

Mining Twitter Data to Understand the Human Sentiment on Hurricane Florence

Seungil Yum 

Design, Construction, and Planning, University of Florida

ARTICLE INFO	ABSTRACT
<p>ORIGINAL ARTICLE</p> <p>Article history: Received: 12 June 2020 Revised: 10 August 2020 Accepted: 16 August 2020</p> <p>*Corresponding author: Seungil Yum</p> <p>Address: Design, Construction, and Planning, University of Florida</p> <p>Email: yumseungil@ufl.edu</p> <p>Tel: -3522832947</p>	<p>Introduction: Most studies have analyzed how natural disasters exert a severe impact on the regional level in the disaster period based on quantitative methods. This study aimed to highlight how Hurricane Florence exerts an impact on human life and societies across US states in a multitude of periods by employing both qualitative and quantitative methods.</p> <p>Method: This study developed a new app called “Twitgis,” collected 1,433,032 tweets, and employed 57,842 data filtered for Hurricane Florence between 08-21-2018 and 10-01-2018.</p> <p>Results: First, this study showed that the spatial patterns of tweets are differentiated by periods. For example, the spatial patterns of tweets are more concentrated in the south region in the pre-hurricane period, the spatial patterns of tweets are heavily concentrated in the Southeast region in the hurricane period, and the spatial patterns of tweets are more located in the Northeast region in the post-hurricane period. Second, the most retweeted tweet shows that human sentiment plays an important role in disaster information more than news of the hurricane in online communication. The first ranked tweet is about two times higher than the sum of the retweet numbers between the top two and top 20. Third, this study found that people actively utilize Twitter to share a lot of emotions, opinions, information, and so on for Hurricane Florence. For instance, about one-fifth of tweets in the sentiment analysis are emotions for the hurricane event.</p> <p>Conclusion: Governments and policymakers should monitor Twitter data to understand the effects of natural disasters on people and the human environment.</p> <p>Keywords: Cyclonic Storm, Disaster, Social Media, Response, Sentiment</p>

Introduction

Natural disasters are some of the most serious catastrophes across the world. After the 2000s, there have been a total of 7,344 natural disasters worldwide as of 2019 (1). More than 8 million deaths and seven trillion US dollars economic have been damaged via natural disasters since the start of the 20th century (2). Therefore, coping with natural

disasters has been one of the main tasks for governments and urban planners (3- 8).

Scholars have tried to understand how natural disasters play an important role in human life (9-15). For instance, the average of natural disasters leads to a fall in growth of 1% of gross domestic product (GDP) upon impact, and a cumulative loss to GDP of 2.6% (16). Natural

disasters exert a negative impact on per capita GDP by up to 6.8% on impact (17).

Many authors have attempted to analyze the effects of natural disasters on human behavior and environment based on Social Network Systems (SNS) with the development of information technology after the 2010s (18-21). For example, individuals actively engage to share information, communicate with each other, and update information based on the 2017 flood in Louisiana (22). Active players and their effectiveness in Twitter play an important role in disseminating critical information during the 2010-2011 Australian Floods (23).

However, most studies have analyzed how natural disasters exert a severe impact on a regional level (22-26). In other words, prior studies have barely highlighted the relationship between natural disasters and human behavior across regions at the national level. Analyzing the impact of natural disasters across regions is important since natural disasters play a crucial role in not only people in the affected region, but also those in the same country. This is because people in other regions have their friends, family, cousins, or are worried about others, animal life, economic loss, and their country. For example, people who do not live geographically proximate to natural disasters express their concern about the disasters by analyzing Twitter logs from the 2010 Philippines typhoon, the 2011 Brazil flood, and the 2011 Japan earthquake (27).

Also, prior studies have heavily focused on quantitative analyses since Twitter provides big data from numerous accounts (28-30). However, qualitative analyses of tweets also can play an important role in developing natural disaster policies since they allow scholars to fully understand complex and nuanced contents in the tweets (31).

Therefore, this study highlights how natural disasters play a significant role in human behavior and environment across the US states according to a multitude of periods (the pre-

hurricane period, the hurricane period, and the post-hurricane period) based on qualitative and quantitative analyses of Twitter data for Hurricane Florence in 2018. Hurricane Florence is a long-lived category 4 hurricane with the maximum sustained winds of 130 mph (215km/h), which made landfall along the southeastern US (see Figure 1). Florence caused devastating freshwater flooding across the southeastern US, resulting in 22 direct deaths and 30 indirect fatalities (7).



Figure 1. Hurricane (32)

Materials and Methods

This study utilized Twitter to explore the human sentiment of Hurricane Florence across the US states in different periods. Twitter is a real-time microblogging platform for users who post and interact with messages known as tweets. According to official Twitter statistics, as of 2018, 326 million people are active on Twitter, and 67 million in the US. Twitter provides a Twitter Application Programming Interface (API), which is an interface program between a client and a server to build the client's software. Twitter Official API offers three tiers of search APIs: Standard, Premium, and Enterprise. Twitter developers are to publish and analyze tweets, optimize ads, and create unique customer experiences. This study created its own application because Twitter Official API has a limitation; it does not provide access to the past seven days of Twitter

data for standard service or 30 days of Twitter data for premium and enterprise service. This study developed a new app called “Twitgis” in Twitter developers to collect older tweets more than 30 days by coding a program written in the R language. The Twitgis is a reliable and accurate app since it obtains the client/server authentication from Twitter (see Figure 2). The Twitgis accesses Twitter Official API and employs an API key and secret and a set of access tokens that are authorized by Twitter. R is a language and environment for statistical computing and graphics supported by the R Foundation for statistical computing. The R language is one of the most popular programming languages among statisticians and data miners for developing statistical software and data analysis. This study employed RStudio, which is an integrated development environment (IDE) for R.

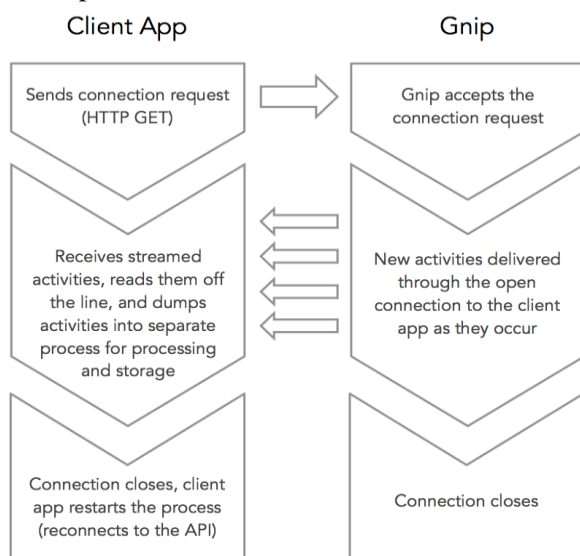


Figure 2. The interaction between the app and Twitter’s API(33)

This study used three keywords (“Florence,” “Hurricane,” and “Storm”) to explore how the

hurricane affects human sentiment. This study collected about 1,433,032 tweets between 08-21-2018 and 10-01-2018 (six weeks), which consists of the pre-hurricane periods (2 weeks), the hurricane periods (2 weeks), and the post-hurricane periods (2 weeks). This study set some selection criteria for tweets data, and the process of sampling is as follows: first, the tweets should be written in English. Second, the tweets should have the keyword (Florence, Hurricane, or Storm) in the text. Third, the tweets should be posted in the US. Fourth, the tweets should have geotagged information to explore spatial reactions. After filtering the data, this study utilized 57,842 samples, which were about 4.0% of raw data (see Table 1). This study did not show the Twitter ID and the specific location of tweets for privacy protection. This article gave a random ID and showed the state uploading tweets and favorites for each tweet. Also, the present study did not change verbal expressions or wrong grammar in tweets to show the original content from users.

Table 1. The number of keywords

	Raw data	Data filtered
Florence	353,778	13,728
Hurricane	473,709	20,526
Storm	605,545	23,588
Total	1,433,032	57,842

The characteristics of the Tweets

Figure 3 shows the number of tweets according to days. Each keyword is highly fluctuated by days. For example, the Keyword “Florence” demonstrates the highest number of tweets on September 11, whereas the keyword “Storm” exhibits the highest number of those on September 12. Overall, the total number of keywords sharply increases from September 6 and decreases from September 17, which is the end date of the hurricane period.

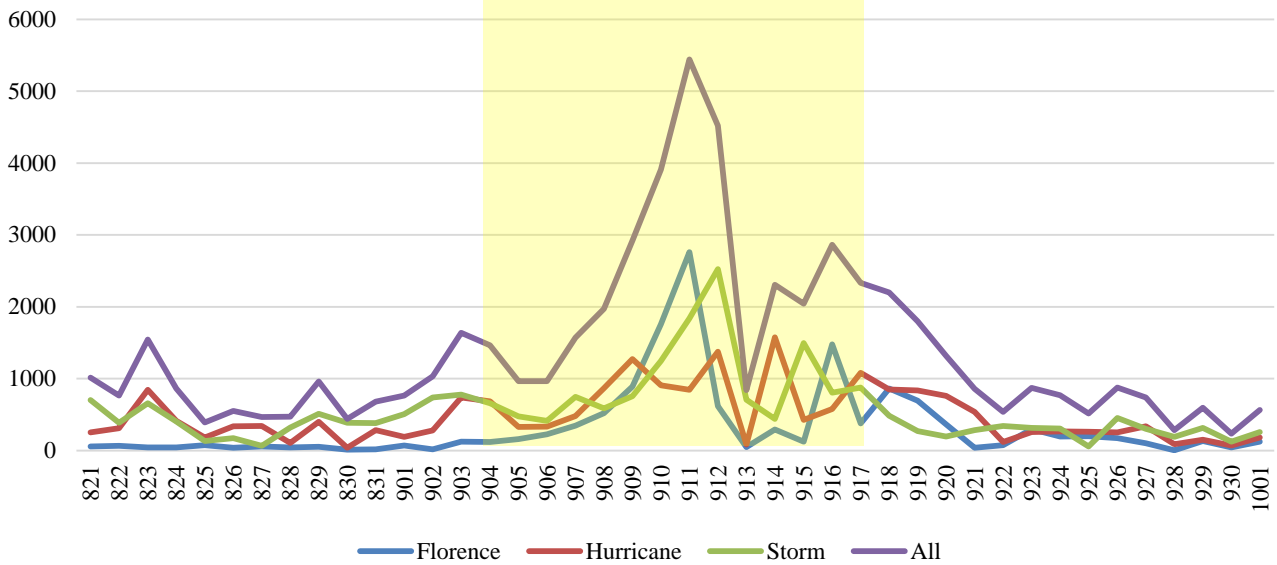


Figure 3. The number of keywords (yellow box: the hurricane period)

Figure 4 shows the locations of tweets across the US states. In the pre-hurricane period, the locations of tweets are more concentrated in the coastal areas of the West region, especially California. In the hurricane period, those of tweets are heavily concentrated along with the

coastal areas of the South-eastern US, especially Florida, North Carolina, South Carolina, and New York. In the post-hurricane period, the tweets are more located in the coastal areas of California and New York.

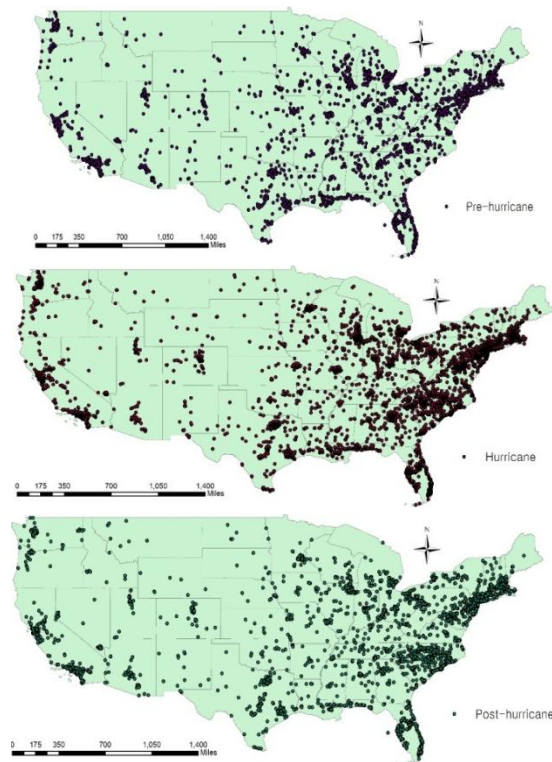


Figure 4. The locations of tweets

Table 2 highlights that the proportion of tweets in the US states is differentiated by periods. For instance, in the pre-hurricane period, Hawaii places first with the proportion of 11.8, followed by Florida (9.9), Texas (8.9), California (7.6), and New York (5.2). All states in the top 5 are coastal states, which are susceptible to hurricanes. In the hurricane period, North Carolina and South Carolina take first and second (21.4 and 10.2,

respectively), ahead of Virginia (8.4), Florida (6.2), and Texas (5.1). This is because North Carolina and South Carolina are the most damaged regions affected by Hurricane Florence during the hurricane period. In the post-hurricane period, North Carolina still ranks first (19.3), whereas New York places second with a value of 7.1. The next states are California (6.7), Florida (6.4), and South Carolina (6.1).

Table 2. The proportion of tweets in periods

	Pre-hurricane	Hurricane	Post-hurricane
1	Hawaii (11.8)	North Carolina (21.4)	North Carolina (19.3)
2	Florida (9.9)	South Carolina (10.2)	New York (7.1)
3	Texas (8.9)	Virginia (8.4)	California (6.7)
4	California (7.6)	Florida (6.2)	Florida (6.4)
5	New York (5.2)	Texas (5.1)	South Carolina (6.1)
6	Louisiana (4.3)	New York (4.7)	Texas (5.9)
7	Illinois (3.0)	California (4.1)	Pennsylvania (3.2)
8	North Carolina (2.8)	Georgia (3.7)	Virginia (3.2)
9	Virginia (2.7)	Pennsylvania (3.4)	Ohio (2.9)
10	Georgia (2.7)	Ohio (2.4)	Georgia (2.8)
11	Ohio (2.5)	Louisiana (2.2)	Illinois (2.2)
12	Pennsylvania (2.4)	New Jersey (2.1)	New Jersey (2.2)
13	South Carolina (2.3)	Maryland (1.9)	Arizona (2.2)
14	Michigan (2.2)	Massachusetts (1.7)	Tennessee (2.1)
15	Arizona (2.2)	Alabama (1.7)	Massachusetts (2.1)
16	Alabama (2.1)	Tennessee (1.6)	Alabama (1.6)
17	Washington (1.9)	Illinois (1.5)	Maryland (1.6)
18	Tennessee (1.8)	District of Columbia (1.4)	Indiana (1.4)
19	Indiana (1.5)	Indiana (1.3)	Kentucky (1.4)
20	Massachusetts (1.4)	Washington (1.2)	Michigan (1.4)

Figure 5 demonstrates that the spatial patterns of tweets are differentiated by periods. In the pre-hurricane period, the spatial patterns of tweets are more concentrated in the south region, such as Texas and Florida. In the hurricane period, the spatial patterns of tweets are heavily concentrated

in the South-eastern region, especially North Carolina, South Carolina, and Virginia. In the post-hurricane period, the spatial patterns of tweets are more located in the Northeast region and California.

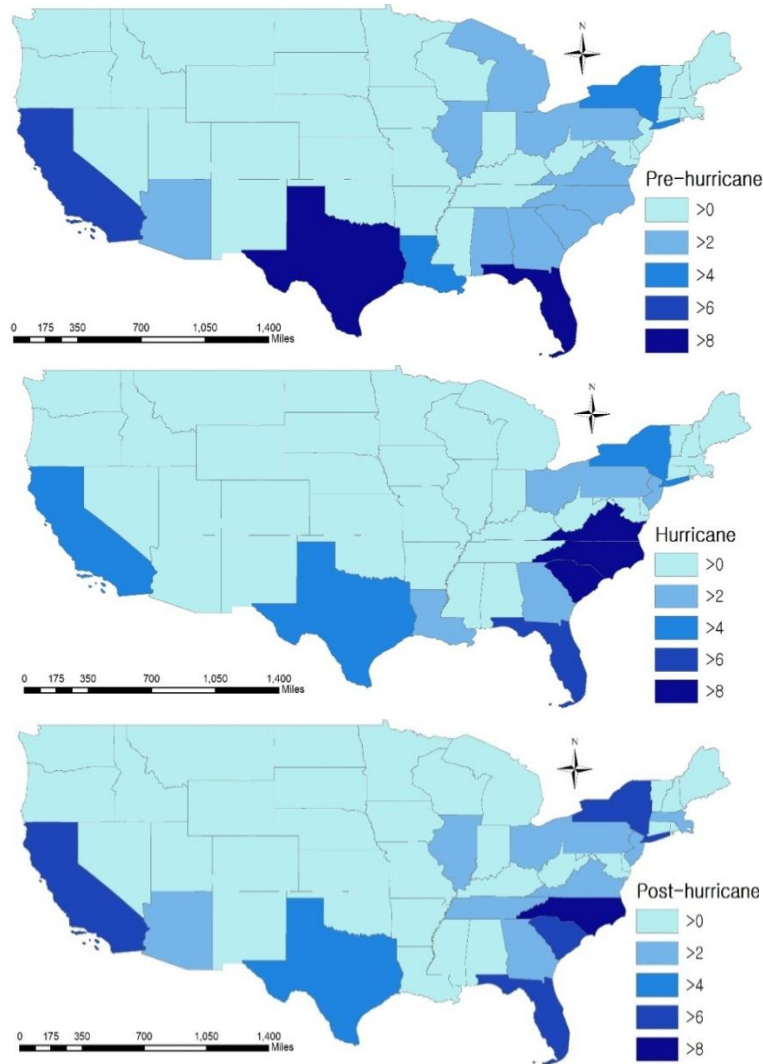


Figure 5. The spatial patterns of tweets

Retweet analyses

This study analyzed human behavior according to Hurricane Florence based on the retweeted number of tweets. A retweet is a re-posting of a tweet, which helps people to share valuable information and interesting news to others quickly. A retweet can represent the magnitude of the importance of information since people retweet the tweet when they think that the

information is valuable for others. This study organized all tweets in the hurricane week in descending order and selects tweets, which are highly related to Hurricane Florence, after reading all texts in tweets.

Table 3 shows that many of the top 20 retweets are located in North Carolina. Eight out of 20 tweets were posted in the state. South Carolina shows the second-highest share of retweets (3).

This is because the two states are the most damaged states among the US states according to Hurricane Florence. The most retweeted tweet shows that people show the highest concern about animals left behind in the hurricane. The tweet posts many poor dogs in the hurricane-damaged region (see Figure 6). The tweet has the number of retweets about 3.5 times higher than the second-highest tweet, meaning that people are highly interested in poor animals affected by the hurricane and abandoned by the owner. In fact, many people post and retweet the tweets for the poor animals and criticize the people abandoning their pets in the hurricane period. The results showed that people spread messages of commiseration more than the forecast and reports of the hurricane.



Figure 6. The pictures in the most retweeted tweet (34)

The second highest tweet is that people were surprised because the waffle house had a storm center to deal with the hurricane problem (see Figure 7). The tweet shows that companies actively consider the hurricane issue to reduce the loss of their profits and plan their business. The tweet shows the number of retweets about 7.6 times higher than the third-highest tweet. Next, people are highly interested in the information and effect of Hurricane Florence (tweet 3, 14, 17, 18, and 20). Also, many people pray that their safety not to be affected by the hurricane (tweet 5, 9, 13, and 15). In contrast, other people showed a good sense of humanity for the hurricane (tweet 4, 10, and 16). Many people also uploaded their opinion related to the hurricane situation (tweet 6, 7, 8, 11, 12, and 19)

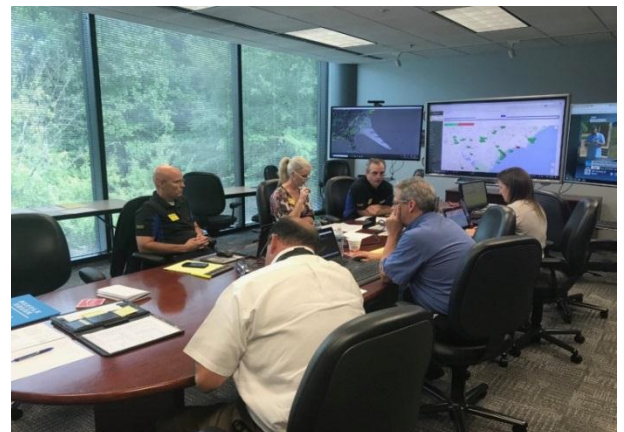


Figure 7. The storm center of the Waffle house(35)

Table 3. Retweets in top 20

No	ID	Retweet	States	text
1	15134233	78077	SC	plz whatever you do for this hurricane do not leave your dogs. if you feel like you can't stay then neither can they... PLAN FOR YOUR DOG
2	14149422	22276	MI	I have questions. Mainly, why does Waffle House have a storm center?
3	12192072	2939	NC	weather networks: North Carolina is in a state of emergency, tropical storm could bring in winds of up to 140 mph and heavy flooding!!
4	18759317	2293	CA	Everyone on west coast watching the hurricanes like https://twitter.com/xoxabstract/status/1039988277321773056
5	19914609	2179	TN	I will not be very active on Twitter for the next two-three days due to the severity of this storm. My daughter, her husband and two year old grandson live in Myrtle Beach SC. Please pray for all who will be impacted by Hurricane Florence
6	13164387	1768	MA	weather: "watch out east coast, florence is headed ur way"
7	12893397	1673	MD	Where is Trump? Who is in Charge? Have not seen POTUS since Tuesday. He's released a photo with him and VP Pence being updated on the Hurricane. Tomorrow the WH just announced he will have another closed press update. But NO public appearances scheduled - again. pisses me off watching commentators blaming @POTUS for 3000 hurricane related deaths in #PuertoRico these folks Never wrote or reported anything about PR. There is total ignorance or avoidance of fact power grid was in chaos Power Authority bankrupt & corrupt before #Maria hit.
8	18097779	988	OH	Pray with me for safety as we prepare on my State of South Carolina for this horrible storm hitting us.
9	18216107	934	SC	If we ride out this storm does that make us Flo Rida's????
10	16391032	740	SC	@tarwanza Considering she has donated for hurricane relief and built apartments to house low-income and formerly homeless residents, yes, we think this is appropriate. We also hope you continue to follow us!
11	17536572	737	TX	I sure hope this semester gets better. In the 1st month we've had a student run-in w/ a bus, a student bit by a snake, people getting shot uptown, a weather-delayed football game that we lost, & a devastating hurricane. Hard to imagine things getting worse. At least we beat UNC.
12	10986873	549	NC	Dear Heavenly Father, I pray that you keep each and every person safe & covered with you grace. I pray for safe travels for those going home. I pray for a hedge of protection around each and every college campus. This storm will pass! I thank you right now.
13	12138515	492	NC	On the way out of Wilmington. This is what flash flooding looks like.
14	19698441	377	NC	This is by far the most scared I've been covering Florence. SR 74 is like this between Wilmington and Whiteville. My daughter and her family are new homeowners in the Myrtle Beach area. They are really concerned about this storm. Unfortunately, they live in a flood zone! Please pray for all of our east coast families over the next few days! FYI:They are bringing our grandson tonight
15	10536017	363	TN	NC: Yo I can't wait for Dreamville Festival Hurricane Florence:
16	14685657	326	NC	The calm before the storm. #DALvsCAR
17	13322321	311	NC	Drone footage from inside the calm eye of Hurricane #Florence spinning 360 degrees showing dark clouds of the eyewall in all directions.
18	19202777	295	NC	Students: Please stop viewing this storm as a blessing because you're excited that classes will probably get cancelled. This storm is likely to cause an extraordinary
19	10292822	293	NC	Hurricane Florence already causing damage. It's crazy #Hurricane Florence
20	10029881	271	AL	

Human sentiment for Hurricane Florence

This study analyzed the human sentiment of 1,000 tweets according to the number of retweets in descending order in the hurricane period by interpreting the tweets in person. While some statistical programs, such as Linguistic Inquiry and Word Count (LIWC), OpenText Sentiment Analysis, and SAP HANA Sentiment Analysis, can be used for sentiment analyses, they cannot interpret human’s delicate expressions, such as metaphorical or irony expressions, can have some bugs in programs, or can put tweets in the wrong categories because they are programmed to just analyze keywords, not interpreting the whole nuance. In contrast, this study interpreted all 1,000 tweets elaborately. This study divided the sentiment categories into strongly positive tweets, positive tweets, natural tweets, negative tweets, and strongly negative tweets.

After analyzing the sentiment of individuals, the tweets were categorized as follows: strongly positive tweets (28), positive tweets (91), natural tweets (727), negative tweets (51), and strongly negative tweets (103) (see Figure 8). Strongly positive tweets tend to express thanks to people who help them or others. For example, “My hero!!!!

Noah’s Ark except it’s a school bus: Truck driver rescues 64 dogs and cats from floods of Hurricane Florence.” Positive tweets are highly related to the cancellation of schools or work and beautiful scenery created by the hurricane. For example, “Beautiful storm near Shorewood, IL. #ILwx @NWSChicago.”

Natural tweets tend to include objective statements, such as breaking news, forecast, reports, information, and notification. For instance, “#BREAKING: #HurricaneFlorence is now a CAT.4 MAJOR hurricane.... winds are now up to 130 MPH with an SLP of 953mb. #Florence looks remarkable on satellite. It is forecast to remain a MAJOR HURRICANE for the majority of the next five days.” Negative tweets are apt to describe their anxiety or damage affected by the hurricane. For example, “It ain't good when you look up and a CNN hurricane reporter is standing on the major road in your hometown...” Strongly negative tweets are inclined to show their anger on people who leave their pets in the hurricane area. For instance, “As everyone is evacuating for this storm PLEASE don’t forget about your pets! Don’t leave them behind!!!! If you don’t feel safe to stay at home why would you make them!”

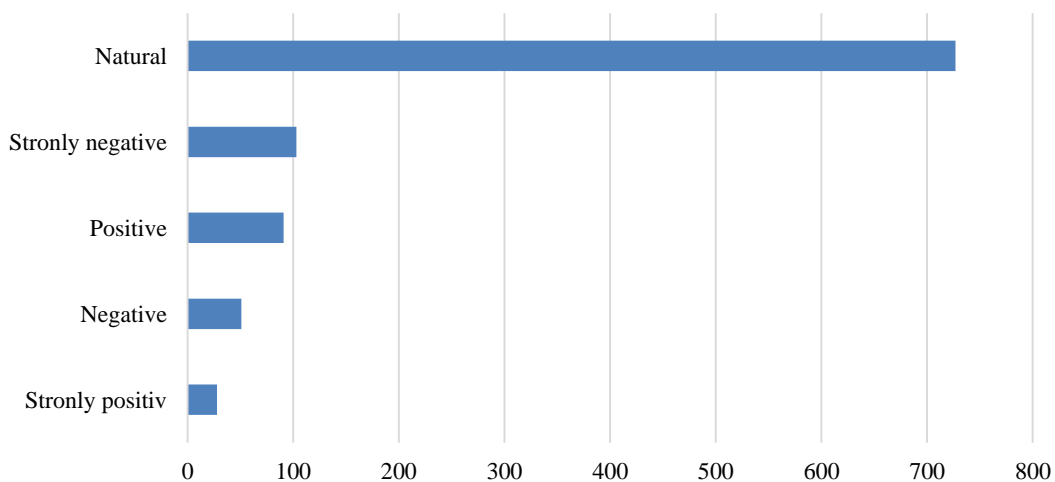


Figure 8. The number of tweets in each category

Next, this study categorized tweets into 15 groups based on the content in the text (see Table 4). After categorizing tweets, tweets in the emotion category showed the highest number [181]. The result demonstrated that people actively express their feeling during the hurricane period. For example, “I have a legit fear of storms. I’m going to need to be sedated during Florence.”

The next highest tweets are in the information category [171]. People upload important information on Twitter to share the information affected by Hurricane Florence. For instance, “Northbound on I-95 comes to an abrupt stop and road closure at exit 181A in Latta, SC to divert people away from #Florence caused flooding. #timelapse.”

The third-highest tweets consist of the opinion category [141]. People tend to strongly express their opinion according to Hurricane Florence. For example, “I think @realDonaldTrump should be very aggressive on twitter outlining what his administration is doing to aid in the Fight against Florence. Suspend media war for a few days and

focus on this. Perhaps I am biased, you can't stop nature, but you can aid in the fight.”

The fourth-highest tweets belong to the forecast category [99]. Many news channels and institutes release the forecast of Hurricane Florence to let people know the movement and impact of it. For instance, “#Florence is now a major Cat. Three hurricanes with 115 MPH winds forecast to Cat.4. Here's the latest track, timing on the arrival of tropical-storm-force winds and a MUST READ, the potentially deadly impacts coastal & inland.”

The fifth-highest tweets are in the notification category [89]. People upload tweets to notify people because of the changed schedule. “@henrymcmaster has issued mandatory evac for Charleston County effective at NOON tomorrow with lane reversals on HWY 26. County schools will be CLOSED. Now is the time to prepare and make proper plans. #Florence #chswx.” The following categories are reports [58], weather [51], daily life [50], pray [25], and scenery [20].

Table 4. Categories of tweets

Category	Number	Example
Emotion	181	I have never in 39 years evacuated #Wilmington #NC for a hurricane but this time is different. I hate to leave @GravityRecords, the business that I've worked so hard for, to fend for itself but it has to be done. #HurricaneFlorence #WilmingtonNC
Information	171	FYI: Due to the forecast of inclement weather related to Hurricane Florence, we are moving this Friday's home football game vs East Rowan to Wednesday, September 12. Start time will be 630pm. Gates will open at 530 pm.
Opinion	141	I think @realDonaldTrump should be very aggressive on twitter outlining what his administration is doing to aid in the Fight against Florence. Suspend media war for a few days and focus on this. Perhaps I am biased, You cant stop nature, but you can aid in the fight
Forecast	99	#Florence is now a major Cat. 3 hurricane with 115 MPH winds forecast to Cat.4. Here's the latest track, timing on the arrival of tropical-storm-force winds and a MUST READ, the potentially deadly impacts coastal & inland.
Notification	89	.@henrymcmaster has issued mandatory evac for Charleston County effective at NOON tomorrow with lane reversals on HWY 26. County schools will be CLOSED. Now is the time to prepare and make proper plans. #Florence #chswx
Reports	58	Update, Hurricane Florence is now a Category 5 with windspeed averages between 163-165mph.
Weather	51	This storm is unbelievable. The torrential rain is still coming down. No let up at all. #TropicalStormFlorence
Daily life	50	Streets are eerily quiet in Charlotte today. Seeing everyone prep for a hurricane is weird. It feels like the impending apocalypse #florence
Pray	25	Not sure how serious this storm about to be but I just pray all my loved ones remain safe
Scenery	20	This storm just produced the best weather footage I've ever personally recorded. @Kentuckyweather @MarcWeinbergWX @StormHour https://t.co/oZ4Muyc8RC

Category	Number	Example
breaking news	14	BREAKING: #UVA in talks to move Saturday's football game against Ohio to Vanderbilt Stadium in Nashville because of Hurricane Florence. https://t.co/LsE9Aw0NUX
Humor	11	“Hurricane Flo coming what are you grabbing?” Me: (a gif file for grabbing a dog)
Damage	11	At least 14 dead!!Let's keep the Carolinas in our prayers!!**LIVE UPDATES** Deadly Florence Pummels Carolinas as Catastrophic Flooding Feared
Warning	11	Hurricane warnings issued for parts of the NC/SC coast. Here is the new NHC package for Hurricane Florence...
Other	68	slow storm

Conclusions

This study provided some important findings as follows: first, the spatial patterns of tweets are differentiated by periods. For example, the spatial patterns of tweets are more concentrated in the south region in the pre-hurricane period, it is heavily concentrated in the Southeast region in the hurricane period, and it is more located in the Northeast region and California in the post-hurricane period.

Second, more than half of the top 20 retweets [11] are located in North Carolina and South Carolina. This is because the two states are the most damaged states among the US states according to Hurricane Florence. The most retweeted tweet shows that people are highly interested in poor pets left behind in the damaged region. The first ranked tweet is about two times higher than the sum of the retweet numbers between the top two and top 20.

Third, this study found that roughly three fourth of tweets consist of natural sentiment. This is because people upload important information, such as notification and forecast, on Twitter. Especially, people retweet the posts to let people understand the changed schedule affected by Hurricane Florence or to share information about how to prepare the hurricane damage. The following tweets are strongly negative (10.3%), positive tweets (9.1%), negative tweets (5.1%), and strongly positive tweets (2.8%). This study also highlighted that people show the highest number of tweets in the emotion category [181], meaning that people actively express their feeling during the hurricane period, followed by the information category [171], the opinion category [141], the

forecast category [99], and the notification category [89].

Discussion

This study suggests some important implications as follows: first, people in indirectly affected regions, as well as those indirectly damaged regions, are also highly interested in the hurricane event. Therefore, governments should manage natural disaster information at the national level to relieve the anxiety of people. Not only that, releasing natural disaster information for other regions would let people in other regions help those in the damaged regions, with materials such as disaster relief and daily necessity, based on the information network and the magnitude of the damages.

Besides, this study suggests an interesting finding, that is, people are interested in messages of commiseration more than the forecast and reports of the hurricane. In other words, human sentiment plays an important role in disaster information more than the news of the natural disaster. Therefore, governments and policymakers should take care of the emotions of people as well as provide the forecast and reports of the hurricane. Relieving negative feeling would be one of the main roles for governments and urban practitioners during natural disaster periods.

Since the people utilize Twitter to share a lot of opinions, information, emotions, and so on, governments and policymakers should monitor Twitter data before, during, and after the natural disaster period to understand the effects of natural disasters on people and property. For instance, people post their tweets when there is a serious accident or damage caused by natural disasters,

and governments and emergency responders could find accidents by monitoring Twitter to save human life or reduce natural disaster damages.

Acknowledgments

Thank you for the reviewers and editor.

Funding source

No funding

Conflict of interest

No conflict of interest

Authors' contribution

Seungil Yum wrote the whole paper.

References

1. Wang T. Global number of natural disasters events 2000-2019. Available at: URL: <https://www.statista.com/statistics/510959/number-of-natural-disasters-events-globally/> Last Access: Jul 16, 2020.
2. Karlsruhe Institute of Technology. Natural disasters since 1900—over 8 million deaths and 7 trillion US dollars damage. Available at: URL: <https://phys.org/news/2016-04-natural-disasters-1900over-milliondeaths.html> Last Access: Jul 16, 2020.
3. Demuth JL, Morss RE, Palen L, et al. Sometimes da# beachlife ain't always da wave. Understanding people's evolving hurricane risk communication, risk assessments, and responses using Twitter narratives. *Weather, climate, and society*. 2018 ;10(3):537-60.
4. Malmstadt J, Scheitlin K, Elsner J. Florida hurricanes and damage costs. *southeastern geographer*. 2009;49(2):108-31.
5. Martín Y, Cutter SL, Li Z. Bridging twitter and survey data for evacuation assessment of Hurricane Matthew and Hurricane Irma. *Natural hazards review*. 2020;21(2):04020003.
6. Pielke Jr RA, Gratz J, Landsea CW, Collins D, Saunders MA, Musulin R. Normalized hurricane damage in the United States: 1900–2005. *Natural Hazards Review*. 2008;9(1):29-42.
7. National hurricane center. Costliest U.S. Tropical Cyclones. National Hurricane. Center: Florida. 2018: 1-3.
8. Thompson MA. Hurricane Katrina and economic loss: an alternative measure of economic activity. *Journal of Business Valuation and Economic Loss Analysis*. 2009;4(2) 1-9.
9. Degg M. Natural disasters: recent trends and future prospects. *Geography*. 1992 Jul 1:198-209.
10. Jonkman SN. Global perspectives on loss of human life caused by floods. *Natural hazards*. 2005;34(2):151-75.
11. Levine M, Thompson K. Identity, place, and bystander intervention: Social categories and helping after natural disasters. *The Journal of social psychology*. 2004;144(3):229-45.
12. Neumayer E, Plümper T. The gendered nature of natural disasters: The impact of catastrophic events on the gender gap in life expectancy, 1981–2002. *Annals of the Association of American Geographers*. 2007;97(3):551-66.
13. Rodriguez-Oreggia E, De La Fuente A, De La et al. Natural disasters, human development and poverty at the municipal level in Mexico. *The Journal of Development Studies*. 2013;49(3): 442-55.
14. Wang B, Zhuang J. Crisis information distribution on Twitter: a content analysis of tweets during Hurricane Sandy. *Natural hazards*. 2017;89(1):161-81.
15. Zou L, Lam NS, Cai H, et al. Mining Twitter data for improved understanding of disaster resilience. *Annals of the American Association of Geographers*. 2018;108(5): 1422-41.
16. Von Peter G, Von Dahlen S, Saxena SC. Unmitigated disasters? New evidence on the macroeconomic cost of natural catastrophes. 2012 Dec; BIS Working Papers No 394: 1-38.
17. Felbermayr G, Gröschl J. Naturally negative: The growth effects of natural disasters. *Journal of development economics*. 2014;111: 92-106.
18. Acar A, Muraki Y. Twitter for crisis communication: lessons learned from Japan's tsunami disaster. *International Journal of Web Based Communities*. 2011;7(3):392-402.
19. Earle PS, Bowden DC, Guy M. Twitter earthquake detection: earthquake monitoring in a social world. *Annals of Geophysics*. 2012;54(6): 708-715.

20. Muralidharan S, Rasmussen L, Patterson D, et al. Hope for Haiti: An analysis of Facebook and Twitter usage during the earthquake relief efforts. *Public Relations Review*. 2011;37(2):175-7.
21. Velez D, Zlateva P. An innovative approach for designing an emergency risk management system for natural disasters. *International Journal of Innovation, Management and Technology*. 2011;2(5):407-413.
22. Kim J, Hastak M. Social network analysis: Characteristics of online social networks after a disaster. *International Journal of Information Management*. 2018;38(1):86-96.
23. Cheong F, Cheong C. Social Media Data Mining: A Social Network Analysis Of Tweets During The 2010-2011 Australian Floods. *PACIS*. 2011;46:1-16.
24. Ahmouda A, Hochmair HH, Cvetojevic S. Using Twitter to Analyze the Effect of Hurricanes on Human Mobility Patterns. *Urban Science*. 2019;3(3):87, 1-20.
25. Kumar D, Ukkusuri SV. Utilizing geo-tagged tweets to understand evacuation dynamics during emergencies: A case study of Hurricane Sandy. In *Companion Proceedings of the The Web Conference 2018* 2018: 1613-1620.
26. Wang Q, Taylor JE. Quantifying human mobility perturbation and resilience in Hurricane Sandy. *PLoS one*. 2014;9(11):e112608.
27. Nagar S, Seth A, Joshi A. Characterization of social media response to natural disasters. In *Proceedings of the 21st International Conference on World Wide Web 2012*, 671-674.
28. Bruns A, Stieglitz S. Quantitative approaches to comparing communication patterns on Twitter. *Journal of technology in human services*. 2012; 30(3-4): 160-185.
29. D'Auria L, Convertito V. Real-time mapping of earthquake perception areas in the Italian region from Twitter streams analysis. *Earthquakes and their impact on society 2016*, 619-630.
30. Wang Q, Taylor JE. Patterns and limitations of urban human mobility resilience under the influence of multiple types of natural disaster. *PLoS one*. 2016;11(1):e0147299.
31. Karamshuk D, Shaw F, Brownlie J, et al. Bridging big data and qualitative methods in the social sciences: A case study of Twitter responses to high profile deaths by suicide. *Online Social Networks and Media*. 2017; 1: 33-43.
32. Available from: CIRA/RAMMB; GOES-16/NOAA
33. Available from: <https://developer.twitter.com>
34. Available from: <https://twitter.com/Michgonewild/status/1038841840605298689>
35. Available from: <https://twitter.com/WaffleHouseNews/status/1039606662234075137/photo/1>.