in a "projects building," which she perceives as structurally safer (L13). Although we do not know for certain, this sequence of tweets suggest that her decision to move was triggered to some extent by these environmental and social cues and associated affect (e.g., symbols of a person praying in L11). After returning home briefly (L15), she gets settled at her relative's home (L18) and tweets about food, Sandy's winds, and concern about Far Rockaway as the storm arrives (L19–L21).

Twitterer6 draws on his past experience with damage from a hurricane, presumably from Hurricane Irene from the previous year, and he decides not to evacuate for Sandy but again suffers losses (Table 13). His first Sandy-relevant tweet comes about two hours after the mayor's announcement of the evacuation order. In conversation with several other Twitterers, he tweets about deciding whether to leave or stay (M1, M2). He does not explicitly reference forecast information or the evacuation order; however, he tweets about uncertainty in official information based on his experience "last time [when] it wasn't as bad as they said," and says he thinks he could have prevented damage had he not evacuated then (M2). Although Twitterer6 does not explicitly say that he

decides not to evacuate, his subsequent tweet narrative reveals that he indeed stayed. As Sandy approaches and makes landfall, he tweets about protective actions, including pumping water out of his basement (M6), and natural and built environmental cues, including winds, flooding, and losing power (M8–M10). Several of his tweets during this period suggest concern. For example, immediately after tweeting about his observations of the "waist high n rising" flooding and associated car lights and alarms (M10), he tweets that he should be okay because he lives on the second floor and has food and water (M11). Eight hours pass before he tweets again, after landfall, at which time he tweets about the extent of Sandy's flooding and impacts (M12, M13, M16, M17). These observations are accompanied by expressions of positive coping, including comments that he and others are okay (M14, M16) and that he is "surviving" (M17).

These examples reveal the ways that the constructs in Fig. 3 evolved and interacted for these at-risk people as the hurricane threat unfolded. The discussion also illustrates how people's experiences with a threat in the context of their lives can be revealed through social media narratives in ways that go beyond the text of individual posts.

5. Summary and discussion

This paper develops new understanding of people's thoughts and behaviors about the risks they faced



FIG. 7. Photo shared by Twitterer33 of the television news coverage he is watching of his neighborhood after evacuating (see tweet J28 in Table 10).

leading up to and during a hurricane landfall through analysis of social media data. Specifically, the findings are based on qualitative analysis of Twitter narratives collected from 53 people who were in Far Rockaway, New York, an area that was under a mandatory evacuation order from Hurricane Sandy. This analysis of people who were at significant risk of harm reveals the different types of risk information that they attended to and their risk perceptions and responses as the threat evolved, viewed through the lens of their tweets. The analysis is informed by the relevant existing literature, but it is grounded in the Twitterers' own words and images shared, which were posted at times and in ways that are meaningful to them.

Some of the findings echo those from past research, but with an added texture from the context that the Twitter narratives lend. Other findings offer novel perspectives about the risk assessments and decisions people make. We note which findings match those from previous research on weather hazards and which are new in our elaboration below of the key results. Overall, the results contribute both theoretically and practically to our understanding of people who are at risk of an extreme weather event.

Very few of the 53 people in our sample explicitly tweeted about Sandy's forecast sources or attributes, and the few explicit references to forecasts were composed mostly of retweeted factual information. Most people, however, tweeted before the storm arrived about their neighborhood or their home being threatened, the timing of landfall, or the possible impacts of Sandy. This reveals

that most users had received forecast information about the threat through some means. This finding is similar to that from Meyer et al. (2014), who found through phone surveys with people threatened by Sandy that every respondent was aware of the hurricane threat but that many were unaware of specific types of forecast information. People's implicit forecast references further tended to include some mention of what the threat meant for them, meaning they personalized the risk in some way.

These findings provide a new perspective on how people access and consider forecast information, compared to past studies that focus on characterizing what forecast information people receive (e.g., Lazo et al. 2015; Sherman-Morris 2013; Stein et al. 2010; Taylor et al. 2009; Zhang et al. 2007). They also suggest a possible mismatch between the ways that experts—including weather forecasters and researchers—think about and measure at-risk populations' attention to a threat versus the ways that people actually are attuned to the threat. Measuring the types of forecast information people received may be less meaningful than measuring what aspects of the forecast threat they interpreted as applicable to them, particularly as it might negatively impact them.

Many people in our sample paid attention to the mandatory evacuation order that included all of Far Rockaway. Moreover, most people who tweeted about the evacuation order also tweeted about what it meant for them, even if they ultimately did not evacuate because of other reasons. This suggests that a mandatory evacuation order serves as an important risk informational cue for many people. This finding corroborates results from other studies that have used surveys and interviews to examine evacuation responses to hurricane risk messages (e.g., Baker 1991; Gladwin et al. 2001; Lindell et al. 2005; Dash and Gladwin 2007; Zhang et al. 2007; Taylor et al. 2009; Morss and Hayden 2010; Huang et al. 2012; Cuite et al. 2017). It further suggests, though, that a mandatory evacuation order has resonance even in the vast constellation of information that is now available during an evolving hurricane threat.

In addition to "official" forecasts and evacuation orders (i.e., risk information issued by public authorities), "unofficial" information in the form of social and environmental cues emerged as particularly salient and influential to people. Businesses closing and certain governmental cues, such as closing roads or suspending public transportation, emerged as types of social cues that tended to heighten people's risk perceptions. Also, many people tweeted, in some cases frequently, about natural and built environmental cues as Sandy approached and made landfall. These cues often triggered concern or fear, and they motivated—and in some cases



FIG. 8. Photo shared by Twitterer48 of flooding and a boarded-up gas station (see tweet L12 in Table 12).

changed—protective decisions for some people. Although social and environmental cues are known to influence how people judge and respond to risks (e.g., Lindell and Perry 2012), they are typically not discussed in much detail or depth in the literature on hurricane risk communication and decision making. The social media narratives allow us to “see” the types of information that are salient to people and their breadth, extent, and power in the context of a weather risk in ways that past research utilizing other methods and datasets has not afforded.

The analysis also reveals important aspects of how people perceive their general risk from hurricanes as well as their storm-specific risk. People’s risk perception-related tweets include assessments of their exposure to harm based on where they live geographically (i.e., proximity to the ocean), vertically (i.e., what floor they live on), and structurally (i.e., what kind of building they reside in). Two common ways of parsing and measuring people’s hurricane risk perceptions are as exposure and severity (Lazo et al. 2015; Morss et al. 2016, 2018; Rickard et al. 2017), but these three aspects of perceived exposure

revealed by our analysis indicate the nuanced ways that people think about their risk.

The analysis also reveals the ways in which these nuanced risk perceptions can influence people’s protective action decision-making. For instance, people who mentioned they are safe because they live on the second floor are at least implicitly considering their risk of flooding due to rain or surge (even if they do not explicitly mention it). Yet, they may not be accounting for uncertainty in the hazard that puts them at risk—as evidenced by Twitterer34, who expressed surprised when the flood waters reached his doorstep (G4, Fig. 6)—nor for secondary effects (e.g., lack of utilities, being stranded due to damaged transportation infrastructure). Also, people who evacuate to a stronger structure may perceive more of a risk from wind than surge. In order for authorities to create risk communication messages that encourage appropriate protective action for people at risk of an approaching hurricane, they need to understand such perceptions—that is, what people believe they are at risk from—and the Twitter narratives help illustrate this.

The Twitterers we analyzed also conveyed their risk perceptions in terms of the severity of the risk. Earlier in the Sandy timeline, these mentions tended to be related to forecast information and were more specific about the type or magnitude of the projected impacts (e.g., “life-threatening storm surge”). As landfall approached, tweets about the storm severity tended to be tied to environmental cues and were more all-encompassing (e.g., that the storm was “real” or “crazy”). Taken together, the ways that the people in our sample discuss their general and storm-specific cognitive risk perceptions suggests ways that this important construct might be further theorized and measured in future studies, especially across the timeline of an event (see also [Lin et al. 2014](#); [Meyer et al. 2014](#)).

Affect is well understood in the risk literature to contribute to people’s risk perceptions and responses ([Slovic et al. 2004](#); [Greenberg et al. 2012](#)), but, as [Peters et al. \(2004, p. 1352\)](#) note, “public reaction to hazards can include more complex feelings than good or bad.” Indeed, in addition to positive or negative affect, the Far Rockaway Twitterers expressed specific emotions about the risk of Sandy. The emotions typically were negative, such as fear and anger. In some cases, these emotions represent heightening risk perception, which triggered protective behaviors. However, in other cases, the emotions represent responses themselves.

Some research has examined how specific emotions, like fear and anger, influence people’s risk assessments ([Peters et al. 2004](#); [Lerner and Keltner 2001](#); [Lerner et al. 2015](#); [Lindell et al. 2016](#)), but overall, this is an understudied area. For example, [Keller et al. \(2012\)](#) identified the importance of research to understand “what are the relevant, specific emotions” (p. 249) and “what are the consequences of specific emotions for decision-making and behavior” (p. 250) for particular environmental risks, such as hazardous weather. People’s use of social media to express their emotions during disaster events has been noted by some ([Houston et al. 2015](#)), but most research on this topic thus far has focused on studying postevent mourning and memorializing. The data presented here reveal that people express a range of different emotions that evolve in complex ways as a threat unfolds. This suggests that further study of this topic is needed, and it suggests that analysis of social media data can help build understanding about the roles that different emotions play in how people perceive and respond to risks.

As discussed in [sections 4b](#) and [4c](#), the analysis illustrates some of the ways that people at risk used evolving information to evaluate the risk that Sandy posed to them personally and to make decisions about evacuating or taking other preparatory actions. In addition to taking

protective actions, the data revealed that people engaged in other types of behaviors to help them cope with the threat of the approaching hurricane. Examples include “everyday” distractions (e.g., watching a sporting event, eating, and spending time with family) that took on new meaning during Sandy, as well as behaviors inspired by the threat (e.g., praying, expressing humor, finding fun activities while evacuated or sheltering in place). Moreover, people’s risk perceptions were not heightened and continuously maintained in an elevated state as the hurricane approached. Rather, people found ways to process and manage their concerns about the risk through these coping behaviors (as well as protective behaviors). Thus, another important area for future work is developing deeper understanding of the dimensions and functions of such emotion- and meaning-based coping behaviors ([Folkman 1997](#); [Parkhill et al. 2011](#)).

Methodologically, the analysis presented here demonstrates how social media data can be sampled and analyzed to richly investigate how people experience and respond to an evolving weather risk. This is useful given that interest is rapidly growing in more fully leveraging the power of “big data,” such as that from social media platforms like Twitter, for risk-related research ([NASEM 2017](#)). Yet, doing so requires careful consideration about who is the population of interest, how to identify and reach them, and how to gather meaningful data from them, all framed within an understanding of the relevant literatures. Designing such studies of social media data are time intensive and come with challenges, however. Most studies that utilize Twitter data rely solely on keyword searches to draw a sample. To address research questions such as those examined here, such types of sampling approaches alone are insufficient because they can miss relevant tweets if people abbreviate or misspell words, tweet phonetically, or tweet without mentioning any of the keywords used. Moreover, interesting and relevant content often lies in nontextual or supplemental content, such as emoticons/emojis, pictures, or links to other social media platforms. Further, most of the interesting constructs that pertain to people’s risk communication, perceptions, and responses are latent, multidimensional, and require context for full understanding. The in-depth analyses like those done here, though, provide essential insight about what can (and cannot) be “found” in the data so that these concepts and processes can be examined at larger scales (e.g., using machine learning and other natural language processing techniques) in order to determine which findings generalize across events, populations, and time. In short, returning to [Palen and Anderson’s \(2016, p. 225\)](#) words, “mak[ing] ‘Big’ data bigger, then smaller” offers potential to make it meaningfully bigger again.

In summary, this research illustrates the complex and dynamic ways that people interact with risk information, think and feel about risks, and respond. It does so from the perspective of individuals at risk as told in their voices through Twitter. Such understanding is vital to developing effective risk communication and preparedness and response policies to reduce harm from future weather threats.

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