Supporting Situational Awareness during Disasters: The Case of Hurricane Irma

ABSTRACT

In a rapidly globalizing world, disasters and the way in which they are managed are changing. Social media, in conjunction with other online resources, now provide a wealth of information throughout the lifecycle of disasters and are relied upon by individuals and emergency responders alike. The study of such data as a lens for analysis has proved valuable in recent years, with many contributing to targeted emergency response protocols and improved methods for the management strategies of future crises. This study seeks to make a similar contribution by reporting on the use of such data for situational awareness during the case of hurricane Irma, which occurred between September and August 2017. Using a mixed methods approach the paper examines data from social media such as Twitter, as well as other online sources such as blogs and news media, to provide original insight into the disaster. A conceptual framework is then applied to determine the uses and users of social media, and to identify how these change throughout the course of the disaster, thus demonstrating situational awareness over time. The paper concludes with proposed improvements for disaster management and emergency response for future similar disasters, specifically in the hurricane season, in addition to more generalized hazards which are predicted to increase in their frequency and severity due to underlying issues such as climate change.

Keywords

Situational Awareness, Hurricane Irma, Conceptual Framework, Disaster Management, Social Media.

INTRODUCTION

In the past decade, social media are being relied upon for a plethora of issues during natural disasters. Understanding such issues, as well as the potential functions, features applications and networks of social media themselves is therefore paramount for disaster management and emergency response in a globalizing world (Kaplan & Haenlein, 2010). Currently, the most common types of social media are Facebook (with roughly 1.86 billion users active users on a monthly basis), YouTube (1 billion), WhatsApp (1 billion), Instagram (500 million), LinkedIn (483 million), Twitter (320 million, and Google + (235 million) (Reuter, 2017). As a result, many governments, non-governmental organisations (NGOs), international humanitarian aid organisations, charities and researchers alike have taken up the analysis of social media during disasters as a vital part of their management (Lindsay, 2011).

Despite this, there remain significant limitations to the effective use of social media during disasters. These are often complex and multi-faceted, and may depend on a range of underlying factors such as population demographics or platform structures (Olteanu et al., 2015). Predominantly, several issues are common across all types of disaster and all online networks: these remain prevalent in many disaster case studies. Firstly, the limitation of information reliability continues to affect crisis communications. This can occur when information spread online is incorrect, not sited from credible sources, or is outdated (Thomson et al., 2012). Secondly, the issue of Web accessibility may still affect the outcomes of a disaster. This is a factor that is commonly overlooked in disaster literature that focus on the benefits of social media use, but one that remains important in modern case study evaluations – especially as the digital divide of populations means that certain groups are likely to experience more risk during crises (Greenstein & Prince, 2006).

The use of social media as a lens for analysis has proved valuable to many studies within disaster literature, resulting in beneficial contributions to the field and changes in policy or best practices (Reuter & Kaufhold, 2017). Specifically, analysis of crisis communications during case studies have proved valuable in defining and understanding the relationship between social media and disasters, alongside revealing and supporting situational awareness throughout crises (Hagen et al., 2017). This has also served to conceptualize disasters in a modern world, where such events are played out on a global stage (Cottle, 2014). As technology, as well as communities both online and offline, continue to evolve and develop, so too must our understanding of their relationship to disasters. This is vital to the outcome of future crises to reduce risk, lessen damages and reduce

death tolls (Huang et al., 2010).

This study seeks to contribute understanding to the relationship between social media and disasters. It does this through a case study analysis of hurricane Irma, a category 5 hurricane which affected large regions of the Caribbean and mainland USA between August and September, 2017. Characterised by its strength and intensity, the hurricane caused high levels of damage and required the coordination and communication of hundreds of organisations over a wide geographical area. This paper evaluates data from multiple online sources as a lens for analysis, which includes Twitter, blogs, news and TV media, resulting in original insight into the disaster. Additionally, content analysis and a conceptual framework proposed by Gray et al., (2016) that categorises the uses and users of social media throughout the disaster lifecycle is applied. The paper concludes with an analysis of the case study which identifies the benefits and limitations of social media and online resources, as well as suggestions for targeted ways disaster management strategies and emergency responders may reduce risk to populations prone to particular hazards.

RELATED WORK

While the study of natural disasters is not a new field, the incorporation of new technologies, methodologies and analyses has resulted in higher levels of interdisciplinarity in recent years (Alexander, 2006). Reuter, Marx and Pipek (2012) loosely trace the beginnings of modern social media use during disasters to several key case studies. One of the first is that of the creation of Wiki's for information exchange and missing peoples following the September 11th 2001 terrorist attacks in the USA (Palen et al., 2007). In a similar methodology, the use of photograph repositories for information exchange following the Indian Ocean tsunami in 2004 revealed the value of social media to disaster-affected communities (Liu et al., 2008).

Specific to emergency response, social media's functionality for knowledge management during Hurricane Katrina in 2005 established the value of social media for a range of networks, but also demonstrated how extremes in poverty and other underlying factors had the power to shape the outcomes of a disaster (Murphy & Jennex, 2006). The use of repositories, as well as the use of social media as a channel for public participation and communications, during the Southern Californian wildfires in 2007 further illustrated the value social media could have to the field of disaster management through inter-agency coordination and information dissemination (Shklovski et al., 2008).

Although social media have value throughout the disaster lifecycle, many case studies have found that there remain significant barriers to their effective use (Lindsay, 2011). Predominantly, issues with the reliability and timeliness of information is a major concern for disaster management the world over (Bharosa et al., 2009; Chow & Chan, 2008). This is dependent on a number of different aspects which include few individuals citing credible sources when disseminating information (Mendoza et al., 2010), anonymous social media profiles creating untraceable information (Thomson, 2012), and a lack of standardised social media protocols for the coordination of emergency responders online (Bharosa, 2009).

In addition, the issue of Web accessibility remains problematic despite disasters becoming less territorially bounded as a result of globalization (Blaikie et al., 2014; Cottle, 2014). This directly impacts the ease of access individuals may have to social media by extension, which is an observed factor in reducing risk (Blaikie, 2014). Communities that are more economically developed generally have a larger percentage of their population who have regular access to the Web, as they are able to invest more into infrastructure and services (Wentz et al., 2014).

Furthermore, an individual's gender, age, ethnicity, social influences, income, geographical location, and social class shape accessibility (Fothergill et al., 1999; Greenstein, 2006; Pelling, 2003). This was apparent in the evacuation of the wards of New Orleans during hurricane Katrina (2009), where the poorest members of the community faced significantly harder problems trying to get to safety as they had little access to transport combined with fewer people owning a device that could connect to the internet (Laska & Morrow, 2006). The remainder of this paper seeks to identify and address these limitations during the case of hurricane Irma, as an example of a severe hazard – the likes of which are predicted to increase in frequency and severity due to underlying factors such as climate change (Kappes et al., 2012).

THE STUDY

Rationale for Analysis

Hurricane Irma was a unique and devastating natural disaster. Not only did it record the strongest storm on

record in the open Atlantic region (as well as setting other records for intensity), it was also a part of the most destructive hurricane season ever experienced (Battistoli et al., 2018). This makes the crisis important for analysis for several key reasons. Firstly, the disaster spanned a large geographical area, which few other types of hazard achieve. This meant that methods of crisis communication, situational awareness, inter-agency disaster management and emergency response occurred on a much larger international scale, as well as on smaller regional scales making management multi-faceted and complex (Zolnikov, 2018).

Secondly, the severity of the disaster stands out as being one of the most destructive in recent history. This warrants detailed study for the management and risk reduction of future disasters: this is especially important for geographical regions that are prone to particular types of hazard, for example, hurricanes across storm paths or earthquakes along fault lines (Smith, 2013). Thirdly, the variations in population demographics as well as other measurements of development between regions affected by the hurricane differ extremely. This represents a valuable area for analysis in the identification of factors that may exacerbate or lessen vulnerability to disasters (Birkman, 2006): within this case study the effects of the same hazards may therefore be evaluated on different communities.

Background Information

In order to understand the extent of the disaster, we must first understand the context of the hurricane itself and the hurricane season of 2017. The season began in June and ended in November (although the first named storm formed in April), featuring 17 named storms and the highest number of major hurricanes since 2005. The severity of the season was caused by three consecutive category 4 and 5 hurricanes – that of Harvey, Irma and Maria – which resulted in the highest total damages of any season. It is the only season to record three hurricanes with an Accumulated Cyclone Energy (ACE) of over 40. It is theorized that the severity of the season was due to the absence of the El Niño climate pattern, which later shifted to a La Niña, causing stronger than average hurricanes in the Atlantic. Hurricane Irma formed near Cape Verde on August 30th. On September 6th, after increasing in intensity from a category 2 to a category 5, it made landfall in Cuba. Following fluctuations in intensity, it continued on a course to make landfall in Florida, and then later in Mississippi. The hurricane caused damages in excess of $64 billion, with a death toll of 146, and caused serious damages to Cape Verde, the Caribbean and Leeward Islands, the Greater Antilles, Turks and Caicos Islands, the Bahamas and Eastern USA. The storm path of hurricane Irma is shown in figure 1 below.

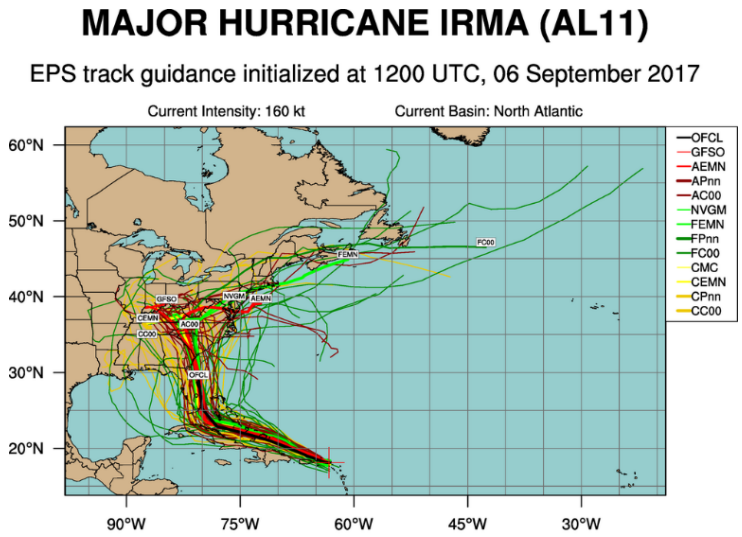

Fig 1. The storm path of Hurricane Irma from August 30th – September 12th. Source: The National Centre for Atmospheric Research (NCAR), 2017.

METHOD

Data relating to hurricane Irma was collected using online content such as Twitter data, blogs and mainstream media content such as news broadcasts. Combined with data such as offline news stories and meteorological data, this provided a timeline of events for the disaster. Content analysis was conducted on Twitter data, which

was collected for featuring key terms, as well as the application of a conceptual framework for the classification of users and uses of social media over time.

Data Collection

Twitter data was collected using the setup provided by the University of Southampton's Web Observatory and the Twitter streaming API. This produced roughly 3 million tweets. Tweets were collected for featuring the terms "Hurricane" and "Irma". Tweets were then systematically selected for a 24-hour period, at 7 day intervals. These smaller datasets can therefore be considered as "sub-samples" of the original larger dataset. This avoids problems with the large size and velocity at which content is created and re-tweeted on Twitter during disasters, while demonstrating content change throughout the crisis and enabling insightful analysis (Hoeber et al. 2016).

Conceptual Framework

The conceptual framework proposed by Gray et al. (2016) is shown in table I below. The framework was applied to online data sets from Twitter, relevant blogs, as well as other online and offline data from research centers and media broadcasts. This was done systematically by the researchers, in which data content was read, assessed, and then assigned the relevant framework categories. The framework was created through the inductive coding of relevant disaster literature which produced 27 unique categories. These are used to understand the uses and users of social media throughout the disaster lifecycle phases, and assess how online content changes over time.

Table 1. A Conceptual Framework for Social Media Crisis Communications.

Disaster Lifecycle Phase	The Uses of Social Media in Crisis Communications
All Stages	1. Evaluate the reliability of information. 2. Identify and/or contain false information.
Pre-Event	3. Provide and seek general disaster preparedness information. 4. Provide and receive general national and regional disaster warnings
Pre-Event - During	5. Detect and warn of disasters and specific hazards locally. 6. Identify the differences between actual and potential uses of social media.
During	7. Send and receive requests for help or assistance. 8. Inform others about ones condition and location.
During – Post-Event	9. Provide, receive and analyze big data generated by the event. 10. Provide, receive and encourage information sharing in multiple formats. 11. Document what is happening during a disaster online and offline. 12. Consume or create news coverage of the disaster. 13. Provide and receive location based real-time warnings. 14. Express public and/or individual emotion or empowerment; reassure others. 15. Raise and develop awareness; donate and receive donations; list ways to help or volunteer. 16. Seek to inform and support existing disaster management strategies. 17. Provide and receive specific disaster response, rescue and evacuation information. 18. Seek and assess mental, behavioral and emotional health support. 19. Filter, categorize critically analyze information. 20. Understanding how online and offline situations differ. 21. Provide and receive information regarding disaster response, recovery and rebuilding; tell and hear stories from the disaster. 22. Understand how ones access to the Web has had an effect on their experiences.
Post-Event	23. Discuss socio-political causes, implications and responsibility. 24. Re-connect community members 25. Discuss the accessibility of the Web as an intermediary to social media. 26. Discuss the accessibility and reliability of specific social media; discuss perceptions.
Post-Event – Pre-Event	27. Consolidate lessons learnt to develop new/improved social media applications.

Content Analysis

Content analysis was conducted on the data collected firstly through automatic python scripts, and secondly through manual analysis conducted by the researchers. This indicated the most popular hashtags and content trends during the disaster life cycle phases, the most active Twitter accounts and websites in terms of the creation of information, the most active accounts and websites in terms of information dissemination, the nature of crisis communications over time, and the extent of situational awareness throughout the disaster.

RESULTS

A Preliminary Overview of Crisis Communications during Hurricane Irma

The Atlantic Hurricane Season is managed in a variety of ways that are dependent on several factors, primarily that of geographical location. As the season is annual, many of the countries and communities in the storm path have relatively high levels of resilience, which affects how well populations may react and respond to hazards. Hurricane Irma was a fairly rare exception in the 2017 hurricane season as it affected more countries than most hurricanes on record. Content analysis of offline data showed that more than 100 different agencies created, discussed or disseminating information regarding hurricane Irma. These fell into four main categories: governmental, commercial, self-funded organisations, and media outlets. Further analysis showed that emergency responders sustained high levels of public engagement through a series of channels such as news broadcasts and a range of different social media platforms.

Of these social media platforms Twitter was one of the most extensively utilised. Using this platform as a lens, the accounts of emergency responders were shown to create the highest levels of information, whereas public accounts were shown to have the highest levels of disseminating (through re-tweeting) such information. "Celebrity" accounts, for example politicians or notable figures in the community, were found to be extremely active throughout the disaster and represented "hubs" – nodes with the highest degrees of centrality. In contrast to many similar case studies, table II below reveals that the top 10 tweeters throughout hurricane Irma did not feature any emergency response accounts. Instead, accounts with political motivations such as 4WilliamLewis, and news outlets such as Infor24US tweeted the most throughout the event. This suggests that there were political and social undercurrents to the management and response of the disaster.

Table 2. The Top Ten Most Active Twitter Accounts

4WilliamLewis	**Lopezgovlaw**
20280 tweets	2877 tweets
4BillLewis	**4RickStaly**
188891 tweets	2066 tweets
2JenniferLewis	**KenyaPOS**
11867 tweets	1208 tweets
BinaFinkKohl	**LivingOnChi**
10081 tweets	1083 tweets
AM1470WWNN	**Info24US**
9120 tweets	1014 tweets

Content Change Over Time

The application of the conceptual framework shows that Tweet content, as expected, changed throughout the disaster lifecycle phases of hurricane Irma. In the pre-disaster phase of the hurricane (the first subsample) the most popular categories were early stage categories of the framework, which included providing and seeking preparedness information, providing and receiving general national and regional warnings, and detecting and warning of specific hazards. These categories remained popular throughout the second subsample (recorded one week after the first sample) as the hurricane was travelling across a wide geographical region. This meant that pre-disaster phase information remained in circulation for a long period due to the fact different communities were experiencing the meteorological event at different times. Emergency response and management of information during these periods can be multi-faceted and complex, especially as different communities require time-critical information at specific times.

During subsamples three and four, the content of Tweets were shifting towards during and post-event categories. These mainly focused on documenting what was happening during the disaster, providing and receiving location based real-time warnings, and seeking to inform and support existing disaster management and emergency response protocols. Unusually for content during the later stages of the disaster lifecycle a large amount of pre-disaster categories were still present in the subsamples. This can be explained by the staggered landfall that the hurricane made, which resulted in continued importance for categories such as the sending and receiving of specific and general hazard warnings. Additionally, this can be further explained by the nature of hurricanes themselves which commonly change in intensity and size based on meteorological conditions, thus requiring constant tracking and monitoring.

In the later subsamples, a range of pre-disaster, during and post-disaster categories were noted: again, this can mainly be attributed to the range of communities affected at different times. Categories such as discussing the socio-political causes and implications, receiving and analysing big data of the event, discussing the differences in Web accessibility, and evaluating the reliability of information became more apparent. This may be attributed to the hurricane making fall in the USA, which saw the largest scale evacuations of any of the communities

previously affected. This, combined with the fact that the country has a much higher percentage of its population with access to devices that can connect to the Web, meant that a majority of tweets and re-tweets originated from the USA.

Information Reliability and the Launch of "Rumor Control"

Content analysis has shown that the issue of information reliability has been prevalent throughout the disaster. This is further evidenced by the most accessed links in the Twitter data, which featured a direct link to a page on FEMA's website entitled "Hurricane Irma Rumor Control". This is part of a series of new resources published by FEMA to support the Hurricane season, which has so far covered hurricanes Harvey, Maria and Irma. On this page there are a number of sections that present up-to-date information about the core issues of emergency response and management, for example about the National Flood Insurance Program (NFIP) and Evacuation Reimbursement, designed to act as definitive resources to avoid the spread of false information and rumor during disasters.

Comparing Web Accessibility across Affected Communities

In the case of hurricane Irma, figure 2 below shows that the populations who experienced the highest risk were in the areas of Antigua and Barbuda, St Barts, St Martin, Anguilla, US Virgin Islands, British Virgin Islands, Turks and Caicos Islands and Cuba. Based on this, the framework results expected to record a higher percentage of geo-located tweets from these areas, but instead found the USA dominated throughout each of the disaster lifecycle phases. The large geographical affected by hurricanes is an extremely important factor for emergency response and disaster management. Especially in the Atlantic hurricane season Web accessibility has become a more pressing issue as the range of communities existing in the hurricane path features a spectrum in GDP, resources, governmental protocol and policy, infrastructure and resilience, preparedness, physical accessibility (i.e. offshore islands only accessible via boat), and level of risk. In this region, island communities that are considered lesser-developed countries (LEDCs) commonly experience the negative impacts of hurricanes more severely than more developed countries (MEDCs).

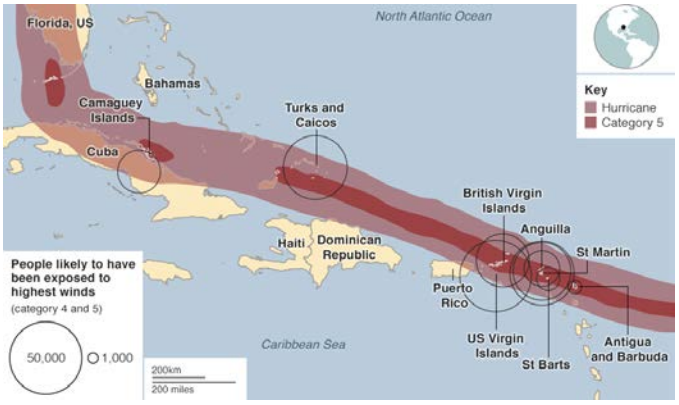

Fig 2. A map of the Caribbean Islands worse-affected by Hurricane Irma. Source: National Hurricane Centre (2017).

CONCLUSION

The use of social media such as Twitter and other online content have proved to be a valuable lens in understanding hurricane Irma. In particular, the issues of information reliability and Web accessibility have directly affected crisis communications. The introduction of FEMAs "Rumor" pages further evidence the scale and importance of time-critical, clear and relevant information through the disaster lifecycle. This is becoming ever more important with the increasing severity and frequency of global hazards that are exacerbated by underlying factors such as climate change. Similarly, the differences in communities and countries must be taken into more detailed regard for emergency response and disaster management strategies that utilise online resources. LEDCs exposed to high levels of risk often have a smaller percentage of their population with access to devices that may connect to the Web, and by extension to social media and crisis communications. Especially during the 2017 Atlantic hurricane season where phone networks went down across several islands, the reliability of information spread via other channels was vital to individuals. In such cases where hazards may affect large geographical regions at staggered times, strategies employed by different types of emergency responders must be integrated with offline methods of management, as well as being targeted to specific

populations.

Towards Improving the Management of Hurricanes

Improving disaster management in the Atlantic hurricane season can be done in a number of ways. Firstly, more collaborative development of tools and software is required to advance the effective sharing of information between agencies. Often large humanitarian aid organisations must coordinate with any number of individual governments that have their own unique protocols, policies and internal structures. This is also the case for organisations, who may also be stretched across working in many different regions. Secondly, future research should consider integrating social media analysis with other qualitative methods of analysis to produce a more in depth understanding of the case. This is especially apparent in cases where online and offline data differ from one another, or where some populations or regions do not have access to the same online resources. Finally, the study of underlying social factors may additionally contribute to understanding the inherent levels of preparedness, resilience, response and recovery present in the countries often affected by the Atlantic hurricane season. Factors alongside information reliability and Web accessibility should also be taken into account, for example information dearth, language barriers, and online human behaviour in social networks. This is becoming increasingly important in a globalizing world where the way in which individuals use, engage with, and perceive disasters is evolving with the development and uptake of new technologies and services.

Future Work

It is important to note that content analysis and conceptual framework applications remain in their preliminary stages. As such, the results presented in this paper may only be considered an indication of the broader picture of the disaster. Future work will see a more detailed understanding and analysis of offline content and Twitter data. Future work will also take into account data from a range of other social media platforms, including YouTube and Facebook, as these (combined with Twitter) are the most popular sites accessed during disasters (Reuter, 2017). It is anticipated that more detailed analysis of multiple data sources will shed further light on crisis communications, and result in more detail-orientated and targeted suggestions for emergency response and disaster management for similar future cases.

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