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Tracking social media conversations on extreme weather discussion: a longitudinal analysis

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Abstract

With the increasing number of extreme weather events and various disasters, people are paying more attention to environmental issues than ever, particularly global warming. Public debate on it has grown on various platforms, including newspapers and social media. This study examines emotions of the general public on global warming in the context of extreme weather events, how emotions differ by location and the change of emotion on those topics over the time. Topic modeling is used to reveal dominant topics for each type of extreme weather. The results show that discussions on Twitter predominantly focus on floods and drought/heatwaves. There has been a consistent increase in Twitter conversations about extreme weather over recent years. Emotion analysis indicates that sadness, followed by anger, are the most prevalent emotions in discussions about various extreme weather events. Topic modeling reveals major topics in extreme weather focusing on their escalating intensity and the resulting environmental, social, and emotional impacts. Additionally, these conversations often involve debates, skepticism, and considerations of risks associated with climate change/global warming.

Keywords: extreme weathers, natural language processing, topic modelling, emotion analysis, global warming

Introduction

Global warming, a phenomenon characterized by the gradual increase in Earth's average surface temperature, has far-reaching impacts on our planet. Primarily driven by human activities, such as the burning of fossil fuels and deforestation, it leads to a cascade of environmental changes. These include more frequent and severe weather events like hurricanes, droughts, and heatwaves, which can devastate communities and ecosystems. The rising temperatures also contribute to the melting of polar ice caps and glaciers, resulting in rising sea levels that threaten coastal regions. Beyond environmental consequences, global warming poses significant challenges to agriculture, threatening food security with unpredictable weather patterns and altered growing seasons. It also exacerbates health risks, as warmer climates can increase the spread of infectious diseases. The economic implications are equally profound, with industries such as agriculture, insurance, and tourism particularly vulnerable to climate-related disruptions. In response, there is a growing emphasis on sustainable practices and policies aimed at reducing greenhouse gas emissions and adapting to the inevitable changes, highlighting the urgent need for global cooperation in addressing this critical issue (IPCC and NASA Report).

Recent years have witnessed a notable shift in public discourse surrounding climate change, partly fueled by skeptical views. Prominent figures like former President Trump have frequently cast doubt on the existence of climate change, contributing to a rise in skepticism among Americans, with a reported increase from 19% to 28% over the past decade. This skepticism is not black and white, as it includes those who

deny climate change's existence, doubt the responsibility of humans, or question its harmfulness. There is nuance within the group, as various skeptics are found to oppose some environmental policies, like CO2 emissions reduction while supporting other pro-environmental policies about energy use (Haltinner et al., 2021).

Social media platforms, such as Twitter, have grown to be critical for analyzing public sentiment. While solicited opinion polls frequently involve small datasets, might be selectively interpreted, and have subjective involvement, Twitter analysis shows a better understanding of the general public (Jiang et al., 2022). In addition, using big data to analyze public engagement allows wider sampling frames that show deviations from historical trends (Leas et al., 2016). Big data analytics, such as visual analytics pipelines, enables the exploration of tweets related to specific topics related to extreme weather. For example, Styve et al. 2022 employed text classification, geographic reference assignment, and interactive visualization to generate insights on public reaction to floods.

The Hedonmeter and Appraisal Theory are two tools that have been used for sentiment analysis in the context of global warming on Twitter. The Hedonmeter quantifies the polarity of text by assigning a sentiment score to words while Appraisal Theory provides an approach to understanding linguistic features. These studies have revealed differing sentiments between political ideologies, with the term 'global warming' being more popular among conservatives and the term 'climate change' being more popular among liberals. Further, extreme weather events have often resulted in increased discussions on global warming that come with a noticeable change in public sentiment (Jiang et al., 2022).

In addition, public figures like Leonardo DiCaprio have had a significant influence on public discourse on climate change. For example, DiCaprio's speech in 2014 had a significant effect on the number of climate change-related news stories and tweets in the following month found using Twitter analysis, underscoring the potential of Twitter as a real-time sensor for public opinion. (Leas et al, 2016).

This literature review sets the stage for a comprehensive analysis of public reaction toward global warming and extreme weather events as reflected on social media, underscoring the changing nature of environmental discourse in the digital age and the crucial role of natural language processing and text analysis in understanding these issues.

Extending previous studies, this study aims to deepen our understanding of global warming, represented by extreme weather discussion in Twitter, in the past decade from 2010 to 2022. The following questions will be explored using various NLP methodologies:

- How has the popularity of extreme weather as a topic evolved from 2010 to 2022?
- What emotions do the public associate with extreme weather, and how have these emotions shifted over the period from 2010 to 2022?
- Are there location variations in the emotions expressed by the public towards extreme weather?
- What are the most frequent words mentioned in tweets by weather type?
- What are the predominant topics discussed in relation to different types of extreme weather events? What are the emotions of each topic?

Research Methodology

This study is based on historical tweets extracted using Twitter API between years 2010 and 2022 using the keyword "Global Warming". The total tweets collected are 26,964,191. Among all tweets, tweets that mention extreme weather (heatwave, drought, flood, hurricane, typhoon, cyclone, tornado, blizzard, and/or

wildfire) are extracted and the total tweets are 848, 536, which will be used for further analysis. It is possible a tweet can mention multiple extreme weather events. In such cases, the tweet will be classified into multiple categories. To simplify the analysis, droughts and heatwaves are combined into a category titled "drought/heatwave", and hurricanes, typhoons, and cyclones are combined into the "tropical storm" category.

Pre-processing the raw dataset

Raw tweets were pre-processed using pyspark and spark-nlp package. The pre-processing plan was as follows:

1. All words were converted into lowercase.
2. All words starting with http were removed since URLs did not contribute to the text analysis. Hashtags and mentions were kept since they represent the popularity/trends of particular topics and users.
3. Special characters, punctuations, and numbers were removed from the dataset as they did not help with detecting the profanity comments.
4. Misspelling was corrected.
5. Lemmatization was applied to switch any word to its base root. For example, stops, stopped, stopping will all be converted to stop.
6. All stop words in English were removed.
7. Additional words that were used to extract tweets (global, warming, #globalwarming) were removed since all tweets include those words.

Analysis and Discussion

This session will first discuss the number of tweets by weather type, by weather type and by year, and by location (measured by state); followed by emotion analysis of the tweets by weather type, by weather type and by year, and by location. A word cloud is then created to reveal the most frequently appearing words in each weather type. This session ends with employing Latent Dirichlet Allocation (LDA), a widely recognized methodology in topic modeling to identify the dominant topics discussed in each type of extreme weather.

Number of Tweets by Weather Type, Year, and State

Table 1 shows the number and percentage of tweets by weather type. Floods and droughts/heatwaves received the most discussion on Twitter, followed by tropical storms and wildfires. Tornadoes and blizzards received the least discussion among all extreme weathers. Figure 1 shows the number of tweets by weather type and by year. There is an increase in extreme weather discussion over the years between 2010 and 2022, showing the heightened concern in climate change in the general population over last decade. Though, in 2020, there was a large drop in the discussion of extreme weather, which could be attributed to a temporary shift in focus toward the more pervasive threat of the COVID-19 pandemic. In addition, there was a large jump in the flood discussion in 2016 and tropical storms in 2017 that parallel the 2016 Louisiana Flood (National Ocean Service) and the major hurricanes that year such as Harvey, Irma, and Maria (National Hurricane Center and Central Pacific Hurricane Center). Drought/heatwave is the weather that had the highest tweets in 2022, which occurred at the same time as the record-breaking heat wave that year in California (NASA Earth Observatory. In addition, there is a noticeable increase in wildfire discussion in the year 2018, corresponding with the devastating 2018 wildfire season in the western US (Cal Fire).

To see whether the number of tweets differs by location, we extracted the location of the Twitter account from each tweet. The location of the account is a self-reported field, therefore not all accounts have a location, and not all locations are valid. For tweets that have a valid location in the United States, the number of tweets by the top 5 states for each weather type is displayed in Figure 2. We found that the top five states discussing each type of extreme weather are the same for each weather type. Figure 2 shows that California, Florida, New York, Texas, and Washington are the top five states that have the highest number of tweets discussing each type of extreme weather. This observation could be attributed to California, Florida, New York, and Texas being the four states with the highest population, which would result in more social media users tweeting about extreme weather events (Stats America). Washington is the only outlier in terms of population, which could be attributed to its being a tech capital, potentially resulting in more users on social media. Further, for most topics, California is the state with the highest number of tweets, which could be because it was disproportionately affected by certain events such as wildfires or droughts, has the largest population in the US, and contains Silicon Valley, a tech capital of the US. As seen in Figure 1 and mentioned previously.

Table 1: Number and Percent of Tweets by Weather Type

Extreme Weather	Number of Tweets	% of tweets
flood	280,472	29.46%
drought/heatwave	249,438	26.20%
Tropical storm	223,059	23.43%
wildfire	114,735	12.05%
tornado	47,489	4.99%
blizzard	36,699	3.86%

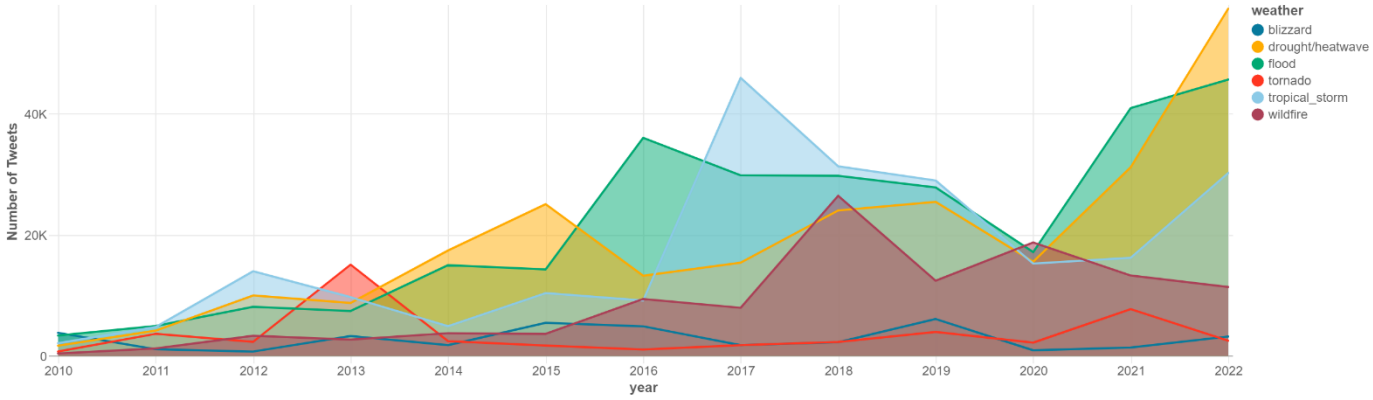


Figure 1: Number of Tweets by Weather Type by Year

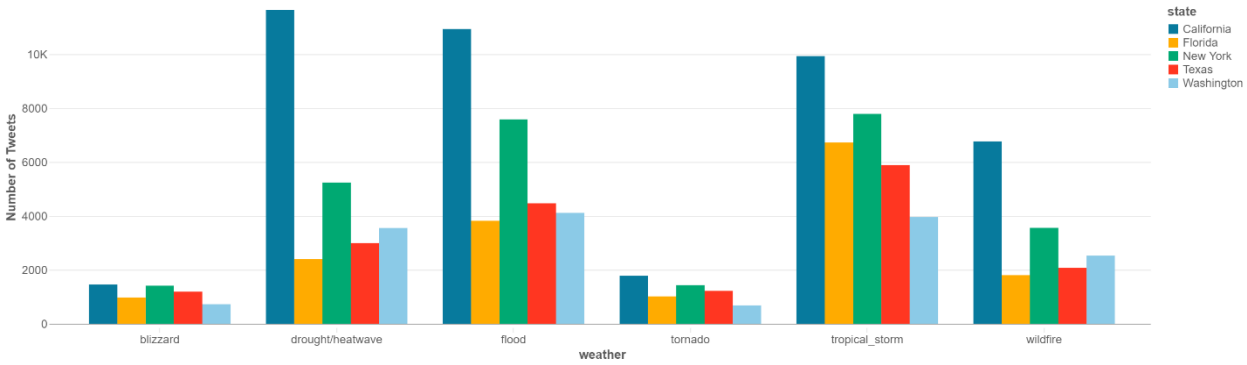


Figure 2: Top 5 States by Weather Type

Emotion analysis was written in Python and performed using a pre-trained model from Hugging Face (Twitter-roBERTa-base for Emotion Recognition). This is a roBERTa-base model trained on ~58M tweets and finetuned for emotion recognition with the TweetEval benchmark. Each tweet is classified into four emotions (joy, optimism, anger, and sadness) with a confidence score.

Figure 3 shows the emotion score for each weather type. Sadness is the dominant emotion when discussing various extreme weather followed by anger. Drought/heatwave has the highest sadness score and blizzard has the highest anger score. Figure 4 shows the percent change in the emotion score for each weather type from the average of all the collected tweets. The data shows that on average, there is a large increase in sadness when referring to any of the extreme weather events. Joy, optimism, and anger all show less of a change, with a clear trend of less sadness and joy when mentioning the weather events. In addition, there isn't a large increase in anger, rather there is very little change or even a decrease in it. This data shows that extreme weather events are more correlated with sadness than anger. And the baseline anger levels when discussing global warming are already high, without being affected much by the mention of extreme weather.

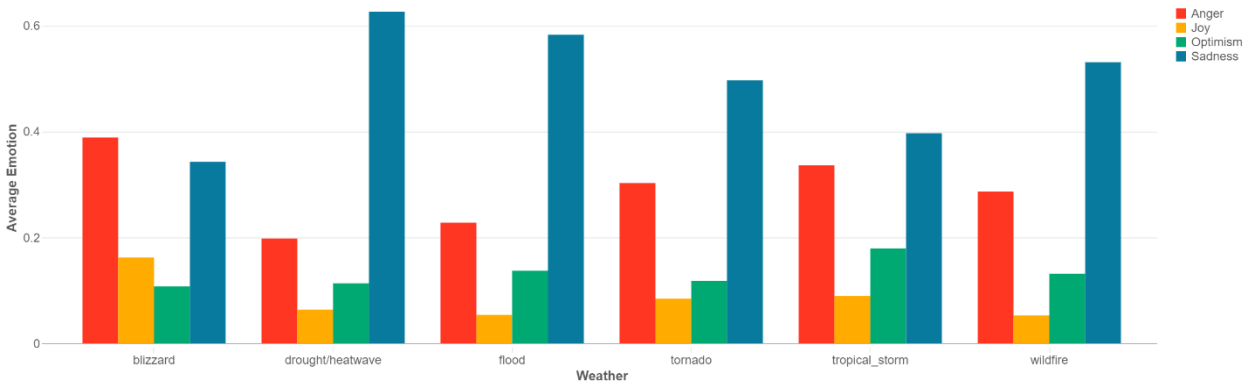


Figure 3: Emotion by Weather Type

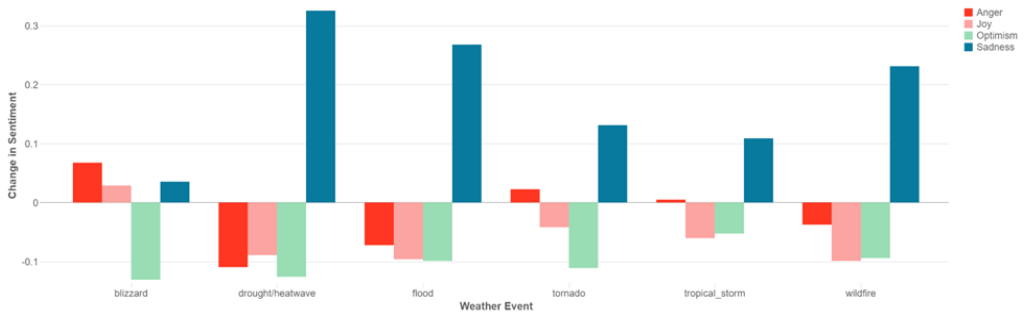


Figure 4: Percent Change in Emotion by Weather Type

Emotion by Weather Type by Year

Since Sadness and Anger are the dominant emotions, a further analysis was conducted to see whether sadness and anger changed over the years for each weather type, and the results are shown in Figure 5 and Figure 6. Drought/heatwave, flood and wildfire have the highest sadness score over the years. There is a large jump in sadness score for tornadoes in year 2013. Interestingly, blizzards have a higher anger score than other types of weather for most years. In addition, anger in 2019 for blizzard has the highest score across all weather types and years. This result may be explained by North American Blizzard occurred between November 27 and December 2019. It was a major winter storm from the Rocky Mountains to the Northeast as well as a record-breaking windstorm along the West Coast particularly in California and Oregon. Since it occurred the week of Thanksgiving, hampering travel for millions across the United States and thus lead to the highest anger expressed in Twitter.

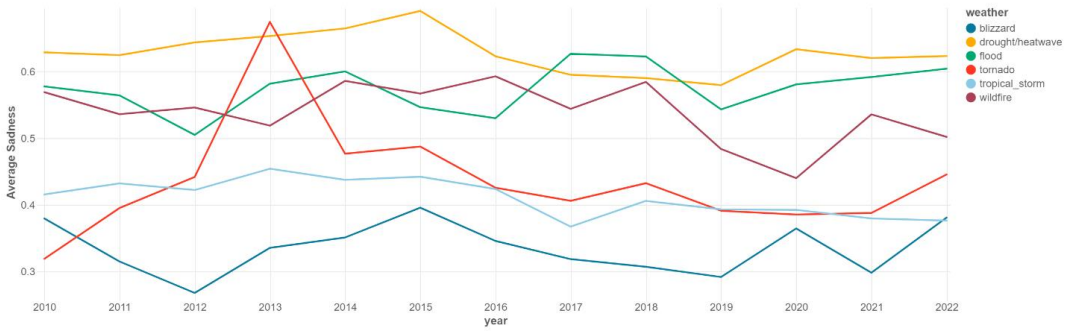


Figure 5: Average Sadness by Weather Type by Year

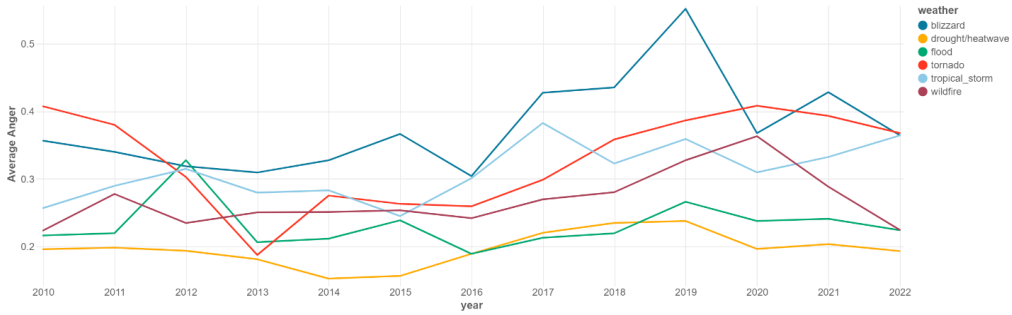


Figure 6: Average Anger by Weather Type by Year

Emotion by Weather Type by State

A similar analysis was conducted to see whether sadness and anger score differ by state for each weather type. We focused on the top 5 states (California, Florida, New York, Texas and Washington) identified from previous analysis and the results are shown in Figure 7 and Figure 8. The results show there are no significant differences among the top 5 states and they all have similar scores in each emotion.

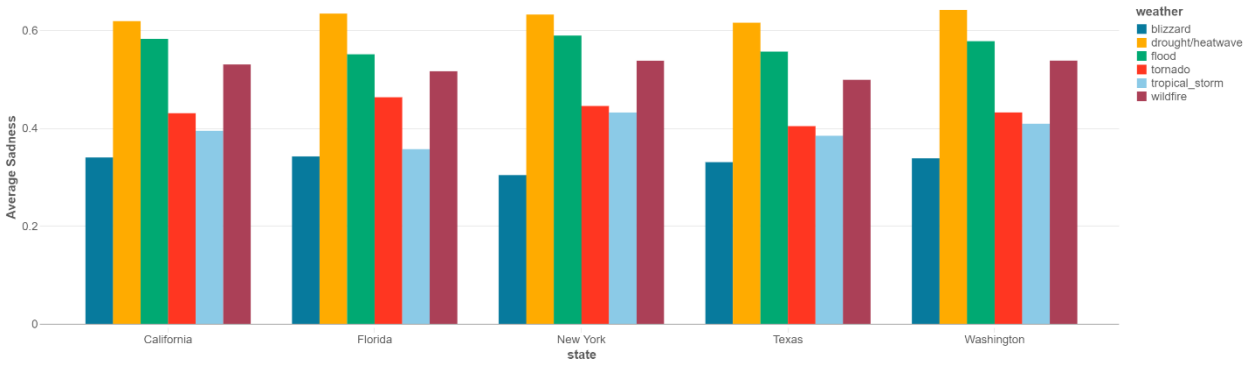


Figure 7: Average Sadness by Weather Type by Top 5 State

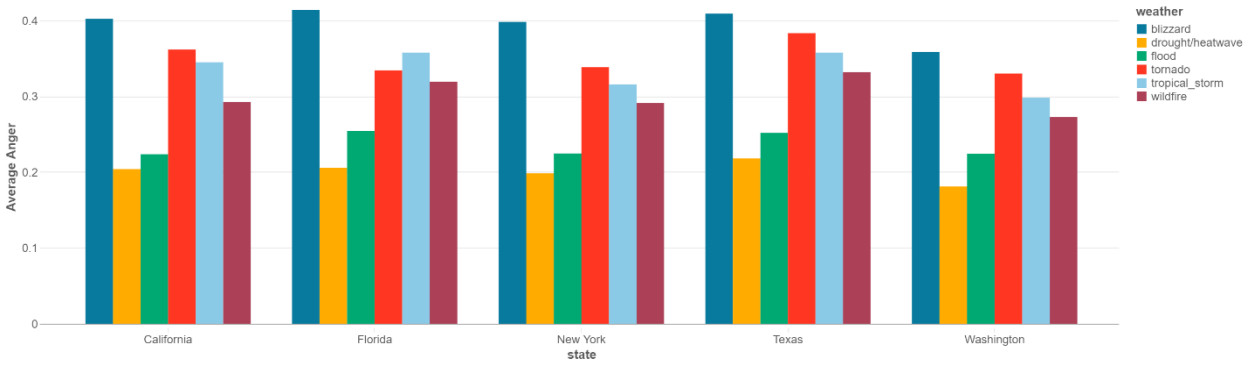


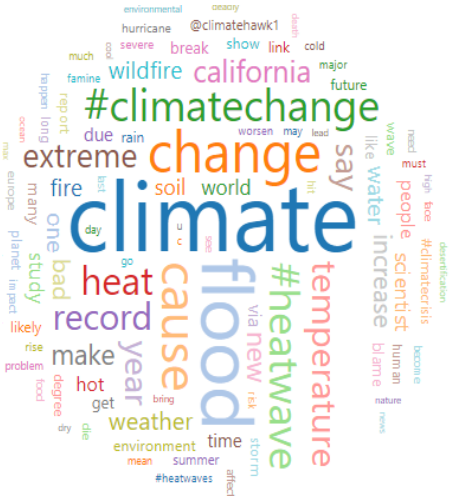
Figure 8: Average Anger by Weather Type by Top 5 States

Word Cloud by Weather Type

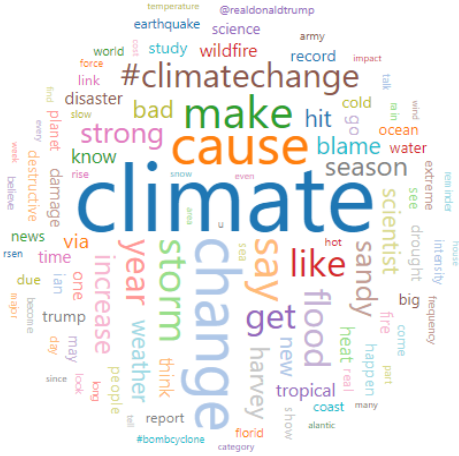
Figure 9 show word clouds for each weather type. Climate, change and hashtag #climatechange appear in all types of weather discussion, showing that there is a clear connection between extreme weather and climate change in the eyes of the public. Additional words for drought/heatwave are California, extreme, flood, and heat, indicate a regional focus (California) and a recognition of the severity and interconnectedness of these events (as droughts and heatwaves often exacerbate each other).

For flood, they are #unprecedented, wildfire, drought, change, and cause, suggesting a growing awareness of the unusual or unprecedented nature of recent flooding events, possibly linking them to climate change

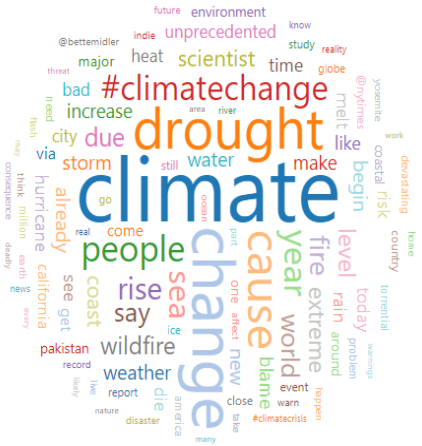
and recognizing their connection to other extreme events like wildfires and droughts. For tropical storms, the dominant words are flood, blame, sandy, season, and cause and reflect concerns about the increasing severity of storm seasons and the search for explanations or accountability, with "sandy" possibly referring to a specific, impactful event like Hurricane Sandy. For wildfire, California is the most frequent word, and it highlights the state as a central locus for discussions and concerns about wildfires, likely due to its high-profile and devastating wildfire events in recent years. For tornadoes, some of the frequent words are pray, affect, scary, and terrify. Those words indicate a more emotional response, emphasizing the fear and impact these events have on individuals and communities. For blizzard, the most frequent words include democrat, trump, make, snow, campaign and disapprove, suggesting that discussions around blizzards may be more politicized, possibly reflecting debates over climate policy or skepticism in the political arena. Overall, the word clouds offer a nuanced view of how the public discusses and perceives different extreme weather events, with a clear overarching theme of connecting these events to climate change.



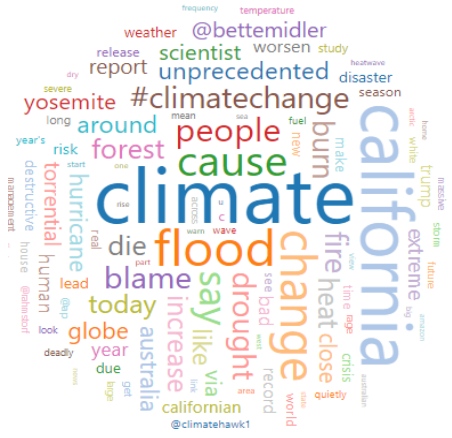
(a) Drought/Heatwave



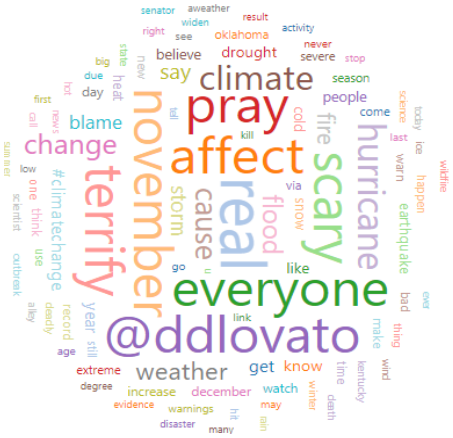
(c) Tropical Storm (Hurricane, Typhoon, Cyclone)



(b) Flood



(d) Wildfire



(e) Tornado

(f) Blizzard

Figure 9: Word Cloud for Extreme Weather Events

Topic modeling is an unsupervised machine learning technique that can scan a set of documents to detect words and phrase patterns within them and then cluster word groups and similar expressions that best characterize a set of documents. One popular methodology in topic modeling is Latent Dirichlet Allocation (LDA), a generative probabilistic model that assumes each topic is a matrix over an underlying set of words, and each document is a mixture of a set of topic probabilities. LDA is used to identify dominant topics in each type of extreme weather, the results are shown in Table 2. Table 2 shows the type of weather, top 30 most relevant terms for each topic. Based on the top 30 most relevant terms and a name was given to each topic. In addition, the average emotion of each topic is calculated and displayed in the last column of Table 2.

Table 2 Topic Modelling by Weather Type

Extreme Weather	Top 30 words	Topic Name	Emotion
Drought/ Heatwave	report, one, soil, cause, climate, heatwave, @climatehawk1, planet, drought, affect, famine, must, degree, study, say, late, bring, expose, increase, main, due, plough, life, @ipcc, @sadhgurujv, #climatechange, #heatwave, rain, #heatwaves, #socialgood	Heatwaves, Drought, and Agricultural Impact	Sadness: 0.64 Anger: 0.18 Joy: 0.08 Optimism: 0.11
	temperature, heatwave, record, heat, extreme, #heatwave, flood, year, break, new, wildfire, show, climate, many, time, drought, fire, wave, weather, rise, change, place, europe, face, water, increase, impact, storm, recently, max	Heatwaves and Wildfires Impact	Sadness: 0.61 Anger: 0.22 Joy: 0.07 Optimism: 0.1
	climate, flood, change, california, drought, say, blame, cause, #climatechange, scientist, environment, make, bad, major, problem, year, desertification, heatwave, #climatecrisis,	Drought, Floods, and Environmental Impact and California	Sadness: 0.63 Anger: 0.19 Joy: 0.04 Optimism: 0.14

	environmental, link, science, nature, get, solution, #savesoil, healthy, #esg, cheat, last		
Flood	cause, drought, #climatechange, make, already, climate, extreme, storm, change, environment, coast, weather, fire, begin, hurricane, heat, year, nature, get, say, future, #esg, text, #climatecrisis, likely, increase, like, lead, part, #dayzero	Extreme Weather and Environmental Crisis	Sadness: 0.59 Anger: 0.23 Joy: 0.05 Optimism: 0.13
	world, rain, climate, change, problem, flash, drought, soil, major, environmental, entire, like, desertification, solution, creature, communicate, healthy, #savesoil, @minxiepop, @climatehawk1, hit, severe, news, #climateemergency, massive, never, earthquake, sea, deadly, #climateaction	Global Environmental Challenges and Climate Action	Sadness: 0.55 Anger: 0.24 Joy: 0.06 Optimism: 0.15
	unprecedented, people, california, die, around, today, close, globe, torrential, wildfire, @nytimes, america, @bettemidler, yosemite, scientist, consequence, warnings, may, come, coastline, true, germane, via, #beforetheflood, damage, seed, fire, begin, link, due	California Wildfires and Global Climate Consequences	Sadness: 0.59 Anger: 0.22 Joy: 0.05 Optimism: 0.15
	rise, level, sea, melt, pakistan, climate, blame, change, devastating, affect, reality, risk, year, live, country, city, threat, indie, warn, still, million, alia, due, ice, predict, @realdonaldtrump, woman, discussion, say, christian	Rising Sea Levels and Global Climate Impact	Sadness: 0.61 Anger: 0.22 Joy: 0.05 Optimism: 0.12
Tropical Storm	climate, typhoon, make, trump, change, increase, say, coast, day, science, intensity, harvey, hit, frequency, sandy, happen, believe, long, storm, link, rain, people, hurricane, east, live, cyclone, one, florid, scientist, yet	Increasing Intensity of Hurricanes and Typhoons	Sadness: 0.34 Anger: 0.36 Joy: 0.09 Optimism: 0.21
	damage, cause, cold, get, big, know, hot, slow, heat, reminder, planet, force, area, #bombcyclone, cost, water, study, push, occur, news, cap, ain, army, gettin, practice, mall, simulator, cuss, @thundercat, bomb	Heatwaves, Cold Spells, and 'Bomb Cyclones'	Sadness: 0.42 Anger: 0.36 Joy: 0.09 Optimism: 0.13
	climate, flood, #climatechange, like, change, cyclone, blame, wildfire, storm, bad, disaster, say, drought, make, report, destructive, cause, season, sea, year, strong, fire, hurricane, may, earthquake, worsen, become, rise, tropical, scientist	Rising Severity of Wildfires, Floods, and Hurricanes	Sadness: 0.43 Anger: 0.31 Joy: 0.08 Optimism: 0.18
Wildfire	like, report, hurricane, say, increase, californian, destructive, disaster, worsen, release, house, white, year's, @ap, quietly, climate, scientist, wave, fuel, look, forest, heat, blame, change, via, deadly, may, rage, bear, brown	Increasingly Destructive Hurricanes and Forest Fires	Sadness: 0.49 Anger: 0.28 Joy: 0.07 Optimism: 0.16
	climate, change, fire, bad, #climatechange, make, burn, record, real, due, weather, new, extreme, season, forest, drought, see, year, world, study, future, get, via, mean, risk, large, amazon, severe, temperature, west	Extreme Weather Fueling Forest Fires and Droughts	Sadness: 0.53 Anger: 0.29 Joy: 0.05 Optimism: 0.13
	flood, people, california, australia, die, cause, today, around, unprecedented, close, globe, yosemite, torrential, @bettemidler, human, trump, lead, crisis, heat, @rahmstorf, view, storm,	Global Climate Crises: Floods,	Sadness: 0.57 Anger: 0.29 Joy: 0.05 Optimism: 0.09

	drought, burn, heatwave, think, say, blame, climate, policy	Heatwaves, and Policy Challenges	
Tornado	flood, hurricane, fire, tornadoes, weather, get, know, storm, snow, like, drought, earthquake, december, still, watch, tornado, use, day, season, one, record, news, come, new, via, change, time, believe, warn, climate	Extreme Weather from Floods to Tornadoes and Hurricanes	Sadness: 0.39 Anger: 0.39 Joy: 0.1 Optimism: 0.12
	cause, tornadoes, climate, say, change, blame, #climatechange, year, cold, think, tornado, make, happen, oklahoma, increase, severe, last, people, weather, hurricane, heat, storm, believe, new, earthquake, via, time, warn, flood, fire	Increasing Severity of Tornadoes, Hurricanes, and Fires	Sadness: 0.43 Anger: 0.34 Joy: 0.08 Optimism: 0.14
	real, affect, november, scary, everyone, pray, terrify, @ddlovato, tornado, warn, blame, record, come, day, last, year, december, snow, tornadoes, oklahoma, get, one, new, flood, cause, weather, season, think, people, time	Public Concern and Emotional Impact of Extreme Weather Events	Sadness: 0.74 Anger: 0.12 Joy: 0.06 Optimism: 0.08
Blizzard	snow, cold, get, trump, think, big, prove, disprove, hoax, news, winter, #blizzard2016, record, via, cause, real, blizzard, know, say, climate, people, change, due, year, make, mean, like, storm, bad, scientist	Winter Weather and Climate Change Debate	Sadness: 0.32 Anger: 0.38 Joy: 0.19 Optimism: 0.11
	climate, change, say, weather, like, time, year, scientist, people, storm, cause, mean, real, winter, snow, via, bad, blizzard, day, cold, know, get, disprove, record, hoax, make, degree, think, east, coast	Climate Change Skepticism and Weather Patterns	Sadness: 0.33 Anger: 0.38 Joy: 0.17 Optimism: 0.12
	make, degree, try, issue, democrat, campaign, midst, @charliekirk11, key, bad, due, east, coast, day, know, mean, blizzard, via, record, #blizzard2016, cause, snow, storm, say, news, time, real, people, year, scientist	Political Discourse in Extreme Weather Events	Sadness: 0.40 Anger: 0.42 Joy: 0.09 Optimism: 0.09

In addition, Figure 10 shows a visual presentation of the result of the LDA Model using pyLDAvis python package for Drought/Heatwave.

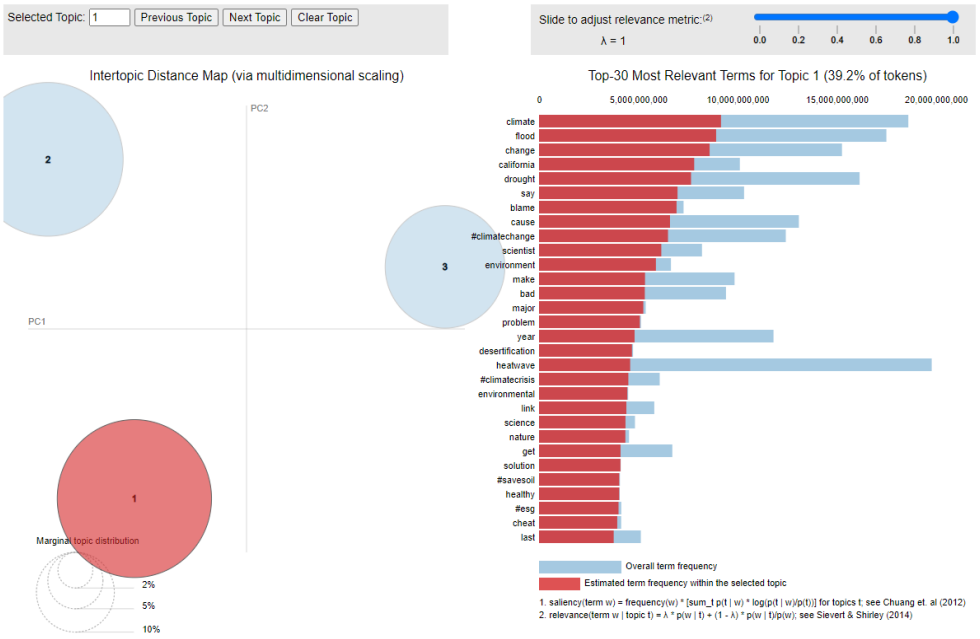


Figure 10: Topic Modelling for Drought/Heatwave

For Drought/Heatwave, three topics are identified, and the topics focus on the impact of extreme weather on agriculture, wildfires and overall environment and the dominant emotion for all three topics are sadness. For the flood discussion, four topics are identified ranging from environmental crisis, global environmental challenges and climate action, California wildfire and global climate consequences, and rising sea levels. The dominant emotion is still sadness.

For tropical storms, the major topics are increasing intensity/severity of hurricanes, typhoons and bomb Cyclones. Besides sadness, there is a higher degree of anger when discussing tropical storms. Regarding wildfires, the three topics are increasingly destructive hurricanes and forest fires, extreme weather fueling forest fires and droughts, and global climate crises and policy challenges. Those topics focus on the impact of tropical storms and policy challenges. The dominant emotion is sadness.

For tornadoes, the major topics have covered hurricane, fires, and hurricanes besides tornadoes. In addition, one topic is associated with policy concerns and emotional impact of extreme weathers. Sadness and anger are the major emotions when discussing those tweets. For blizzards, the major topics include winter weather and climate change debate, climate change skepticism and weather patterns, and political discourse and the 2016 blizzard. Anger became the highest emotion, followed by sadness.

In summary, topic modeling reveals that key discussions surrounding various extreme weather events focus on their escalating intensity and the resulting environmental, social, and emotional repercussions. Additionally, these conversations often involve debates, skepticism, and considerations of risks associated with climate change. Predominant emotions identified in these discussions are sadness and anger.

In addition, a visualization using Gephi is created to show the top 30 words for each topic for each weather and the results are shown in Figure 11. Each word is represented by a node and connects to a topic (also represented by a node) it belongs to. Nodes in red appear in more than four topics, nodes in green appear in 2 topics and those in blue appear in 3 topics, and nodes in purple only appear in one topic. Most words

only appear in one topic, and they are at the outside of the circle. red nodes (words that appear in more than four topics) in the middle of the graph include climate, change, storm, drought, record, flood, fire, blame, bad, increase, heat, hurricane, snow, news, coast, heatwave, earthquake, warn, and season. Those words represent the most frequently mentioned words when discussing extreme weather events.

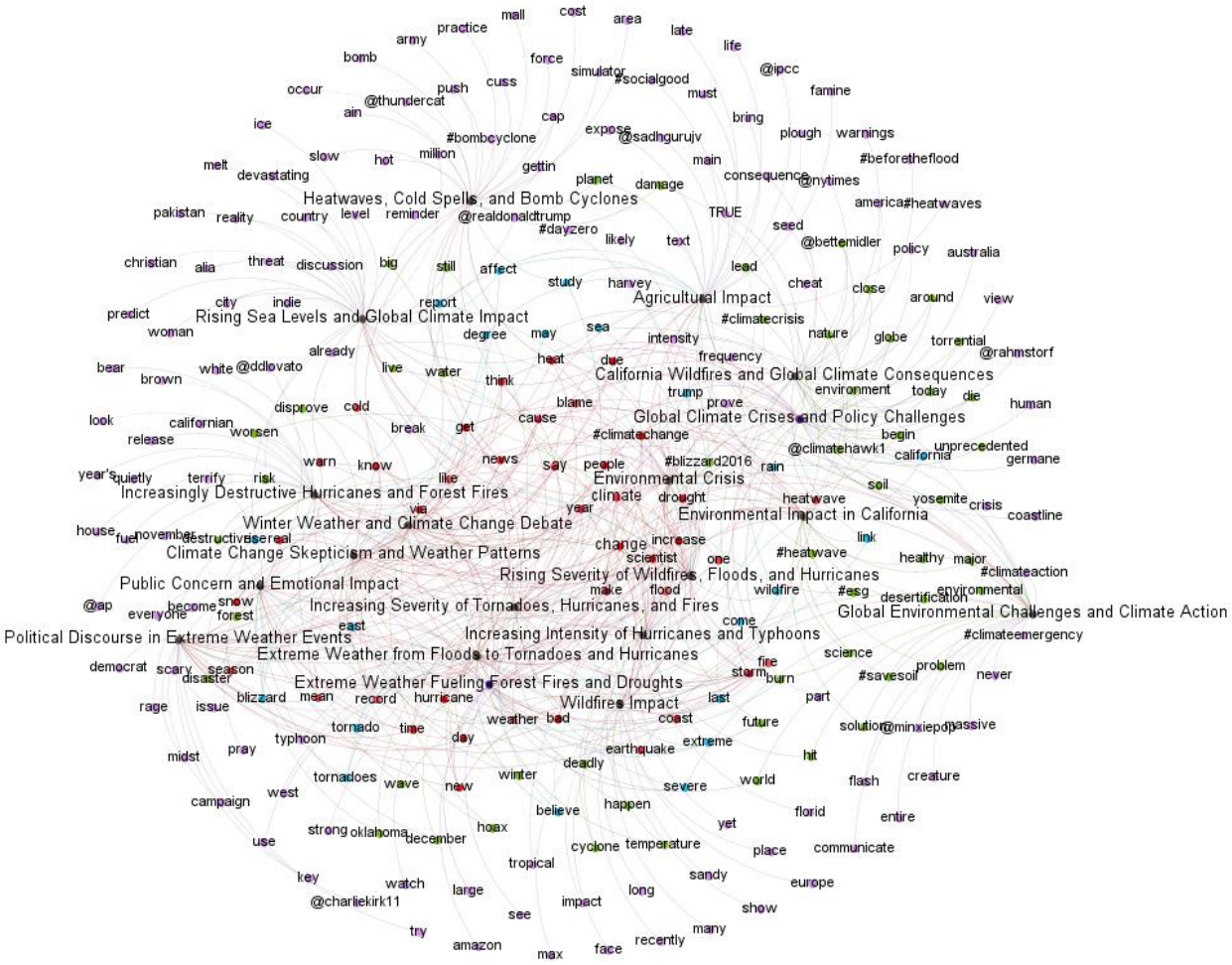


Figure 11: Visualization of Top 30 Words for Each Topic

Those top words across multiple topics collectively paint a picture of growing public awareness and concern about the impacts of climate change on weather patterns. "Climate" and "change" are central, highlighting the overarching theme of global environmental shifts. Words like "storm," "drought," "flood," "fire," "heat," "hurricane," "snow," "heatwave," and "earthquake" represent various extreme weather events, indicating a broad spectrum of natural phenomena that are increasingly occupying public discourse. The inclusion of "record" and "increase" suggests that these events are not only becoming more frequent but also more severe, often breaking historical records. "Blame" and "bad" reflect a sense of urgency and concern, possibly pointing to discussions around accountability and the negative impacts of these events. "News" indicates the role of media in shaping and disseminating information about these events. The mention of

"coast" could signify a specific focus on coastal regions, which are often more vulnerable to climate-related events like hurricanes and rising sea levels. "Warn" and "season" suggest a temporal aspect, with warnings issued for specific seasons that are increasingly characterized by such extreme weather events. Overall, these words underscore a heightened collective consciousness about the severity and frequency of extreme weather events, linking them to broader climate change narratives and emphasizing the need for informed discussion and action..

Conclusion and Implication

This study delves into the public's emotional responses to global warming and extreme weather events, examining variations in these responses based on geographic location and their evolution over time. Additionally, the research investigates the predominant themes associated with different types of extreme weather events, thereby shedding light on public perceptions and discourse surrounding these pivotal environmental challenges.

The findings show that discussions on Twitter predominantly focus on floods and drought/heatwaves. There has been a consistent increase in Twitter conversations about extreme weather over recent years. Emotion analysis indicates that sadness, followed by anger, are the most prevalent emotions in discussions about various extreme weather events, reflecting the emotional toll of global warming on the public. Through topic modeling, we identified diverse themes in these discussions for each type of extreme weather event. The findings demonstrate that conversations about extreme weather events are frequently framed within the broader context of climate change. These discussions encompass a range of topics, including the challenges and crises posed by climate change, the escalation of extreme weather events, their global, social, and emotional impacts, as well as related political discourse.

This study not only maps the emotional landscape of public discourse on extreme weather events but also provides insights into the thematic structures of these conversations. The results underscore the importance of understanding public sentiment and the thematic nuances in discussions about climate change and extreme weather, which are crucial for informing policy decisions and public awareness campaigns.

Overall, our study reaffirms the role of social media as a critical tool to gauge public opinion. However, Using Twitter data may not fully represent the broader population's views, especially those not active on social media or with limited internet access. Future research could expand on this work by incorporating a more diverse range of data sources, including other social media platforms, news articles, and/or surveys, to capture a wider spectrum of public opinion. In addition, cross-cultural studies could examine how these discussions and emotions vary in different global contexts, offering a more comprehensive understanding of the worldwide response to climate change and extreme weather events.

References

2017 Atlantic Hurricane Season. 2017 atlantic hurricane season. (n.d.). https://www.nhc.noaa.gov/data/tcr/index.php?basin=atl&season=2017

2018 incident archive. Cal FIRE. https://www.fire.ca.gov/incidents/2018

Haltinner, K., Sarathchandra, D., & Ptak, T. (2021). How Believing That Climate Change Is a Conspiracy Affects Skeptics' Environmental Attitudes. *Environment : Science and Policy for Sustainable Development*, *63*(3), 25–33. https://doi.org/10.1080/00139157.2021.1898900

Intergovernmental Panel on Climate Change (IPCC). (2021). "Climate Change 2021: The Physical Science Basis." . https://www.ipcc.ch/report/ar6/wg1/

Leas, E. C., Althouse, B. M., Dredze, M., Obradovich, N., Fowler, J. H., Noar, S. M., Allem, J.-P., & Ayers, J. W. (2016). Big Data Sensors of Organic Advocacy: The Case of Leonardo DiCaprio and Climate Change. *PloS One*, *11*(8), e0159885–e0159885. https://doi.org/10.1371/journal.pone.0159885

National Aeronautics and Space Administration (NASA). "Global Climate Change: Vital Signs of the Planet." https://climate.nasa.gov/

NASA. (n.d.). *A long-lasting western heatwave*. NASA. https://earthobservatory.nasa.gov/images/150318/a-long-lasting-western-heatwave

Qiao, F., & Jiang, K. (2022). Attitudes Towards Global Warming on Twitter: A Hedonometer-Appraisal Analysis. *Journal of Global Information Management*, *30*(7), 1–20. https://doi.org/10.4018/JGIM.296708

State Population Rankings. Rank List: States in Profile. (n.d.). https://www.statsamerica.org/sip/rank_list.aspx?rank_label=pop1

Styve, L., Navarra, C., Petersen, J. M., Neset, T.-S., & Vrotsou, K. (2022). A Visual Analytics Pipeline for the Identification and Exploration of Extreme Weather Events from Social Media Data. *Climate (Basel)*, *10*(11), 174-. https://doi.org/10.3390/cli10110174

US Department of Commerce, N. O. and A. A. (n.d.). August 2016 Louisiana Flooding Damage Assessment Images. https://oceanservice.noaa.gov/news/aug16/louisiana-flooding.html