Communication and Hazard Perception Lessons from Category Five Hurricane Michael

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Abstract: Hurricane Michael made landfall on 10 October 2018 as only the third Saffir Simpson Hurricane Wind Scale (SSHWS) category 5 storm in the USA in the named era. The storm's intensity, rapid intensification, October landfall, high inland winds, and uncommon landfall location all combined to complicate the communication and preparation efforts of emergency managers (EMs) and broadcast meteorologists (BMs), while clouding the comprehension of the public. Interviews were conducted with EMs, BMs, and a small public sample to hear their stories and identify and understand common themes and experiences. This information and previous research was used to inform the creation of questions for a large sample public survey. Results showed that 61% of our sample did not evacuate, and approximately 80% either underestimated the intensity, misinterpreted or did not believe the forecast, or realized the danger too late to evacuate. Hazard perception from a survey of the public revealed that wind followed by tornadoes, and falling trees were the major concerns across the region. According to their counties of residence, participants were divided into Coastal or Inland, and Heavily Impacted or Less Impacted categories. Inland participants expressed a significantly higher concern for wind, tornadoes, falling trees, and rainfall/inland flooding than Coastal participants. Participants from Heavily Impacted counties showed greater concern for storm surge, tornadoes, and falling trees than participants from Less Impacted counties. These results reinforce the continued need for all parties of the weather enterprise to strengthen communication capabilities with EMs and the public for extreme events.

Keywords: hurricane; perception; communication; hazards; category 5; USA

1. Introduction

Hurricanes are a naturally occurring aspect of the climate system on the Atlantic and Gulf of Mexico coasts. Hurricane Michael [1], a category 5 on the Saffir Simpson Hurricane Wind Scale (SSHWS), was anomalous for its intensity and rapid intensification. The recurrence intervals for major hurricanes, SSHWS category 3 and greater, vary from a rare 105 years near the northeast coast in Jacksonville to active zones across South Florida ranging from 13–18 years and the northwest Florida Panhandle coast near Pensacola of 21 years (Keim et al., 2007). The recurrence interval for major hurricanes at Panama City Beach, FL, near the landfall location of Hurricane Michael was a rare 105 years [2]. Malmstadt et al. [3] also found similar results for a wind threshold of 50 m·s^{-1} (SSHWS category 3) of 12 years for Miami, 24 years for Pensacola, but a much lower 40 years for Panama City than Keim et al. [2]. Additional modeling research in the Florida Panhandle just west of Panama City found a 100 year peak wind gust of 58 m·s^{-1}, which corresponds with the start of SSHWS category 4 conditions [4]. Therefore, Hurricane Michael was a statistical example of an extreme event that exceeded what many people thought was realistic for wind speeds on this stretch of coastline.

Hurricane Michael highlights the need to understand how the public, emergency managers (EMs), and members of the meteorological community perceived an extreme event both before and after landfall. The possibility of more intense or more frequent tropical cyclones in a changing climate remains a debated topic according to observed data and modeling scenarios incorporating a range of projections and uncertainties for future climate [5]. There has been no trend in the frequency or intensity of hurricane landfalls in the USA since 1900, nor has there been a trend in normalized loss estimates [6]. Despite the lack of a trend in the USA, there is medium to high confidence that the projected increase in lifetime maximum surface wind speeds will be about 5%, and the global proportion of tropical cyclones that reach very intense (category 4–5) levels has a median projected change of +13% [7]. The relationship between wind speed and loss is exponential and loss increases with wind speed at a rate of 5% per m·s^{-1} [8]. More intense hurricanes will result in greater wind damage and economic loss in the future. Furthermore, rapid intensification of hurricanes in the Atlantic Basin has seen a 29% increase between 1900 and 2017, and rapid intensification usually begins in the western Caribbean or Gulf of Mexico with lifetime maximum intensity occurring in the Gulf of Mexico [9]. Additionally, with warmer sea surface temperatures expected, the time interval between very intense hurricanes will most likely decrease with the Gulf of Mexico becoming the most prominent region for this to occur [10]. Storms with the intensity of Hurricane Michael that undergo rapid intensification are likely to be a more common aspect of the hurricane climatology of the Gulf of Mexico in the future.

The post-landfall geophysical hazard perception of Hurricane Michael is important to understand when considering public response to future hurricanes; particularly for storms that undergo rapid intensification prior to and near landfall. The National Hurricane Center's cone of uncertainty is widely used and disseminated on national and local television weather to inform people about storm characteristics, likely impacted areas, and timing. An imminent land-falling hurricane causes residents within the cone of uncertainty and warning areas to appraise the risk at their residence from wind, tornadoes, falling trees, storm surge, and rainfall/inland flooding [11,12]. The size of the storm, changing forecast tracks, and forward speed are also factors exacerbating the geophysical hazards and complicating evacuation decision-making [13]. Evacuation decision-making varies individually, but the primary geophysical concerns when making decisions are wind [12], storm severity, and forecast track [14]. Most evacuees overestimate the winds speeds they think they will experience at their residences, although this is not true for every storm [12]. An additional layer that may cause residents to constantly reassess decision-making in response to wind and other geophysical hazards is a rapidly intensifying and violent hurricane, such as Michael.

Along with appraising risk from geophysical hazards, residents can be overwhelmed with preparedness and planning. This may involve their safety decision-making related to the visualization of forecast products, their social networks and social connections, and possible employer obligations among a host of other cognitive, affective, cultural, economic, or political factors [15,16]. Denser and more diverse social networks were strong influencers on evacuation compliance for Hurricane Irma in 2017 [17]. An analysis of social media data for evacuation decisions for Hurricane Matthew in 2016 revealed evacuees have larger long-term activity spaces than non-evacuees, people in the same social network tend to make the same evacuation decisions, and that evacuees have smaller long-term sentimental variances than non-evacuees [18]. The most significant variables for predicting evacuation were the official evacuation order times or official warnings, prior experience, and talking with others or social cues [19,20]. These variables and influences along with cognitive and affective dimensions of decision-making [16] are considered when evaluating comments and themes in this research from EMs, broadcast meteorologists (BMs), and the public. Before proceeding to the Methods and Results, it is first necessary to explain the unique characteristics of Hurricane Michael.

Hurricane Michael Characteristics and Storm Track

The information summarized in this paragraph comes from The National Hurricane Center's Tropical Cyclone Report for Hurricane Michael [1]. After careful reanalysis using a number of

techniques and information sources, Hurricane Michael was officially recognized as a category 5 hurricane on the SSHWS post-season. It is the only category 5 hurricane known to have ever made landfall in the Florida Panhandle. It was categorized as an upper-end category 4 at landfall on 10 October 2018. Its landfalling pressure of 919 mb ranks as the third lowest ever in the USA behind the Labor Day Florida Keys hurricane of 1935 and Hurricane Camille in 1969. The estimated winds of 140 knots, 161 mph, 72 m·s^{-1} at landfall existed over only a small portion of the coastline; however, Michael maintained its powerful winds farther inland than any previous category 4 or 5 storm to make landfall on the northern coast of the Gulf of Mexico. Wind gusts of 46 m·s^{-1} were recorded at Marianna, FL, slightly west of the decaying eyewall and 51 m·s^{-1} at Donalsonville, GA, closer to the center of the track (Figure 1). When the center of Michael passed just east of Marianna, it was 90 km inland from the landfall point at Tyndall Air Force Base, and, when it tracked near Donalsonville, it was 130 km inland. Hurricane force gusts were recorded as far inland as Albany, GA, at 220 km from the landfall point. These inland wind speeds in this region have only been exceeded by a few strong Enhanced Fujita (EF) 2 and EF 3 tornadoes that have occasionally struck much smaller areas of land.

Figure 1. Hurricane Michael track with city names mentioned.

Further exacerbating the extraordinary wind damage was the size of Hurricane Michael. There are several ways to measure hurricane size. A common metric is dividing the storm into quadrants and measuring the radial distance from the center to various thresholds, such as hurricane force winds (r64 knots) and tropical storm force winds (r34 knots). Other popular metrics are the radial distance to the outermost closed isobar (ROCI), and the radius of maximum winds (RMW). As hurricanes intensify beyond category 3, they usually undergo a contraction of the wind field and a tightening of the pressure gradient [21]. This normally results in a reduction of the r64 size, and a smaller RMW as the eye becomes well defined and wind speeds near the eyewall accelerate.

The International Best Track Archive for Climate Stewardship (IBTrACS) database [22,23] contains size data for all Atlantic basin tropical cyclones after 2004. Much of this information is also found in the Extended Best Track (EBT) dataset [24] since 1988, although the time intervals in the EBT dataset may not correspond with the exact landfall time. There are numerous sources and reanalysis efforts for storms prior to 2005. Compared to the other SSHWS category 5 hurricanes to make landfall in the USA since 1950 (Camille 1969) [25] and Andrew (1992) [26], Michael had a larger outermost r34 and much larger ROCI than Camille and Andrew, but only a slightly larger RMW (Table 1). Essentially, this means that it had almost the same intense sustained winds as Camille and Andrew while being a larger storm, thus impacting a greater land area. Michael was also larger than category 4 Harvey (2017) and category 4 Charley (2004), a very small but intense hurricane. Although Michael is the largest SSHWS category 4 or 5 hurricane to make landfall in the USA in the past 15 years, it is dwarfed by

category 4 Hurricanes Hugo (1989) (see Table 1) and Carla (1961) [27]. In size, Michael seems to be a hybrid between northern Gulf of Mexico storms that made landfall farther west, such as SSHWS category 3 Hurricane Ivan (2004), category 3 Rita in (2005), and its category 5 brethren Camille and Andrew. These hybrid qualities define Michael as an abnormal hurricane when compared to other category 4 and 5 storms. Its physical storm traits along with Michael's rapid intensification proved to confound the hurricane hazard perception of people, hamstring the preparedness capabilities of EMs, and hinder the communication efforts of BMs.

Table 1. Size and intensity characteristics of notable landfalling USA hurricanes. The SSHWS category at landfall is the number next to each hurricane name. Hurricane Michael is in bold. Outermost r34, radius of maximum winds (RMW), and radial distance to the outermost closed isobar (ROCI) are in kilometers. Data compiled from [22–27].

Hurricane	Year	Landfall Location	Landfall Pressure (mb)	Winds at Landfall m/s (mph)
Camille 5	1969	Waveland, MS	900	77 (173)
Andrew 5	1992	Homestead, FL	922	77 (173)
Michael 5	**2018**	**Tyndall Air Force Base, FL**	**919**	**72 (161)**
Charley 4	2004	Cayo Costa, FL	941	67 (150)
Hugo 4	1989	Bulls Bay, SC	935	62 (138)
Harvey 4	2017	Rockport, TX	937	59 (132)
Katrina 3	2005	Bay Saint Louis, MS	928	54 (121)
Ivan 3	2004	Gulf Shores, AL	946	54 (121)
Irma 3	2017	Naples, FL	936	51 (115)
Rita 3	2005	Port Arthur, TX	937	51 (115)
Ike 2	2008	Galveston, TX	950	49 (109)
Hurricane	**Year**	**Outermost r34**	**RMW**	**ROCI**
Camille	1969	232	13.0	259
Andrew	1992	222	15.7	232
Michael	**2018**	**259**	**18.5**	**389**
Charley	2004	139	11.1	185
Hugo	1989	417	64.8	444
Harvey	2017	222	27.8	333
Katrina	2005	352	40.7	556
Ivan	2004	463	46.3	444
Irma	2017	611	27.8	611
Rita	2005	296	37.0	556
Ike	2008	417	55.6	602

2. Methods

In this research, a mixed-methods exploratory design approach was taken to better understand the perception of Hurricane Michael. Qualitative small group interviews were conducted with several county EM agencies in Florida and Alabama, as well as two broadcast meteorology (BM) staffs from television stations in Panama City, FL. These small group interviews were semi-structured and participants were allowed to discuss their responses to scripted questions with minimal redirection. The objective in this format was to capture information that participants deemed most important as they told their stories, so that themes could be identified across all interviews. In addition to the EM and BM interviews, five members of the public were also interviewed individually in a similar format. These public participants were recruited with the assistance of one of the county EM agencies. The purpose of interviewing members of the public was to compare their stories to those of EMs and also to use their answers to inform questions to be included for a quantitative large sample public survey. The large sample public survey contained many of the same questions as the interviews but, additionally, contained many hazard perception questions. It was distributed in February 2019.

The following paragraphs describe the structure of the interviews and survey in more detail, including explanations for the procedures, sampling, and data analysis for each part of this research.

2.1. Emergency Management and Broadcast Meteorology Interviews

In December 2018, county EMs and BMs in the areas of the Florida Panhandle and southeast Alabama were asked to describe the lessons learned and best practices associated with Hurricane Michael. All of these people personally experienced the storm. The interviews were organized and arranged by the University of Alabama Center for Advanced Public Safety in coordination with National Weather Service (NWS) Tallahassee. NWS Tallahassee has frequent communication and professional contacts with county EMAs in their forecast area. The BMs shared their stories and challenges from a forecasting and communication perspective. The most common format for EMs was to have the entire staff in one room for the interview. Occasionally certain members were called away with obligations and later rejoined the interview. Although questions were scripted to guide the interviews, these were often conversation starters that took on a freestyle format. For example, the introduction statement to the first question was often an icebreaker: "We are going to ask you about your plans, decision-making, and actions throughout different times of the pre-landfall process. Let's start with Monday, 8 October." At that point, most EMs began to describe every detail of each day with remarkable precision. When our interviews occurred, it had been two months since Michael made landfall and that two month period was stressful with job obligations in the aftermath and cleanup of the storm. For many, it was their first week with a less hectic schedule, and they wanted to tell their stories even though it was sometimes painful to recall those memories.

Researchers of disasters are often conducting research as participant observers. Participant observation is a method of investigation that requires researchers to constantly balance their methods and analysis at the crossroads of being both an outsider but also a member of a community. Consequently, in interacting with our research subjects we had the ethical and professional responsibility to engage individuals as members of a shared community and communicate with sensitivity and non-judgmentally. Expressions of emotion, passion, distress, and relief are typical as individuals recount their disaster experiences to a trusted other—a privileged role that is the result of utilizing participant observation strategies. As researchers of disaster events, our positionality is one of identification with the enterprise partners in responding to a disaster. We have studied these partners, including EMs, BMs, and weather forecasters, through numerous types of events in a variety of locations. Our positionality stance allowed us to structure our tools and processes in a way that would elicit the data we desired to obtain. The unexpected situation in this study was that these professionals were not only emergency enterprise partners who responded to Hurricane Michael, but they were also survivors of this event. We were talking to them as disaster partners but quickly realized we were also talking to catastrophic storm survivors. In the moment, we had to switch our positionality stance to that of a disaster survivor. Using our experience with studying the public in disasters, as well as our own disaster experiences, we had to reframe our questions and our approach as needed. The respondents became emotional when they were responding as survivors, which triggered an emotional response in us, the researchers. We were aware of the need to balance emotions in a sensitive way with respondents, while checking our own emotions in order to maintain cognitive neutrality.

In addition to the EM and BM interviews, five members of the public were also interviewed individually in a similar format. These public participants were recruited with the assistance of one of the county EM agencies. This provided a chance to compare experiences from the public with the stories from EMs and BMs and identify common areas. The scripted questions were as follows and each included a follow up question probing for more information about the reason: (1) Did you evacuate for Hurricane Michael? (2) If you stayed home, would you do it again in the future? (3) If you evacuated, what helped you to make the decision to evacuate? When did you leave? Would you evacuate again in the future? (4) What products did you use to obtain weather information for this event? (5) Did you ever lose the ability to attain information about the storm? (6) When did you first

learn that Hurricane Michael was going to be a threat to your area? (7) How did this evolve from the weekend through the storm? (8) How were you impacted by Hurricane Michael? What kind of impacts did you expect? (9) Did you understand the storm was rapidly intensifying? (10) What would have helped you understand the threat better? These answers were used to develop the large sample public survey. All five members of the public provided remarkably similar answers to these 10 questions, providing confidence of responses nearing a saturation point.

2.2. Public Survey

The public survey consisted of 78 questions, and it was at least partially answered by 1523 participants. The questions were developed by the authors specifically for this research, although the more general questions are common to many of the articles cited. The number of responses was different for each question because it was a long survey, and participants were not required to answer every question. It was distributed to people in counties at least somewhat impacted by Hurricane Michael across Florida, Georgia, and Alabama using the social media (Facebook and Twitter) accounts of BMs, National Weather Service (NWS) Tallahassee, and emergency management agencies. Due to its length, the types of questions are summarized into categories here: Q1–Q4: demographics; Q5–Q8: participant location; Q9–Q10: previous storm experience; Q11–Q19: evacuation or shelter in place; Q20–Q29: SSHWS, Intensity, and Michael characteristics; Q30–Q46: information sources and warning information; Q47: hurricane hazard concern; Q48–Q53: winds and recovery; Q54–Q61: future actions, what worked, what did not; Q62–Q78: questions about housing, construction, recovery, and insurance.

One open-ended question was used to gain a better understanding of the risk perception and expectations of participants. Question 25 asked, "What were your expectations of the strength of Hurricane Michael?" Over 1100 answers to this open-ended question were manually organized into 35 codes by 2 raters. The codes were then collapsed and arranged into 12 themes. The 2 raters then independently categorized each comment into one of the 12 themes. The percentages of responses for the 12 themes were then calculated for each rater along with the percentage of common responses shared by both raters for each theme. Cohen's kappa was performed using the 12 nominal themes to evaluate inter-rater agreement. Selected quotes were pulled for each theme as examples of responses that were common to both raters as representations of that theme.

2.3. Hazard Perception from the Public Survey

Participants were grouped by their county of residence and asked to rank their concern for six geophysical storm hazards or storm characteristics using a Likert scale from one to five with five indicating the greatest concern. Geographic Information System analysis was used to map and overlay the track of Hurricane Michael and the wind field after landfall onto participant counties. Counties were then divided into four categories for classification with latitude away from the coastline and classification of distance away from the storm track to determine the degree of impact for each county. The latitude categories with increasing distance from the coastline were Coastal (bordering the Gulf of Mexico), Gulf (bordering Coastal counties and estuaries), Inland (inland from Gulf counties), and Continental (north of Inland counties). The impact categories were Heavy (within the hurricane force wind swath), Major (affected by hurricane gusts), Minor (within the tropical storm force wind swath), and Not Impacted. Due to uneven group membership and two categories dominating the sample size (Coastal and Heavy), the latitude and impact county categories were collapsed into Coastal (Coastal and Gulf) or Inland (Inland and Continental) and Heavily Impacted (Heavy) or Less Impacted (Major, Minor, Not). A county was included in the Heavily Impacted category if approximately 40% or more of the land area was within the hurricane force wind swath. A 75% area threshold was also used to evaluate the robustness of the 40% method with no change in results; therefore, the 40% method is reported in the results. Mann–Whitney tests were used due to unequal group sample sizes, ordinal data, and tests between only two groups. Since the counties were divided into two categories (either Coastal

vs. Inland or Heavily Impacted vs. Less Impacted), Mann–Whitney tests were used to test hazard concern for wind, storm surge, inland flooding/rainfall, falling trees, tornadoes, and storm size.

3. Results and Discussion

3.1. Emergency Management and Broadcast Meteorology Efforts

The most significant challenge for the EMs was to convey the seriousness of the storm in a short time frame, especially in the counties that were anticipating landfall impacts. Other counties would be preparing for evacuation traffic. The short time frame before landfall precluded the EM's ability to consistently message about the severity of the storm. In this region, the experiences have been that storms weaken and change paths, so the EMs had to work hard to convey that Michael would be different. Unfortunately, they had very little time to do that. The public survey confirmed this scenario and many people did not evacuate in a timely manner. Many residents decided that if it got bad, then they would evacuate. The problem was that their perception of "bad" was far milder than how "bad" it became. As the storm neared landfall, it was too late to evacuate. As disseminators of the storm information, BMs faced the same challenge as the EMs. They indicated that they used every tool at their disposal to disseminate graphics and messages, trying to convince the public of the severity of the impending event. Broadcasts, social media, mobile apps, and alert notifications were utilized to reach as many people as they could.

As the storm got closer to landfall and began to turn NNE and NE and grow in strength, the messaging became more intense, stressing the EMs and BMs considerably. People were not going to have enough time to get out of the way and some people who thought they would be safe would not be. As the storm made landfall, people were caught in conditions more severe than they expected. People living inland who did not anticipate the need to evacuate would later wish they had. As this became evident, the EMs, first responders, and BMs tried to respond to victims. The loss of power meant that they had lost many ways of communicating with the public, and much of their information was probably not reaching those who needed it most. The BMs resorted to using Facebook (FB) Live to communicate, not knowing if they were reaching people, but knowing it was all they could do. Many people received their FB broadcasts, and that was the only lifeline in many cases. The damage and debris was so widespread after the storm had passed that first responders could not reach victims in time to help. The impacts of this storm stressed and psychologically affected EMs, BMs, and first responders.

How could the weather enterprise get their messages across with the methods and messages that they normally use? They adapted very quickly to this event and modified their messages to capture the severity of this storm. The messages of the National Weather Service and the National Hurricane Center conveyed location, timing, impacts, wind speed, and storm surge and those messages were disseminated locally, regionally, and nationally. When the power went out very early in the storm, over 50% of respondents lost their ability to receive information. The enterprise improvised and found ways to communicate with the population, such as through FB Live, text messages, two-way radios, and other adaptations they discovered as the storm progressed. Informal contacts were used to share information when all else failed. Friends and family outside the impacted areas called and texted with information, providing a lifeline that ended up being the only source of information for many.

3.2. Public Survey

3.2.1. Demographics and Sample Characteristics

The survey generated a total of 1523 responses. Of these 45% reported being aged 50 or older and 39.5% reported being between 18 and 49, and the remaining chose not to respond. Males and females were almost evenly split, and 26% preferred not to answer gender. A substantial majority of respondents identified as Caucasian (92%), followed by Other at 4%, Hispanic or Latino at 2%,

and Asian and African American at 1% each. The African American population in many of these Florida counties is higher than the state average, and it was not adequately sampled. This possibly indicates that a smaller proportion of the African American population in these counties follows the social media feeds of the NWS, BMs, and EMA. Other meteorological hazards survey research disseminated via social media or through website links also failed to obtain a representative sample of particular categories [28,29]. A total of 87% of our sample reported being in a previous tropical storm or hurricane, and 4% reported working at Tyndall Air Force Base. When asked, 56% reported living in an evacuation zone, 34% did not, and 9% were not sure. The majority, 61%, chose not to evacuate.

3.2.2. Information Sources and Expectations

Consistent with prior research findings, a range of sources of weather related information are accessed by members of the public. In our sample, 26% of people reported using the local media as a source of hazard information, while national media use was 15%. Both national Wireless Emergency Alerts (WEA) on cell phones and county/community generated cell phone messaging were each reported by 20% of respondents. Another 10% reported using NOAA Weather Radio, and 9% reported other means of information gathering. These other sources of information often referred to websites, including different NOAA sites (such as the National Hurricane Center or local NWS office page), specific weather based web pages run by individuals and not part of the local/national traditional media nor government agencies (Mike's Weather Page), social media sites (such as FB), and contact with family/friends not living in the area via phone.

Responses to question 25 about expectations for Michael's intensity provided a window into the decision-making process of participants (Table 2). The responses across all 12 themes sum to 100% for each rater. The Cohen's kappa result ($\kappa = 0.851$, $p < 0.01$) revealed almost perfect agreement between the raters on labeling the comments into one of the 12 themes [30] (see Table 2). When describing the intensity, the most common response was for participants to provide the SSHWS scale category they thought Michael would be at landfall. Most participants did not specify if they thought they would experience these conditions at their residence, or if those would only be experienced near the eyewall. Regardless, 31% answered a SSHWS scale category of 3 or lower, while only 6% answered a category 4 or 5 as the updated forecast showed on the day of landfall. Taking the mean of the 2 raters, an additional 21.6% provided comments that were classified as underestimation; accurate estimation was at 10.1%, and overestimation was at 1.9%. The majority of the underestimation comments indicated an expected weakening and surprise by the rapid intensification (Table 3). The overestimation comments were from participants on the periphery of the storm track who expected a more direct impact and did not receive it. People with a lack of hurricane experience were the primary demographic represented by the No Expectation theme.

A total of 6% of participants provided an answer that could only be classified as an incorrect forecast interpretation. These responses showed false confidence that the forecast track and other details from the National Hurricane Center were wrong (see Table 3). Another common response in this category was overhype by the news or BMs. The track forecast from The National Hurricane Center was accurate, but the intensity forecast was not until the last 12 h before landfall. Forecasting rapid intensification of a tropical cyclone remains challenging and progress continues to show improvements for the future.

Almost 7% specifically mentioned an aspect of evacuation in their comments. Just under 4% of participants specifically indicated that they wanted to evacuate, but the conditions had become too hazardous, and it was too late on the morning of 10 October. These people were waiting to see if Michael became a category 4 or stronger hurricane before deciding to evacuate. For some people, a period of time greater than 24 h is necessary to plan an evacuation and coordinate responsibilities with employers and other obligations. A smaller percentage specifically mentioned a last-second evacuation on the morning of 10 October.

A total of 6.2% of participants mentioned something about damage at their residence or in their neighborhood. These comments demonstrated surprise about the number of downed trees, high winds, storm surge, or the time without power. Another 2% evacuated early but were dismayed to see or hear about even more damage than they thought upon returning home. These comments were also shared by similar beliefs from participants who voiced general concern that they might be dealing with an unprecedented event despite their preparations and previous storm experiences. In summary, when the accurate intensity comments are taken together with the evacuation but surprised by intensity, evacuation last second, and general concern comments, it reveals that almost 20% of the participants in our sample had a reasonable expectation of what they would experience in enough time to take appropriate actions.

3.2.3. Factors that Influenced Evacuation or Shelter in Place Decisions

A total of 61% of participants chose not to evacuate. Of those who evacuated, responses revealed a wide range of geographic locations, but also included remaining local and staying with family members or friends in a safer structure. The survey confirmed that the public generally did not believe that the storm could be as severe as it was. Some held the belief that storms perform in certain ways in the Gulf, such as weakening and changing path. This created a significant challenge for message disseminators. It was clear from the answers to multiple questions in the survey that the public received the messaging but chose to disregard it in many cases because of their storm perceptions. Their reasoning for sheltering in place and their emergency plans were based on varied factors.

Table 2. Responses to question 25, "What were your expectations of the strength of Hurricane Michael?" Responses were organized into 12 themes and percentages were calculated by 2 raters (R1 and R2). The agreement column indicates the percentage of comments for each theme that were labeled by both raters.

	R1 (%)	R2 (%)	Agreement (%)
Underestimation	21.5	21.7	91.3
Accurate Intensity Comments	10.3	9.9	90.6
Overestimation	2.1	1.7	100.0
Incorrect Forecast Interpretation	6.4	5.6	96.7
No Expectations/Unsure	2.6	2.1	100.0
Too Late to Evacuate	3.7	3.6	100.0
Evacuated Last Second	1.1	1.1	100.0
Evacuated but Surprised	2.1	1.9	100.0
General Concern	6.2	5.8	71.0
Damage Description Indicating Surprise	4.7	5.2	68.0
Unclassified	2.2	3.0	91.7
SSHWS Category	37.2	38.5	
SSHWS1	1.7	1.9	88.9
SSHWS2	9.3	11.4	92.0
SSHWS3	19.4	19.3	90.3
SSHWS4	5.8	5.0	96.3
SSHWS5	0.9	0.9	100.0

Table 3. Representative comments for themes in Table 2.

Underestimated Intensity	Decided It Was Too Late To Evacuate
That it would be minimal by the time it reached my area.	Cat. 3 when we went to bed on Tuesday. Strong Cat. 4 when we got up Wednesday. Too late to evacuate at that point.
It turned out to be far more dangerous than anticipated. It did not weaken as it came ashore and moved inland.	This storm literally blew up at the last minute making it virtually impossible to leave.
I expected it to weaken as all the previous storms had done in the past.	I was not expecting to be in the eyewall. By the time it looked like the eyewall was going to hit Mexico Beach the bridges had been closed.
Strong rain and winds but nothing like what we experienced.	He was a strong 3 . . . no need to panic . . . then when he strengthened it was too late to do anything but sit tight
I did not expect it to strengthen so rapidly before landfall.	**Evacuated Last Second**
Accurate Intensity	About 1 a.m. the morning of 10 October 2018 our local news was saying Michael had grown in strength and we were looking at catastrophic storm headed our way. My family and I made the decision to leave and we got out just ahead of landfall.
Expected it to be very damaging, was monitoring wind speed on my iPhone via bookmarked NOAA tropical storm pages.	I didn't expect the strength of the storm, nor the direct impact of it. By the time the forecast models had its track and strength correct it was almost too late to leave.
Very strong, potential to be catastrophic	**Evacuated, but Surprised**
I expected it would strengthen, just as was predicted and we were repeatedly warned.	When we left, it was a Category 3, but I didn't expect to wake up the next morning and get notifications asking if I was safe or if I'd evacuated because it was now a Category 4, almost 5.
It strengthened so quickly and stayed on track, I knew it was going to be bad.	I did not expect it to be as strong as it ultimately was at landfall. At my time of evacuation, it had risen from a "2" to a "3". My rationale for leaving at that time was that I didn't want to be without utilities for a couple of days.
It was exactly what I expected.	**General Concern**
Overestimated Intensity	That it was probably going to be stronger than anticipated.
Expected much worse.	Bad but manageable with my experience and preparations.
I expected it to be worse and slower.	I was concerned that the storm was getting stronger. Exactly how strong it was going to get was unknown.
Incorrectly Interpreted Forecast	Scary.
Low because they were uncertain of the track.	Life threatening.
That it would weaken once it hit the shallower waters like every other storm that has come ashore here.	**Damage Descriptions Indicating Surprise**
It wouldn't hit us, and would be windy and rain. The news always over reacts.	Did not anticipate how much damage wind would cause, was mainly concerned with surge
We expected it to shift east or west and to lose strength before it hit the coast.	It was pretty on point for my home in Panama City beach; I was shocked at how bad the damage was at my 2nd home 50 miles away from the coast!
Original forecast had it making landfall as a tropical depression so not that much.	Severe storm surge—did not expect extensive wind damage.

Their previous experiences with storms influenced survey participants greatly. Many had evacuated for other storms that had weakened or changed path, particularly SSHWS category 3 Hurricane Opal in October 1995, which made landfall approximately 100 km (62 miles) farther west than Michael. They had evacuated for Opal and had not been allowed back to their homes and businesses. Many of them did not want to experience this again, so they decided to stay and evacuate later if the storm strengthened. Those who stayed were thinking the storm track would shift and weaken, like previous storms. They also did not think a storm could be as serious in October, the month before hurricane season ends. Three quarters of the participants did not believe a hurricane could even happen in October.

Most of the participants had a good understanding of the SSHWS, and 69% found it helpful for their planning. When asked what wind speeds would encourage them to evacuate, a Category 3 or higher was relevant for 84%. The comments from surveys and interview results suggest that people did not believe the storm would be stronger than category 3, or that category 3 wind gusts would be observed inland. They also believed they had more time to put their plan into place. This would cause problems for them when the storm strengthened from a category 3 to a strong category 4 very quickly. The upgrade to category 5 occurred after post landfall reanalysis. Results from the previous section about the SSHWS category, suggest that many people made their evacuation or shelter in place decision 24 h before landfall and refused to reconsider that decision in light of new information. It also suggests that many people made a decision and then stopped closely following storm updates as they prepared. The increase in intensity to a strong category 4 happened overnight, and it was too late and too dark to evacuate at that point. The population density of the region is low and only one major interstate (I-10) serves the region running east to west. Traveling on smaller and dark rural roads can be hazardous in this region due to potential wildlife collisions and other road hazards. About a third of the respondents did not believe they had enough time to put their plan into place.

Interviews with local officials in Mexico Beach answered many questions about the decision-making of residents there. Michael became a SSHWS category 4 hurricane at 1 a.m. CDT on 10 October with landfall near Tyndall Air Force Base at approximately 12:30 p.m. CDT. The rapid intensification of Michael and a track that veered directly toward Mexico Beach forced an estimated 100–500 people to evacuate in the last 5 h prior to landfall. Some elderly and less mobile residents did not have time or the resources to evacuate. The participants who did not evacuate from Mexico Beach experienced a storm surge of 14–15 feet [1] (Figure 2). They, too, had evacuated for Hurricane Opal and did not want to leave this time. Opal did not make a direct landfall in Mexico Beach, providing an example of how people may not understand the spatial variability of damage potential in relation to where storms make landfall [31]. They described realizing that it was not a good idea to stay and they would never stay again. Four storm surge fatalities occurred there. If the experiences of Mexico Beach residents could be captured for future preparedness outreach, it might help people make the decision to evacuate ahead of a storm surge.

It was evident that the information was available to the public and that the weather enterprise did everything possible in the moment to adapt to the unique aspects of this storm. The lessons learned are that message disseminators should be aware of their publics' perceptions and rationalizations about their risk and do everything possible to overcome those rationalizations. What the weather enterprise professionals did to overcome challenges are now elements of best practices for future events of this nature.

Figure 2. Mexico Beach storm surge damage zone in December 2018 (**a**–**d**). The same stretch of coastline in September 2019 (**e**–**h**). In September 2019, property had been mostly cleared of debris, and some owners were staying in campers (**g**,**h**) as they rebuilt.

3.3. Hazard Perception

A total of 1047 participants answered questions about hazard concern for Hurricane Michael. This number changed slightly for each hazard since some participants skipped questions. Rankings for concern were first assessed for the entire sample for each hurricane hazard using descriptive statistics (Table 4). Wind was the hazard of greatest concern, with a mean ranking of 4.05, followed by other wind related hazards of falling trees at 3.85 and tornadoes at 3.41. These results were expected in a post-landfall survey of a storm with historic wind damage conducted less than a year after landfall. Tree failure was catastrophic. The number of tornadoes from Michael was lower than many landfalling storms, with only 16 tornadoes all within the EF0 and EF1 intensities. In the following subsections, the perception of hazards between Coastal and Inland residents and Heavily Impacted and Less Impacted participants are compared.

Table 4. (Top) Overall hazard concern and sample size ranked in descending order by greatest concern. (Middle) Hazard concern mean rankings, and statistical significance of Mann–Whitney tests comparing concern for participants from Coastal versus Inland counties. (Bottom) Same as middle but for Heavily Impacted versus Less Impacted counties. Bold indicates $p < 0.05$.

Hazard	Mean Concern	n			
Wind	4.05	1042			
Falling Trees	3.85	1036			
Tornadoes	3.41	1028			
Storm Size	3.14	1026			
Rainfall/Inland Flooding	2.8	1024			
Storm Surge	2.14	1017			
Hazard	**Coastal**	**n**	**Inland**	**n**	***p***
Wind	3.97	699	4.19	343	**0.011**
Falling Trees	3.63	693	4.29	343	**<0.001**
Tornadoes	3.27	684	3.69	344	**<0.001**
Storm Size	3.15	688	3.12	338	0.714
Rainfall/Inland Flooding	2.75	687	2.90	337	**0.045**
Storm Surge	2.55	688	1.28	329	**<0.001**
Hazard	**Heavily**	**n**	**Less**	**n**	***p***
Wind	4.03	743	4.09	299	0.932
Falling Trees	3.71	736	4.20	300	**<0.001**
Tornadoes	3.34	729	3.58	299	**0.006**
Storm Size	3.16	732	3.10	294	0.489
Rainfall/Inland Flooding	2.79	731	2.82	293	0.510
Storm Surge	2.30	728	1.73	289	**<0.001**

3.3.1. Coastal vs. Inland Counties

The sample was divided into Coastal (n = 702) and Inland participants (n = 345) according to their county of residence (Figure 3). The counties with the largest representation for each category were Bay (518) and Gulf (96) Counties for Coastal and Leon (101) for Inland. Leon County contains Tallahassee, the largest city in the region. A Mann–Whitney test revealed that Coastal participants were significantly more concerned about storm surge than Inland participants ($p < 0.001$). The storm surge from Hurricane Michael devastated Mexico Beach on the periphery of the eastern eyewall on the border of Bay and Gulf Counties. Although Mexico Beach had made significant progress 11 months after the storm, there were still numerous properties that were completely barren or marked by slabs (see Figure 2). Despite the tragedy in Mexico Beach, the storm surge concern findings are encouraging to see simply because it shows geographical awareness and hazard competence.
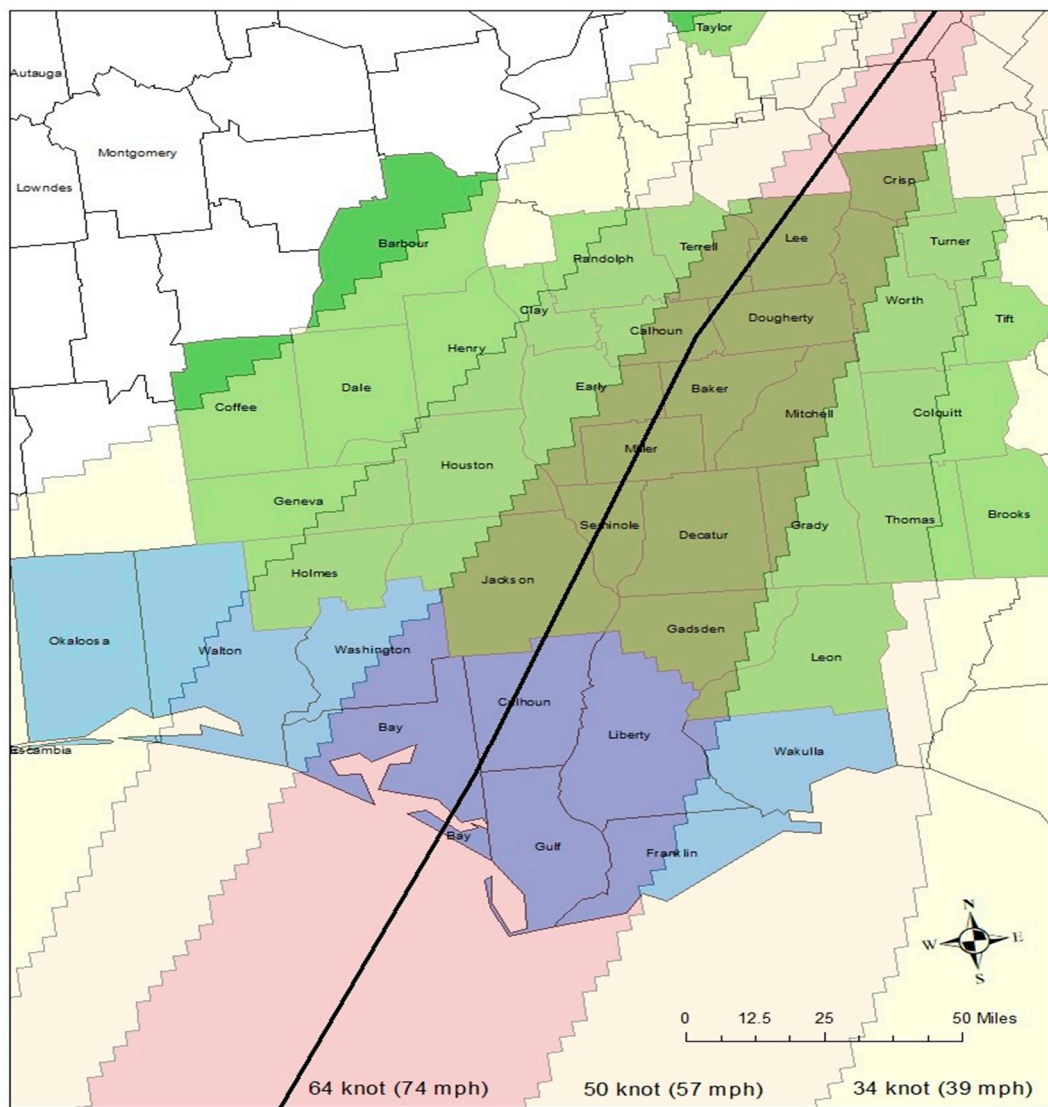
Figure 3. The track and wind swath of Hurricane Michael with Coastal counties (blue) and Inland counties (green).

Inland participants showed statistically significantly greater concern for every other hurricane hazard with the exception of hurricane size ($p = 0.714$; see Table 4). As previously discussed, wind, falling trees, and tornadoes were the greatest concern before dividing the participants into categories. It is evident that this finding is driven primarily from the smaller number of Inland participants who witnessed extreme wind speeds far beyond what they expected. An Extreme Wind Warning was issued by The National Weather Service in Tallahassee, and this warning was communicated via the WEA system. Even with this warning, participants were still shocked by the wind speeds they experienced. This sentiment was shared by EMs, BMs, and the public participants in our interviews, who all became emotional when compelled to remember the events of 10 October when Michael made landfall and tracked over their locations.

Rainfall and inland flooding were not a major problem with Hurricane Michael, but Inland residents were concerned about the possibility ($p = 0.045$). Hurricane Florence one month earlier in September 2018 had inundated portions of North and South Carolina, and record-breaking floods from Hurricane Harvey (2017) in Texas were still on the minds of some participants. Hurricane Michael will be known for its intensity and rapid intensification, but its inland intensity and devastation and lasting impacts on those who experienced it are evident in both qualitative and quantitative results.

3.3.2. Heavily Impacted vs. Less Impacted Counties

The sample was also divided into Heavily Impacted (n = 746) and Less Impacted participants (n = 301) according to their county of residence (Figure 4). The counties with the largest representation for each category were the same as the previous subsection. Another Mann–Whitney test revealed that Heavily Impacted participants were significantly more concerned about storm surge than Less Impacted participants ($p < 0.001$) (see Table 3). Over 600 participants resided in the two most directly affected storm surge counties, Bay and Gulf, likely explaining why this was so significant. Wind was not significant between the two categories because it was a major concern for all participants, even in Less Impacted counties. Falling trees ($p < 0.001$) and tornadoes ($p = 0.006$) were of more concern in the Less Impacted counties. Similar to the storm surge result for Coastal participants, these findings suggest geographical awareness and hazard competence since the fringes of a landfalling hurricane are the most common locations for tropical cyclone tornadoes which can produce falling trees. This logic should also indicate that storm size was a greater concern for those in the Less Impacted category, but it was not ($p = 0.489$; see Table 3).
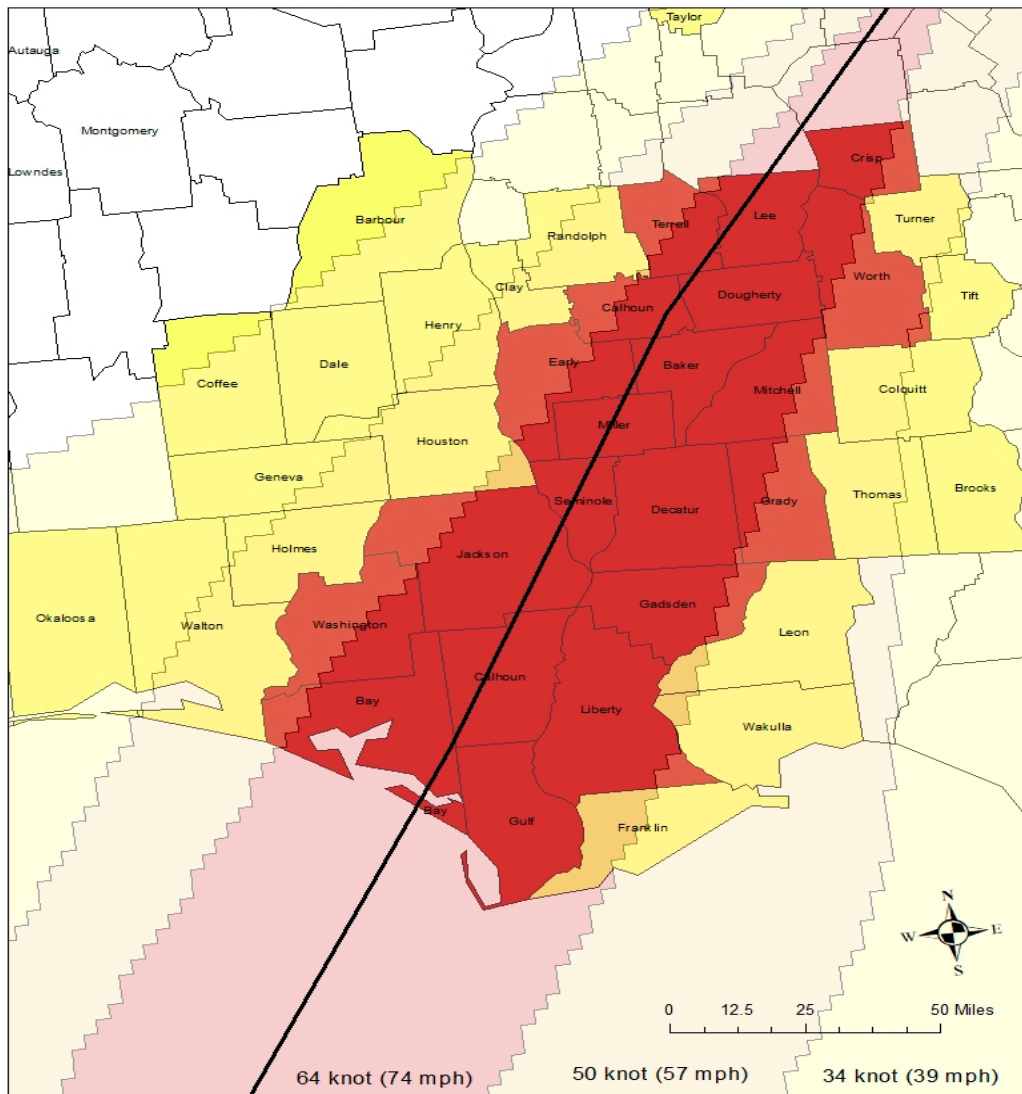

Figure 4. The track and wind swath of Hurricane Michael with Heavily Impacted counties (red) and Less Impacted counties (yellow).

3.4. Lessons Learned and Best Practices

The lessons learned from these interviews were numerous, as were the best practices. A valuable lesson learned was that people's myths and beliefs about hurricanes play a major role in their acceptance of emergency messaging. Traditional messaging will not work for a catastrophic event like this one. The weather enterprise was challenged with a short duration timeline and a storm that was strengthening to an intensity that would cause catastrophic damage. It was a storm of such proportions that most participants struggled to conceive the magnitude of the potential damage. These findings support the results of Stewart (2011) [32], who found that most Gulf Coast residents think the destructive potential of increasing categories on the SSHWS follows a linear relationship, when in fact it is exponential. This misunderstanding would cause the public to greatly underestimate the potential damage from category 4 and category 5 hurricanes.

Another lesson learned from this research was that people had many reasons for not evacuating and taking proper shelter. In many cases, people did not realize their location could be and would be so severely impacted. Over half of the participants relied on the cone of uncertainty to determine their risk. Some people used it to minimize their risk; others improperly interpreted it. Many people could not evacuate because their employers threatened to fire them if they left and did not come back for work. This may have been a reason that some chose to wait for a higher wind speed or SSHWS category to justify their evacuation. This points to a need for communities to form collaborations among business owners and managers, civil government, federal agencies, citizen groups, and nonprofits aimed at increasing individual and community resilience through establishing norms across sectors for how to respond and improve decision-making in the face of hazards and disasters.

One of the most important factors when deciding to evacuate or stay at home is prior experience with hurricanes. This points to a need to deepen and broaden the public understanding of storms and impacts well beyond the SSHWS categories. Meaning is always developed contextually and collectively. Because we cannot control everyone's direct experience nor rewrite their memories, the weather enterprise needs to look for ways to shape the context in which urgent warning and watch period messages are received by members of the public. This is substantiated by Drake et al. (2012) [33], "The forecast interpretation problem encompasses not only the forms in which the information is presented or communicated (e.g., text versus graphics), but even more so the complexity and transparency of the scientific content contained between those forms." The authors reference to the "complexity and transparency of the scientific content", in combination with their observation that members of the public require a message that contains " . . . restructured content comprehensible to populations not generally schooled in those disciplines", is pointing directly at the lack of a shared knowledge context between those creating the hazard messages and those who are reliant upon those messages for informing their decision-making and action choices.

4. Conclusions

Hurricane Michael made landfall as only the third SSHWS category five in the named era and the strongest storm ever in the Florida Panhandle. This research examined the experiences of both public safety professionals and members of the public in December 2018 following the landfall of Hurricane Michael. Interviews were conducted with EMs, BMs, and the public to understand their experiences, actions, and decision-making. These answers were used to inform the questions for a large sample public survey disseminated in February 2019. The survey asked a mixture of qualitative open-ended and quantitative responses. Both the survey and interviews documented the powerful impact of that experience. Because Hurricane Michael was atypical of landfalling tropical cyclones on the Gulf Coast, it offered an opportunity to examine the human response to a rapidly intensifying category five hurricane.

The results show that Hurricane Michael's intensity, rapid intensification, landfall location, and public perception of October being past the peak of hurricane season combined with pre-existing perceptions of hurricane hazards in the region to shock participants with its high winds and other

hazards. These pre-existing perceptions complicated the efforts of EMs and BMs to accurately warn the public and convey the urgency of the evolving threat. SSHWS category 3 Hurricane Opal was frequently mentioned as a benchmark storm, and participants went to sleep on the night of 9 October anticipating another Opal; however, the center of the cone of uncertainty for 48 h prior to landfall showed a remarkably consistent forecast with a landfall on Panama City or Tyndall Air Force Base. The National Hurricane Center track forecast was almost exactly correct, and this was a different track from Opal. On the morning of 10 October, Michael was an intensifying category 4 hurricane that had veered northeast following its forecast. The overnight intensification and northeast turn eliminated a safe evacuation time window and resulted in a high number of people who did not evacuate. This was the primary reason why the public response to Michael was different when compared to recent hurricanes that allowed residents to make and alter their decisions over several days. People did not have enough time to consider all aspects of their social connections, social diversity, and social networks when compared to a week of watching the Hurricane Irma forecasts in 2017. Some of the most important pieces of evacuation information people use are official evacuation orders, prior storm experience, and talking with others. Although evacuation orders were issued, most people on this low-to-medium population density coastline adopted to wait for more information because Michael had not yet crossed into that exceptional category 4 and greater threshold. Prior storm experiences did not offer enough damage on this coastline to warrant evacuation for most people. Conversations with family, friends, and neighbors only confirmed these beliefs until the morning of 10 October. At that time, some people made a hastened evacuation, but others could not evacuate. Our results showed that approximately 80% of our sample either underestimated, misunderstood, misinterpreted, or realized the dangers too late. This is even more alarming considering the characteristics of our sample participants being social media followers of NWS, BMs, and EMs in the region, likely making them a more weather salient group compared to a general public sample.

The inland wind damage from Hurricane Michael was immense. In the large sample survey, participants from Inland counties showed statistically significantly greater concern for wind, tornadoes, falling trees, and rainfall/inland flooding. An Extreme Wind Warning was issued by The National Weather Service in Tallahassee, and this warning was communicated via the WEA system. Even with this warning, participants were still shocked by the wind speeds they experienced. This sentiment was also shared by EMs, BMs, and the public participants in our interviews who all became emotional when forced to remember the events of 10 October when Michael tracked over their locations. Hurricane Michael will be known for its intensity and rapid intensification, but its inland devastation, and lasting impacts on those who experienced it are evident in both qualitative and quantitative results.

Examining the communication and perceptions of people affected directly by Hurricane Michael points to the conclusion that messaging just before and during a major weather event is not sufficient as a means of improving resilience and protecting lives. Phenomena that can rapidly change and develop into large scale, intense events challenge even the most robust of communication strategies and tactics. One line of future research needs to ascertain exactly what strategies and reconfigured content will be the most effective in fostering a better understanding of the dynamic quality of specific kinds of storms and what kind of simple, perhaps graphical, tools might be used to easily trigger greater or increased attention on the part of various publics. A mixed method approach using some experimental efforts followed by focus group discussion and then iterations of the strategies and tools is suggested. In addition, this points toward future research plans of the authors for community action targeting a deeper and more comprehensive development of resilience. Ideas are being considered for doing virtual/phone interviews of BMs, EM staff, business owners/managers, department of transportation managers, local law enforcement, and members of various publics to gain insight into how the scientific information and uncertainty are being interpreted by each of the groups and then communicated to others.

References

1. Beven, J.L., II; Berg, R.; Hagen, A. *National Hurricane Center Tropical Cyclone Report Hurricane Michael*; AL142018; National Hurricane Center: Miami, FL, USA, 2019.

2. Keim, B.D.; Muller, R.A.; Stone, G.W. Spatiotemporal Patterns and Return Periods of Tropical Storm and Hurricane Strikes from Texas to Maine. *J. Clim.* **2007**, *20*, 3498–3509. [CrossRef]

3. Malmstadt, J.C.; Elsner, J.B.; Jagger, T.H. Risk of Strong Hurricane Winds to Florida Cities. *J. Appl. Meteorol. Clim.* **2010**, *49*, 2121–2132. [CrossRef]

4. Scheitlin, K.N.; Elsner, J.B.; Lewers, S.W.; Malmstadt, J.C.; Jagger, T.H. Risk assessment of hurricane winds for Eglin air force base in northwestern Florida, USA. *Theor. Appl. Clim.* **2011**, *105*, 287–296. [CrossRef]

5. Seneviratne, S.I.; Nicholls, N.; Easterling, D.; Goodess, C.M.; Kanae, S.; Kossin, J.; Luo, Y.; Marengo, J.; McInnes, K.; Rahimi, M.; et al. Tropical Cyclones in Changes in climate extremes and their impacts on the natural physical environment. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*; Field, C.B., Barros, V., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G.-K., Allen, S.K., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2012; pp. 158–163.

6. Weinkle, J.; Landsea, C.; Collins, D.; Musulin, R.; Crompton, R.P.; Klotzbach, P.J.; Pielke, R. Normalized hurricane damage in the continental United States 1900–2017. *Nat. Sustain.* **2018**, *1*, 808–813. [CrossRef]

7. Knutson, T.; Camargo, S.J.; Chan, J.C.L.; Emanuel, K.; Ho, C.-H.; Kossin, J.; Mohapatra, M.; Satoh, M.; Sugi, M.; Walsh, K.; et al. Tropical Cyclones and Climate Change Assessment: Part II: Projected Response to Anthropogenic Warming. *Bull. Am. Meteorol. Soc.* **2020**, *101*, E303–E322. [CrossRef]

8. Murnane, R.; Elsner, J.B. Maximum wind speeds and US hurricane losses. *Geophys. Res. Lett.* **2012**, *39*. [CrossRef]

9. Benedetto, K.M.; Trepanier, J.C. Climatology and Spatiotemporal Analysis of North Atlantic Rapidly Intensifying Hurricanes (1851–2017). *Atmosphere* **2020**, *11*, 291. [CrossRef]

10. Trepanier, J.C. North Atlantic Hurricane Winds in Warmer than Normal Seas. *Atmosphere* **2020**, *11*, 293. [CrossRef]

11. Senkbeil, J.C.; Brommer, D.M.; Comstock, I.J. Tropical Cyclone Hazards in the USA. *Geogr. Compass* **2011**, *5*, 544–563. [CrossRef]

12. Senkbeil, J.; Collins, J.M.; Reed, J. Evacuee Perception of Geophysical Hazards for Hurricane Irma. *Weather Clim. Soc.* **2019**, *11*, 217–227. [CrossRef]

13. Senkbeil, J.; Reed, J.; Collins, J.; Brothers, K.; Saunders, M.; Skeeter, W.; Cerrito, E.; Chakraborty, S.; Polen, A. Perceptions of Hurricane-Track Forecasts in the United States. *Weather Clim. Soc.* **2020**, *12*, 15–29. [CrossRef]

14. Sherman-Morris, K.; Poe, P.S.; Nunley, C.; Morris, J.A. Perceived Risk, Protective Actions and the Parasocial Relationship with the Local Weathercaster: A Case Study of Hurricane Irma. *Southeast. Geogr.* **2020**, *60*, 23–47. [CrossRef]

15. Millet, B.; Carter, A.P.; Broad, K.; Cairo, A.; Evans, S.D.; Majumdar, S.J. Hurricane Risk Communication: Visualization and Behavioral Science Concepts. *Weather Clim. Soc.* **2020**, *12*, 193–211. [CrossRef]

16. Trumbo, C.W.; Peek, L.; Meyer, M.A.; Marlatt, H.L.; Gruntfest, E.; McNoldy, B.D.; Schubert, W.H. A Cognitive-Affective Scale for Hurricane Risk Perception. *Risk Anal.* **2016**, *36*, 2233–2246. [CrossRef] [PubMed]

17. Collins, J.M.; Ersing, R.; Polen, A.; Saunders, M.; Senkbeil, J. The Effects of Social Connections on Evacuation Decision Making during Hurricane Irma. *Weather Clim. Soc.* **2018**, *10*, 459–469. [CrossRef]

18. Jiang, Y.; Li, Z.; Cutter, S.L. Social Network, Activity Space, Sentiment, and Evacuation: What Can Social Media Tell Us? *Ann. Am. Assoc. Geogr.* **2019**, *109*, 1795–1810. [CrossRef]

19. Pham, E.O.; Emrich, C.T.; Li, Z.; Mitchem, J.; Cutter, S.L. Evacuation Departure Timing during Hurricane Matthew. *Weather Clim. Soc.* **2020**, *12*, 235–248. [CrossRef]

20. Huang, S.-K.; Lindell, M.K.; Prater, C.S. Who Leaves and Who Stays? A Review and Statistical Meta-Analysis of Hurricane Evacuation Studies. *Environ. Behav.* **2016**, *48*, 991–1029. [CrossRef]

21. Kimball, S.K.; Mulekar, M.S. A 15-Year Climatology of North Atlantic Tropical Cyclones. Part I: Size Parameters. *J. Clim.* **2004**, *17*, 3555–3575. [CrossRef]

22. Knapp, K.R.; Kruk, M.C.; Levinson, D.H.; Diamond, H.J.; Neumann, C.J. The International Best Track Archive for Climate Stewardship (IBTrACS). *Bull. Am. Meteorol. Soc.* **2010**, *91*, 363–376. [CrossRef]

23. Knapp, K.R.; Diamond, H.J.; Kossin, J.P.; Kruk, M.C.; Schreck, C.J., III. International Best Track Archive for Climate Stewardship (IBTrACS) Project, Version 4. [Global Tropical Cyclones]. *NOAA Natl. Cent. Environ. Inf.* **2018**. [CrossRef]

24. Tropical Cyclone Extended Best Track Dataset. Available online: http://rammb.cira.colostate.edu/research/tropical_cyclones/tc_extended_best_track_dataset/index.asp (accessed on 29 May 2020).

25. Kieper, M.E.; Landsea, C.W.; Beven, J.L. A Reanalysis of Hurricane Camille. *Bull. Am. Meteorol. Soc.* **2016**, *97*, 367–384. [CrossRef]

26. Landsea, C.W.; Franklin, J.L.; McAdie, C.J.; Beven, J.L.; Gross, J.M.; Jarvinen, B.R.; Pasch, R.J.; Rappaport, E.N.; Dunion, J.P.; Dodge, P.P. A Reanalysis of Hurricane Andrew's Intensity. *Bull. Am. Meteorol. Soc.* **2004**, *85*, 1699–1712. [CrossRef]

27. Delgado, S. Reanalysis of the 1954–1963 Atlantic Hurricane Seasons. *J. Clim.* **2017**, *31*, 4177–4192. [CrossRef]

28. Gutter, B.F.; Sherman-Morris, K.; Brown, M.E. Severe Weather Watches and Risk Perception in a Hypothetical Decision Experiment. *Weather Clim. Soc.* **2018**, *10*, 613–623. [CrossRef]

29. Saunders, M.E.; Ash, K.D.; Collins, J.M. Usefulness of the United States National Weather Service Radar Display as Rated by Website Users. *Weather Clim. Soc.* **2018**, *10*, 673–691. [CrossRef]

30. Koch, J.R.L.G. The Measurement of Observer Agreement for Categorical Data. *Biometrics* **1977**, *33*, 159. [CrossRef]

31. Senkbeil, J.C.; Sheridan, S.C. A Postlandfall Hurricane Classification System for the United States. *J. Coast. Res.* **2006**, *225*, 1025–1034. [CrossRef]

32. Stewart, A.E. Gulf Coast Residents Underestimate Hurricane Destructive Potential. *Weather Clim. Soc.* **2011**, *3*, 116–127. [CrossRef]

33. Drake, L. Scientific Prerequisites to Comprehension of the Tropical Cyclone Forecast: Intensity, Track, and Size. *Weather Forecast.* **2012**, *27*, 462–472. [CrossRef]