

An In-Person Survey Investigating Public Perceptions of and Responses to Hurricane Rita Forecasts along the Texas Coast

FUQING ZHANG

Department of Atmospheric Sciences, Texas A&M University, College Station, Texas

REBECCA E. MORSS

National Center for Atmospheric Research, Boulder, Colorado*

J. A. SIPPEL, T. K. BECKMAN, N. C. CLEMENTS, N. L. HAMPSHIRE, J. N. HARVEY, J. M. HERNANDEZ,
Z. C. MORGAN, R. M. MOSIER, S. WANG, AND S. D. WINKLEY

Department of Atmospheric Sciences, Texas A&M University, College Station, Texas

(Manuscript received 26 December 2006, in final form 26 March 2007)

ABSTRACT

Hurricane Rita made landfall near the Texas–Louisiana border in September 2005, causing major damage and disruption. As Rita approached the Gulf Coast, uncertainties in the storm’s track and intensity forecasts, combined with the aftermath of Hurricane Katrina, led to major evacuations along the Texas coast and significant traffic jams in the broader Houston area. This study investigates the societal impacts of Hurricane Rita and its forecasts through a face-to-face survey with 120 Texas Gulf Coast residents. The survey explored respondents’ evacuation decisions prior to Hurricane Rita, their perceptions of hurricane risk, and their use of and opinions on Hurricane Rita forecasts. The vast majority of respondents evacuated from Hurricane Rita, and more than half stated that Hurricane Katrina affected their evacuation decision. Although some respondents said that their primary reason for evacuating was local officials’ evacuation order, many reported using information about the hurricane to evaluate the risk it posed to them and their families. Despite the major traffic jams and the minor damage in many evacuated regions, most evacuees interviewed do not regret their decision to evacuate. The majority of respondents stated that they intend to evacuate for a future category 3 hurricane, but the majority would stay for a category 2 hurricane. Most respondents obtained forecasts from multiple sources and reported checking forecasts frequently. Despite the forecast uncertainties, the respondents had high confidence in and satisfaction with the forecasts of Rita provided by the National Hurricane Center.

1. Introduction

The 2005 Atlantic hurricane season was record breaking, with 28 named storms and 15 hurricanes, including 4 major hurricanes that hit the United States. One of those major hurricanes, Hurricane Rita, affected a large area of the Gulf Coast during late Sep-

tember 2005. As a measure of its strength, Rita attained the fourth lowest surface pressure on record in the Atlantic basin. Although Rita weakened before making landfall near the Texas–Louisiana border, the hurricane still caused at least seven deaths and an estimated \$10 billion in damage in Florida, Texas, Louisiana, and other states (Knabb et al. 2006). Rita also caused major disruption; uncertainties in the track and intensity forecasts (Fig. 1), combined with the aftermath of Hurricane Katrina, led to one of the largest evacuations in U.S. history. The massive evacuation caused major traffic jams, including 100-mi traffic backups and travel delays of 10 h or longer (Blumenthal and Barstow 2005). Many evacuees were trapped on roadways for close to a day, experiencing fuel, food, and water short-

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

Corresponding author address: Dr. Fuqing Zhang, Dept. of Atmospheric Sciences, Texas A&M University, College Station, TX 77845-3150.
E-mail: fzhang@tamu.edu

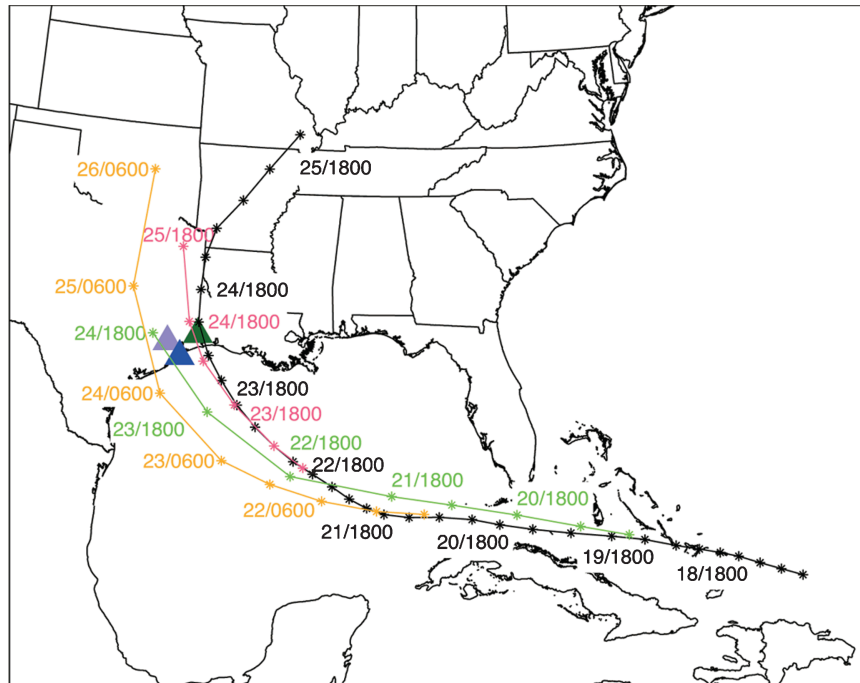


FIG. 1. The observed track of Hurricane Rita (black curve; NHC postevent best-track analysis) and the NHC official track forecasts for Rita issued approximately 108 h (green), 72 h (orange), and 36 h (red) before landfall. The days and times (UTC) of the forecast–observed positions are denoted in the format day/hour (DD/HHMM; e.g., 24/0600). The three interview areas are depicted with triangles (green, Beaumont–Port Arthur; blue, Galveston; and purple, Houston).

ages; lack of access to facilities; and significant frustration. Had the storm hit the Houston–Galveston area directly, the consequences would likely have been formidable, especially given that so many people were trapped on roads.

After witnessing Rita and its impacts, several meteorology students at Texas A&M University became interested in investigating Rita’s forecasts and societal impacts in greater depth. This led to a student research project in the form of an undergraduate “directed studies” course at Texas A&M in the spring semester of 2006, involving a research team of two principal investigators, three graduate students, and seven undergraduates. The research study included a meteorology and an interdisciplinary component. The meteorology component was an investigation of uncertainties in forecasts of Rita, through three small group projects. The interdisciplinary component investigated the public’s preparation and evacuation decisions prior to Hurricane Rita, their perceptions of hurricane risk, and their sources, perceptions, and uses of Rita forecasts. Using a structured interview questionnaire developed by the research team, the students conducted 120 in-person interviews with residents of three Texas Gulf

Coast regions (Galveston, Beaumont–Port Arthur, and Houston). The questionnaire included both closed-ended questions, allowing the students to help analyze quantitative results, and open-ended questions, giving the students an opportunity to learn first hand about people’s perceptions of hurricane risk and their hurricane experiences.

The research project generated significant educational benefits for the students. Based on these benefits and the instructors’ and students’ experiences, we propose that the project and class serve as a prototype undergraduate research model for linking meteorological education to reality. This research–education paradigm, which can be implemented at both colleges and research universities, can give students experience with the full research process, expose students to the science–society interface, and be used to investigate a variety of topics of interest to students, teachers, the research community, and society. Interested readers are referred to Morss and Zhang (2008, hereafter MZ) for further details.

The remainder of this article reviews the methodology for the face-to-face survey study and presents the survey results. Related surveys have been conducted

following a number of previous hurricanes, examining issues such as evacuation behavior and decision making, information sources, effects of false alarms, transportation demand, and residents' ability to identify their risk area (e.g., Baker 1979, 1991; Gladwin and Peacock 1997; Dow and Cutter 1998, 2000, 2002; Dash and Morrow 2000; Gladwin et al. 2001; Zhang et al. 2004; Lindell et al. 2005). Other related studies have examined coastal residents' general perceptions of hurricane risk or expected response to hypothetical hurricanes (e.g., Cross 1990; Baker 1995; Whitehead et al. 2000; Arlikatti et al. 2006). The scientific results presented here augment this previous work by examining people's impressions of, and behavior during, a new hurricane, Rita. Rita was unique for several reasons; most notably it was the first hurricane to make landfall in the United States after the widely covered devastation associated with Hurricane Katrina. In addition to examining hurricane evacuation decisions and risk perception, our survey also explored a topic that has rarely been investigated in previous work: the public's perceptions of hurricane forecasts. In particular, we asked respondents about their confidence in and satisfaction with forecasts for Rita and their desire for additional hurricane forecast information in the future.

An overview of Hurricane Rita's meteorology, forecasts, and evacuation is provided in section 2, followed by a presentation of the survey methodology and sample in section 3. Section 4 presents the survey results, and section 5 provides a summary and discussion.

2. Overview of Hurricane Rita meteorology, forecasts, and evacuation

The tropical depression that preceded Rita formed just east of Grand Turk Island around 0000 UTC 18 September 2005 (Fig. 1), and the system reached tropical storm strength ($>17.5 \text{ m s}^{-1}$ maximum sustained winds) around 1800 UTC 18 September. Rita attained hurricane strength ($>35 \text{ m s}^{-1}$ winds) in the Florida Straits around 1200 UTC 20 September and strengthened rapidly thereafter. As Rita moved west into the Gulf of Mexico, very warm sea surface temperatures in the Loop Current and weak wind shear allowed the storm to strengthen to a category 5 hurricane ($>70 \text{ m s}^{-1}$ winds) by 1800 UTC 21 September. Although Rita maintained category 5 intensity for less than 24 h, its central surface pressure bottomed at 895 hPa and its winds peaked at 77.5 m s^{-1} (Knabb et al. 2006).

After 21 September, Rita turned more northward around the edge of a mid- to upper-level ridge centered over the southeastern United States. Inner-core dy-

namics, cooler ocean temperatures, and increasing shear then took their toll on the hurricane's strength. Rita gradually weakened and was a minimal category 3 hurricane (50 m s^{-1} winds) at landfall at 0740 UTC 24 September. Because of its large size, however, Rita caused sustained tropical storm-force winds across much of Louisiana and southeastern Texas.

Official track forecast errors associated with Hurricane Rita were smaller than the average track errors for the past decade. However, official forecasts issued on 19–21 September predicted that the hurricane would turn northward more slowly than it did (Fig. 1). As a result, several days prior to landfall, forecasts of Rita's landfall exhibited a westerly bias and were centered near the middle of the Texas Gulf Coast region. Because Rita's rapid intensification and subsequent weakening were not well predicted, the official intensity forecast error for Rita was nearly double that of the past decade. These forecast challenges contributed to mandatory evacuations of many Texas Gulf Coast communities, including areas such as Galveston Island, which ended up experiencing only minor damage. The Texas governor urged coastal residents from Beaumont to Corpus Christi—much of the Texas Gulf Coast—to leave. The Houston mayor ordered or recommended evacuation for parts of the city, telling people: "Don't follow the example of New Orleans" (Blumenthal and Barstow 2005). Significant shadow evacuations occurred across much of southeastern Texas. An estimated 2.5 million people evacuated, twice as many as expected in area evacuation plans (Blumenthal and Barstow 2005).

3. Methodology and survey sample

The goal of the project was to explore the societal impacts of Rita and its forecasts through structured in-person interviews of Texas Gulf Coast residents. The face-to-face survey methodology was selected to fulfill the project's research and educational goals and to complement a mail survey of the Hurricane Rita evacuation that was, at the time of our study, being developed by the Texas A&M University Hazard Reduction and Recovery Center (HRRRC).

To develop the interview questionnaire, we started by creating a list of potential questions based on previous related surveys and ideas from members of the research team. Through many iterations among the research team and incorporating feedback from two hazards researchers with survey experience, we selected the most pertinent questions and phrased each question in a way understandable to the public. After receiving 1.5 h of interview training from an HRRRC researcher, each student conducted at least two practice interviews

TABLE 1. Summary of interviews used in analysis.

Location	Date(s) of interviews	No. of students who conducted interviews	No. of interviews conducted*	No. of area residents interviewed*
Galveston	25–26 Mar 2006	4	62	58
Beaumont–Port Arthur	1–2 Apr 2006	3	39	38
Houston	1 Apr 2006	2	19	24
Total			120	120

* Four of the respondents interviewed in Galveston and one interviewed in Beaumont–Port Arthur resided in the Houston area.

to obtain interview experience and to pretest the questionnaire. Based on feedback from the pretest, the questionnaire was then further refined.

The questionnaire¹ opened by asking respondents if they were in the Texas Gulf region when Rita was approaching and if they were a primary household decision maker regarding hurricane evacuation. Respondents who answered yes to both were then asked a series of questions focusing primarily on the respondent's preparation and evacuation decisions related to Hurricane Rita, perceptions of hurricane-related risks, and sources and perceptions of Rita forecasts. Basic demographic questions were also included. The majority of the questions were closed ended, requesting responses in a yes/no, multiple choice, Likert scale (1–5 ranking), or brief-worded format. To provide richer, more detailed data, the questionnaire also included open-ended questions, such as follow-up questions requesting respondents to elaborate on or explain responses to earlier questions.

Given limited resources, interviews were conducted in three Texas coastal areas: Beaumont–Port Arthur, Galveston, and Houston (Fig. 1). These areas were selected because of their different experiences with Hurricane Rita: Beaumont–Port Arthur experienced mandatory evacuations and significant damage, Galveston experienced mandatory evacuations and minor damage, and Houston experienced a mix of mandatory, voluntary, and no evacuation orders and minimal damage but major evacuation traffic. Students traveled to the interview areas and identified respondents through a convenience sampling strategy, approaching potential respondents in locations such as beaches, fishing piers, stores, hotels, restaurants, and residences. Using this strategy, the rate of response to interview requests was 80%–90%, providing 120 valid interviews for analysis (summarized in Table 1). All respondents are categorized by their area of residence (rather than area of interview) in the subsequent discussion.

The students conducted interviews by following the structured questionnaire, recording responses on the interview sheet. The interviews were designed to last 15 min, but some lasted significantly longer when respondents gave extended responses to open-ended questions. Each student was also equipped with a digital voice recorder, but only about half of the interviews were taped because of tape and/or battery issues or because respondents declined being recorded. After conducting the interviews, each student coded the responses to his or her interviews and entered them into computer data files based on uniform standards. These data files were then verified against the interview sheets by another student. Numerical responses were analyzed using FORTRAN and Matlab programs. Worded responses were analyzed by coding (categorizing) responses using standard qualitative data analysis techniques.

Despite the convenience sampling strategy, the survey population was similar to the general coastal population in terms of age, gender, race, education, income, and home ownership (based on year 2000 U.S. Census Bureau data available online at <http://factfinder.census.gov>). The sample also exhibits reasonable diversity in each of these characteristics. Respondents' ages ranged from 17 to 92, with an average of 45. They had resided in the Texas Gulf Coast region between 1 and 93 yr, with an average of 30. Fifty percent of the respondents were male, and the average household size was 2.6 people. Other demographic characteristics of the sample are summarized in Table 2.

Because of the relatively small convenience sample, one cannot generalize from these results to the general Texas Gulf Coast population, and we did not perform any detailed analysis of subpopulations or correlations among responses. The general results are, however, indicative of the public's decisions and perceptions in the three areas studied. Several of our survey questions are included in a larger mail survey of the Hurricane Rita evacuation being performed by the HRRC, which will allow more in-depth analysis (W. Peacock 2006, personal communications). It also worth noting that the results are based on people's retrospective reports of

¹ A copy of the questionnaire is available from the authors upon request.

TABLE 2. Demographic characteristics of interview sample.

Type of residence					
Detached single-family home	Townhouse, duplex, condominium, or apartment	Mobile home	Homeless	No response	
65.0%	28.3%	0.8%	0.8%	5.0%	
Ownership of residence					
Yes	No	No response			
59.2%	37.5%	3.3%			
Household vehicle ownership					
Yes	Yes (>1 vehicle)	No	No response		
95.0%	61.7%	2.5%	2.5%		
Race or ethnic background					
White	African American or Black	Hispanic or Latino	Asian or Pacific Islander	Other	No response
60.0%	20.0%	13.3%	1.7%	2.5%	2.5%
Education level					
Did not complete high school	High school	Some college	College graduate	Postgraduate	No response
6.7%	20.0%	33.3%	30.0%	7.5%	2.5%
Annual (2005) household income					
<\$25,000	\$25,000–50,000	\$50,000–75,000	\$75,000–100,000	>\$100,000	No response
15.8%	35.0%	21.7%	9.2%	8.3%	10.0%

their decisions and impressions, as well as hypothetical decisions about future scenarios. Although this type of study is often conducted several months or longer after a hazardous event, people’s recollections may not accurately represent the details of their real-time opinions and actions. In addition, previous research suggests that, when given hypothetical situations, people tend to overestimate their likelihood to take an action such as evacuating for a future hurricane (e.g., Baker 1995). The results should be interpreted with these caveats in mind, but the retrospective and hypothetical questions asked are typical for this type of study.

Some of the research questions investigated in this study have been explored in previous research on other hurricanes, mostly in other U.S. regions. Where such previous research exists, we discuss how our results compare with those from previous work, to indicate the extent to which our results can be generalized beyond the region, sample of residents, and hurricane case studied. Other research questions, particularly those related to Hurricane Katrina and to the public’s perceptions of hurricane forecasts, have not (to our knowledge) previously been investigated in the literature. Further study of these topics, as the memory of Katrina fades and across a broader population, is an important area for future research.

4. Survey results

a. Previous hurricane experience and preparation for Rita

To frame our study, we asked respondents about their previous hurricane-related experience. Although previous hurricane experience is a difficult variable to measure because it depends on people’s recollection and their definition of experience (e.g., Baker 1979, 1991; Lindell et al. 2005), more than half of the respondents reported experiencing a hurricane prior to Hurricane Rita. Slightly less than half reported previously evacuating in response to a hurricane threat. Approximately one-quarter reported experiencing hurricane-related harm or property damage prior to Hurricane Rita.

When asked if they prepared their residence during the week prior to Hurricane Rita reaching the Texas Gulf Coast, about 60% of respondents said yes. Preparation varied by location: approximately three-quarters of Galveston area respondents prepared their residences, compared with slightly more than half in the Port Arthur area and about one-third in the Houston area. The majority of those that prepared their residences shuttered or sealed windows and/or doors or moved furniture and fragile items. Many prepared their yard, and some reported packing documents and valu-

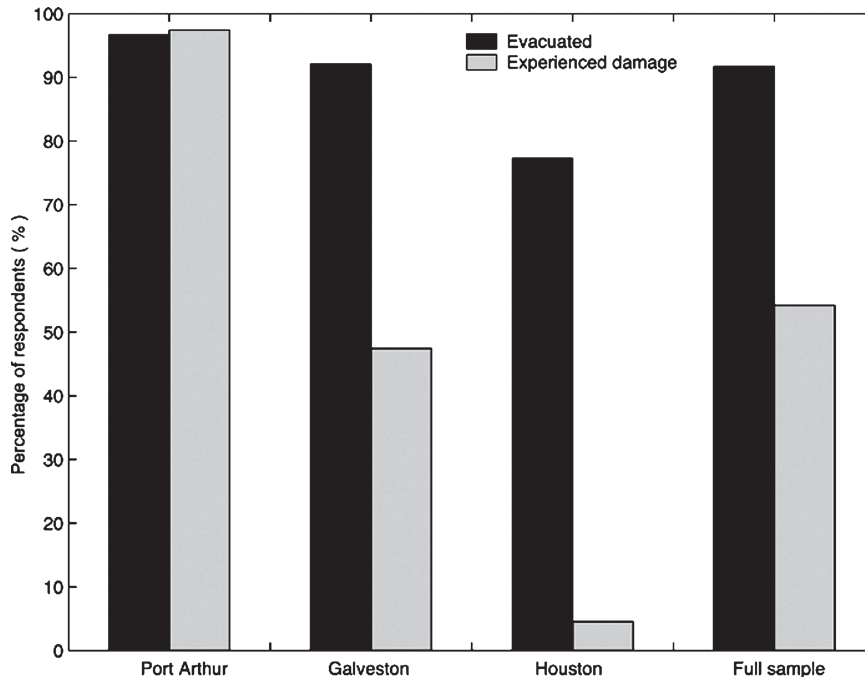


FIG. 2. Percentage of respondents who evacuated from Rita (black) and who experienced property damage due to Rita (light gray). Results are shown for residents of the three interview areas—Beaumont–Port Arthur (58 respondents), Galveston (38), and Houston (24)—and for the full sample (120).

ables or purchasing supplies. A few reported making arrangements for pets.

b. Property damage due to Rita

Just over half of our sample reported experiencing harm or property damage due to Hurricane Rita. As expected given Rita's track, damage varied widely by location (Fig. 2). Among Port Arthur area respondents, all but one who answered the question experienced property damage. About half of these had major damage.² Among Galveston area respondents, just under half experienced property damage, two of whom had major damage. Only one Houston area respondent experienced damage, which was minor.

c. Evacuation decision

When asked whether they left their residence to go someplace safer in response to the threat from Hurricane Rita, over 90% of respondents said yes. Nearly all of the Galveston and Port Arthur area respondents

evacuated, compared with approximately three-quarters of Houston area respondents (Fig. 2). In our sample, about 80% said that local authorities had encouraged or ordered people in their location to evacuate to a safer place.

Traffic difficulties in recent hurricane evacuations have motivated research on how and where people evacuate in order to aid evacuation transportation planning (e.g., Dow and Cutter 2002). In our survey population, evacuees traveled an average distance of approximately 320 km (200 mi).³ Fourteen of the 111 evacuees interviewed traveled out of the state of Texas (7 to Louisiana, 7 to other states). Seven respondents evacuated to a safer place within their city of residence. Although we did not ask if or to where other household members evacuated, the responses indicated that at least three respondents' households split up during the evacuation.

² We asked respondents to describe damage to their property and then categorized responses as major, moderate, or minor damage. Damage was categorized as major if they described a significant breach in the home's exterior and/or significant water in the home's interior.

³ Evacuation distances were estimated by mapping the route of shortest travel time between the town of residence and town of evacuation, using *DeLorme Street Atlas USA* (www.Delorme.com). Multiple destinations within the same family were included separately. When respondents evacuated within their town of residence, 0 mi was assigned; when only a state was provided for the evacuation location, a city near the geographical center of the state was used.

A major question in hurricane evacuation and other hazards research is how people decide whether to evacuate. To investigate this in the case of Rita, we asked respondents in an open-ended format for the primary factor(s) that influenced their evacuation decision. Of the 109 evacuees who answered the question, only 17 stated that a mandatory evacuation order (or an imminent order) was the most influential factor. Thirty-one respondents said that the primary factor was personal or family safety or wanting to live. Half of these (16) specifically mentioned the safety of family members, most often children in the household. One of these respondents attributed her family's evacuation to her special needs children and another to her spouse's medical condition.

Another 33 responded by describing some aspect of the approaching hurricane or its forecasts, such as the storm's intensity, track, or size, or its potential to cause flooding, storm surge, damaging winds, or tornadoes. Eleven respondents stated that Hurricane Katrina was the primary reason why they evacuated (discussed further below). Seven respondents said that they were scared of hurricanes or feared for their lives. Four said they evacuated primarily because family members convinced them to leave, and two left because they volunteered to evacuate a group of people. Other reasons for evacuation included animals, news or TV coverage, family history of evacuation, and personal experience with hurricanes and hurricane damage.

These results indicate that while some people follow official recommendations when making evacuation decisions, many also make their own assessments of risk based on storm characteristics, the vulnerability of their residence and/or family, and other factors. This agrees with recent results from Dow and Cutter (1998, 2000) for Carolina residents and Gladwin et al. (2001) for Florida residents, yet some meteorologists and members of the hazards community still believe that evacuation orders are the leading consideration in most residents' hurricane evacuation decisions. Illustrating their decisions, several respondents described the process by which they evaluated the risk that the storm posed for their residence location. In addition, the results indicate that, as discussed by Gladwin et al. (2001) for Hurricane Andrew, people's evacuation decisions are often not individually based but are intimately linked with the safety and decisions of other household members.

Of the nine nonevacuees interviewed, four resided in the Port Arthur and Galveston areas. Although all four reported that they were under a mandatory evacuation order, two said that they did not evacuate because of work (one of whom works on a hospital emergency team), one said he did not have a car, and the other

stayed to protect pictures and property. The remaining five nonevacuees interviewed resided in the Houston area, where the risk was lower. Of these five, two said they did not evacuate because of traffic, one stayed because of work, one stayed after evaluating the direction of the storm track, and one decided to "take my chances." Although we cannot draw general conclusions from this small sample of nonevacuees, the reasons given for nonevacuation are similar to those reported in previous studies (Baker 1991; Dow and Cutter 1998, 2002). These responses suggest that people choose not to evacuate for different reasons, some of which may appear to be intelligent and others less so. As noted by Baker (1979), although evacuation is often assumed to be the proper response to a warning, it may not be. The most appropriate response depends on the situation and may not be obvious without the benefit of hindsight.

Overall, our survey results indicate that, for better or for worse, many people are evaluating risk for themselves when making hurricane evacuation decisions. In doing so, they are using multiple sources of information, including hurricane forecasts. Different people also have different perceptions of risk and consider different factors when making evacuation decisions.

d. *The Katrina factor*

Hurricane Rita followed the devastation of Hurricane Katrina by only 1 month. Not only was Katrina covered widely in the media, but officials and the media referenced the Katrina devastation as Rita approached. Thus, the large number of Rita evacuees was attributed in part to Katrina. To investigate the extent of this "Katrina factor," we asked respondents whether the recent events from Hurricane Katrina and New Orleans, Louisiana, influenced their evacuation decision, and if so, how. As noted above, approximately 10% of the evacuees in our sample stated that Hurricane Katrina was their *primary* reason for evacuating. Moreover, 55% of our respondents said that Katrina *influenced* their evacuation decision (Fig. 3).

Approximately half of those respondents influenced by Katrina said that it was because they saw Katrina's flooding, damage, death, personal misery, devastation, and other effects. Approximately one-quarter said they were concerned about events similar to those in post-Katrina New Orleans happening to them or their family. Several respondents specifically said that Hurricane Katrina made them scared, worried, or concerned about their personal safety related to hurricanes and hurricane-induced flooding, and many other responses indicated similar concerns. Several said that Katrina made them more cautious or reluctant to take any

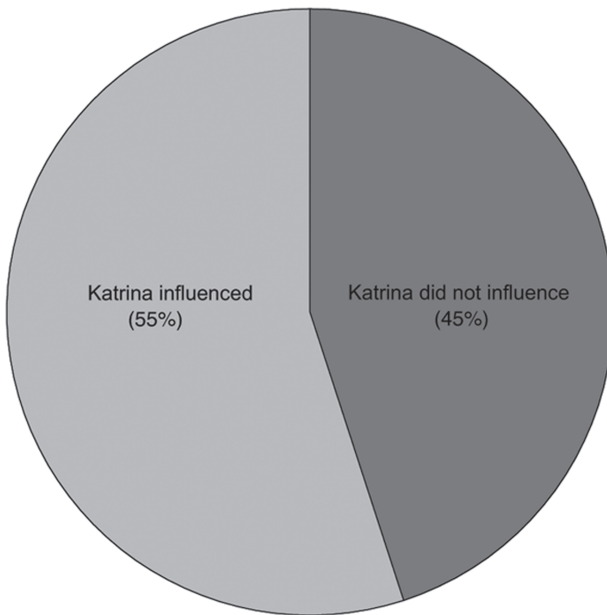


FIG. 3. The Katrina factor: Percentage of respondents who said that Hurricane Katrina influenced their evacuation decision [yes (light grayshading) and no (dark grayshading)].

chances, and two specifically said they were influenced by the shock caused by Katrina. One respondent had experienced Hurricane Katrina in Florida, and another had relatives in New Orleans. The extent to which this Katrina effect will last or wane is an interesting question for future study.

e. Decision regret?

Because many Texas Gulf Coast residents who evacuated prior to Rita experienced major traffic jams and minimal damage to their homes and communities, we were interested in people's reflections on their Rita-related decisions. We therefore asked respondents whether, looking back on their decisions as Hurricane Rita approached the coast, they would do anything differently next time. In response, about 60% said yes, including 6 (of 9) nonevacuees and 62 (of 111) evacuees.

Two of the nonevacuees said they would leave next time, including the one person who did not evacuate from Rita because of lack of a car. One, who did not evacuate from Rita because of traffic, said that if he left, he would do so a day sooner. Another nonevacuee would buy supplies sooner, one would have his wife (who evacuated) take more things, and one (who did not prepare her residence but experienced damage) would prepare her residence.

Of the evacuees who would do something differently

next time, more than half (32) said they would leave earlier, 9 of whom specifically said they would do so to avoid traffic. Another respondent, who is from Houston, said that next time she would leave at the last minute. Nine respondents said that next time they would buy or bring more supplies, including clothes, food and water, documents, and gas. Five respondents, all from the Port Arthur area, said they would do more to prepare their residence. Two of these, both of whom experienced significant property damage due to Rita, said that they would purchase better insurance or flood insurance. Others said they would evacuate to a different location, look for a hotel or arrange a place to stay, evacuate with a smaller group, or evacuate with someone else instead of being alone.

Overall, these results indicate that for a majority of our respondents (nonevacuees and evacuees), their experience during Rita affected how they expect to respond to a similar hurricane threat in the future. A significant majority of respondents who would do something differently next time would leave earlier or prepare more. Most of the evacuees interviewed in all three study areas would evacuate again, and several nonevacuees would evacuate. This corroborates previous findings that, despite significant speculation in the meteorological and emergency management communities, unnecessary or premature evacuations due to "false alarms" play only a minor role in coastal residents' hurricane evacuation decisions (Baker 1991; Dow and Cutter 1998, 2000).

Eleven of the evacuees interviewed—about 10% of the respondents who evacuated—said that next time they definitely or probably would not leave. One of these said that next time he would send his family to evacuate while he stayed to protect property. Of the 11, 1 resided in the Houston area, 2 in the Port Arthur area, and the remaining 8 in the Galveston area. Seven experienced no property damage due to Rita, and the other four experienced only minor damage to the exterior of their homes. Three said that they had evacuated prior to Rita primarily because family members convinced them to do so, and another had evacuated primarily because he volunteered to transport a group of evacuees.

Given the small sample, we cannot draw firm conclusions about these future nonevacuees. However, these results suggest that the Texas Gulf Coast may include a small evacuation-resistant population, a local disaster culture similar to that discussed in Dow and Cutter (1998) for the Carolinas. Among our respondents, this population included people who experienced minimal or no damage due to Rita (particularly residents of Galveston, which experienced less damage

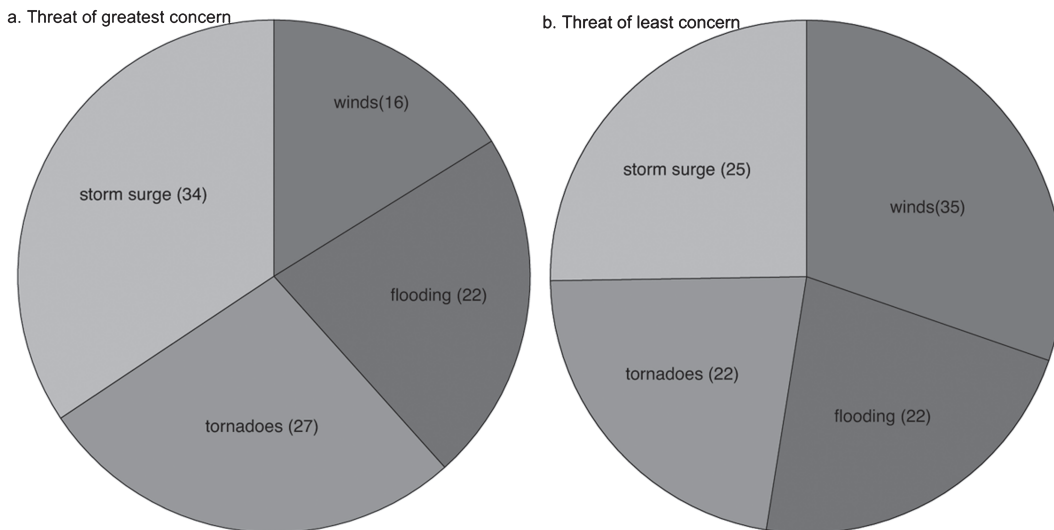


FIG. 4. Number of respondents who ranked each threat as their (a) greatest and (b) least concerns, when asked to rank four threats from greatest to least concern with respect to personal safety and property damage with a landfalling hurricane. Results are presented for only the 99 respondents who provided unique rankings for the four threats.

than forecast several days prior to landfall) and those who evacuated for reasons other than personally feeling at risk. Next time a hurricane threatens, some of these people may again be convinced to leave by family members, obligations, or other factors, and some may not.

f. Perceptions of hurricane risk and response to future hurricanes

To assess respondents' perceptions of hurricane risk, we asked them to rank four hurricane-related threats—storm surge, wind, flooding, and tornadoes—in order of increasing concern with regard to property damage and personal safety. The threats of greatest and least concern are depicted in Fig. 4. When responses are weighted and combined, the level of concern about the four threats is not significantly different. This could be, in part, because some respondents did not understand or clearly differentiate among the threats; for example, they did not differentiate between storm surge and flooding. Interviewers noted that several Galveston residents believed that the island seawall would protect them from storm surge in any hurricane.

We also asked whether respondents would, in the future, evacuate their households if local authorities recommended evacuation because of different storm conditions. As shown in Fig. 5, the likelihood that respondents will evacuate increases with increasing storm classification. This also held for most individual responses, indicating that respondents generally under-

stand that the Saffir–Simpson scale indicates storm strength. The results also suggest a jump between respondents' perceptions of the risk posed by a category 2 hurricane and that posed by a category 3 hurricane. Respondents exhibited a range of evacuation thresholds, including some who said they would evacuate for all storm levels. This may reflect people's different levels of risk, based on their residence location and type, but it also reinforces that people have different risk perceptions and preferences.

Five respondents said they would not leave even if local authorities recommended evacuation because of a category 5 hurricane. Although this sample is small, all five resided in the Galveston area, again indicating the possibility of a small evacuation-resistant culture.

g. Sources of Rita forecasts and frequency of forecast checking

With technological advances and increasing availability and diversity of information on cable television and the Internet, people's sources of hurricane-related information are evolving. As discussed by Dow and Cutter (1998, 2000), this may be changing how people make hurricane evacuation decisions. To explore this issue, we asked people from what sources they obtained forecasts of Rita, offering eight options and an "other" category. We then asked which of these sources was most important. As shown in Fig. 6, the vast majority of respondents obtained Rita forecast information from television, and the majority said television was their

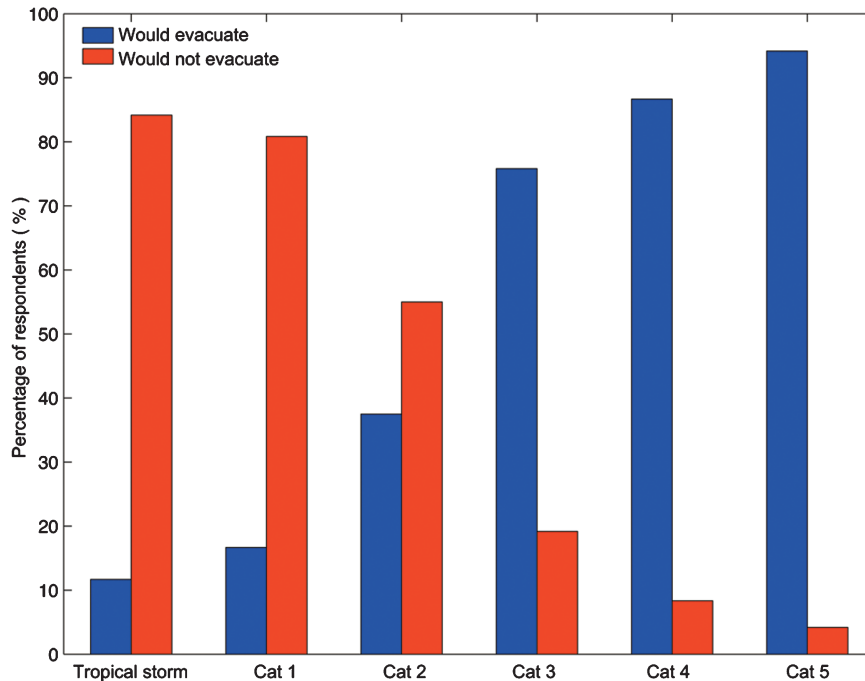


FIG. 5. Percentage of respondents who would (blue) and would not (red) evacuate their household if local authorities recommended evacuation because of the storm conditions indicated on the *x* axis (tropical storm and category 1–5 hurricane). Results are shown as a percentage of all respondents (including those who did not provide a response for each hypothetical storm condition).

most important source of forecast information [concurring with previous studies, e.g., Gladwin and Peacock (1997); Dow and Cutter (1998)]. However, many other sources were used and, on average, respondents reported using 4.4 of the 8 sources. This suggests that people consulted and combined forecast information from multiple sources when making prehurricane evacuation and preparation decisions. Only eight people said they used only one of the sources of information, most of whom used only broadcast television.

We also asked respondents how frequently they checked forecasts of Rita as the storm approached. Three to five days before Rita reached the Texas coast, 88% of our respondents checked the Rita forecast at least twice daily, and 56% checked the forecast at least every hour. One to two days before Rita reached the Texas coast, this increased to 93% and 76%, respectively, and more than half said they checked the forecast “constantly.” This indicates that, as discussed by Gladwin and Peacock (1997) for Hurricane Andrew and Dow and Cutter (2000) for Hurricane Floyd, during Rita most of our respondents were aware of the evolving hurricane threat and obtained frequent forecast information to aid their preparation and evacuation decisions.

h. Confidence in Rita forecasts

Given the changing track and intensity forecast for Rita and previous hurricane false alarms, we were interested in people’s confidence in Rita forecasts. To investigate this, we first reminded respondents that the National Hurricane Center (NHC) was the main source for forecasts of Hurricane Rita’s track, and most major media outlets base their forecasts on official NHC forecasts. We then briefly described the 5-day NHC landfall forecast (timing and location) and asked if they were aware of this forecast. Those who responded yes were asked to rate the confidence they had in that forecast on a scale of 1 to 5 (with 5 indicating high confidence). The awareness and confidence questions were then repeated for the 3- and 1–2-day forecasts.

Respondents’ awareness of Rita forecasts was over 85%, even 5 days in advance. Only two respondents said they were not aware of the 1–2-day NHC forecast. Overall, respondents reported high confidence in Rita forecasts (Fig. 7) and increasing confidence as the storm approached. The average confidence in the 5-, 3-, and 1–2-day forecasts was 3.6, 3.8, and 4.5, respectively. This high confidence is particularly striking given that we reminded people that, at 5 and 3 days out, landfall

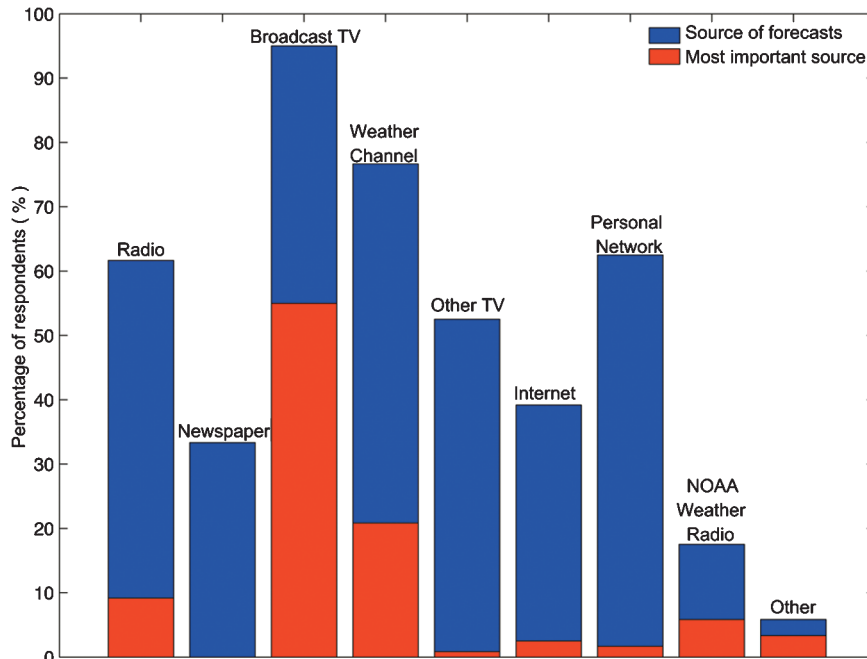


FIG. 6. Percentage of respondents who obtained weather forecasts of Hurricane Rita from the sources indicated (blue plus red) and who identified the sources indicated as their most important source of Rita forecast information (red). Personal network includes friends, family members, coworkers, and/or neighbors. Most of the “other” responses were more specific examples of the eight sources provided.

was forecasted near Galveston or farther west along the Texas Gulf Coast. When asked how much confidence they will have in future NHC forecasts, again on a scale of 1 to 5, the average response was 4.3.

i. Satisfaction with Rita forecasts and interest in future forecast improvements

To evaluate people’s satisfaction with Rita forecasts, we asked the extent to which they thought new forecast information for Hurricane Rita was released in a timely manner and overall, how well they thought the NHC forecasted for Hurricane Rita (on a scale from 1 to 5, with 5 indicating high timeliness and quality). As shown in Fig. 8, despite the issues with the evacuation, most respondents were very satisfied with Rita forecasts. The average rankings for timeliness and quality were 4.4 and 4.3, respectively.

Despite this overall satisfaction, hurricane forecasts can still be improved in many ways. To help researchers and forecasters improve future forecasts, we asked respondents if there was other information about Hurricane Rita that they would have liked to have but did not. Of the nearly 20% of respondents who answered yes, many requested better posthurricane information or better traffic reports and other evacuation-related information. Several requested more local coverage.

Only a few respondents requested more hurricane forecast information, including improved track forecasts and more information about forecast uncertainty.

At the end of the interview, 27 respondents accepted the option to provide additional comments on Hurricane Rita forecasts. Eight of these suggested improvements in evacuation planning or coordination, commented on the timing of evacuation decisions, or criticized local officials’ decisions. Three respondents requested information sooner or more frequent forecast updates, and one respondent requested more information about forecast track uncertainty. The remaining 15 commented positively on the forecasts. Common responses were that the forecasts were “good” or “great,” that the forecasters did a good job, or that the forecasters did the best they could with the information they had. This corroborates the findings discussed above that respondents were overall highly satisfied with forecasts of Hurricane Rita. Some respondents also recognized the challenging nature of hurricane forecasting and appreciated forecasters’ efforts.

5. Summary and discussion

We investigated societal aspects of Hurricane Rita using a face-to-face survey 6 months after the event, as

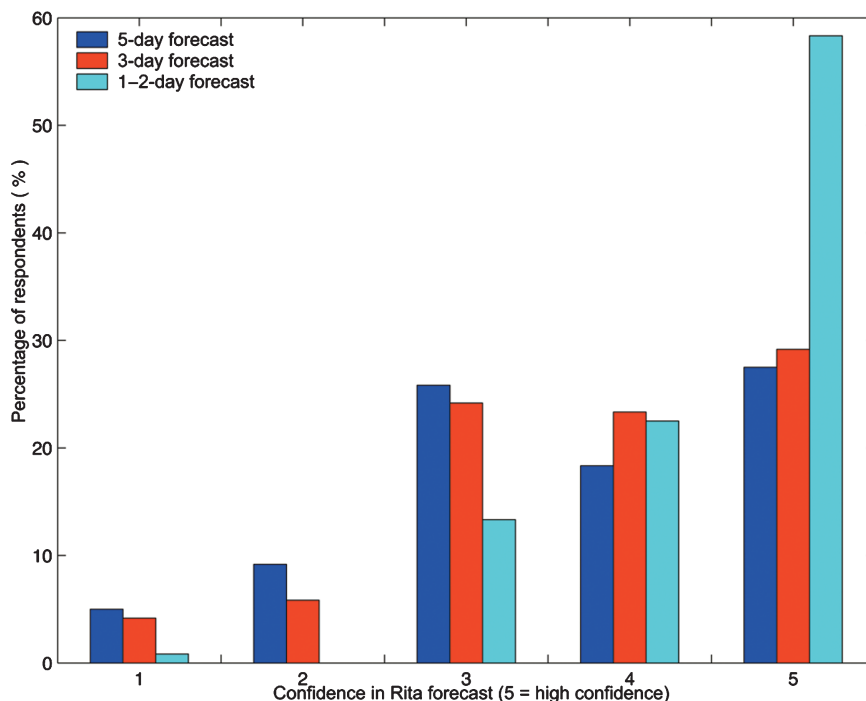


FIG. 7. Respondents' confidence in forecasts in NHC forecasts of Hurricane Rita issued 5 days (blue), 3 days (red), and 1-2 days (cyan) before landfall, ranked on a scale from 1 to 5 (with 5 meaning high confidence). Results are shown as a percentage of all respondents (including those who said they were not aware of the forecast and thus were not asked to rate their confidence).

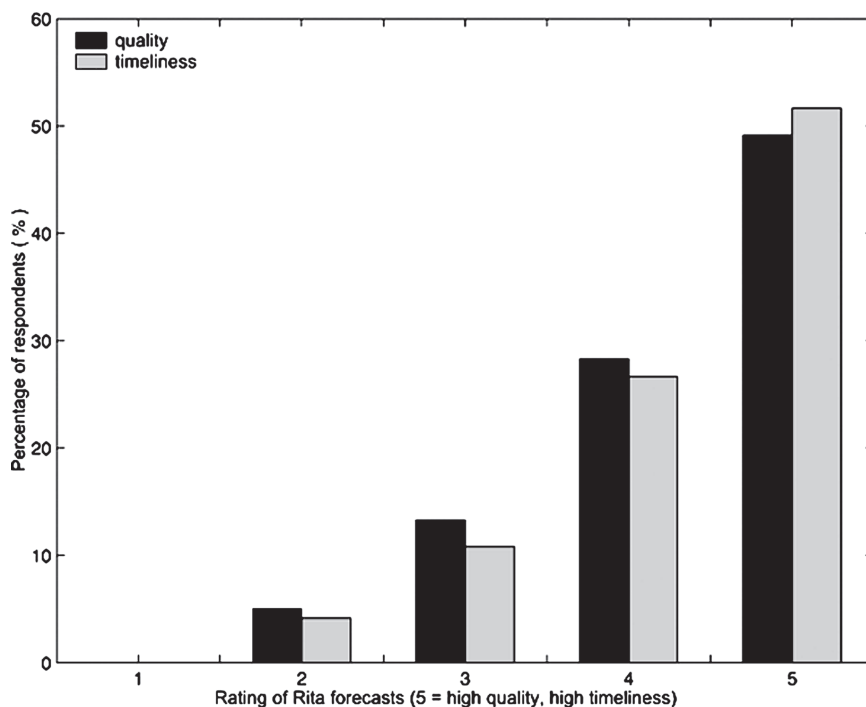


FIG. 8. Respondents' rankings of the overall quality (black) and timeliness (light gray) of NHC forecasts of Hurricane Rita, on a scale from 1 to 5 (with 5 meaning high quality and high timeliness). Results are shown as a percentage of all respondents.

part of an undergraduate research class in the spring semester of 2006. The research team developed a structured interview questionnaire to explore coastal residents' hurricane preparation and evacuation decisions, their perceptions of hurricane risk, and their use and opinions of hurricane forecasts. The students conducted 120 in-person interviews in the Texas Gulf Coast cities of Galveston, Port Arthur, and Houston. The results were analyzed and interpreted by the research team using standard quantitative and qualitative data analysis methods.

Findings from the survey illustrate how coastal residents perceive hurricane risk and hurricane forecasts and the types of information they use in making hurricane evacuation decisions. This knowledge can help the meteorological community communicate more effectively about future hurricane threats. The vast majority of our respondents evacuated in response to the threat of Hurricane Rita. In deciding whether to evacuate, the respondents considered a variety of information sources, including evacuation orders, evolving hurricane forecasts, family members' wishes and other obligations, and the risk they believed Rita posed for their residences, themselves, and their families. Together with findings from a few recent postevacuation studies of hurricane cases in other regions of the United States, these results illustrate that hurricane evacuation decision making is complex for many households and incorporates information from multiple sources.

Even though most of our respondents reported being under an evacuation order, most did not say that the evacuation order was the primary reason for their evacuation decision. Instead, when asked why they evacuated, many of the evacuees interviewed discussed characteristics of the hurricane or aspects of the hurricane forecast. Moreover, most respondents obtained forecast information frequently, starting several days before landfall, from multiple information sources. This suggests that most respondents were paying close attention to the hurricane's evolution and many were using forecast information in their evacuation-related decisions. Effective communication with the public is therefore an important issue for the hurricane forecasting community.

Rita was the first major hurricane to make landfall in the United States following Hurricane Katrina, prompting a massive evacuation along the Texas Gulf Coast. More than half of the respondents stated that Katrina and its aftermath in New Orleans affected their Rita evacuation decision. Despite the major traffic jams during the evacuation and the minimal property damage experienced by many evacuees, most evacuees interviewed do not regret their decision to evacuate.

Most of those who would do something differently next time said they would prepare better or evacuate sooner. This indicates that false alarms are not a concern for most of our respondents, and in fact may help people plan future evacuations. It also suggests that a massive evacuation may occur again when the next major hurricane threatens the Texas Gulf Coast, causing similar traffic issues—or even larger traffic volumes—if inland residents leave sooner. A small group of coastal residents, however, said they would not evacuate in the future, even for a major hurricane. How long the Katrina effect will last is an important question for further research, as are the size and characteristics of the at-risk evacuation-resistant population.

The majority of respondents stated that they intend to evacuate in response to a future category 3 hurricane, but a majority intends to stay for a category 2 hurricane. This suggests that respondents differentiate between a major and moderate hurricane. However, the risk posed by hurricanes and tropical storms depends on factors other than storm strength, including the storm's size, travel velocity, and precipitation, as well as characteristics of the affected region. Informing the public about these aspects of storms may therefore also be important. The results indicate that communicating hurricane forecasts via television still reaches a broad audience. However, many coastal residents are gathering forecast information from a variety of sources, including cable TV and the Internet, suggesting that as media sources evolve further, new strategies for communicating hurricane risk may need to be developed.

Despite changes in the predicted path as the storm approached, most respondents had high confidence in the Rita forecasts provided by the NHC, and they had more confidence as the storm approached the coast (when there was more certainty about where and when it would hit). Overall, they were also highly satisfied with the forecast timeliness and quality. Future improvements in hurricane forecast skill and communication remain important, however, for two major reasons. First, as coastal populations continue to increase, hurricane forecasts are an important tool for local and state officials in planning evacuations. Second, our results, along with those in Dow and Cutter (1998, 2000) and Gladwin et al. (2001), suggest that many coastal residents are using hurricane forecasts in conjunction with other information to evaluate risk for themselves, rather than simply heeding hurricane warnings or evacuation orders. An important area for future research is therefore how to communicate hurricane forecasts and hurricane risk information, including uncer-

tainty, to different audiences in ways that promote understanding and benefit decision making.

The participating students gained significant educational benefits from the project through linking their classroom knowledge to decisions made by real people faced with warnings for a major hurricane. The education–research paradigm that we successfully implemented in this project, which is discussed in further detail in MZ, can be used as an example for other efforts to incorporate societal aspects of science into classrooms, enrich undergraduate curricula, and provide student research experiences in meteorology and other disciplines.

Acknowledgments. We thank Walt Peacock and Carla Prater at the Texas A&M University HRRC for sharing their mail survey questionnaires and for their insightful comments on the project and our questionnaire. We also thank Carla Prater for providing interview training for the students and Eve Grunfest for providing comments on our questionnaire. The project and manuscript also benefited from discussions with and comments from Arlene Laing, Julie Demuth, John Nielsen-Gammon, and Courtney Schumacher. We are grateful to Lauri Hampshire and Lauren Leggett for providing free accommodations to the students during the survey. We also thank Richard Orville, the head of the Department of Atmospheric Sciences at Texas A&M University, for allocating department funds to purchase the digital voice records and for student’s travel support. NCAR’s Societal Impacts Program provided funding for REM’s travel for the project. This research is partially funded by the U.S. Office of Naval Research through the Young Investigator’s Program (Award N000140410471).

REFERENCES

- Arlikatti, S., M. K. Lindell, C. S. Prater, and Y. Zhang, 2006: Risk area accuracy and hurricane evacuation expectations of coastal residents. *Environ. Behavior*, **38**, 226–247.
- Baker, E. J., 1979: Predicting response to hurricane warnings: A reanalysis of data from four studies. *Mass Emerg.*, **4**, 9–24.
- , 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.
- Blumenthal, R., and D. Barstow, 2005: “Katrina effect” pushed Texans into gridlock. *New York Times*, 24 September, final ed., A1.
- Cross, J. A., 1990: Longitudinal changes in hurricane hazard perception. *Int. J. Mass Emerg. Disasters*, **8**, 31–47.
- 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**, 133–142.
- Dow, K., and S. L. Cutter, 1998: Crying wolf: Repeat responses to hurricane evacuation orders. *Coast. Manage.*, **26**, 237–252.
- , and —, 2000: Public orders and personal opinions: Household strategies for hurricane risk assessment. *Environ. Hazards*, **2**, 143–155.
- , and —, 2002: Emerging hurricane evacuation issues: Hurricane Floyd and South Carolina. *Nat. Hazards Rev.*, **3**, 12–18.
- 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.
- Knabb, R. D., D. P. Brown, and J. R. Rhome, cited 2006: Hurricane Rita. Tropical Cyclone Rep., National Hurricane Center. [Available online at http://www.nhc.noaa.gov/pdf/TCR-AL182005_Rita.pdf.]
- Lindell, M. K., J.-C. Lu, and C. S. Prater, 2005: Household decision making and evacuation in response to Hurricane Lili. *Nat. Hazards Rev.*, **6**, 171–179.
- Morss, R. B., and F. Zhang, 2008: Linking meteorological education to reality: A prototype undergraduate research study of public response to Hurricane Rita forecasts. *Bull. Amer. Meteor. Soc.*, in press.
- Whitehead, J. C., B. Edwards, M. Van Willigen, J. R. Maiolo, K. Wilson, and K. T. Smith, 2000: Heading for higher ground: Factors affecting real and hypothetical hurricane evacuation behavior. *Environ. Hazards*, **2**, 133–142.
- 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.