

# **Social-Media-based Crisis Communication: Assessing the Engagement of Local Agencies in Twitter during Hurricane Irma**

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## **ABSTRACT**

As social media platforms have become vital means of communication, it has become imperative for emergency managers and policy makers to understand how people are interacting with different agencies on these platforms for enhancing community response coordination during disasters. Although many public agencies have already adopted social media platforms for crisis communication purposes, empirical evidence on whether and how these agencies are effectively engaged on these platforms is lacking. This research aims to examine crisis communication activities of a variety of agencies in Twitter (now X) in response to Hurricane Irma in 2017. The study analyzed 13,353 hurricane-related tweets posted by the local agencies from eight counties in East Central Florida as well as federal and state agencies and other nonprofit and private organizations during the hurricane response period. An engagement metric was applied on these tweets to determine which agencies were most active in disseminating information during Hurricane Irma. The results revealed the most engaged local agencies in Twitter during Hurricane Irma for crisis communication and the Emergency Support Functions (ESFs) associated with them in coordinating disaster response activities. The study further investigated Twitter profiles and relevant attributes of these actively engaged agencies, and the contents of the hurricane-related tweets during Hurricane Irma. The study found that local agencies remain active and engaged in Twitter during a disaster compared to other levels of agencies. The ESF representing communication (ESF #2) was one of the most frequent ESFs associated with these active agencies; however, ESF #6 (Mass Care and Sheltering) was also found to be highly utilized. The results also provided insights on crisis communication performance of these agencies in terms of the three dimensions of social media engagement including popularity, commitment, and virality, which are correlated to the counts of like, reply, and retweet of each post, respectively. The study includes recommendations to local government and partner organizations and emergency managers to improve crisis communication in social media and suggests future research directions.

**Keywords:** Social Media, Crisis Communication, Hurricane Irma, Emergency Management

## 1 INTRODUCTION

Natural disasters have become more frequent and bolstering community resilience has become an urgency for government agencies and public leaders. Building community resilience is considered as a shared responsibility and collaboration among all sectors—allowing a community to efficiently function during and after disasters and increase its adaptive capacities through coordinated networked resources (1, 2). But building community resilience is a complex process which requires continuous communication and coordination among participant organizations and partner agencies. One of the primary objectives of community resilience is to successfully recover from a disaster with coordinated actions. Crisis communication, therefore, plays a critical role within the broader community resilience framework. It is a crucial feature of emergency management, and poor communication can result in great harm in financial, physical, health and other forms for people and businesses (3–5).

Collecting, organizing, and disseminating timely information in response to emergencies and crises are critically important for effective disaster response and recovery (6). Disasters of different severity and sizes, such as catastrophic disasters of extreme events, can overwhelm emergency managers in coordinating response efforts. Specially, during large-scale natural disasters such as hurricanes, response tasks become more complicated and require effective coordination among various agencies (7). To execute this coordination among different agencies at federal, state, and local levels, Emergency Support Functions (ESFs) have been utilized in frameworks and emergency management plans. ESFs provide the structure of integrating response tasks, service, and resource support by grouping the various functions such as communication, firefighting, transportation, and public works to save lives, protect properties, assets, and the environment, and reduce the amount of suffering (7–9).

The wide adoption of smartphones, apps, and online social media platforms has facilitated communication to a great extent (10–12). Taking proactive actions during a disaster requires the affected population to be constantly informed regarding potential threats of a disaster. Emergency managers at all levels also need updates for the constantly changing needs of a community during different stages of a disaster (13). Social media platforms allow this two-way communication (13, 14) in real time, which differs from traditional media and communication strategies, allowing a disaster-impacted community to be well-connected and better-informed throughout a disaster.

Many public agencies responsible for emergency and crisis management have already adopted social media platforms for crisis communication (10, 15–18). Despite being widely adopted, we still need to examine how local organizations are utilizing these platforms for communication during disaster response. Although previous studies considered crisis communication among social media users in general and public organizations (13, 19–22), to the best of our knowledge, no study has focused solely on the engagement of local agencies on social media. Specifically, previous studies have not investigated the role of ESFs in crisis communication in social media, which can provide valuable insights for future emergency management planning, policies, and practice. In this study, we aim to answer the following research questions: *Which local agencies are leading in disseminating crisis information during a disaster in social media? How should engagement activities of local agencies in social media for effective crisis communication be measured? How are the Emergency Support Functions (ESFs) associated with the engagement of the agencies that are active through their crisis communication posts?*

For this study, we considered crisis communication in Twitter (now X) as a social media platform during Hurricane Irma in the East Central Florida region (Lake, Sumter, Seminole, Orange, Marion, Osceola, Brevard, and Volusia counties). Hurricane Irma was first identified as a potential threat on August 27<sup>th</sup>, 2017 and hit Florida Keys as a Category 4 storm on September 10<sup>th</sup>, 2017 (23–25). It resulted in almost 129 direct and indirect deaths and an estimated damage of \$50 billion, making Irma the fifth costliest

hurricane in the United States (24, 25). We analyzed 13,353 hurricane-related tweets posted by 299 agencies during Hurricane Irma to assess the engagement activities of these organizations in Twitter. We adopted a metric from the literature to gauge the engagement activities made by each agency in Twitter. From the results, we identified which specific local agencies were leading in disseminating information during Hurricane Irma in Twitter. We also assessed which specific Emergency Support Functions (ESFs) were frequently associated with the active agencies. These functions are typically assigned to agencies within policy and process documents for emergency response plans. Besides the three primary research objectives mentioned above, we also analyzed the attributes of the agency profiles and the content of the tweets that gained high engagement during Hurricane Irma.

This exploratory research contributes to the literature on the use of social media for crisis communication. The contributions that will be discussed as a result of this study are as follows:

- This study has adopted a social media engagement metric from literature, applied it on a comprehensive list of agency profiles, and further utilized it in a novel way by correlating with different characteristics (levels, verified status, ESFs, etc.) of these agencies.
- It provides empirical evidence on how local agencies are engaging with the public in Twitter during a hurricane for crisis communication—demonstrating their roles and significance beyond federal and state level agencies in bolstering community resilience.
- The study identifies the local agencies who showed the most engagement in Twitter during Hurricane Irma. These findings will aid emergency managers to improve crisis management decisions on these platforms during future disasters. They will be able to boost the outreach of the crisis awareness posts to the local public by letting them know which local agency profiles to follow to get authentic information fast during different phases of a hurricane.
- The findings also show the performance of the agencies along three important dimensions of social media-based communication – popularity, commitment, and virality. This will make local agencies aware of the aspects of their social media-based crisis communication where they can be more effective and engaged in future.
- The study sheds light on examples of tweets that gained greater engagement from the users during Hurricane Irma—allowing local agencies to improve the content of their crisis communication posts to gain more engagement on Twitter during future disasters.

## 2 BACKGROUND AND RELEVANT WORK

From an organizational perspective, a crisis can be defined as: “an unpredictable event that threatens important expectancies of stakeholders and can seriously impact an organization’s performance and generate negative outcomes” (26). Crisis response strategies are defined as the words and actions used by crisis managers while a crisis occurs (26–29). An effective crisis response from managers must include three categories of information: instructing information (tells people how to physically protect themselves from the crisis), adjusting information (helps people cope with the crisis psychologically), and internalizing information (let people formulate an image of the organization) (29–32). A crisis response must be regarded as a collection of coordinated activities directed toward achieving essential objectives and facilitated by efficient communication links (33).

As a two-way communication platform, social media is a channel to fit all these categories of information. Users can post status updates, comment on others' posts, share what others have posted, and tag other users to posts—allowing it to be an effective medium for information dissemination. With its ever-evolving nature, social media is defined to be internet-based applications “that allow the creation and exchange of user generated contents” (34). Social media also allows an interactive communication as well as exchange of contents between organizations and stakeholders (35). Past studies indicated increasing use of social media during crises, making public participation on social media a crucial form of emergency management (20, 35). Nan and Lu (36) showed how self-organization in online communities can lead to rapid information sharing, problem-solving, and resource allocation during crises. Eriksson (37) provided five lessons for effective social media crisis communication: (i) right message, source, and timing, (ii) being prepared, understanding social media logic, and increasing friends, (iii) utilizing social media for monitoring, (iv) prioritizing traditional media, and (v) just using social media as a strategic crisis communication. MacKay et al. (38) identified seven key features (call to action, clarity, compassion and empathy, conversational tone, correction of misinformation, timeliness, and transparency) of guiding principles for social media-based crisis communication that help maintain public trust. Eismann et al. (39) built a framework of social media characteristics which include intuiting, interpreting, integrating, and institutionalizing for organizational learning in crisis management. Thus, social media profiles of organizations can help provide critical support to the people during a disaster as they have a large number of followers. These findings suggest that to bolster resilience on a community level, organizations/agencies must integrate social media into their emergency management strategies.

Twitter is a social media platform used by about 23% of Americans to share information with a large number of users (40, 41). Twitter is often useful for rapidly delivering and finding information on the latest events, particularly for a public agency needing to release time-sensitive information on an incoming or occurring disaster (42, 43). Twitter data have been analyzed to understand different aspects of emergency management including service attributes (44, 45), retweeting behavior (46–50), crisis awareness (51, 52), online communication of emergency responders (36, 53, 54), text categorization and event identification (50, 55–60), developing strategies for early crisis perception (61), and quantification of human mobility (62, 63). Previous studies focused on the role of Twitter users, tweet hashtags, and tweet keywords in enhancing situational awareness and community resilience during disasters. For instance, during Hurricane Sandy, New York City Fire department (FDNY)'s tweets with #sandy resulted in continuous and a high number of retweets by its large number of followers including other government agencies (20). Lachlan et al. (64) focused on the tweeting rates for Winter storm Nemo using hashtags #nemo and #bosnow and tweeting rates by agencies until landfall. Hashtags in tweets were found to have the potential to be used for information dissemination during disasters (65, 66). Previous studies proposed the Tweak the Tweet (TtT) syntax which was designed for filtering and classifying emergency related tweets during any disaster (65, 67). Since then, this method has been utilized in numerous studies. Researchers also analyzed Twitter data by keyword-based data collection (e.g., searching disaster-related terms) and demonstrated how this can boost situational awareness (68). Rachunok et al. (69) explained the advantages and limitations of keyword-based, location-based Twitter data collection methods. Based on hashtags, keyword and location-based data collection and analysis, these studies have shown how Twitter has been useful in building community resilience to disasters.

Previous studies also focused on public agencies and their use of social media platforms during disasters. Ahmed et al. (21) published a Twitter-based COVID-19 study on six major public organizations during the period of February to June 2020 demonstrating how they engaged users in Twitter by analyzing the topic dynamics of their tweets communicating health risk information. The results showed a significant difference among each organization's tweeting patterns. Wang et al. (70) investigated public health agencies' role using Twitter for COVID-19. Change in tweeting pattern and topics over time during COVID-19 was also investigated (71). Vera-Burgos et al. (72) investigated how Mayor Turner of Houston

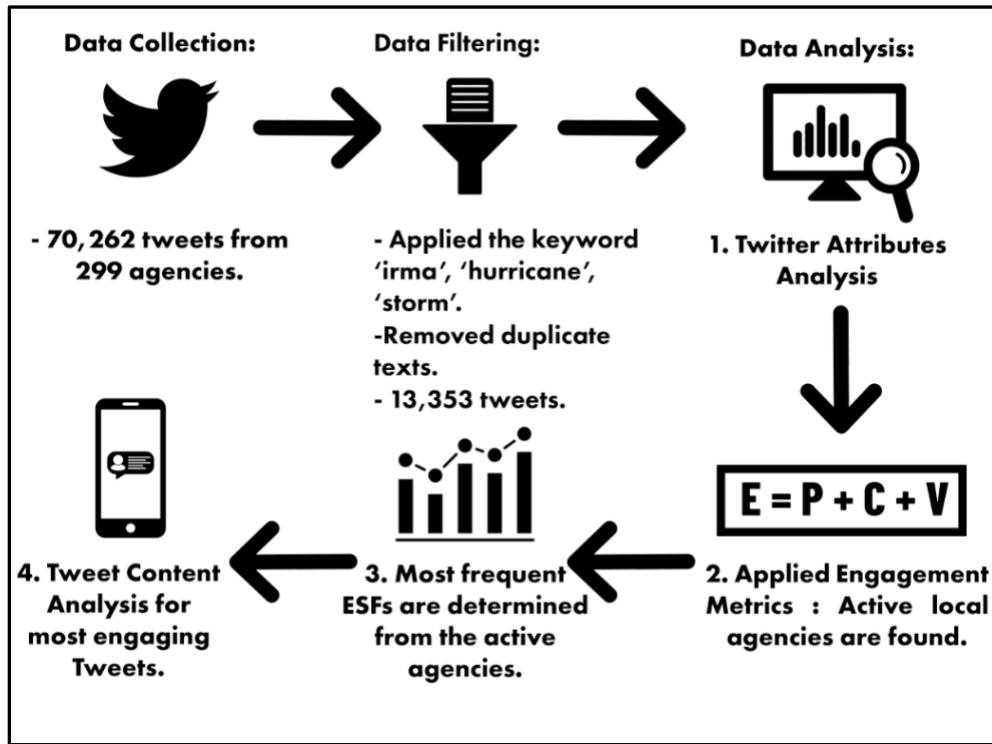
effectively used social media during Hurricane Harvey by providing updates on the hurricane, linking credible news sources on the crisis, and using inclusive language in his tweets. Sadri et al. (73) investigated crisis communication patterns from Twitter posts during Hurricane Sandy focusing on tweets from individuals users but not from public agencies on Twitter. Fan et al. (74) identified local influential users in public warning on social media and their role in spreading situational information for Hurricane Harvey. Lachlan et al. (60) investigated commonly found contents in retweets by a human coder analysis on top 200 original tweets based on retweets during Hurricane Irma. Some studies suggested that audiences are using Twitter for solidarity/social cohesion (75) and uncertainty reduction (76) during crises, while some indicated that it is a helpful source of initial warnings, relief, damage, and updates (50, 60) for crisis communication. These studies mainly focused on contents from all types of Twitter users and not particularly on what local agencies do for crisis communication during extreme events. Some studies focusing on tweets from public agencies, but only for health hazard such as COVID-19. Analyzing text-based information from Twitter, these studies mainly showed how it can be used for effective crisis communication, and why it is important to look at their shared contents to understand what needs to be improved.

Few studies investigated how different agencies at regional and local levels utilize social media platforms for crisis communication. In 2015, Neely et al. (77) conducted a survey of local government agencies in Florida regarding the adoption of social media for crisis communication. The survey administrators contacted managers of 180 cities, and of the 83 responses, 42 (50.6%) agencies reported that they do not use any social media platforms for crisis communication. Facebook was found to be the most frequently used social media tool (used by 49.4% of the agencies), and Twitter was used by 27.7%. The study concluded that social media adoption among local government agencies was lower compared to federal and private sector agencies. They suggested that further in-depth research, especially on a county level, is necessary to confirm the concern that local agencies lack proper digital and management skills to utilize the social media platforms in ways that meet people's expectations during a disaster. In the last few years following some major hurricanes in Florida (e.g., Matthew in 2016, Irma in 2017, Michael in 2018, Dorian in 2019, Ida in 2021), a few studies have focused on social media use of local agencies (county and regional level) for crisis communication. Recently, Knox (78) investigated Florida county emergency management agencies' use of social media during Hurricane Irma and found that, out of the 24 After Action Reports (AARs) analyzed, 95% of the county AARs reported the usage of social media before and during disasters in positive terms. About 81% of the counties mentioned only pushing information on these platforms and only 48% reported implementing two-way communication on social media. Many counties reported facing problems to effectively manage these two-way communication tools. As such, emergency managers face numerous technological, financial, and managerial challenges while adopting these social media platforms during disasters (78).

Twitter has been widely adopted as a crisis communication tool for sharing situational information to communities facing disasters. However, prior research has provided a general overview of how local agencies are using social media during disasters—without investigating engagement activities of these agencies among themselves through their social media profiles. In this study, we aim to understand engagement activities of a variety of agencies through their crisis communication posts, considering Twitter as a social media platform and Hurricane Irma as a disaster event.

### 3 METHOD

The goal of this study was to obtain an overall perspective of crisis communication during disasters, through online engagement of different local agencies using a social media platform. For that, it was important to take both a qualitative approach to analyzing the characteristics and content of their social media profiles, and a quantitative approach to assessing their overall engagement performance. The step-by-step methodological approach adopted in this research is shown in Figure 1.



**Figure 1. Methodological Approach and Workflow Diagram.**

### 3.1 Data Source and Collection

For this study, Twitter was selected as the social media platform as it is widely used for crisis communication. Additionally, Facebook historical data from individual profiles is unavailable to the public for use. The local study testbed includes eight counties in the East Central Florida region of USA including Brevard, Lake, Marion, Orange, Osceola, Seminole, Sumter, and Volusia.

For the data collection, we first created a list of 377 organizations (including county, regional, state, federal, international, and non-public sectors) and searched their corresponding social media accounts (i.e., Twitter screennames or IDs). The list of organizations was collected from a content analysis of all comprehensive emergency management plan (CEMP) documents in Central Florida. The names of the agencies and their county-wise Emergency Support Functions (ESFs) were obtained using this 'Content analysis codebook'(79). The purpose of this content analysis codebook development and use was to ensure that the source list is comprehensive and consistent. It was used as a reference to determine which agencies fulfilled the same transaction for a specific purpose (e.g., ESF)—and these agencies would be marked as such for the relationship. This codebook utilized CEMPs for key descriptive information of agencies within the documents, and any likening factors (i.e., same response transaction for an ESF). Each CEMP was analyzed, and any agencies with actionable transactions were reflected in the codebook. All agencies were then extracted with any reflected ESFs for social media engagement purposes (79). These response agency ESFs have been designated by the organization that the CEMP documents belong to. For instance, one county may have certain agencies highlighted for planned response under ESF 6 (Mass Care and Sheltering), while another county may have more or less number of agencies than that--but both counties would typically include Red Cross, as this agency is critical for shelter and care support. The ESFs at the federal level are dictated by the FEMA National Response Framework (8), which specifies 15 functions that must be considered during disasters, whereas the State of Florida has 3 more ESFs in addition to these

15 ESFs. Although there are 15 core ESFs designated by FEMA, as long as state and local agencies reflect these support functions in their plans, they have flexibility in their ESF divisions. The State of Florida has 18 functions, with local law enforcement separated from military support, the inclusion of animal protection, and volunteers and donations separated from mass care. For the purposes of consistency of ESFs among different counties in Central Florida, the state ESFs were used for this study's organizational designations, but certain county-level agencies' ESFs (with more than the 18 state functions) were included as well for their significance (e.g., local agencies with ESF #19: Damage Assessment).

Twitter gave us access to its historical archive known as 'Search tweets v2' archive (80) through its academic research program. Using Twitter's API credentials, we searched for the tweets posted by 377 agencies during the one-month period of Hurricane Irma (30<sup>th</sup> August 2017 to 30<sup>th</sup> September 2017). A total number of 70,262 tweets were collected from 299 agencies out of the initial 377 agencies. Tweets could not be found for the rest of the 78 agencies due to reasons such as the Twitter profile was created after the hurricane period or the Twitter profile did not post any tweet during that time period. Among these 299 agencies, there were 42 federal, 21 national, 44 state, 161 county, 1 federal-state-county, 21 regional, and 9 other types of agencies. Therefore, the total number of local (county and regional level) agencies was 182. Here 'federal' indicates U.S. government agencies under the federal government, 'national' indicates all other agencies that have a national presence, and 'regional' indicates all agencies that have presence across the East Central Florida region. The overall percentage of verified profiles was only 39% (118 organizations out of 299). For each tweet posted by an agency, this dataset contains the tweet text and the number of likes, replies, and retweets. These collected tweets include retweeted tweets by the profiles besides their original tweets, and the retweet count for those tweets was associated with the source tweet. Using Twitter API, we also collected the attributes of these agency profiles, including the counts of their friends and followers.

For the Data Filtration, the keywords of 'Irma', 'hurricane', and 'storm' (case insensitive) were applied on the primary dataset of tweets. After removing duplicate tweets, 13,353 tweets related to Hurricane Irma were found. For comparison purposes, in addition to the agencies from East Central Florida region, we considered federal/national, state, international, and other levels of organizations.

### **3.2 Analyzing Twitter Attributes**

To understand overall activities and reach of an agency in Twitter, we first analyzed the basic attributes of their Twitter profiles. By Twitter attributes, we refer to the total number of followers, friends, tweets, retweets, likes, and replies. Followers count refers to the number of users following a profile and Friends count refers to the number of profiles a certain user/profile is following. After collecting these attributes using Twitter API, the 299 organizations were sorted according to each of the attribute counts from the highest to the lowest. We plotted these counts in correspondence with the levels of agencies in a bar chart for each of the Twitter attributes and the percentage of verified Twitter profiles among the 299. The followers and friends counts are based on the time of our data collection period (April, 2022) but the other attributes (tweets, retweets, likes, replies) are based on the time period during Hurricane Irma. This is because the historical record of a tweet provided by Twitter does not contain the number of followers and friends at the time when the tweet was posted, rather it reports the current number of followers and friends when data query is made.

### **3.3 Applying Engagement Metrics**

To measure the engagement of all levels of agencies beyond their individual-level Twitter attributes, we need an appropriate metric (19). We sought the literature to check whether any method had been used to measure social media engagement in related studies. Bonson and Ratkai (81) proposed a set of metrics to assess stakeholder engagement of corporate Facebook pages. These metrics included Popularity, Commitment, and Virality (81). Recently, Kankanamge et. al (22) utilized these three metrics

to determine social media user Engagement (Facebook and Twitter) of three Australia-based organizations. Table 1 shows the metrics adopted in this study and the formula to calculate these metrics.

**Table 1 Engagement metrics to gauge engagement of local agencies, adopted from Kankamamge et al. (22).**

Metric	Formula	Significance
<b>Popularity (P)</b>	$\frac{\text{Total Number of Likes}}{\text{Total Number of Tweets}} \times 1000$	Represents the attractiveness of the tweets posted by a profile through 'Likes'.
<b>Commitment (C)</b>	$\frac{\text{Total Number of Replies}}{\text{Total Number of Tweets}} \times 1000$	Represents deeper engagement with other users through 'Replies'.
<b>Virality (V)</b>	$\frac{\text{Total Number of Retweets}}{\text{Total Number of Tweets}} \times 1000$	Represents other users' interest in sharing the content of the tweets posted by a profile through 'Retweets'.
<b>Engagement (E)</b>	P + C + V	Represents the overall engagement performance of a profile through cumulative results of popularity, commitment, and virality scores.

Previous studies (82, 83) found relationship between follower counts and engagement on the user end. For example, an agency account is likely to get more retweets, likes, and replies if it has a higher number of followers (82); those engagement activities do not necessarily result from the tweet's content. Thus, it is important to account for follower count to normalize the popularity, commitment, and virality scores.

In this study, we applied this simple formula on our dataset to gauging the Engagement Score (E) of the agencies. We first removed all the organizations who posted less than 10 tweets during the Hurricane Irma's period. Without this condition, the results would indicate some agencies as the most engaged ones even with one or two viral posts during the hurricane. Then, we also removed the agencies with zero followers, as required by the formula shown in Table 1. This led to the final 180 'active' agencies for the study. After that, the Popularity (P), Commitment (C), and Virality (V) scores were calculated applying formula given in Table 1. The P, C, and V scores were then normalized to be scaled in a range between 0 to 1 and compared. Otherwise, there were instances where one score was largely greater than the other two scores, resulting in Engagement Scores that were not comparable across agencies. After the normalization, the final Engagement Scores (E) were calculated. The active agencies were then sorted according to their engagement scores from the highest to the lowest. Furthermore, we visualized which levels of government (federal/ national/ state/ regional/ county/ others) and sectors they belong to. Among the 180 active agencies, 101 were found to be local (county and regional). We determined which local agencies had the highest engagement scores and their corresponding ESFs.

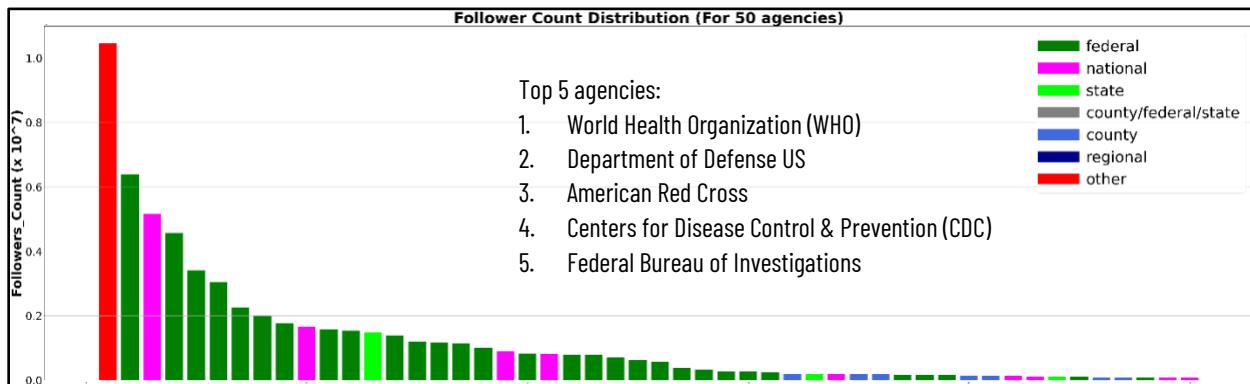
From the 180 active agencies, we determined which ESFs had been most frequently found on Twitter during Hurricane Irma. We also found out the most frequent ESFs among local agencies specifically. Finally, we analyzed the tweets shared by the most engaged local agencies during Hurricane Irma's period. From this manually observed content analysis, the most prominent topics and trends of tweets

were determined. Moreover, the difference in the dynamics of tweet sharing among the topmost leading agencies was noted. This step shed light on which contents attract the most engagement from people in Twitter during a disaster situation. Having examples of these tweet contents from past disasters will allow emergency managers perform better in disseminating information during future disasters.

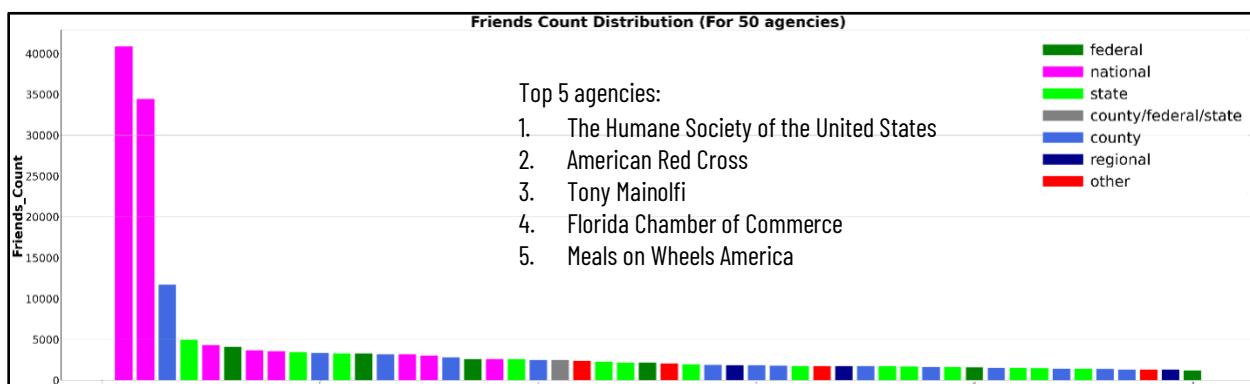
## 4 RESULTS

### 4.1. General observations on the Twitter attributes

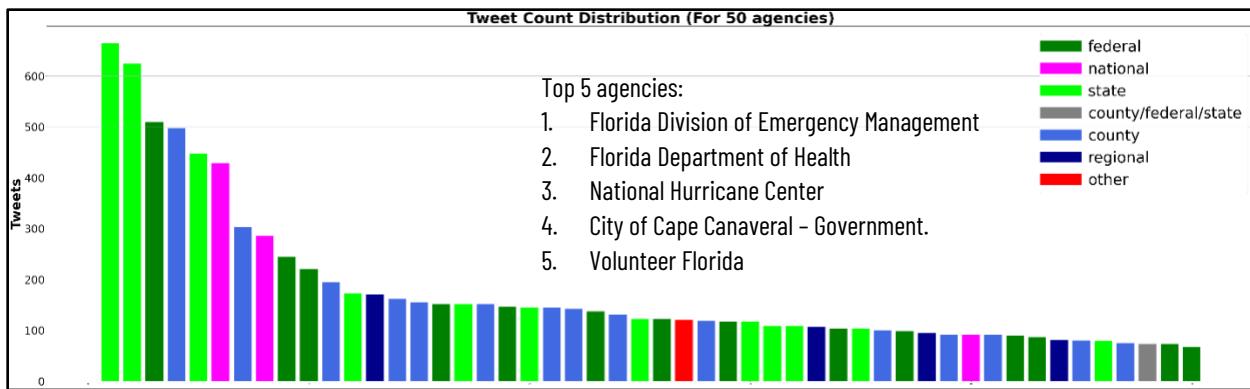
As mentioned in Section 3.2, the 299 agencies were sorted according to each of the Twitter attribute counts from the highest to the lowest and visualized in the form of bar plots demonstrating the levels of the agencies. For the convenience of visualization, among 299 agencies, only the top 50 agencies are shown in Figure 2a-2f. In Figure 2a, federal / national / international level organizations have higher number of followers. It was also noted that all these leading Twitter profiles (in terms of followers count) are verified. A verified Twitter profile is more likely to have a large number of followers. However, in terms of total friends count (Figure 2b), the regional and county level organizations are also as active as the federal/national and state level ones. Although local agencies have lower numbers of followers compared to the federal and national ones, they are active in following others in Twitter to establish an active communication network. As mentioned earlier, these followers and friends counts are from the current status of their Twitter profiles, not necessarily from the Hurricane Irma's period.



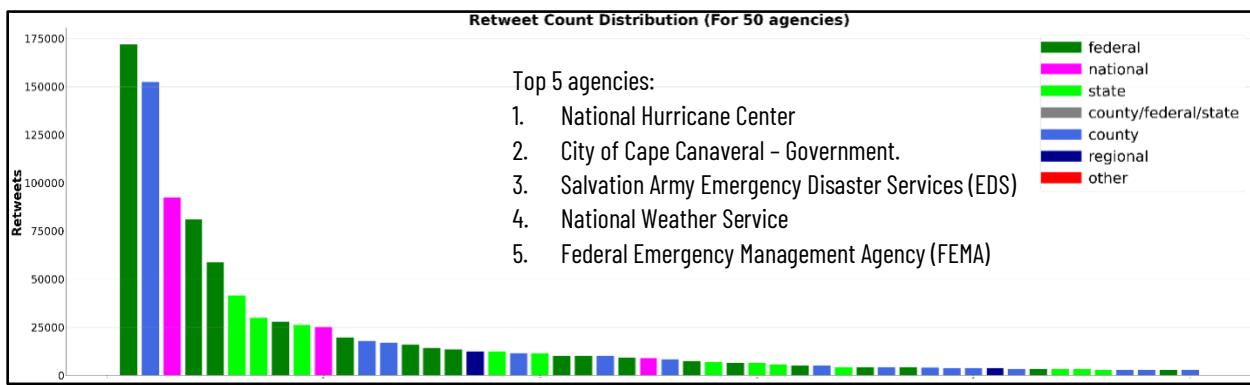
**Figure 2a. Distribution of the Number of Followers for 50 top agencies.**



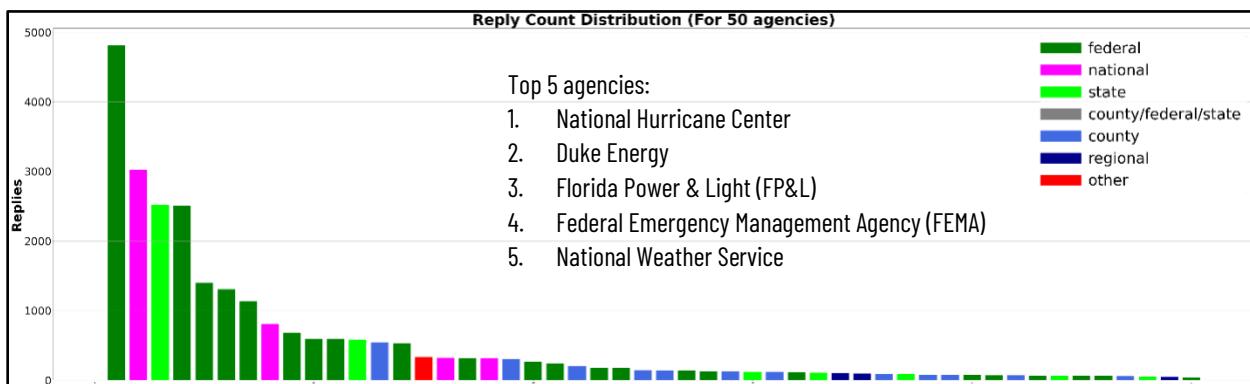
**Figure 2b. Distribution of the Number of Friends for 50 top agencies.**



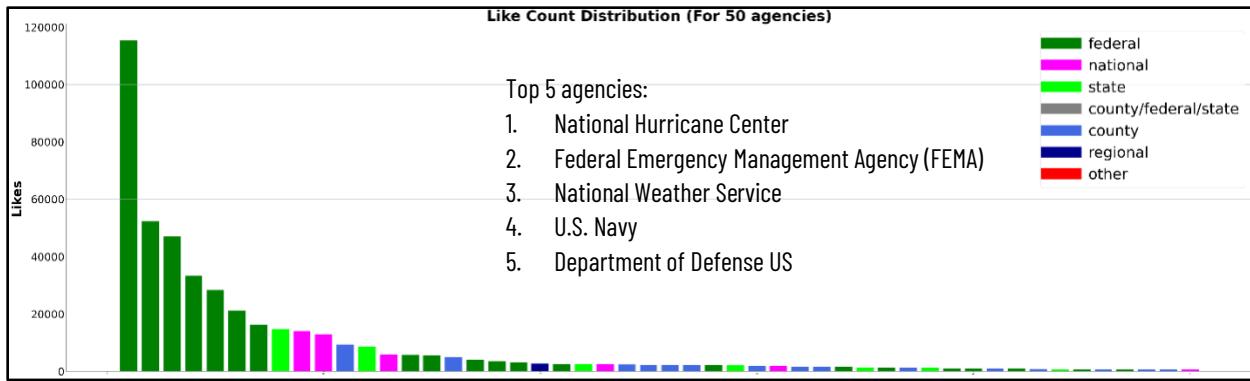
**Figure 2c. Distribution of the Number of Tweets for 50 top agencies.**



**Figure 2d. Distribution of the Number of Retweets for 50 top agencies.**



**Figure 2e. Distribution of the Number of Replies for 50 top agencies.**



**Figure 2f. Distribution of the Number of Likes for 50 top agencies.**

While analyzing the other Twitter attributes (total tweets, likes, replies, retweets from the Hurricane Irma's period), it becomes evident (from Figure 2c) that beyond the federal/national and state-level agencies, several county-level and regional agencies are also leading in crisis information sharing.

It is further noteworthy that although county and regional level organizations were very active in posting tweets, similar to the other levels of organizations, federal/national and state-level organizations seem to have higher numbers of retweets, replies, and likes (Figures 2d-2f). The only exception occurred in the case of City of Cape Canaveral-Government in terms of total retweet counts during Hurricane Irma, having the second highest number of retweets among all the agencies. However, agencies from Orange, Osceola, and Brevard counties have appeared leading in all these four attributes in general.

Analyzing the Twitter attributes of the profiles, we found that federal/national, and state level organizations had higher numbers of followers (see Figure 2a). However, many of the local agencies had a high number of friends count (see Figure 2b) indicating that they are as active as the well-known federal/national and state level agencies in following Twitter profiles for building a network on the platform. Although county and regional level agencies were very active in posting tweets similar to the other levels of agencies (see Figure 2c), the numbers of retweets, replies, and likes were generated more for the federal/national and state level agencies (see Figures 2d –2f) due to a higher number of followers. The attributes in these figures are supported by Roy et al. (19), who indicated that efficiency of crisis communication on Twitter does not only depend on tweeting activity, but also on the number of followers and friends, user category, bot score, and activity patterns.

#### 4.2. Overall Engagement of Local Agencies Based on the Engagement Metrics

After applying the engagement metrics from Table 1 (Section 3.3) to the 180 active agencies, they were sorted from the highest to the lowest based on their overall engagement in Twitter (i.e., the Engagement Score, E). From the results, it was clear that local agencies, such as the county-level and regional agencies, were much more engaged in Twitter compared to the federal/ national/ state levels of organizations during Hurricane Irma based on their Engagement Scores (E). Among these 180 agencies, about 49% ( $n=89$ ) were verified profiles.

For the purpose of visualization, Figures 3a-3d show only the top 50 active agencies according to the four engagement metrics (Engagement, Popularity, Commitment, and Virality), respectively. These results show that county and regional level agencies are leading in terms of not only the Engagement Scores, but also the other three metrics (Popularity, Commitment, and Virality), separately. Many agencies with a

very high engagement score did not have a verified profile. This indicates that a higher engagement score is not necessarily associated with the verified status of a profile.

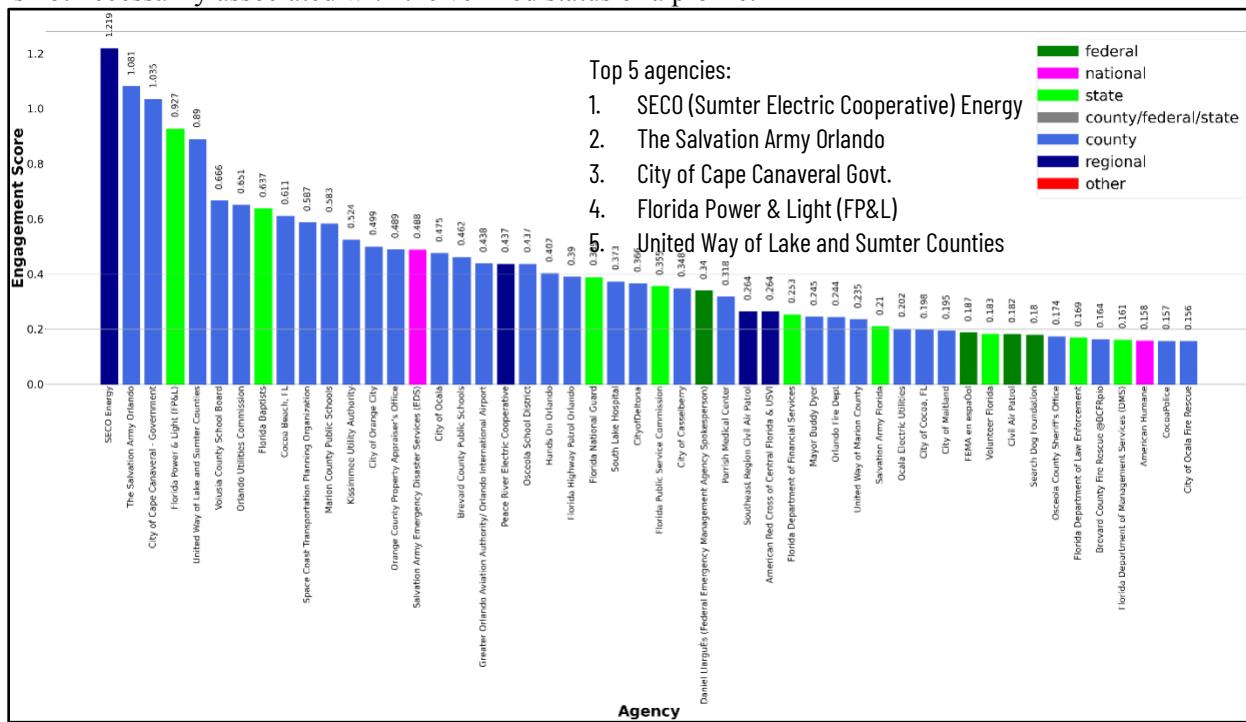


Figure 3a. Engagement Scores of 50 active agencies (Showing levels of the agencies)

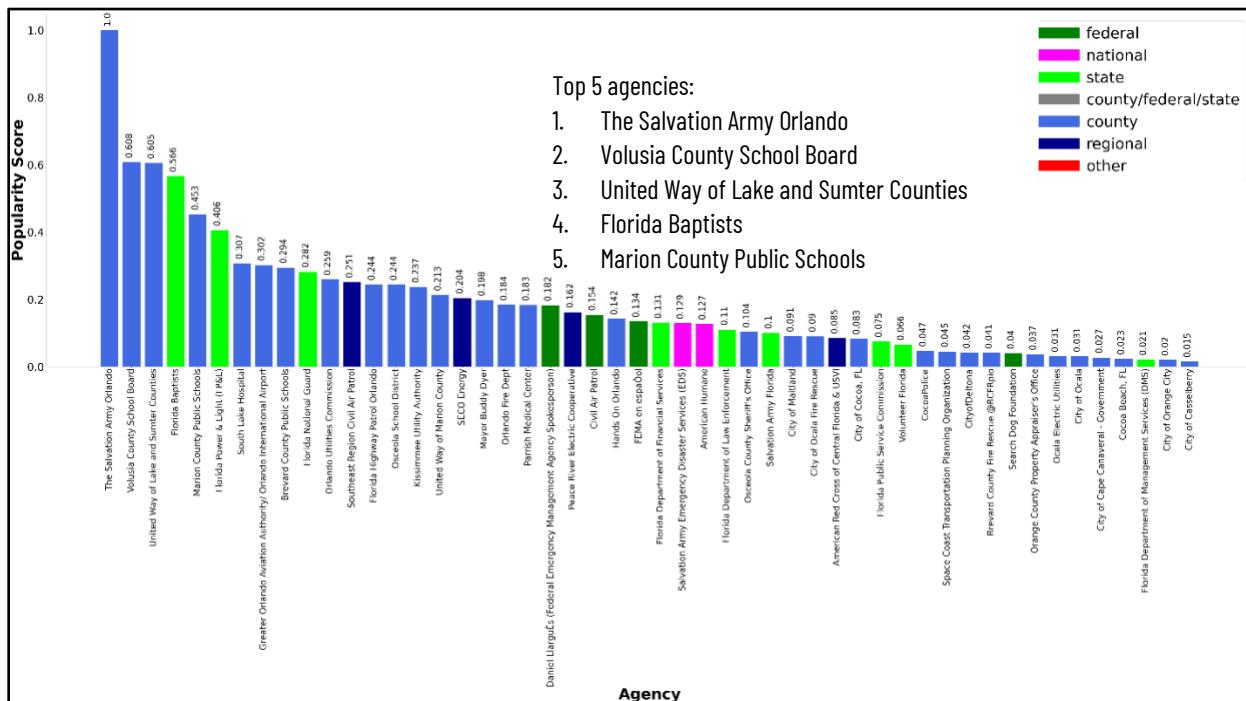
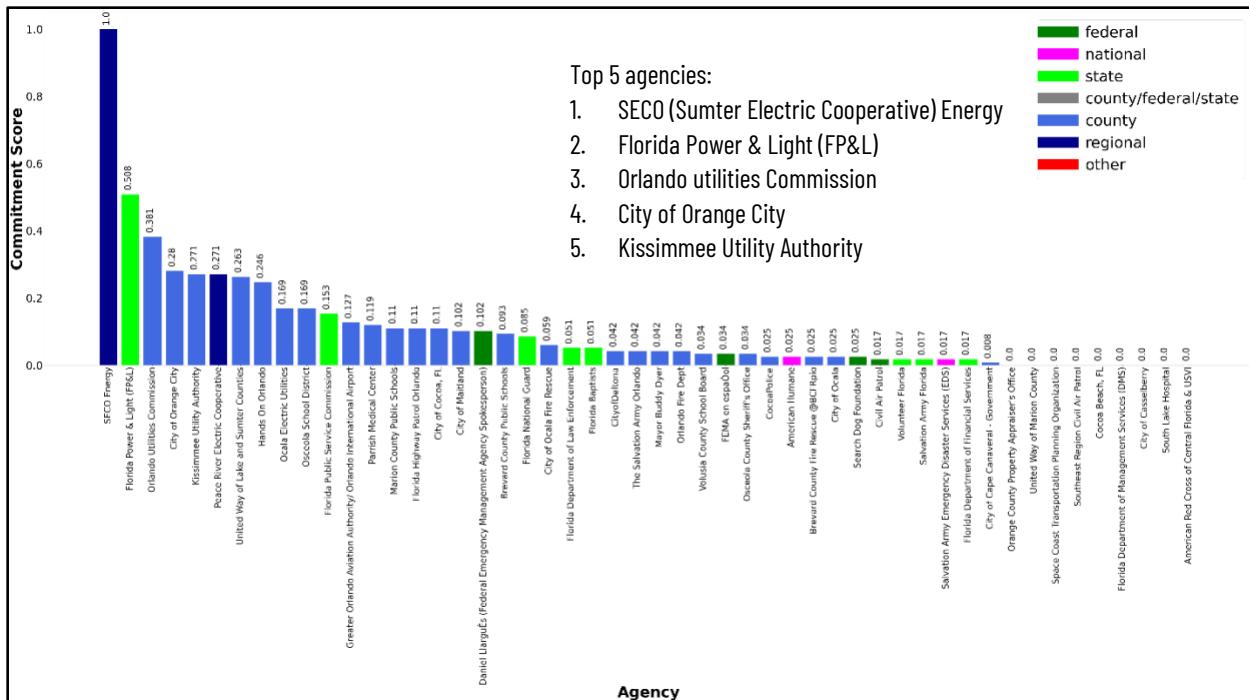
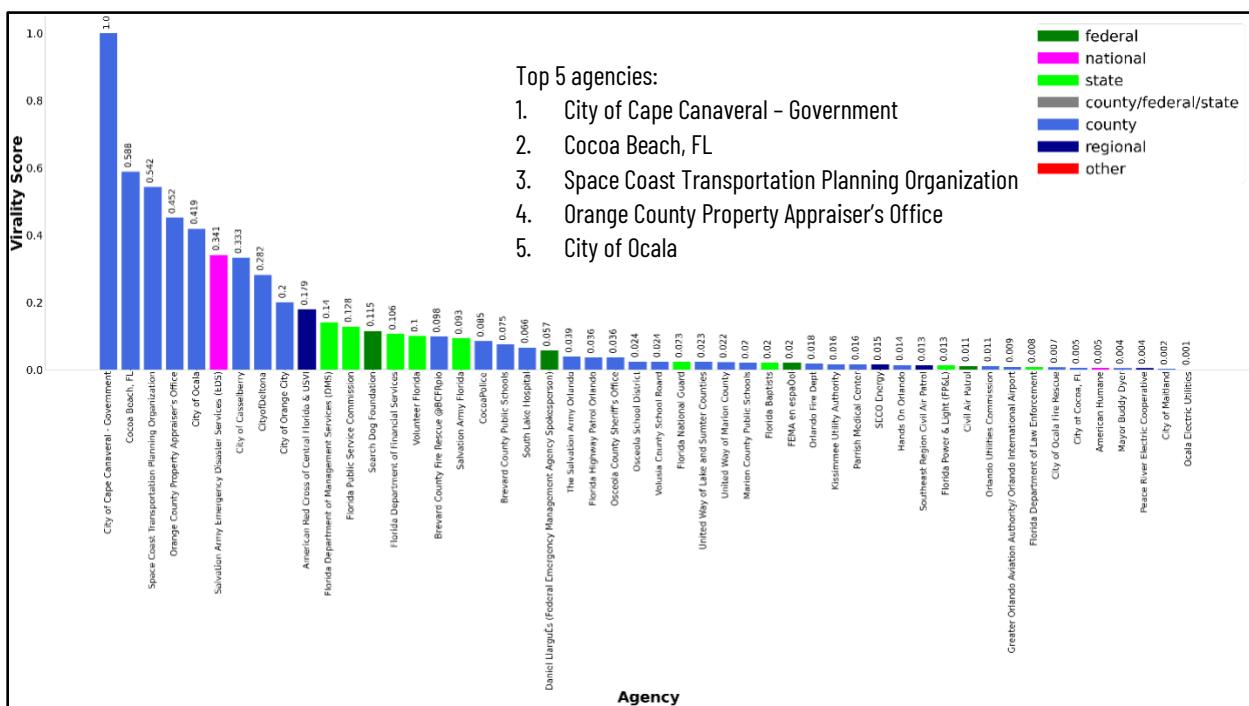


Figure 3b. Popularity Scores of 50 Active Agencies (Showing levels of the agencies)



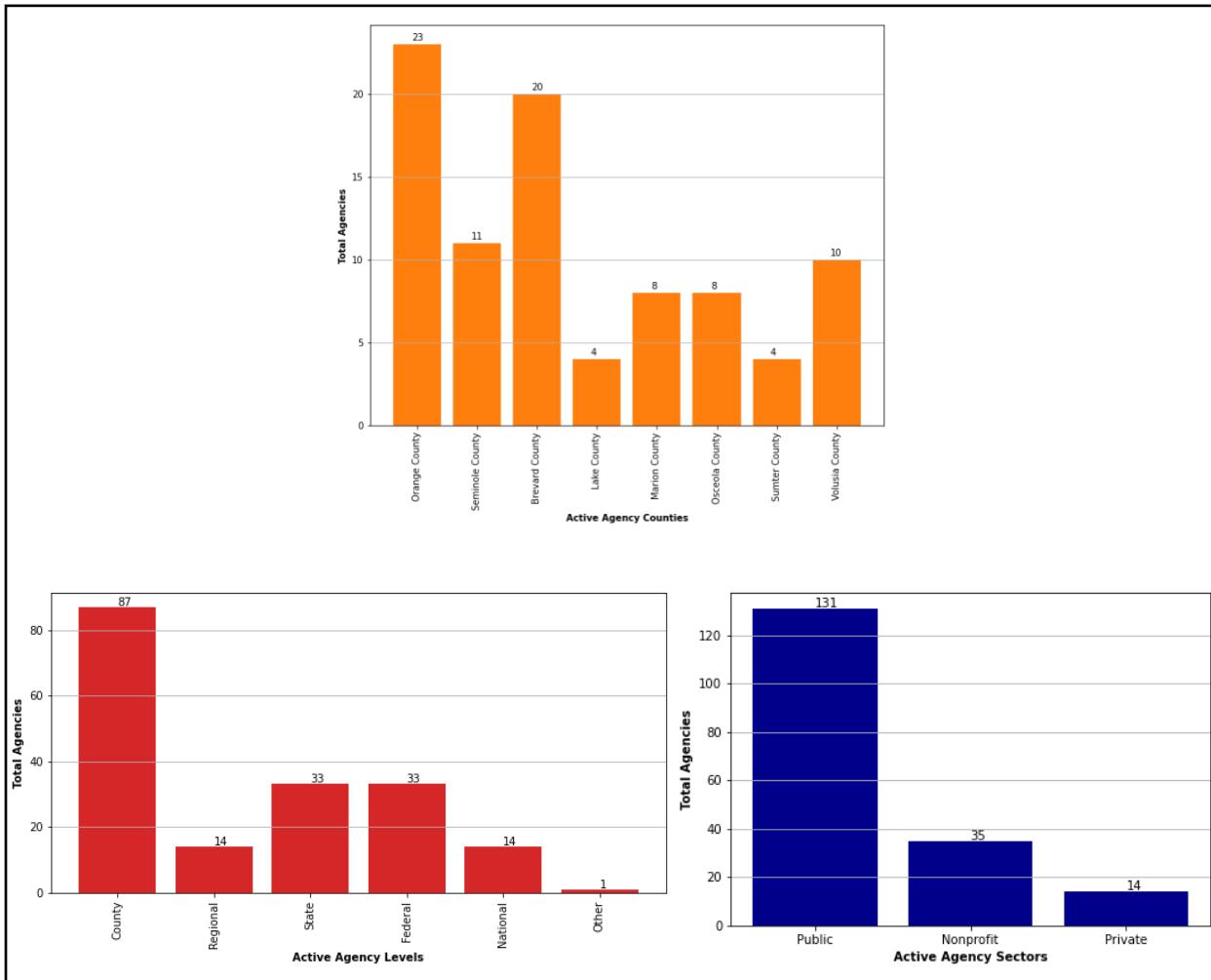
**Figure 3c. Commitment Scores of 50 Active Agencies (Showing levels of the agencies)**



**Figure 3d. Virality Scores of 50 Active Agencies (Showing levels of the agencies)**

Figure 4 demonstrates which levels, counties, and sectors the 180 active agencies belong to. For instance, among these active agencies, public agencies have a greater presence than nonprofit or private ones. However, the results from the engagement metrics show many of the nonprofit agencies among the most highly engaged agencies. Some of these nonprofit agencies include SECO Energy, The Salvation

Army Orlando, United Way of Lake and Sumter Counties, and Florida Baptists. Figure 4 also compares the different levels of government (of which 87—almost half, are county) and counties in the East Central Florida region, indicating that Orange and Brevard Counties have the highest number of agencies reflected on Twitter.



**Figure 4. Number of agencies from different counties and their corresponding organizational levels and sectors among the 180 active agencies**

Table 2 presents a list of the top 30 local agencies (among the 180 active agencies) in terms of their engagement scores and their ESFs. Some of the most prominent leading local agencies include **utility agencies** (SECO Energy, Orlando Utilities Commission, Kissimmee Utility Authority), **charity-based organizations** (The Salvation Army, United Way of Lake and Sumter Counties), **city governments** (City of Cape Canaveral – Govt., Cocoa Beach, FL, City of Orange City), and **county school boards** (Volusia County School Board, Marion County Public Schools).

**TABLE 2. Top 30 Local Active Agencies with respect to Engagement Score and corresponding ESFs**

Agency Name	E	P	C	V	ESFs
SECO Energy	1.219	0.204	1.000	0.015	12
The Salvation Army Orlando	1.081	1.000	0.042	0.039	3, 6, 8, 10, 11, 15, 16, 19, 22
City of Cape Canaveral - Government	1.035	0.027	0.008	1.000	2,5,7
United Way of Lake and Sumter Counties	0.89	0.605	0.263	0.023	6, 11, 15
Volusia County School Board	0.666	0.608	0.034	0.024	19
Orlando Utilities Commission	0.651	0.259	0.381	0.011	3, 4, 8, 9, 10, 12, 20
Cocoa Beach, FL	0.611	0.023	0.000	0.588	2,5,7
Space Coast Transportation Planning Organization	0.587	0.045	0.000	0.542	1, 2, 5, 7
Marion County Public Schools	0.583	0.453	0.110	0.020	6
Kissimmee Utility Authority	0.524	0.237	0.271	0.016	3, 4, 8, 9, 10, 12, 18
City of Orange City	0.499	0.020	0.280	0.200	19
Orange County Property Appraiser's Office	0.489	0.037	0.000	0.452	3, 5, 19
City of Ocala	0.475	0.031	0.025	0.419	2, 5, 7
Brevard County Public Schools	0.462	0.294	0.093	0.075	1, 6, 11, 15, 19
Orlando International Airport	0.438	0.302	0.127	0.009	1, 14
Peace River Electric Cooperative	0.437	0.162	0.271	0.004	3, 4, 8, 9, 10, 12, 20
Osceola School District	0.437	0.244	0.169	0.024	1, 2, 6, 7, 11, 13, 15, 17
Hands On Orlando	0.402	0.142	0.246	0.014	15
Florida Highway Patrol Orlando	0.39	0.244	0.110	0.036	16
South Lake Hospital	0.373	0.307	0.000	0.066	8
City of Deltona	0.366	0.042	0.042	0.282	19
City of Casselberry	0.348	0.015	0.000	0.333	8, 10
Parrish Medical Center	0.318	0.183	0.119	0.016	6, 8
Southeast Region Civil Air Patrol	0.264	0.251	0.000	0.013	4, 6, 9, 13, 19
American Red Cross of Central Florida & USVI	0.264	0.085	0.000	0.179	1, 2, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19
Mayor Buddy Dyer	0.245	0.198	0.042	0.004	2, 5, 7
Orlando Fire Dept	0.244	0.184	0.042	0.018	4
United Way of Marion County	0.235	0.213	0.000	0.022	6, 11, 15
Ocala Electric Utilities	0.202	0.031	0.169	0.001	12, 19
City of Cocoa, FL	0.198	0.083	0.110	0.005	2,5,7

It should be mentioned that we considered the ESFs following the definitions given by the State of Florida and the eight (8) counties utilized for the Content Analysis Codebook (79). Moreover, when assigning an ESF to an agency we made the following assumptions:

(a) While Twitter accounts are specific to the exact regional 'sub-agency' that is providing the information, many of the Comprehensive Emergency Management Plans (CEMPs) did not specify a regional sub-agency. For instance, the "Salvation Army" was mentioned across many of the county CEMPs within a range of different ESFs, but the exact regional offices that are active on Twitter might not have been indicated. Tweets come from specific accounts, which, in this case, may be from a regional sub-agency of the Salvation Army (e.g., 'The Salvation Army Orlando'). Therefore, this study included the ESFs of the CEMPs that reflected the overarching agency as a part of the 'active' regional sub-agency on Twitter.

(b) While counties follow a general format for the CEMPs that are created for potential emergencies and crises, they have the flexibility within them to provide as basic or extensive information as they choose. In this instance, there is a variation of similar types of agencies and the ESFs that they are utilized under for different counties. For instance, the school boards for the different counties all have different ESFs because within the CEMPs of each of the counties, their school boards are utilized for different functions. Therefore, the list of active Twitter agencies may have various school boards with different ESFs because each county's CEMPs indicated those various ESFs for their school boards' inclusion.

(c) For those agencies found as active during the disaster on Twitter, but not reflected in the CEMPs (e.g., charity agencies, specific city profiles, Mayor's office profile, news media profiles, etc.), the 'general' ESFs that highlight communication (#2), information and planning (#5), mass care (#6), and logistical/resource support (#7) have been utilized. There are some discrepancies between the CEMP and Twitter agency lists because social media is a complementary communication strategy to other existing ones, so there will naturally be certain agencies that are specific to this strategy.

### 4.3 Frequency Distribution of the Emergency Support Functions (ESFs)

We determined which ESFs were most frequently identified by the content analysis of the plan and policy documents during the Hurricane Irma's period among the 180 active agencies (Figure 5a) and among 101 local (county and regional level) agencies (Figure 5b).

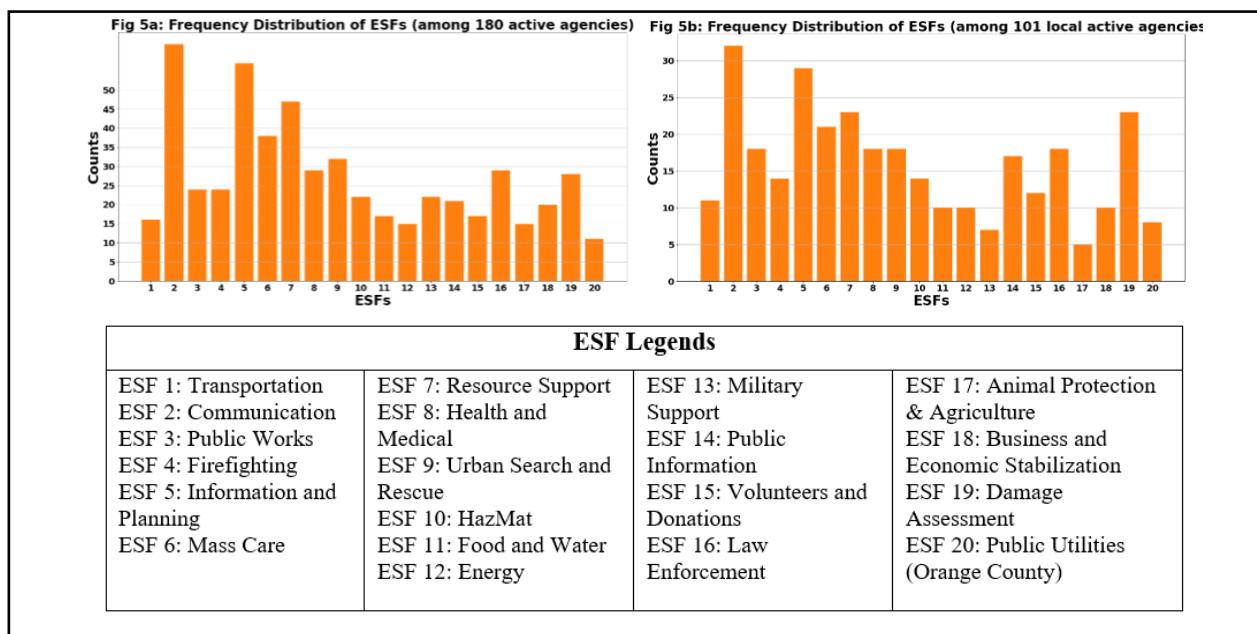


Figure 5: Most Frequent ESFs during Hurricane Irma.

Figure 5 shows that ESF #2 (Communication) was the most frequent while considering all 180 active agencies during the Hurricane Irma's period. ESF #5 (Information and Planning), #6 (Mass Care), and #7 (Resource Support) were also prominently active. Similarly, when it comes to the 101 local active agencies, ESF #2 (Communication) was still the most frequent one. Besides ESFs #5, #6, and #7, ESF #19 (Damage Assessment) was also highly frequent. These findings answer the third research question about how the Emergency Support Functions (ESFs) are correlated with the engagement of the local agencies on social media platforms when it comes to crisis communication. This can further support what type of crisis information is most sought after on social media such as Twitter. To illustrate, a surprising ESF that was active among local agencies was ESF 19 – Damage Assessment. This suggests that agencies designated with this ESF in the plan and policy documents were on Twitter and they had high engagement based on the criteria presented in this study. This means that these agencies can and should continue to provide necessary information about damage assessments through Twitter.

#### **4.4 Analyzing the Tweet Content of the Most Engaged Local Agencies**

To understand the types of tweet contents that may have contributed to a higher engagement score of the local agencies, we investigated their highly retweeted posts. Some of the noteworthy observations and tweet examples are demonstrated in Figures 6-9.

Figure 6 shows that among the utility-related local agencies, SECO Energy gained most engagement from users through retweeting a post from NWS (National Weather Service) Tampa Bay. They also posted some original tweets, but these tweets did not gain much engagement from the users. On the contrary, Orlando Utilities Commission (OUC) was active during different stages of Hurricane Irma and posted original tweets regarding public contacts, water/electric outage reports, restoration, and repairs. They also conveyed support, gratitude, and positivity to the users through their tweets. All their original tweets had gained significant engagement from the users. Among the charity-related local agencies, the Salvation Army Orlando also posted many original tweets throughout the hurricane period regarding topics of hurricane preparation, the personnel working in emergency management, recovery crew, and providing meals at different places (Figure 7).



NWS Tampa Bay @NWSTampaBay · Sep 4, 2017  
 #Irma may or may not affect Florida, but it's best to be prepared anyway. Here are a few things you need in your Hurricane kit! #Irma



SECO Energy @SECOenergy · Sep 14, 2017  
 Crews worked overnight restoring power to SECO members after HurricaneIrma. Lots of trucks - beautiful sight! #HurricaneIrma.

↑

SECO Energy gained most interaction through retweeting a post from NWS Tampa Bay.



Orlando Utilities Commission @OUCrelatives · Sep 3, 2017  
 Ahead of HurricaneIrma, be sure to update your contact info via OUC.com or 407-423-9018 (Orlando) 407-957-7273 (Osceola).



Orlando Utilities Commission @OUCrelatives · Sep 10, 2017  
 These are the quickest, most efficient ways to report outages/problems. #HurricaneIrma

**TO REPORT A WATER/ELECTRIC OUTAGE:**

- Call 407-423-9018 (Orlando/Orange County)
- Call 407-957-7373 (St. Cloud/Osceola County)

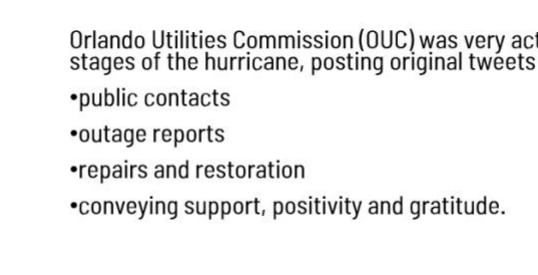
Visit OUC.com



Orlando Utilities Commission @OUCrelatives · Sep 11, 2017  
 Restoration efforts in full force. #HurricaneIrma



Orlando Utilities Commission @OUCrelatives · Sep 19, 2017  
 THANK YOU for the support, patience and positivity as we worked to quickly and safely restore power following Irma! #publicpower #OUCproud



Orlando Utilities Commission @OUCrelatives · Sep 12, 2017  
 Crews continue to work hard in the field making repairs and restoring power. As of 6:30a, 50,000 customers restored. #HurricaneIrma

Orlando Utilities Commission (OUC) was very active during different stages of the hurricane, posting original tweets including topics:

- public contacts
- outage reports
- repairs and restoration
- conveying support, positivity and gratitude.

**Figure 6. Tweets posted by the most engaged Utility related local agencies in the study region during Hurricane Irma.**

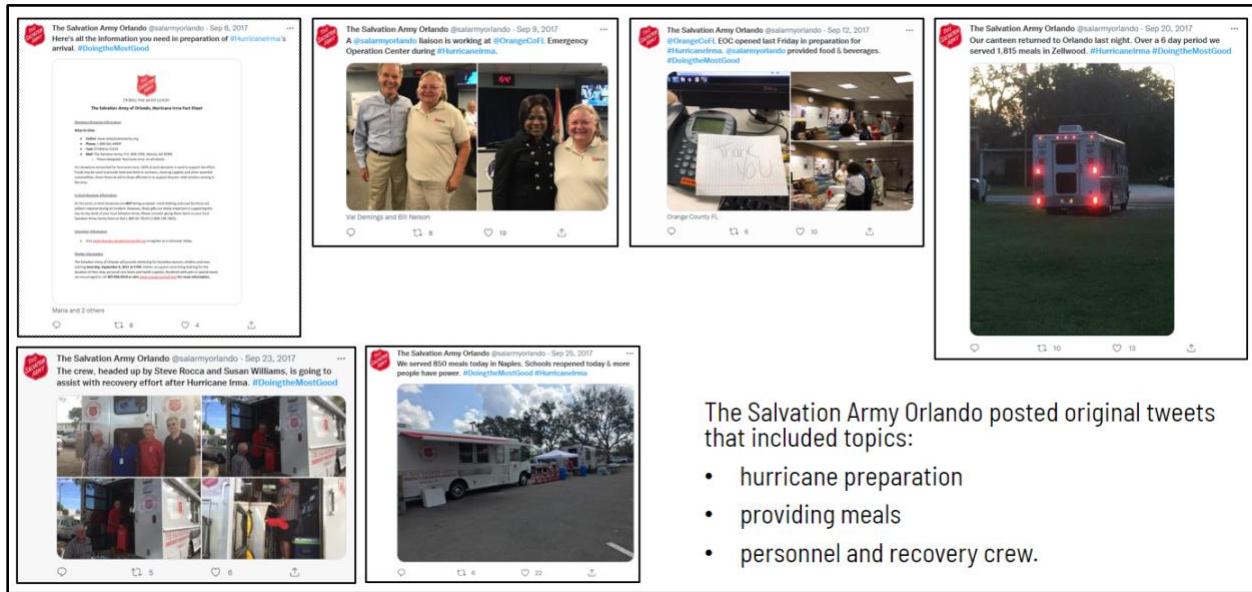


Figure 7. Tweets posted by the Salvation Army Orlando during Hurricane Irma.

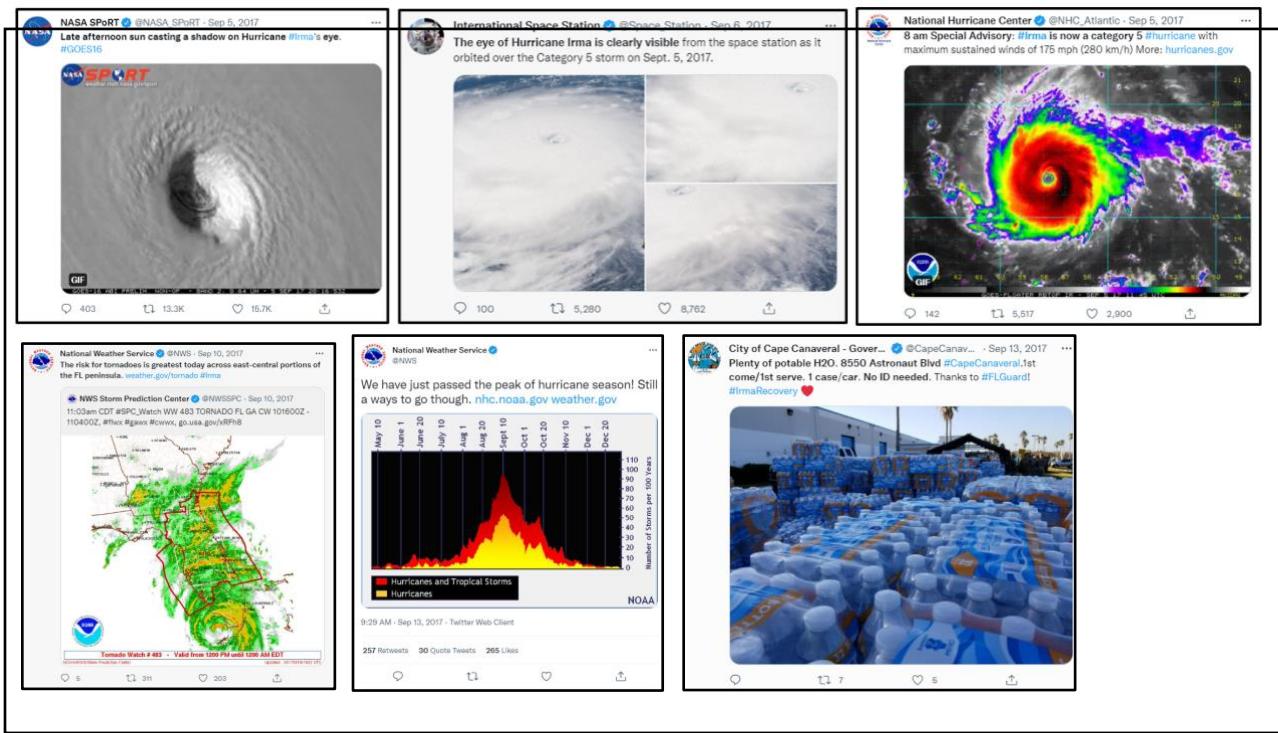


Figure 8. Tweets posted by the city government profiles during Hurricane Irma.

Some city government profiles (City of Cape Canaveral – Govt., Cocoa Beach, FL, City of Orange City) retweeted posts from federal/national and state agency profiles (Figure 8) to gain attention from the users. Even though some city profiles posted some original tweets (e.g., City of Cape Canaveral's water supply related tweets), these did not gain much attention as retweets. County School profiles (Volusia County School Board, Marion County Public Schools) mostly engaged through original tweets regarding class operation times, shelter information, voluntary work, free resources, hurricane updates, etc. (Figure 9).

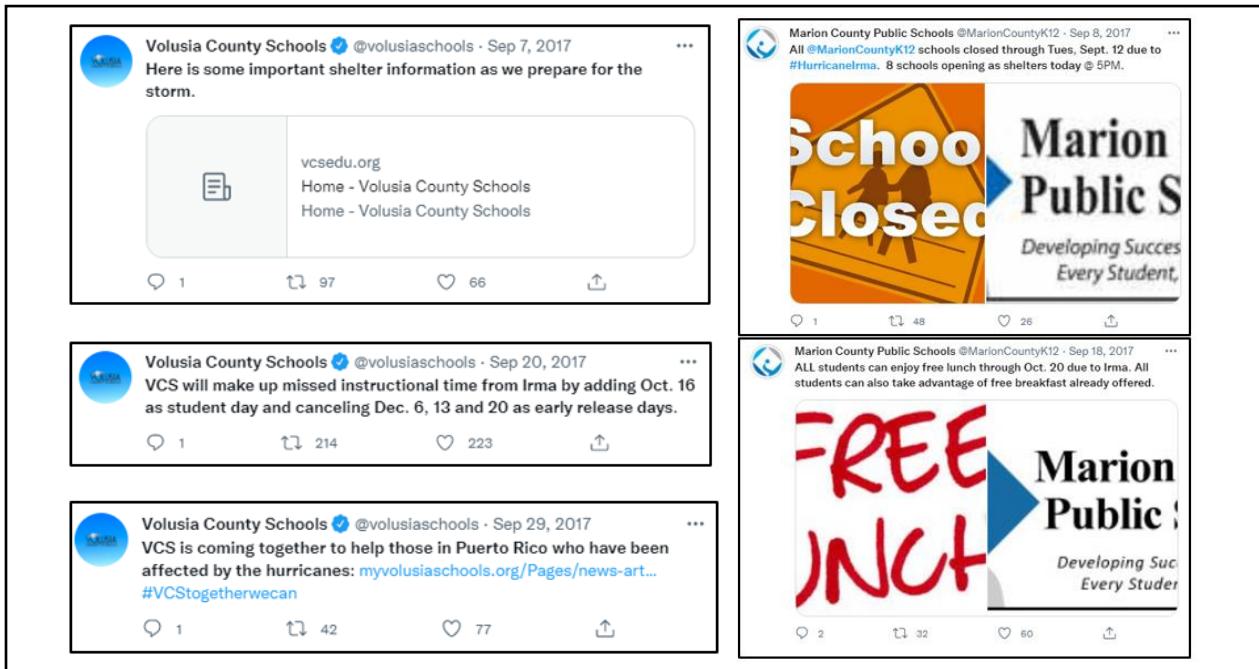


Figure 9. Tweets posted by the county school profiles during Hurricane Irma.

## 5 DISCUSSIONS

### 5.1 Contributions to literature

We believe that this investigation is novel and important because it reports new findings related to crisis communication in Twitter, contributing to literature in several ways.

First, we identify the need to understand the role of local agencies on social media during a natural disaster. While previous studies (22) showed that what type of tweets (for example, warning and updates related to disaster conditions) received highest community engagement, we contribute to the literature by investigating which agencies and what types of agencies received high community engagement on Twitter. From the engagement metric, we observed that local agencies were more engaged in Twitter during Hurricane Irma compared to other levels of organizations not only in terms of the engagement score, but also in all three metrics (Popularity, Commitment, and Virality). These findings provide evidence that, beyond federal- and state-level agencies, the local agencies of a region play a significant role in terms of social-media-based crisis communication during a disaster event by engaging with the public and bolstering community resilience.

Secondly, while most of the previous studies analyzed the tweets or texts (49, 60, 64), we take the advantages of the attributes other than text of the tweets to find the leading agencies during a hurricane. When a major disaster such as a hurricane causes severe damage, it often overwhelms the capacity of local emergency management agencies, and it becomes difficult for them to provide updates and/or respond to community members individually. Hence, it is highly beneficial to identify agencies which can provide timely and correct information to people during a disaster through social media platforms. This refers to our first research question: *Which local agencies are leading in disseminating crisis information during a disaster in social media?* By implementing the engagement metrics, we were able to determine the 180 active agencies and further filter top local agencies in terms of the engagement scores. From the results, it

was observed that despite the nonprofit agencies being only 35 in number among the 180 active agencies, they appeared frequently among the topmost 10 active agencies. Some of these agencies include the Salvation Army Orlando, United Way of Lake and Sumter Counties, and Florida Baptists. However, private agencies did not appear much among the topmost engaged agencies.

Thirdly, while previous studies mainly focused on retweet metric and behavior (46–50), this study emphasizes all three metrics (e.g., likes, replies, and retweets) to effectively measure the engagement performance of the agencies during a hurricane. When measuring the overall performance of a social media account, one important factor is to analyze 'how' people are engaged with the content posted by the account. The methods of engagement include, but are not limited to, features such as likes, comments, retweets, etc. These dimensions indicate different levels and types of engagement that a post extracts from public. The engagement metrics used in the study consider these different dimensions of engagement and convert them into a quantitative score. The results included Popularity (P), Commitment (C), and Virality (V) scores of the local agencies, where the P, C, and V scores represent how the local agencies and general public have engaged in terms of likes, replies, and retweets respectively during the hurricane period. This answered the second question: *How should engagement activities of local agencies in social media for effective crisis communication be measured?* By knowing the performance of their profiles in each of these three metrics, agencies can be aware of their shortcomings in terms of their crisis communication posts on Twitter. For example, some of the highest engaged local agencies in Table 2 have a C score of zero (e.g., Cocoa Beach, FL). This suggests that these agencies should focus on improving their 'commitment' score during a disaster by engaging with public through replying to more tweets. On the other hand, it was noted that utility agencies had a higher C score (e.g., SECO Energy, Orlando Utilities Commission) indicating that these agencies tend to engage more through replying to tweets to address public concerns regarding utility disruption during and after a disaster.

Lastly, we address the need to understand the association between Emergency Support Functions (ESF) and engagement performance of the active agencies. Apart from identifying specific local agencies' profiles on social media platforms, it is also important to be aware of the Emergency Support Functions that are most frequently active on these platforms in terms of crisis communication. Having that knowledge allows local emergency managers to quickly refer information through social media to people as they would know which agencies are disseminating what specific types of information. This refers to our third research question: *How are the Emergency Support Functions (ESFs) associated with the engagement of agencies active in crisis communication posts?* ESFs #2 (Communication) was found to be the most frequent ESF while considering both the 180 active agencies and the 101 local active agencies. From Table 2, it is apparent that ESFs #2, #3, #4, #5, #6, #7, #10, #12, and #19 appeared frequently among the topmost local active agencies. However, we observe that some of the important ESFs appeared less frequently among the active agencies, including ESF #1 (Transportation) and ESF #17 (Animal Protection & Agriculture). Future research should investigate whether the agencies related to these ESFs are less active on Twitter. Similar research should also be done for other disasters to see if there is any change in the frequency of these ESFs among the active agencies. Additionally, considering that agencies are assigned to specific ESFs in the plan and policy documents, practitioners need to ensure that organizational CEMPs' annexes for the ESFs are accurate and updated as necessary, and that for those agencies that are active on Twitter, there is a communication plan in place for engagement on social media.

Despite increasing usage of social media in the context of crisis communication by organizations, there remain questions regarding the engagement performance of their shared contents on these platforms during disasters, especially at a local level. As local agencies are the immediate emergency management contacts of a community when a disaster strikes, it is important to understand the significance of their roles beyond federal and state level agencies. The engagement of their social media crisis-communication posts should be analyzed to understand whether they are utilizing these platforms in the best possible manner to reach people during these times. The engagement metric used in this study has been utilized in previous

studies to assess the social media contents of certain public agencies. However, to the best of our knowledge, it has not yet been adopted in case of crisis communication posts of local agencies.

These findings lead to three propositions for literature on crisis communication in social media for future research consideration:

1. Social-media-based crisis communication can impact public's engagement with emergency management agencies based on their immediate needs during disasters.
2. Different types of local agencies in a region can play a leading role to address the varying needs of a community through crisis communication in social media.
3. Emergency management agencies can characterize, monitor, and improve public engagement of their crisis communication efforts in social media and eliminate public complacency during disaster response.

## **5.2 Implications for practice**

This study provides practical insights on how various public agencies use social media, specifically Twitter, for communication during a crisis like Hurricane Irma. The practical implications of this study are summarized as follows:

- (i) The results show that local agencies were highly engaged in Twitter through their crisis communication posts during Hurricane Irma compared to other levels of agencies. The engagement metrics specified which local agencies were leading according to their Engagement, Popularity, Commitment, and Virality scores. These results will help local emergency managers to determine which Twitter profiles can provide the highest engagement with the public and disseminate information faster during a disaster. By applying the simple engagement metrics on the tweets posted by local agencies, emergency managers can identify which specific agencies to reach out to share information with more people in a short time through Twitter. Additionally, the Popularity, Commitment, and Virality scores of the agencies can shed light on which aspects of communication need further improvements. Allowing local agencies to have this information will improve the content of their crisis communication to local communities.
- (ii) Having the knowledge of the most frequent Emergency Support Functions (ESFs) can further help in determining which group of local agencies may post same types of crisis communication. People can get the most relevant situational updates of their region by following these local agency profiles. Furthermore, these local agencies can build a network among themselves and boost public trust by sharing information through each other's profiles.
- (iii) It is suggested that county-level and regional agencies should receive a verified status from Twitter to generate more followers and gain more attention to their posts. Furthermore, a verified status will allow these local agencies to counteract misinformation during a disaster and to boost their overall engagement with public in terms of other Twitter attributes such as number of retweets, replies, and likes. Besides getting their profiles verified on Twitter, local agencies can post more original tweets containing visual information to gain more engagement from the users.
- (iv) Social media contents that gain greater engagement from people during a disaster can serve as lessons for preparing for future events. Since profiles of the well-known federal/national and state-level organizations are verified and have a large number of followers, retweeting their posts by the local agencies can draw the attention of a large number of local general users and disseminate information.

These efforts can provide opportunities for emergency managers and partner agencies to develop new social media strategies and practices to further improve emergency management at local levels.

## **5.3 Theoretical Implications**

The study also provides theoretical implications centering around the evolving role of social media in crisis communication for better coordinating disaster response operations. The use of social media in crisis communication is seen as complementary to traditional communication strategies such as press releases and reverse 911 calls or text messaging. In particular, in the big data era, when big influxes of needs and requests emerge from community members and organizations during and after a major disaster event (such as Hurricane Irma), social media platforms as an instrument to collect life-essential real-time data from those at risk have shared the burdens of high-volume calls into the 911 or 311 call centers in the localities. Additionally, machine learning and other artificial intelligence techniques have streamlined big data analytics (e.g., interpreting images and extract the meaning they deliver, and verify with the text posted along with these images) and made information sorted and presented in a timely fashion for decision-makers to issue protective actions (such as evacuation and shelter in place). Researchers can build on these findings to develop and refine communication theories or models that incorporate social media as a vital communication channel during disasters and crises. The role of social-media-based crisis communication can also be discussed in effective and timely coordination of response operations. The use of engagement metrics (Popularity, Commitment, Virality, and Engagement scores) in this study highlights their importance in assessing the effectiveness of social media communication during crises. Theoretical implications could involve the development of more nuanced metrics or models for measuring engagement and its impact on information dissemination and public response in disaster situations.

By analyzing various levels of government agencies and organizations engage in disaster response, the study sheds light on differences in their social media engagement strategies in disaster response and coordination response efforts to help individuals, families, and communities impacted by disasters. Theoretical implications may relate to organizational communication theories (84), considering how the structure, resources, and goals of different agencies influence their social media practices during crises. The qualitative content analysis of tweets from the most engaged agencies offers theoretical implications related to the types of information and messaging that resonate with the public during disasters. This can inform crisis communication theories and practices, emphasizing the importance of tailoring messages to audience needs and preferences.

## 6 CONCLUSION

This study presents the results of an exploratory analysis of the local agencies from eight counties of the East Central Florida Region on the engagement of their crisis communication posts in a social media platform. Although the focus was on local (county and regional level) agencies, we also considered federal, national, state, and other levels of agencies to compare the significance of the roles of local agencies in bolstering crisis communication in social media. The primary aim was to have a quantitative analysis to gauge the overall engagement of the agency profiles and find out correlating ESFs. We also undertook a qualitative approach to provide preliminary insights on the role of Twitter profile attributes and tweet contents on engagement metrics. These methods and analyses demonstrate the critical role of collecting, organizing, and disseminating relevant information using crisis communication strategies in a timely manner from trusted sources for effective disaster response coordination.

This study has some limitations. We considered only one disaster (Hurricane Irma) and one social media platform (Twitter). Our results could vary for other hurricanes or other disasters such as the COVID-19 pandemic. Future research should consider multiple disasters to test the validity of our findings across different types of disasters and to obtain insights on which agency profiles should be followed during a specific type of disaster situation. Another limitation was that due to the limitations of Twitter API, the number of followers and friends of the agencies could not be extracted from Hurricane Irma's period. Therefore, when applying the engagement metrics, the current numbers of followers were used. It should be considered that the number of Twitter users has increased significantly over time. According to the

official Twitter statistics, the total number of daily monetizable active users is currently 217 million, whereas it was only 110 million by the end of the year 2017 (the year of Hurricane Irma). Hence, it is recommended that future research collects and analyzes Twitter data immediately following an event as the historical data may not reflect the current follower counts of profiles.

Furthermore, some of the agencies were found to be active on Twitter but not reflected in the Content Analysis Codebook, for which general ESFs (such as #2, #5, #6, and #7) were applied. Moreover, a limitation was that we could not determine the number of retweets an agency gained from their own followers when retweeting a post of a well-known agency. As such the specific contribution of an agency to the number of retweets is unknown. If the information was available from Twitter on how many retweets an agency attained by retweeting a post, beyond what the source agency has attained, the corresponding engagement metric could be calculated more accurately.

In this study, we manually reviewed the contents of the highly retweeted posts. Future research can develop advanced machine learning models (e.g., topic models) to obtain quantitative insights on the prevalent topics during a disaster. Moreover, cross-sector partnerships among different local agencies on social media platforms should be analyzed to understand how their networking patterns are influencing the engagement of their crisis communication posts.

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## REFERENCES

1. Kapucu, N., Y. 'Gurt' Ge, Y. Martín, and Z. Williamson. Urban Resilience for Building a Sustainable and Safe Environment. *Urban Governance*, Vol. 1, No. 1, 2021, pp. 10–16. <https://doi.org/10.1016/J.UGJ.2021.09.001>.
2. Norris, F. H., S. P. Stevens, B. Pfefferbaum, K. F. Wyche, and R. L. Pfefferbaum. Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness. *American Journal of Community Psychology*, Vol. 41, No. 1–2, 2008, pp. 127–150. <https://doi.org/10.1007/s10464-007-9156-6>.
3. Marra, F. J. Crisis Communication Plans: Poor Predictors of Excellent Crisis Public Relations. *Public Relations Review*, Vol. 24, No. 4, 1998, pp. 461–474. [https://doi.org/10.1016/S0363-8111\(99\)80111-8](https://doi.org/10.1016/S0363-8111(99)80111-8).
4. Millar, D. P., and R. L. Heath. Responding to Crisis: A Rhetorical Approach to Crisis Communication. *Responding to Crisis: A Rhetorical Approach to Crisis Communication*, 2003, pp. 1–379. <https://doi.org/10.4324/9781410609496>.
5. Roshan, M., M. Warren, and R. Carr. Understanding the Use of Social Media by Organisations for Crisis Communication. *Computers in Human Behavior*, Vol. 63, 2016, pp. 350–361. <https://doi.org/10.1016/j.chb.2016.05.016>.

6. Kapucu, N., E. M. Berman, and X. H. Wang. Emergency Information Management and Public Disaster Preparedness: Lessons from the 2004 Florida Hurricane Season. *International Journal of Mass Emergencies and Disasters*, Vol. 26, No. 3, 2008, pp. 169–196.
7. Emergency Support Functions: Why Are They Important? | NOAA's Office of Response & Restoration Blog. <https://blog.response.restoration.noaa.gov/emergency-support-functions-why-are-they-important>. Accessed Jul. 24, 2022.
8. National Response Framework | FEMA.Gov. <https://www.fema.gov/emergency-managers/national-preparedness/frameworks/response#esf>. Accessed Jul. 24, 2022.
9. Kapucu, N., R. Okhai, and Q. Hu. Network Governance for Coordinated Disaster Response. *Public Administration Quarterly*, Vol. 46, No. 4, 2022, pp. 309–333. <https://doi.org/10.37808/PAQ.46.4.2>.
10. Palen, L., and A. L. Hughes. Social Media in Disaster Communication. *Handbooks of Sociology and Social Research*, 2018, pp. 497–518. [https://doi.org/10.1007/978-3-319-63254-4\\_24](https://doi.org/10.1007/978-3-319-63254-4_24).
11. Ohme, J., M. M. P. vanden Abeele, K. van Gaeveren, W. Durnez, and L. de Marez. Staying Informed and Bridging “Social Distance”: Smartphone News Use and Mobile Messaging Behaviors of Flemish Adults during the First Weeks of the COVID-19 Pandemic. *Socius: sociological research for a dynamic world*, Vol. 6, 2020, p. 2378023120950190. <https://doi.org/10.1177/2378023120950190>.
12. Saroj, A., and S. Pal. Use of Social Media in Crisis Management: A Survey. *International Journal of Disaster Risk Reduction*, Vol. 48, 2020, p. 101584. <https://doi.org/10.1016/J.IJDRR.2020.101584>.
13. Chandra Roy, K., M. Ashraf Ahmed, S. Hasan, and A. Mohaimin Sadri. Dynamics of Crisis Communications in Social Media: Spatio-Temporal and Text-Based Comparative Analyses of Twitter Data from Hurricanes Irma and Michael Understanding Community Response in the Emergence and Spread of Novel Coronavirus through Health Risk Communications in Socio-Technical Systems View Project.
14. Brown, J. Is Social Media the Key to Effective Communication During Campus Emergencies? <https://www.govtech.com/em/disaster/social-media-communication-campus-emergencies.html>. Accessed Jul. 20, 2022.
15. Kim, J., J. Bae, and M. Hastak. Emergency Information Diffusion on Online Social Media during Storm Cindy in U.S. *International Journal of Information Management*, Vol. 40, 2018, pp. 153–165. <https://doi.org/10.1016/J.IJINFOMGT.2018.02.003>.
16. Lovari, A., and C. Valentini. Public Sector Communication and Social Media. *The Handbook of Public Sector Communication*, 2020, pp. 315–328. <https://doi.org/10.1002/9781119263203.CH21>.
17. Lovari, A., and S. A. Bowen. Social Media in Disaster Communication: A Case Study of Strategies, Barriers, and Ethical Implications. *Journal of Public Affairs*, Vol. 20, No. 1, 2020, p. e1967. <https://doi.org/10.1002/PA.1967>.
18. Zhang, C., C. Fan, W. Yao, X. Hu, and A. Mostafavi. Social Media for Intelligent Public Information and Warning in Disasters: An Interdisciplinary Review. *International Journal of*

*Information Management*, Vol. 49, 2019, pp. 190–207.  
<https://doi.org/10.1016/J.IJINFOMGT.2019.04.004>.

19. Roy, K. C., S. Hasan, A. M. Sadri, and M. Cebrian. Understanding the Efficiency of Social Media Based Crisis Communication during Hurricane Sandy. *International Journal of Information Management*, Vol. 52, 2020. <https://doi.org/10.1016/j.ijinfomgt.2019.102060>.
20. Chatfield, A. T., and C. G. Reddick. All Hands on Deck to Tweet #sandy: Networked Governance of Citizen Coproduction in Turbulent Times. *Government Information Quarterly*, Vol. 35, No. 2, 2018, pp. 259–272. <https://doi.org/10.1016/j.giq.2017.09.004>.
21. Ahmed, M. A., A. M. Sadri, and M. H. Amini. Data-Driven Inferences of Agency-Level Risk and Response Communication on COVID-19 through Social Media Based Interactions. 2020. <https://doi.org/10.5055/jem.0589>.
22. Kankanamge, N., T. Yigitcanlar, and A. Goonetilleke. How Engaging Are Disaster Management Related Social Media Channels? The Case of Australian State Emergency Organisations. *International Journal of Disaster Risk Reduction*, Vol. 48, 2020. <https://doi.org/10.1016/j.ijdrr.2020.101571>.
23. 5 Years Later: Hurricane Irma in Florida | FEMA.Gov. <https://www.fema.gov/fact-sheet/5-years-later-hurricane-irma-florida>. Accessed Oct. 20, 2022.
24. Hurricane Irma: The Landfall, The Aftermath, The Recovery. <https://www.teamcomplete.com/hurricane-irma/>. Accessed Oct. 20, 2022.
25. 2017 Hurricane Irma: Facts, FAQs, and How to Help | World Vision. <https://www.worldvision.org/disaster-relief-news-stories/2017-hurricane-irma-facts#facts>. Accessed Oct. 20, 2022.
26. Ongoing Crisis Communication: Planning, Managing, and Responding - W. Timothy Coombs - Google Books. <https://books.google.com/books?hl=en&lr=&id=CkkXBAAAQBAJ&oi=fnd&pg=PR1&ots=NIxe3oji8h&sig=MlyYswgMPPuGOx0gpl8AwhndiH4#v=onepage&q&f=false>. Accessed Dec. 5, 2021.
27. Coombs, W. T. The Protective Powers of Crisis Response Strategies. [https://doi.org/10.1300/J057v12n03\\_13](https://doi.org/10.1300/J057v12n03_13), Vol. 12, No. 3–4, 2008, pp. 241–260. [https://doi.org/10.1300/J057V12N03\\_13](https://doi.org/10.1300/J057V12N03_13).
28. Coombs, W. T. Protecting Organization Reputations During a Crisis: The Development and Application of Situational Crisis Communication Theory. *Corporate Reputation Review*, Vol. 10, No. 3, 2007, pp. 163–176. <https://doi.org/10.1057/PALGRAVE.CRR.1550049/TABLES/3>.
29. Coombs, W. T. The Value of Communication during a Crisis: Insights from Strategic Communication Research. *Business Horizons*, Vol. 58, No. 2, 2015, pp. 141–148. <https://doi.org/10.1016/j.bushor.2014.10.003>.
30. Sturges, D. L. Communicating through Crisis: A Strategy for Organizational Survival. <http://dx.doi.org/10.1177/0893318994007003004>, Vol. 7, No. 3, 2016, pp. 297–316. <https://doi.org/10.1177/0893318994007003004>.

31. Roshan, M., M. Warren, and R. Carr. Understanding the Use of Social Media by Organisations for Crisis Communication. *Computers in Human Behavior*, Vol. 63, 2016, pp. 350–361. <https://doi.org/10.1016/J.CHB.2016.05.016>.
32. Hu, Q., S. An, N. Kapucu, T. Sellnow, M. Yuksel, and R. Freihaut. Dynamics of Interorganizational Emergency Communication on Twitter: The Case of Hurricane Irma. *Disasters*, 2022. <https://doi.org/10.1111/DISA.12547>.
33. Hale, J. A Layered Communication Architecture for the Support of Crisis Response. *Journal of Management Information Systems*, Vol. 14, No. 1, 1997, pp. 235–255. <https://doi.org/10.1080/07421222.1997.11518160>.
34. Kaplan, A. M., and M. Haenlein. Users of the World, Unite! The Challenges and Opportunities of Social Media. *Business Horizons*, Vol. 53, No. 1, 2010, pp. 59–68. <https://doi.org/10.1016/J.BUSHOR.2009.09.003>.
35. Jin, Y., B. F. Liu, and L. L. Austin. Examining the Role of Social Media in Effective Crisis Management: The Effects of Crisis Origin, Information Form, and Source on Publics' Crisis Responses. *Communication Research*, Vol. 41, No. 1, 2014, pp. 74–94. <https://doi.org/10.1177/0093650211423918>.
36. Nan, N., and Y. Lu. Harnessing the Power of Self-Organization in an Online Community During Organizational Crisis HARNESSING THE POWER OF SELF-ORGANIZATION IN AN ONLINE COMMUNITY DURING ORGANIZATIONAL CRISIS 1. *Source: MIS Quarterly*, Vol. 38, No. 4, 2014, pp. 1135–1158. <https://doi.org/10.2307/26627965>.
37. Eriksson, M. Lessons for Crisis Communication on Social Media: A Systematic Review of What Research Tells the Practice. *International Journal of Strategic Communication*, 2018. <https://doi.org/10.1080/1553118X.2018.1510405>, Vol. 12, No. 5, pp. 526–551. <https://doi.org/10.1080/1553118X.2018.1510405>.
38. Mackay, M., T. Colangeli, D. Gillis, J. McWhirter, and A. Papadopoulos. Examining Social Media Crisis Communication during Early COVID-19 from Public Health and News Media for Quality, Content, and Corresponding Public Sentiment. *International Journal of Environmental Research and Public Health* 2021, Vol. 18, Page 7986, Vol. 18, No. 15, 2021, p. 7986. <https://doi.org/10.3390/IJERPH18157986>.
39. Eismann, K., O. Posegga, and K. Fischbach. Opening Organizational Learning in Crisis Management: On the Affordances of Social Media. *Journal of Strategic Information Systems*. 4. Volume 30.
40. Brooke Auxier, B., and M. Anderson. *Social Media Use in 2021 FOR MEDIA OR OTHER INQUIRIES*. 2021.
41. Xu, J. Does the Medium Matter? A Meta-Analysis on Using Social Media vs. Traditional Media in Crisis Communication. *Public Relations Review*, Vol. 46, No. 4, 2020, p. 101947. <https://doi.org/10.1016/j.pubrev.2020.101947>.
42. Olofinlua, T., and D. Murthy. Twitter: Social Communication in the Twitter Age. *Information, Communication & Society*, Vol. 22, No. 13, 2019, pp. 2037–2038. <https://doi.org/10.1080/1369118X.2019.1620824>.

43. Eriksson, M., and E.-K. Olsson. Facebook and Twitter in Crisis Communication: A Comparative Study of Crisis Communication Professionals and Citizens. *Journal of Contingencies and Crisis Management*, Vol. 24, No. 4, 2016, pp. 198–208. <https://doi.org/10.1111/1468-5973.12116>.

44. Li, J., and H. R. Rao. Twitter as a Rapid Response News Service: An Exploration in the Context of the 2008 China Earthquake. *The Electronic Journal of Information Systems in Developing Countries*, Vol. 42, No. 1, 2010, pp. 1–22. <https://doi.org/10.1002/j.1681-4835.2010.tb00300.x>.

45. Guy, M., P. Earle, C. Ostrum, K. Gruchalla, and S. Horvath. Integration and Dissemination of Citizen Reported and Seismically Derived Earthquake Information via Social Network Technologies, pp. 42–53.

46. Kogan, M., L. Palen, and K. M. Anderson. Think Local, Retweet Global. 2015.

47. Starbird, K., and L. Palen. *Starbird et al. Pass It On? Retweeting in Mass Emergency Pass It On? Retweeting in Mass Emergency*. 2010.

48. Rao, H. R., N. Vemprala, P. Akello, and R. Valecha. Retweets of Officials' Alarming vs Reassuring Messages during the COVID-19 Pandemic: Implications for Crisis Management. *International Journal of Information Management*, Vol. 55, 2020. <https://doi.org/10.1016/j.ijinfomgt.2020.102187>.

49. Lin, X., K. A. Lachlan, and P. R. Spence. Exploring Extreme Events on Social Media: A Comparison of User Reposting/Retweeting Behaviors on Twitter and Weibo. *Computers in Human Behavior*, Vol. 65, 2016, pp. 576–581. <https://doi.org/10.1016/j.chb.2016.04.032>.

50. Son, J., H. K. Lee, S. Jin, and J. Lee. Content Features of Tweets for Effective Communication during Disasters: A Media Synchronicity Theory Perspective. *International Journal of Information Management*, Vol. 45, 2019, pp. 56–68. <https://doi.org/10.1016/j.ijinfomgt.2018.10.012>.

51. Power, R., B. Robinson, J. Colton, and M. Cameron. Emergency Situation Awareness: Twitter Case Studies, pp. 218–231.

52. Vieweg, S., A. L. Hughes, K. Starbird, and L. Palen. Microblogging during Two Natural Hazards Events. 2010.

53. Hughes, A. L., L. A. A. St. Denis, L. Palen, and K. M. Anderson. Online Public Communications by Police Fire Services during the 2012 Hurricane Sandy. 2014.

54. Hiltz, S., M. Pfaff, L. Plotnick, A. Robinson, L. Ann St Denis, L. Palen, and K. M. Anderson. *Mastering Social Media: An Analysis of Jefferson County's Communications during the 2013 Colorado Floods*. 2013.

55. Caragea, C., N. McNeese, A. Jaiswal, G. Traylor, H.-W. Kim, P. Mitra, D. Wu, A. H. Tapia, L. Giles, B. J. Jansen, and J. Yen. *Classifying Text Messages for the Haiti Earthquake*. 2011.

56. Paul S., Daniel C., and Michelle Guy. Twitter Earthquake Detection: Earthquake Monitoring in a Social World. *Annals of Geophysics*, Vol. 54, No. 6, 2012. <https://doi.org/10.4401/ag-5364>.

57. Sakaki, T., M. Okazaki, and Y. Matsuo. Earthquake Shakes Twitter Users. 2010.

58. Imran, M., S. Elbassuoni, C. Castillo QCRI, F. Diaz, and P. Meier QCRI. *Extracting Information Nuggets from Disaster-Related Messages in Social Media*. 2013.

59. Kumar, S., X. Hu, and H. Liu. A Behavior Analytics Approach to Identifying Tweets from Crisis Regions. 2014.

60. Lachlan, K. A., Z. Xu, E. E. Hutter, R. Adam, and P. R. Spence. A Little Goes a Long Way: Serial Transmission of Twitter Content Associated with Hurricane Irma and Implications for Crisis Communication. *Journal of Strategic Innovation and Sustainability*, Vol. 14, No. 1, 2019. <https://doi.org/10.33423/jsis.v14i1.984>.

61. Kryvasheyev, Y., H. Chen, E. Moro, P. Van Hentenryck, and M. Cebrian. Performance of Social Network Sensors during Hurricane Sandy. *PLOS ONE*, Vol. 10, No. 2, 2015, p. e0117288. <https://doi.org/10.1371/journal.pone.0117288>.

62. Wang, Q., and J. E. Taylor. Quantifying Human Mobility Perturbation and Resilience in Hurricane Sandy. *PLoS ONE*, Vol. 9, No. 11, 2014, p. e112608. <https://doi.org/10.1371/journal.pone.0112608>.

63. Wang, Q., and J. E. Taylor. Resilience of Human Mobility Under the Influence of Typhoons. *Procedia Engineering*, Vol. 118, 2015, pp. 942–949. <https://doi.org/10.1016/j.proeng.2015.08.535>.

64. Lachlan, K. A., P. R. Spence, X. Lin, K. Najarian, and M. Del Greco. Social Media and Crisis Management: CERC, Search Strategies, and Twitter Content. *Computers in Human Behavior*, Vol. 54, 2016, pp. 647–652. <https://doi.org/10.1016/j.chb.2015.05.027>.

65. Starbird, K., and L. Palen. “Voluntweeters”: Self-Organizing by Digital Volunteers in Times of Crisis. *Conference on Human Factors in Computing Systems - Proceedings*, 2011, pp. 1071–1080. <https://doi.org/10.1145/1978942.1979102>.

66. Twitter Hashtags for Emergency Coordination and Disaster Relief – Factory Joe. <https://factoryjoe.com/2007/10/22/twitter-hashtags-for-emergency-coordination-and-disaster-relief/>. Accessed Jul. 28, 2022.

67. Starbird, K., and J. Stamberger. Tweak the Tweet: Leveraging Microblogging Proliferation with a Prescriptive Syntax to Support Citizen Reporting. *Proceedings of the 7th International ISCRAM Conference –Seattle, USA*, 2010. <https://doi.org/10.1184/R1/6711668.V1>.

68. Vieweg, S., A. L. Hughes, K. Starbird, and L. Palen. *Microblogging During Two Natural Hazards Events: What Twitter May Contribute to Situational Awareness*.

69. Rachunok, B., C. Fan, R. Lee, R. Nateghi, and A. Mostafavi. Is the Data Suitable? The Comparison of Keyword versus Location Filters in Crisis Informatics Using Twitter Data. *International Journal of Information Management Data Insights*, Vol. 2, No. 1, 2022. <https://doi.org/10.1016/j.jjimei.2022.100063>.

70. Wang, Y., H. Hao, and L. S. Platt. Examining Risk and Crisis Communications of Government Agencies and Stakeholders during Early-Stages of COVID-19 on Twitter. *Computers in Human Behavior*, Vol. 114, 2021, p. 106568. <https://doi.org/10.1016/j.chb.2020.106568>.

71. Abramova, O., K. Batzel, and D. Modesti. Collective Response to the Health Crisis among German Twitter Users: A Structural. *International Journal of Information Management Data Insights*, Vol. 2, No. 2, 2022. <https://doi.org/10.1016/j.jjimei.2022.100126>.

72. Vera-Burgos, C. M., and D. R. Griffin Padgett. Using Twitter for Crisis Communications in a Natural Disaster: Hurricane Harvey. *Heliyon*, Vol. 6, No. 9, 2020, p. e04804. <https://doi.org/10.1016/j.heliyon.2020.e04804>.

73. Sadri, A. M., S. Hasan, S. V. Ukkusuri, and M. Cebrian. Crisis Communication Patterns in Social Media during Hurricane Sandy. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2672, No. 1, 2018, pp. 125–137. <https://doi.org/10.1177/0361198118773896>.

74. Fan, C., Y. Jiang, and A. Mostafavi. The Role of Local Influential Users in Spread of Situational Crisis Information. *Journal of Computer-Mediated Communication*, Vol. 26, No. 2, 2021, pp. 108–127. <https://doi.org/10.1093/jcmc/zmaa020>.

75. Gongora-Svartzman, G., and J. E. Ramirez-Marquez. Social Cohesion: Mitigating Societal Risk in Case Studies of Digital Media in Hurricanes Harvey, Irma, and Maria. *Risk Analysis*, Vol. 42, No. 8, 2022, pp. 1686–1703. <https://doi.org/10.1111/risa.13820>.

76. Vera-Burgos, C. M., and D. R. Griffin Padgett. Using Twitter for Crisis Communications in a Natural Disaster: Hurricane Harvey. *Heliyon*, Vol. 6, No. 9, 2020. <https://doi.org/10.1016/j.heliyon.2020.e04804>.

77. Neely, S. R., and M. Collins. Social Media and Crisis Communications: A Survey of Local Governments in Florida. *Journal of Homeland Security and Emergency Management*. 1. Volume 15.

78. Knox, C. C. Local Emergency Management’s Use of Social Media during Disasters: Case Study of Hurricane Irma. *Disasters*, 2022. <https://doi.org/10.1111/DISA.12544>.

79. Kapucu, N., R. Okhai, Y. Ge, and C. Zobel. The Use of Documentary Data for Network Analysis in Emergency and Crisis Management. *Natural Hazards*, 2022, pp. 1–21. <https://doi.org/10.1007/S11069-022-05681-5/FIGURES/6>.

80. Search Tweets Introduction | Docs | Twitter Developer Platform. <https://developer.twitter.com/en/docs/twitter-api/tweets/search/introduction>. Accessed Jul. 30, 2022.

81. Bonsón, E., and M. Ratkai. A Set of Metrics to Assess Stakeholder Engagement and Social Legitimacy on a Corporate Facebook Page. *Online Information Review*, Vol. 37, No. 5, 2013, pp. 787–803. <https://doi.org/10.1108/OIR-03-2012-0054>.

82. Rahman, R., K. C. Roy, M. Abdel-Aty, and S. Hasan. Sharing Real-Time Traffic Information with Travelers Using Twitter: An Analysis of Effectiveness and Information Content. *Frontiers in Built Environment*, Vol. 5, 2019. <https://doi.org/10.3389/fbuil.2019.00083>.

83. Wies, S., A. Bleier, and A. Edeling. Finding Goldilocks Influencers: How Follower Count Drives Social Media Engagement. *Journal of Marketing*, Vol. 87, No. 3, 2023, pp. 383–405. <https://doi.org/10.1177/00222429221125131>.

84. Lindell, M. K., C. S. Prater, and W. Gillis Peacock. Organizational Communication and Decision Making for Hurricane Emergencies. *Nat. Hazards Rev.*, Vol. 8, No. 3, 2007, pp. 50–60. <https://doi.org/10.1061/ASCE1527-698820078:350>.