TWITTER NARRATIVES DURING HURRICANE MATTHEW:

EVALUATION OF IMMEDIATE

DISASTER STAGES

By

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Abstract:

The objective of this thesis is to investigate the effectiveness of foundational disaster literature using a contemporary data platform. Due to the recency of social media over the last decade, novel opportunities now exist to study disaster preparation, response, recovery, and mitigation through *in-situ* accounts. The author characterizes immediate disaster stages based upon overarching themes identified by Twitter users impacted by Hurricane Matthew in Savannah, Georgia. Using both quantitative and qualitative methods, the author identifies the frequency of tweets within each immediate disaster stage, as well as the context of each tweet. In addition, the author uses individual social media narratives to gauge the resident's story through the duration of Hurricane Matthew. The author's findings suggest the continuing effectiveness of foundational disaster literature through both quantities and qualitative methods. Results emphasize prior studies that address residents' narratives during a disaster event. The further incorporation of social media proves to be an additional outlet for research in the meteorological field.

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CHAPTER I

INTRODUCTION

As Hurricane Matthew approached the Southeastern coast of the United States, I made

the spontaneous decision to drive from Stillwater, Oklahoma to the coastline of Florida to

observe the evacuation process as residents left and returned home. I departed Stillwater the

evening of October 6, driving overnight to get to the Florida coastline, near St. Augustine, as

Hurricane Matthew impacted the region. After speaking with a few residents along the I-95

corridor from Jacksonville to St. Augustine, I continued north towards Savannah, GA the day

following Matthew's impacts. I spent two days in the Savannah area, driving north towards

Hilton Head Island at one point to purposefully get stuck in a traffic jam as residents tried to

make their way back to their residence. I spoke with several residents of Savannah, as well as

those on Tybee Island, discussing their evacuation procedure and if they would have changed

their preparation, evacuation methods based upon what took place. These interactions led to the

production of an article with the [Washington Post](#), addressing the importance of stepping into

residents' shoes during disaster events. I wrote this article for the Washington Post to help bridge

the gap of understanding between officials releasing warning information, including

meteorologists, journalists, and emergency managers, and members of the public. It is important

for both to comprehend the challenges on side of the spectrum to further understand how to

improve the warning response process to ensure public safety during a disaster. However, I

wanted to continue my research on this topic beyond an article, to further identify evacuation procedures, and thoughts and actions expressed real-time as Hurricane Matthew impacted those along the Southeastern coastline, specifically those in Savannah. Thus, this unexpected, spontaneous trip I took with my dog became the foundation for my Master's thesis. Despite an abundance of literature surrounding evacuation processes and warning responses made by residents, the issue as to why some do not evacuate remains apparent during disasters. At an individual level, the lack of evacuation has been attributed to three basic social psychological processes: risk perception, social influence, and access to resources (Riad et al., 1999). To identify emergent issues in individual responses to a natural hazard warning, Perry (1979) constructed a flowchart, addressing the human act of evacuation. The model indicates multiple steps an individual takes during the evacuation decision-making process. If an individual responds "no" at any step during the process, one can assume the lack of adaptive response to the natural hazard warning. The consequential steps that facilitate decision patterns are: (1) *milling* (confirming warning message, retrieving additional information); (2) *assessing personal risk* (impact proximity, certainty, and severity); (3) *assessing logistics* (availability of a plan and taking protection) (Perry, 1979). If these emergent norm issues are addressed by the individual, adaptive response is then undertaken.

Compounding the issue of lack of evacuation action taken during crisis events by residents is a dearth of research based on real time data collection. This can be attributed to the complications of collecting the data, as natural, political, and economic challenges exist (Morton and Levy, 2011). In addition, Kinnell and Dellinger (2007) identified multiple challenges when collecting survey data along the Mississippi Coast after Hurricane Katrina: locating subjects, gaining subject participation, and procuring consent. Furthermore, the effects of data collection,

survey or interview, on the individuals' condition must also be recognized (Kinnell and Dellinger, 2007) despite their willingness to participate (Quarantelli, 1997). Compounding the issue of lack of evacuation action taken during crisis events by residents is a dearth of research based on real time data collection. This can be attributed to the complications of collecting the data, as natural, political, and economic challenges exist (Morton and Levy, 2011). In addition, Kinnell and Dellinger (2007) identified multiple challenges when collecting survey data along the Mississippi Coast after Hurricane Katrina: locating subjects, gaining subject participation, and procuring consent. Furthermore, the effects of data collection, survey or interview, on the individuals' condition must also be recognized (Kinnell and Dellinger, 2007) despite their willingness to participate (Quarantelli, 1997).

To obtain *in-situ* accounts of residents during disaster events, research should continue to expand through the use of novel methods that take advantage of recent technological advancements. The platform of social media has grown in popularity over the past decade, providing a unique route for data collection and analysis. Both Facebook and Twitter serve as outlets for the public to communicate their thoughts, opinions, and actions during disaster events. Research in this area is becoming prominent with studies ranging from floods in Queensland and Victorian, Australia (Bird et al., 2012) to the role of Twitter during Hurricane Katrina (Barnes et al., 2008) as well as Hurricane Sandy (Demuth et al., 2016). However, little work identifies the progression of stages disaster residents go through during an event, despite social media providing an *in-situ* account of one's experience. In addition, social media may provide continued evidence of the lack of uniformity within the disaster phases (Guion, 2007). This study exists at the intersection of examining prior, foundational, disaster research through the use of a contemporary dataset. Twitter data is used to supplement the goal of analyzing the progression

taken through chosen Socio-Temporal Disaster stages (Powell, 1954) by residents impacted by Hurricane Matthew. Twitter, as a medium to study *in-situ* accounts, can continue compounding upon prior research done in order to validate findings or further knowledge on a certain subject area. Prior work in disaster research, along with previous methods of analyzing social media data, are addressed to discuss foundational studies to incorporate into this research. The data collection process, assisted by the National Center for Atmospheric Research and the University of Colorado Boulder, yielded an initial dataset of 42,000 tweets, which were then analyzed to identify a total of 208 Twitter users, 1,682 tweets, used as the comprehensive dataset for the study. With individual tweets categorized into the disaster stages based upon their content, both qualitative as well as qualitative information was produced. Findings suggest similar experiences, that of awareness, during the Pre-Disaster stage, with experiences of a greater variety founded upon the decision to evacuate one's residence or stay during the storm. The Impact stage was seemingly dominated by the Twitter users who remained at their residence, providing information on their personal condition. Personal recognition, along with the condition of one's neighborhood, were identified as the overarching themes during the Inventory stage. These themes were further seen in the individual narratives of Twitter users as this information provided knowledge into the story of those residents who remained, as well as evacuated, during the storm. The unique aspect of using social media as a dataset provides advantages to studying real-time events that may be hard to gather information on; however, limitations do exist, which are further discussed. In addition, the recency of social media, such as Twitter, provides overwhelming opportunities to continue future research in the disaster field, as well as other areas of research, some of which are identified within this study.   I will begin through a discussion of the prevalent research previously conducted to serve as the foundation for the

thesis. The literature review will comprise of a discussion of disaster literature with a focus on the immediate Socio-Temporal disaster stages (Powell and Rayner, 1952; Powell, 1954) and an overview of research in social media, primarily within the realm of disaster research. In addition, a review of the hurricane evacuation process will be identified to set the foundation for this research. Following the literature review, the research questions will be addressed to identify the objectives of study. The methods section will comprise of a thorough meteorological background of Hurricane Matthew along with its impacts to the region affected. A review of the data analysis and collection process will follow, addressing how the data was collected along with the platforms used to study the dataset in both quantitative and qualitative fashion. Each of the immediate disaster stages in the results section includes a quantitative review as well as examples of tweets to address the qualitative component. In addition, social media narratives, stories of individuals through their tweets, were included to further elaborate on the information identified through a combination of tweets compared to individual examples as given in each disaster stage. Areas of future research, as well as limitations, are addressed within the discussion section, followed by the references.

CHAPTER II

LITERATURE REVIEW

With the intent to study the progression taken by residents during Hurricane Matthew in

Savannah, GA, literature on the stages of disasters and hurricane evacuation processes were

reviewed. Critical examination of the disaster stages in prior literature led to the identification of

the Socio-Temporal Disaster Stages; the foundation for the study. Furthermore, the literature on

the use of social media during disasters and disaster research was reviewed to recognize methods

of data collection and analysis. A specific focus on studies incorporating Twitter as well as

disaster-based work round-out where continued research is necessary to fill gaps in the literature.

Disaster Stages

The phases of disaster (Drabek, 1986) are evident within natural disasters, such as

hurricanes. Preparedness, response, recovery, and mitigation each play a role through the

lifecycle of those impacted by tropical systems. Additionally, these phases are identified within

defined system levels: Individuals, groups, organizations, communities, societies, and

internationally (Drabek, 1986). Regarding warning response at the individual level, researchers

have acquired a solid foundation of information for future studies. However, despite increased

research on warning response and increased success in implementation, casualties and fatalities

continue to exist during disasters. Because of this, the continued study of warning response, especially using real-time data, is imperative.

A wealth of literature has focused on the Disaster Management Cycle (Neal, 1997; Khan et al., 2008; Montoya, 2003) a term used interchangeably with emergency management to signify the process established to maintain normal activities in government and other agencies surrounding a disaster event (Moe and Pathranarakul, 2006). The Disaster Management Cycle has been adjusted since it's development, with the inclusion of six different phases (Baird et al., 1975) to as few as two (Alexander, 2002; Coetzee and Niekerk, 2012). With the intent of studying the social aspect conveyed by individuals within the public, a foundation more suited to this specific dimension was chosen for this research. The Socio-Temporal Disaster-time Stages, initially developed by Powell and Rayner (1952), is considered one of the earliest proposals for stages of a disaster. Along with the aspect of time existing through the Socio-Temporal disaster stages, a unique area of study exists by intertwining a foundational theory in disaster research with a more modern dataset in social media.

Socio-Temporal
Disaster Stages

Powell and Rayner (1952)

Figure 1: Immediate disaster stages

Powell (1954) specified eight Socio-Temporal disaster-time stages, based upon the
foundational approach of seven phases identified by Powell and Rayner (1952). These are: (1)
Pre-disaster, familiarity with specific hazard that threatens the population; (2) Warning,
preventive action taken prior to disaster impact; (3) Threat, the actions taken relating to surviving
the specific disaster; (4) Impact, time period when disaster strikes, leading to fatalities and
destruction; (5) Inventory, recognition of what has happened and their own personal condition;
(6) Rescue, efforts to help those in immediate need, aid the wounded, etc.; (7) Remedy,
additional efforts to relieve the individuals and communities taken by outside agencies and
professional responders; (8) Recovery, an extended period when the community and individuals
attempt to return to a stable environment and resume normal activities. Prior studies have utilized

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the work by Powell and Rayner as a foundational approach to study the progression of human behaviors in disasters (Palen et al., 2007). In addition, work by Dynes (1970) specifies social behavioral changes during crisis events using aforementioned disaster-time stages. Lopatovska and Smiley (2013) used it as a conceptual framework to model information behavior during Hurricane Sandy. Further study of Powell's temporal stages may identify the existence of interactions amongst the phases, specifically the immediate stages of warning, threat, impact, as found during industrial contamination disasters (Mitchell, 1996). Thus, the Socio-Temporal Disaster-time Stages identified by Powell (1954) will be used as the foundation for the study.

Hurricane Evacuation Process

Included within the immediate disaster stages is the evacuation process - the act of leaving one's place of residence to seek shelter in another location, which can be associated with hurricane events. The process can begin, however, days to weeks beforehand with regards to preparation for an event. Specifically, in regards to hurricanes, the evacuation procedure typically begins with monitoring of weather patterns in the tropics. Once a threat appears possible, steps are taken to ensure readiness, with the process being initiated if the threat for a tropical storm is imminent (Wolshon et al., 2005). Although preparedness efforts differ by state, similar responses to hurricane threats are taken by emergency management. A five-step activation process is used by Louisiana Office of Emergency Preparedness to coordinate preparedness, response, and recovery during hurricane situations (Wolshon et al., 2005). These levels of activation span from Level V, where normal activities are completed with no additional duties, to Level I, where landfall is imminent and the highest state of readiness is enacted. These activation levels are based upon the weather forecast of track and strength for the tropical

system. Evacuation advanced notification time varies by state (Urbina and Wolshon, 2003), but the foundation for the time is rooted within the category strength of the hurricane.

Public behavior related to hurricane evacuation has been researched extensively and yet, our understanding of evacuation decisions by individuals and groups is limited (Dash and Gladwin, 2007). Predictability remains minimal because those who are expected to evacuate may decide not to, and those who do not need to evacuate may do so anyway. Previous literature identifies five variables that largely account for the variation in hurricane evacuations: Risk level, action by public authorities, housing, prior perception of personal risk, and storm-specific threats (Baker, 1991).

In addition to evacuation decision making methods undergone by the public, the process of warning response remains a complex. Sorenson et al. (1987) identified a three-step procedure that comprises the warning system: a detection subsystem, a warning subsystem, and a public response subsystem. Thus, each of these subsystems play a vital role in members of the public acting to ensure their safety. Mileti and Peek (2000) recognize six main stages that categorizes the elements of warning response: (1) hearing the risk information; (2) understanding the risk information; (3) belief in the risk and the accuracy of the information; (4) personalization of the risk; (5) the decision-making process of what to do about the risk; (6) performing the action. Within each of these categories exists important factors regarding the warning message content, including the addressment of time, as well as the source of the warning. Furthermore, the channel in which the warning is received, as well as the social ties and characteristics of the warning receiver play a factor in warning response. For these reasons, the recently developed platform of social media plays a key factor in warning response.

Studies also identify the role demographic factors play in hurricane evacuation behavior (Smith and McCarty, 2009; Perry, 1985). With regards to gender, females have been found more likely to evacuate during hurricanes (Bateman and Edwards, 2002). This has been attributed to the gender differences in caregiving roles, along with women's more acute perception to risk and evacuation preparation (Bateman and Edwards, 2002). Furthermore, race and class have been identified as factors during the hurricane evacuation process (Elliot and Pais, 2006). Findings show low-income blacks and low-income individuals in general were less likely to evacuate during Hurricane Katrina and remain in their residence during the disaster (Elliot and Pais, 2006). However, some previous research argues demographic factors are a not significant predictor of evacuation (Burnside et al., 2007).

Despite inconsistencies regarding the role of demographic characteristics in hurricane evacuation, storm strength and storm-specific threats consistently factor into the evacuation decision-making process (Whitehead et al., 2000; Lazo et al., 2010). One of the first studies to gauge the effect of storm intensity on evacuation patterns found that households rely heavily upon storm intensity when making evacuation decisions (Whitehead et al., 2000). Additional research identifies the importance of perceived storm characteristics (Huang et al., 2012). However, complications arise when communicating individual storm impacts at an individual level given the mesoscale details existent when hurricane forecasting. Adjustments in weather communication has led to increased information, such as storm surge interactive maps, being released to the public. Previous research, though, identifies issues with such graphics, specifically surrounding respondent's ability to identify their risk area (Arlikatti et al., 2006).

Prior work classifies the evacuation process into four stages: (1) Threat, evacuation is possible; (2) Warning, evacuation is necessary; (3) Impact, evacuation is inevitable but

ultimately difficult due to the impact of the disaster; (4) Rescue, evacuation is sometimes acute due to the existence of physical damage and injuries (Vorst, 2010). However, due to the difficulties of accessibility to achieve real time data, little work has gauged the relationship between these stages with the steps taken by residents during the evacuation process. For this reason, additional sources of information should be used in research to garner a more extensive scope of the progression of evacuation decisions taken by those impacted by a natural disaster, along with the effectiveness of such information.

Sources of Information

With the use of social media as an information source increasing over the past decade (Pepitone, 2010), the continuous need for risk messaging across multiple media platforms is necessary (Feldman et al., 2015). Information through television, radio, newspaper, print, websites, Facebook, and Twitter continue to be used and desired by the public during risk events (Feldman et al., 2015).

In part, due to the expansion of technology and availability of forecasts, recent research suggests incorporating multiple public and private sources during hurricane events (Zhang et al., 2007). A reliable source of information is essential to make decisions necessary for evacuation. Prior research identifies differences in information conditions where public sources lead to an increased evacuation intention. Meanwhile, evacuation intent increased within those who saw a hurricane forecast that would hit where they lived through a personal source rather than public (Lazo et al., 2015). Although additional sources allow for individuals to retrieve information from multiple outlets, additional sources also present issues. As resources surge, hurricane forecasts are no longer confined to the National Hurricane Center. Private industry companies are becoming increasingly prominent, releasing their own hurricane forecast within the weather

industry. Additionally, the existence and spread of social media has allowed for any individual to disperse a weather forecast.

Information sources have been shown to play a significant factor within an individual's protective action decision making process, as identified in the Protection Action Decision Model (PADM) (Lindell and Perry, 2004). The PADM is a theoretical model that captures much of what is known of how an individual reacts to the potential for a disaster, with a focus on the Pre-Disaster and Warning stages (Powell and Rayner, 1954) leading up to an event. Prior studies, focused on public response to weather events, has incorporated the PADM to tornadoes (Nagele and Trainor, 2012), hurricanes (Kang et al., 2007), and wildfires (Cova et al., 2009). However, despite the inclusion of information sources within the PADM, little work has been conducted that uses social media data to study the validity of the PADM through in-situ accounts by individuals threatened by a natural or technological hazard.

The increasingly diverse set of information sources discussed may lead to conflicting messages. It is essential to understand how individuals handle these conflicting messages, sift through the data, and perceive the hurricane forecasts (Gladwin et al., 2007) as well as the progression residents go through during the decision-making process. One such platform, that can provide *in situ* accounts of disaster events, as well as analyze the progression of disaster stages taken by the public, is social media.

Social Media in Disasters

Integration of social media, specifically micro-blogging, into our daily lives provides insight into real-time events. The role of social media during natural disaster events has been recognized over the past decade from disaster relief efforts (Gao et al., 2011; Kumar et al., 2011; Abbasi et al., 2012), to resilience (Dufty, 2012; Taylor et al., 2012) to mitigation (Alexander,

2014; Teodorescu, 2015). A comprehensive literature review conducted by Houston et al. (2015) identifies a framework for social media work in disaster planning, response, and research. The context for the functions of disaster social media was further categorized into three disaster phases: pre-event, event, and post-event. Functions for disaster social media use include: (1) providing and receiving disaster warnings and preparedness information (pre-event); (2) sending and receiving requests for help or assistance (event); (3) providing and receiving disaster response information (event -> post-event). Each of these functions provides *in situ* accounts to the individual experiences throughout the disaster process.

Prior literature (Fraustino et al., 2012) highlights events of Hurricane Katrina, the Joplin Tornado, and the Haitian Earthquake to identify three measurement categories for use of social media during disasters: (1) output (i.e. measure how many people pay attention to influential social media during disasters); (2) outtake (i.e. measure social capital and social networking); (3) outcomes (i.e. measure how social media affects the public's behaviors and relationships.

Social media also provides individuals an opportunity to decrease vulnerability and build community resilience, contributing to both mitigation and preparedness (Belblidia, 2012). Through connections made on social media outlets, residents can gather information that is less readily available to those without SNS (social networking sites), especially given the increased use of Twitter to communicate with other organizations and members of the public during disaster events (Sutton et al., 2012). In addition, the inclusion of agencies, universities, and other personnel on SNS creates additional lines of communication during times of disaster (Belblidia, 2012). In addition to increasing resilience, individuals more active on SNS can acquire more social capital due to further influences on the outlets (Kaigo, 2012). In the case of the Great East Japan Earthquake of 2011, Twitter served as a lifeline for residents affected. Those with access

to Twitter information received additional information compared to those without access to this outlet (Kaigo, 2012). Through the duration of the Japan tsunami of 2011, Twitter served as a medium for warnings, help requests, and reports of the residents' surrounding environment (Acar and Muraki, 2011). Additionally, Facebook served as an effective media outlet after the 7.1 magnitude earthquake near Canterbury, New Zealand in 2010, providing valuable information to those impacted (Dabner, 2012).

The use of social media has become pronounced in the response and recovery phase due to increasing technological support. Geographic Information Systems (GIS) has emerged as a common tool during crisis management. The use of social media in crisis situations was further realized during Project Epic, a research effort through the University of Colorado to monitor and improve upon gathering and disseminating public information during crisis situations (Palen et al., 2010; McClendon and Robinson, 2012). For example, in one research effort, through raw Twitter data, information was identified and defined based upon the content. A cartographic representation was then created to demonstrate the capabilities of information during crisis events (McClendon and Robinson, 2012). The convergence of GIS and social media has been further analyzed, identifying future research with dual trends of SNS and GIS can lead to fruitful results despite several setbacks (Sui and Goodchild, 2011). Prior work identifies GIS and Crowdsourcing uses in disaster relief, studying the techniques and information technologies that were used during and after the Haitian Earthquake of 2010. Essentially, social media, Twitter in specific, has the opportunity to provide information to members of the public who rely on personal networks as well as secondary information to those seeking additional material to base decisions on (Sutton, 2010).

Twitter

One of the most common current social media platforms is Twitter. Twitter is a free, online, social-networking service that allows individuals to send short (140 character) posts to other users and groups. Twitter also provides the capability of the users to "follow" other users, subscribing to their Twitter updates. The interactive nature of Twitter offers potential for supporting disaster emergency response (Mills et al., 2014).

Communication on Twitter travels through a term coined a "tweet". A "tweet" on the Twitter social media platform consists of 140 characters, which can include embedded links to images and other electronic material. The user also can add a hashtag (#); this mechanism can help facilitate conversation between users interested in the topic on the social media platform. For example, during Winter Storm Nemo in February of 2013, users tweeted the term #nemo between 2 and 5 times per second during the hours leading up to the event (Lachlan, 2016). Wukich and Steinberg (2013) address the effectiveness of the use of a hashtag during four separate disaster incidents: Boston Marathon bombing; West, Texas fertilizer plant explosion; Peoria, Illinois flooding; and the Moore, Oklahoma tornado. Their findings suggest the significance of Twitter in the realm of managing extreme events. They argue that Twitter is an additional member of a larger toolset within communication technology heading into the future. With an increase in social media usage over time, the role of social intelligence in the aspect of real-time data is expected to increase.

Although the body of qualitative research using Twitter data to study disasters is still growing, some available studies have taken a content analysis approach to analyzing Twitter data. For example, a Twitter study surrounding the 2009 H1N1 Outbreak aimed to achieve the following: (1) monitor the use of the terms "H1N1" versus "swine flu" over time; (2) conduct a content analysis of tweets; (3) validate Twitter as a product for real-time content and trend

tracking tool (Chew and Eysenbach, 2010). Tweets collected in the study were further

categorized by both content and qualifier, illustrating the uses of SNS to respond to public health

concerns (Chew and Eysenbach, 2010). A term-based approach was also used to analyze cervical

and breast cancer screening dialogue on Twitter (Lyles et al., 2012). Through this method,

Twitter was demonstrated to be a rich source of information that could be used to design health-

related interventions (Lyles et al., 2012). Twitter has also been the foundation for content

analysis in the study of professional athletes (Hambrick et al., 2010; Sullivan et al., 2011),

politics (Small, 2011; Tumasjan et al., 2010; Adams, 2013), and ideology (Himelboim et al.,

2013; Conover, 2011).

In regards to hurricane disaster research, more recent work has focused on social media

narratives and the role of Twitter during Hurricane Sandy (Morss et al., 2016; Demuth et al.,

2016). Social media presents *in situ* accounts of experiences during disasters; through various

personal accounts during Hurricane Sandy, Anderson et al. (2016) identified experiences,

attitudes, and actions taken by residents in geographic areas that were not always well

represented in the broader conversation about disaster. Twitter provides the opportunity to study

the public during natural disasters, as it is difficult to observe residents before and during such

situation.

Social media narratives, from platforms such as Twitter, offer potential for building new

understanding about societal importance (Palen and Anderson, 2016). Twitter provides first-hand

accounts during the event for an area of study. People often have valuable knowledge regarding

their insights during an event, which they try to convey in a fashion that meteorologists, along

with emergency managers, may not realize (Morss et al.; 2017). In order to consider the wide

scope and issues surrounding natural disasters, we must approach the study of the public during

these situations through their own eyes. We can ultimately have a greater understanding of the public through a content analysis of carefully sampled Twitter data (Palen and Anderson, 2016).

Research Objectives

Although there is an ample amount of literature regarding stages of disaster, there is a dearth of research regarding the analysis of disaster stages as viewed through the disaster social media posts of people at risk. Social media provides an in-situ account of experiences from the user rather than information collected after the disaster. Additionally, despite studies identifying overlap within the disaster stages, there is a continued need for this based on real-time data collection, especially through varying platforms. Given Hurricane Matthew's geographical location spanning a wide expanse, this storm can serve as a foundation for this project. Twitter data was collected through the University of Colorado to identify in-situ perceptions of residents who experienced Hurricane Matthew. Given this topic of study, the following research objectives will be used through the study:

(1) How do the stages of disaster (Powell, 1954; Dynes, 1970) present themselves during a disaster event through Twitter users affected?

(2) What interaction(s) exist within the immediate disaster stages (i.e. pre-disaster, warning, impact, inventory, and rescue)?

(3) What themes emerge surrounding the hurricane evacuation process?

(4) What themes present themselves in the immediate disaster stages analyzed?

CHAPTER III

METHODS

A brief meteorological overview of the storm's lifecycle is provided to introduce the
storm-related impacts of Hurricane Matthew on the United States. The background provides the
grounds for the reasoning of the geographic-region of study, from a meteorological standpoint.
The data collection process is further elaborated upon, addressing the procedure of amassing the
Twitter data and limiting the dataset to the necessary information. The Twitter data is analyzed
by both individual tweets, founded upon the Socio-Temporal Disaster stages, along with the
narratives of chosen Twitter users.

Hurricane Matthew: Background

Hurricane Matthew formed because of a tropical wave that moved off the African coast on
September 25, 2016. On September 28, the National Hurricane Center (NHC) officially
designated Matthew. Matthew's westward track took it over deep, warm waters of the Caribbean
Sea, a prime environment for continued strengthening. On the evening of September 30,
Matthew's estimated winds peaked at 145 kts, making it a Category 5 hurricane, the first in the
Atlantic since Hurricane Felix in 2007. In addition, the track of Matthew made it the southern-
most category 5 hurricane in the Atlantic basin on record, exceeding the record previously set by
Hurricane Ivan in 2004 (Stewart et al., 2017).

Matthew began its northward turn in the Caribbean Sea due to a weakened subtropical ridge on October 2, approaching Haiti as a Category 4 hurricanes. After slight fluctuations in movement, Matthew made landfall on the southeastern coast of Haiti on October 4, becoming the first category 4 hurricane to make landfall in Haiti since Cleo in 1964.

On the morning of October 4, the forecast track issued by the National Hurricane Center predicted Matthew would continue north, scraping the east coast of Florida, Georgia, and the Carolinas, before moving out to the Atlantic. (Figure 2)
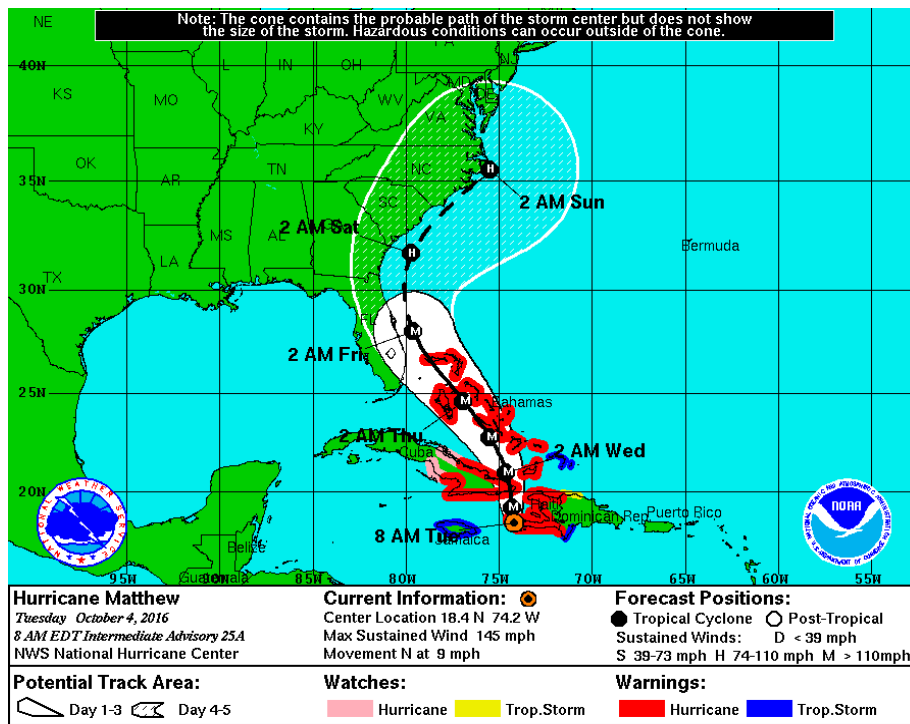
Figure 2: NHC forecast issued 8am EDT, October 4

A gradually eroding ridge northeast of Matthew allowed the hurricane to turn north-northwestward as it closed in on the Bahamas. As it progressed northwestward, Matthew moved into an environment of increased vertical wind shear. This, paired with an eyewall replacement cycle (ERC), led to the slow weakening of Matthew. By October 7, Matthew was positioned approximately 30 miles east of Vero Beach, FL as a category 3 storm. As it continued its

northwestward track, Matthew grazed the coast of Florida Friday, October 7. Matthew began its

north-northeastward turn as it approached Georgia overnight October 7 into October 8 due to an

approaching mid-latitude trough. Category 2 wind gusts were recorded along the barrier islands

of Georgia and South Carolina as it progressed northeastward. Matthew weakened to a Category

1 storm on October 8 as it made U.S. landfall near McClellanville, South Carolina around 1500

UTC. The center of Matthew moved back offshore by 1800 UTC, October 8, and continued to

parallel the coast of the Carolinas through October 9. Matthew transitioned to an extratropical

low late October 9 due to increased vertical wind shear. The assimilation into a frontal system

associated with a mid-latitude trough ushered the remnants of Matthew east into the Atlantic by

October 10. The best track positions through Hurricane Matthew's life cycle are shown in Figure

3.
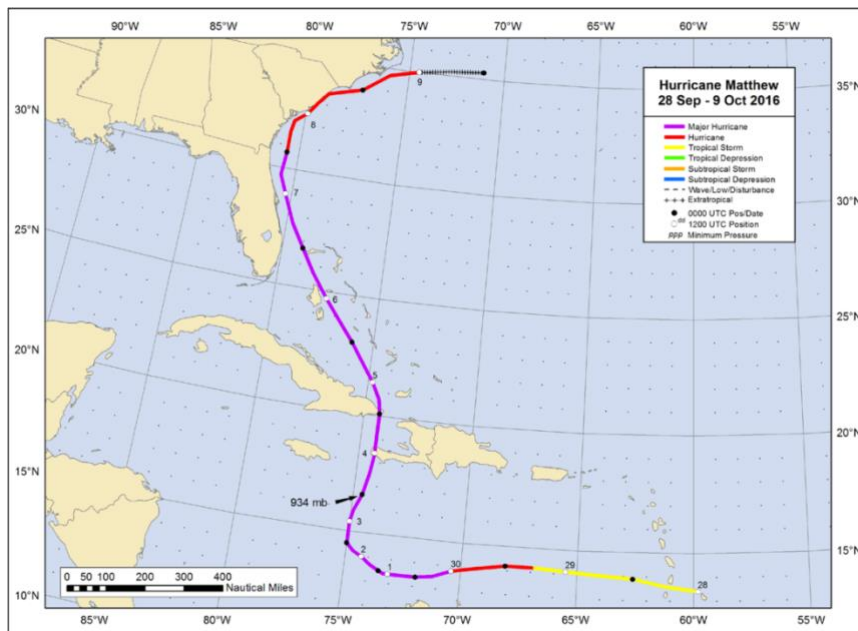
Figure 3: Hurricane Matthew Track

Hurricane Matthew was one of the first major hurricanes to impact the United States

since the rise of Twitter. In addition, the coastline impacted from northern Florida to Georgia has

a longer average return period for hurricanes compared to areas in proximity (Figure 4). From the period of 1900-2010, no major hurricanes struck the parishes from Flagler County, FL, north to Chatham County, GA, home of Savannah (Figure 4). This is primarily due to the curvature along the coastline, making it harder for a direct hit from a hurricane. Finally, the track itself lent to a sizeable portion of the coastal population affected. Hurricane wind-force gusts were felt along a stretch from Cape Canaveral, FL to the South Carolina coast as Matthew traveled along the U.S. coast and then made landfall.
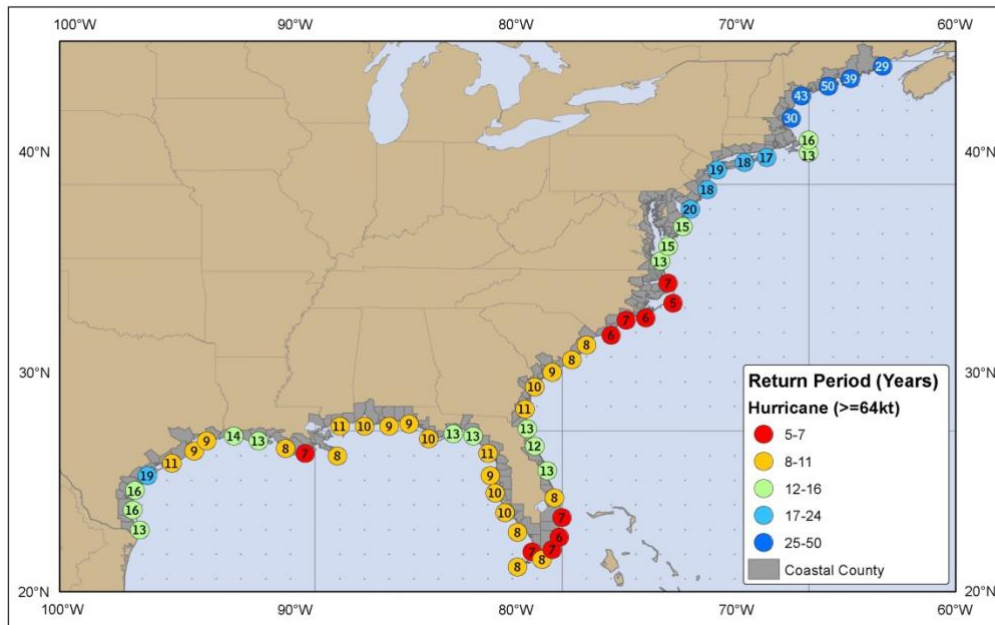
Figure 4: *Return Period (Years) for hurricanes (National Hurricane Center)*

Hurricane Matthew: Impacts

Due to the track of Hurricane Matthew, significant surge occurred along the coast of Florida, Georgia, South Carolina, and North Carolina. The combination of tide and surge led to inundation levels of 5 to 7 feet above ground level (Stewart et al., 2017). Elsewhere, estimated maximum inundation levels of storm surge spanned from 2 to 5 feet above ground level, on average (Figure 5). Coastal Georgia, specifically the Fort Pulaski vicinity, experienced the

highest level of storm surge recorded during Matthew as a tide gauge measured 7.70 feet above

normal tide levels (Stewart et al., 2017). In addition to storm surge, Matthew produced

significant rainfall on the order of 10-15 inches across coastal portions of Georgia, South

Carolina, and inland North Carolina. The combination of storm surge and rainfall flooding led to

28 of the 34 fatalities directly attributed to Matthew in the United States. Per the National

Hurricane Center Cyclone Report (Stewart et al., 2017), more than 1 million structures were

damaged or impaired by Hurricane Matthew because of flooding and storm surge inundation.

Over 3.5 million customers lost electrical power due to Hurricane Matthew. The combination of

both wind and water damage totaled approximately $10.0 billion in the United States, the 10th

most destructive hurricane to impact the United States as of October, 2016. Chatham County,

home of Savannah, GA, received the brunt of Hurricane Matthew's storm surge inundation,

where a record storm surge was recorded at the Fort Pulaski National Monument on Tybee

Island.
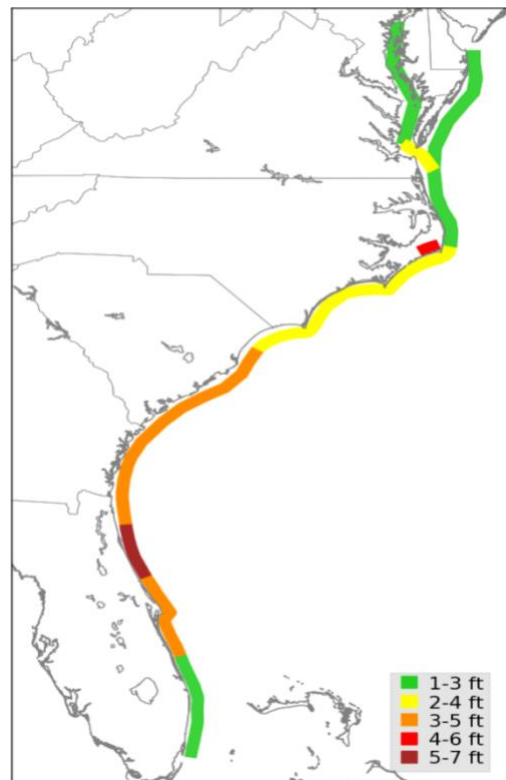
Figure 5: Estimated maximum storm surge inundation (ft. above ground) (Stewart et al., 2017)

Data Collection and Analysis

Working in partnership with the National Center for Atmospheric Research (NCAR) and my committee members at Oklahoma State University, I used content analysis of Twitter data to examine the disaster cycle and address overlaps within the phases, reconstructing the idea of a nonlinear process. To do this, it was necessary to identify a study location: an area impacted by Hurricane Matthew. Localities were analyzed, both meteorologically and demographically, to determine a place that was prudent to study. Given the longer return period for hurricanes, its position along the concave portion of the southeast coast, and varying demographics, I chose Savannah, GA, as my study area. The coastal community of Savannah is home to a population of 146,763, as of the 2016 census. African-American residents account for the majority of racial or ethnic groups in Savannah at 53.5% of the population, followed by White (36.8%) and Hispanic (5.2%). Additionally, the median age of Savannah is 31.4, approximately six years younger than the United States' average age. This is important since the majority of Twitter users fall within the ages of 18-49 (Pew Research Center, 2017). Only three hurricanes struck the Georgia coastline in the 1900s, the most recent being David in 1979, a category 1 hurricane that made landfall south of Savannah, GA. The rarity of hurricanes in this region presented an additional opportunity to study those who may have less familiarity with tropical systems and the risk they pose.

After establishing Savannah as my study location, a date range was established to collect tweets within a certain timeframe. Given the focus of the study, it was important to identify a date range that embodied the entire disaster cycle. The first forecast for Hurricane Matthew was issued by the National Hurricane Center on September 28, 2017. Because of this, I chose to begin the collection of data on September 25 and continue through October 21, approximately two weeks after landfall of Hurricane Matthew. This provided data for a sufficiently longer

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period to study the preparation phase prior to landfall of Hurricane Matthew, as well as initial

recovery efforts by residents after Matthew passed.

The data collection process was conducted through the University of Colorado Boulder.

During the Hurricane Matthew event, tweets were collected based on a keyword search using

Twitter's streaming Application Programming Interface (API). This keyword search gathered all

tweets regarding Matthew according to the following words:

hurricane, ouragan, siklón, haiti, hurricanematthew, matthew, ouraganmathieu, mathieu,

matthewhaiti, matye ayiti, matyeayiti, port salut, les cayes, jeremie, jérémie, pray for

haiti, prayforhaiti, pray4haiti, jeremie, jérémie, tiburon penninsula, tiburonpenninsula,

península de tiburón, bahamas, jamaica, cuba, pray for florida, prayforflorida,

pray4florida, flwx, ncwx, scwx, gawx, vawx, invest97l

These data were then filtered to tweets for users who listed their profile locations for Savannah,

including common misspellings of Savannah and various ways to identify a city, state

combination, or that included Savannah keywords within the 140 characters of the tweet or

elsewhere in the metadata. This yielded an initial dataset of approximately 42,000 tweets posted

from September 25-October 21, 2016.

My research objective was to identify themes with regard to the stages of disaster during

Hurricane Matthew through the lives of residents impacted, with Twitter as the medium. Because

of this, I chose to initially filter the tweets using Savannah keywords rather than by identifying

geotagged tweets in Savannah. As discussed in Anderson et al. (2016) and Morss et al. (2017),

this provides additional opportunity to collect tweets in which the Twitter user does not geotag a

certain tweet, or their tweets at all. This decision was made as it is my intent to include those

who may not have their geotagged location on, despite being located in Savannah. In addition,

the keyword dataset will include residents of Savannah who may be away from their residence

(i.e. on vacation), but are still discussing Hurricane Matthew through their tweets.

I took substantial time at the onset of the thesis to examine the initial keyword dataset of

42,000 tweets to identify Twitter users who provided "noteworthy" information in their tweets.

Here, noteworthy is defined as information that made it evident the user lived in the Savannah

area or was out of town, or planned on visiting the Savannah area and had to make the decision

to adjust their plans. During this process, I constructed a list of users and their corresponding

tweets to ensure no user was duplicated, despite having multiple tweets within the dataset. I

identified 324 users after examining the keyword dataset.

To provide a comprehensive, detailed account of the users' experiences through

Hurricane Matthew, I then worked through University of Colorado Boulder collaborators to

obtain all tweets by those users during a period of time, called the Twitter users' "Tweet stream"

or "Twitter narrative" – the story that develops during the time period of interest (Morss et al.,

2017). The University of Colorado Boulder attempted to obtain tweet streams for the 324 Twitter

users previously identified from the Savannah keyword dataset; however, due to the privacy

restrictions on many Twitter accounts, data were only gathered from 208 of those users. This was

accomplished by downloading the prior 3,000 tweets for each of the 208 Twitter users, as of

August, 2017. For the analysis shown here, the tweet streams were then confined to a set period

to identify disaster narratives the Twitter user progressed through. The start date of September 25

remained the same as the initial dataset downloaded because Hurricane Matthew did not form

until September 28. The end date was set to 0000 UTC Oct. 13 to include the rescue and

inventory stages. This resulted in a dataset of 1,682 tweets from 208 users.

For reporting in this study, tweets were chosen as representative of larger themes identified within the entire dataset. Themes were recognized following the categorization of individual tweets in the Socio-Temporal disaster stages used. I also chose to report in this study several of the tweet streams the entire narrative of a user's experience during Hurricane Matthew shown through their tweets, to illustrate the evolving stories of their experiences. These example Twitter streams were chosen due to their rich context, as well as evidence of the compounding themes identified in the initial analysis of categorizing tweets into disaster stages.

Data Analysis and Results

Event	Time	Stage	Color Coding Scheme	
Savannah, Georgia in the Forecast Cone	0900 UTC Oct 3	Pre-Disaster/Warning		
Landfall, Haiti	1100 UTC Oct 4	Pre-Disaster/Warning		
Voluntary Evacuation	1900 UTC Oct 5	Pre-Disaster/Warning		
Mandatory Evacuation	1400 UTC Oct 6	Pre-Disaster/Warning		
Outer Bands Impact Savannah, Georgia	0900 UTC Oct 7	Impact		
Final Rain Bands Depart Savannah, Georgia	1400 UTC Oct 8	Inventory/Rescue		

Table 1. Temporal events used to categorize the stages of disaster for the study

A qualitative content analysis (QCA) strategy was employed to analyze the data (Schreir, 2012). Using Microsoft Excel, the initial dataset of 42,000 tweets were analyze to identify those Twitter users who provided information of interest on Hurricane Matthew. Excel continued to be the platform that was utilized to code the tweet streams into the Socio-Temporal Disaster Stages (Powell and Rayner, 1952). The Socio-Temporal Disaster stages that guided the analysis of the tweets were the following: Pre-Disaster, Warning, Impact, Inventory, and Rescue. The stage of "Threat" as identified by Powell and Rayner, 1952 was included in this study with the Warning stage given their similar characteristics and to simplify interpretation. In addition, the stages of

Remedy and Recovery were not included given the intent to study the immediate disaster stages. The stages of disaster were categorized temporally by meteorological events as the event progressed (Table 1). This was done to simplify the interpretation of the Twitter users' content in each tweet. The start date for the data analyzed was 0900 UTC October 3 given that this was the earliest forecast issued by the National Hurricane Center in which Savannah, Georgia was in the forecast threat cone. Both the Pre-Disaster and Warning stages occupied the period up until the beginning of Hurricane Matthew's outer rain bands impacting Savannah, Georgia. The meteorological evidence for precipitation timing was gathered from archived radar data collected by the National Centers for Environmental Information. The Inventory and Rescue stages began as the final rain bands exited the Savannah region. The data was analyzed through 0000 UTC Oct 13. A color coding technique was implemented to identify the coding of tweets into the various stages of disaster (Table 1). Reference numbers were assigned to Twitter users tweets (Anderson et al., 2016) to maintain confidentiality.

Once categorized into the immediate Socio-Temporal Disaster Stages through a color coding scheme, the tweets were then coded in NVivo 11 to ascertain the primary themes within each stage. Tweets were generalized to capture the overarching themes, by frequency, within the stage (Bergin, 2011). The immediate Socio-Temporal Disaster Stages were analyzed through word queries in addition to frequency of terms. Links included in the tweets, URL's, were not included as a theme, despite being prominent in every disaster stage, due to the intent to recognize the main themes within the 140 characters. These results were then used to identify the Twitter users in which a more comprehensive background would be analyzed, in order to garner an inclusive analysis into the temporal aspect of the user's experience.

The temporal evolution of the initial keyword dataset generating of 42,000 tweets relative to the disaster stages shown in Figure 6. As discussed above, this initial dataset was used as the starting point for developing a more focused dataset of 1,682 tweets through the process of identifying Twitter users with noteworthy tweets directly relating to Hurricane Matthew. The Socio-Temporal Disaster Stages were analyzed quantitatively, identifying the frequency of tweets temporally, as well as qualitatively through categorizing each tweet into the disaster
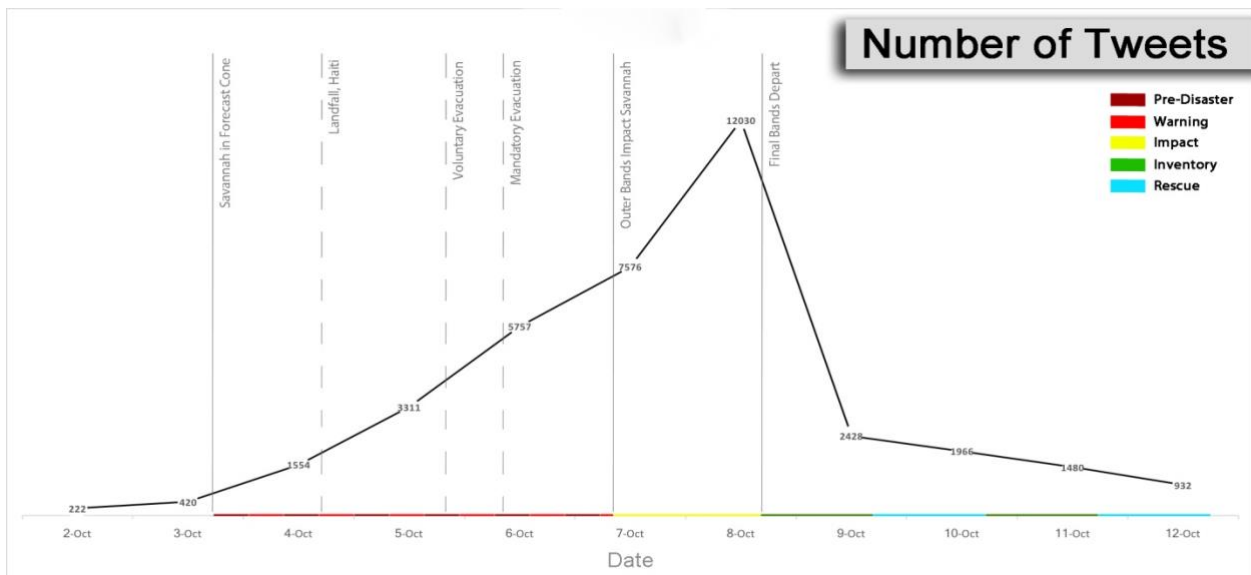
Figure 6. Keyword dataset of 42423 tweets and their total tweets per day

stages. The Twitter narratives, an additional area of analysis, provided in-situ accounts and a deeper insight into the first-person narrative of the user, to walkthrough the disaster stages at an individual level. The Twitter users were chosen based upon the wealth of information they conveyed through Hurricane Matthew. Users who discussed their experience throughout Matthew thoroughly provided the most extensive information for the study. For this reason, along with the consideration of gender and evacuation methods, five Twitter users were chosen to explore the user's narrative (sequence of individual tweets) as they progressed through the event.

Event	Total Number of Tweets	Proportion of Total
Pre-Disaster	288	17.10%
Warning	318	18.90%
Impact	464	27.60%
Inventory	530	31.50%
Rescue	82	4.90%

Table 2. Total number of tweets analyzed within each of the Socio-Temporal Disaster Stages

The foundation for the methods of this study were outlined here to identify the steps taken to determine the dataset to be analyzed. An initial dataset of over 42,000 tweets was examined to concentrate the focus on 1,682 tweets that provided significant information relating to Hurricane Matthew. These tweets were then classified into the five disaster stages used for analysis based upon temporal events prior to, during, and after Hurricane Matthew's impacts. The following section will outline the findings from the content of tweets within each of the disaster stages. In addition, the inclusion of social media narratives will address the uniqueness of analyzing a Twitter users entire tweet-stream during the event.

CHAPTER IV

RESULTS

The results of the Twitter analysis are categorized per the relevant Socio-Temporal stage identified within the tweets: Pre-Disaster and Warning, Impact, and Inventory and Rescue. Each stage includes multiple example tweets classified given the content of the tweet. The tweet streams, also known as the Twitter narratives for each user, are elaborated upon, exploring further themes from the users' stories.

Pre-Disaster and Warning Stages

The Pre-Disaster stage, as defined by Powell, 1954, is the familiarity with a specific hazard that threatens the Twitter user; meanwhile, the Warning stage, combined with the Threat stage for this analysis, is defined as the preventive action taken prior to disaster impact to survive the disaster, Hurricane Matthew. To be included within the Pre-Disaster stage, the Twitter users' tweets had to communicate their awareness of the storm system approaching. If action taken was mentioned in the tweet, the tweet was categorized in the Warning stage, otherwise, the tweet was noted to be in the Pre-Disaster stage. A total of 288 Pre-Disaster stage tweets were identified from the 1682 tweets in the 208 Twitter user's narratives analyzed, accounting for approximately 17% of the total tweets (Table 2). 318 tweets from the selected Twitter users were classified into the Warning stage, just under 19% of the total tweets. The respective Pre-Disaster and Warning stage tweets were grouped into three-hour intervals to quantify the temporal nature of the tweets
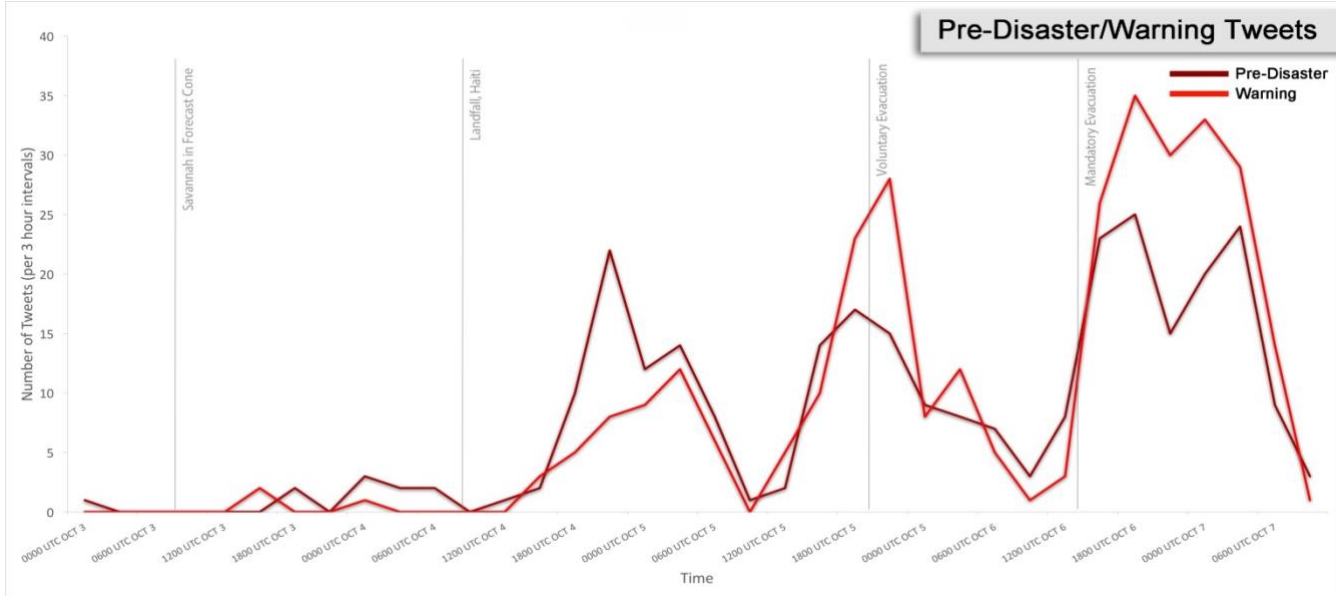
Figure 7. Timeline of Pre-Disaster and Warning Stage Tweets

(Figure 7). An increase in tweets related to these stages over time is evident, with a significant rise in tweets pertaining to actions taken near the initial voluntary evacuation order. Similar results are seen the day prior to impact with an upsurge in Warning tweets following the mandatory evacuation order issued.

Time	Tweet	Ref. Number
10/4/18 16:56	Hurricane party this weekend @kate_westra	P1
10/4/18 17:31	I ain't feeling this hurricane talk the weather man got going on	P2
10/5/18 19:38	I got this professor I hate and I hope my boy #HurricaneMatthew blow his ass away	P3
10/6/18 10:19	I am mildly pissed when my co-workers roll their eyes and use air quotes when saying "state of emergency" talking about a Cat 3 hurricane...	P4
10/6/18 13:28	Hurricane season is so fun. We throw black out parties and grape everyone	P5
10/6/18 13:51	Hurricane ready on my end, wbu	P6
10/6/18 17:23	I don't even fear natural disasters. This will be fun. #Quakes74 #HurricaneMatthew https://t.co/DLl9icmLbT	P7
10/6/18 21:20	i am a wreck	P8
10/6/18 21:45	I think many cities learned from Katrina. That's a good thing	P9
10/7/18 2:21	Hurricane Matthew will definitely be one to remember.	P10
10/7/18 7:25	I apparently want to go back in time. I keep typing Hurricane Andrew instead of Matthew. #amnewsers #producerproblems	P11

Table 3. Pre-Disaster Tweets

Twitter-active users conveyed awareness of Hurricane Matthew in the Pre-Disaster Stage in multiple ways (Table 3). For example, both P1 and P5 identified the existence of "Hurricane parties" being thrown by the authors. Multiple residents communicate their concern with the impending event, expressing similar anxiety (P2, P8, P18), a common theme seen throughout the Pre-Disaster stage leading up to Matthew. Connections were made by numerous residents to previous tropical systems including Hurricane Katrina (P9, P19), Hurricane Andrew (P11), Hurricane Floyd (P13), and tropical storm Hermine (P12, P15, P16) which made impact early September, 2016, approximately one month prior to Matthew. Two residents suggest their frustration with another co-worker (P4) and professor (P3), expressing animosity surrounding Hurricane Matthew. Similar to P1 and P5, other Twitterers expressed excitement in experiencing Matthew, suggesting their lack of fear as the hurricane approached (P7, P20). Another common theme conveyed throughout the Pre-Disaster stage was noting the potential for evacuation orders, or actual evacuation orders as they were issued (P14, 17). Such tweets also included information regarding the weather forecasts, whether for their benefit or their followers.

Time	Tweet	Ref. Number
10/4/18 22:04	*there was never an evacuation for hermine. It just happened to come the weekend people were going home https://t.co/022wajwbEu*	P12
10/4/18 22:09	*Savannah hasn't had to evacuate since Hurricane Floyd in 1999. They always seem to curve away from us.*	P13
10/5/18 1:33	*#HurricaneMatthew is going to make Savannah have a mandatory evacuation.*	P14
10/5/18 2:19	*Man savannah is still not cleaned up from the tornado hurricane hermine made and now Matthew. This should be fun.*	P15
10/5/18 16:49	*this is honestly ridiculous that they canceled school for hermine but can't cancel for a category 4 hurricane?!? https://t.co/bbpRuQPGPs*	P16
10/5/18 20:08	*Evacuation on Tybee Island is now mandatory.*	P17
10/6/18 4:47	*I'm not about to lie this hurricane is scary after listening to the weather channel hype it up.*	P18
10/6/18 16:27	*Why are people in #SavannahGa being so stubborn? Like #HurricaneKatrina never happened to teach them a lesson. #HurricaneMatthew*	P19
10/6/18 16:49	*Very excited to get to fight another act of God this weekend. V pumped*	P20

Table 4. Pre-Disaster Tweets (Continued)

A significant rise in Warning related tweets was observed on the afternoon of October 5, near the time when the initial Voluntary Evacuation order was issued. The number of Warning

related tweets increased following the Mandatory Evacuation order on October 6, the day prior to Matthew's impact (Figure 2). The major themes identified within the Warning stage surrounded the evacuation, or lack thereof, of the resident, family, or friend.

This is further identified by the most frequent terms utilized throughout the stage: evacuation, staying, going, and leave. Subsidiary themes branched off of this overarching concept, as residents identified the location they were evacuating to, as well as their progression while evacuating, including details regarding traffic. These evacuation measures taken by the Twitter users dominated the topics conveyed throughout the Warning stage, as shown in Table 5.

Time	Tweet	Ref. Number
10/4/18 14:36	*Time for #breadandmilk. Keep an eye out folks. At the very least, we will get wind and high tides. #Matthew https://t.co/qR6a4aSl8E*	W1
10/4/18 17:08	*I did not want to deal with a Hurricane scare this week...mainly cuz I just bought groceries and the last thing I want to do is evacuate*	W2
10/4/18 17:27	*A level 3 hurricane? Awww hell no. Heading west. Not cool Mother Nature, not cool. Asheville or Atlanta here we come #HurricaneMatthew*	W3
10/5/18 20:45	*Even though it wasn't a mandatory evacuation yet, I-16 driving out of Savannah towards Macon is a lot worse than the 5 o'clock Traffic Jam!*	W4
10/6/18 2:10	*Gonna be live tweeting from the rooftop during this hurricane*	W5
10/6/18 22:08	*Me and my mom are sitting on the front deck of my grandparents condo just watching this hurricane*	W6
10/7/18 0:55	*Everyone is evacuating bc of #HurricaneMatthew but Im at home watching the #ALDS and enjoying a beer #RedSox #Savannah #ImNotGoingAnywhere*	W7
10/7/18 2:17	*It took me 8 hours to drive from Savannah to Columbus. Bruh it's only a 3 hour trip. Traffic is so bad because of the hurricane evacuation*	W8
10/7/18 12:39	*First-ever hurricane evacuation for me. All things considered, I'll still take a hurricane over tornados - at least you know it's coming*	W9
10/7/18 13:07	*After evacuating Savannah early I realize I didn't bring anything important. Hoping it's not as bad as it's supposed to be #HurricaneMatthew*	W10

Table 5. Warning Tweets

Multiple themes can be identified temporally. Early tweets during the period addressed the preliminary steps to prepare for Matthew, with W1 and W2 both highlighting the recent purchase of groceries. Early decisions to evacuate were noticeable early in the Warning period by multiple Twitter users (W3, W4), both identifying their intended evacuation location. Additional evacuation comments were shared the evening prior to the event, following the mandatory evacuation (W8), as the number of traffic concerns expressed became more abundant.

Residents discussed their plans to not evacuate (W5, W6, W7) with similar accounts like W6 suggesting the progression of Matthew prior to impacts of Matthew being felt in Savannah. The author of W10 conveyed their concern of leaving important materials in Savannah, consequently hoping that the impacts of Matthew are not as bad as predicted.

Time	Tweet	Ref. Number
10/5/18 16:48	@CoxRobbie Doing that as well. Cars are gassed up and husband has just gotten back from the grocery store in case we don't have to evacuate.	W11
10/6/18 14:47	@Chris_Meloni hurricane party at my place!	W12
10/6/18 16:37	@AlfaFilly Are you able to get out okay?	W13
10/6/18 16:38	@StupidShepherd Are you gonna get out okay or are you staying?	W14
10/6/18 16:54	@GeorgiaDOTSE @GADeptofTrans Do you anticipate shutting down SB state routes? Hwy 17, for instance? Curious about SAV-VLD routing..	W15
10/6/18 18:28	@ForbesRicky Hey! We live 15 miles from the Atlantic Ocean (Georgia) & we're staying & #Periscope ing #HurricaneMatthew #WatchMe	W16
10/6/18 20:08	@CodyRyle stay safe these next few days dude. love u	W17
10/7/18 2:34	@Chief275 did you evacuate?	W18
10/7/18 2:46	@bruisedyou There is! A lot of people have been evacuated out of the city and they aren't allowing people back in but we're fine!	W19
10/7/18 11:11	@ChathamEMA Where can drivers enter Contra-flow lanes? Is there only 1 entry point? Most cars are on the regular lanes. #HurricaneMatthew	W20

Table 6. Warning Tweets (Replies)

Conversational tweets in which the Twitter user replied to someone in their tweet using the "@" symbol at the beginning, comprised of approximately 12% of the total Warning tweets. As previously identified, having a social networking site provides the foundation for increased social capital, in addition to access to supplemental informational outlets (Kaigo, 2012). The benefits of Twitter to discuss with organizational outlets are seen through W15 and W20, in which Twitter users reach out to governmental organizations of Twitter (Georgia Transportation and Chatham County Emergency Management) to gain further insight into plans for evacuation procedure as well as traffic arrangements. Multiple users (W13, W14, W17, W18, 19) express concern for others they are connected to on Twitter, with two users inquiring about evacuation decisions taken (W14, W18). Some users utilized Twitter as a communication means comparable to texting, to discuss actions taken surrounding evacuation (W11). The author of W16 announced

their intention to stay in Savannah through Matthew, communicating to a well-known storm chaser their plan to Periscope (record live video) during the event.

Impact Stage

Powell and Rayner (1952) defined the Impact stage of the Socio-Temporal Disaster cycle as the period when disaster strikes, leading to fatalities and destruction. Tweets that were dated during Hurricane Matthew, from 5:00 AM EST, October 7, to 10 AM EST, October 8, were categorized in the Impact stage. A total of 464 Disaster stage tweets were recorded out of the original dataset of 1682 tweets from 208 Twitter users, accounting for nearly 28% of total tweets, the second most from the identified socio-temporal disaster stages (Table 2).

The Impact stage tweets were classified into one-hour intervals due to the shorter time span compared to Pre-Disaster/Warning stage and quantified to analyze the temporal aspect of the tweets (Figure 8). The number of tweets per hour stayed relatively steady through the morning and afternoon on October 7. An increasing trend became evident beginning the evening of October 7 into the overnight period, despite the regular diurnal shift evident during the Pre-Disaster and Warning stages (Figure 7). Tweets regarding Matthew spiked near the midnight hour October 7th into October 8th, reaching nearly 40 tweets per hour during that time. This spike in the quantity of tweets associates rather well with the timeframe in which Matthew was the closest to Savannah, when the strongest winds would be felt by residents. A significant drop-off is apparent following the 2 AM hour on October 8, paralleling the decreasing effects from Matthew as it progressed eastward, away from Savannah.
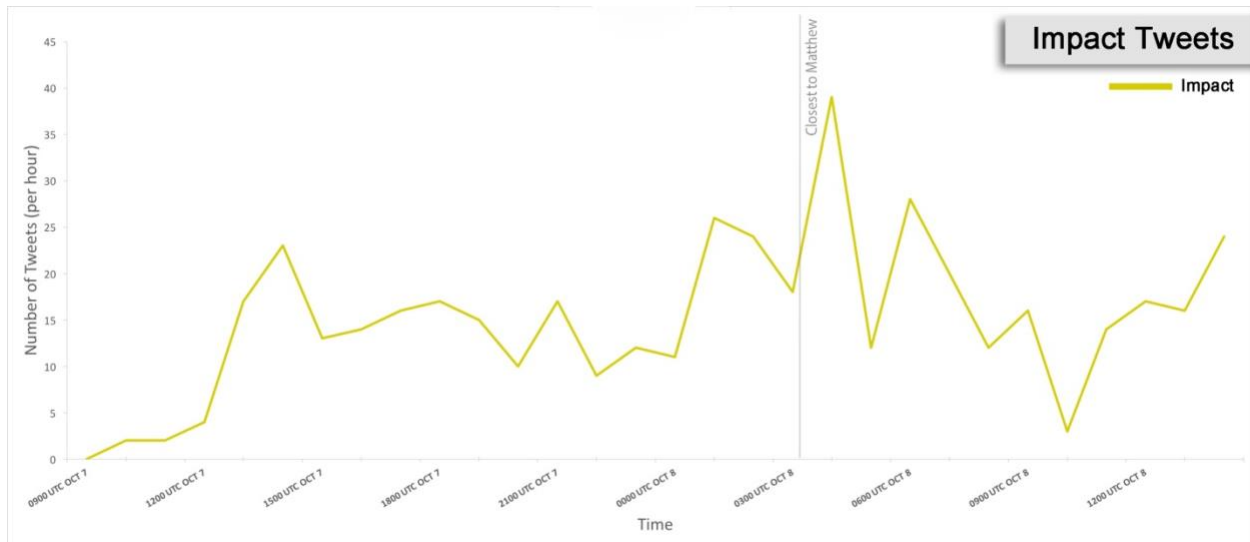
Figure 8. Timeline of Impact Stage Tweets

The act of reporting one's experience dominated the Impact stage as Twitter users communicated their first-hand accounts as Hurricane Matthew impacted Savannah. Two primary themes of reporting were identified, confirming prior findings (Anderson et al., 2016): environmental and personal. Environmental reporting focuses on reports that identify meteorological information, such as winds, flooding, rainfall and the damage caused by them (Anderson et al., 2016). Personal reporting conveys information regarding the users personal experience and immediate surroundings, with a prominent focus on Matthew's impact to them directly (Anderson et al., 2016). In addition, these themes can be seen through some of the most frequent utilized words during the Impact stage: power, house, storm, winds, and rain. Each term provides insight into the residents' immediate surroundings, be that from the environmental standpoint (storm, winds, rain) or the personal reporting (power, house).

Time	Tweets	Ref. Number
10/7/18 13:20	*Beautiful skies as we leave Isle of Hope and Savannah. Be safe everyone! Matthew 8:23-27.â¦ https://t.co/HzKStZrEU8*	I1
10/7/18 17:50	*It's been raining for the past 2 hours. It's just regular rain right now. Nothing spectacular*	I2
10/7/18 20:09	*bro! I am waiting for the hyped up storm! there is nothing but rain in savannah! and its not even heavy rain #hurricanematthew*	I3
10/8/18 1:55	*Safe and sound here in Savannah, winds gusting & howling and rain pouring down, but I am safe #HurricaneMatthew*	I4
10/8/18 8:18	*Winds are currently reading 67 btw*	I5
10/8/18 8:24	*It sure is. River street is flooded. I am sure my house is getting slammed. Wind is ridiculous and non stopâ¦ https://t.co/97hHMfe3nq*	I6
10/8/18 8:41	*Hunkering down as the wind and rain pick up in #savannah #HurricaneMatthew*	I7
10/8/18 9:42	*The winds are serious. Its not raining anymore but these winds are furious*	I8
10/8/18 11:47	*Daybreak and I can see the river raging right outside the doors and the wind doesn't seem to've let up... https://t.co/ihEesmzLJV*	I9
10/8/18 13:17	*Crazy. Flooding all around me. #hurricanematthew #hunkerdown @ Pooler/Savannah https://t.co/JJcMHP3rLT*	I10

Table 7. Impact Tweets: Environmental Reporting

The focus of environmental reporting varied with Matthew's impact, with tweets concerning rainfall (I2, I3, I4, I7, I8), wind (I4, I5, I6, I7, I8, I9), and flooding (I6, I9, I10). The author of tweet I3 conveyed thoughts regarding the lack of Matthew's impacts, despite most major effects holding off until the early morning of October 8, suggesting a possible lack of knowledge into the forecast. Several authors included a link to imagery within their tweet, linking their tweet to their Instagram account (I1, I10).

I1 Image: Environmental Reporting

I10 Image: Environmental Reporting

Time	Tweets	Ref. Number
10/8/18 0:03	I'm at my aunt's house & it seems like the lights have gone out for good. Its been flickering but now power is out	I11
10/8/18 0:28	Lost power watched a transformer blow	I12
10/8/18 2:06	Who can sleep when you have no power and it's going to hit at 1am-3am the hardest. And these whistling winds! #savannah #HurricaneMatthew	I13
10/8/18 3:22	Lol we still got power	I14
10/8/18 4:37	Huge "kaboom" and a flash-at first I thought it was lightning. Now absolutely no lights on in the neighborhood. #Savannah #HurricaneMatthew	I15
10/8/18 5:32	Alright I'm starting to hear trees crack...	I16
10/8/18 7:06	At home outside of Savannah. 3am. #HurricaneMatthew https://t.co/66ctNg6DGV	I17
10/8/18 13:05	Made it through #Matthew. Fortunate to still have power and only a few downed limbs. Still very windy this AM. Nowâ€¦ https://t.co/J7ME7xDhVZ	I18
10/8/18 13:09	I'm safe! Some limbs/trees down but I'm not in the flooded areas. No power for 15 hours, but safe #HurricaneMatthew https://t.co/dfPduNWxgM	I19
10/8/18 13:18	No power but still have hot coffee. Doin ok. https://t.co/l5vh9ALYD8	I20

Table 8. Impact Tweets: Personal Reporting

The majority of personal reporting tweets focused on the access to electricity during the progression of Matthew (Table 8). Personal reporting tweets were most noticeable later in the event, due to the increasing impact from Matthew. Similarly to environmental reporting, photos were included in several tweets, especially at the tail end of the event (I18, I19, I20), with humor infused into the tweets of some residents (I17).

I18: Personal Reporting

I17: Personal Reporting

I19: Personal Reporting

In addition to reporting techniques taken to Twitter by Savannah residents, the Impact stage included a variety of supplementary themes. Those residents who evacuated Savannah took to Twitter to express their concern for their residence (I21, I28) as well as family and friends (I30). The author of I22 used Twitter as an outlet to disseminate information to followers, while the user of I29 inquired about information surrounding evacuation procedures after Matthew. As previously identified in the Pre-Disaster and Warning stages, the mention of a "Hurricane Party" appeared in the Impact stage (I23). Periscope, the video sharing platform, was used by a Savannah resident to show current conditions in Savannah during Matthew (I25). Another user addressed the complications of deciding to evacuate were addressed (I26) suggesting disagreement between group members. Residents who evacuated expressed concerns about their residence (I21, I28), and another Twitter user who stayed behind used Twitter to express willingness to check on others' residences (I24), though the tweet was made prior to most significant impacts from Matthew.

Time	Tweet	Ref. Number
10/7/18 14:27	*I can't imagine having to rebuild the only place I've ever known*	I21
10/7/18 17:17	*Text FOLLOW CHATHAMEMA to 40404 to stay up to date on #HurricaneMatthew and all emergency warnings for our area.*	I22
10/7/18 17:51	*I just checked on my Aunt Frenchye. She told me to come back over there tonight for the "hurricane party". Lol!!*	I23
10/7/18 20:41	*Anyone who evacuated from the island need an update on their house? If so let me know bc I'm about to drive around the island*	I24
10/7/18 22:49	*LIVE on #Periscope: #HurricaneMatthew picking up!!!! #Savannah #storm WE STAYED https://t.co/HbFNhiYbA8*	I25
10/8/18 1:19	*Either we all go or nobody goes at all.. By the time everyone agreed, it was too late. Welp. Lol. Seriously though be safe every1*	I26
10/8/18 2:37	*I'm done listening to the media like honestly how many times are they right about the weather?*	I27
10/8/18 3:30	*Here's hoping my apartment is still there tomorrow morning. #HurricaneMatthew*	I28
10/8/18 5:53	*I'm hearing you have to have proof that you live in Savannah in order to return?*	I29
10/8/18 13:28	*Boarding our flight to #HoustonTX. Can't wait to see my parents. #Family in #SavannahGA made it through #HurricaneMatthew safely*	I30

Table 9. Impact Tweets (Continued)

Inventory and Rescue Stages

The Inventory stage, as defined by Powell and Rayner (1952), is the recognition of what has happened and personal condition of those impacted while the Rescue stage consists of efforts to help those in immediate need and to aid the wounded. For this study, both the Inventory and Rescue stage were analyzed over the same period, 10:00 AM EST October 8 to 8:00 PM EST October 12. This was done because both stages can occur simultaneously following a disaster event. The period was restricted to end on the evening of October 12 as the focus on the study was the immediate disaster stages. To be included within the Inventory stage, the tweets had to convey the authors own personal condition, or discuss the impacts of Matthew. If the tweet identified the work of local organizations, such as Georgia Power or Chatham Emergency Management Association (ChathamEMA), or the community coming together to help those in need, the tweet was categorized in the Rescue stage.

A total of 530 tweets were recorded in the Inventory stage from the 1682 tweets out of the 208 Twitter user's narratives analyzed, the most tweets recorded out of any Socio-Temporal Stage (Table 2). 82 total tweets were classified into the Rescue stage, comprising of approximately 5% of the total dataset. The majority of Inventory and Rescue tweets were recorded up to two days following Matthew's impact (Figure 4). A spike in Inventory tweets immediately followed the Impact stage, as residents took to Twitter to convey and assess their surroundings. The major themes identified during this period focused on the return journey home, the lack of electricity, the condition of their residence, and impact to surrounding neighborhoods. A steady decline in Inventory and Rescue tweets occurred from October 8 to October 12, with little reference to Hurricane Matthew five days following the storm.
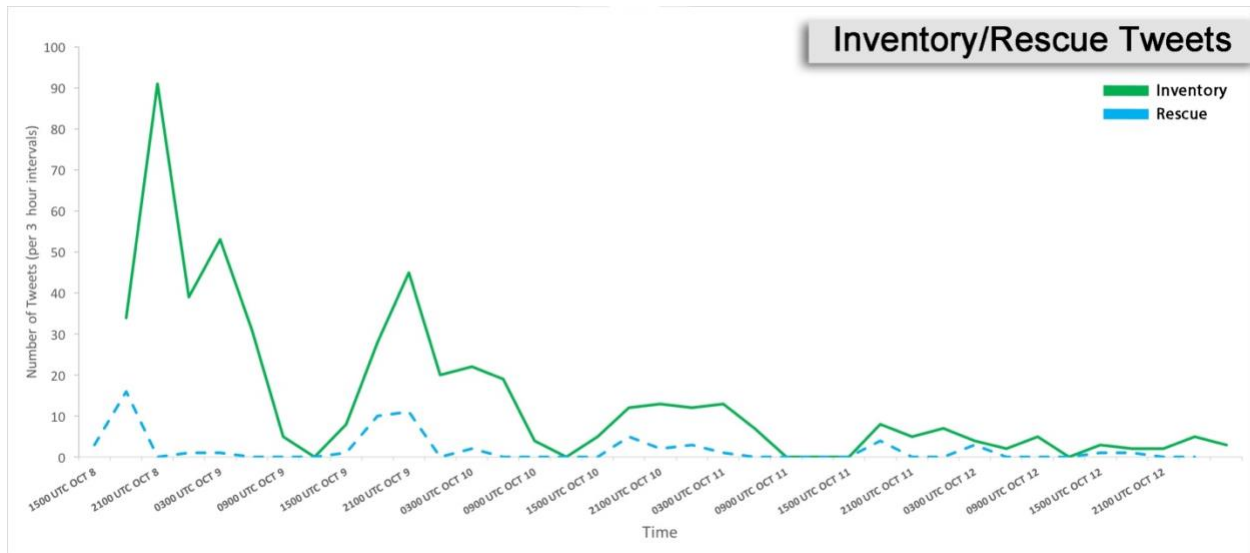
Figure 9. Timeline of Inventory and Rescue Stage Tweets

The theme of personal reporting continued through the Inventory stage as residents of Savannah conveyed information regarding their immediate surroundings following Matthew (Table 10). The authors of V3, V6, V9, and V10 report their environment, with a focus on the majority identifying the lack of electricity in their residence. Twitter users in Savannah also used the platform to express their desires following the storm, with V4 and V7 presenting examples of residents yearning to have electricity back, as well as sleeping back in their own bed. Some of

Time	Tweet	Ref. Number
10/8/18 16:14	*Alright turning my phone off who knows when we get power. Keep you all updated later! Only come back if you need too and live here!*	V1
10/8/18 17:41	*Anyone in #HHI or #Bluffton - can you tell me about damage at #MossCreek or #PalmettoBluff? #Matthew #HiltonHead #HiltonHeadIsland*	V2
10/8/18 19:30	*No damage, no flooding, no trees fallen, and power is still on at my apartment. :)*	V3
10/8/18 21:21	*Now all we need is the power back on!*	V4
10/8/18 21:22	*And I completely understand why we cannot go home yet but I just wish we had never had to leave in the first place! #evacuation*	V5
10/9/18 10:45	*Currently sitting in my pitch black room with no water or power, and I can't go to the station since there's a curfew in place in Savannah.*	V6
10/9/18 15:25	*Just wanna sleep in my own bed*	V7
10/9/18 20:11	*Even though I been wanting to get out of #Savannah this hurricane really got me wanting to move to safer location in case this happens again*	V8
10/10/18 0:22	*Good news: my house survived the hurricane* *Bad news: no electricity for probably a weekish*	V9
10/10/18 11:27	*#Verizon tower service for Noel C Conaway & Midland Rd Guyton GA intermitting service no LTE @VZWSupport @VerizonNews*	V10

Table 10. Inventory Tweets

those who evacuated their residence reached out through Twitter, utilizing location terms with a

hashtag (#), to attempt to retrieve information about a how a certain geographic location fared

through Matthew (V2). Other Twitter users recontemplated their decisions to evacuate (V5) in

the events aftermath as they could not make it home sooner. In addition, the author of V8

expressed concern living in Savannah due to the likelihood of future events similar to Hurricane

Matthew.

Time	Tweet	Ref. Number
10/8/18 15:15	*Supposedly this is how Savannah is looking rn rip to my beautiful city. This sucks really bad https://t.co/AIWsuD1vl5*	V11
10/8/18 16:26	*Hurricane: Savannah-Power is still out. Ate ice cream for breakfast before it completely melted! #HurricaneMatthewâ€¦ https://t.co/ytxU48sucl*	V12
10/8/18 18:21	*Not even a fraction of our disaster from Hurricane Matthew https://t.co/sl4B31ylld*	V13
10/8/18 21:23	*Harbour town pier demolished, but lighthouse stands tall ##HHIStrong https://t.co/zzXAm4q0Iz*	V14
10/8/18 22:18	*Screw you #HurricaneMatthew here in South GA we watch football. No power no water but we have sec football on¦ https://t.co/svw6HgAR0x*	V15
10/8/18 23:58	*It doesn't matter what's going on, there's always a liquor store open. #HurricaneMatthew. #NoPower #cashonly¦ https://t.co/UiR95InalV*	V16
10/10/18 2:30	*For sure the least romantic thing I've ever done by candlelight. Thanks #HurricaneMatthew #debate https://t.co/11Ko75N4zm*	V17
10/10/18 2:31	*Crisis averted! Matthew may have gotten some of our trees and our power lines but he is not¦ https://t.co/3t98XzJqle*	V18
10/10/18 18:49	*One of my favorite walls here in Savannah, damn you Matthew! #damnyoumatthew #hurricanematthew¦ https://t.co/UK2GitAlV1*	V19
10/13/18 19:12	*3. One tree fell over. #TreeCarnage #HurricaneMatthew https://t.co/KRTcThd95B*	V20

Table 11. Inventory Tweets (Continued)

Twitter users frequently incorporated multimedia into their tweets throughout the

Inventory stage, conveying an assortment of information (Table 11). Tweets often included

damage photos of the Savannah area, depicting wind damage with trees down as well as flooding

(V11, V13, V14, V19, V20). Coping mechanisms through food and beverage were

communicated by authors of V12, V16, V18, each including a photo of their food, ice cream

(V12) and egg rolls (V18) as well as the liquor store (V16), in agreement with findings in

Demuth et al. (2016). Twitterers also shared their experiences without power, still watching their

programs of interest with V15 watching college football and V17 streaming the Presidential debate through their laptop.

V13: Inventory (Damage)

V19: Inventory (Damage)

V20: Inventory (Damage)

V12: Inventory (Coping)

V16: Inventory (Coping)

The Rescue stage contained only a small subset of the total number of tweets from the 208 Twitter users narratives analyzed (Table 12). Twitterers primarily highlighted the work done by electrical companies during the Rescue stage, thanking Georgia Power and Alabama Power for their hard work to return power to their residence (V22, V23, V25). Gratitude was also

expressed for the cleanup crews cleaning trees and debris (V24) along with the general outpouring of assistance state and nationwide (V21).

Time	Tweet	Ref. Number
10/10/18 0:14	*The fact that people are coming from all over the state and country to help us recover is incredible*	V21
10/10/18 1:42	*Huge thank you to @GeorgiaPower @alabamapower and all the other amazing companies and people working hard #hurricanematthew #savannahga*	V22
10/10/18 21:09	*The general view of the restoration. Good work! @GeorgiaPower #IHeartLinemen https://t.co/iltdn6MEIr*	V23
10/11/18 18:18	*Thank you to the cleanup crews working hard to clear the trees and debris to bring our citâ¦ https://t.co/5wqStLGGyg https://t.co/F4zSb6NMLx*	V24
10/13/18 1:43	*Never heard so many good comments about a power company till @alabamapower showed up here in #savannah to turn our lights on. Thanks guys!*	V25

Table 12. Rescue Tweets

Social Media Narratives

Several narratives were examined to further delve into individual experiences of the Twitter users studied (Anderson et al., 2016; Demuth et al., 2016), specifically to gain further insight into the broad themes identified within each stage. In addition, a better temporal grasp can be identified by observing the individuals' actions taken throughout Hurricane Matthew, as each provides a unique perspective to the situation. Both users who evacuated and those who stayed at their residence, were examined to gain further insight into occurrences. The following Twitter users were chosen to elaborate upon the main themes aforementioned within the immediate disaster stages analyzed. To maintain confidentiality, the Twitter handle for each user was adjusted. A pseudonym was also assigned to the users.

Bethany's Story

Bethany, a resident of Savannah, Georgia during the time of Hurricane Matthew, made the decision to not evacuate from the storm. In total, Bethany tweeted 21 times concerning Hurricane Matthew with most her tweets in the Warning (6) and Impact (8) stages. Bethany's

first tweet, on October 4, elaborated her thoughts regarding SVA (St. Vincent's Academy), a private school in Savannah:

> **(October 4, 4:39 pm):** *Knowing SVA during situations involving weather, we'll most likely have to come in*

Her recognition of the oncoming storm was earlier than most on Twitter, as Savannah had only been placed in the NHC's hurricane forecast cone the day before (Figure 1). Multiple tweets within the Pre-Disaster and Warning stages from Bethany discussed evacuation:

> **(October 4, 9:19 pm):** *Whenever I think of evacuation I see Atlanta in the walking dead*
>
> **(October 5, 10:38 am):** *fav if u not evacuating*

As shown here, and previously identified, one of the major themes found in the Warning stage was the communication with other followers regarding their evacuation procedures. This is seen through a variety of methods, primarily through an individual conversation or asking for interaction from their audience. Table 13 identifies other discussion tweets, not sent by Bethany, within the Warning stage.

Time	Tweet	Ref. Number
10/5/18 14:36	@okokbryce my mom said we're staying here & im terrified	E1
10/6/18 16:38	@StupidShepherd Are you gonna get out okay or are you staying?	E2
10/6/18 20:24	SAV PEEPS - roll call for who's staying so we can all check in on each other #hurricanematthew #putsavannahonthemapweatherchannel	E3
10/6/18 22:10	@maxgood09 you staying?	E4

Table 13. Tweets that discuss evacuation methods

The recognition of Matthew's current and future impacts to other geographical locations, Florida and Haiti, were recognized by Bethany and other Savannah residents prior to impact:

> **(October 6, 6:28 pm):** *Hurricane Matthew isn't just hitting on 10/7, its already hit and impacted so many people's lives so quit with all that*

As the outer bands of Matthew impacted Savannah, a tornado warning was issued for the region the afternoon of October 7. Though tornadoes are not unique in hurricanes, Savannah residents, including Bethany, took to Twitter to convey their frustration and overwhelm:

(**October 7, 1:11pm**): *OK SO NOW A TORNADO WHAT HHEHECK IS GOING IN*

Bethany provided insight into her experience as Matthew impacted Savannah through multiple tweets, once again reaching out to her audience in Savannah that stayed, suggesting their safety throughout the storm:

(**October 7, 7:55 pm**): *Just ran outside for 30 seconds and I am SOAKED*

(**October 7, 8:24 pm**): *To anyone stuck in Savannah, cheers to you we'll get through this together #HurricaneMatthew*

Following Matthew, Bethany once again asked for interaction from her audience, identifying if they made it through Matthew. In addition, she discussed both having electricity with a follower, as well as damage to Wilmington, both major themes found in the Inventory stage.

(**October 7, 2:41 pm**): *some damage in Wilmington): https://t.co/POYNETphTw*

(**October 8, 10:23 am**): *Fav if u made it through the storm*

(**October 8, 2:11 pm**): *@brookebarr0n GIRL AT LEAST U HAVE POWER*

John's Story

John, a resident of Savannah, decided to remain at his residence during Hurricane Matthew and tweeted the most during the Impact (16) and Inventory (5) stages. Prior to Matthew's impacts, John identified his intent to "hunker down" and even included some humor into his tweets:

(**October 6, 12:11 pm**): *#HurricaneMatthew #prepared I am ready. Just like Lt Dan. It is either you or me. https://t.co/RJ055VWxer*

After identifying his preparation, John's tweets were minimal until the Impact Stage, once

Matthew's impacts were beginning to be felt. At first, John believed that the storm was being

"overblown" by forecasters, using winter events as a foundation for this line of thinking:

> **(October 7, 8:11 am):** *Call me crazy; chief deplorable, but this storm is over blown. Like all the winter disasters. Riding it out in Savannah. #HurricaneMatthew*

> **(October 7, 8:17 am):** *Every weather forecasters is claiming storm surge up to 11 feet. I bet it doesn't even get to 3 feet*

> **(October 7, 11:10 am):** *Winds aren't as strong, pressure is rising yet coastal GA will still get 7 ft storm surge? You are the @weatherchannel not the hypechannel*

However, his thought process changed throughout the afternoon of October 7, as he identified to

a follower that he did evacuate his home by the evening:

> **(October 7, 9:02 pm):** *@docsteinig thank you we did evacuate to Hampton inn. Life is great*

John continued to remain awake at his evacuation location for a portion of the night as Hurricane

Matthew's impacts continued in Savannah. During the 4 am hour in Savannah, John sent multiple

tweets discussing his surroundings, along with admitting the storm was stronger than he

originally expected the day prior:

> **(October 8, 4:21 am):** *To all of my Savannah friends don't rush home. I was wrong Matthew is the real deal. It is bad #HurricaneMatthew #savannah #Godawgs*

> **(October 8, 4:24 am):** *It sure is. River street is flooded. I am sure my house is getting slammed. Wind is ridiculous and non stopâ€¦ https://t.co/97hHMfe3nq*

> **(October 8, 4:25 am):** *The entire city is dark https://t.co/nFYjwI7qLI*

The following day John returned to tweeting his interests of college football; however, Matthew

played a factor in his ability to watch football games:

> **(October 8, 10:27 am):** *All I want to do is watch @CollegeGameDay but #HurricaneMatthew destroyed Savannah*

> **(October 8, 6:18 pm):** *Screw you #HurricaneMatthew here in South GA we watch football. No power no water but we have sec football onâ€¦ https://t.co/svw6HgAR0x*

(October 8, 8:09 pm): *Come on TAMU. I have refilled the generator twice watching this game #ihateorange #hurricanematthew*

One reason of interest for focusing on John's story is his expectation that Hurricane Matthew's impacts would be less extreme than predicted. This led him to evacuate to a nearby hotel, while Matthew's impacts were occurring, once he realized that Hurricane Matthew would be stronger than he had anticipated.

Maria's Story

Maria, a resident of Savannah, made the decision to evacuate from Hurricane Matthew. The majority of her 13 Matthew-related tweets took place during the Warning (6) and Inventory (5) stages. As one might expect, tweets categorized as Impact related were more numerous by residents who stayed in Matthew, rather than those who evacuated. Maria's initial tweet, on October 4, focused on evacuation, as well as knowledge of prior tropical systems:

(October 4, 6:39 pm): *But you guuuuuys I don't feel like evacuating!! And didn't we just have a hurricane? #GoAwayMatthew*

In this case, Maria is describing Hurricane Hermine, a system which brought tropical storm strength winds to Savannah approximately one month prior. The following day, Maria expressed her actions related to evacuating with packing important materials from her residence:

(October 5, 1:17 pm): *Packing; watching weather & deciding "what's important" in the house is a weird Wednesday. Hope it's all for nothing! #HurricaneMatthew*

Maria conveys her evacuation location the next day, expressing hope for her residence to withstand Matthew. Hope, a common theme during the Warning stage, was expressed for both homes, as well as family members and friends who stayed in Savannah during Matthew (Table 14).

Time	Tweet	Ref. Number
10/6/18 2:05	*Beautiful sunset this evening. I hope everyone is taking precautions for Hurricane #Mathew https://t.co/w6hlhiRyrh*	H1
10/6/18 22:53	*I just hope nothing bad happens to my grandma or anyone else that has to stay in Savannah during this storm.*	H2
10/7/18 0:43	*Leaving Savannah tomorrow morning before the storm arrives, I hope everybody gets through this safely and I'm back teaching classes Monday.*	H3
10/7/18 1:14	*Is officially a refuge. Hope I have a home to go back to. #HurricaneMatthew*	H4

Table 14. Tweets that express hope during the Warning Stage

Given her evacuation, there was a lack of tweets from Maria during the Impact stage, with one lone tweet identifying boredom away from Savannah:

(October 7, 9:23 pm): *Man if I had known @jakeowen was playing in Augusta tonight this evacuation would have been a whole lot cooler. #Evacuee #bored*

The desire for resident who evacuated to return home was a common premise expressed during both the Impact and Inventory Stages (Table 15), Maria conveyed similar sentiments:

(October 9, 1:01 pm): *I am so ready to go home. #Savannah #FUMatthew*

Time	Tweet	Ref. Number
10/7/18 13:14	*i just want to go home i don't even care about going back to school i just want to fucking go home*	R1
10/8/18 14:56	*I wanna go home so bad! This hurricane mess is really blowing me.*	R2
10/9/18 1:29	*I'm ready to go home so bad.*	R3
10/8/18 14:04	*I definitely wanna go home now*	R4

Table 15. Tweets that reflect the desire to return home

Once Maria made it back home in Savannah, she identified the lack of electricity she had at her residence, as did many throughout the Inventory stage.

(October 10, 9:31 pm): *Good thing red doesn't need to be refrigerated. No power, no problem. #HurricaneMatthew #Savannah #HOME!!!! https://t.co/OKSo3E5lAf*

Maria expressed gratitude to Alabama Power (@alabamapower) days after Matthew for the return of electricity, the prominent theme identified during the Rescue stage.

> **(October 12, 9:43 pm):** *Never heard so many good comments about a power company till @alabamapower showed up here in #savannah to turn our lights on. Thanks guys!*

Robert's Story

Robert, a resident of Savannah, chose to evacuate the area prior to Matthew. Although Robert's tweets are limited during Matthew with only Warning (3) and Inventory (4) stage tweets, mainly due to his evacuation, the inclusion his story helps illustrate additional themes from these data related to the evacuation process.

Robert made the decision to evacuate on Wednesday, October 5, four days prior to landfall. This is evident through multiple tweets regarding the length of gas lines as well as his plan to leave for Atlanta:

> **(October 5, 10:08 am):** *LONG lines at gas stations everywhere near me in Savannah due to impending hurricane. #GladIWentYesterday*

> **(October 5, 10:23 am):** *Classes cancelled til Monday. I feel like I should be frustrated that my syllabi are now in disarray. (1/2)*

> **(October 5, 10:25 am):** *But I'm more relieved that I get an impromptu and much needed vacation. Off to ATL! (2/2)*

Following these tweets, Robert did not tweet until after Hurricane Matthew passed Savannah, a theme evident in these data among residents who did evacuate. Robert thanked both the Savannah-Chatham Police Department, as well as Verizon, through Twitter, "tagging" them in a tweet. Robert also discussed his current whereabouts with a Twitter follower of his, as seen through the following tweet:

> **(October 8, 4:05 pm):** *@nmemmelhainz Thanks! I'm OK; staying w/ relatives in ATL until I'm allowed to return. Trying to avoid pics of flooding/damage on the news!*

Time	Tweet	Ref. Number
10/8/18 22:11	@KVHendry thanks much. My Uncle's place is 1 Wax Myrtle Lane. Just trees down or also flooding in that area? Any idea?	N1
10/8/18 22:33	@euphemiisms All in all, we're safe.	N2
10/9/18 13:42	@baseball_girly2 @KyleDennisWx It means "no water" in Montgomery, too! Glad you are safe!	N3
10/9/18 21:13	@radrc No power as yet friend	N4

Table 16. Tweets that included a conversation regarding condition

Robert also discussed his condition once he returned to his residence on October 11:

(October 11, 9:01 am): *Back in SAV, and relieved that there's only minimal water damage. The city as a whole got hit pretty hard, though. Debris everywhere.*

Twitter, along with social media as a whole, may be able to help identify the successfulness of the evacuation process for those who evacuated. As expected, Impact tweets are minimal for those Twitter users who decided to make the trip out of Savannah prior to Hurricane Matthew. These residents instead provide information regarding the evacuation process, during the Pre-Disaster, Warning, and Inventory stages, as they travel to and from their residence.

Heather's Story

Heather, a resident of Savannah, remained at her home during Matthew. She expressed a variety of emotions during the storm, with most of her tweets being emotion based rather than providing other information. The majority of her tweets were focused during the Impact (7) and Inventory (5) stages. Tweets prior to Matthew from Heather expressed concern with the oncoming storm:

(October 5, 9:07 pm): *#staysafesavannah*
(October 6, 10:21 pm): *Hurricane Matthew will definitely be one to remember.*

Heather then reached out to another Twitter user in the Warning stage to gauge their evacuation plan:

(October 6, 10:34 pm): *@Chief275 did you evacuate?*

For reasons not expressed on Twitter, Heather remained behind in Savannah rather than

evacuating. She expressed difficulty sleeping the night before the storm:

(October 7, 5:20 am): *Possibly the worst night of sleep I have ever had*

Heather also conveyed in a conversation a need for prayers, a desi re by multiple Twitter

residents as Matthew impacted Savannah (Table 17).

(October 7, 6:47 am): *@_MissLittle35 @RobaelEnyew starting to rain here now! Say a few extra prayers for us please!*

Time	Tweet	Ref. Number
10/7/18 12:54	*everyone pray for my mom because she isn't leaving and I am seriously scared to death for her*	P1
10/7/18 13:32	*please keep my dad in yall's prayers while he has to go out and shoot video of the hurricane today and tomorrow*	P2
10/8/18 1:54	*#PrayForThePote pray for my city https://t.co/rJgmXlbRyk*	P3
10/8/18 5:37	*If anyone is up please pray for us*	P4

Table 17. Tweets that conveyed the desire for prayer

Anxiousness and fear was expressed by Heather during the height of the storm:
(October 7, 10:22 pm): *Anxiety at an all time high right now*

(October 8, 2:32 am): *This is terrifying #HurricaneMatthew*

Personal and environmental reporting were both evident during the time of Matthew from

Heather, with tweets addressing the impact of the winds and rain to her apartment and a photo of

flooding in the parking lot:

(October 7, 11:34 pm): *The wind sounds like it is going to shatter all of the windows at Candler. #HurricaneMatthew*

(October 8, 12:49 am): *This is my apt complex ðŸ˜¢ðŸ˜¢ðŸ˜¢ https://t.co/4RH8eGFW6l*

Following the storm, Heather addressed the impacts of Matthew on Savannah, identifying

damage in the area:

(October 8, 3:02 pm): *Some of the biggest trees we have in savannah are now laying across the roads.*

The use of #SavannahStrong expressed by multiple Twitter users suggested the pride of their town felt by residents of Savannah, identifying the strength of their community (Table 18).

(October 9, 7:13 pm): *Hurricane Matthew truly did a number on Savannah. #savannahstrong*

Time	Tweet	Ref. Number
10/9/18 0:28	*No matter how destructive this hurricane was it just reinforces how strong our community is. #SavannahStrong #HurricaneMatthew*	S1
10/10/18 5:29	*Water moccasins seem appropriate ☐¤ #hoorayforwhiskey #HurricaneMatthew fucked us up but we will recover like everyone else. #SavannahStrong*	S2
10/10/18 22:03	*Beautiful way to end the day. #Savannah Strong https://t.co/31Tab6AMn9 https://t.co/F0s6qxfdPr*	S3
10/11/18 17:39	*Well, another update from @GeorgiaPower concering restoration progress. #SavannahStrong https://t.co/lkAvEQHKG1*	S4

Table 18. Tweets that included #SavannahStrong

Heather also discussed the power situation at her residence, also expressing her gratitude to Georgia Power:

(October 10, 2:42 pm): *No chance of power for my apt for at least another 2-4 days. Praying mold doesn't take over!*

(October 10, 6:58 pm): *Georgia Power deserves raises after this.*

With a comprehensive overview of the findings from the dataset, the 1,682 tweets were able to be classified into one of the disaster stages. Each disaster stage analyzed was outlined here, with example tweets to show the major themes within each stage. Tweets were also further expounded in the Impact Stage to show the incorporation of multimedia to convey a Twitter users surrounding environment. Narratives provided further detail into the account of residents during Hurricane Matthew by exploring their entire story as seen on Twitter.

CHAPTER V

DISCUSSION

A comprehensive dataset comprised of 1682 total tweets from 208 Twitter users in or
near the Savannah area as Hurricane Matthew approached and made landfall was analyzed to
provide insight into the Socio-Temporal Disaster Stages (Powell and Rayner, 1952; Powell,
1954). General themes were mapped (Figure 4) to identify the progression taken by the 208
Twitter users' narratives analyzed. The overarching premise of the Pre-Disaster stage was
awareness of the incoming natural disaster. Familiarity with Hurricane Matthew was identified
by the majority of residents, whether that was through knowledge of the forecast or evacuation
procedures. Connections to prior hurricanes were made through this stage, along with occasional
humor in regards to school assignments and the scheduling of hurricane parties.

Narratives varied following the decision to evacuate, or not, by residents of Savannah.
Evacuation decisions were primarily identified throughout the Warning stage; residents
discussed their evacuation location as well as traffic patterns if leaving Savannah. Residents who
made the decision to stay behind discussed some preparation efforts (Table 5), along with their
intention to stay. Residents who evacuated from Savannah rarely shared their experiences during
the Impact stage. Tweets from evacuated residents often discussed their boredom in the location
they evacuated to along with their desire to return home (Table 13). Despite the lack of tweets
from residents who evacuated, the Impact stage saw the most tweets per minute (Figure 4) by a
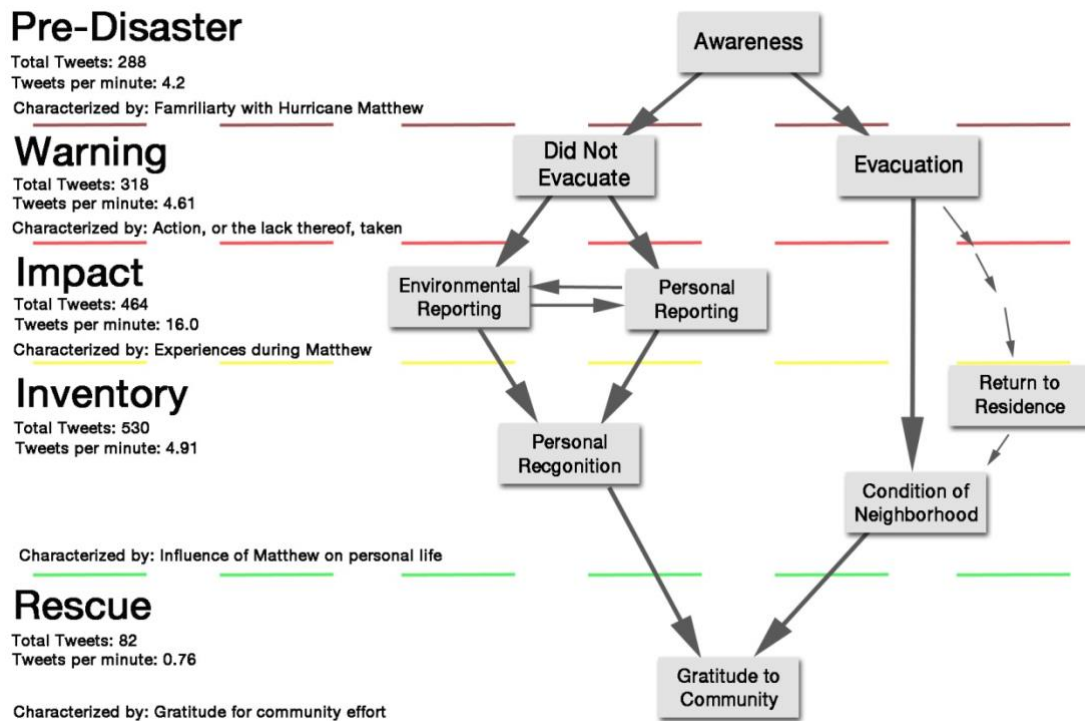
Pre-Disaster
Total Tweets: 288
Tweets per minute: 4.2
Characterized by: Famriliarty with Hurricane Matthew

Warning
Total Tweets: 318
Tweets per minute: 4.61
Characterized by: Action, or the lack thereof, taken

Impact
Total Tweets: 464
Tweets per minute: 16.0
Characterized by: Experiences during Matthew

Inventory
Total Tweets: 530
Tweets per minute: 4.91

Characterized by: Influence of Matthew on personal life

Rescue
Total Tweets: 82
Tweets per minute: 0.76

Characterized by: Gratitude for community effort

Figure 10. Socio-Temporal Disaster Stages with major themes

significant margin compared to the other Socio-Temporal Disaster Stages. Residents who

remained in Savannah dominated the Impact stage through informative tweets categorized as

Environmental and Personal Reporting (Anderson et al., 2016). Residents often reported the

current weather conditions along with its impact on their residence simultaneously. In addition,

the peak number of tweets during the Impact stage correlates well with the height of the storm,

despite this occurring at night; this suggests, and is identified by numerous Twitter users, that

sleep was a rarity until the strongest portion of the storm passed.

Following Matthew, residents who remained in Savannah conveyed their personal

condition, with a focus on both their safety as well as the nature of their residence. Residents

consistently discussed the stage of their electricity for their residence, suggesting its importance.

Given their safety from Matthew, evacuees instead focused on conveying the condition of their

surrounding neighborhood once they made it back to their residence. Damage photos were also

prominent during the Inventory stage as Twitter users captured the impact of Matthew to their surroundings. Furthermore, the theme of thankfulness, for making it through Matthew with their residence, was a sentiment shared by both non-evacuees and evacuees.

Gratitude continued into the Rescue stage as residents expressed an appreciation for the community efforts made to restore Savannah after Matthew. Those on Twitter primarily thanked electrical companies, such as Georgia and Alabama Power, for their continuous efforts to return power to their residence. Residents' pride in Savannah became evident through the use of #SavannahStrong, a trend that showcased their strong feelings towards their community and their dedication to recovery following Matthew.

In this study tweets are used to identify themes prevalent within the immediate Socio-Temporal Disaster stages (Powell and Rayner, 1952). Specifically, insight into the actions and sentiments of residents of Savannah, GA on Twitter are observed prior to, during, and following Hurricane Matthew. In these data, experiences observed were dependent on evacuation measures taken prior to Matthew. Residents who stayed in Savannah during Matthew shared significantly different experiences during and following Matthew, then those who evacuated.

Although the process of evacuation has been well studied, this research continues to bridge the gap, using *in situ* accounts to explore these themes. Although limited by the constraints of character limits on Twitter, *in situ* accounts delve into the current mindset of residents during a disaster. Such information is invaluable to the field of disasters as similar insight may be forgotten or adjusted by residents following the event. This study works to continue to bridge the knowledge gap of the use of Twitter by the public impacted by a disaster event, through both a quantitative and qualitative approach. This study incorporates foundational research in the disaster literature with a modern dataset to discuss the practicality of prior

research today. In addition, this piece further expounds on the work by Demuth et al. (2016) by analyzing Twitter information qualitatively in two fashions: individual tweets and social media narratives. As discussed, the immediate disaster stages studied from the work of Powell and Rayner (1954) still remains prevalent in today's society, even through a different medium. However, the stages of Warning, Impact, and Inventory can further be categorized based upon the results as shown in Figure 4. For this reason, the use of Twitter in research must continue, specifically in disaster research, as information can be analyzed as *in situ* accounts rather than after the event. In regards to the methods of studying Twitter data, this study shows both the pros and cons of individual tweets compared to that of social media narratives. Although individual tweets from multiple Twitter users are useful for quantitative information, they do not tell the narrative of specific users during the event. Each method has its convenience and researchers must make the decision based upon their research which suits their objectives. The use of social media information must continue to play a role in research to further our knowledge of *in situ* accounts during events.

Limitations and Future Reserach

There a number of limitations that exist with this study. First is the lack of generalizability and overall representativeness of the Twitter data, which may not reflect the population. As of 2018, approximately 48.2 million residents of the United States are on Twitter, making up 20% of the entire population. For this reason, this study is not generalizable to the entire population. In addition, further insight into the Twitter user's thoughts beyond their tweets of 140 characters is unknown. For this reason, interpretation into the context of the user's tweets plays a significant role and may not be comparable to another researcher. For this reason, inter-coder reliability should remain in the forefront of research regarding social media. In addition,

future work should continue finding supplementary ways to gain additional understanding of a social media user's experience to compensate for the lack of information provided in a tweet.

Another limitation of this study, and an area for future research, is the incorporation of retweets into the dataset and narratives analyzed. The intent was to strictly study the residents own words and actions taken, however, the use of retweets may also serve as thoughts conveyed through their Twitter. In addition, although briefly analyzed here, both multimedia attached to tweets, along with discussions had with other Twitter users, should be studied, to identify the importance of relationships on Twitter, along with the use of images and video.

Although this study was submitted and accepted for IRB approval, the continuing effort to ensure confidentiality with social media users is essential. Residents' Twitter user names were kept private for this study, through the use of Reference Numbers for tweets, along with pseudonyms when elaborating upon individual narratives. However, further work should study other techniques to maintain privacy of the Twitter user. A portion of social media users, whether Facebook, Twitter, or Instagram, may not realize the opportunities their content has for study, for this reason, gaining permission may be essential for studies regarding certain geographical accuracies.

This study ultimately helps identify the progression of major themes expressed by residents over Twitter before, during, and following a natural disaster. Findings echo similar results from Anderson et al. (2016), especially the incorporation of reporting techniques, environmental and personal, during the Impact stage. Besides the aforementioned areas of future research suggested, incorporating social media in disaster events to identify strengths and weaknesses within *in-situ* accounts over media platforms should continue. Both quantitative and qualitative information can be gleaned through social networking sites, especially Twitter, due to

its ease of data collection compared to that of other social media platforms. With this in mind, the content of tweets in disasters can be focused on a variety of topics, such as evacuation patterns, disaster knowledge, and emotions conveyed throughout the event.

Research should continue to broaden the scope of disasters to include other events, such as tornadoes (Blandford et al., 2017), wildfires, floods, and earthquakes (Dabner, 2012) using social media. In addition, the identification of evacuation routes and procedures taken by residents can be visualized spatially (Martin et al., 2017) to analyze patterns by demographics and region. The presence of stages within prior identified disaster cycles, be that work by Drabek (1986) or other researchers, can be further founded using real-time, *in-situ* accounts presented in social media data. As shown within this study, the actions taken, as well as the thoughts expressed through tweets, can be categorized into the Socio-Temporal stages of disaster. In addition, the use of real-time data has the ability to identify the existence of a non-linear cycle that residents take through the stages of a disaster. However, due to the recency of social media, additional work is necessary to identify supplementary approaches to studying disaster cycles using real-time information.

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