Understanding Public Hurricane Evacuation Decisions and Responses to Forecast and Warning Messages*

REBECCA E. MORSS AND JULIE L. DEMUTH

Mesoscale and Microscale Meteorology Laboratory, National Center for Atmospheric Research,+ Boulder, Colorado

JEFFREY K. LAZO AND KATHERINE DICKINSON

Research Applications Laboratory, National Center for Atmospheric Research, Boulder, Colorado

HEATHER LAZRUS

Mesoscale and Microscale Meteorology Laboratory, National Center for Atmospheric Research, Boulder, Colorado

BETTY H. MORROW

SocResearch Miami, Miami, Florida

(Manuscript received 14 May 2015, in final form 10 December 2015)

ABSTRACT

This study uses data from a survey of coastal Miami-Dade County, Florida, residents to explore how different types of forecast and warning messages influence evacuation decisions, in conjunction with other factors. The survey presented different members of the public with different test messages about the same hypothetical hurricane approaching Miami. Participants' responses to the information were evaluated using questions about their likelihood of evacuating and their perceptions of the information and the information source. Recipients of the test message about storm surge height and the message about extreme impacts from storm surge had higher evacuation intentions, compared to nonrecipients. However, recipients of the extreme-impacts message also rated the information as more overblown and the information source as less reliable. The probabilistic message about landfall location interacted with the other textual messages in unexpected ways, reducing the other messages' effects on evacuation intentions. These results illustrate the importance of considering trade-offs, unintended effects, and information interactions when deciding how to convey weather information. Recipients of the test message that described the effectiveness of evacuation had lower perceptions that the information was overblown, suggesting the potential value of efficacy messaging. In addition, respondents with stronger individualist worldviews rated the information as significantly more overblown and had significantly lower evacuation intentions. This illustrates the importance of understanding how and why responses to weather messages vary across subpopulations. Overall, the analysis demonstrates the potential value of systematically investigating how different people respond to different types of weather risk messages.

1. Introduction

People's protective decisions when hazardous weather threatens are influenced by multiple factors, ranging from their vulnerabilities and resources to their risk perceptions to the forecast and warning messages they receive. When creating weather forecast and warning messages, meteorologists and others must decide which information to include, what to emphasize, and how to convey it (Demuth et al. 2012; Morss et al.

* Supplemental information related to this paper is available at the Journals Online website: http://dx.doi.org/10.1175/WAF-D-15-0066.1.

+ The National Center for Atmospheric Research is sponsored by the National Science Foundation.

Corresponding author address: Dr. Rebecca E. Morss, National Center for Atmospheric Research, P.O. Box 3000, Boulder, CO 80307.
E-mail: morss@ucar.edu

DOI: 10.1175/WAF-D-15-0066.1

2015; Bostrom et al. 2016). To make these decisions, it is helpful to understand how different people are likely to respond to different types of weather risk messages. Without this understanding, it is difficult to know how to communicate forecast and warning information in ways that support protective decision-making and, thus, to help society benefit from advances in forecast and warning capabilities.

To explore these issues, we conducted a survey of 255 residents of coastal Miami-Dade County, Florida, that presented different respondents with different messages about the same hypothetical hurricane forecasted to make landfall near the city of Miami. Respondents were then asked, given the information they received, about their likelihood of evacuating and taking other protective actions and about their perceptions of the risks and the information. The survey also included questions about respondents' prior hurricane experience, cultural worldviews, and other characteristics and perceptions that can influence protective decisions. We analyzed these data to investigate 1) how prior hurricane experience, cultural worldviews, and other factors influenced respondents' evacuation intentions and 2) how people responded to the experimentally manipulated hurricane risk messages.

A number of previous studies have examined individual and household protective decision-making for hurricane threats [see, e.g., Dash and Gladwin (2007), Lazo et al. (2015), and Huang et al. (2016) for reviews]. The study reported here contributes to advancing this existing understanding in two major ways. First, building on prior work, we investigate how differences among members of the public influence their responses to information about a hypothetical approaching hurricane. This includes examining new issues, such as whether cultural worldviews (in conjunction with other factors) can help explain why at-risk members of the public respond to hurricane risk information differently and make different protective decisions given the same hurricane threat. Second, although previous related work has found that hurricane risk messages (e.g., evacuation orders, forecasts, and warnings in general) often play an important role in protective decision-making, there has been little systematic attention to the influence of different types of messages. Thus, the test message component of this research contributes to filling an important gap in the literature.

The test messages were designed to explore several topics of current interest in the communication of hurricane and other weather risks. These topics include 1) communication and use of forecast uncertainty information (e.g., Baker 1995; NRC 2006; Broad et al. 2007; Morss et al. 2008, 2010; Joslyn et al. 2009; Hirschberg et al. 2011; Wu et al. 2014; Ash et al. 2014; Marimo et al. 2015), 2) communication of storm surge risks (e.g., Morss and Hayden 2010; NOAA 2012, 2013; Rappaport 2014; Morrow et al. 2015), 3) communication of weather impacts (e.g., NRC 2010; NOAA 2011b, 2012, 2013; Jones and Golding 2014), and 4) responses to weather risk messages that convey dramatic, personalized impacts with the goal of motivating protective behavior (e.g., Morss and Hayden 2010; Harrison et al. 2014; Perreault et al. 2014; Wei et al. 2014; Ripberger et al. 2015). In designing the study, we also incorporated relevant theories and knowledge from work on risk communication and decision-making more broadly.

The study's aim was to develop foundational knowledge about how different members of the at-risk public respond to different types of information about approaching weather hazards. To do so, we asked respondents about their protective decisions in a simplified context using a hypothetical scenario, which allowed us to experimentally manipulate the hurricane risk information received. Although anticipated evacuation behavior in a hypothetical hurricane situation is an imperfect predictor of actual behavior, several studies have found that the two are closely correlated (e.g., Dow and Cutter 2000; Whitehead 2005; Kang et al. 2007).

To enhance the relevance of the hypothetical scenario and experimental message manipulation to the real world, we presented respondents with information about a hurricane scenario developed by the National Hurricane Center (NHC), using messages adapted from forecast and warning information provided to the public in real-world hurricane events (e.g., Broad et al. 2007; Morss and Hayden 2010). We implemented the survey with an at-risk population in a geographically focused region where, given the scenario, similar hurricane-related conditions would be anticipated and similar protective behaviors would be recommended. We also asked respondents about their perceptions and decisions based on their own real-life circumstances relative to the scenario. Given the limited previous related work on hurricane risk messaging and the nongeneralizable survey sample, the study is exploratory in nature. Nevertheless, the findings from the study can be used to help understand real-world responses to weather risk messages, and they identify several areas for future research. They also build our understanding of how forecast and warning messages can (or cannot) be used to help motivate people at high risk to take protective action.

Section 2 briefly reviews some of the relevant concepts and the literature utilized in the study, section 3

TABLE 1. Measures of hurricane experience and summary statistics (N = number of respondents, excluding missing responses).

Concept	Measure	Summary statistics			
		N	Yes	No	DK
Hurricane experience	Have you or anyone in your household ever…[a]				
	-evacuated or left your residence to go someplace safer in response to the threat of a hurricane?	254	46.1%	53.5%	0.4%
	-been injured (including loss of life) as a result of a hurricane?	255	2.0%	97.6%	0.4%
	-had damage to or loss of property because of a hurricane?	255	56.1%	43.5%	0.4%
	-had any other financial losses such as business losses or loss of income because of a hurricane?	252	27.0%	71.4%	1.6%
	-had emotional impacts or personal distress because of a hurricane?	255	43.9%	54.9%	1.2%
		N	Mean	Std dev	DK/NE
	Overall, how severe have the impacts of your own hurricane experience(s) been?[b]	254	3.7	1.6	10.2%

[a] Response options: "yes," "no," "don't know" (DK).
[b] Response options: ratings on a 7-point scale (from 1 = "not at all severe" to 7 = "extremely severe," with the midpoint 4 labeled "moderately severe") or "don't know/no experience" (DK/NE).

describes the study methodology, and section 4 presents results. Section 5 summarizes key findings and discusses implications for hazardous weather risk communication and future research.

2. Background: Factors influencing protective behavior and test message design

The study discussed in this article builds on previous work on protective decisions for hurricanes and other hazards [see, e.g., Baker (1991), Sorensen (2000), Dash and Gladwin (2007), Lindell and Perry (2012), Sherman-Morris (2013), Lazo et al. (2015), and Huang et al. (2016) for reviews], with an emphasis on investigating 1) the roles of hurricane experience and cultural worldviews in explaining protective decisions, in conjunction with other factors, and 2) people's responses to different types of hurricane risk messages, including extreme-impacts messages. This section reviews how we designed the study to investigate these issues, utilizing concepts, theories, and findings from previous relevant literature.

a. Risk perceptions, efficacy beliefs, and protective behavior

In the risk communication and decision-making literature, people's responses to risks and to risk information are often examined in terms of cognitive risk perceptions (e.g., perceived likelihood of threat occurrence, perceived seriousness of threat consequences) and affective responses (e.g., fear or worry associated with the threat). These, along with other factors such as response efficacy (beliefs about how effective an activity is in protecting against the threat) and self-efficacy (beliefs about one's ability to perform an activity), can influence protective decisions (e.g., Rogers 1983; Witte 1992, 1994; Loewenstein et al. 2001; Ruiter et al. 2001; Slovic et al. 2004; Grothmann and Reusswig 2006; McComas 2006; Bubeck et al. 2012).

As will be discussed below, we have used these concepts to help develop the survey and the test messages. We also use them to help interpret how and why the messages and other factors influence evacuation intentions. The influence of risk perceptions and efficacy beliefs on hurricane evacuation decisions is investigated further in related work (e.g., Demuth et al. 2016, manuscript submitted to *Wea. Climate Soc.*, hereafter DMLT).

b. Prior hurricane experience

Previous research on relationships between past hurricane experience and protective decisions has found inconsistent results (e.g., Lazo et al. 2015; Huang et al. 2016). This is likely because these relationships are complicated by the different aspects of events and responses that are embedded within hurricane "experience," both within and across events (e.g., Baker 1991; Gladwin and Peacock 1997; Dow and Cutter 2000; Dash and Morrow 2000; Peacock et al. 2005; Morss and Hayden 2010; Lazrus et al. 2012; Meyer et al. 2013; Lazo et al. 2015). These different aspects of experiences, as interpreted and accumulated over time, can have different influences on people's perceptions of hurricane risks, their attitudes toward protective behaviors, and their decisions (Demuth 2015; DMLT).

To compare the effects of different hurricane experiences among the same coastal respondent population, we measured six different aspects of hurricane experience on the survey (Table 1). We then used the data to begin exploring the relationships between different

TABLE 2. Cultural worldview measures and factor loadings from factor analysis. Survey question: "Agree or disagree? The following statements do not relate specifically to Hurricane Julia but provide us information about your thoughts about society and government." Response options: ratings on a 7-point scale (1 = "very strongly disagree," 2 = "strongly disagree," 3 = disagree," 4 = "neither agree nor disagree," 5 = "agree," 6 = "strongly agree," 7 = "very strongly agree"). Letters E and I wrapped in braces ({E} and {I}) indicate items that formed the egalitarian and individualist indices, respectively, in Smith and Leiserowitz (2014).

Item	Worldview	
	Individualist	Egalitarian
If the government spent less time trying to fix everyone's problems, we'd all be a lot better off. {I}	0.84	−0.22
Our government tries to do too many things for too many people. We should just let people take care of themselves. {I}	0.65	−0.36
The government interferes too much in our everyday lives. {I}	0.74	−0.25
Government regulation of business usually does more harm than good. {I}	0.53	−0.30
People should be allowed to make as much money as they can, even if it means some make millions while others live in poverty. {I}	0.22	−0.51
The world would be a more peaceful place if its wealth were divided more equally among nations. {E}	−0.22	0.67
In my ideal society, all basic needs (food, housing, health care, education) would be guaranteed by the government for everyone. {E}	−0.17	0.65
I support government programs to get rid of poverty. {E}	−0.41	0.60
Discrimination against minorities is still a very serious problem in our society. {E}	−0.20	0.37
% of total variance explained	45.1%	12.7%
Cronbach's α (scale reliability)	0.80	0.71

aspects of people's hurricane experiences and their protective decisions. Building on the results presented here, DMLT examine these different hurricane experiences in greater depth.

c. *Cultural worldviews*

Previous research within a variety of contexts has found that how people perceive risks, risk information, and risk management options can be strongly influenced—and sometimes determined—by their cultural beliefs, that is, their beliefs about ideal social organization and priorities (e.g., Douglas 1970; Douglas and Wildavsky 1982; Dake and Wildavsky 1990; Peters and Slovic 1996; Leiserowitz 2006; Kahan et al. 2007, 2011; Goebbert et al. 2012; McNeeley and Lazrus 2014; Greenberg et al. 2014; Lazrus 2015, manuscript submitted to *Human Ecol.*). In this study, following Leiserowitz et al. (2013) and Smith and Leiserowitz (2014), we examine these cultural beliefs in terms of two worldviews: individualist and egalitarian, each measured on a different scale (Table 2). According to the cultural theory of risk, people with egalitarian worldviews are expected to perceive higher environmental risk, while people with individualist worldviews are expected to perceive lower environmental risk and to view certain risk management options as an infringement on their preferences for weak social ties and individual autonomy.

Based on this previous work on cultural theory and previous studies of hurricane evacuation decision-making (e.g., Morss and Hayden 2010), we anticipated that cultural worldviews would also interact with attitudes toward and responses to hurricane risks. We expected that people with stronger egalitarian worldviews would perceive higher risks from a landfalling hurricane and thus be more likely to evacuate, while people with stronger individualist worldviews would perceive lower risks and be less likely to evacuate. We also anticipated that people with stronger individualist worldviews would perceive messages from official sources trying to motivate evacuation as a threat to autonomy, which would further decrease their evacuation intentions.

d. *Experimental hurricane forecast and warning messages*

Next, we discuss how the relevant literature was utilized to design the messages tested in the survey. The survey (described further in section 3b) presented information about the hurricane scenario (Julia) at two points in time: first, the information in Fig. 1 (which introduced the scenario), followed by a combination of the test messages shown in Fig. 2. The messages were designed to investigate topics of current interest in hurricane and weather forecast communications (discussed in the introduction) as well as concepts that have been found important in other risk communication contexts (discussed in section 2a and below).

1) HURRICANE TRACK UNCERTAINTY MESSAGES

A key component of many meteorologists' messages about approaching hurricanes is the forecasted track, including landfall location, which is often communicated along with estimates of the forecast uncertainty. To

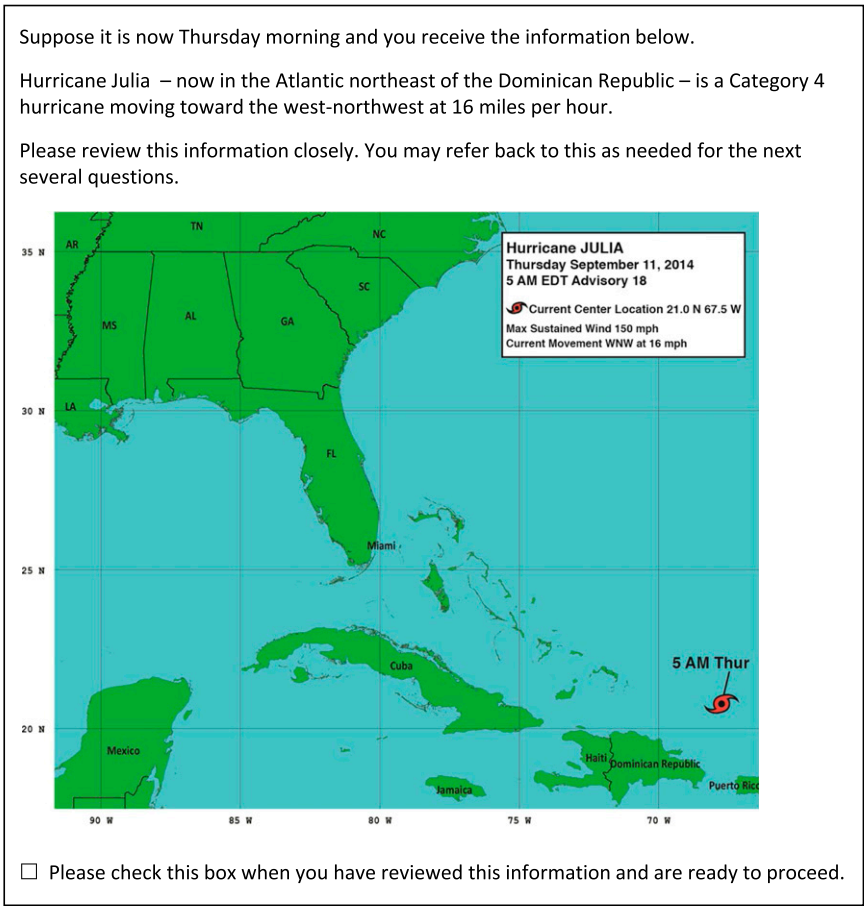


FIG. 1. First Hurricane Julia situation presented in the survey, prior to the test message presentation shown in Fig. 2. All respondents received the same information.

explore public responses to different ways of conveying hurricane track uncertainty, we tested two types of messages: the graphical CONELINE (compared to NO-CONELINE) and the textual 55%LANDFALL (Fig. 2). The NHC cone graphic is familiar to most Miami-Dade County residents; we tested two versions because, several years earlier, NHC had begun also disseminating a NO-CONELINE version based in part on concerns about misinterpretations of the original (CONELINE) version (Broad et al. 2007). The 55%LANDFALL tool was tested as an alternate, nongraphical way of conveying uncertainty in landfall location.

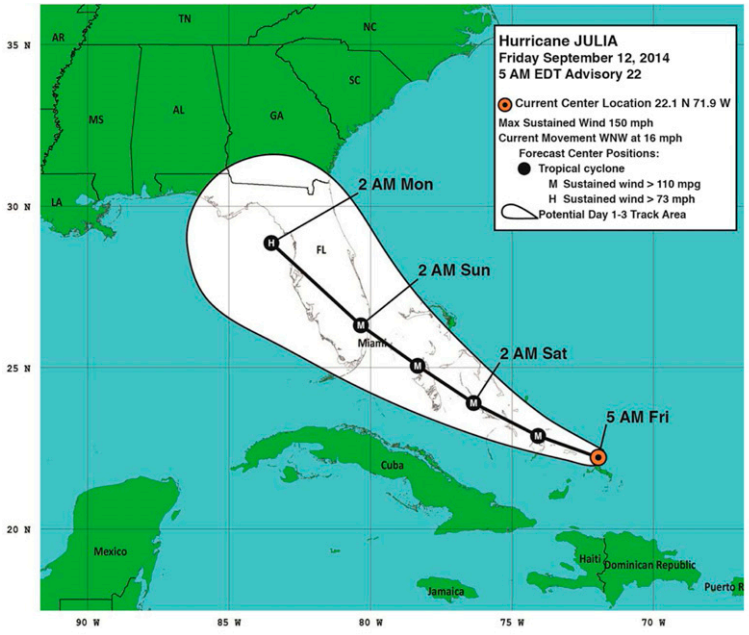
2) STORM SURGE MESSAGES

Storm surge is a cause of many hurricane deaths, and recent research has found that many coastal residents misperceive the risks posed by storm surge flooding (Morss and Hayden 2010; Stein et al. 2010; Meyer et al. 2014; Rappaport 2014; Wei et al. 2014). Thus, improving storm surge risk communication is currently a topic of major interest (NOAA 2012, 2013; Rappaport 2014; Morrow et al. 2015). To investigate public responses to different ways of conveying hurricane storm surge risks, we tested two types of storm surge messaging: 4FTSURGE and SURGEIMPACTS (Fig. 2). The 4FTSURGE message was tested to explore responses to information about expected storm surge depth and extent (which, at the time of the survey, was not readily available to the public at 48-h lead times); the language was adapted from existing NWS hurricane forecast products. The SURGEIMPACTS message was tested to explore responses to hurricane risk messages conveying impacts, discussed in the next section.

3) FEAR APPEALS, IMPACTS MESSAGES, AND EFFICACY MESSAGES

In the United States and internationally, the weather community is placing a growing emphasis on improving the communication of information about weather-related impacts, with a goal of enhancing forecast and warning decision-making (NRC 2010; NOAA 2011a; Jones and Golding 2014). In some situations, this has

Suppose it is now 24 hours later (Friday morning) and you receive the information below. This now indicates that Miami may be impacted by Hurricane Julia, a Category 4 hurricane, within the next 48 hours (2 days). Please review this information closely.



CONELINE

Please check each box below as you read each paragraph

THERE IS A 55% CHANCE THAT THE EYE OF THE HURRICANE WILL MAKE LANDFALL IN MIAMI-DADE COUNTY.	☐	55%LANDFALL
THERE WILL BE STORM SURGE OF 4 FEET OR HIGHER ALONG COASTAL AREAS, REACHING AS MUCH AS A MILE OR MORE INLAND.	☐	4FTSURGE
THIS STORM SURGE WILL BE EXTREMELY VIOLENT, DESTRUCTIVE, AND DEADLY. IF YOU LIVE IN AN AREA AT RISK FROM STORM SURGE AND YOU STAY IN THE AREA, YOU MAY DIE.	☐	SURGEIMPACTS
ESSENTIAL SERVICES SUCH AS FOOD AND WATER, ELECTRICITY, TRANSPORTATION, COMMUNICATION, ETC. MAY NOT BE AVAILABLE FOR SEVERAL WEEKS OR LONGER.	☐	
IF YOU LIVE IN AN AREA AT RISK FROM STORM SURGE OR FLOODING, EVACUATION IS THE MOST EFFECTIVE WAY TO PROTECT YOURSELF AND YOUR FAMILY.	☐	EVACPROTECT

☐ Please check this box when you have reviewed this information and are ready to proceed.

FIG. 2. Example presentation of the five messages tested in the survey, with red annotation added for this article. Each respondent was randomly assigned to receive one of two graphics, either the CONELINE version shown (CONELINE = 1) or a NO-CONELINE version, which did not have a black line connecting the forecasted hurricane locations within the white cone (CONELINE = 0). Along with a graphic, each respondent was randomly assigned to receive (=1) or not receive (=0) each of the four textual messages (55%LANDFALL, 4FTSURGE, SURGEIMPACTS, and EVACPROTECT). In other words, respondents received one of the two graphics, and they could receive any combination (or none) of the four textual messages. In the example shown, the respondent received all four textual messages.

included the use of messages that convey potential impacts using strong, personalized language, referred to here as ''extreme impacts'' messages. For example, as Hurricane Ike approached the Texas-Louisiana coastline in 2008, the NWS issued products that included statements such as ''persons not heeding evacuation orders in single-family one- or two-story homes may face certain death,'' which were widely disseminated in the

media (Morss and Hayden 2010; Wei et al. 2014). Several NWS regions now formally use this type of language (e.g., ''complete destruction,'' ''you could be killed if not underground or in a tornado shelter'') in their ''impacts based'' tornado warning messages (Harrison et al. 2014, NOAA 2015). A primary goal of these extreme-impacts messages is to help convey severity and urgency, in order to alert people about the life-threatening nature of the approaching event and prompt protective action (NOAA 2011b, 2012, 2015; Harrison et al. 2014).

Work in other (nonweather) risk contexts, however, has found that messages designed to motivate behavior by using dramatic impact information to evoke fear (called fear appeals) can have unintended, undesirable effects (e.g., Rogers 1983; Witte 1992; Witte and Allen 2000; Ruiter et al. 2001; Peters et al. 2013). For example, some recipients of fear appeals may engage in defensive responses (to cope with their fear) rather than protective action. Examples of such defensive responses (also called ''fear control'') include defensive avoidance (not wanting to think or learn about the risk), denial (refusing to believe the risk information), and negative reactance (thinking the information is misleading or overblown). Such responses are associated with message rejection and can sometimes lead to ''boomerang effects,'' in which the message produces the opposite of the desired response (e.g., riskier behavior) among some recipients. The literature on fear appeals indicates that message recipients are less likely to take protective action and more likely to have defensive responses when their efficacy (beliefs about their ability to effectively protect against the threat) is low (e.g., Witte 1992, 1994; Witte and Allen 2000; Peters et al. 2013).

In interviews conducted after Hurricane Ike, Morss and Hayden (2010) found that many of the interviewees who heard the ''certain death'' message evacuated before the storm made landfall, and some viewed the message favorably. However, some reported having undesirable responses such as those discussed above. Examples include opinions that the message was overblown, funny, or too stress inducing and disturbing; decreased confidence in hurricane messages; and decreased desire to evacuate (Morss and Hayden 2010 and unpublished data). Building on this past work, here we begin to systematically investigate the potential effects of extreme-impacts hurricane risk messaging by testing such a message (SURGEIMPACTS) within an experimental context. The first two sentences of SURGEIMPACTS were designed to investigate responses to information similar to that in the NWS certain-death hurricane local statements disseminated prior to Ike's landfall. The last sentence of SURGEIMPACTS, about the lack of essential services, was added based on the survey pretests and work in related projects, and it also begins to test conveying other types of weather impacts that may influence evacuation decisions. Based on the literature discussed above, we expected that an extreme-impacts message would produce some undesirable responses. We also anticipated that such responses might be especially prevalent among people with strong individualist worldviews (who may view messages aimed at convincing them to evacuate as a threat to their personal freedom).

As discussed above, efficacy beliefs can play an important role in people's decisions about protective actions and their responses to risk messages. Thus, we tested the EVACPROTECT message (Fig. 2) to explore the effects of adding an efficacy message to the information about the storm and its potential impacts.[1] More specifically, based on the fear appeals literature, we anticipated that including the efficacy message would increase evacuation intentions and reduce defensive responses to the information.

3. Methodology

a. Survey implementation and sample

The hazards associated with a landfalling hurricane depend significantly on location, both along the coast and relative to (inland from) the coastline. From an emergency management perspective, evacuation is the desired protective action for a landfalling hurricane only for those residents at high risk. To simplify interpreting responses to the hurricane evacuation question, we implemented the survey in a geographically focused coastal region where all respondents would be at high risk in the hurricane scenario presented in the survey and would be advised to evacuate by public officials: evacuation zones A and B in Miami-Dade County[2] (Fig. 3). In 2011, approximately 15% of the county population resided in these two zones. Although this sampling approach affects the generalizability of the results, it facilitates comparing results from the experimental message manipulation across respondents.

Survey sampling and data collection were managed by Knowledge Networks (KN),[3] a company specializing in survey research. An Internet-based implementation was

[1] Efficacy messaging is usually included in NWS warning products, for example, in the form of call-to-action statements, although this is not always retained in redissemination of the warning.

[2] Miami-Dade County evacuation zones were updated in 2013, after the data were collected.

[3] Now GfK.

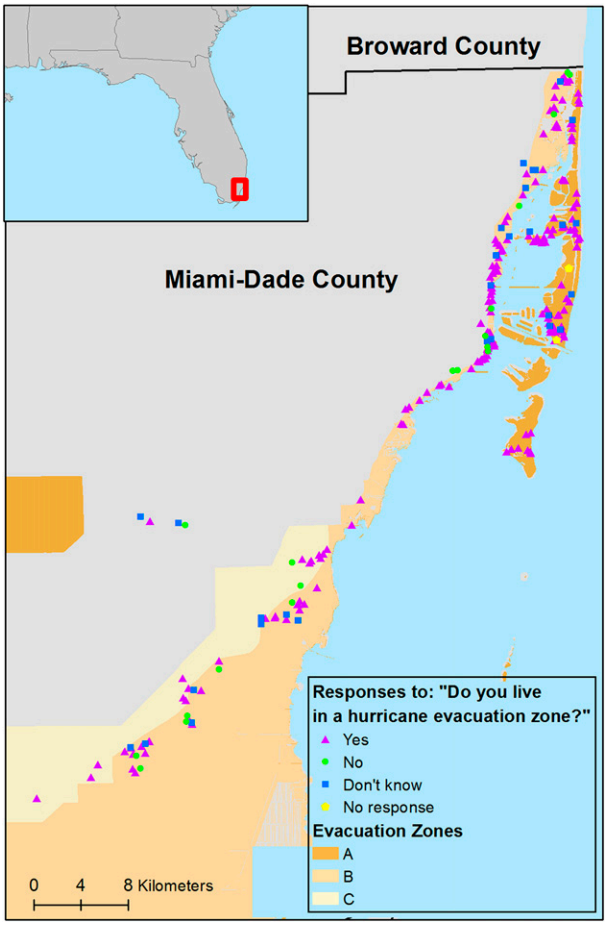


FIG. 3. Respondents' residence locations and perceived evacuation zones, depicted along with the Miami-Dade County hurricane evacuation zones at the time of the survey. Of the 255 respondents, 35.7% reside in evacuation zone A, 51.8% in zone B, 6.7% in zone C, and 5.9% not in an evacuation zone. Summary statistics for respondents' perceived evacuation zones are presented in Table 4.

used to facilitate presenting multiple graphics, controlling information flow, and randomizing messages among respondents, while also enabling recruitment of a broad (nonconvenience and nonstudent) sample of at-risk Miami-Dade residents. Because more than one-quarter of adult residents of Miami-Dade County identify themselves as primarily Spanish speaking, the survey was fielded in both English and Spanish.

During survey development, hard-copy versions of the draft survey were pretested by the survey lead (JKL) in person with members of the Miami-Dade public, using one-on-one verbal protocols (Ericsson and Simon 1993) to assess respondents' understanding and interpretation of the survey questions (Lazo et al. 2009, 2010). Before the final survey was fielded, the Internet-based version was pretested with 20 Miami-Dade County residents in KN's panel. For most questions with multiple items, the item order was randomized.

KN recruited respondents from the target geographic region by mail. In November 2011, KN mailed invitation letters to 17 050 addresses, randomly sampled from all Miami-Dade County census blocks containing some portion of evacuation zone A and/or B. One month later, postcard reminders were mailed that included a $10 incentive for completion. To ensure that all respondents were unique members of the targeted population, the invitations directed recipients to a web page where they entered the unique code provided in their invitation and were asked to confirm their mailing address. The survey was closed in January 2012. Most respondents completed the English version of the survey, with 7.1% completing the Spanish version.

The dataset used here contains 255 respondents.[4] The response rate was much lower than anticipated, and the resulting smaller sample size gives us limited power to test some of the hypotheses. It is important to interpret the results with this in mind. Nevertheless, several relationships still strongly emerge from the data (see section 4). Thus, as an exploratory study, the analysis provides useful knowledge about how some residents of at-risk U.S. coastal areas respond to different hurricane messages, for further investigation in future work.

As shown in Table 3, the sample reflects some of the ethnic, linguistic, and other diversity of Miami-Dade County. Compared to the Miami-Dade County population in 2011 (U.S. Census Bureau 2012), the sample is similar on median age; it has a lower percentage of females, people who report less education, nonwhites, Hispanics, and people whose primary language is not English. However, Chakraborty et al. (2014) found that lower-income, black, and Hispanic populations are underrepresented in coastal flood zones in the Miami area. Thus, the sample is likely more similar sociodemographically to the target population than is indicated by the comparison with the full Miami-Dade County population. Nevertheless, because of the geographic focus and other aspects of the implementation, the results cannot be generalized beyond the current sample.

Using respondents' confirmed addresses, KN provided latitude–longitude information for all respondents (randomly shifted by up to several hundred meters to

[4] KN received 260 completed surveys from respondents 18 yr or older with confirmed mailing addresses matching the respondents' invitation code. The median time taken to complete the survey was 33 min. Four respondents had completion times less than 10 min, and one did not provide responses to most of the questions on the latter half of the survey. These five respondents were removed from the final dataset, leaving 255 respondents.

TABLE 3. Sociodemographic characteristics of survey sample.

Sociodemographic characteristic	Survey sample[a]
Age (yr): median (range)	46 (19–86)
Gender: % male	56.0
Education (yr): median (range)	16 (8–22)
Employment: % employed	72.4
Length of residence in Miami-Dade County (yr): median (range)	12 (1–65)
Residence ownership: % yes	61.2
Residence type: % in building with two or more apartments	63.5
Household size (no. of people): median (range)	2 (1–7)
Race: % white	83.5
Ethnicity: % of Spanish, Hispanic, or Latino descent[b]	38.5
Primary language: % English	75.7
Primary language: % Spanish	18.0
Primary language: % other[c]	6.3

[a] Calculated excluding missing data.
[b] In the text, ethnicity is referred to as Hispanic or non-Hispanic, for brevity.
[c] The primary language question was open ended. Other than English and Spanish, respondents reported eight different primary languages, with the most common being French and Portuguese (four respondents each).

preserve anonymity). As shown in Fig. 3, approximately one-third of respondents reside in evacuation zone A and one-half in zone B. Because respondents were targeted based on census blocks overlapping the zones, the remaining respondents reside just outside these zones.

b. *Survey instrument: Hypothetical hurricane scenario, presentation of test messages, and measures*

The survey instrument was drafted through iteration and discussion among the project team and was informed by related prior work. To ensure that important issues in hurricane forecasting, warning, and communication practice were addressed, input was also solicited from members of the project's expert advisory group, which included meteorological researchers, NHC and NWS Weather Forecast Office (WFO) forecasters, media personnel, and emergency managers. The hurricane messages provided in the survey were based on forecast information and products developed for this study by the NHC and the Miami-South Florida WFO for a scenario of a hypothetical hurricane (Julia) approaching Miami-Dade County.

At the beginning of the survey, prior to receiving any information about Hurricane Julia, respondents were asked about their past hurricane experiences and reasons they might not evacuate in general. The experience questions (Table 1) measured six different aspects of respondents' experiences with hurricanes and their impacts that, based on previous work, we anticipated might be influential. The question on reasons for not evacuating, which includes measures of possible evacuation barriers and perceptions of residence safety (Table 4), was adapted from Lazo et al. (2010).

Next, the survey introduced respondents to the Hurricane Julia scenario by presenting the information in Fig. 1. In this first situation, Julia was located in the Atlantic and moving toward the U.S. coastline, but no specific track predictions were provided. Respondents were then asked several questions about information sources (not discussed in this article).

Respondents then proceeded to the test message section of the survey in which they were given different messages about the same forecast situation, 24 h later in the Hurricane Julia scenario. Respondents were informed that Julia is now a category 4 hurricane that may affect Miami within 48 h. Along with this information, they were presented with a randomly assigned combination of the five test messages discussed in section 2d and shown in Fig. 2. Each respondent received one of the two graphics depicting the NHC track forecast and uncertainty cone, either with (CONELINE) or without (NO-CONELINE) a line connecting the track forecast points. Along with one graphic, each respondent received any combination (or none) of the four textual messages in Fig. 2 (55%LANDFALL, 4FTSURGE, SURGEIMPACTS, and EVACPROTECT).

After reviewing the messages presented to them, respondents were asked about their protective behavioral intentions given this information, including their likelihood of evacuating and of taking five other types of preparatory action (e.g., boarding up or shuttering their home, withdrawing cash from bank; Table 5). Respondents were then asked questions to measure other responses to the hurricane scenario and the messages, including their cognitive and affective risk perceptions; efficacy beliefs; intended information behaviors; and attitudes toward the information received and its source. These questions were adapted from previous work, including the literature discussed in section 2.[5] At any time while responding to these questions, respondents could review the Hurricane Julia messages they had received earlier.

In this article, our examination of responses to messages focuses primarily on data from the protective behavioral intention questions, along with a subset of the

[5] These questions focused primarily on measuring constructs from two risk communication theories: the extended parallel process model [related to the fear appeals discussion in section 2, e.g., Witte (1992, 1994)] and the risk information seeking and processing (RISP) model (e.g., Griffin et al. 1999). The risk perception and efficacy measures are described further in DMLT.

TABLE 4. Measures of perceived barriers to hurricane evacuation, perceived residence safety from hurricanes, and perceived residence exposure to hurricanes, and summary statistics.

Concept	Measure	Summary statistics			
		N	Mean	Std dev	DNA
Perceived evacuation barriers and residence safety	Agree or disagree? Statements about possible reasons for why you may decide NOT to evacuate if a hurricane threatens where you live.[a]				
	-It would cost too much	254	3.5	1.9	3.5%
	-I don't want to leave my residence unattended	254	4.0	1.9	0.8%
	-I would be worried that there would be so much traffic	255	4.4	1.9	2.4%
	-I don't have transportation to evacuate	255	2.4	2.1	7.1%
	-My residence is safe from hurricane-related flooding	255	3.9	1.9	0.0%
	-My residence is safe from hurricane-related winds	253	3.8	1.7	0.8%
		N	Yes	No	DK
Perceived residence exposure	Do you live in a hurricane evacuation zone?[b]	253	79.4%	8.3%	12.3%

[a] Response options: ratings on a 7-point scale (from 1 = "very strongly disagree" to 7 = "very strongly agree," with all response options labeled as in Table 2), or "does not apply" (DNA).
[b] Response options: "yes," "no," "don't know" (DK).

questions about attitudes toward the information and source. These include two measures of negative reactance (Table 6) and one measure of the reliability of the source[6] of the Hurricane Julia information provided (rated on a seven-point scale with "unreliable" and "reliable" at the extremes).

Toward the end of the survey, respondents were asked whether they believe that they live in an evacuation zone (Table 4). They were also asked questions to measure individual and household characteristics (including those in Table 3) and individualist and egalitarian worldviews [measured with the nine items in Table 2, from Smith and Leiserowitz (2014)].

c. *Data analysis*

A primary focus of the data analysis for this article was investigating how respondents' protective behavioral intentions vary with their hurricane experience, their cultural worldviews, and the hurricane messages they received, along with other factors. To examine this, we performed multiple linear regressions with evacuation likelihood as the dependent variable. To explore the potential for defensive reactions to the information presented about Hurricane Julia [discussed in section 2d(3)], we also regressed the measures of negative reactance onto the same set of predictor variables.[7] For the regression results, we report unstandardized coefficients, along with significance values and, to compare the explanatory power of different independent variables, effect sizes.[8]

We also regressed each of the five nonevacuation preparatory actions on the same predictor variables. However, as indicated in Table 5, most respondents reported high intentions to take the five nonevacuation preparatory actions. This limited variance in the preparatory action data reduced the potential explanatory power of those regressions.[9] Consequently, we focus in this article on explaining variations in evacuation intentions.

To investigate the results in greater depth and explore some of the issues discussed in section 2, we also performed regressions with different sets of independent variables and with interaction terms (including interactions between pairs of the test messages and interactions between cultural worldview and the test messages). For brevity, the full additional regression results are not shown in the main text. Given the sample size and the exploratory nature of the study, we present and discuss only a subset of the interaction results, as illustrations of potential effects that may be important to examine further in future work.

[6] The source was not specified in the survey.

[7] The measures of negative reactance (on a scale from 1 to 7 with all response options labeled) are ordinal variables. We also performed ordinal regressions, and all of the results discussed in the text are substantively similar.

[8] The effect sizes reported in this article are squared semipartial correlations, which represent the proportion of the total variance in the dependent variable that is uniquely explained by each independent variable, controlling for all other independent variables (Hayes 2005).

[9] For the five nonevacuation protective actions, between 56% and 72% of respondents selected 7 on a scale from 1 to 7, resulting in a median response of 7. For comparison, the median value for evacuation likelihood is 8 on a scale from 0 to 10.

TABLE 5. Measures of protective behavioral intentions and summary statistics.

Concept	Measure	Summary statistics				
		N	Median	Mean	Std dev	
Evacuation intention	On a scale of 0 to 10, where zero means definitely would NOT evacuate and 10 means definitely WOULD evacuate, please indicate how likely it is that you would evacuate if you received this information about Hurricane Julia.[a]	255	8	7.0	2.9	
		N	Median	Mean	Std dev	NA
Intention to take other preparatory actions	Agree or disagree? Statements about how you would prepare for Hurricane Julia if you received this information.[b]					
	-I would make sure I have emergency supplies	254	7	6.3	1.2	0.8%
	-I would make sure my car has a full tank of gas	254	7	6.5	1.1	3.5%
	-I would board up windows and doors or put up shutters	255	7	5.8	1.7	13.3%
	-I would put lawn furniture, trash bins, etc., in a secure location	255	7	6.3	1.3	11.4%
	-I would withdraw cash from the bank	254	7	6.1	1.4	1.2%

[a] Response options: ratings on an 11-point scale from 0 = "I definitely would NOT evacuate" to 10 = "I definitely WOULD evacuate" (with response options 1–9 not labeled).

[b] Response options: ratings on a 7-point scale (from 1 = "very strongly disagree" to 7 = "very strongly agree," with all response options labeled as in Table 2), or "not applicable to me" (NA).

The location data provided by KN were analyzed using ArcGIS to estimate each respondent's elevation above sea level, distance from the closest coastal body of water, and location relative to official evacuation zones (Fig. 3). For use in the multivariate analyses, we recoded "don't know" or "does not apply" responses and imputed missing data[10] for the measures of individuals' characteristics, experiences, and perceptions (Harrell 2001).[11]

For the cultural worldview measures, we conducted a confirmatory factor analysis with a forced two-factor extraction using principal axis factoring and an orthogonal varimax rotation, following DeVellis (2012) [see also Garson (2012) and Demuth et al. (2011)]. Four of the five items that formed the individualist scale in Smith and Leiserowitz (2014) loaded onto the first factor (hereafter called individualist), and the four items that formed the egalitarian scale in Smith and Leiserowitz (2014) loaded onto the second factor (hereafter called egalitarian). The fifth item in Table 2 was part of the individualist scale in Smith and Leiserowitz (2014), but in these data, it loaded more heavily, negatively, onto the egalitarian factor.[12] The factor scores were retained for use in subsequent analysis.

4. Results

This section examines how evacuation intentions given the hypothetical Hurricane Julia scenario vary across respondents (sections 4a–c) and how people responded to the five experimentally manipulated test messages (section 4d). As noted earlier, a number of previous studies have examined factors influencing hurricane evacuation decisions [see, e.g., recent literature reviews in Lazo et al. (2015) and Huang et al. (2016)]. In discussing the findings, we therefore focus primarily on the novel contributions of this study.

a. Individual and household characteristics, perceived residence exposure and safety, and evacuation barriers

As shown in the regression results in Table 7, hurricane evacuation likelihood was higher for female

[10] For the sociodemographic and cultural theory questions, data were missing for 0%–8.6% of respondents. For all of the remaining survey questions examined in this article, data were missing for 0%–1.2% of respondents.

[11] For the experience question measuring severity of impacts (Table 1), all respondents who selected "don't know/no experience" had responded no to all of the five items in the first experience question (indicating no experience), and so these data were recoded to 1 = "not at all severe." For the items in the reasons for not evacuating question (Table 4), "does not apply" responses were recoded to 1 = "very strongly disagree." For missing worldview data, respondents who provided data for at least two of the egalitarian (individualist) items had data for the missing egalitarian (individualist) items imputed with their own median values of the other items for that worldview; otherwise, missing data were imputed using the sample's median values for each item. Missing data for the other independent variables used in the analyses were imputed using the sample's median values.

[12] Lazo et al. (2015) used the same nine items to measure worldviews with a different sample and also found that this same item loaded onto both factors.

TABLE 6. Measures of negative reactance and summary statistics.

Concept	Measure	Summary statistics			
		N	Median	Mean	Std dev
Negative reactance	*Agree or disagree? S*tatements about this information about Hurricane Julia.[a]				
	This information about Hurricane Julia is. . .				
	-misleading	255	2	2.4	1.2
	-overblown	255	3	2.5	1.3

[a] Response options: ratings on a 7-point scale (from 1 = ''very strongly disagree'' to 7 = ''very strongly agree,'' with all response options labeled as in Table 2).

respondents than males, consistent with some (but not all) previous related research (e.g., Riad et al. 1999; Bateman and Edwards 2002; Dash and Gladwin 2007; Smith and McCarty 2009; Lazo et al. 2015; Huang et al. 2012, 2016). Overall, the evacuation likelihood increased with age in this sample. This is counteracted to some extent by a lower evacuation likelihood among respondents who have lived in Miami-Dade County longer, controlling for other variables. Evacuation intentions were also somewhat lower for respondents who owned their residence (see also Huang et al. 2016).

More than one-third of the sample is Hispanic, and nearly one-quarter reported speaking a primary language other than English (Table 3). Ethnicity and primary language are correlated in the sample; for example, all Spanish-speaking respondents reported Hispanic ethnicity. Thus, to better represent these subpopulations in the analysis, we combined ethnicity and primary language into three dummy variables in the regressions: 1) Hispanic and primarily Spanish speaking (18.0% of respondents), 2) Hispanic and primarily English speaking (17.3%), and 3) any ethnicity and other non-English-language speaking (6.3%); the reference category is non-Hispanic and primarily English speaking (58.4%).

As Table 7 shows, evacuation likelihood was higher among both groups of Hispanic respondents, with the Spanish-speaking-Hispanic variable having the largest effect on evacuation likelihood of any of the sociodemographic characteristics tested. This relationship between ethnicity and hurricane evacuation is consistent with findings in Riad et al. (1999). However, other work suggests that ethnicity (in conjunction with other factors) interacts with hazard warning interpretation and decision-making in ways that often contribute to decreases in protective behaviors (e.g., Perry and Green 1982; Fothergill et al. 1999; Phillips and Morrow 2007; Thomas et al. 2013). As this literature indicates, there is also considerable diversity within ''Hispanic'' populations. Thus, this relationship may not apply beyond our coastal Miami-area Hispanic sample.

Although all respondents in this study lived in or near a hurricane evacuation zone, prior work has shown that some coastal residents misperceive their location relative to evacuation zones (e.g., Zhang et al. 2004; Arlikatti et al. 2006; Lazo et al. 2015). In this sample, 7% of those who lived in an evacuation zone said that they did not, and an additional 11% said that they did not know. As shown in Table 7, evacuation likelihood was somewhat higher for respondents who thought that they did live in an evacuation zone.[13] Because exposure varies even within evacuation zones, and because distance from the coast varied across the sample (Fig. 3), we also tested actual residence elevation and distance from the coast as independent variables in the regressions. Neither was a significant predictor of evacuation likelihood for this sample (see Table S1 in the online supplement to this article).

Because of the recent interest in storm surge risk perception and communication (section 2d), we included in the analyses respondents' perceptions of their residence's safety from winds and flooding, measured separately as possible reasons for not evacuating (Table 4). Some of our analyses suggested that respondents who thought their residence was safer from flooding were less likely to evacuate, and so further work on these perceptions is warranted. However, neither of the two perceived residence safety variables was significantly related to evacuation likelihood in the regression in Table 7, once other independent variables such as evacuation experience and perceived evacuation zone were included.

Even when people believe they are at risk from an approaching hurricane, factors such as cost, concerns about traffic or protecting property, family constraints, or lack of transportation inhibit some people from evacuating (e.g., Baker 1991; Riad et al. 1999; Gladwin et al. 2001; Elder et al. 2007; Eisenman et al. 2007; Zhang et al. 2007; Smith and McCarty 2009; Morss and Hayden 2010; Lazo et al. 2015). Thus, we included in the analysis several of these potential evacuation barriers, measured

[13] Because relatively few respondents said they did not live in an evacuation zone or did not know (Table 4), we did not have sufficient statistical power to compare these two groups in the regressions.

TABLE 7. Multiple linear regression with evacuation intention as the dependent variable ($N = 255$). Independent variables that are significant at the 10% (or higher) level are indicated in boldface.

Independent variables	Parameter estimate	Significance (p value)	Effect size (%)
Sociodemographic characteristics			
Age (yr)	**0.05**[a]	**0.002**	**2.6**
Gender (female = 1; male = 0)	**0.79**[b]	**0.02**	**1.5**
Education (yr)	0.002	0.98	0.0
Employed (yes = 1; no = 0)	0.45	0.25	0.4
Length of residence (yr)	**−0.04**[a]	**0.01**	**1.8**
Residence ownership (yes = 1; no = 0)	**−0.73**[b]	**0.05**	**1.0**
Residence type (apartment = 1, other = 0)	−0.66	0.11	0.7
Household size (No. of people)	0.11	0.48	0.1
Race (white = 1; other = 0)	−0.09	0.84	0.0
Language + ethnicity: Spanish + Hispanic	**1.57**[a]	**<0.001**	**3.4**
Language + ethnicity: English + Hispanic	**1.12**[b]	**0.02**	**1.5**
Language + ethnicity: other non-English + any	−0.37	0.59	0.1
Perceived residence exposure/safety and evacuation barriers			
In evacuation zone (yes = 1; no, don't know = 0)	**0.74**[c]	**0.08**	**0.9**
Safe from hurricane winds (1–7 scale)	−0.15	0.15	0.5
Safe from hurricane flooding (1–7 scale)	−0.12	0.24	0.4
Cost is too much (1–7 scale)	**−0.33**[a]	**0.005**	**2.2**
Don't want to leave residence unattended (1–7 scale)	**−0.26**[a]	**0.008**	**1.9**
Worried about traffic (1–7 scale)	0.10	0.31	0.3
Don't have transportation (1–7 scale)	**0.25**[b]	**0.04**	**1.1**
Hurricane experience			
Prior evacuation (yes = 1; no, don't know = 0)	**1.42**[a]	**<0.001**	**4.4**
Injury or loss of life (yes = 1; no, don't know = 0)	1.63	0.15	0.5
Property damage (yes = 1; no, don't know = 0)	−0.36	0.36	0.2
Financial loss (yes = 1; no, don't know = 0)	−0.15	0.73	0.0
Emotional impacts (yes = 1; no, don't know = 0)	−0.22	0.57	0.1
Overall severity of impacts (1–7 scale)	0.05	0.70	0.0
Cultural worldviews			
Individualism factor	**−0.41**[b]	**0.03**	**1.3**
Egalitarianism factor	−0.003	0.99	0.0
Test messages received (Fig. 2)			
CONELINE = 1; NO-CONELINE = 0	0.50	0.12	0.6
55%LANDFALL (received = 1; not received = 0)	−0.30	0.35	0.2
4FTSURGE (received = 1; not received = 0)	**0.52**[c]	**0.10**	**0.7**
SURGEIMPACTS (received = 1; not received = 0)	**1.46**[a]	**<0.001**	**5.2**
EVACPROTECT (received = 1; not received = 0)	0.28	0.38	0.2
Adjusted R^2	0.32		
F	**4.78**[a]	**<0.001**	

[a] Significant at $p < 0.01$.
[b] Significant at $p < 0.05$.
[c] Significant at $p < 0.1$.

as respondents' level of agreement with the barrier as a possible reason for not evacuating (Table 4).

As expected, evacuation likelihood was lower for respondents who rated cost or not wanting to leave their residence unattended as stronger evacuation barriers (Table 7). Counterintuitively, evacuation likelihood was higher for respondents who more strongly agreed with lack of transportation as a possible evacuation barrier. However, only 17 respondents agreed with lack of transportation as a barrier, and additional analysis suggests that this result may be associated with the characteristics of these respondents in our sample [e.g., many were renters living in apartments; see also Lazo et al. (2015)]. Although many respondents agreed with worries about traffic as a reason they might not evacuate (Table 4), this was not a significant predictor of evacuation intentions in this sample [see also Dow and Cutter (1998) and Zhang et al. (2007)].

b. *Prior hurricane experience*

To explore how different aspects of individuals' hurricane experiences interact with their evacuation

decisions, we included six measures of hurricane experience as independent variables in the regression analysis. As shown in Table 7, experience with hurricane evacuation was a strong, positive predictor of evacuation likelihood (see also Riad et al. 1999; Burnside et al. 2007; Lazo et al. 2015). In fact, evacuation experience had a larger effect on evacuation likelihood in the regression than any of the other independent variables tested, besides the messages.

Evacuation intentions may be higher among respondents with prior evacuation experience because the past hurricane-related experiences were influential (e.g., they enhanced risk perceptions or efficacy, which increased future evacuation intentions). Or this relationship may reflect the fact that many people tend to act consistently, either evacuating or not evacuating, across hurricane threats (Dow and Cutter 1998; Dash and Morrow 2000; Gladwin et al. 2001). These issues are explored further by DMLT.

Only five respondents reported experience with injury or loss of life (to themselves or a household member) because of a hurricane. Although this limits the analytic power for this variable, Table 7 indicates that evacuation likelihood may be higher among those who reported this form of experience.

None of the other experience measures tested was a significant predictor of evacuation likelihood. However, some did have potentially important influences on other variables measured on the survey (e.g., on risk perceptions and efficacy beliefs). This is investigated further by DMLT.

c. *Cultural worldviews*

As discussed in section 2, we anticipated that cultural worldviews would influence responses to the Hurricane Julia scenario. Table 7 shows that egalitarian worldview did not have a significant relationship with evacuation likelihood in these data. As expected, though, respondents with stronger individualist worldviews were significantly less likely to say they would evacuate.

The relationship between individualist worldview and evacuation likelihood is depicted in greater detail in Fig. 4a. Although evacuation likelihood varied widely among respondents with similar levels of individualism, the analysis in Fig. 4a illustrates that, overall, having a stronger individualist worldview was significantly associated with lower evacuation intentions. Respondents with strong individualist worldviews indicated, on average, evacuation likelihoods that were approximately three points (30%) lower than those with weak individualist worldviews.

Individualist worldview was also strongly related to many of the other variables measuring responses to hurricane risk on the survey. For example, as shown in Fig. 4b, stronger individualists had significantly higher negative reactance to the Hurricane Julia information, including perceptions that the information is overblown. They also had significantly lower cognitive risk perceptions, negative affect, and self- and response efficacy given the Hurricane Julia scenario, and they rated the information source as less reliable and less expert. Together with the evacuation intention results, this indicates that cultural worldviews may have important relationships with people's attitudes toward and responses to hazardous weather risks and risk information.

A concurrent study by Lazo et al. (2015) also found a relationship between cultural worldviews and hurricane evacuation intentions. However, in their analyses, these relationships varied across the two regions (Florida and Texas) and the two decision contexts (seeing a forecast and receiving an evacuation order) that they studied. Thus, further work is needed to understand the influence of cultural worldviews in different hazardous weather situations.

d. *Responses to hurricane messages*

1) EVACUATION LIKELIHOOD

Next, we examine how individuals responded to the experimentally manipulated messages shown in Fig. 2. Figure 5 depicts the effects of each test message by comparing the mean evacuation likelihood among respondents who did and those who did not receive each message. Table 7 shows the effects of the five test message variables on evacuation likelihood using regression analysis, controlling for the independent variables discussed in sections 4a–4c.

Of the messages tested, SURGEIMPACTS had the strongest influence, significantly increasing evacuation likelihood. The effect sizes in Table 7 indicate that the SURGEIMPACTS message had a stronger effect than any of the other independent variables tested in the regression. These results, together with those in Morss and Hayden (2010), indicate that messages conveying anticipated impacts of an approaching hurricane have the potential to help motivate some residents of high-risk areas to evacuate, at least in some situations. However, as discussed in section 2, extreme-impacts messages such as SURGEIMPACTS can also have unintended, undesirable effects, which we examine in the next subsection.

Regarding the graphical messages about hurricane track uncertainty, our analyses suggest that CONELINE recipients may have had higher protective behavioral intentions than NO-CONELINE recipients. Although

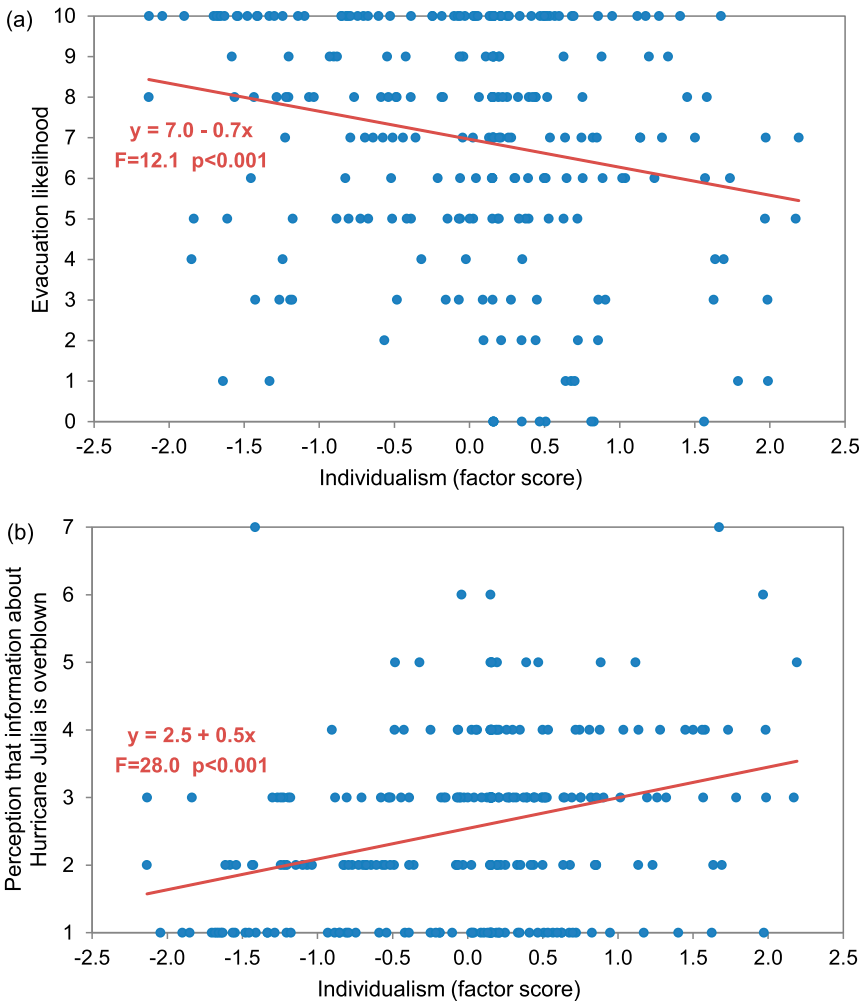


FIG. 4. (a) Plot of each respondent's evacuation likelihood vs their individualism factor score (blue circles), along with a linear best fit to the data (red line and equation with F and p values). (b) As in (a), but for respondents' perceptions that the information provided about Hurricane Julia is overblown. In both best-fit analyses, $p < 0.001$ for individualism.

this result is not statistically significant at the 10% level for the evacuation intention results shown in Table 7 and Figure 5, it is consistent with results in Meyer et al. (2013).

The 55%LANDFALL message appears to have had little effect on evacuation intentions, based on Table 7 and Fig. 5. However, further analysis indicates that 55%LANDFALL had important interactions with some of the other messages. Figure 6 shows that, in the absence of 55%LANDFALL, each of the three textual messages (4FTSURGE, SURGEIMPACTS, and EVACPROTECT) increased (had a positive effect on) evacuation likelihood. Receiving 55%LANDFALL in combination with these messages, however, reduced or eliminated these effects. This suggests that even though 55%LANDFALL was intended to provide probabilistic information only about hurricane track, some respondents may have applied the 55% probability to the information (e.g., about storm surge) provided in the other textual messages, leading them to weigh this information differently in their evacuation decision.

The analyses in Table 7 and Figs. 5 and 6 show that 4FTSURGE increased evacuation likelihood, especially among respondents who did not receive 55%LANDFALL. Although we did not test messages with different information about storm surge height or extent, we expect that such modifications could have important effects. Additional analysis indicates that recipients of either storm surge message (4FTSURGE or

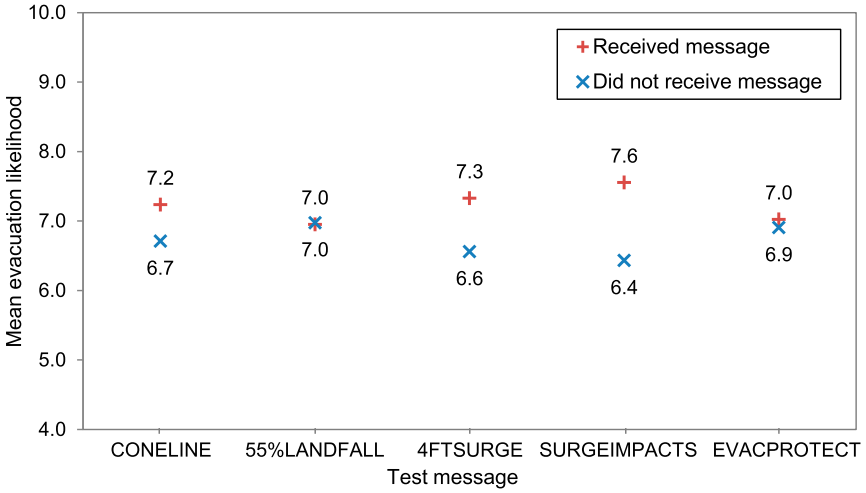


FIG. 5. For each of the five test messages, comparison of mean evacuation likelihood between respondents who did receive the message (=1) and those who did not receive the message (=0). Results for CONELINE are compared to results for those who received NO-CONELINE. Differences are statistically significant at the 10% level for SURGEIMPACTS [$t(253) = -3.1$, $p = 0.002$] and 4FTSURGE [$t(253) = -2.1$, $p = 0.03$] but not for CONELINE [$t(253) = -1.4$, $p = 0.15$], 55%LANDFALL, or EVACPROTECT.

SURGEIMPACTS) had higher evacuation intentions, on average, but providing the two messages together did not have an additive effect.[14]

Regarding the efficacy message, Table 7 indicates that across the sample, EVACPROTECT did not have a significant effect on evacuation likelihood. However, Fig. 6 suggests that EVACPROTECT did positively influence evacuation intentions, but only among respondents who did not receive 55%LANDFALL.

As discussed in section 2c, we anticipated that cultural worldviews would influence responses to hurricane risk messages. Counter to expectations, we did not find strong, statistically significant interactions between individualist worldview and any of the messages. Additional analysis suggests that SURGEIMPACTS had stronger effects on evacuation likelihood among nonindividualists, but the survey sample is not large enough to fully explore this issue. We did find a statistically significant interaction between egalitarian worldview and the efficacy message: EVACPROTECT increased evacuation intentions among respondents with egalitarian worldviews, and it decreased evacuation intentions among nonegalitarians.

In summary, the 4FTSURGE and SURGEIMPACTS results indicate that, at least for the storm surge information tested here, providing information about storm surge risks along with information about hurricane track helped motivate evacuation intention among some members of this sample (of people who reside in high-risk areas). The CONELINE and 55%LANDFALL results illustrate that communicating forecast uncertainty in different ways can have important—and sometimes unexpected or counterintuitive—effects. The 55%LANDFALL results also suggest that, when communicating weather forecast uncertainty, it may be important to consider interactions with other proximate messages. The EVACPROTECT results indicate the potential role of efficacy messaging as a component of hurricane risk communication. Finally, the exploratory analysis of interactions between cultural worldviews and the messages suggests that people with different worldviews may tend to respond to different types of hurricane risk messages differently, but further work is needed to examine this issue.

2) NEGATIVE REACTANCE AND RESPONSES TO EXTREME-IMPACTS MESSAGES

As discussed in section 2d, much of the literature on fear appeals suggests that some people can have undesirable, defensive responses to personalized, extreme-impacts messages such as SURGEIMPACTS. Thus, along with investigating the influence of the test

[14] The mean evacuation likelihood is 7.1 for respondents who received 4FTSURGE but not SURGEIMPACTS and 7.5 for those who received SURGEIMPACTS but not 4FTSURGE, compared to 5.8 for those who received neither message. For those who received both messages, the mean evacuation likelihood is 7.6. For those who received 4FTSURGE, a planned pairwise comparison indicates no statistically significant difference between respondents who did or did not receive SURGEIMPACTS [$F(1, 251) = 0.97$, $p = 0.33$].

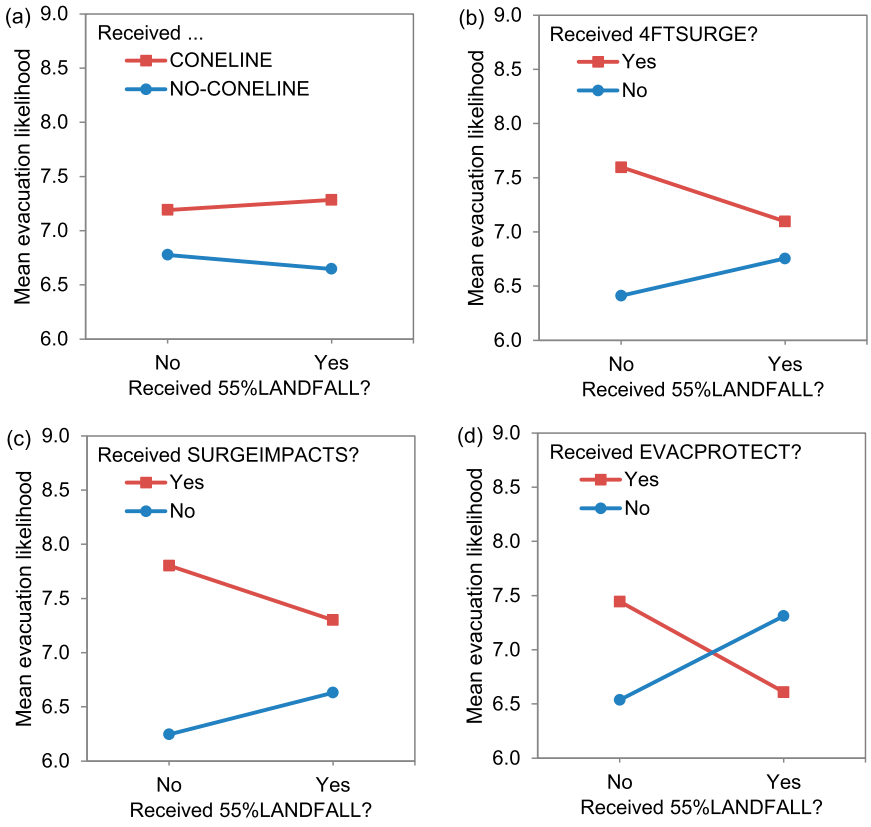


FIG. 6. Interaction effects between the 55%LANDFALL message and the (a) CONELINE, (b) 4FTSURGE, (c) SURGEIMPACTS, and (d) EVACPROTECT messages, in influencing evacuation intentions. For the respondents who did not receive 55%LANDFALL, planned pairwise comparisons indicate that the differences in mean evacuation likelihood between respondents who did or did not receive 4FTSURGE [$F(1, 251) = 5.51$, $p = 0.02$], SURGEIMPACTS [$F(1, 251) = 9.70$, $p = 0.002$], and EVACPROTECT [$F(1, 251) = 3.22$, $p = 0.07$] in (b), (c), and (d), respectively, are significant at the 10% level; all other differences are not statistically significant.

messages on evacuation intentions, we also examined other responses to the test messages, including the measures of negative reactance in Table 6.

As shown in the regression in Table 8, recipients of SURGEIMPACTS had significantly higher perceptions that the information about Hurricane Julia was overblown. Moreover, the language in SURGEIMPACTS is less dramatic and personalized than the language in some of the messages used for recent real-world hazardous weather events [section 2d(3)]. This indicates that when using extreme-impacts weather messages, it may be important to consider the potential for undesirable effects [see also Morss and Hayden (2010) and Ripberger et al. (2015)].

SURGEIMPACTS recipients also rated the (hypothetical) source of the Julia information they received as significantly less reliable (mean = 5.5) than nonrecipients [mean = 5.9; $t(250) = 1.99$, $p = 0.05$]. This finding is similar to Perreault et al.'s (2014) result that "scary" tornado warning messages were perceived as less credible. However, compared to nonrecipients, SURGEIMPACTS recipients did not have significantly higher ratings on the other measure of negative reactance [i.e., that the message was misleading (Table 6)]. As discussed in section 4d(1), SURGEIMPACTS recipients also had significantly higher evacuation intentions. Thus, further research is needed to investigate how different people respond to extreme-impacts weather messages and how this interacts with decision-making.

Table 8 also indicates that EVACPROTECT recipients rated the information about Hurricane Julia as less overblown than those who did not receive this efficacy message. This is consistent with the literature discussed in section 2, that defensive responses tend to be lower among people with high efficacy.

TABLE 8. Multiple linear regression with perceptions that the information provided about Hurricane Julia is overblown as the dependent variable ($N = 255$). Independent variables that are significant at the 10% (or higher) level are indicated in boldface.

Independent variables	Parameter estimate	Significance (p value)	Effect size (%)
Sociodemographic characteristics			
Age (yr)	**−0.02**[b]	**0.02**	**1.8**
Gender (female = 1; male = 0)	0.13	0.42	0.2
Education (yr)	−0.02	0.50	0.2
Employed (yes = 1; no = 0)	0.07	0.70	0.0
Length of residence (yr)	−0.003	0.71	0.0
Residence ownership (yes = 1; no = 0)	**0.42**[b]	**0.02**	**1.8**
Residence type (apartment = 1, other = 0)	0.30	0.14	0.7
Household size (No. of people)	0.04	0.62	0.1
Race (white = 1; other = 0)	**−0.56**[a]	**0.01**	**2.2**
Language + ethnicity: Spanish + Hispanic	0.18	0.41	0.2
Language + ethnicity: English + Hispanic	0.003	0.99	0.0
Language + ethnicity: other non-English + any	0.51	0.13	0.8
Perceived residence exposure/safety and evacuation barriers			
In evacuation zone (yes = 1; no, don't know = 0)	−0.10	0.63	0.1
Safe from hurricane winds (1–7 scale)	0.07	0.18	0.6
Safe from hurricane flooding (1–7 scale)	−0.03	0.50	0.1
Cost is too much (1–7 scale)	0.05	0.36	0.3
Don't want to leave residence unattended (1–7 scale)	0.009	0.85	0.0
Worried about traffic (1–7 scale)	−0.004	0.93	0.0
Don't have transportation (1–7 scale)	−0.005	0.93	0.0
Hurricane experience			
Prior evacuation (yes = 1; no, don't know = 0)	0.02	0.91	0.0
Injury or loss of life (yes = 1; no, don't know = 0)	0.03	0.95	0.0
Property damage (yes =1; no, don't know = 0)	**−0.32**[c]	**0.10**	**0.9**
Financial loss (yes = 1; no, don't know = 0)	−0.16	0.44	0.2
Emotional impacts (yes = 1; no, don't know = 0)	0.03	0.86	0.0
Overall severity of impacts (1–7 scale)	**0.10**[c]	**0.08**	**1.0**
Cultural worldviews			
Individualism factor	**0.27**[a]	**<0.001**	**5.5**
Egalitarianism factor	−0.04	0.71	0.0
Test messages received (Fig. 2)			
CONELINE = 1; NO-CONELINE = 0	0.10	0.52	0.1
55%LANDFALL (received = 1; not received = 0)	0.02	0.89	0.0
4FTSURGE (received = 1; not received = 0)	0.18	0.24	0.5
SURGEIMPACTS (received = 1; not received = 0)	**0.33**[b]	**0.05**	**1.3**
EVACPROTECT (received = 1; not received = 0)	**−0.27**[c]	**0.09**	**0.9**
Adjusted R^2	0.17		
F	**2.58**	**<0.001**	

[a] Significant at $p < 0.01$.
[b] Significant at $p < 0.05$.
[c] Significant at $p < 0.1$.

Again, this suggests the potential value of efficacy messaging.

Finally, Table 8 shows that, as discussed in section 4c, respondents with stronger individualist worldviews had significantly higher perceptions that the Hurricane Julia information is overblown—a larger effect than any of the other variables tested, including the messages. This again illustrates the importance of understanding how different subpopulations respond to weather risks differently and how cultural worldviews interact with perceptions of weather risk messages.

5. Summary and discussion

This study investigates 1) how and why different people respond differently to information about an approaching hurricane threat, and 2) how people respond to different types of hurricane risk information, using data from a survey of residents of high-risk coastal areas of Miami-Dade County, Florida. The survey examined people's anticipated protective decisions and responses to messages for a hypothetical hurricane approaching Miami. The study was designed to explore

issues of current interest in weather risk communication and decision-making, and to investigate how members of the public respond to message types that are currently being proposed—and in some cases, used operationally—for communicating the risks of hurricanes and other types of hazardous weather. We employed relevant theories and concepts from the social and behavioral sciences to guide the research design, data analysis, and interpretation of results.

One key result is study participants' responses to the extreme-impacts message tested, SURGEIMPACTS. On average, respondents who received SURGEIMPACTS indicated significantly higher evacuation likelihood than nonrecipients. However, SURGEIMPACTS recipients also perceived the Hurricane Julia information as more overblown and the information source as less reliable. Further investigation of these initial findings is needed, but these results suggest the trade-offs and possible disadvantages of using messages that convey strong, personalized information about impacts to try to motivate protective action. Considering the possible unintended effects of these kinds of messages over time may also be important, especially if the forecasted extreme impacts do not materialize for many (or all) message recipients. Thus, as discussed in the literature on fear appeals and boomerang effects (e.g., Rogers 1983; Witte 1994; Witte and Allen 2000; Hart 2013; Ruiter et al. 2014), it is important to use such messages with caution, and to design and test them carefully.

The analysis also suggests that the efficacy message tested, EVACPROTECT, increased protective behavioral intentions and decreased perceptions that the information is overblown. This is consistent with multiple studies of fear appeals in nonweather contexts, which find that people with lower perceived efficacy are more likely to have undesirable, defensive reactions (such as message rejection) and less likely to take protective action (e.g., Witte 1992, 1994; Witte and Allen 2000; Peters et al. 2013). As discussed in the risk communication literature, in some circumstances, helping people believe that they can protect against a risk can be more important for promoting desired behaviors than heightening risk perceptions (e.g., Witte and Allen 2000; Grothmann and Reusswig 2006; Ruiter et al. 2001, 2014; Bubeck et al. 2012; Peters et al. 2013). Thus, further investigation of efficacy messaging as a component of hazardous weather risk communication is warranted.

Another potentially important finding is how the 55%LANDFALL message interacted with the other test messages. The 55%LANDFALL message was designed to convey a relatively high probability (55%) of landfall near Miami, and we anticipated that it would supplement the information provided in the cone graphic. Instead, the analysis suggests that 55%LANDFALL interacted with the three other textual messages, decreasing those messages' effects on evacuation intentions. For example, 4FTSURGE recipients had higher evacuation intentions, but only when 4FTSURGE was not combined with 55%LANDFALL. Thus, it appears that at least some recipients of 55%LANDFALL applied the 55% probability to the information in the 4FTSURGE message, which on its own conveys certainty that "there will be storm surge." This illustrates the importance of considering (unintended) interactions between different pieces of information about an approaching hazardous weather event.

We also found that respondents with stronger individualist worldviews were less likely to say they would evacuate in the Hurricane Julia scenario, and they had higher perceptions that the Hurricane Julia information was overblown. In fact, there were strong signals from more individualist worldviews across many of the questions on the survey, more than any other variable (including the messages). These findings suggest that, at least in some situations, cultural worldviews may be associated with important differences in perceptions of hazardous weather risks, attitudes toward protective actions, and responses to weather forecast and warning information; we further investigate this in follow-on work.

Interviews conducted after Hurricane Ike (Morss and Hayden 2010) indicated that the defiant refusal to evacuate among some people at high risk may be associated with their preferences for personal autonomy. Together with the survey results discussed here, this suggests that worldviews may be related to why some people at high risk do not evacuate as a hurricane approaches, as well as being a contributor to "disaster cultures" of evacuation-resistant individuals in some locations (Wenger and Weller 1973; Dow and Cutter 1998; Dash and Morrow 2000).

Understanding the influence of cultural beliefs has potential to help forecasters, media, and public officials improve communication of hazardous weather information. For example, when a person's interpretation of a hazardous weather situation interacts strongly with cultural worldviews, providing more information, issuing stronger warnings, or explaining the meaning of the information is unlikely to be beneficial. A more effective approach may be to frame the information in ways that decrease message rejection among certain populations, for example, by presenting information in a way that affirms rather than threatens cultural values and narrative templates (e.g., Kahan et al. 2011; Hart and Nisbet 2012). More generally, when communicating weather

forecast and warning information, it is important to remember that different people approach weather risks from different perspectives. Each message will fall on people with different ''ears,'' who may interpret the information and make decisions very differently than a meteorologist or forecaster would.

Because this survey targeted residents of evacuation zones, one important consideration not addressed in this study is messaging to people at different levels of risk. Most forecast and warning information communicated by meteorologists is disseminated over a geographic region. Yet ''shadow evacuations,'' in which people in areas at lower risk decide to evacuate, can be problematic if they hamper evacuations (e.g., by clogging evacuation routes) for people at high risk. This suggests that if extreme-impacts or other types of evacuation-promoting messaging are to be used, it is important to geographically target the information and, to the extent possible, the dissemination. When evaluating weather risk messages, it is also important to keep in mind the potential effects on people who may not need to take certain protective actions.

The study's findings demonstrate that deciding to convey the risks of an approaching hurricane in different ways can have important—and sometimes counterintuitive or undesirable—effects. Thus, to design effective strategies for communicating about hazardous weather risks, it is important to evaluate how different audiences are likely to respond to different pieces of information, in conjunction with the other factors influencing their decisions. The study does not fully capture the complex, dynamic, socially and culturally mediated processes through which people obtain information, interpret risks, and evaluate actions as a real hurricane threatens (e.g., Gladwin et al. 2001; Bateman and Edwards 2002; Phillips and Morrow 2007; Taylor et al. 2009; Lazrus et al. 2012; Thomas et al. 2013). By exploring selected key issues within a simplified context, however, the article makes important contributions to advancing our limited understanding of how people interpret and use different types of weather risk information. The knowledge gained can be used to help elucidate and explain responses to weather risk messages observed in more complex contexts, and it can inform future related work.

Acknowledgments. The authors thank H. Dan O'Hair, Claude Miller, Matthew Jensen, Ann Bostrom, and members of the project's expert advisory group for their contributions to the survey design. This research was supported by National Science Foundation Award 0838702, which was jointly funded by the National Oceanic and Atmospheric Administration. The National Center for Atmospheric Research is sponsored by the National Science Foundation. Views and opinions in this paper are those of the authors.

REFERENCES

Arlikatti, S., M. K. Lindell, C. S. Prater, and Y. Zhang, 2006: Risk area accuracy and hurricane evacuation expectations of coastal residents. *Environ. Behav.*, **38**, 226–247, doi:10.1177/0013916505277603.

Ash, K. D., R. L. Schumann III, and G. C. Bowser, 2014: Tornado warning trade-offs: Evaluating choices for visually communicating risk. *Wea. Climate Soc.*, **6**, 104–118, doi:10.1175/WCAS-D-13-00021.1.

Baker, E. J., 1991: Evacuation behavior in hurricanes. *Int. J. Mass Emerg. Disasters*, **9**, 287–310.

——, 1995: Public response to hurricane probability forecasts. *Prof. Geogr.*, **47**, 137–147, doi:10.1111/j.0033-0124.1995.00137.x.

Bateman, J. M., and B. Edwards, 2002: Gender and evacuation: A closer look at why women are more likely to evacuate for hurricanes. *Nat. Hazards Rev.*, **3**, 107–117, doi:10.1061/(ASCE)1527-6988(2002)3:3(107).

Bostrom, A., R. E. Morss, J. K. Lazo, J. L. Demuth, H. Lazrus, and R. Hudson, 2016: A mental models study of hurricane forecast and warning production, communication, and decision-making. *Wea. Climate Soc.*, doi:10.1175/WCAS-D-15-0033.1, in press.

Broad, K., A. Leiserowitz, J. Weinkle, and M. Steketee, 2007: Misinterpretations of the ''cone of uncertainty'' in Florida during the 2004 hurricane season. *Bull. Amer. Meteor. Soc.*, **88**, 651–667, doi:10.1175/BAMS-88-5-651.

Bubeck, P., W. J. W. Botzen, and J. C. J. H. Aerts, 2012: A review of risk perceptions and other factors that influence flood mitigation behavior. *Risk Anal.*, **32**, 1481–1495, doi:10.1111/j.1539-6924.2011.01783.x.

Burnside, R., D. S. Mille, and J. D. Rivera, 2007: The impact of information and risk perception on the hurricane evacuation decision-making of greater New Orleans residents. *Sociol. Spectrum: Mid-South Sociol. Assoc.*, **27**, 727–740, doi:10.1080/02732170701534226.

Chakraborty, J., T. W. Collins, M. C. Montgomery, and S. E. Grineski, 2014: Social and spatial inequities in exposure to flood risk: A case study in Miami, Florida. *Nat. Hazards Rev.*, **15**, doi:10.1061/(ASCE)NH.1527-6996.0000140.

Dake, K., and A. Wildavsky, 1990: Theories of risk perception: Who fears what and why? *Daedalus*, **119**, 41–60.

Dash, N., and B. H. Morrow, 2000: Return delays and evacuation order compliance: The case of Hurricane Georges and the Florida Keys. *Environ. Hazards*, **2**, 119–128, doi:10.1016/S1464-2867(01)00008-0.

——, and H. Gladwin, 2007: Evacuation decision making and behavioral responses: Individual and household. *Nat. Hazards Rev.*, **8**, 69–77, doi:10.1061/(ASCE)1527-6988(2007)8:3(69).

Demuth, J. L., 2015: Developing a valid scale of past tornado experiences. Ph.D. dissertation, Colorado State University, 195 pp.

——, J. K. Lazo, and R. E. Morss, 2011: Exploring variations in people's sources, uses, and perceptions of weather forecasts. *Wea. Climate Soc.*, **3**, 177–192, doi:10.1175/2011WCAS1061.1.

——, R. E. Morss, B. Hearn Morrow, and J. K. Lazo, 2012: Creation and communication of hurricane risk information. *Bull. Amer. Meteor. Soc.*, **93**, 1133–1145, doi:10.1175/BAMS-D-11-00150.1.

DeVellis, R. F., 2012: *Scale Development: Theory and Applications*. Sage Publications, 205 pp.

Douglas, M., 1970: *Natural Symbols: Explorations in Cosmology*. Barrie and Rockliff, 177 pp.

——, and A. Wildavsky, 1982: *Risk and Culture: An Essay on the Selection of Technological and Environmental Dangers*. University of California Press, 224 pp.

Dow, K., and S. L. Cutter, 1998: Crying wolf: Repeat responses to hurricane evacuation orders. *Coastal Manage.*, **26**, 237–252, doi:10.1080/08920759809362356.

——, and ——, 2000: Public orders and personal opinions: Household strategies for hurricane risk assessment. *Global Environ. Change*, **2B**, 143–155, doi:10.1016/S1464-2867(01)00014-6.

Eisenman, D. P., K. M. Cordasco, S. Asch, J. F. Golden, and D. Glik, 2007: Disaster planning and risk communication with vulnerable communities: Lessons from Hurricane Katrina. *Amer. J. Public Health*, **97**, S109–S115, doi:10.2105/AJPH.2005.084335.

Elder, K., S. Xirasagar, N. Miller, S. Bowen, S. Glover, and C. Piper, 2007: African Americans' decisions not to evacuate New Orleans before Hurricane Katrina: A qualitative study. *Amer. J. Public Health*, **97**, S124–S129, doi:10.2105/AJPH.2006.100867.

Ericsson, K. A., and H. A. Simon, 1993: *Protocol Analysis: Verbal Reports as Data*. Rev. ed. The MIT Press, 443 pp.

Fothergill, A., E. G. M. Maestas, and J. D. Darlington, 1999: Race, ethnicity and disasters in the United States: A review of the literature. *Disasters*, **23**, 156–173, doi:10.1111/1467-7717.00111.

Garson, G. D., 2012: *Factor Analysis*. Statistical Publishing Associates, 149 pp.

Gladwin, C. H., H. Gladwin, and W. G. Peacock, 2001: Modeling hurricane evacuation decisions with ethnographic methods. *Int. J. Mass Emerg. Disasters*, **19**, 117–143.

Gladwin, H., and W. G. Peacock, 1997: Warning and evacuation: A night for hard houses. *Hurricane Andrew: Ethnicity, Gender and the Sociology of Disasters*, W. G. Peacock, B. H. Morrow, and H. Gladwin, Eds., Routledge, 52–73.

Goebbert, K., H. Jenkins-Smith, K. Klockow, M. Nowlin, and C. Silva, 2012: Weather, climate and worldviews: The sources and consequences of public perceptions of changes in local weather patterns. *Wea. Climate Soc.*, **4**, 132–144, doi:10.1175/WCAS-D-11-00044.1.

Greenberg, M., M. Weiner, R. Noland, J. Herb, M. Kaplan, and A. Broccoli, 2014: Public support for policies to reduce risk after Hurricane Sandy. *Risk Anal.*, **34**, 997–1012, doi:10.1111/risa.12203.

Griffin, R. J., S. Dunwoody, and K. Neuwirth, 1999: Proposed model of the relationship of risk information seeking and processing to the development of preventive behaviors. *Environ. Res.*, **80**, S230–S245, doi:10.1006/enrs.1998.3940.

Grothmann, T., and F. Reusswig, 2006: People at risk of flooding: Why some residents take precautionary action while others do not. *Nat. Hazards*, **38**, 101–120, doi:10.1007/s11069-005-8604-6.

Harrell, F. E., Jr., 2001: *Regression Modeling Strategies: With Applications to Linear Models, Logistic Regression and Survival Analysis*. Springer-Verlag, 568 pp.

Harrison, J., C. McCoy, K. Bunting-Howarth, H. Sorensen, K. Williams, and C. Ellis, 2014: Evaluation of the National Weather Service Impact-based Warning Tool. NWS Central Region Headquarters, 37 pp. [Available online at http://aqua.wisc.edu/publications/pdfs/ImpactBasedWarningTool.pdf.]

Hart, P. S., 2013: Boomerang effects in risk communication. *Effective Risk Communication*, J. Arvai and L. Rivers III, Eds., Routledge, 304–318.

——, and E. C. Nisbet, 2012: Boomerang effects in science communication: How motivated reasoning policies and identity cues amplify opinion polarization about climate mitigation. *Commun. Res.*, **39**, 701–723, doi:10.1177/0093650211416646.

Hayes, A. F., 2005: *Statistical Methods for Communication Science*. Routledge, 517 pp.

Hirschberg, P. A., and Coauthors, 2011: A weather and climate enterprise strategic implementation plan for generating and communicating forecast uncertainty information. *Bull. Amer. Meteor. Soc.*, **92**, 1651–1666, doi:10.1175/BAMS-D-11-00073.1.

Huang, S.-K., M. K. Lindell, C. S. Prater, H. C. Wu, and L. K. Siebeneck, 2012: Household evacuation decision making in response to Hurricane Ike. *Nat. Hazards Rev.*, **13**, 283–296, doi:10.1061/(ASCE)NH.1527-6996.0000074.

——, ——, and ——, 2016: Who leaves and who stays? A review and statistical meta-analysis of hurricane evacuation studies. *Environ. Behav.*, doi:10.1177/0013916515578485, in press.

Jones, S., and B. Golding, 2014: HIWeather: A research activity on High Impact Weather within the World Weather Research Programme. WMO, 87 pp. [Available online at http://www.wmo.int/pages/prog/arep/wwrp/new/documents/HIW_IP_v1_4.pdf.]

Joslyn, S., L. Nadav-Greenberg, and M. U. Taing, 2009: The effects of wording on the understanding and use of uncertainty information in a threshold forecasting decision. *Appl. Cogn. Psychol.*, **23**, 55–72, doi:10.1002/acp.1449.

Kahan, D. M., D. Braman, J. Gastil, P. Slovic, and C. K. Mertz, 2007: Culture and identity-protective cognition: Explaining the white male effect in risk perception. *J. Empirical Leg. Stud.*, **4**, 465–505, doi:10.1111/j.1740-1461.2007.00097.x.

——, H. Jenkins-Smith, and D. Braman, 2011: Cultural cognition of scientific consensus. *J. Risk Res.*, **14**, 147–174, doi:10.1080/13669877.2010.511246.

Kang, J. E., M. K. Lindell, and C. S. Prater, 2007: Hurricane evacuation expectations and actual behavior in Hurricane Lili. *J. Appl. Soc. Psychol.*, **37**, 887–903, doi:10.1111/j.1559-1816.2007.00191.x.

Lazo, J. K., R. E. Morss, and J. L. Demuth, 2009: 300 billion served: Sources, perceptions, uses, and values of weather forecasts. *Bull. Amer. Meteor. Soc.*, **90**, 785–798, doi:10.1175/2008BAMS2604.1.

——, D. M. Waldman, B. H. Morrow, and J. A. Thacher, 2010: Assessment of household evacuation decision making and the benefits of improved hurricane forecasting. *Wea. Forecasting*, **25**, 207–219, doi:10.1175/2009WAF2222310.1.

——, A. Bostrom, R. E. Morss, J. L. Demuth, and H. Lazrus, 2015: Factors affecting hurricane evacuation intentions. *Risk Anal.*, **35**, 1837–1857, doi:10.1111/risa.12407.

Lazrus, H., B. H. Morrow, R. E. Morss, and J. K. Lazo, 2012: Vulnerability beyond stereotypes: Context and agency in hurricane risk communication. *Wea. Climate Soc.*, **4**, 103–109, doi:10.1175/WCAS-D-12-00015.1.

Leiserowitz, A., 2006: Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climatic Change*, **77**, 45–72, doi:10.1007/s10584-006-9059-9.

——, E. Maibach, C. Roser-Renouf, N. Smith, and E. Dawson, 2013: Climategate, public opinion, and the loss of trust. *Amer. Behav. Sci.*, **57**, 818–837, doi:10.1177/0002764212458272.

Lindell, M. K., and R. W. Perry, 2012: The Protective Action Decision Model: Theoretical modifications and additional evidence. *Risk Anal.*, **32**, 616–632, doi:10.1111/j.1539-6924.2011.01647.x.

Loewenstein, G. F., E. U. Weber, C. K. Hsee, and N. Welch, 2001: Risk as feelings. *Psychol. Bull.*, **127**, 267–286, doi:10.1037/0033-2909.127.2.267.

Marimo, P., T. R. Kaplan, K. Mylne, and M. Sharpe, 2015: Communication of uncertainty in temperature forecasts. *Wea. Forecasting*, **30**, 5–22, doi:10.1175/WAF-D-14-00016.1.

McComas, K. A., 2006: Defining moments in risk communication research: 1996–2005. *J. Health Commun.*, **11**, 75–91, doi:10.1080/10810730500461091.

McNeeley, S. M., and H. Lazrus, 2014: The cultural theory of risk for climate change adaptation. *Wea. Climate Soc.*, **6**, 506–519, doi:10.1175/WCAS-D-13-00027.1.

Meyer, R., K. Broad, B. Orlove, and N. Petrovic, 2013: Dynamic simulation as an approach to understanding hurricane risk response: Insights from Stormview lab. *Risk Anal.*, **33**, 1532–1552, doi:10.1111/j.1539-6924.2012.01935.x.

——, J. Baker, K. Broad, J. Czajkowski, and B. Orlove, 2014: The dynamics of hurricane risk perception: Real-time evidence from the 2012 Atlantic hurricane season. *Bull. Amer. Meteor. Soc.*, **95**, 1389–1404, doi:10.1175/BAMS-D-12-00218.1.

Morrow, B. H., J. K. Lazo, J. Rhome, and J. Feyen, 2015: Improving storm surge risk communication: Stakeholder perspectives. *Bull. Amer. Meteor. Soc.*, **96**, 35–48, doi:10.1175/BAMS-D-13-00197.1.

Morss, R. E., and M. H. Hayden, 2010: Storm surge and "certain death": Interviews with Texas coastal residents following Hurricane Ike. *Wea. Climate Soc.*, **2**, 174–189, doi:10.1175/2010WCAS1041.1.

——, J. L. Demuth, and J. K. Lazo, 2008: Communicating uncertainty in weather forecasts: A survey of the U.S. public. *Wea. Forecasting*, **23**, 974–991, doi:10.1175/2008WAF2007088.1.

——, J. K. Lazo, and J. L. Demuth, 2010: Examining the use of weather forecasts in decision scenarios: Results from a U.S. survey with implications for uncertainty communication. *Meteor. Appl.*, **17**, 149–162, doi:10.1002/met.196.

——, J. L. Demuth, A. Bostrom, J. K. Lazo, and H. Lazrus, 2015: Flash flood risks and warning decisions in Boulder, Colorado: A mental models study of forecasters, public officials, and media broadcasters. *Risk Anal.*, **35**, 2009–2028, doi:10.1111/risa.12403.

NOAA, 2011a: NOAA'S National Weather Service strategic plan: Building a weather-ready nation. NOAA/NWS, 44 pp. [Available online at http://www.nws.noaa.gov/com/weatherreadynation/files/strategic_plan.pdf.]

——, 2011b: NWS Central Region service assessment: Joplin, Missouri, tornado – May 22, 2011. NOAA/NWS, 35 pp. [Available online at http://www.nws.noaa.gov/om/assessments/pdfs/Joplin_tornado.pdf.]

——, 2012: Service assessment: Hurricane Irene, August 21-30, 2011. NOAA/NWS, 91 pp. + appendixes. [Available online at http://www.nws.noaa.gov/om/assessments/pdfs/Irene2012.pdf.]

——, 2013: Service assessment: Hurricane/post-Tropical Cyclone Sandy, October 22–29, 2012. NOAA/NWS, 46 pp. + appendixes. [Available online at http://www.nws.noaa.gov/os/assessments/pdfs/Sandy13.pdf.]

——, 2015: Impact based warnings. Accessed 16 September 2015. [Available online at http://www.weather.gov/impacts/.]

NRC, 2006: *Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts*. The National Academies Press, 124 pp.

——, 2010: *When Weather Matters: Science and Service to Meet Critical Societal Needs*. The National Academies Press, 208 pp.

Peacock, W. G., S. D. Brody, and W. Highfield, 2005: Hurricane risk perceptions among Florida's single family homeowners. *Landscape Urban Plann.*, **73**, 120–135, doi:10.1016/j.landurbplan.2004.11.004.

Perreault, M. F., J. B. Houston, and L. Wilkins, 2014: Does scary matter?: Testing the effectiveness of new National Weather Service tornado warning messages. *Commun. Stud.*, **65**, 484–499, doi:10.1080/10510974.2014.956942.

Perry, R. W., and M. R. Green, 1982: The role of ethnicity in the emergency decision-making process. *Sociol. Inq.*, **52**, 306–334, doi:10.1111/j.1475-682X.1982.tb01257.x.

Peters, E., and P. Slovic, 1996: The role of affect and worldviews as orienting dispositions in the perception and acceptance of nuclear power. *J. Appl. Soc. Psychol.*, **26**, 1427–1453, doi:10.1111/j.1559-1816.1996.tb00079.x.

Peters, G.-J. Y., R. A. C. Ruiter, and G. Kok, 2013: Threatening communication: A critical re-analysis and a revised meta-analytic test of fear appeal theory. *Health Psychol. Rev.*, **7**, S8–S31, doi:10.1080/17437199.2012.703527.

Phillips, B. D., and B. H. Morrow, 2007: Social science research needs: Focus on vulnerable populations, forecasting, and warnings. *Nat. Hazards Rev.*, **8**, 61–68, doi:10.1061/(ASCE)1527-6988(2007)8:3(61).

Rappaport, E. N., 2014: Fatalities in the United States from Atlantic tropical cyclones: New data and interpretation. *Bull. Amer. Meteor. Soc.*, **95**, 341–346, doi:10.1175/BAMS-D-12-00074.1.

Riad, J. K., F. N. Norris, and R. B. Ruback, 1999: Predicting evacuation in two major disasters: Risk perception, social influence, and access to resources. *J. Appl. Soc. Psychol.*, **29**, 918–934, doi:10.1111/j.1559-1816.1999.tb00132.x.

Ripberger, J. T., C. L. Silva, H. C. Jenkins-Smith, and M. James, 2015: The influence of consequence-based messages on public responses to tornado warnings. *Bull. Amer. Meteor. Soc.*, **96**, 577–590, doi:10.1175/BAMS-D-13-00213.1.

Rogers, R. W., 1983: Cognitive and physiological processes in fear appeals and attitude change: A revised theory of protection motivation. *Social Psychophysiology*, J. Cacioppo and R. E. Petty, Eds., Guilford, 153–176.

Ruiter, R. A. C., C. Abraham, and G. Kok, 2001: Scary warnings and rational precautions: A review of the psychology of fear appeals. *Psychol. Health*, **16**, 613–630, doi:10.1080/08870440108405863.

——, L. T. E. Kessels, G.-J. Y. Peters, and G. Kok, 2014: Sixty years of fear appeal research: Current state of the evidence. *Int. J. Psychol.*, **49**, 63–70, doi:10.1002/ijop.12042.

Sherman-Morris, K., 2013: The public response to hazardous weather events: 25 years of research. *Geogr. Compass*, **7**, 669–685, doi:10.1111/gec3.12076.

Slovic, P., M. L. Finucane, E. Peters, and D. G. MacGregor, 2004: Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk, and rationality. *Risk Anal.*, **24**, 311–322, doi:10.1111/j.0272-4332.2004.00433.x.

Smith, N., and A. Leiserowitz, 2014: The role of emotion in global warming policy support and opposition. *Risk Anal.*, **34**, 937–948, doi:10.1111/risa.12140.

Smith, S., and C. McCarty, 2009: Fleeing the storm(s): An examination of evacuation behavior during Florida's 2004 hurricane season. *Demography*, **46**, 127–145, doi:10.1353/dem.0.0048.

Sorensen, J. H., 2000: Hazard warning systems: Review of 20 years of progress. *Nat. Hazards Rev.*, **1**, 119–125, doi:10.1061/(ASCE)1527-6988(2000)1:2(119).

Stein, R., L. Dueñas-Osorio, and D. Subramanian, 2010: Who evacuates when hurricanes approach? The role of risk, information, and location. *Soc. Sci. Quart.*, **91**, 816–834, doi:10.1111/j.1540-6237.2010.00721.x.

Taylor, K., S. Priest, H. Fussell Sisco, S. Banning, and K. Campbell, 2009: Reading Hurricane Katrina: Information sources and decision-making in response to a natural disaster. *Soc. Epistemol.*, **23**, 361–380, doi:10.1080/02691720903374034.

Thomas, D. S. K., B. D. Phillips, W. E. Lovekamp, and A. Fothergill, Eds., 2013: *Social Vulnerability to Disasters*. CRC Press, 513 pp.

U.S. Census Bureau, 2011: American community survey. [Available online at http://www.census.gov/acs/www.]

Wei, H.-L., M. K. Lindell, and C. S. Prater, 2014: "Certain death" from storm surge: A comparative study of household responses to warnings about Hurricanes Rita and Ike. *Wea. Climate Soc.*, **6**, 425–433, doi:10.1175/WCAS-D-13-00074.1.

Wenger, D. E., and J. M. Weller, 1973: Disaster subcultures: The cultural residues of community disasters. University of Delaware Disaster Research Center Preliminary Paper 9, 18 pp. [Available online at http://udspace.udel.edu/handle/19716/399.]

Whitehead, J. C., 2005: Environmental risk and averting behavior: Predictive validity of jointly estimated revealed and stated behavior data. *J. Environ. Resour. Econ.*, **32**, 301–316, doi:10.1007/s10640-005-4679-5.

Witte, K., 1992: Putting the fear back into fear appeal: The extended parallel process model. *Commun. Monogr.*, **59**, 329–349, doi:10.1080/03637759209376276.

——, 1994: Fear control and danger control: A test of the extended parallel process model (EPPM). *Commun. Monogr.*, **61**, 113–132, doi:10.1080/03637759409376328.

——, and M. Allen, 2000: A meta-analysis of fear appeals: Implications for effective public health campaigns. *Health Educ. Behav.*, **27**, 591–615, doi:10.1177/109019810002700506.

Wu, H.-C., M. K. Lindell, C. S. Prater, and C. D. Samuelson, 2014: Effects of track and threat information on judgments of hurricane strike probability. *Risk Anal.*, **34**, 1025–1039, doi:10.1111/risa.12128.

Zhang, F., and Coauthors, 2007: An in-person survey investigating public perceptions of and response to Hurricane Rita forecasts along the Texas coast. *Wea. Forecasting*, **22**, 1177–1190, doi:10.1175/2007WAF2006118.1.

Zhang, Y., C. S. Prater, and M. K. Lindell, 2004: Risk area accuracy and hurricane evacuation from Hurricane Bret. *Nat. Hazards Rev.*, **5**, 115–120, doi:10.1061/(ASCE)1527-6988(2004)5:3(115).