Understanding the Correlation Between NWS Impact-Based Flash Flood Warning Categories and Various NWS Flash Flood Tools

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ABSTRACT

Flash floods are dangerous natural hazards that can cause damage to life and property. Currently, they are one of the primary causes of weather-related fatalities in the United States. Recently, the National Weather Service has started issuing an Impact-Based Warnings (IBW) for flash flood events, which allows forecasters to add stronger language to their warning text products based on the impacts that are possible or occurring. The IBW categories are Base, Considerable and Catastrophic. This project classified a database of 141 flash flood events from 2013-2019 bases on their perceived IBW categories using specific keywords found in each report. To help with the classification, information from social media such as Twitter and Facebook posts, news articles, pictures and videos were also analyzed. The classification of the events was done twice depending on how to account for reports of closed roadways. For the first time the results showed that 19.3% of the events were base, 62.1% were considerable and 18.6% were catastrophic. After re-classifying the roadway reports as base (instead of considerable), the results showed that 35.5% were base, 47.5% were considerable and 17.0% were catastrophic. It was concluded that the analysis of the events depends on perspective which creates a major challenge at the time of the classification due to the keywords being ambiguous some of the times.

1. Introduction

Flash flooding is a dangerous natural hazard that can cause damage to life and property. Calianno et al. (2013) found that these events have been increasing over the past few years. A flash flood is defined by the National Weather Service (NWS) as "A rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within six hours of the causative event. However, the actual time threshold may vary in different parts of the country. Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising flood water" (from http://w1.weather.gov/glossary/index.php?letter=f). In simple words, we can say flash flooding is a rapid rise of water. Schroeder et al. (2016) and Špitalar et al. (2014) stated that this can be determined by a number of natural and anthropogenic factors such as rainfall duration and intensity, and geomorphological factors. Kellar and Schmidlin (2012) showed that the majority of weather-related fatalities in the United States are a result of flash flooding and most of them are related to vehicles.

When a flash flood is occurring or imminent a forecaster at a National Weather Service Forecast Office (WFO) is required to issue a flash flood warning. NWS

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(2019) states that a flash flood warning is issued when an overflow or inundation event is occurring or imminent with rapid rise of stage that threatens life and property.

As of 2020, the National Weather Service has started issuing an Impact-Based Warnings (IBW) for flash flood events. This system allows forecasters to add stronger language to their warning text products based on the impacts that are possible or occurring. The Impact Based Warning tags are divided into three categories: Base, Considerable and Catastrophic. The Base category is used most of the time, when flash flood impact damage is possible. Considerable is used rarely, when there are indications flash flooding capable of unusual severity impact is imminent or ongoing and urgent action is needed to protect lives and property. And lastly, Catastrophic is used exceedingly rare when there is an imminent or occurring catastrophic threat to life and property. Additionally, the Catastrophic category is used when Flash Flood Emergency criteria are met (NWS DIRECTIVE 10-922). The last two categories activate the Wireless Emergency Alert which automatically sends emergency messages to wireless devices within the warning area.

Each category has some keywords that are used to classify flash flood events:

- Base: heavy rain reported/expected, high standing water, runoff, any uncertain language "flooding possible", generic call to action language.
- Considerable: basement, house and building flooded; bridges, roads and highways washed out; closed; impassable highway interstate and major road; evacuations; major dam and levee failure; debris flow, slides; vehicles stranded; water rescues; more urgent/serious call to action language.
- Catastrophic: multiple swift-water rescues, homes destroyed, life threatening situations, total failure of major dam.

Stackhouse (2019) analyzed verified Flash Flood Warnings from 2018 to determine common keywords used in the events and then classified them with their respective IBW category. Results showed that 80% of the events were Base, 12% Considerable and only 3% of them were Catastrophic.

Current research is being conducted within the National Weather Service that classifies Local Storm Reports from several Gulf Coast Weather Forecast Offices. The goal is to assign a magnitude (from 1-3) for each report based on the impacts that occurred.

This project will classify a database of recent flash flood events from 2013-2019 based on their perceived Impact Based Warning categories by looking at reports, news articles, events summaries and information from social media. A statistical analysis will be performed to determine what percentage of these flash flood events are categorized as base, considerable or catastrophic. The goal of the project is to provide forecasters with information that can help increase their confidence during warning decisions by identifying the specific keywords for each category.

2. Data

The flash flood event database used for this project is from the National Weather Service Storm Data. The Flash Flood Reports are from the Weather Forecast Office in Norman, Oklahoma from 2013-2019. Social media information and news reports/articles were also used for the research.

National Weather Service Storm Data

The database used from the NWS Storm Data contained 671 flash flood events from the states of Oklahoma and Texas from 2013 through 2019 [1]. Each event in the database had the day, time and location of the event. The database was filtered to only include flash flood events caused by heavy rain. Also, the source was indicated which could be emergency manager, trained spotter, amateur radio, social media, public, broadcast media, law enforcement, county, local or state official, federal agencies, department of highways, National Weather Service employee or storm chasers. These reports also contained a description of the impacts of the event and direct or indirect fatalities. Additionally, a detailed description of the event was given.

Iowa Environmental Mesonet

Another database used for this research is the Iowa Environmental Mesonet from Iowa State University [2]. Two specific tools were used for the project, the Local Storm Reports and IEM Cow (NWS Storm Based Warning Verification). The Local Storm Reports provided a description of the impacts of the event, icons that showed the exact location of where the flash flooding occurred, date and time, source and the Weather Forecaster Office where the warning was issued. The IEM Cow tool was used as well. This tool provided a description of the impacts of the events, location, time of issuance and expiration date. Both tools were very helpful in supporting and confirming that the data from the NWS Storm Data matched with them and add any other information provided by them.

[1] https://www.ncdc.noaa.gov/stormevents/ftp.jsp
[2] https://mesonet.agron.iastate.edu

Social Media Reports

Information from Social Media was used as well for the project. News reports/articles, tweets, Facebook posts, YouTube videos and pictures were collected to support the information from the NWS Storm Data and the Iowa Environmental Mesonet. Many times, the social media reports added necessary details that helped to better categorize the flash flood events.

3. Methods

To analyze the data, a Microsoft Excel spreadsheet was created with several columns. The columns contained the Impact-Based Warning maximum category, keywords, links to news articles/reports, videos, pictures and social media, links to associated flash flood warnings (Iowa Environmental Mesonet) and notes that contained levels of uncertainty.

To classify the flash flood events, the following process was completed. Beginning with all 671 flash flood events from the NWS Storm Data database, the daily maxima were determined. This narrowed down the analysis to only the 141 highest-impact daily events. This method was chosen due to workload constraints and to focus the analysis on the strongest keywords. Next, each daily maximum event description was examined to identify keywords that would be important for the classification. Based on these keywords the initial IBW classification was narrowed down to two categories. Then, tools from the Iowa Environmental Mesonet were used to verify that the reports matched and additional information and keywords if necessary. Lastly, news reports/articles, pictures from social media and/or videos from YouTube were analyzed in order to make a final decision in the classification process.

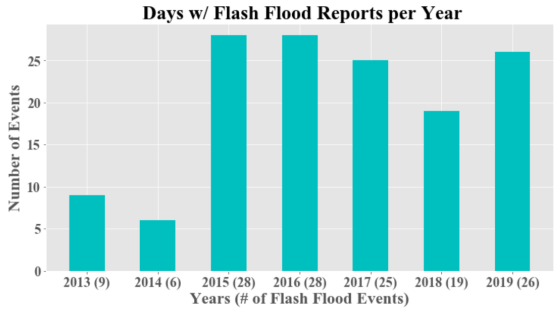

FIG. 1. Distribution of Daily Max Flash Flood Events per Year

Figure 1 shows the distribution of the 141 daily max events provided by the NWS Storm Data. The majority of the events occurred in 2015 and 2016. There were 28 flash flood events for both years. The years with less events were 2014 and 2013 with 6 and 9 flash flood events respectively.

Seasons	Months	Number of Events
Winter	December, January, February	2
Spring	March, April, May	59
Summer	June, July, August	60
Autumn	September, October, November	20
Total		141 events

TABLE 1. Days w/ Flash Flood Reports per Season

Table 1 shows the distribution of the 141 daily max flash flood events per season. The majority of the events occurred during the spring and summer seasons with 59 and 60 events respectively. The winter season was the season with least amount of events, with only two daily max events.

Base	Considerable	Catastrophic
roads close (8)	water rescues (18)	killed (11)
water over highway (10)	vehicles stranded (15)	swept away (5)
roads flooded (2)	evacuations (2)	multi. water rescues (8)
impassable (6)	homes flooded (8)	homes flooded (6)
closed (9)	interstate closed (4)	evacuations (2)
roads impassable (5)	washed out (7)	closed (21)
water over roadway (6)	submerged (3)	washed out (7)

TABLE 2. Keywords

Table 2 shows the most common keywords used for the classification of the flash flood events and how many times they showed up. For the Base category the most common keywords were “water over highway” and “closed”. The keyword “closed” specifically refers to roads and highways closed. “Water rescues” and “vehicles stranded” were the keywords that showed up the most for the Considerable category. And lastly, for the Catastrophic category “closed” and “killed” were the most common keywords. Here, the keyword “closed” meant interstate closed.

4. Results

The flash flood events were classified twice. During the first classification the keywords “roads closed” and “highways closed” were put into the Considerable category. For the re-classification of the events the same keywords were considered but for the Base category. This process was done because there was a level of uncertainty during the first classification due to the keywords being ambiguous and able to fit into any of the three categories.

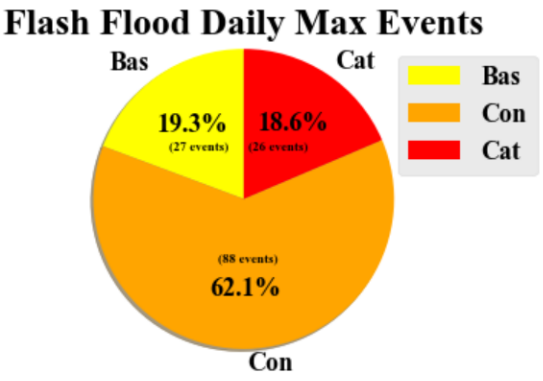

FIG. 2. Distribution of the Flash Flood Events based on IBW Category

Figure 2 shows the distribution for the Flash Flood Events. This pie chart was generated using the first classification of the events which showed that the majority of the 141 flash flood daily max events were classified as Considerable. The distribution shows that 19.3% of the events were base, 62.1% considerable and 18.6% catastrophic.

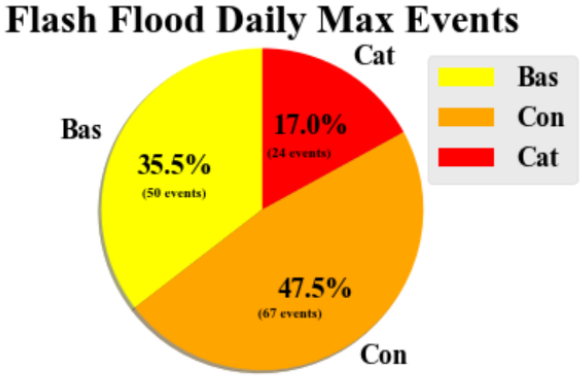

FIG. 3. Distribution of the Flash Flood Events based on IBW Category, reclassified

Figure 3 shows the distribution of the Flash Flood Events based on IBW Category after being re-classified. The re-classification included the keyword "roads closed" in the Base category. This pie chart shows that the majority of the events still are Considerable but they went down in comparison to Figure 2. The distribution was 35.5% for the base events, 47.5% of the events were considerable and 17.0% were catastrophic.

5. Discussion and Future Work

While doing the classification of the flash flood events there was a major challenge faced. Some of the keywords on the reports used for the classification were ambiguous and vague which created a level of uncertainty at the time of the classification. This concludes that the analysis is very subjective and depends on perspective. The classification may vary depending on who is classifying the events. To address this problem the Flash Flood Severity Index (FFSI) proposed by Schroeder et al. (2016) could be added to the NWS Storm Data as a column. The FFSI was implemented outside the NWS and would be analogous to the tornado EF-scale because it is a post-event damage index. Adding the FFSI categories to Storm Data would create more objective entries, and therefore, a better understanding of the severity of each event.

Table 1
Proposed flash flood severity index.

Category	Impact
1 – Minor flood	River/creek overflowing; cropland/yard/basement flooding
2 – Moderate flood	Street/road flooding; road closures
3 – Serious flood	Vehicles, homes and/or buildings inundated with water; road/bridge damage
4 – Severe flood	Vehicles and/or mobile homes swept away
5 – Catastrophic flood	Buildings/Large infrastructures submerged; permanent homes swept away

FIG. 4. Proposed FFSI (Schroeder et al. 2016)

In conclusion there is a need to conduct more IBW studies in order to establish an automated methodology for these classifications. This would help address the challenge of uncertainty when analyzing the flash flood events and would increase confidence when classifying the events and determining important keywords.

For future work this project could be expanded to other WFO's around the country. This would create an even greater database to work with and could help increase confidence when analyzing the events. Also, the 671 flash flood events could be all analyzed one by one instead of taking the "daily max" of them. Finally, it would be very useful and interesting to see a correlation between IBW classifications and NWS tools such as rainfall rates from Multi-Radar/Multi Sensor system (MRMS) v12, Flooded Locations and Simulated Hydrographs (FLASH) product suite and Flash Flood Monitoring and Prediction (FFMP).

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