Social Media in Disaster Communication

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Social media[1] have changed the ways in which the public can participate in disaster and other mass emergencies. For instance, users of social media have demonstrated how broad and ready access to other people during a disaster event enables new forms of information seeking and sharing, as well as exchanges of assistance (Hughes, Palen, Sutton, Liu, & Vieweg, 2008; Palen & Liu, 2007). Through social media, a growing number of eyewitness texts, photos, videos, maps, and other information are available around disaster events, information that was hard to access before social media. Meanwhile, emergency management organizations seek to respond to the new content and these new communication platforms: the initial focus on developing and executing best practices for outward communications is now giving way to discussions about augmenting response efforts with inclusion of data from the public (Hughes & Palen, 2012; Latonero & Shklovski, 2011; Ludwig, Reuter, & Pipek, 2015). The research field of *crisis informatics* (Hagar & Haythornthwaite, 2005; Palen, Vieweg, Liu, & Hughes, 2009) has arisen in response. Researchers of crisis informatics investigate the nature of socio-behavioral phenomena in mass emergency mediated by social media environments and devise new methods for its investigation (Foot & Schneider, 2004; Foot, Warnick, & Schneider, 2005).

The chapter begins with a brief history of the emergence of social media activity in relation to disasters and other mass emergencies to help the reader to understand how crisis informatics research has evolved in scope and depth to address the changing socio-technical environment. We then survey the major themes that have emerged in the field of crisis informatics over the decade since

[1]Social media are Internet-based applications that promote high social interaction and user-content generation often at a one-to-many or a many-to-many scale. Most social media services are supported across multiple devices including smartphones, computers, and tablets. Examples of popular social networking applications include Facebook, Twitter, YouTube, and Flickr.

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its inception. After presenting these themes, we then aim to clarify an issue about the differences in social media behavior arising from natural hazards versus criminal events—an issue that has confused researchers and readers of the growing array of papers across a field comprised of many disciplines and audiences. We call this the *social media and crisis confound*, and we believe that foregrounding this issue will support better communication of crisis informatics knowledge to the interdisciplinary audiences that might engage with it. We conclude with a discussion of future directions for crisis informatics research.

24.1 A Brief History

As social media use began to take hold in about 2007, research on the phenomena in mass emergencies emerged soon after. Predating this period, however, interaction via the web (including web sites and blog sites) around mass emergencies events was gaining, portending that collective action would soon become commonplace across social media. In response to the September 11, 2001 attacks in the US, researchers examined how people expressed themselves on the web during disaster events (Foot & Schneider, 2004; Foot et al., 2005). In the aftermath of the December 2004 Indian Ocean Tsunami, researchers noted the use of Flickr, what could be considered the first "social media" image-sharing site even though "social media" was not a term in use at that time (Liu, Palen, Sutton, Hughes, & Vieweg, 2008). Additionally, the Sahana Software Foundation emerged as a result of the tsunami. Sahana employed *open source* disaster management software to enable rapid development and wide access, appealing to the same broad participation and self-organizing ideals that propelled social media development and adoption (Careem, De Silva, De Silva, Raschid, & Weerawarana, 2006; Currion, De Silva, & Van de Walle, 2007).

Hurricane Katrina in 2005 drew even more attention to the potential of peer-to-peer communication in response to a crisis event (Macias, Hilyard, & Freimuth, 2009; Palen & Liu, 2007; Procopio & Procopio, 2007; Robinson, 2009; Shklovski, Burke, Kiesler, & Kraut, 2010; Torrey et al., 2007). Blogs and online forums following Hurricane Katrina provided places where displaced citizens could connect with members of their geographically-based communities to exchange information and cope with their loss (Procopio & Procopio, 2007; Shklovski et al., 2010). Torrey et al. (2007) found that several citizens used online means to coordinate disaster relief, such as the donation of clothes, toys, and other items. Additional research discovered cases where citizens used social media to help find missing persons as well as housing for victims (Macias et al., 2009; Palen & Liu, 2007). These initial studies demonstrated that through social media, citizens could offer and obtain crisis-related information (Palen & Liu, 2007) as well as participate in disaster response and recovery efforts even when remotely-located from physical disaster sites (Heverin & Zach, 2010; Hughes et al., 2008; Qu, Huang, Zhang, & Zhang, 2011; Vieweg, Hughes, Starbird, & Palen, 2010).

After Hurricane Katrina, research continued to explore social media activity in times of mass emergency, expanding to a variety of hazards. College students took advantage of already established networks in social media, most notably on Facebook during the 2007 Virginia Tech shootings and the 2008 Northern Illinois University shooting (Palen & Vieweg, 2008). Students accessed Facebook but also instant and text messaging services to assess the impact of the event on their wide and diffuse social network, discovering who among their colleagues were safe or not (Palen et al., 2009; Vieweg, Palen, Liu, Hughes, & Sutton, 2008). Public participation during the 2007 Southern California wildfires demonstrated how social media could function as an important "backchannel," where members of the public could informally obtain, provide, and seek information that clarified and expanded upon the information they received from formal emergency response channels (Sutton et al., 2008). It was here, too, that the Twitter *hashtag* was invented by users in need of filtered information (Credited to Chris Messina, personal communication; Starbird et al., 2012b). Other

studies looked at the role that social media could play in repairing human infrastructure and creating a sense of normalcy amid on-going conflict and war (De Choudhury, Monroy-Hernández, & Mark, 2014; Mark, Al-Ani, & Semaan, 2009a; Mark & Semaan, 2008), and in supporting civic journalism in "urban warfare" (Monroy-Hernández, boyd, danah, Kiciman, De Choudhury, & Counts, 2013). Qu, Wu, & Wang (2009) studied a popular online forum in China —*Tianya*—following the 2008 Sichuan Earthquake and found that the forum provided a place for information sharing, seeking, gathering, and integrating as well as a place where community members could provide emotional support. These research findings demonstrated social media's range of use and captured the attention of emergency responders who were beginning to consider whether social media could benefit formal response efforts.

Emergency management groups attended to the rise of social media platforms and considered how they might be included in their communication activities. Public risk communications were largely imagined as one-way pathways that flowed from emergency response organizations to members of the public (Palen & Liu, 2007), and so adoption of social media challenged this frame. Members of the public made use of new opportunities for participating in crisis response and recovery efforts, which made newly visible the socio-behavioral phenomena that were always present—that of a public who informally participates in disaster response. Emergency managers had to consider not only the new role social media would play in outgoing communications, but how they would participate in the digital information ecosystem (Denef, Bayerl, & Kaptein, 2013; St. Denis, Hughes, & Palen, 2012). With readily-available ways for the public to communicate with peers, to generate information that could be tactically valuable to response, and to perform support functions that could complement emergency response strategies (Meraz, 2006; Palen & Liu, 2007), crisis informatics research launched investigations of these behaviors and how they could be shaped for future visions of emergency management.

24.2 Research Themes

The growth of the field of crisis informatics, like the growth of social media adoption, has been rapid and diverse. In the following sections, we distill a majority of the research literature into eight broad themes organized into three groups. First, we review the socio-technical innovations that arose with the advent of social media. Mirroring the first empirical observations of social media activity in mass emergencies, we describe activities by the public (citizen reporting, community-oriented computing, and collective intelligence and distributed problem solving) and demonstrate how social media have shaped—and continue to shape—perceptions around how members of the public can participate in emergencies. Next, we discuss how social media communications are being treated and explored as data sources, and specifically as a way to contribute to situational awareness, along with the then accompanying challenges in collecting, processing, and verifying large amounts of social media data around crisis events. Finally, we address applications to emergency management, considering how emergency response groups are reacting to the communicative shifts and adapting their policies and practices in response.

24.2.1 Part 1. Socio-Technical Innovations Afforded by Social Media

24.2.1.1 Citizen Reporting

The ability for people to report from on-the-ground during and after an event drives much of the attention to social media use, and is attached to ideas of citizens as "sensors" (Goodchild, 2007)—people who detect, measure, and report local emergency information—as well as journalists (Gillmor, 2006)—people who collect, report, analyze, and disseminate information

as news. In the world of emergency response, the idea of first-hand reporting—particularly in the form of visual documentation through the use of camera phones and photo-sharing sites—made an indelible early impression of what the future of public participation could bring to both the tactical aspects of response (Fontugne, Cho, Won, & Fukuda, 2011; Liu et al., 2008), as well as the longer-term aspects of a community's cultural heritage (Liu, 2011; Liu, Palen, & Giaccardi, 2012). The ability to broadcast messages to wide or selective audiences (Dabner, 2012; Palen & Vieweg, 2008; Sutton et al., 2008) and provide commentary on events through blogs and public forums continues to reinforce the idea of highly localized but widespread "journalism" and "sensing" (Al-Ani, Mark, & Semaan, 2010; Jin & Liu, 2010; Macias et al., 2009).

Studies of disaster events around the world have documented instances of citizen reporting, as well as the ubiquity of this kind of reporting. During a five-day media ban following a controversial election in Kenya, social media provided a means for citizens to act as on-the-ground reporters who provided and consolidated information (Mäkinen & Kuira, 2008). Meier and Brodock (2008) reported on this same Kenya election and found that citizen reports of protest activity and violence were published well before traditional media channels reported them, a behavior that gave rise to the Ushahidi platform, discussed later. Similarly, the first widely-available video footage of the 2008 Sichuan Earthquake was shot by a Sichuan University undergraduate student with his camera phone (Wang, 2010). Monroy-Hernandez and colleagues have examined the social media and blog responses to the drug wars in Mexico, showing how they have become an important part of the information ecosystem that affects people's interpretation of events (De Choudhury et al., 2014; Monroy-Hernández et al., 2013).

24.2.1.2 Community-Oriented Computing

Social media have been described as facilitating online communities where members share and seek information during times of crisis (Qu et al., 2009; Wang, 2010). An early instance followed Hurricane Katrina, when some New Orleans residents went online in an attempt to locate friends and neighbors—with the hope of reducing the geographical distance between their newly dispersed community (Macias et al., 2009; Procopio & Procopio, 2007). During the Southern California wildfires of 2007, the fires were so diffuse across the region that acquiring information about particular locations and neighborhoods from traditional media sources was difficult. In this environment, innovations around social media emerged that let some mountain communities share information specific to their concerns (Shklovski, Palen, & Sutton, 2008). They were in a sense able to "project" their geographical community activities to the digital sphere.

By providing community members with tools to engage in crisis preparedness, response, and recovery, social media may have a role to play in building community resilience—a measure of a community's ability to respond to, withstand, and recover from adverse situations (Belblidia, 2010; Dufty, 2012; Mark, Al-Ani, & Semaan, 2009b). Hjorth and Kim (2011) found instances, following the Great East Japan Earthquake of 2011, in which social media provided means for residents to express emotion and to grieve with their community. Several studies examined how members of the public create collective histories of crisis events by sharing photos, videos, and personal experiences over social media (Liu, 2010; Mark et al., 2012). Social media may also create a sense of solidarity and social support during political protests (Starbird & Palen, 2012; Tonkin, Pfeiffer, & Tourte, 2012), times of war (Mark et al., 2009b; Mark & Semaan, 2008), and acts of terror (Eriksson, 2016; Glasgow, Vitak, Tausczik, & Fink, 2016). In addition, studies have demonstrated that social media have a place in crisis recovery and the restoration of a sense of normalcy (De Choudhury et al., 2014; Mark et al., 2009a; Mark & Semaan, 2008).

Network analysis, which examines social media behavior in the large, concurs with qualitative examination, showing that people who

have a close relationship to the region where an event is taking place make use of social media differently than those who are global onlookers. In the 2009 Red River Flood threat, people who lived near the Red River or who came there to assist in flood mitigation were more likely to offer original tweets to the information sphere. They were also more likely to provide information that locals understood. Those more distant from the flood were more prone to retweet "the abstract" of the event, redistributing messages or images that communicated what was happening to the rest of the world more broadly (Starbird et al., 2010). Follow on work by Kogan, Palen, and Anderson (2015) examined social networks of social media communications before, during and after the 2012 Hurricane Sandy. This research also saw that in a high-volume event, locals were more likely to interact with locals. Finally, in an examination of image-sharing in the aftermath of the 2015 Nepal Earthquakes, people close to the region again showed differences in the images that they shared. People not from the region also seemed more likely to appropriate images from other events to describe the Nepal earthquakes (Bica et al., 2017).

24.2.1.3 Collective Intelligence and Distributed Problem Solving

Social media have been shown to facilitate collective intelligence—where large, distributed groups of people solve complex problems (Palen et al., 2009; Vivacqua & Borges, 2010). For example, students affected by the Virginia Tech shootings converged on popular social media sites to first report their own safety in the early, uncertain moments, and then from these data (and their absence) began compiling lists of those who had died as they learned how extensive the trauma was to their community. This happened across more than one group, and though no single list was complete, across all lists, every name was correctly identified before the names were publically released (Palen et al., 2009; Vieweg et al., 2008). Keegan and colleagues have studied the structure and dynamics of Wikipedia (an open content online encyclopedia) during crisis events (Keegan, 2015; Keegan, Gergle, & Contractor, 2013). They find that Wikipedia supports collective behavior where people come together to share and seek information and to make sense of the event as it unfolds. Starbird and Palen (2012) examined Twitter posts (or tweets) during the 2011 Egyptian uprisings and noted how members of the crowd recommended and filtered tweets by rebroadcasting (or retweeting) them. The most frequently retweeted messages among remote, world-wide observers tended to be those with broad appeal, such as high-level news reports and messages of solidarity with the Egyptian cause. In contrast, related subsequent work on the Occupy Wall Street movement suggests that those on the ground seek more particular kinds of information (Starbird, Muzny, & Palen, 2012a). Research on the use of Reddit (a social media discussion site) has found that users of the site play an important role in making information more or less visible during a crisis event, which in turns shapes the narrative surrounding the event (Leavitt & Clark, 2014; Leavitt & Robinson, 2017). Citizens may also provide geographically-tagged localized and distributed reports—known as volunteered geographic information—of crisis events through social media (DeLongueville, Luraschi, Smits, Peedell, & De Groeve, 2010; Goodchild, 2007). This geographic information can then be collated and mapped by volunteers who call themselves "crisis mappers" using open source mapping software that includes, Ushahidi[2] which pulls its base layer map from OpenStreetMap[3] (Goodchild & Glennon, 2010; Heipke, 2010; Meier, 2015; Norheim-Hagtun & Meier, 2010; Zook, Graham, Shelton, & Gorman, 2010). In addition, the OpenStreetMap community has grown to complete maps of regions that are affected by disaster, but do not have complete geospatial data, so that emergency responders have accurate maps from which to make decisions and plans (Palen, Soden, Anderson, & Barrenechea, 2015; Soden & Palen, 2014, 2016).

[2]http://www.ushahidi.com/ (accessed January 16, 2017).

[3]http://www.openstreetmap.org/ (accessed January 16, 2017).

24.2.1.4 Digital Volunteers

Members of the public, social media advocates, technologists, emergency managers, humanitarian activists, and researchers continue to experiment, design, question, and develop new ways to use social media during crises. A successful effort is Ushahidi—an open source application for collecting and analyzing citizen-generated information (Meier & Brodock, 2008). Ushahidi relies on both the public as well as "digital volunteers" to populate maps that are helpful to humanitarian efforts. Digital volunteers donate time to performing tasks that aid in crisis efforts and can be completed remotely with online applications like social media (Starbird & Palen, 2011). A spontaneous version of this activity was observed following the 2010 Haiti earthquake when remotely-located citizens self-organized over Twitter to collect and donate funds to those affected by the earthquake (Starbird & Palen, 2011). A group that had coalesced prior to the Haiti earthquake also converged to help Haiti. The OpenStreetMap (OSM) community created a base layer map for Port-Au-Prince in the aftermath of the earthquake, all by the work of volunteer "crisis mappers," the "neocartographers" (Liu & Palen, 2010; Shanley, Burns, Bastian, & Robson, 2013) of the humanitarian space. The Humanitarian OSM Team (HOT) evolved out of this effort to deploy on the ground to make maps usable to the international response, and later, to foster community mapping activity within post-earthquake Haiti (Soden & Palen, 2014) and in subsequent disasters around the world (Dittus, Quattrone, & Capra, 2016; Palen et al., 2015; Soden & Palen, 2016).

Digital volunteerism is related to grassroots efforts that develop applications or provide services to meet humanitarian needs. Some of the earliest groups included the Random Hacks of Kindness "barcamps" and the CrisisCommons[4] organization. These groups were composed of "technology volunteers" with software development and emergency management experience who donated their time to building tools and applications that help those affected by crisis (Boehmer, 2010). A global volunteer organization—HumanityRoad[5]—seeks to provide members of the public with crisis information by teaching people how to "crisis tweet," and by monitoring social media streams to collate information (Starbird & Palen, 2013). Similarly, the Standby Task Force[6] organizes digital volunteers in response to humanitarian needs with a focus on crisis mapping. Organizations like these help to sustain digital volunteer efforts across time and disaster responses.

Seeking to find ways to monitor and maintain social media streams and capitalize on the behaviors exhibited by these early digital volunteers, emergency managers experimented with groups of digital workers (who are pre-selected and trusted) to manage some of the social media communications responsibility (Cobb et al., 2014; St. Denis et al., 2012). These groups call themselves Virtual Operations Support Teams (VOSTs). A similar effort by Wickler, Potter, Tate, and Hansberger (2011) created a Virtual Collaboration Environment that leverages Web 2.0 technologies in support of virtual experts that can participate and assist in an emergency response remotely. Following the 2011 Libya Crisis, volunteer crisis mappers collaborated with the World Health Organization to map over 600 Libyan health facilities (Chan, Colombo, & Musani, 2012).

Many questions still remain around how digital volunteer efforts can work with emergency management effectively and sustainably (Hughes & Tapia, 2015). The American Red Cross has established the Digital Operations Center which employs trained digital volunteers to help with social media monitoring (Meier, 2012). Initiatives like this will be critical to follow as we think about the role of planned and spontaneous digital volunteers in disaster response. The Woodrow Wilson Center for International Scholars has sponsored legal research that examines this issue in the US, and reports that

[4] http://crisiscommons.org/ (accessed January 16, 2017).

[5] http://www.humanityroad.org/ (accessed January 16, 2017).

[6] http://www.standbytaskforce.org (accessed January 16, 2017).

digital volunteers are not covered under Good Samaritan laws because the volunteers seek situations in which to assist. Instead they need to reduce their liability by establishing standards of care against which they want to be evaluated (lest a court determine that after the fact) and other liability-limiting measures (Robson, 2012).

24.2.2 Part 2. Social Media Communications as Data Sources

24.2.2.1 Deluge of Data

Social media use has become so widespread that during a major crisis, the vast amount of information available becomes difficult to monitor and analyze (Castillo, 2016). For instance, during Hurricane Sandy (2012), the University of Colorado Boulder collected over 26 million publically available tweets in an attempt to comprehensively collect the world-wide tweet communications about the warning, onset, and two-week post period of the hurricane. Such representative data sets enable rigorous data analysis of how social media were used during the event using a specialized infrastructure designed to handle large data sets—itself a research project on its own (Anderson & Schram, 2011; Schram & Anderson, 2012). At this point in time, it is almost impossible to make sense of the large amount of socially-generated data for applications to emergency management without adequate tools to filter, analyze, and visualize the data (Palen & Anderson, 2016). The goal of doing real-time collection and analysis remains an open problem in the technology research community.

In response to this challenge, researchers have designed and built several systems that filter and analyze social media streams in times of crisis. The Enhanced Messaging for the Emergency Response Sector (EMERSE) system classifies and aggregates tweets and text messages using supervised learning techniques so that emergency responders and members of the public can more easily access them (Caragea et al., 2011). A research group from Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) has developed a Twitter tool with burst detection, message summary, machine learning and classification, and history analysis (Yin, Lampert, Cameron, Robinson, & Power, 2012). Twitcident uses semantics techniques to filter tweets and provide better search capabilities to help people explore Twitter data, making use of the uniqueness of languages spoken in the Netherlands to do so (Abel, Hauff, Houben, & Stronkman, 2012). These systems demonstrate proof-of-concept of such ideas, but they are not deployable at scale.

An alternative approach to filtering large information sets is to shape the social media data itself, making it easier to parse and analyze. The Tweak the Tweet project proposes a prescriptive syntax using descriptive hashtags (e.g. #location, #status, #needs, #damage). Twitter users then insert these hashtags into their message as they compose their tweets to make them more machine-readable and allow for automatic analysis (Starbird et al., 2012b; Starbird & Stamberger, 2010). Several projects have developed methods for extracting and disambiguating location names from social media data, thus providing valuable contextual information that can allow the data to be visualized with mapping software (Intagorn & Lerman, 2011; Sultanik & Fink, 2012). "Ushahidi"[7] was originally developed during the 2008 post-election fallout in Kenya and allowed citizens to report and map accounts of violence online. Since that time, Ushahidi has become a computing platform that supports human-entered data and analysis in an array of humanitarian situations (Meier & Brodock, 2008; Morrow et al., 2011). The Artificial Intelligence for Disaster Response (AIDR) system combines crowdsourcing and machine learning to classify tweets (Imran, Castillo, Lucas, Meier, & Vieweg, 2014). During a crisis event, AIDR collects relevant tweets and asks members of a crowd to manually label a subset of these messages. These labeled messages are then used to train an automatic classifier. This approach improves classifier accuracy because it

[7] http://www.ushahidi.com/ (accessed January 16, 2017).

has been trained on messages specific to that particular crisis.

For those seeking more information on the topic, Imran, Castillo, Diaz, and Vieweg, (2015) offer a more complete survey of the tools, methods, and techniques that researchers have used to automatically process social media data.

24.2.2.2 Contributions to Situational Awareness

An important contribution social media offer in times of crisis is their potential to enhance situational awareness through the data that many users offer (Cameron et al., 2012; Ireson, 2009; Johnson, Zagorecki, Gelman, & Comfort, 2011; Vieweg, Hughes, Starbird, & Palen, 2010). *Situational awareness,* in the emergency domain, describes human perceptions of the multifaceted circumstances around a crisis event that allow for interpreting situations, making decisions, and predicting future outcomes. Obtaining situational awareness is vital for those dealing with crisis because these situations are unusually complex and poor decision-making may lead to adverse consequences (Johnson et al., 2011; Vieweg et al., 2010).

Examples of situational awareness research include the in-depth analysis of tweets sent during the 2009 Red River floods and the 2009 Oklahoma City fires, where tweets were found by searching on relevant keywords (e.g. #redriver and #okfires). Researchers analyzed tens of thousands of tweets by hand to identify and extract information that could enhance situational awareness such as flood level status and fire locations (Vieweg et al., 2010). Subsequent research has focused on developing natural language processing classifiers that analyzes text to help identify tweets contributing to situational awareness (Corvey, Verma, Vieweg, Palmer, & Martin, 2012; Verma et al., 2011), though in general the state-of-the-art of the field is such that automation behind situational awareness derivation is difficult to do dependably. Ireson (2009) assessed the extent to which public forum postings could add to situational awareness during the 2007 floods around Sheffield, UK and found extractable relevant event information despite the inconsistent quality and conversational nature of the posts.

Research has demonstrated that data from social media interactions can provide situational awareness for specific crisis-related tasks and domains. Using natural language processing (a field of study which enables computers to analyze and understand the human language), machine learning (techniques that provide computers with the ability to learn), and crowdsourcing (the process of accomplishing a task by dividing it into subtasks that can be performed by a large group of people), several research groups have developed methods and tools for detecting and monitoring epidemics through social media data analysis (Brennan, Sadilek, & Kautz, 2013; Chen, Hossain, Butler, Ramakrishnan, & Prakash, 2016; Munro, 2011; Olteanu, Vieweg, & Castillo, 2015). One study used Internet reports to create early estimates of the death toll for the Great East Japan Earthquake of 2011 (Yang, Wu, & Li, 2012). The estimate was correct within one order of magnitude—an improvement over early static estimation models that can be off by as much as 3 orders of magnitude—and it could be updated as more information became available. Another study augments standard evacuation models with evacuee sentiment obtained from social media with the aim of improving evacuation planning (Gottumukkala, Zachary, Kearfott, & Kolluru, 2012). Researchers at several institutions have used geographic information contained in social media reports to detect earthquakes and predict earthquake impact and damage (Avvenuti, Cresci, Marchetti, Meletti, & Tesconi, 2014; Earle, Bowden, & Guy, 2012; Sakaki, Okazaki, & Matsuo, 2012). Dashti et al. (2014) found that visual data contained in social media messages could be used to help experts digitally survey a disaster affected region.

24.2.2.3 Trustworthiness and Veracity of Citizen-Generated Data

When choosing to act—or to not act—on citizen-generated crisis data, emergency responders and citizens must assess information credibility. Despite the free, unregulated production of

information in this type of environment, researchers have found that much of the information provided over social media is self-regulated, meaning that members of the community will question and correct the information (Mendoza, Poblete, & Castillo, 2010; Palen et al., 2009; Qu et al., 2009). Building upon this finding, Starbird and Palen (2010) explored the role of retweeting (rebroadcasting) and found that retweeted messages tended to correspond with information that was accurate or contributed to situational awareness. Recognizing the value of a retweet, one research group has developed a fine-grained predictive model to predict what information will be retweeted (Zhu, Xiong, Piao, Liu, & Zhang, 2011). Tapia, Bajpai, Jansen, and Yen (2011) explored how Twitter could fit the information needs of NGOs in disaster and described methods to overcoming trust issues, such as using a private online environment where all users are known or using Twitter for ambient or contextual data only.

Relying on citizens to filter trustworthy information and restricting who can contribute information is not the only way of creating veracity; as an alternative, several researchers are developing computational methods that seek to automate the process of finding the most credible social media data. Xia, Yang, Wu, Li, and Bao (2012) have developed an unsupervised learning algorithm for detecting credible information on Twitter, while another research group (Gupta & Kumaraguru, 2012) adopted a supervised machine learning and relevance feedback approach to ranking tweets using a credibility score. Preliminary evidence suggests that social media users geographically closer to the physical disaster location tend to share more accurate information (Thomson & Ito, 2012). Consequently, several efforts have created computational methods which use social media features (e.g. profile information, social connectedness, recommendation data) to identify on-the-ground social media users (Schlieder & Yanenko, 2010; Starbird et al., 2012a).

Another approach to ensuring credible information is to identify the information that cannot be trusted. To this end, Starbird and colleagues have employed computational and qualitative methods to identify false rumors and misinformation in social media streams and examine how they spread during crisis events (Arif et al., 2016; Starbird, Maddock, Orand, Achterman, & Mason, 2014, Starbird et al., 2016). This line of research has found recent evidence that "official" accounts (such as those of formal emergency responders) can help to slow the flow of misinformation during a crisis event through their social media posting behavior (Andrews, Fichet, Ding, Spiro, & Starbird, 2016).

24.2.3 Part 3: Applications to Emergency Management

Research had shown that social media channels allow for two-way communication between members of the public and emergency response organizations (Artman, Brynielsson, Johansson, & Trnka, 2011; Hughes & Palen, 2012; Latonero & Shklovski, 2011; Palen & Liu, 2007). Through these channels emergency responders can both distribute important information and make themselves available for dialogue, questions, and feedback (Hughes, St. Denis, Palen, & Anderson, 2014; Hughes & Chauhan, 2015). Furthermore, the information contained in citizen-generated data shows potential for contributing to situational awareness (Cameron et al., 2012; Ireson, 2009; Vieweg et al., 2010) which could benefit emergency response operations (Hughes & Palen, 2012).

However social media adoption in formal emergency response has lagged behind that of public uptake (Hughes & Palen, 2012; Latonero & Shklovski, 2011; Plotnick, Hiltz, Kushma, & Tapia, 2015; Tapia & Moore, 2014). Latonero and Shklovski (2011) investigated the use of social media by the Los Angeles Fire Department (LAFD) in 2009. At the time, the LAFD's active use of social media (monitoring, message distribution and response) was unusual for an emergency response organization and Latonero and Shklovski (2011) suggest that much of the LAFD's advanced adoption could be attributed

to having a single social media evangelist in the department. Around this same time (in 2009), Hughes and Palen (2012) interviewed 25 Colorado public information officers (PIOs) and reported that PIOs wanted to use social media but did not have permission or support from their management to do so. In addition, many of the participants reported that they lacked training as well as the resources to commit to maintaining a social media presence between emergency events. For those PIOs who had managed to obtain permission and resources to use social media, social media were most often used for one-way message distribution. More recently, Plotnick et al. (2015) conducted a survey of 241 U.S. emergency managers at the county level in 2014. In addition to finding many of the same barriers to social media use, they found that only about half of the surveyed agencies reported using social media in their work. Reuter et al. (2016) report that 44% of European emergency services reported using social media based on a 2014 survey of 761 emergency service staff across 32 European countries.

A growing body of empirical research documents innovative on-line behaviors that enlighten what contributions of social media could be. A number of policy and research visioning meetings have been held (Burns & Shanley, 2013; Committee on Public Response to Alerts and Warnings Using Social Media, Computer Science and Telecommunications Board, Division on Engineering and Physical Sciences, & National Research Council, 2013; Computing Community Consortium, 2012). Emergency managers continue to face mounting pressure from members of the public to use social media (Hughes & Palen, 2012); if emergency managers do not provide adequate social media information around a crisis event, citizens may obtain their information elsewhere (Stephens & Malone, 2009). These factors made emergency responders more likely to support and incorporate social media in their practice.

In this changing environment, several empirical research efforts have studied emergency management social media use. One study looked at whether international medical response teams and organizations coordinated through Twitter during the 2010 Haiti Earthquake (Sarcevic et al., 2012). Though there was little evidence of direct coordination between these international groups distributed across Haiti, the researchers identified an important pre-condition to coordination: that of on-line "beaconing behavior," where responders broadcast messages hoping that the message would be heard by a large audience. This is taken as a sign that groups are anxious to assist, to make themselves known, and to coordinate in a highly-decentralized activity. They perceive the digital sphere as important in this regard but it does not automatically provide the social connections that are needed (Sarcevic et al., 2012). Another study looked at social media use by two different police organizations during the August 2011 UK riots. Each organization took a different approach to their Twitter communications ("instrumental" and "expressive"), each which yielded advantages and disadvantages in terms of relationships with the public and the abilities to sustain communications over a period of time when internal resources were taxed (Denef et al., 2013). Briones, Kuch, Liu, and Yin (2011) interviewed 40 members of the American Red Cross to understand how they use social media to build relationships with their public and found that members perceived social media as both an effective and necessary public relations tool. Research around the 2013 Boston Bombings discovered that with the wide-spread attention focused on the event, emergency officials needed to tailor their Twitter communications to both a local audience seeking help and guidance as well as a remote audience wanting to know more about the attacks (Sutton et al., 2014). Research by Hughes et al. (2014) offers insight about the on-line communication behaviors of 840 fire and police departments within a 100 mile radius of where Hurricane Sandy made landfall in 2012. They found that even though use of Facebook, Twitter, websites and Nixle was relatively low overall, the ways in which departments employed the technology varied widely. Creative uses by some departments suggest new possibilities for public engagement in the future, and such variance suggests that a social media practice

remains highly emergent as groups experiment with different styles of engagement. In addition, Potter (2016) conducted a two-year ethnography of the Queensland Fire and Emergency Services (QFES) and their social media use. Despite evidence that social media supports more interaction with the public, the QFES primarily used them to distribute information. Frictions with internal processes often kept QFES from sharing information through social media in a timely manner, such as difficulty in getting information from responders on-the-ground and a culture of prioritizing operational duties over public information tasks.

24.3 Reflections on the Field: Social Media Behavior Is Tied to the Hazard

The research on social media use in disaster warning, response and mitigation has grown rapidly in the last decade, extending and contributing to the social science research in this space. However, we advise that researchers read this new literature knowing that lessons learned from one kind of emergency may not apply to others kinds of emergencies, even when the medium of social media is the same. The review offered in this chapter focuses on research from natural hazards, though selectively draws insights from other kinds of hazards to address additional socio-behavioral phenomena. We explain why a careful reading of the interpretation of socio-behavioral phenomena is important vis a vis the kind of emergency event being studied.

Social science research of mass emergency response has sought to investigate and represent the human behavior that arises in response to hazards threat, onset, and aftermath (Dynes, 1970; Mileti, Drabek, & Haas, 1975; Stallings, 1971; Tierney, Lindell, & Perry, 2001). This research makes distinctions between hazards and the resulting social-behavioral phenomena, and in so doing, has systematically portrayed the nature of those phenomena. It makes distinctions between local and mass emergencies, which give rise to different consequences socially and societally. In addition, social science attends to differences in emergencies that arise from natural hazards, and those that arise from criminal behavior because the nature of the response and mitigation of these two different sets of hazards differ. For example, mass emergencies arising from natural hazards might, first, be mitigated through better policies and practices of development. Gilbert White famously warned against the building of structures in the flood plain (White, 1945) to reduce flooding disasters. Improved detection and prediction of weather-based hazards can mitigate risk (Gillespie, Chu, Frankenberg, & Thomas, 2007; Mileti, 1999; Morss, Wilhelmi, Meehl, & Dilling, 2011), as can risk communication to the public (Fitzpatrick & Mileti, 1994; Morss, Demuth, & Lazo, 2008; Reynolds & Seeger, 2005). However, natural hazards themselves cannot easily be eliminated: rivers rise and lighting-born wildfires burn. In contrast, criminal activity is managed by a set of circumstances that are psychologically and socially complex and systemic; we seek to take control of crime to preserve the basic workings of civil society.

In social media studies of emergency, the literature reports on all kinds of emergency events, sometimes without these important distinctions that readers of this volume care about. Social media studies of collective action of bombings and hurricanes are reported side-by-side, and so it is up to the reader to consider the differences such hazards give rise to in the social media sphere. We make this point because we worry that the very idea of "social media" flattens the many meanings of "crisis" and "emergency" for which social science fields have worked to provide insight. For example, because Twitter or Facebook are available for use in any kind of crises, it is easy to make these applications the salient concern, and ask "Is Twitter or Facebook better in emergency response?," rather than question how the very nature of emergency response might beg for different forms of information seeking and reporting. We refer to this flattening of communication medium and hazard as the *social media and crisis confound.*

We find *endogeneity* and *exogeneity* of hazards to be a meaningful distinction in social media in mass emergencies research, one that readily clarifies for a range of researchers and readers who are outside the social science discipline. Just as events that arise from exogenous and endogenous hazards differently impact legal, political, health, and other societal systems, so do they differently impact social media behavior.[8] With exogenous events, the culprit is beyond reach, and unstoppable. With endogenous agents, the suspect lies within. Therefore, organizing features of the communication are distinctly different, because the source(s) of the problem(s), the nature of their solutions, *and the ability for the perception of the collective control of the outcome* are different. Online participation focuses on in-common salient problems when they are present; when the problems are less in-common and must be addressed in parallel, the crowd organizes in many smaller groupings and, often endogeneity and exogeneity of hazards predicts this (Palen & Anderson, 2016).

Here we offer a brief illustration of the distinction for the social media world. The 2012 Hurricane Sandy and the 2013 Boston Bombings were events that affected major US cities. Though the investigations of social media behavior are many and nuanced (Hughes et al., 2014; Leavitt & Clark, 2014; Starbird et al., 2014; Sutton et al., 2014; White, Palen, & Anderson, 2014), for the point of this chapter, we can broadly characterize the nature of those interactions in the immediate aftermaths. As with other exogenous hazards, the social media response to Hurricane Sandy can be characterized as a set of many simultaneous social interactions that sought to ask questions and provide information about the status of a range of issues (e.g., transportation, utilities, flooding, public service assistance, evacuation directions). In contrast, after the bombings during the Boston Marathon (an endogenous hazards event), the social media behavior is better characterized as addressing matters of safety from criminal activity and forensics: who is the culprit? Has the person been found? Famously, a community on the popular social media discussion site Reddit fingered several innocent people as the culprit before the community was shut down (Potts & Harrison, 2013).

This distinction enlightens the reading of the growing social media and mass emergency literature for three reasons. First, without it, this new literature risks undoing decades of work by social scientists who have dismantled the myths of disaster, with a dominant discourse that includes panic and unlawful behavior by victims. But in disasters arising from natural hazards, we know such behaviors are not typical. Mass emergencies arising from criminal behavior can have a much wider range of collective behavior because the source of the hazard is unknown, unpredictable and perhaps more imminently dangerous. Therefore, when events like gun shootings and bombings are examined as "crises," they are collapsed with other events that are also considered to be "crises" without distinction, even though the behaviors exhibited online will parallel the behaviors we see in the physical world. The curiosity of social media as an element of the behavior seems to override these important hazard-based differences. Though social media brings an interesting new means by which people interact and perhaps coordinate, we must not lose sight of the natural phenomena that first influences socio-behavioral phenomena.

Second, lessons for practitioners out of the new social media literature become clouded. Whereas criminal events might require a law-based response with limited participation by members of the public, natural hazards events do not require a law-based response (even though police and fire resources are used for both), and may in fact benefit from broad participation of residents helping each other with many localized problems that tax public services.

This ties to a third point, which is that the dangers of misinformation might not be the same in different kinds of disaster events. Misinformation diffused in an endogenous hazard event—

[8]Furthermore, beyond the natural versus criminal hazard divide, the term "crisis" encompasses war and other political unrest. It also encompasses long-ranging environmental hazards arising from global warming, including sea level rise and drought.

where the social media communication might dwell on matters of forensics—could put safety and security at risk. Innocent people might be unfairly pursued; would-be victims could experience greater risk if they evacuate to the wrong area. Activity tends to be concentrated and faster moving, and so the implications for misinformation are also intensified. One must also question if the misinformation is being propagated as part of the criminal activity itself. Misinformation arising from natural hazards or exogenous events might be greater in kind, but less in impact, with fewer in-common readers as it traverses a network that can move a little slower than it might in criminal mass emergency events. Because the problem-solving tends to be more diffuse in exogenous events, the same message might not reach enough people; in other words, the misinformation might also be thinly diffused. Misinformation in such events is more likely to age out, or not be relevant to enough locations to pose a big threat—in other words, all information in the first place is less likely to be categorically correct or incorrect, and as such, it is hard to find as much value in pursuing the threat of misinformation in such situations.

Social media research on mass emergency events is burgeoning. A range of practitioners, application developers, researchers are considering social media as both a site of social interaction worthy of study, and as a source of information that can reveal a lot about what is happening on-the-ground across many people. The potential that such investigations have for examining and supporting socio-behavioral phenomena in the large is high. We encourage a wide reading of this rapidly expanding interdisciplinary literature, but with the precaution that lessons that follow mass emergencies from endogenous and exogenous hazards might differ, and should be a knowing part of the synthesis of that literature.

24.4 Future Directions

Future directions for crisis informatics research are exciting and promising. One important turn is examination of the role of social media participation in resilience, rather than in only warning and response. As social computing platforms expand into new areas of interaction, the immediacy that characterizes the platforms of today—a characteristic that favors the rapid response aspects of disasters—might give way to longer horizon engagement with people and data. This engagement is what characterizes the hope of some working in the geospatial data space (Soden, 2017).

Furthermore, little research has focused on the needs of the disadvantaged with respect to social media and crisis (Bricout & Baker, 2010; Cinnamon & Schuurman, 2012). The majority of the literature discussed in this chapter has studied populations with widespread access to social media and the hardware technology to use it. In the United States, Crutcher and Zook (2009) observed how access to Google Earth following Hurricane Katrina fell strongly along disadvantaged economic and racial lines. Majid and Spiro (2016) examined Twitter messaging from formal emergency responders in the US and noted a lack of cross-language messaging despite evidence that many communities contain a significant number of non-English speakers. Elwood (2008) looked at how citizen-generated data is shaped during a crisis, and observed that what information is available as well and who it empowers or disempowers is a function of access. However, some also suggest that social media has the potential to provide crisis communications in places where emergency response infrastructure is poor (White & Fu, 2012). The need to create a trajectory of research that combines the study of the vulnerable with the increasingly necessary tools for large-scale social media analysis is essential.

Another direction is the ever-sharpening precision around understanding information diffusion, as well as the changing socio-political landscape that is changing our assumptions in 2017 about what constitutes "fact." It could well be that the ideas of misinformation are going to be challenged definitionally with the rise of "fake news" and its possible encroachment into the disaster space. In this way, the overlap of news reporting on any number of kinds of hazards

events is going to change the information landscape in ways that are currently unpredictable. We look to the work of Starbird and colleagues on the examination of fake news (Starbird, 2017) and its possible intersections with disaster reporting.

Network analysis of social media communications will improve as researchers develop new data science techniques for wrangling with units of analysis in discourse and other forms of on-line interaction (Kogan, Anderson, Palen, Anderson, & Soden, 2016). Such advances are crucial to move beyond the observation that people are interacting on-line in interesting ways to explain in what ways they are coordinating that propagates solutions or idea diffusion. It will also be an important contributing method for understanding how people react to weather forecast information and other information artifacts that attempt to communicate uncertainty to affected populations. Similarly, it is important to expand existing research that mostly focuses on Twitter, to include other social media platforms; people do not confine their online activity to one platform during a crisis event. Thus, Hughes, Starbird, Leavitt, Keegan, and Semaan (2016) propose a new research agenda to explore how information is moved and propagated across multiple social media platforms.

Efforts to parse, filter, and make sense of "crisis big data" (Castillo, 2016) using machine learning learning methods will continue. Natural language processing methods are essential, but so will be methods for image diffusion. This research combined with service-side application development will help make hypertemporal and hyperlocal data accessible (Palen & Anderson, 2016) in a real-time fashion that is not currently possible.

Finally, the application of all this knowledge to practical response, recovery and mitigation efforts is the reason such research is important. As public participation continues to grow, questions regarding how the social media efforts of the public fit with formal response agencies will continue to be explored. What is the best way to leverage the collective knowledge of the public and the emergency experts? How do members of the public and emergency responders work together and what roles should each play? How can disasters be mitigated or even averted? These are the essential questions that drive the social media and crisis research agenda.

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References

Abel, F., Hauff, G. -J., Houben, K. T., & Stronkman, R. (2012). Semantics + filtering + search = twitcident exploring information in social web streams. In *Proceedings of the 23rd ACM Conference on Hypertext and Social Media* (pp. 285–294). New York, NY, USA: ACM Press.

Al-Ani, B., Mark, G., & Semaan, B. (2010). Blogging in a region of conflict: Supporting transition to recovery. In *Proceedings of the 2010 International Conference on Human Factors in Computing Systems (CHI 2010)* (pp. 1069–1078). New York, NY, USA: ACM Press. https://doi.org/10.1145/1753326.1753485.

Anderson, K. M., & Schram, A. (2011). Design and implementation of a data analytics infrastructure in support of crisis informatics research. In *Proceedings of the 2011 International Conference on Software Engineering (ICSE 2011)* (pp. 844–847). Waikiki, Honolulu, HI, USA.

Andrews, C., Fichet, E., Ding, Y., Spiro, E. S., & Starbird, K. (2016). Keeping up with the tweet-dashians: The impact of "official" accounts on online rumoring. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing* (pp. 452–465). New York, NY, USA: ACM. https://doi.org/10.1145/2818048.2819986.

Arif, A., Shanahan, K., Chou, F. -J., Dosouto, Y., Starbird, K., & Spiro, E. S. (2016). How information snowballs: Exploring the role of exposure in online rumor propagation. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing* (pp. 466–477). New York, NY, USA: ACM. https://doi.org/10.1145/2818048.2819964.

Artman, H., Brynielsson, J., Johansson, B. J., & Trnka, J. (2011). Dialogical emergency management and strategic awareness in emergency communication. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM*

2011). Lisbon, Portugal. Retrieved from http://www.iscramlive.org/ISCRAM2011/proceedings/papers/116.pdf.

Avvenuti, M., Cresci, S., Marchetti, A., Meletti, C., & Tesconi, M. (2014). EARS (Earthquake Alert and Report System): A real time decision support system for earthquake crisis management. In *Proceedings of the 20th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining* (pp. 1749–1758). New York, NY, USA: ACM. https://doi.org/10.1145/2623330.2623358.

Belblidia, M. S. (2010). Building community resilience through social networking sites: Using online social networks for emergency management. *International Journal of Information Systems for Crisis Response and Management*, *2*(1), 24–36. https://doi.org/10.4018/jiscrm.2010120403.

Bica, M., Palen, L., & Bopp, C. (2017). Visual representations of disaster. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (pp. 1262–1276). New York, NY, USA: ACM. https://doi.org/10.1145/2998181.2998212.

Boehmer, E. (2010, July 22). *Coordinating efforts by volunteer and technical communities for disaster preparedness, response, and relief.* Science and Technology Innovation Program—Woodrow Wilson International Center for Scholars. Retrieved from http://www.sts.virginia.edu/PIP/research_papers/2011/Boehmer.pdf.

Brennan, S., Sadilek, A., & Kautz, H. (2013). Towards understanding global spread of disease from everyday interpersonal interactions. In *Proceedings of the Twenty-Third International Joint Conference on Artificial Intelligence* (pp. 2783–2789). Beijing, China: AAAI Press. Retrieved July 14, 2016, from http://dl.acm.org/citation.cfm?id=2540128.2540530.

Bricout, J. C., & Baker, P. M. A. (2010). Leveraging online social networks for people with disabilities in emergency communications and recovery. *International Journal of Emergency Management, 7*(1). Retrieved from http://www.ingentaconnect.com/content/ind/ijem/2010/00000007/00000001/art00006.

Briones, R. L., Kuch, B., Liu, B. F., & Yin, Y. (2011). Keeping up with the digital age: How the American Red Cross uses social media to build relationships. *Public Relations Review, 37*(1), 37–43.

Burns, R., & Shanley, L. (2013). *Connecting grassroots to government for disaster management: Workshop report*. Washington, D.C., USA: Commons Lab of the Woodrow Wilson International Center for Scholars.

Cameron, M. A., Power, R., Robinson, B., & Yin, J. (2012). Emergency situation awareness from Twitter for crisis management. In *Proceedings of the 21st International Conference Companion on World Wide Web* (pp. 695–698). New York, NY, USA: ACM Press. https://doi.org/10.1145/2187980.2188183.

Caragea, C., McNeese, N., Jaisw, A., Traylor, G., Kim, H.-W., Mitra, P., et al. (2011). Classifying text messages for the Haiti Earthquake. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2011)*. Lisbon, Portugal. Retrieved from http://www.iscramlive.org/ISCRAM2011/proceedings/papers/155.pdf.

Careem, M., De Silva, C., De Silva, R., Raschid, L., & Weerawarana, S. (2006). Sahana: Overview of a disaster management system. In *Proceedings of the International Conference on Information and Automation* (pp. 361–366). Washington, D.C., USA: IEEE Computer Society.

Castillo, C. (2016). *Big crisis data: Social media in disasters and time-critical situations*. New York, NY, USA: Cambridge University Press.

Chan, J. L., Colombo, R., & Musani, A. (2012). Mapping Libyan health facilities—A collaboration between crisis mappers and the World Health Organization. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2012)*. Vancouver, BC, USA. Retrieved from http://www.iscramlive.org/ISCRAM2012/proceedings/298.pdf.

Chen, L., Hossain, K. S. M. T., Butler, P., Ramakrishnan, N., & Prakash, B. A. (2016). Syndromic surveillance of flu on Twitter using weakly supervised temporal topic models. *Data Mining and Knowledge Discovery, 30*(3), 681–710. https://doi.org/10.1007/s10618-015-0434-x.

Cinnamon, J., & Schuurman, N. (2012). Confronting the data-divide in a time of spatial turns and volunteered geographic information. *GeoJournal*, 1–18. https://doi.org/10.1007/s10708-012-9458-6.

Cobb, C., McCarthy, T., Perkins, A., Bharadwaj, A., Comis, J., Do, B., et al. (2014). Designing for the Deluge: Understanding & supporting the distributed, collaborative work of crisis volunteers. In *Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing* (pp. 888–899). New York, NY, USA: ACM. https://doi.org/10.1145/2531602.2531712.

Committee on Public Response to Alerts and Warnings Using Social Media, Computer Science and Telecommunications Board, Division on Engineering and Physical Sciences, & National Research Council. (2013). *Public response to alerts and warnings using social media: Report of a workshop on current knowledge and research gaps*. Washington, D.C., USA: The National Academies Press. Retrieved from http://www.nap.edu/openbook.php?record_id=15853.

Computing Community Consortium. (2012). *Computing FOR Disasters: A report from the community workshop*. Retrieved from http://www.cra.org/ccc/disaster-management.php.

Corvey, W. J., Verma, S., Vieweg, S., Palmer, M., & Martin, J. H. (2012). Foundations of a multilayer annotation framework for Twitter communications during crisis events. In *Proceedings of the Eighth International Conference on Language Resources and Evaluation (LREC 2012)*. Istanbul, Turkey. Retrieved from http://epic.cs.colorado.edu/wp-content/uploads/lrec_2012_final_120523.pdf.

Crutcher, M., & Zook, M. (2009). Placemarks and waterlines: Racialized cyberscapes in post-Katrina Google Earth. *Geoforum, 40,* 523–534.

Currion, P., De Silva, C., & Van de Walle, B. (2007). Open source software for disaster management. *Communications of the ACM, 50*(3), 61. https://doi.org/10.1145/1226736.1226768.

Dabner, N. (2012). "Breaking Ground" in the use of social media: a case study of a university earthquake response to inform educational design with Facebook. *The Internet and Higher Education, 15*(1), 69–78.

Dashti, S., Palen, L., Heris, M. P., Anderson, K. M., Anderson, J., & Anderson, S. (2014). Supporting disaster reconnaissance with social media data: A design-oriented case study of the 2013 Colorado Floods. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 20014)*. University Park, PA. Retrieved March 26, 2017, from http://idl.iscram.org/files/dashti/2014/423_Dashti_etal2014.pdf.

De Choudhury, M., Monroy-Hernández, A., & Mark, G. (2014). "Narco" emotions: Affect and desensitization in social media during the Mexican Drug War. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 3563–3572). New York, NY, USA: ACM. https://doi.org/10.1145/2556288.2557197.

DeLongueville, B., Luraschi, G., Smits, P., Peedell, S., & De Groeve, T. (2010). Citizens as sensors for natural hazards: A VGI integration workflow. *Geomatica, 64* (1), 41–59.

Denef, S., Bayerl, P. S., & Kaptein, N. (2013). Social media and the police-tweeting practices of British police forces during the August 2011 Riots. In *Proceedings of the 2013 Conference on Human Factors in Computing Systems (CHI 2013)* (pp. 3471–3480). New York, NY, USA: ACM Press.

Dittus, M., Quattrone, G., & Capra, L. (2016). Analysing volunteer engagement in humanitarian mapping: Building contributor communities at large scale. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing* (pp. 108–118). New York, NY, USA: ACM. https://doi.org/10.1145/2818048.2819939.

Dufty, N. (2012). Using social media to build community disaster resilience. *The Australian Journal of Emergency Management, 27*(1), 40–45.

Dynes, R. R. (1970). *Organized behavior in disaster*. Lexington, Massachusetts: D.C. Heath.

Earle, P. S., Bowden, D. C., & Guy, M. (2012). Twitter earthquake detection: Earthquake monitoring in a social world. *Annals of Geophysics, 54*(6). https://doi.org/10.4401/ag-5364.

Elwood, S. (2008). Volunteered geographic information: Future research directions motivated by critical, participatory, and feminist GIS. *GeoJournal*, *72*(3–4), 173–183. https://doi.org/10.1007/s10708-008-9186-0.

Eriksson, M. (2016). Managing collective trauma on social media: the role of Twitter after the 2011 Norway attacks. *Media, Culture & Society, 38*(3), 365–380. https://doi.org/10.1177/0163443715608259.

Fitzpatrick, C., & Mileti, D. S. (1994). Public risk communication. In R. R. Dynes & K. J. Tierney (Eds.), *Disasters, collective behavior, and social organization* (pp. 71–84). Newark, DE, USA: University of Delaware Press.

Fontugne, R., Cho, K., Won, Y., & Fukuda, K. (2011). Disasters seen through Flickr Cameras. In *Proceedings of the Special Workshop on Internet and Disasters* (p. 5:1–5:10). New York, NY, USA: ACM Press. https://doi.org/10.1145/2079360.2079365.

Foot, K., & Schneider, S. M. (2004). Online structures for citizen engagement in the September 11th Web Sphere. *Electronic Journal of Communication, 14*(3 & 4).

Foot, K., Warnick, B., & Schneider, S. M. (2005). Web-based memorializing after September 11: Toward a conceptual framework. *Journal of Computer-Mediated Communication, 11*(1), 72–96. https://doi.org/10.1111/j.1083-6101.2006.tb00304.x.

Gillespie, T. W., Chu, J., Frankenberg, E., & Thomas, D. (2007). Assessment and prediction of natural hazards from satellite imagery. *Progress in Physical Geography, 31*(5), 459–470. https://doi.org/10.1177/0309133307083296.

Gillmor, D. (2006). *We the media: Grassroots journalism by the people, for the people*. Sebastopol, CA, USA: O'Reilly Media.

Glasgow, K., Vitak, J., Tausczik, Y., & Fink, C. (2016). Grieving in the 21st century: Social media's role in facilitating supportive exchanges following community-level traumatic events. In *Proceedings of the 7th 2016 International Conference on Social Media & Society* (p. 4:1–4:10). New York, NY, USA: ACM. https://doi.org/10.1145/2930971.2930975.

Goodchild, M. F. (2007). Citizens as sensors: The world of volunteered geography. *GeoJournal, 69*(4), 211–221.

Goodchild, M. F., & Glennon, J. A. (2010). Crowdsourcing geographic information for disaster response: A research frontier. *International Journal of Digital Earth, 3,* 231–241.

Gottumukkala, R., Zachary, J., Kearfott, B., & Kolluru, R. (2012). Real-time information driven decision support system for evacuation planning. In *2012 IEEE International Multi-Disciplinary Conference on Cognitive Methods in Situation Awareness and Decision Support (CogSIMA)* (pp. 206–209). https://doi.org/10.1109/CogSIMA.2012.6188383.

Gupta, A., & Kumaraguru, P. (2012). Credibility ranking of tweets during high impact events. In *Proceedings of the 1st Workshop on Privacy and Security in Online Social Media* (p. 2:2–2:8). New York, NY, USA: ACM Press. https://doi.org/10.1145/2185354.2185356.

Hagar, C., & Haythornthwaite, C. (2005). Crisis, farming & community. *The Journal of Community Informatics, 1*(3), 41–52.

Heipke, C. (2010). Crowdsourcing geospatial data. *Journal of Photogrammetry and Remote Sensing, 65*(6), 550–557.

Heverin, T., & Zach, L. (2010). Microblogging for crisis communication: Examination of Twitter use in response to a 2009 violent crisis in Seattle-Tacoma, Washington area. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2010)*. Seattle, WA, USA.

Hjorth, L., & Kim, K.-H. Y. (2011). Good grief: The role of social mobile media in the 3.11 earthquake disaster in Japan. *Digital Creativity, 22*(3), 187–199. https://doi.org/10.1080/14626268.2011.604640.

Hughes, A. L., & Chauhan, A. (2015). Online media as a means to affect public trust in emergency responders. In *Proceedings of the 2014 Information Systems for Crisis Response and Management Conference (ISCRAM 2015)*. Retrieved March 26, 2017, from http://iscram2015.uia.no/?p=2020.

Hughes, A. L., & Palen, L. (2012). The evolving role of the public information officer: An examination of social media in emergency management. *Journal of Homeland Security and Emergency Management*, *9*(1). Retrieved from http://www.degruyter.com/view/j/jhsem.2012.9.issue-1/1547-7355.1976/1547-7355.1976.xml.

Hughes, A. L., Palen, L., Sutton, J., Liu, S. B., & Vieweg, S. (2008). "Site-Seeing " in disaster: An examination of on-line social convergence. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2008)*. Washington, D. C., USA. Retrieved from http://www.iscramlive.org/dmdocuments/ISCRAM2008/papers/ISCRAM2008_Hughes_etal.pdf.

Hughes, A. L., St. Denis, L. A., Palen, L., & Anderson, K. M. (2014). Online public communications by police & fire services during the 2012 hurricane sandy. In *Proceedings of the 2014 International Conference on Human Factors in Computing Systems (CHI 2014)* (pp. 1505–1514). New York, NY, USA: ACM Press.

Hughes, A. L., Starbird, K., Leavitt, A., Keegan, B. C., & Semaan, B. (2016). Information movement across social media platforms during crisis events. In *Following User Pathways: Cross Platform and Mixed Methods Analysis in Social Media Studies Workshop at the 2016 Conference on Human Factors in Computing Systems (CHI 2016)*. San Jose, CA, USA. Retrieved March 26, 2017, from http://amandaleehughes.com/MultiSMPlatformWorkshop_Final.pdf.

Hughes, A. L., & Tapia, A. H. (2015). Social media in crisis: When professional responders meet digital volunteers. *Journal of Homeland Security and Emergency Management, 12*(3), 679–706. https://doi.org/10.1515/jhsem-2014-0080.

Imran, M., Castillo, C., Diaz, F., & Vieweg, S. (2015). Processing social media messages in mass emergency: A survey. *ACM Computing Surveys, 47*(4), 67:1–67:38. https://doi.org/10.1145/2771588.

Imran, M., Castillo, C., Lucas, J., Meier, P., & Vieweg, S. (2014). AIDR: Artificial Intelligence for Disaster Response. In *Proceedings of the Companion Publication of the 23rd International Conference on World Wide Web Companion* (pp. 159–162). Republic and Canton of Geneva, Switzerland: International World Wide Web Conferences Steering Committee. https://doi.org/10.1145/2567948.2577034.

Intagorn, S., & Lerman, K. (2011). Mining geospatial knowledge on the social web. *International Journal of Information Systems for Crisis Response and Management, 3*(2), 33–47. https://doi.org/10.4018/jiscrm.2011040103.

Ireson, N. (2009). Local community situational awareness during an emergency. In *Proceedings of the 3rd IEEE International Conference on Digital Ecosystems and Technologies (DEST 2009)* (pp. 49–54). Washington, D.C., USA: IEEE Computer Society. https://doi.org/10.1109/DEST.2009.5276763.

Jin, Y., & Liu, B. F. (2010). The blog-mediated crisis communication model: Recommendations for responding to influential external blogs. *Journal of Public Relations Research, 22*(4), 429–455. https://doi.org/10.1080/10627261003801420.

Johnson, D., Zagorecki, A., Gelman, J. M., & Comfort, L. K. (2011). Improved situational awareness in emergency management through automated data analysis and modeling. *Journal of Homeland Security and Emergency Management, 8*(1). Retrieved March 4, 2013, from http://www.degruyter.com/view/j/jhsem.2011.8.issue-1/jhsem.2011.8.1.1873/jhsem.2011.8.1.1873.xml.

Keegan, B. C. (2015). Emergent social roles in wikipedia's breaking news collaborations. In E. Bertino & S. A. Matei (Eds.), *Roles, trust, and reputation in social media knowledge markets* (pp. 57–79). Springer International Publishing. https://doi.org/10.1007/978-3-319-05467-4_4.

Keegan, B., Gergle, D., & Contractor, N. (2013). Hot off the wiki: Structures and dynamics of Wikipedia's coverage of breaking news events. *American Behavioral Scientist*, *57*(5), 595–622. https://doi.org/10.1177/0002764212469367.

Kogan, M., Anderson, J., Palen, L., Anderson, K. M., & Soden, R. (2016). Finding the way to OSM mapping practices: Bounding large crisis datasets for qualitative investigation. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (pp. 2783–2795). New York, NY, USA: ACM. https://doi.org/10.1145/2858036.2858371.

Kogan, M., Palen, L., & Anderson, K. M. (2015). Think local, retweet global: Retweeting by the geographically-vulnerable during Hurricane Sandy. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing* (pp. 981–993). New York, NY, USA: ACM. https://doi.org/10.1145/2675133.2675218.

Latonero, M., & Shklovski, I. (2011). Emergency management, Twitter, and social media evangelism. *International Journal of Information Systems for Crisis Response and Management, 3*(4), 1–16.

Leavitt, A., & Clark, J. A. (2014). Upvoting Hurricane Sandy: Event-based news production processes on a social news site. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1495–1504). New York, NY, USA: ACM. https://doi.org/10.1145/2556288.2557140.

Leavitt, A., & Robinson, J. J. (2017). The role of information visibility in network gatekeeping: Information aggregation on Reddit during crisis events. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (pp. 1246–1261). New York, NY, USA: ACM. https://doi.org/10.1145/2998181.2998299.

Liu, S. B. (2010). The rise of curated crisis content. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2010)*. Seattle, WA, USA.

Liu, S. B. (2011). *Grassroots heritage: A multi-method investigation of how social media sustain the living heritage of historic crises* (Ph.D. Dissertation). University of Colorado at Boulder.

Liu, S. B., & Palen, L. (2010). The new cartographers: Crisis map mashups and the emergence of neogeographic practice. *Cartography and Geographic Information Science, 37*(1), 69–90. https://doi.org/10.1559/152304010790588098.

Liu, S. B., Palen, L., & Giaccardi, E. (2012). Heritage matters in crisis informatics: How information and communication technology can support legacies of crisis events. In C. Hagar (Ed.), *Crisis information management: Communication and technologies* (pp. 65–86). Cambridge, UK: Chandos Publishing.

Liu, S. B., Palen, L., Sutton, J., Hughes, A. L., & Vieweg, S. (2008). In search of the bigger picture: The emergent role of on-line photo sharing in times of disaster. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2008)*. Washington, D.C., USA. Retrieved September 22, 2010, from.

Ludwig, T., Reuter, C., & Pipek, V. (2015). Social haystack: Dynamic quality assessment of citizen-generated content during emergencies. *ACM Transactions on Computer-Human Interaction (TOCHI), 22*(4), 17:1–17:27. https://doi.org/10.1145/2749461.

Macias, W., Hilyard, K., & Freimuth, V. (2009). Blog functions as risk and crisis communication during Hurricane Katrina. *Journal of Computer-Mediated Communication, 15*(1), 1–31. https://doi.org/10.1111/j.1083-6101.2009.01490.x.

Majid, A. M., & Spiro, E. S. (2016). Crisis in a foreign language: Emergency services and limited english populations. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 20016)*. Retrieved from http://idl.iscram.org/files/amirahmmajid/2016/1363_AmirahM.Majid+EmmaS.Spiro2016.pdf.

Mäkinen, M., & Kuira, M. W. (2008). Social media and postelection crisis in Kenya. *The International Journal of Press/Politics, 13*(3), 328–335. https://doi.org/10.1177/1940161208319409.

Mark, G., Al-Ani, B., & Semaan, B. (2009a). Repairing human infrastructure in war zones. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2009)*. Gothenburg, Sweden.

Mark, G., Al-Ani, B., & Semaan, B. (2009b). Resilience through technology adoption: Merging the old and the new in Iraq. In *Proceedings of the 2009 Conference on Human Factors in Computing Systems (CHI 2009)* (pp. 689–698). New York, NY, USA: ACM Press. https://doi.org/10.1145/1518701.1518808.

Mark, G., Bagdouri, M., Palen, L., Martin, J., Al-Ani, B., & Anderson, K. (2012). Blogs as a collective war diary. In *Proceedings of the 2012 Conference on Computer Supported Cooperative Work (CSCW 2012)* (pp. 37–46). New York, NY, USA: ACM Press. Retrieved July 23, 2012, from http://dl.acm.org/citation.cfm?id=2145215.

Mark, G., & Semaan, B. (2008). Resilience in collaboration: Technology as a resource for new patterns of action. In *Proceedings of the 2008 Conference on Computer Supported Cooperative Work (CSCW 2008)* (pp. 137–146). New York, NY, USA: ACM Press. https://doi.org/10.1145/1460563.1460585.

Meier, P. (2012, April 17). Behind the scenes: The digital operations center of the American Red Cross [Blog]. Retrieved from http://irevolution.net/2012/04/17/red-cross-digital-ops/.

Meier, P. (2015). *Digital humanitarians: How big data is changing the face of humanitarian response*. London: Routledge.

Meier, P., & Brodock, K. (2008). *Crisis mapping Kenya's election violence: Comparing mainstream news, citizen journalism and Ushahidi* (Harvard Humanitarian Initiative). Boston, MA, USA: Harvard University. Retrieved from http://irevolution.wordpress.com/2008/10/23/mapping-kenyas-election-violence.

Mendoza, M., Poblete, B., & Castillo, C. (2010). Twitter under crisis: Can we trust what we RT? In *Proceedings of the First Workshop on Social Media Analytics* (pp. 71–79). New York, NY, USA: ACM Press. https://doi.org/10.1145/1964858.1964869.

Meraz, S. (2006). Citizen journalism, citizen activism, and technology: Positioning technology as a "Second Superpower" in times of disasters and terrorism. In *International Symposium on Online Journalism*. University of Texas at Austin.

Mileti, D. S. (1999). *Disasters by design: A reassessment of natural hazards in the United States*. Joseph Henry Press.

Mileti, D. S., Drabek, T. E., & Haas, J. E. (1975). *Human systems in extreme environments: A sociological perspective*. Boulder, CO, USA: Institute of Behavioral Science, University of Colorado.

Monroy-Hernández, A., boyd, danah, Kiciman, E., De Choudhury, M., & Counts, S. (2013). The new war correspondents: The rise of civic media curation in urban warfare. In *Proceedings of the 2013 Conference on Computer Supported Cooperative Work* (pp. 1443–

1452). New York, NY, USA: ACM. https://doi.org/10.1145/2441776.2441938.

Morrow, N., Mock, N., Papendieck, A., & Kocmich, N. (2011). *Independent evaluation of the Ushahidi Haiti Project*. Development Information Systems International. Retrieved from http://www.alnap.org/pool/files/1282.pdf.

Morss, R. E., Demuth, J. L., & Lazo, J. K. (2008). Communicating uncertainty in weather forecasts: A survey of the U.S. public. *Weather and Forecasting, 23*(5), 974–991. https://doi.org/10.1175/2008WAF2007088.1.

Morss, R. E., Wilhelmi, O. V., Meehl, G. A., & Dilling, L. (2011). Improving societal outcomes of extreme weather in a changing climate: An integrated perspective. *Annual Review of Environment and Resources, 36*(1), 1–25. https://doi.org/10.1146/annurev-environ-060809-100145.

Munro, R. (2011). Tracking epidemics through crowdsourcing and natural language processing. *Presented at the International Conference of Crisis Mappers (ICCM), Geneva*.

Norheim-Hagtun, I., & Meier, P. (2010). Crowdsourcing for crisis mapping in Haiti. *Innovations: Technology, Governance, Globalization, 5*, 81–89.

Olteanu, A., Vieweg, S., & Castillo, C. (2015). What to expect when the unexpected happens: Social media communications across crises. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing* (pp. 994–1009). New York, NY, USA: ACM. https://doi.org/10.1145/2675133.2675242.

Palen, L., & Anderson, K. M. (2016). Crisis informatics—New data for extraordinary times. *Science, 353* (6296), 224–225. https://doi.org/10.1126/science.aag2579.

Palen, L., & Liu, S. B. (2007). Citizen communications in crisis: Anticipating a future of ICT-supported public participation. In *Proceedings of the 2007 Conference on Human Factors in Computing Systems (CHI 2007)* (pp. 727–736). New York, NY: ACM Press. Retrieved from April 27, 2010.

Palen, L., Soden, R., Anderson, T. J., & Barrenechea, M. (2015). Success & scale in a data-producing organization: The socio-technical evolution of OpenStreetMap in response to humanitarian events. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (pp. 4113–4122). New York, NY, USA: ACM. https://doi.org/10.1145/2702123.2702294.

Palen, L., & Vieweg, S. (2008). The emergence of online widescale interaction in unexpected events. In *2008 ACM Proceedings of Computer Supported Cooperative Work Conference* (pp. 117–126). New York, NY, USA: ACM Press. https://doi.org/10.1145/1460563.1460583.

Palen, L., Vieweg, S., Liu, S. B., & Hughes, A. L. (2009). Crisis in a networked world. *Social Science Computing Review, 27*(4), 467–480.

Plotnick, L., Hiltz, S. R., Kushma, J. A., & Tapia, A. H. (2015). Red Tape: Attitudes and issues related to use of social media by U.S. county-level emergency managers. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 20015)*. Kristiansand, Norway. Retrieved March 26, 2017, from http://idl.iscram.org/files/lindaplotnick/2015/1225_LindaPlotnick_etal2015.pdf.

Potter, E. (2016). Balancing conflicting operational and communications priorities: Social media use in an emergency management organization. In *Proceedings of the 2016 Information Systems for Crisis Response and Management Conference (ISCRAM 2016)*. Retrieved March 26, 2017, from http://idl.iscram.org/files/emmapotter/2016/1398_EmmaPotter2016.pdf.

Potts, L., & Harrison, A. (2013). Interfaces as rhetorical constructions: Reddit and 4Chan During the Boston Marathon Bombings. In *Proceedings of the 31st ACM International Conference on Design of Communication* (pp. 143–150). New York, NY, USA: ACM. https://doi.org/10.1145/2507065.2507079.

Procopio, C., & Procopio, S. (2007). Do you know what it means to Miss New Orleans? Internet communication, geographic community, and social capital in crisis. *Journal of Applied Communication Research, 35*(1), 67–87. https://doi.org/10.1080/00909880601065722.

Qu, Y., Huang, C., Zhang, P., & Zhang, J. (2011). Microblogging after a major disaster in China: A case study of the 2010 Yushu Earthquake. In *Proceedings of the 2011 Conference on Computer Supported Cooperative Work* (pp. 25–34). New York, NY, USA: ACM Press.

Qu, Y., Wu, P. F., & Wang, X. (2009). Online community response to major disaster: A study of Tianya Forum in the 2008 Sichuan Earthquake. In *Proceedings of the 2009 Hawaii International Conference on System Sciences (HICSS 2009)* (pp. 1–11). Washington, D.C., USA: IEEE Computer Society.

Reuter, C., Ludwig, T., Kaufhold, M.-A., & Spielhofer, T. (2016). Emergency services' attitudes towards social media: A quantitative and qualitative survey across Europe. *International Journal of Human-Computer Studies*. https://doi.org/10.1016/j.ijhcs.2016.03.005.

Reynolds, B., & Seeger, M. W. (2005). Crisis and emergency risk communication as an integrative model. *Journal of Health Communication, 10*(1), 43–55.

Robinson, S. (2009). "If You Had Been with Us": Mainstream press and citizen journalists jockey for authority over the collective memory of Hurricane Katrina. *New Media & Society, 11*(5), 795–814. https://doi.org/10.1177/1461444809105353.

Robson, E. (2012). *Responding to liability: Evaluating and reducing tort liability for digital volunteers*. Commons Lab, Science and Technology Innovation Program, Woodrow Wilson Center. Retrieved from http://www.scribd.com/doc/106278311/Responding-to-Liability-Evaluating-and-Reducing-Tort-Liability-for-Digital-Volunteers.

Sakaki, T., Okazaki, M., & Matsuo, Y. (2012). Tweet analysis for real-time event detection and earthquake reporting system development. *IEEE Transactions on Knowledge and Data Engineering, 25*(4), 919–931. https://doi.org/10.1109/TKDE.2012.29.

Sarcevic, A., Palen, L., White, J., Starbird, K., Bagdouri, M., & Anderson, K. (2012). "Beacons of Hope" in decentralized coordination: learning from on-the-ground medical Twitterers during the 2010 Haiti Earthquake. In *Proceedings of the 2012 Conference on Computer Supported Cooperative Work* (pp. 47–56). New York, NY, USA: ACM. https://doi.org/10.1145/2145204.2145217.

Schlieder, C., & Yanenko, O. (2010). Spatio-temporal proximity and social distance: A Confirmation framework for social reporting. In *Proceedings of the 2nd ACM SIGSPATIAL International Workshop on Location Based Social Networks* (pp. 60–67). New York, NY, USA: ACM. https://doi.org/10.1145/1867699.1867711.

Schram, A., & Anderson, K. M. (2012). MySQL to NoSQL: Data modeling challenges in supporting scalability. In *Proceedings of the 3rd annual conference on Systems, programming, and applications: software for humanity* (pp. 191–202). New York, NY, USA: ACM Press. https://doi.org/10.1145/2384716.2384773.

Shanley, L. A., Burns, R., Bastian, Z., & Robson, E. S. (2013). Tweeting up a storm: The promise and perils of crisis mapping. *Photogrammetric Engineering & Remote Sensing, 79*(10), 865–879.

Shklovski, I., Burke, M., Kiesler, S., & Kraut, R. (2010). Technology adoption and use in the aftermath of Hurricane Katrina in New Orleans. *American Behavioral Scientist, 53*(8), 1228–1246. https://doi.org/10.1177/0002764209356252.

Shklovski, I., Palen, L., & Sutton, J. (2008). Finding community through information and communication technology in disaster response. In *Proceedings of the 2008 Conference on Computer Supported Cooperative Work (CSCW 2008)* (pp. 127–136). New York, NY, USA: ACM Press. Retrieved from April 27, 2010.

Soden, R. (2017). Crisis Informatics in the Anthropocene: Disasters As Matters of Care and Concern. In *Companion of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (pp. 93–96). New York, NY, USA: ACM. https://doi.org/10.1145/3022198.3024945.

Soden, R., & Palen, L. (2014). From crowdsourced mapping to community mapping: The post-earthquake work of OpenStreetMap Haiti. In *Proceedings of the 11th International Conference on the Design of Cooperative Systems*.

Soden, R., & Palen, L. (2016). Infrastructure in the wild: What mapping in post-earthquake Nepal reveals about infrastructural emergence. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (pp. 2796–2807). New York, NY, USA: ACM. https://doi.org/10.1145/2858036.2858545.

St. Denis, L. A., Hughes, A. L., & Palen, L. (2012). Trial by fire: The deployment of trusted digital volunteers in the 2011 shadow lake fire. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2012)*. Vancouver, BC, USA. Retrieved from http://epic.cs.colorado.edu/wp-content/uploads/TrustedDigitalVolunteersStDenisHughesPalen.pdf.

Stallings, R. A. (1971). *Communications in natural disasters*. Disaster Research Center, Ohio State University.

Starbird, K. (2017, March 15). Information wars: A window into the alternative media ecosystem. Retrieved March 26, 2017, from https://medium.com/hci-design-at-uw/information-wars-a-window-into-the-alternative-media-ecosystem-a1347f32fd8f#.yvblefllli.

Starbird, K., Maddock, J., Orand, M., Achterman, P., & Mason, R. M. (2014). Rumors, false flags, and digital vigilantes: Misinformation on Twitter after the 2013 Boston Marathon Bombing. In *iConference 2014*. Berlin, Germany. https://doi.org/10.9776/14308.

Starbird, K., Muzny, G., & Palen, L. (2012a). Learning from the Crowd: Collaborative filtering techniques for identifying on-the-ground Twitterers during mass disruptions. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2012)*. Retrieved from http://epic.cs.colorado.edu/wp-content/uploads/LearningfromCrowdStarbirdMuznyPalen.pdf.

Starbird, K., & Palen, L. (2010). Pass it on?: Retweeting in mass emergency. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2010)*. Seattle, WA, USA.

Starbird, K., & Palen, L. (2011). "Voluntweeters:" Self-organizing by digital volunteers in times of crisis. In *Proceedings of the 2011 Conference on Human Factors in Computing Systems (CHI 2011)* (pp. 1071–1080). New York, NY, USA: ACM Press.

Starbird, K., & Palen, L. (2012). (How) will the revolution be Retweeted?: Information propagation in the 2011 Egyptian uprising. In *Proceedings of the 2012 Conference on Computer Supported Cooperative Work (CSCW 2012)* (pp. 7–16). New York, NY, USA: ACM Press.

Starbird, K., & Palen, L. (2013). Working & sustaining the virtual "Disaster Desk." In *Proceedings of the 2013 Conference on Computer Supported Cooperative Work (CSCW 2013)* (pp. 491–502). New York, NY, USA: ACM Press.

Starbird, K., Palen, L., Hughes, A. L., & Vieweg, S. (2010). Chatter on the Red: What hazards threat reveals about the social life of microblogged information. In *Proceedings of the ACM 2010 Conference on Computer Supported Cooperative Work (CSCW 2010)* (pp. 241–250). New York, NY, USA: ACM. Retrieved from April 27, 2010.

Starbird, K., Palen, L., Liu, S. B., Vieweg, S., Hughes, A. L., Schram, A., et al. (2012b). Promoting structured data in citizen communications during disaster

response: An account of strategies for diffusion of the "Tweak the Tweet" syntax. In C. Hagar (Ed.), *Crisis information management: Communication and technologies* (pp. 43–63). Cambridge, UK: Chandos Publishing.

Starbird, K., Spiro, E., Edwards, I., Zhou, K., Maddock, J., & Narasimhan, S. (2016). Could this be true?: I think so! Expressed uncertainty in online rumoring. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (pp. 360–371). New York, NY, USA: ACM. https://doi.org/10.1145/2858036.2858551.

Starbird, K., & Stamberger, J. (2010). Tweak the Tweet: Leveraging microblogging proliferation with a prescriptive grammar to support citizen reporting. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2010)*. Seattle, WA, USA.

Stephens, K. K., & Malone, P. C. (2009). If the organizations won't give us information…: The use of multiple new media for crisis technical translation and dialogue. *Journal of Public Relations Research, 21*(2), 229–239. https://doi.org/10.1080/10627260802557605.

Sultanik, E. A., & Fink, C. (2012). Rapid geotagging and disambiguation of social media text via an indexed gazetteer. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2012)*. Vancouver, BC, USA. Retrieved from http://www.iscramlive.org/ISCRAM2012/proceedings/190.pdf.

Sutton, J. N., Palen, L., & Shklovski, I. (2008). Backchannels on the front lines: Emergent use of social media in the 2007 Southern California fires. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2008)*. Washington, D.C., USA. Retrieved from http://www.iscramlive.org/dmdocuments/ISCRAM2008/papers/ISCRAM2008_Sutton_etal.pdf.

Sutton, J., Spiro, E. S., Fitzhugh, S., Johnson, B., Gibson, B., & Butts, C. T. (2014). Terse message amplification in the Boston bombing response. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2014)*. Retrieved from March 26, 2017, http://idl.iscram.org/files/sutton/2014/986_Sutton_etal2014.pdf.

Tapia, A. H., Bajpai, K., Jansen, B. J., & Yen, J. (2011). Seeking the trustworthy Tweet: Can microblogged data fit the information needs of disaster response and humanitarian relief organizations. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2011)*. Lisbon, Portugal. Retrieved from http://www.iscramlive.org/ISCRAM2011/proceedings/papers/161.pdf.

Tapia, A. H., & Moore, K. (2014). Good enough is good enough: Overcoming disaster response organizations' slow social media data adoption. *Journal of Computer Supported Cooperative Work*, 1–30. https://doi.org/10.1007/s10606-014-9206-1.

Thomson, R., & Ito, N. (2012). Social responsibility and sharing behaviors online: The Twitter-sphere's response to the Fukushima disaster. *International Journal of Cyber Society and Education, 5*(1), 55–74.

Tierney, K. J., Lindell, M. K., & Perry, R. W. (2001). *Facing the unexpected: Disaster preparedness and response in the United States*. Washington, D.C., USA: John Henry Press.

Tonkin, E., Pfeiffer, H. D., & Tourte, G. (2012). Twitter, information sharing and the London riots? *Bulletin of the American Society for Information Science and Technology, 38*(2), 49–57. https://doi.org/10.1002/bult.2012.1720380212.

Torrey, C., Burke, M., Lee, M., Dey, A., Fussell, S., & Kiesler, S. (2007). Connected giving: Ordinary people coordinating disaster relief on the internet. In *Proceedings of the 40th Annual Hawaii International Conference on System Sciences* (p. 179a). Washington, D.C., USA: IEEE Computer Society. Retrieved from January 24, 2013, http://dx.doi.org/10.1109/HICSS.2007.144.

Verma, S., Vieweg, S., Corvey, W., Palen, L., Martin, J. H., Palmer, M., et al. (2011). NLP to the rescue?: Extracting "Situational Awareness" tweets during mass emergency. *Fifth International AAAI Conference on Weblogs and Social Media*. Retrieved from December 20, 2012, http://works.bepress.com/vieweg/1.

Vieweg, S., Hughes, A. L., Starbird, K., & Palen, L. (2010). Microblogging during two natural hazards events: What Twitter may contribute to situational awareness. In *Proceedings of the ACM 2010 Conference on Computer Human Interaction* (pp. 1079–1088). New York, NY, USA: ACM Press. Retrieved from September 22, 2010.

Vieweg, S., Palen, L., Liu, S. B., Hughes, A. L., & Sutton, J. (2008). Collective intelligence in disaster: Examination of the phenomenon in the aftermath of the 2007 virginia tech shooting. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2008)*. Washington, D.C., USA. Retrieved December 10, 2010, from http://www.iscramlive.org/dmdocuments/ISCRAM2008/papers/ISCRAM2008_Vieweg_etal.pdf.

Vivacqua, A. S., & Borges, M. R. S. (2010). Collective intelligence for the design of emergency response. In *Proceedings from the 2010 International Conference on Computer Supported Cooperative Work in Design (CSCWD)* (pp. 623–628). https://doi.org/10.1109/CSCWD.2010.5471897.

Wang, J. (2010). Beyond information: The sociocultural role of the internet in the 2008 Sichuan Earthquake. *The Journal of Comparative Asian Development, 9*(2), 243–292. https://doi.org/10.1080/15339114.2010.528299.

White, G. F. (1945). *Human adjustment to floods*. Department of Geography Research Paper no. 29, Chicago, IL, USA: The University of Chicago.

White, J. D., & Fu, K.-W. (2012). Who do you trust? Comparing people-centered communications in

disaster situations in the United States and China. *Journal of Comparative Policy Analysis: Research and Practice, 14*(2), 126–142. https://doi.org/10.1080/13876988.2012.664688.

White, J., Palen, L., & Anderson, K. M. (2014). Digital mobilization in disaster response: The work & self-organization of on-line pet advocates in response to Hurricane Sandy. In *Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing* (pp. 866–876). New York, NY, USA: ACM. https://doi.org/10.1145/2531602.2531633.

Wickler, G., Potter, S., Tate, A., & Hansberger, J. (2011). The virtual collaboration environment: New media for crisis response. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2011)*. Lisbon, Portugal. Retrieved from http://www.iscramlive.org/ISCRAM2011/proceedings/papers/142.pdf.

Xia, X., Yang, X., Wu, C., Li, S., & Bao, L. (2012). Information credibility on Twitter in emergency situation. In *Proceedings of the 2012 Pacific Asia Conference on Intelligence and Security Informatics* (pp. 45–59). Berlin, Heidelberg, NY, USA: Springer. https://doi.org/10.1007/978-3-642-30428-6_4.

Yang, X., Wu, Z., & Li, Y. (2012). Using internet reports for early estimates of the final death toll of earthquake-generated tsunami: The March 11, 2011, Tohoku, Japan, Earthquake. *Annals of Geophysics*, *54*. Retrieved from http://www.annalsofgeophysics.eu/index.php/annals/article/view/5169.

Yin, J., Lampert, A., Cameron, M., Robinson, B., & Power, R. (2012). Using social media to enhance emergency situation awareness. *IEEE Intelligent Systems*, *27*(6), 52–59. https://doi.org/10.1109/MIS.2012.6.

Zhu, J., Xiong, F., Piao, D., Liu, Y., & Zhang, Y. (2011). Statistically modeling the effectiveness of disaster information in social media. In *2011 IEEE Global Humanitarian Technology Conference (GHTC)* (pp. 431–436). https://doi.org/10.1109/GHTC.2011.48.

Zook, M., Graham, M., Shelton, T., & Gorman, S. (2010). Volunteered geographic information and crowdsourcing disaster relief: A case study of the Haitian Earthquake. *World Medical & Health Policy, 2*(2), 7–33. https://doi.org/10.2202/1948-4682.1069.