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Assessing Effective Rhetoric on Twitter in Relation to Forecast Uncertainty in Hurricane Tracks

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Abstract

A forecast is only as good as the way it is communicated. As the National Weather Service (NWS) transitions to an Impact-Based Communication style, the new public forecasts discuss how to effectively prepare and protect oneself from harm in the face of severe and significant weather. After severe events, meteorologists need to take the time to analyze the language and style of the rhetoric to assess how effective it was at getting people in harm's way to take protective actions. It is even more important to understand how information was communicated when there is large uncertainty in the forecast. Uncertainty can lead to confusion in the public, which in turn, leads to potential life-and-death situations.

Hurricane Irma's (2017) impacts in Florida provides one such occasion where reflection could prove beneficial in understanding how people respond to forecast information, especially when there is large uncertainty and shifts in that forecast. Using the social media platform Twitter, tweets to and from the Florida NWS offices, local Emergency Management Offices, and politicians were collected to assess how Irma forecast information was disseminated on the platform. Gauging the public's reception and reaction to this information provides essential insight to meteorologists. The information collected can be used to tailor their future forecasts to ensure protective actions are taken if, and when, the next severe weather outbreak occurs.

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1. Introduction

A meteorologist today is no longer just a forecaster. They must be good communicators as well. A forecast could be one hundred percent accurate, but if the end user misunderstands the forecast, or if it is miscommunicated by the forecaster, the result is just as bad as having a bad forecast. As meteorologists, it is also known that a forecast can never be one hundred percent accurate, one hundred percent of the time. For this reason, it is even more integral that the communication of the forecast is as comprehensible as possible. The National Weather Service (NWS) tries to communicate weather forecasts and warnings for the "protection of life and property" as part of its mission statement ("Mission Statement", 2016). After major events, where a lot of information is reported, reflection on the effectiveness of the information provided by NWS in different forms would help the forecasters improve their future forecasts by understanding what format of information is most engaging to the public.

Many different platforms are used to communicate information today. Television media, newspapers, word of mouth, and social media are just some examples of the different platforms information can be disseminated on today. Social media can be defined as a web-based or mobile service that allow users to create and share content, as well as browse other user-generated content (Hyvärinen and Saltikoff, 2010). These specialized platforms have shifted how information is communicated and disseminated by and to the public. Since the purpose of social media is to have an interactive platform where users can create and share their own information, complications arise when trying to determine how information is best engaged with and understood by all parties on the various platforms. The platform being examined in this study specifically will be the social media website Twitter. Vieweg et al. (2010) defined Twitter as a platform which allowed users to post short message of up to 280 characters, called tweets, from

two different clients, web-based and mobile-based users. Twitter provides for an interesting microcosm to assess information engagement due to the limited amount of material that can be shared due to the character limit. Because there is a continuity to a user's timeline, Twitter provides for a good platform for the distribution of information to the masses, compared to other platforms such as Facebook, which has no set timeline to its posts.

Communication must be at its best during high impact situations. During the 2017 Atlantic Hurricane Season, high impacts hurricanes affected Texas, Florida, and the Caribbean. This study will focus on the how information during Hurricane Irma was communicated on Twitter. Irma caused devastation throughout the Caribbean Islands and Florida. In Florida specifically, approximately 6 million people evacuated leading up to the landfall of this major hurricane. Irma first made landfall near Sugarloaf Key in Key West on 10 September as a Category 4 storm before moving through the keys and making land fall on Marco Island on the west coast of Florida later that same day. Irma's track is depicted in Figure 1. There were four direct deaths associated with Irma in Florida, with an additional 80 that were indirectly related. In the Florida Keys, 25% of all homes were destroyed, with an additional 65% being significantly damaged. If the forecast of this event was not well communicated, the death count could have been significantly higher (Cangialosi et al. 2018).

The lingering question here asks what the best way to communicate forecast information to the public is, to promote protective actions. There are three prongs to this question. Collecting the tweets that were sent out and received from 5 NWS Weather Forecast Offices (WFO) in Florida, an assessment of their communication styles was conducted to address each of the following questions.

1. NWS WFO Information: How does each individual WFO communicate and engage with their followers?
2. NWS Forecast Graphic Information: How does each WFO communicate Hurricane Irma forecast information?
3. Engagement with Public: What formats and tweet content type did the public engage with the most?

By understanding how each office communicates, by text or image, conversationally or not, it is possible to discern the best methods for engagement with the public on Twitter. Ultimately, the answer to these questions can help forecasters determine what the most effective communication tactics are to promote protective action, and as a result uphold, and improve, the mission of the NWS.

2. Data and Methodology

Tweets to and from five NWS offices in Florida were collected for this assessment. The five offices selected were Key West (KEY), Miami (MFL), Tampa Bay (TBW), Melbourne (MLB), and Jacksonville (JAX). Figure 2 displays the locations of the five offices selected. These offices all communicated high impact information for large swaths of populations with different demographic backgrounds. Over 7000 tweets were collected by the conclusion of this study for the collection period (CP) of 4 September 2017 to 15 September 2017. The tweets came from Florida, other states in the United States (US), and from people around the globe. The locations were extracted from the body of the tweet themselves, if the user stated where they were posting from.

A user can interact with a tweet in three forms, a like, a comment, and a retweet. A like saves the tweet to a user's personal timeline, archiving it. A comment on a post acts as a reply to the information. A retweet of a post by a user, copies and reposts the original tweet of a certain account. The user retweeting a post can add a comment or leave the tweet as just the original post. Engagement in this study was defined as any sort of like, retweet, or comment a tweet had received. Total engagement is the sum of all likes retweets, and comments. To normalize the data for all offices, the total engagement was divided by the number of followers that each WFO had as of 31 December 2017. For reference, Table 1 displays the total number of followers each office has.

Tweets were classified in two different ways for this study, by content and by characterization. Tweet content consists of the different formats the tweets were posted as: reply, text, image, gif, video, and retweet. A reply was considered any form of response from either a WFO post or a follower's response to a post. Text tweets were posts that had no additional media – text only. Any tweet that had an image attached to the post was automatically classified as an image. A gif is a short video, typically less than 10 seconds long, and were classified automatically on Twitter as this type of content. A video is any post with a video that was longer than 10 seconds. The retweeted content is the same definition as stated earlier. Tweet characterization describes what type of message was trying to be disseminated in the tweet: emergency management (EM), forecast, warning, damage, and observations. An EM tweet was considered anything associated with impact information or information sent directly (or indirectly) from Emergency Management Officials. Forecast information was considered any sort of tweet format that provided forecasts about the upcoming weather. Damage tweets were

considered anything providing information about flooding or debris. Observations came from both user input, follower uploads an image, or meteorological data measurements.

3. Results and Analysis

Preliminary assessment of Twitter data revealed that every WFO communicates to its followers in different formats, has different interactions with its followers, and provides different characterized information. While this result may not be bad, it does complicate the ability to standardize how NWS reports information on social media. This observation suggests that each WFO needs to be looked at individually to properly see the impact that the communication had on the individual WFO's audience. There is one exception to this observation. Every office posts Tornado Warnings and Flash Flood Warnings in the exact same fashion. The only variation found in this information was whether the offices shared the warning in multiple languages or not.

For each office tweet content and tweet characterization are plotted. Characterization only plots the distribution of emergency management, forecast, damage, and observation information and not the warnings or other categories. Because tornado and flash flood warnings are disseminated by each office in the same fashion as images, they were not plotted. In the Appendix, examples of different tweets are provided, including forecast infographics and impact information.

3.1 National Weather Service Office Information

3.1.1 NWS Key West

Complications arise when analyzing the Twitter information in Key West after 10 September. First, Monroe Country Emergency Management lost internet access on 10

September. Consequently, Monroe Country Emergency Managers started disseminating information through NWS Key West until internet access was restored. Second, NWS Key West also lost internet access later in the day on 10 September. As a result, NWS's satellite office protocol went into effect. This meant that NWS Austin-San Antonio, Key West's satellite office, took over the Twitter feed at the end of the day on 10 September, and continued posting through the rest of the CP. Despite the takeover by NWS Austin-San Antonio Key West was the only office that went down during the storm.

NWS Key West forecasts for all of Monroe County, Florida: the Florida Keys. The office sent out a total of 429 tweets throughout the CP. Figure 3 shows the distribution of tweet content sent out for Key West from 4 Sept. 2017 to 15 Sept. 15. Key West primarily disseminated information in the form of either images or replies. Figure 4 depicts the distribution of the tweet characterization. Primarily, Key West sent out tweets regarding the forecast and emergency management related information. Their feed shifts after 10 September, the date of Irma's landfall in the Keys, to report more of the observations. Key West also posted a total of 5 tornado warnings over 9 and 10 September.

While Key West may have only sent 429 tweets, they received 4,000 tweets. Tweet postages peaked on 9 and 10 September. With approximately 1500 tweets and 1000 tweets respectively, the public was looking for information regarding current and future impacts most frequently. They did so by asking questions to acquire the information. There was a good chunk of posts which had nothing to do with the storm. Since impacts in Key West were forecast to be significant, individuals determined that Key West's twitter feed would likely be popular. Taking advantage of the situation, people in the public would tweet at NWS Key West trying to promote some agenda they had or their own business. Many of these agenda tweets contained anti-Trump

statements and claims that the storm was either “fake news” or caused by a certain political party. In addition, people would push forward their own business agendas such as one Twitter user who was trying to promote his album. While this information is not the focus of this study, it is an important aspect to include when trying to assess the overall conversation going on regarding the storm.

3.1.2 NWS Miami

The NWS office in Miami services the highly diverse demographics of southern Florida. Table 2 depicts the Hispanic population breakdown of the counties within Miami’s NWS office’s responsibility. According to the US Census Bureau, nearly one half (43.4%) of Miami’s demographic is of Hispanic descent, likely speaking Spanish as a first language. To account for this large segment of the population’s background, Miami posted tweets in both English and Spanish. All forecast information, impact information, and warnings were double posted in English and in Spanish.

Examining the breakdown of tweets from Miami, Figure 5 illustrates the distribution of the content type, and Figure 6 depicts the categorization of the feed. Assessing the information prior to landfall, Miami’s social media team replied to a lot of posts made by the public. Images were posted consistently throughout the CP, apart from 9 and 10 September.

Postings peaked on 9 September followed closely by 10 September, the day prior to and the day of landfall. Miami replied frequently over these two days to followers asking questions regarding current storm condition updates, explaining the spike seen in Figure 5. There is a smaller peak which occurred on 6 September. Most of these tweets were replies made by NWS Miami. On this day, the center line of the hurricane track cone of uncertainty was directly over

Miami. Many of Miami's followers were questioning what the impact such a track would have on the city and where to evacuate to. After the 6th, the total number of posts decreased. This decrease coincides with the westward shift in the forecast track.

Warnings, which are not depicted in Figure 6, were reported on Twitter as infographics – an image. Miami posted a total of 118 warnings to its feed. These warnings were both tornado and flash flood warnings. As mentioned earlier, tweets were doubled in English and Spanish, so 59 of the 118 warning tweets were in Spanish. After warnings, the next largest characterization during the impact stage of the CP is the observation category.

While Miami may have only sent 429 tweets, they received around 950 tweets. These tweets ranged in scope to cover many different topics. Around 25% of the tweets contained questions asking the Key West office for highly specific information including impact location and storm hazards. In addition, approximately 10% of the tweets contained jokes and memes. All humorous tweets occurred in the days before, and the day of, landfall. The largest percentage of tweets were of members of the public expressing their prayers and gratitude to the Office for the work they did.

3.1.3 NWS Melbourne

NWS Melbourne forecasts for East Central Florida, including Orlando. Though Melbourne, was the third most followed account from the five offices assessed, it had the second fewest number of posts at 169 tweets. Of the 169 tweets, 68 tweets were tornado and flash flood warnings. Prior to landfall, Melbourne posted images as its primary content source, as shown in Figure 7. The images described information from two main sources: emergency management (impacts) and forecast classifications. Traffic posts from Melbourne peak on 10 September. Most

of the tweets, as depicted in Figure 7, were text posts. Shown in Figure 8, these posts primarily stated storm observations primarily, but also contained written out warning information.

NWS Melbourne received more tweets, 192 posts, from the public than they sent out. Peak traffic occurred on 10 September. People were asking Melbourne for additional, specific storm information while also passing on their own well wishes for the safety of those being impacted by the storm. Melbourne's followers also posted many tweets with memes and jokes trying to add levity to the severity of the situation.

3.1.4 NWS Tampa Bay

NWS Tampa Bay forecasts for West Central Florida. This office out nearly 650 tweets during the CP. The majority of these were text output. However, Tampa Bay's office sent out automated tweets whenever a new product came out on their homepage. These products, which are automatically posted, include the area forecast discussions, surf zone forecasts, and notifications when warnings began, were extended, or ended. There is a large skew in the data towards text products when comparing Tampa Bay to other offices (Figure 9). The tweet breakdown by characterization for Tampa Bay is depicted in Figure 10. Primarily, the tweets sent prior to landfall concerned the forecast. The next largest component to the Tampa Bay feed were observational reports. Tampa Bay also sent out 12 tornado and flash flood warnings throughout the CP.

Tampa Bay received another 600 tweets from the public through the CP. Prior to landfall, individuals were seeking two main types of information. Some followers asked about how and where to evacuate to, but most followers were looking for specifics on how strong, where, and when, Irma would impact their region. After questions, people sent appreciative messages to the

Office for the work they were doing, and also sent their thoughts and prayers. Peak traffic occurred on 10 September, the day of landfall. On this day, most of the populace were looking for storm updates on specific locations in Tampa Bay's forecast area. In addition to storm updates, the public was also looking for information regarding the movement and strength of the storm.

3.1.5 NWS Jacksonville

Jacksonville's NWS office forecasts for northeastern Florida and southern Georgia. Jacksonville has the smallest number of followers, and posted the least throughout the CP. They sent out 128 tweets and received 79 tweets from the public. Figures 11 and 12 depict the distribution of the tweets sent out from Jacksonville's office. Much of the data prior to landfall, similar to the other offices, were primarily images. These images, however, were classified as emergency management and impact related posts. Of the 22 tweets sent out prior to landfall, 12 had to do with emergency management, with 8 relating to the forecast. Peak traffic occurs on 10 September and 11 September. This makes sense since there was very little impact by Irma in the Jacksonville region on 9 September. Content over these two days came in the form of texts providing information on storm observations. Of the 79 tweets that were sent at Jacksonville, peak traffic occurred on 11 September. On this day, impacts in Jacksonville were most severe. There was record flooding in the region caused predominantly by storm surge. People were posting damage from where they were located and looking for additional information on storm impacts in specific locations.

3.2 National Weather Service Forecast Graphic Information

Each NWS Office can create their own information graphics for a storm. These infographics highlight different sorts of information, with very little standardization across NWS. As a result, different formats are used, which may speak more effectively to the populace. Assessing the various forms of information graphics shared by the WFOs will provide insight on best practices for construction and information dissemination.

For each office, a 5-day forecast (5 September), 3-day forecast (7 September), and when available, 1-day forecast (9 September) infographic will be assessed to determine if there is any variation in formatting as the lead time shortens. All assessed graphics may be referenced in the Appendix.

3.2.1 NWS Key West

On the left-hand side of the infographic (Appendix Figure 1), the current coordinates (latitude and longitude), geographic location, movement (direction and speed), maximum sustained winds, and minimum sea level pressure are displayed. On the right-hand side of the infographic, a map from the National Hurricane Center (NHC) displays the hurricane track cone of uncertainty, current watches and warnings, and the strength of the storm. Overlaid on this graphic is information that the Key West WFO wants to add to provide to its followers regarding either forecast or impact information.

As the forecast progresses from the 5-day to the 3-day and to the 1-day forecast, information descriptions become more impactful in nature. 5-days out, all text discusses potential hazards, and evacuation information. The text is white with nothing bolded or underlined. The 3-day graphic is similarly formatted, but more information is added to the infographic. “Potential” hazards changed to “likely” hazards, for example. The announcement of hurricane and storm

surge watches are also placed on the graphic at this time. The shift in the 1-day forecast graphic is even more drastic with 3 text boxes overlaid on the graphic information. The hurricane and storm surge warnings, and tornado watch information, are written in red with all underlined, capital letters. This formatting demands attention. In addition, a second box with letters underlined and colored bright yellow warns that the Florida Keys may be uninhabitable for a period following the storm. Finally concerning the impacts, "likely" hazards shifted to "expected" hazards, using words such as "catastrophic" and "life-threatening" to emphasize the severity of the storm.

3.2.2 NWS Miami

NWS Miami varied the formatting of the infographics they provided from update to update, which causes issues when trying to compare the different formats stylistically. Selected for analysis was the 11AM infographic, as these reports were the most consistent.

The 5-day infographic did not provide any impact information rather it was just an update on the current storm statistics. Beginning with the 3-day infographic, additional information was provided in subsequent image in the tweet to describe different impacts of the storm. Specifically, by this time, hurricane and storm surge watches were out for the counties in south Florida, which were reported in red, underlined text. There were short statements included regarding impacts, storm timing, and a statement asking the public to heed evacuation orders. The 1-day graphic just provides the current storm information and graphic from the National Hurricane Center. NWS Miami instead speaks about impacts such as storm surge, flooding, wind, and tornado hazards in a separate graphic.

3.2.3 NWS Melbourne

NWS Melbourne had consistent formatting, but inconsistent posting of the infographics. As a result, the 5-day infographic is assessed with the 5AM infographic, while the 3-day and 1-day infographics are assessed with the 11AM infographic. Each infographic has a hurricane track cone of uncertainty on the left portion of the graphic, with important information written on the right-hand side. If there was additional space on the graphic after listing the important information, a satellite image of Hurricane Irma was also added.

The written information 5-days out conveys the uncertainty of the forecast, but still urges all residents to prepare. The 3-day graphic introduces colors and bolded text. Melbourne used red text to highly impact timing and to continue urging precautionary measures. Melbourne also used bolded, black text to describe the hurricane watches. The largest formatting shift occurs at the 1-day forecast graphic. This graphic's text box is colored light red, with bolded, red, underlined information. They also used asterisks and capital lettering to capture attention.

3.2.4 NWS Tampa Bay

NWS Tampa Bay did not have similar formatting to its infographics (Appendix Figure 4). In addition, they varied greatly from other offices because Tampa also included gifs as part of the infographics. The gifs displayed the current satellite imagery of the storm at that time, along with forecast information. The 1-day outlook, however, only showed the NHC hurricane cone, with an additional image displaying the location of storm surge warnings.

The 5-day infographic had a satellite loop displaying the development and intensification of Irma as the storm moved across the open Atlantic. The other image showed the NHC hurricane track cone of uncertainty. The 3-day infographic was much more informative. In capital, yellow letters, Tampa Bay highlighted the storm surge and hurricane watches that had

been posted for Florida. Additionally, below the satellite gif, Tampa Bay also listed storm facts and impending impact information.

3.2.5 NWS Jacksonville

Only posting a few infographics, Jacksonville was not consistent with its reporting scheme (Appendix Figure 5). Since they posted very infrequently, they chose to post new briefing graphics once every few days but did discuss other hazard information in additional formats (images and text). The 5-day infographic provided the NHC hurricane track cone of uncertainty, and additional text information on the left-hand side of the graphic. This information spoke about the current location, and potentially hazardous impacts such as rip tides. The 3-day graphic provided more cautionary advice regarding the forecast, the cone of uncertainty, and track errors. NWS Jacksonville specifically mentioned on three separate occasions in this graphic not to focus on the exact track of the storm, emphasizing impacts were likely to be significant regardless of Irma's eventual path.

3.2.6 Forecast Graphic Discussion

Ultimately, certain tactics were used for most offices. Most offices used red text to emphasize certain information. According to Leonard 1999, risk perception is higher in individuals when written in the color red. The attempts made by the WFOs to emphasize certain information over others by using various colors, does have a psychological reasoning behind it. In addition, the use of asterisks, bolded text, or underlined text also provides quick and easy ways to capture the followers' attention. One additional suggestion might be to include gifs in infographics like Tampa Bay does to capture users' attention. This format worked well with

Tampa Bay's followers as indicated by the higher engagement found when comparing infographics with gifs to infographics without gifs.

3.3 Engagement with the Public

The results from Sections 3.1 and 3.2 provide insight into what sort of information is shared between the public and the NWS WFOs, and how the formats of information vary office to office. With this information, public engagement will determine how effective different formats of information communication are in disseminating information.

3.3.1 NWS Key West

NWS Key West was constantly engaging with its followers. The office would respond to many questions the public would ask of them. When there was confusion or misinformation being spread, they would step into that conversation to correct and clarify the situation. Key West would also constantly try and implore its followers to take protective action. In most cases, the public took their suggestions and listen to the Key West postings (indicated by replies to these tweets). There was one instance, however, where a tweet that was sent in all capital letters with asterisks to capture users' attentions annoyed some of the public. The followers responded angrily claiming that the forecasters were over-hyping Irma's actual impacts. From that point forward, with that feedback, NWS Key West did not post any other tweets with all capital letters.

The most engaged tweets, before landfall, were tweets which contained images and videos. Figure 13 shows the distribution throughout the week of peak engagement per content type. The video with the highest engagement from 8 September was of a difficult radiosonde launch. The data being depicted in Figure 14 is more interesting to analyze. The data indicates that Key West followers were more engaged with content that contained either impact

information (classified as emergency management) and forecast information. It is understandable why observations are also highly ranked during and after Irma's impact. Since many followers of the region evacuated, they were searching for, and engaging with, content which provided them insight into what was occurring back at home. The content acts as a proxy to journalists reporting outside during severe weather conditions. Many news agencies justify sending reporters out into hazardous weather conditions to give the public information about current conditions. The content Twitter users were requesting was also for storm conditions, just for more specific locations.

3.3.2 NWS Miami

In Miami, followers were constantly asking questions regarding impact information, such as when and where the storm would hit, what sort of damage may result, and about evacuation information. This last item, the evacuation information, is very important to rationalize and respond to. Some followers were asking about whether they were in evacuation zones, while others were trying to determine when and where to evacuate to. NWS does not announce evacuation notices, only local County Officials announce the evacuations. In response to the question, "Am I in an evacuation zone?", NWS Miami did respond by posting images of the evacuation zones, courtesy of the County Emergency Managers. These images were constantly liked and retweeted as a result, being one of the more highly engaged pieces of content.

Overall, NWS Miami's highest type of content came in the form of images, which is depicted in Figure 15. The gifs and videos were from 9 September, where storm impacts were highest. Captured video of damage and radar imagery typically encompassed most of the videos and gifs, which were both highly engaged. The highest engagement seen was a text post on 9 September. This post reported upon imminent danger of catastrophic storm surge and reiterated

the need to evacuate. The followers responded to this tweet well, overall. There were some replies which contained memes and jokes, and only a few that were negative or contained claims of over-hyping an already stressful situation. Only two words were written with all capital letters, “ALERT” and “CATASTROPHIC” (@nwsmiami, 2017). These two words are eye catching and easily understood by the public. The warning this tweet provided was clear, but also provided an actionable instruction by telling the public to evacuate immediately.

Figure 16 illustrates the categorical distribution of the highest engaged tweet for each day. Forecast information as the most highly, and most consistently engaged information. The peak in the in forecast information falls on 7 September, 2-days prior to the initial impacts of Irma. This suggests that the public who interacted with this tweet, likely did so at this time to leave ample time to prepare for, and potentially evacuate from, the storm. At this time, Irma was still predicted to have a direct impact in Miami. At the time, the track of the hurricane was still predicting a landfall impact in Miami-Dade County. Information attention was at its peak when people still assumed that Irma would make landfall in Miami-Dade County since the center line of the hurricane was positioned over it. The Twitter data indirectly suggests that the public is still too concentrated on the center line in the hurricane track cone of uncertainty graphic.

3.3.3 NWS Melbourne

Images were the primary source of engagement in Melbourne’s feed according to Figure 17. Text reports during the peak engagement for this content type on 10 and 11 September were reporting observations from the storm. As depicted in Figure 18, Melbourne’s forecasts were the most engaged type of characterized tweet. The peaks in the forecast category coincide with peaks in the image graphics, illustrating that Melbourne’s followers engage most with this type of communication.

3.3.4 NWS Tampa Bay

NWS Tampa Bay provides for an interesting study. Figure 19 depicts a much more diverse data range when assessing the engagement by content. Images still primarily hold the lead as most consistently engaged content, but gifs are also well engaged in the data. The gif engagement peaks on 9 and 10 September, when Tampa Bay would post radar and satellite images of Irma. These two types of content are eye catching, which can explain why they are likely highly engaged. Forecast information and observations are the two most highly engaged sorts of tweets, as shown in Figure 20. Some forecast infographics from Tampa Bay contained gifs of satellite images of Irma. These types of forecast graphics were among the most engaged content, along with other forecast information.

3.3.5 NWS Jacksonville

Jacksonville, as stated previously, sent out the least number of tweets, and have the fewest number of followers. In this instance, images were the most consistently interacted with content on Twitter, followed by text output. Shown in Figure 21, image engagement peaked on 10 September. This peak is associated with a Jacksonville tweet illustrating different threat category graphics. The threat graphics depicted forecast risk for certain hazards associated with Irma. This peak is also highlighted in the characterization plot in Figure 22. Forecast information was most consistently engaged in Jacksonville, followed by the observations. The observations reported upon the storm conditions, such as wind and rainfall amounts. The most engaged observations however were associated with information regarding the inland flooding and the storm surge flooding in the Jacksonville region.

4. Conclusions and Recommendations

The results above provide critical insight into information communication via social media. Every office communicates with its followers in a different fashion. This is likely due to lack of personnel and/or a lack of resources dedicated to running the social media webpage. The one exception to this variation is tornado and flash flood warning graphics, which are standardized across the offices.

One large source of variation comes because of demographic differences between the offices. Offices whose populations contained predominantly Hispanic cultures tended to post in English and in Spanish. Challenges arise when these offices also stop posting in Spanish. Melbourne and Tampa Bay, prior to Irma's landfall posted bilingual infographics to keep their Spanish population informed. These offices did not continue to post in Spanish throughout the storm. Bilingual posting stopped the day before landfall which could have proven problematic. Since Tampa Bay and Melbourne had been posting in Spanish, the Spanish speakers likely continued to look towards these offices for their weather updates. When the offices stopped, it potentially left these persons without a source of information. This did not occur with the Miami office, since they intentionally posted every forecast and impact infographic in both English and Spanish throughout the storm.

Forecast information was communicated most effectively in infographics. The most engaged graphics were those that contained gifs, colored text, and underlined or bolded text. These additional characteristics were used to capture the attention of the public and to emphasize important information. Less engagement occurred when impact information was placed in a tweet but as two separate images. These graphics were still engaged with, but not as highly as the single image tweet. Despite the lower engagement, this method is still likely better than trying to

place all impact information and storm data in the same graphic and potentially overwhelming the observer with information.

Some frustration was seen in the public during the forecast period. The angry and annoyed followers complained about multiple aspects of the formats of tweets. They were concerned that the way WFOs were using information (all capital letters or too many asterisks) were overhyping the event. Along with this portion of the feed, there were some tweets expressing the follower's anxiety due to Irma's forecast shift. These followers were concerned about where and when to evacuate with the new shift in the forecast track.

Based off these results, the following recommendations are offered. Addressing first the evacuation concerns, potential outreach events to discuss how, where, and when to evacuate may prove beneficial. Secondly, since gifs were highly engaged, each infographic should include some form of gif such as satellite or radar image to capture users' attention. Alongside these infographics, color usage should be limited to only the most highly impactful information. Red is a good indicator color of risk, but if all text in the infographic is red, it is not possible to determine what is or is not impactful. Finally, standardization of formatting would also be valuable, to remain consistent in storm messaging and attempt to limit confusion.

Before any changes are made to current formatting practice, future research should be conducted to ascertain the public's responses to packaging of tweets. Surveys and focus groups could be used to enhance this research. Regardless, this study helps start the conversation in the social media context. More research is necessary to determine the most effective communication practices to disseminate severe and hazardous weather information to enable the public to make the correct decisions.

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Figures and Tables

Weather Forecast Office	Number of Followers
NWS Key West	53, 500
NWS Miami	53, 100
NWS Melbourne	37, 300
NWS Tampa Bay	28, 900
NWS Jacksonville	15,000

Table 1. NWS Forecast Offices Twitter followers as of 31 December 2017

County	Population	Percent Population: Hispanic
Glades	13,754	21.4%
Hendry	40,347	52.0%
Collier	372,880	27.0%
Palm Beach	1,471,150	21.5%
Broward	1,935,878	28.7%
Miami-Dade	2,751,756	67.7%
Total	6,585,765	43.4%

Table 2. Population by county under NWS Miami's forecast jurisdiction. Also listed, percentage of population of Hispanic descent. (US Census Bureau, 2017 July)

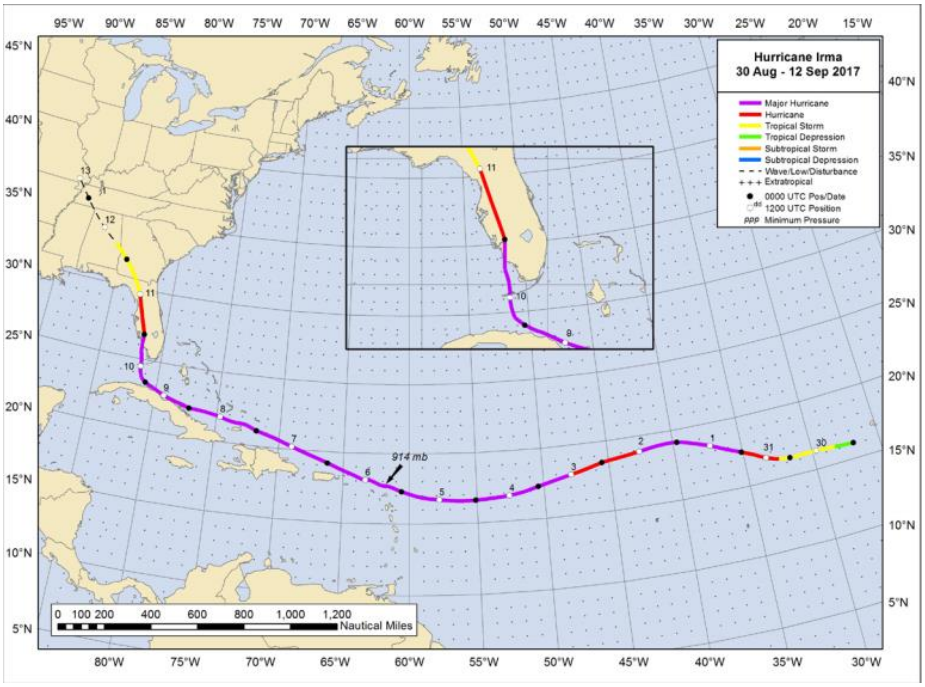


Figure 1. Hurricane Irma Track (Cangialosi et al. 2018)

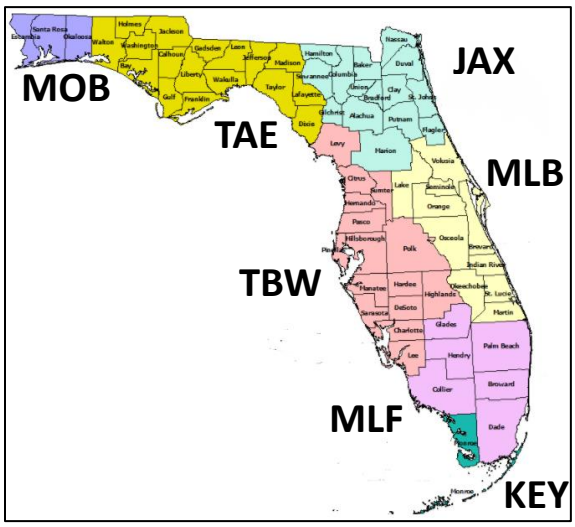


Figure 2. Florida NWS County Warning Areas. Mobile, Alabama (MOB), Tallahassee, Florida (TAE), Tampa Bay, Florida (TBW), Miami (MFL), the Florida Keys (KEY), Melbourne, Florida (MLB), and Jacksonville, Florida, (JAX). (National Weather Service)

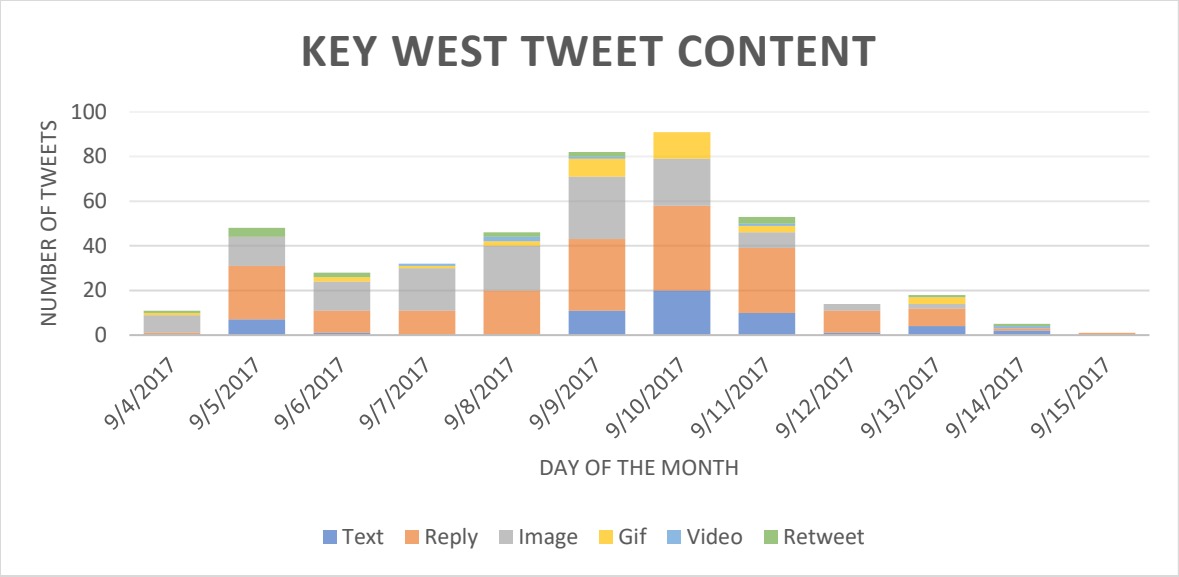


Figure 3. NWS Key West Tweet Content, displaying the number of each content type of tweet for the entire CP.

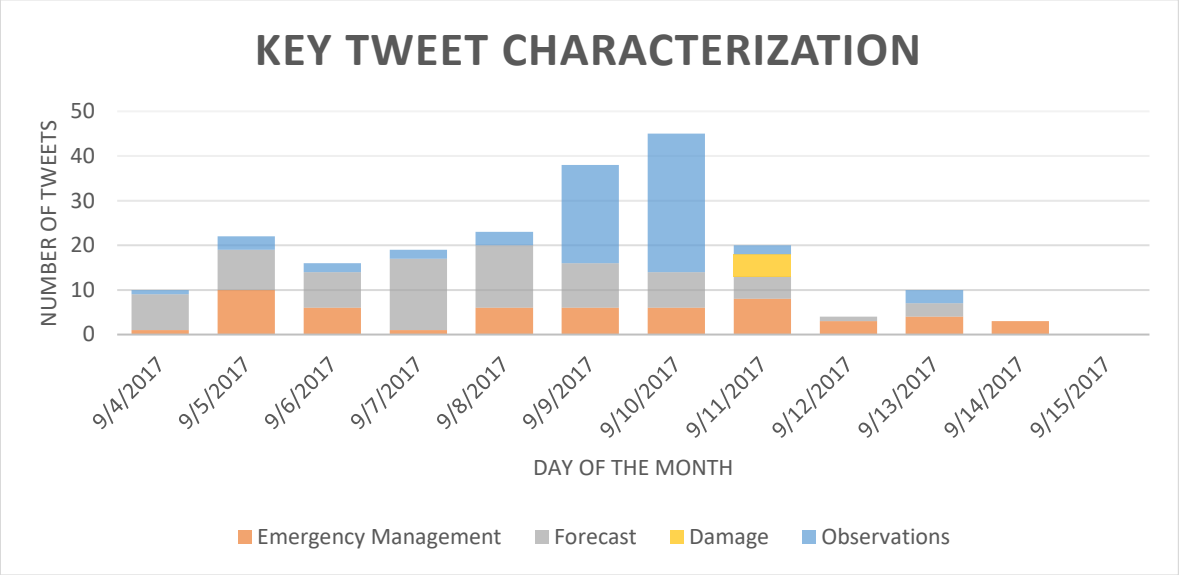


Figure 4. NWS Key West Tweet Characterization, displaying the number of each characterized type of tweet for the entire CP.

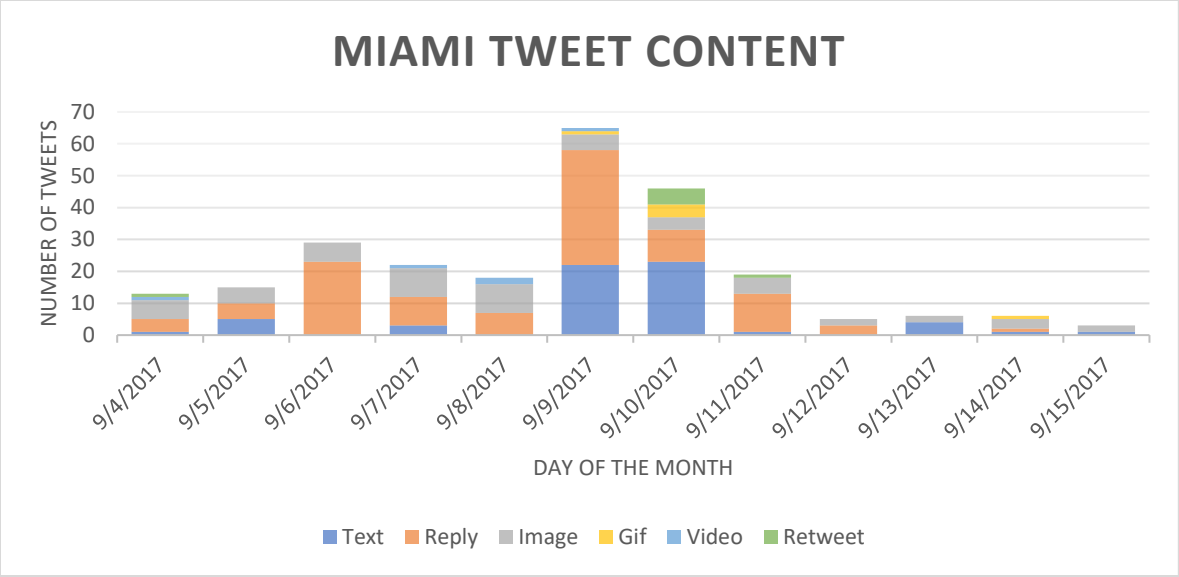


Figure 5. NWS Miami Tweet Content, displaying the number of each content type of tweet for the entire CP.

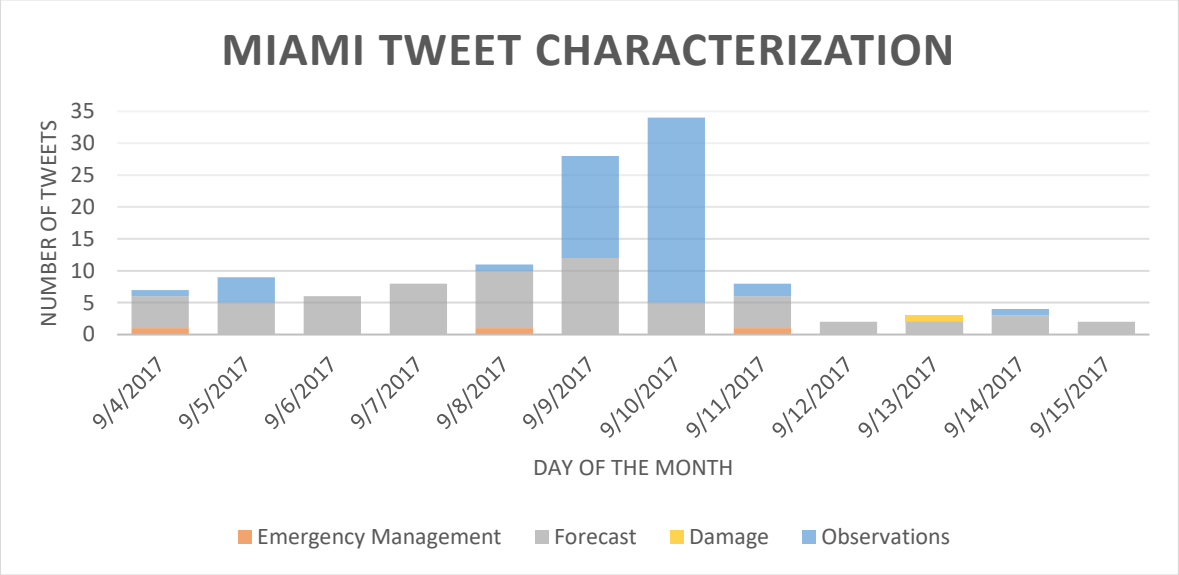


Figure 6. NWS Miami Tweet Characterization, displaying the number of each characterized type of tweet for the entire CP.

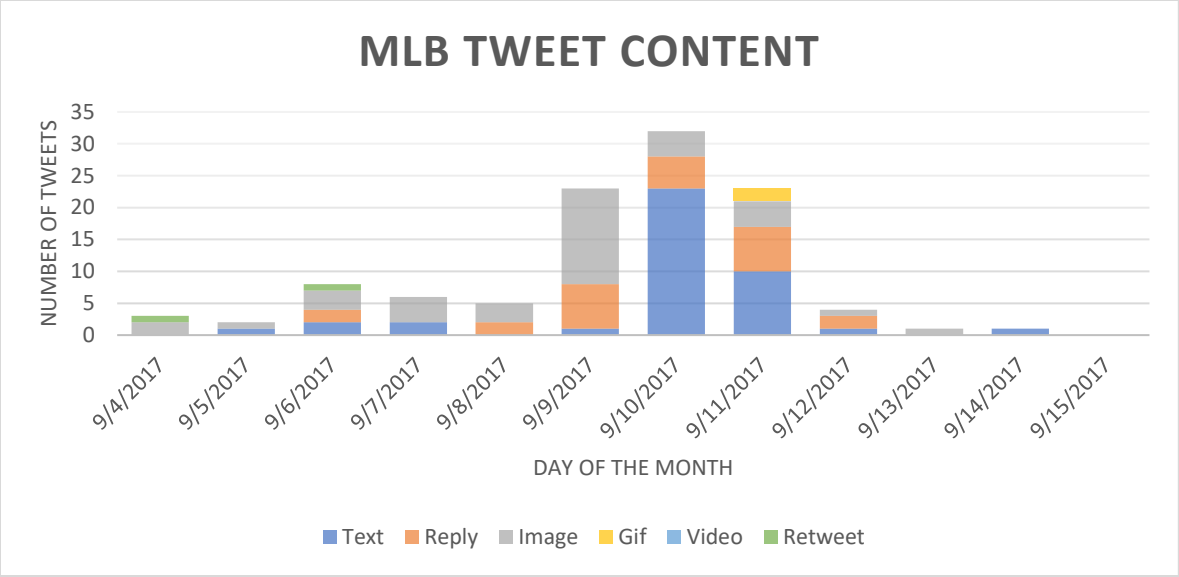


Figure 7. NWS Melbourne Tweet Content, displaying the number of each content type of tweet for the entire CP.

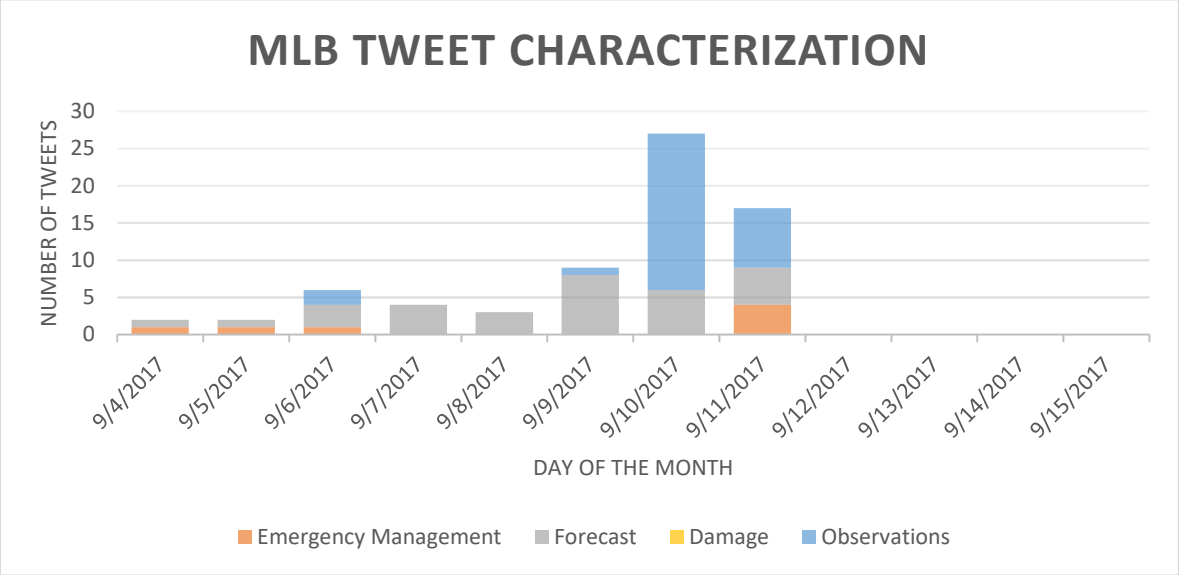


Figure 8. NWS Melbourne Tweet Characterization, displaying the number of each characterized type of tweet for the entire CP.

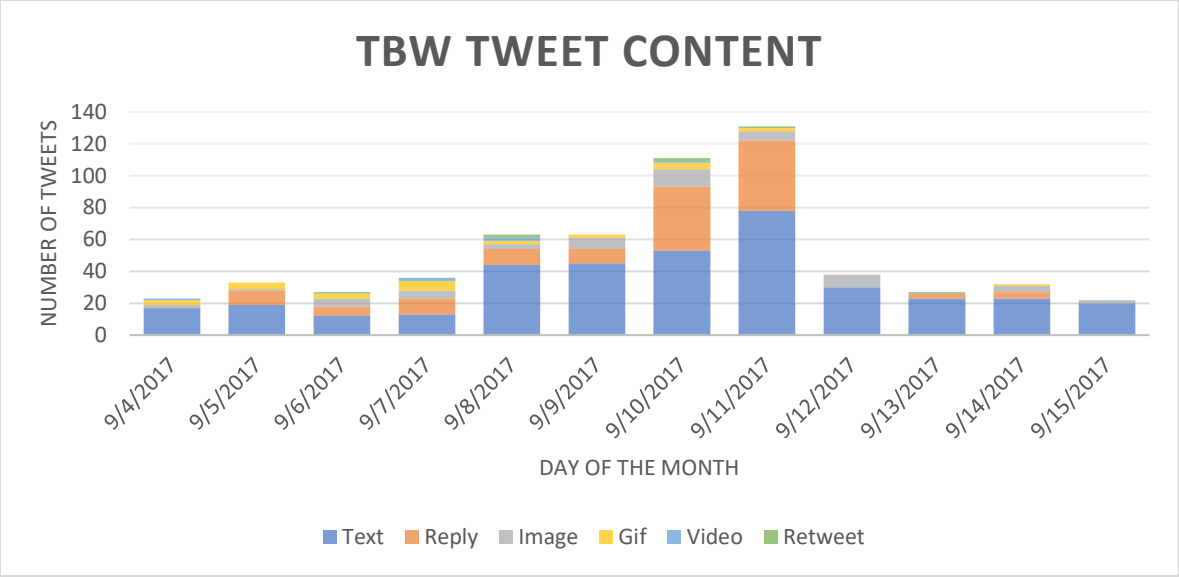


Figure 9. NWS Tampa Bay Tweet Content, displaying the number of each content type of tweet for the entire CP

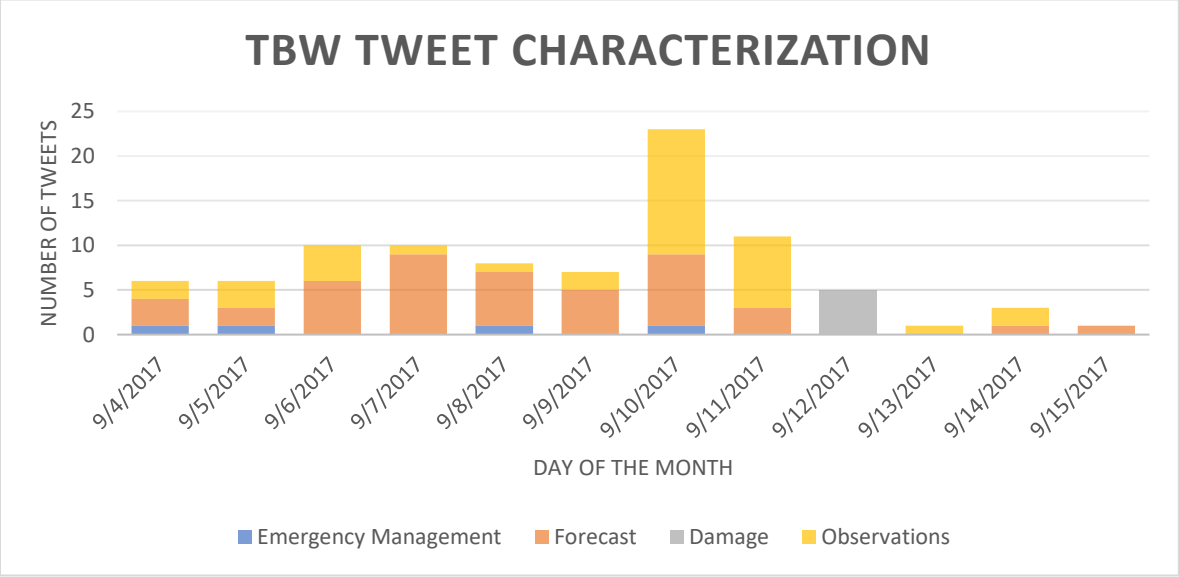


Figure 10. NWS Tampa Bay Tweet Characterization, displaying the number of each characterized type of tweet for the entire CP

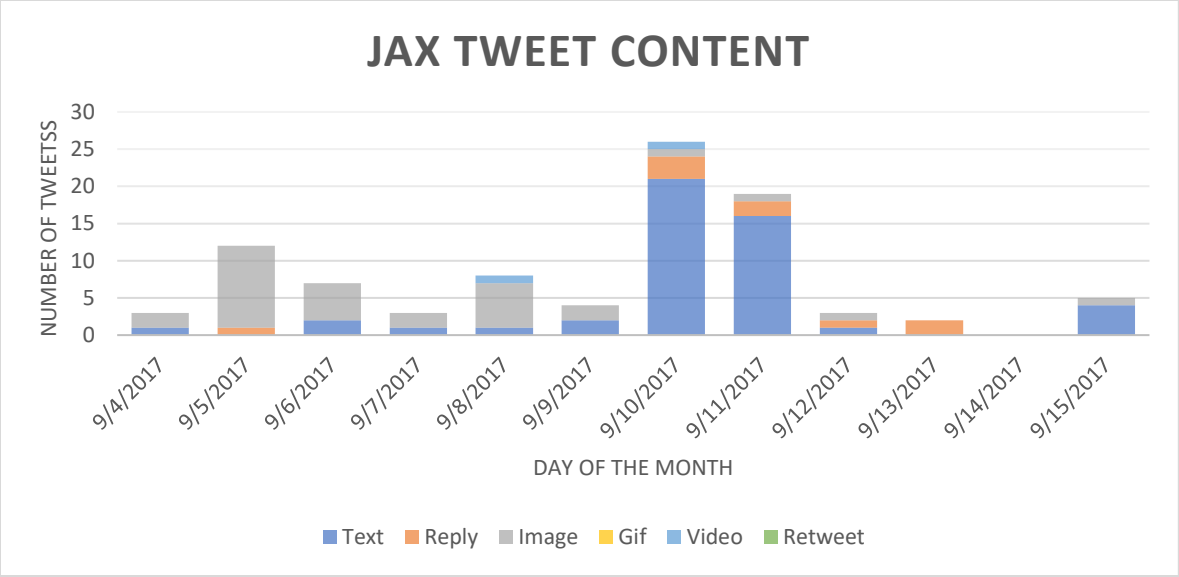


Figure 11. NWS Jacksonville Tweet Content, displaying the number of each content type of tweet for the entire CP

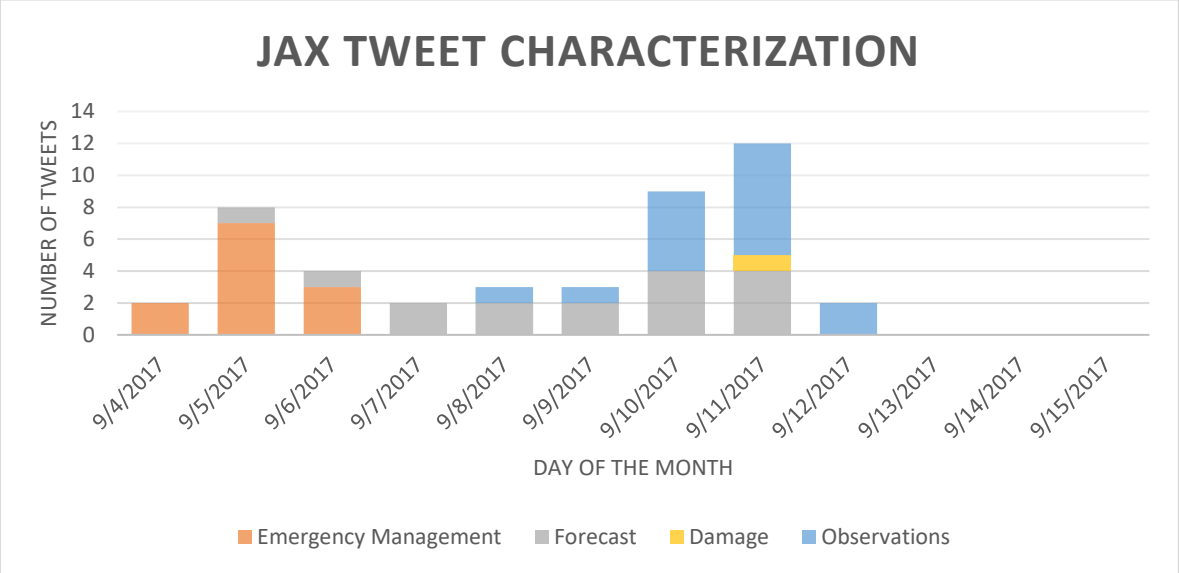


Figure 12. NWS Jacksonville Tweet Characterization, displaying the number of each characterized type of tweet for the entire CP

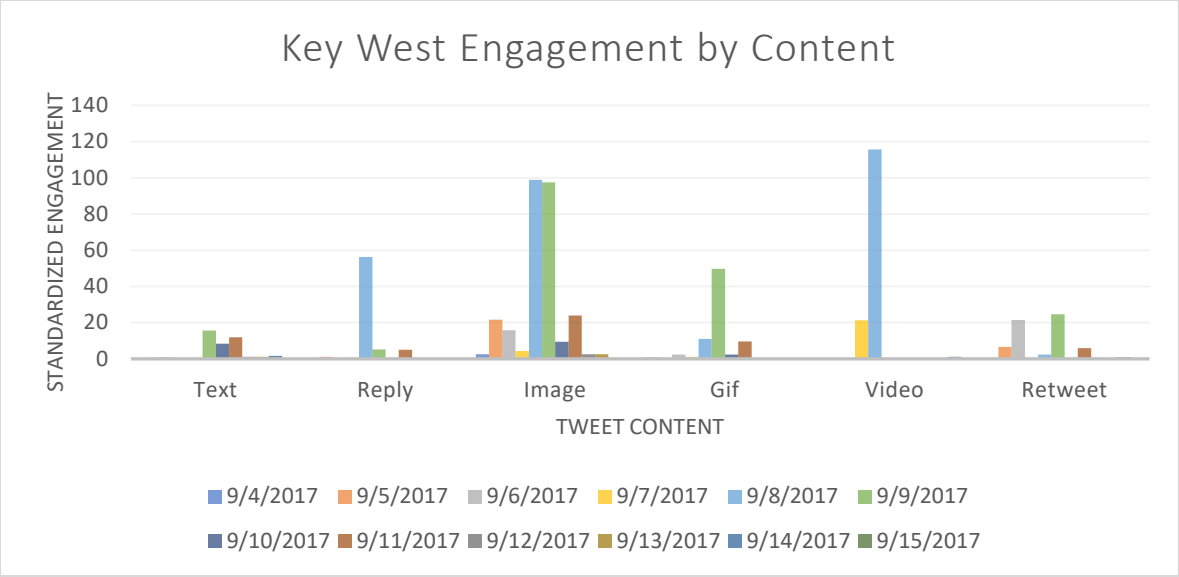


Figure 13. NWS Key West public engagement by content. The most engaged tweet is plotted by content type per day of the CP.

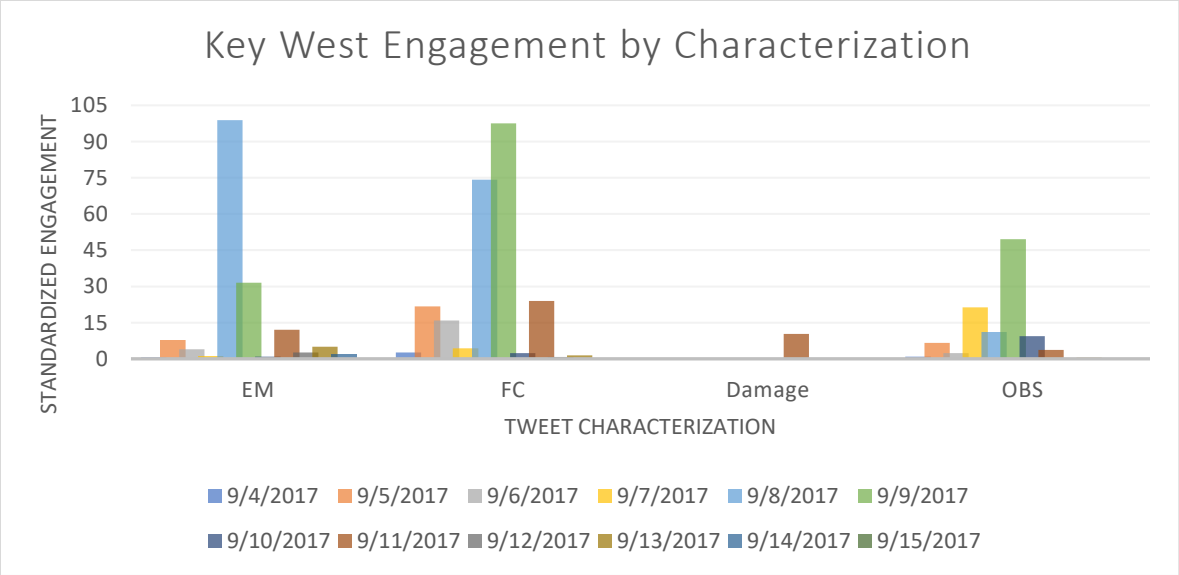


Figure 14. NWS Key West public engagement by characterization. The most engaged tweet is plotted by characterization type per day of the CP.

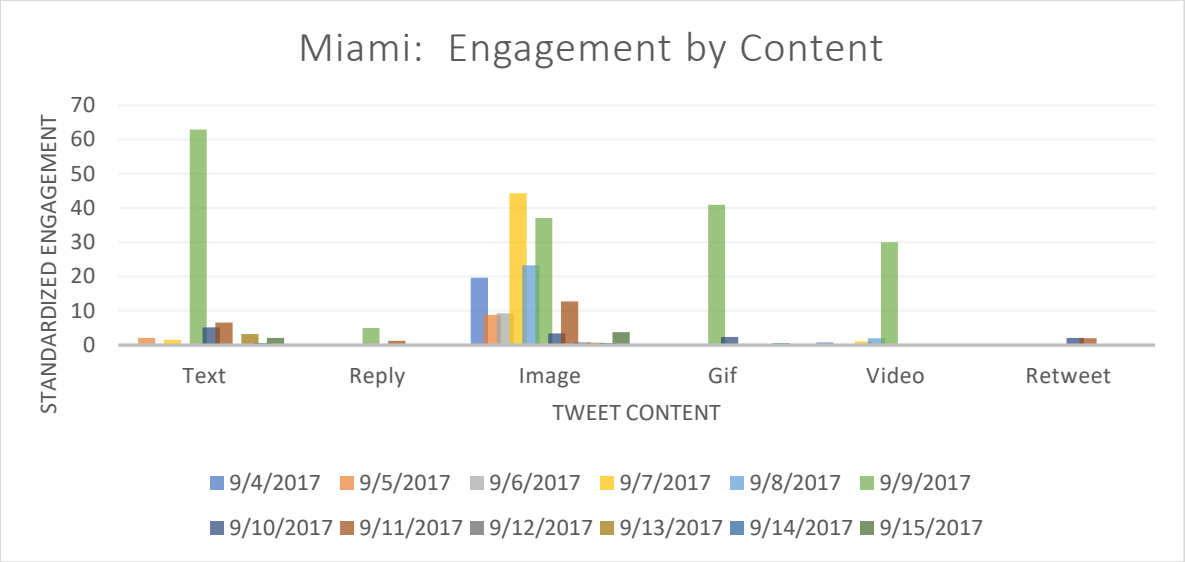


Figure 15. NWS Miami public engagement by content. The most engaged tweet is plotted by content type per day of the CP.

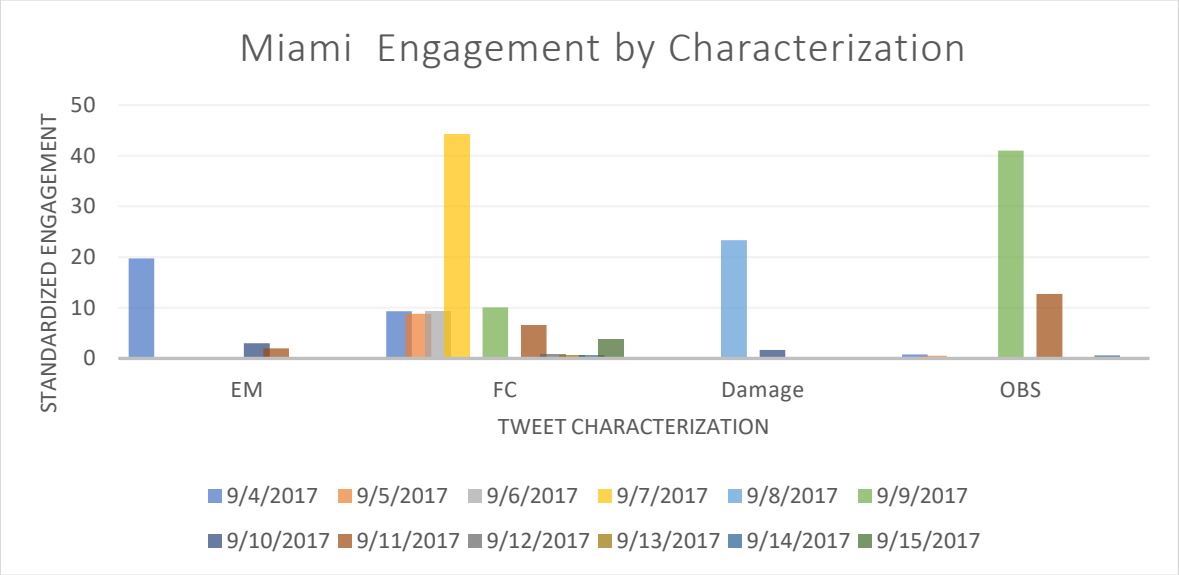


Figure 16. NWS Miami public engagement by characterization. The most engaged tweet is plotted by characterization type per day of the CP.

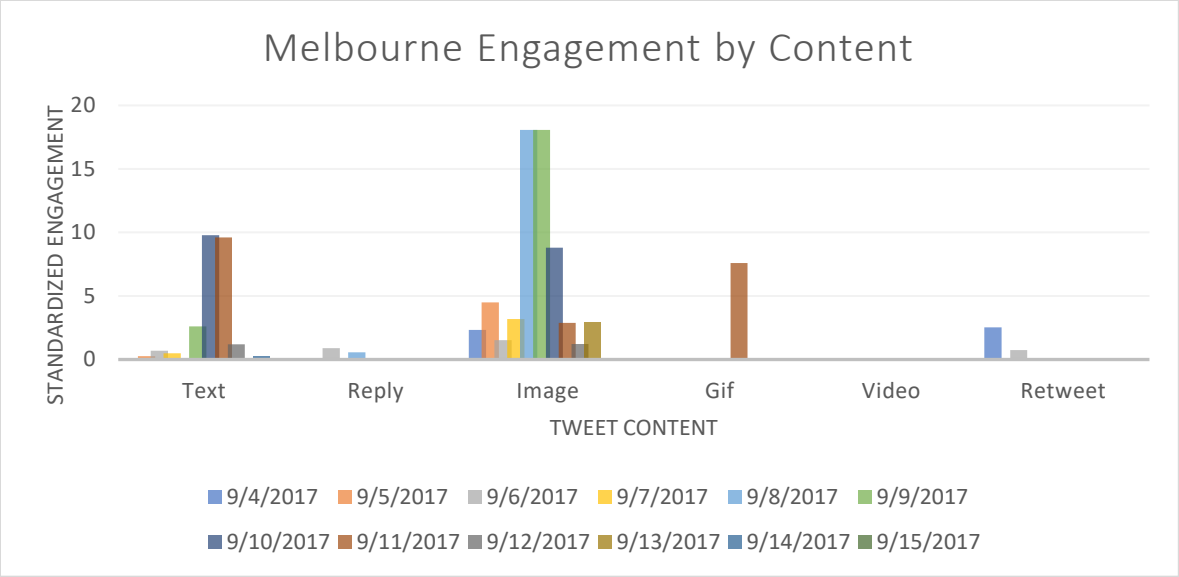


Figure 17. NWS Melbourne public engagement by content. The most engaged tweet is plotted by content type per day of the CP.

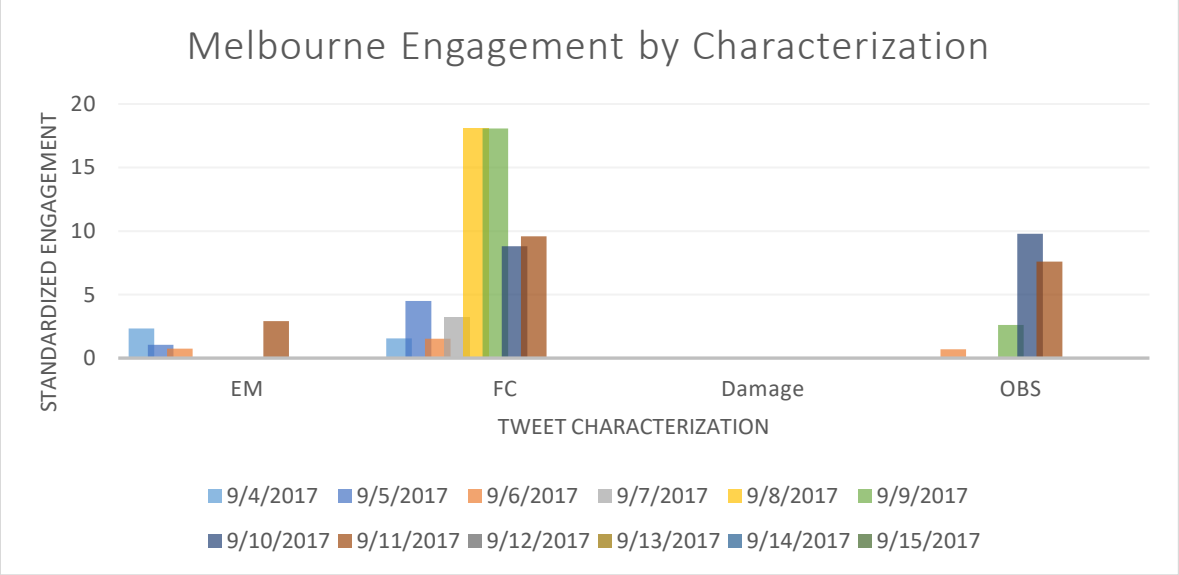


Figure 18. NWS Melbourne public engagement by characterization. The most engaged tweet is plotted by characterization type per day of the CP.

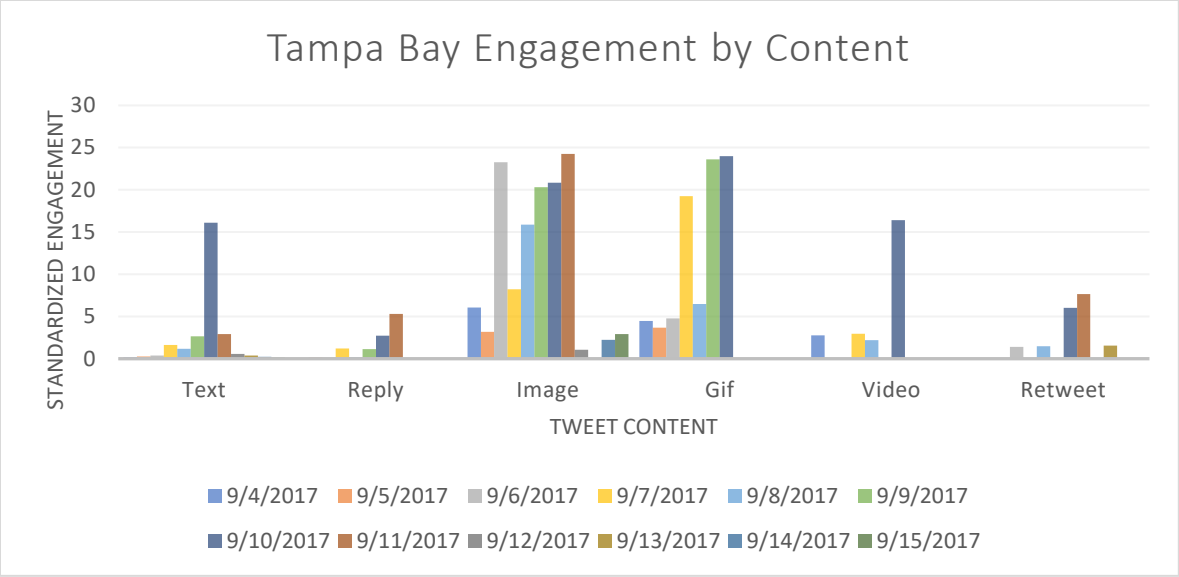


Figure 19. NWS Tampa Bay public engagement by content. The most engaged tweet is plotted by content type per day of the CP.

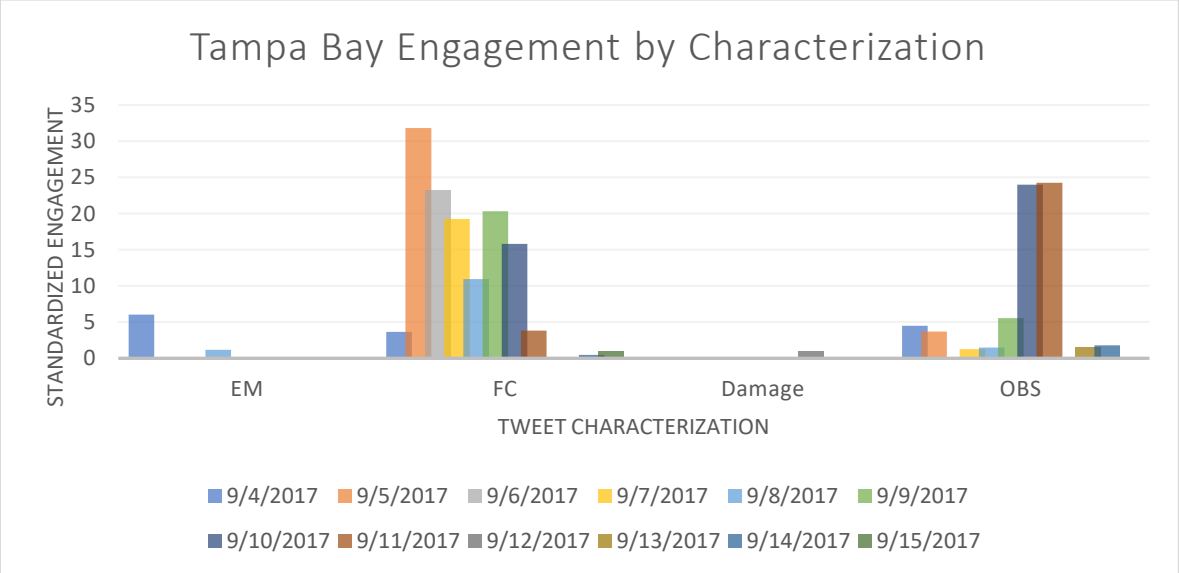


Figure 20. NWS Tampa Bay public engagement by characterization. The most engaged tweet is plotted by characterization type per day of the CP.

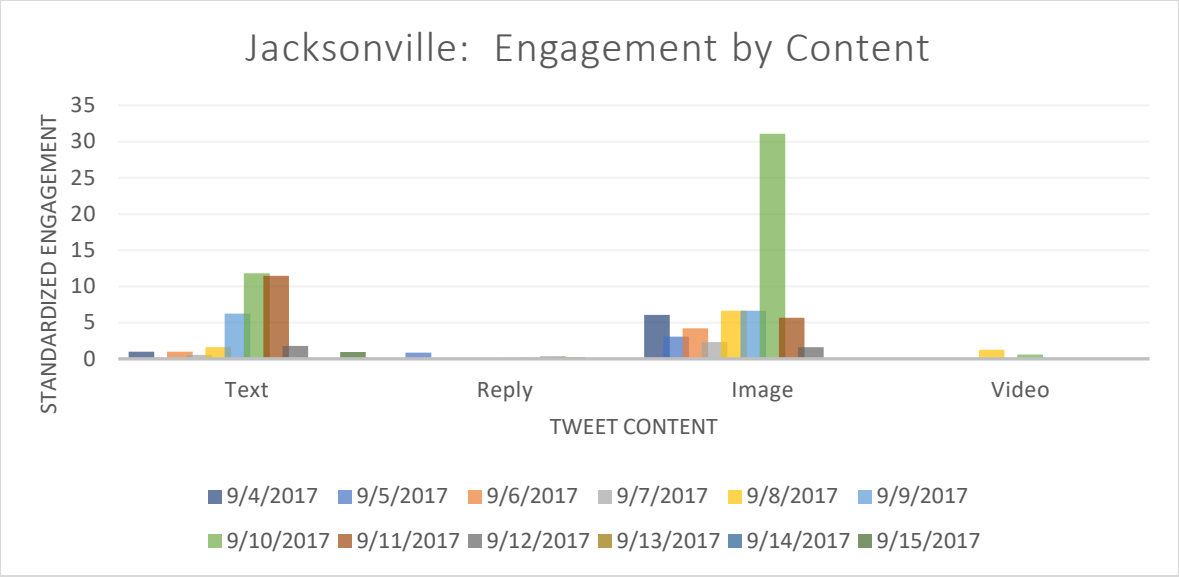


Figure 21. NWS Jacksonville public engagement by content. The most engaged tweet is plotted by content type per day of the CP.

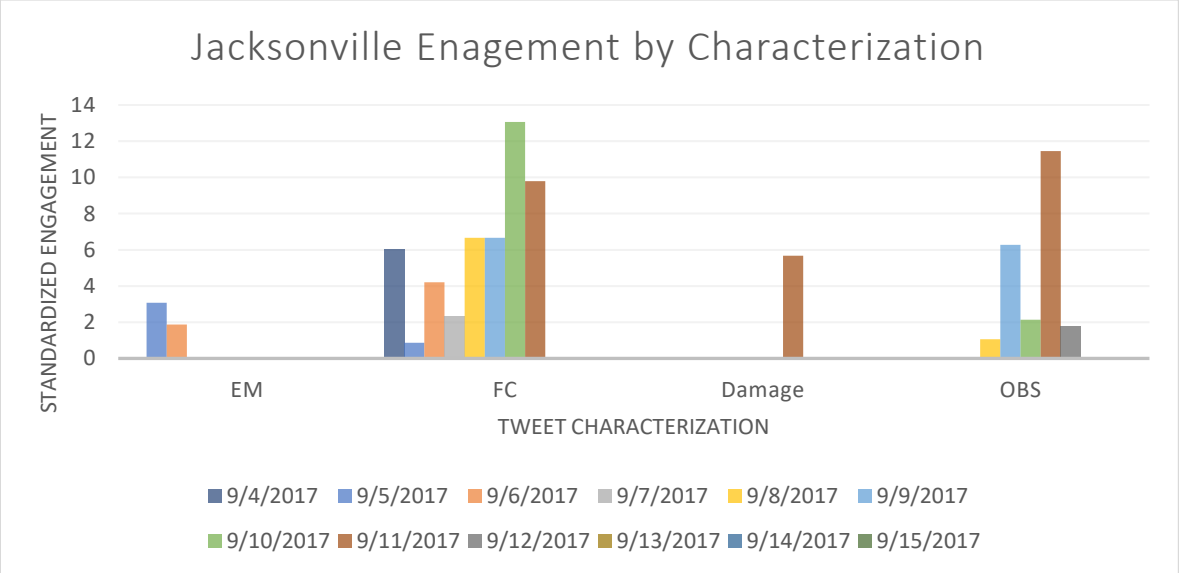
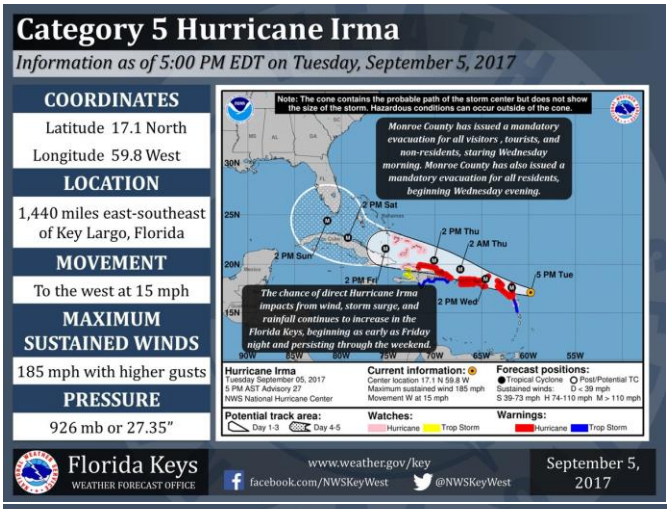
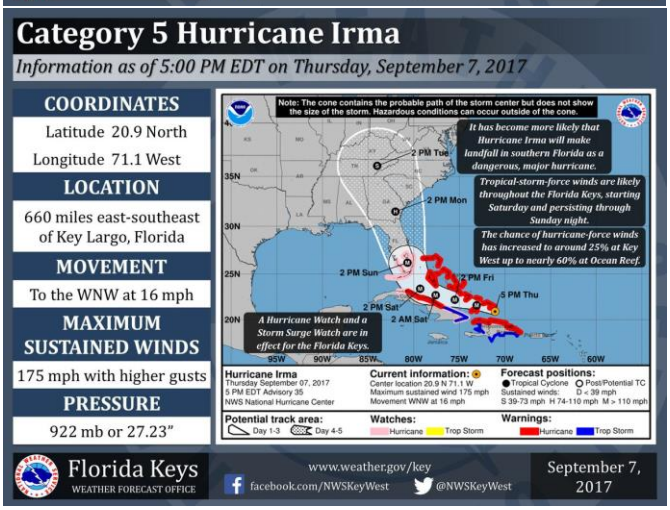
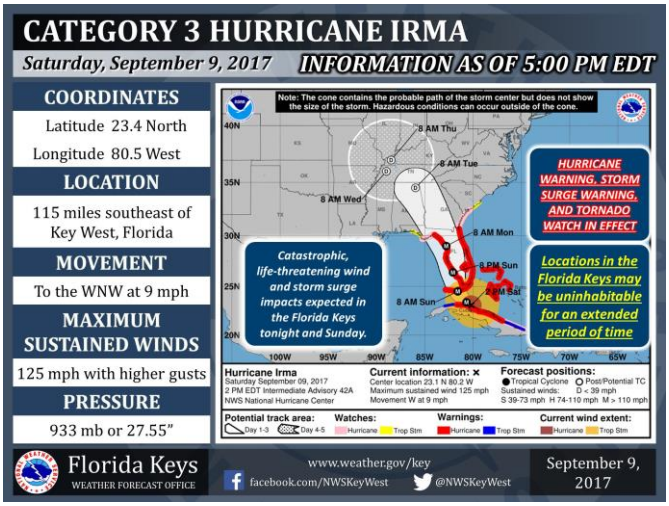


Figure 22. NWS Jacksonville public engagement by characterization. The most engaged tweet is plotted by characterization type per day of the CP.

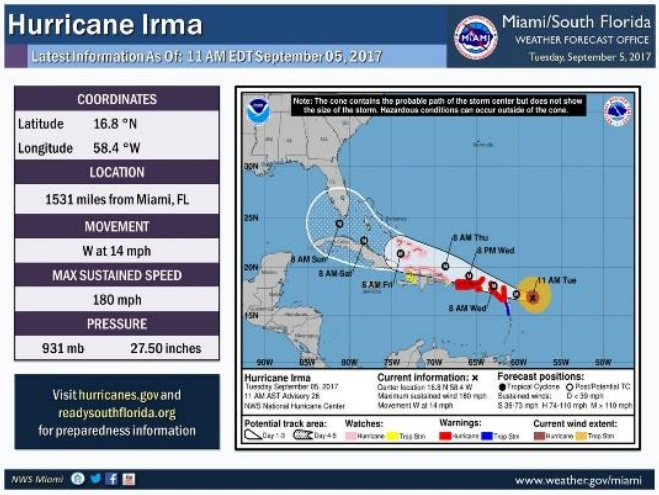
Appendix

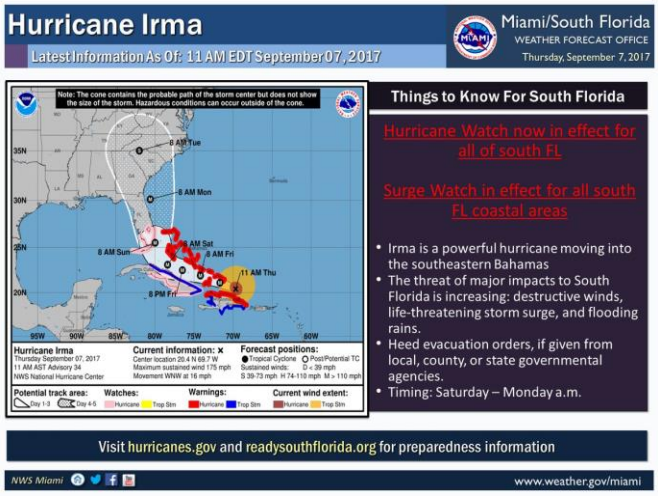


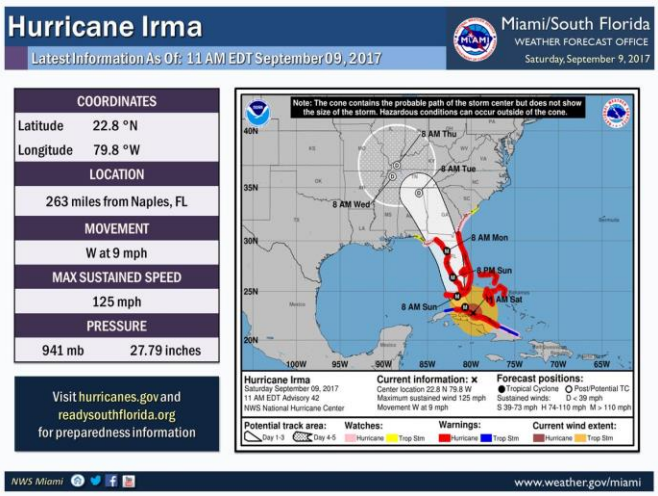




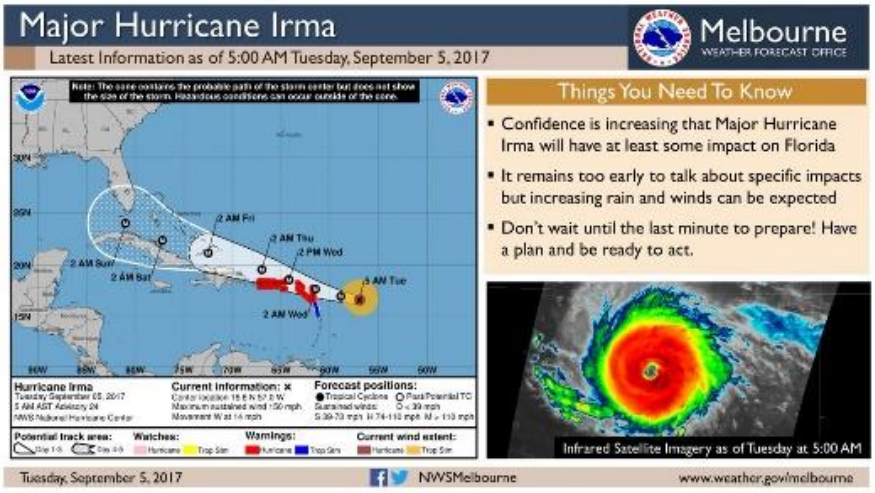
Appendix 1. Examples of Infographics created and posted by NWS Key West. Infographics are from 5-days, 3-days, and 1-day before Irma's landfall

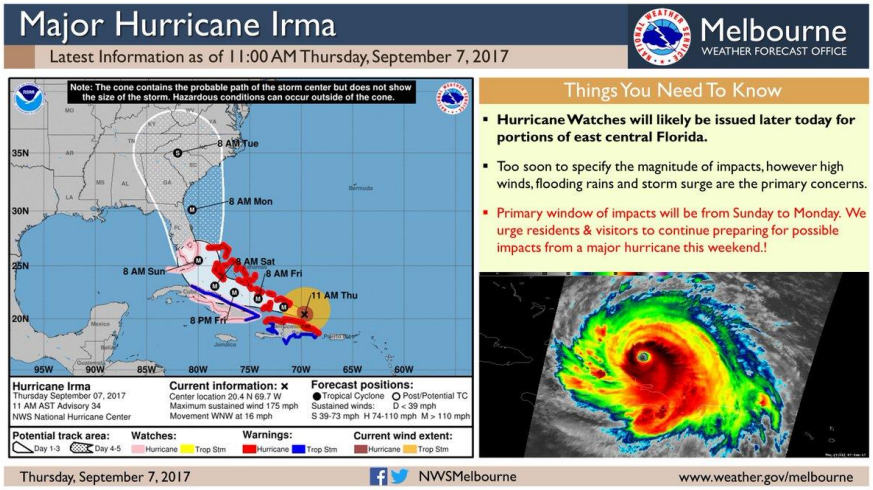


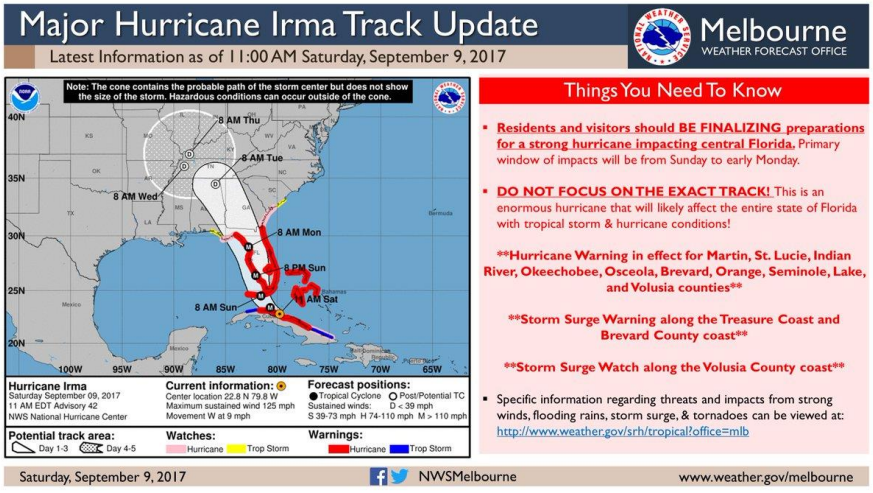




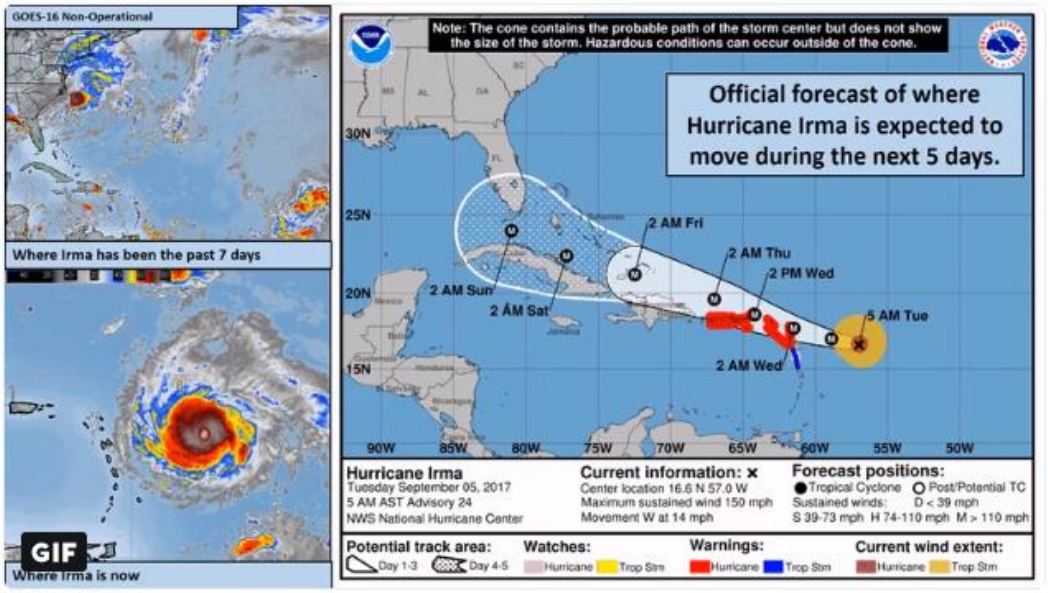
Appendix 2. Examples of Infographics created and posted by NWS Miami. Infographics are from 5-days, 3-days, and 1-day before Irma's landfall.

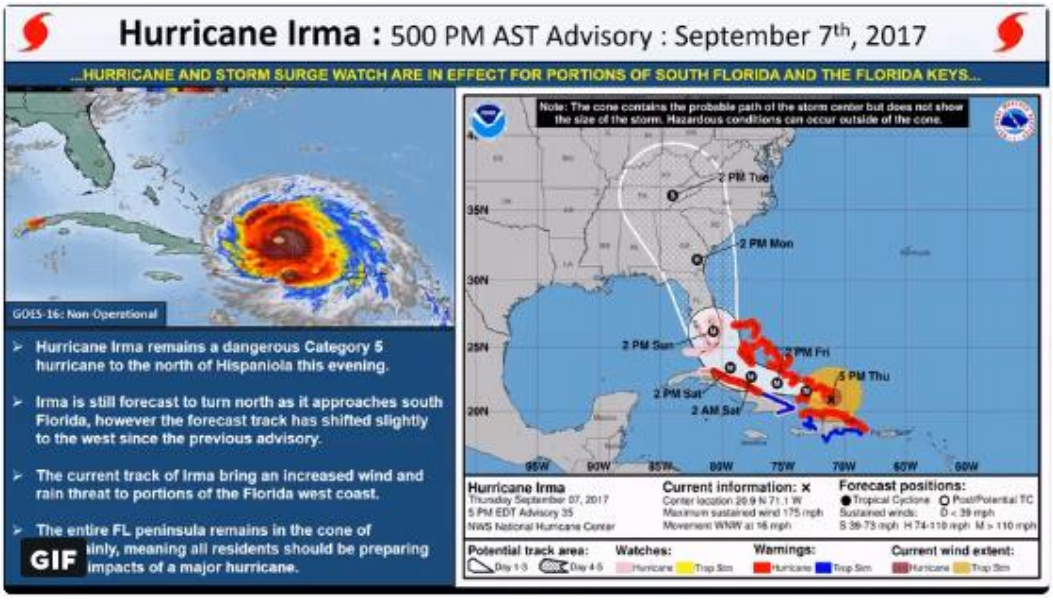




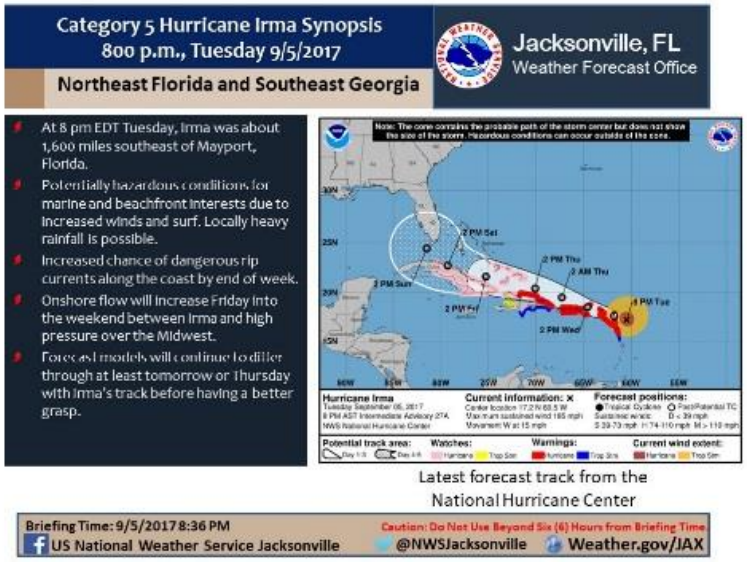


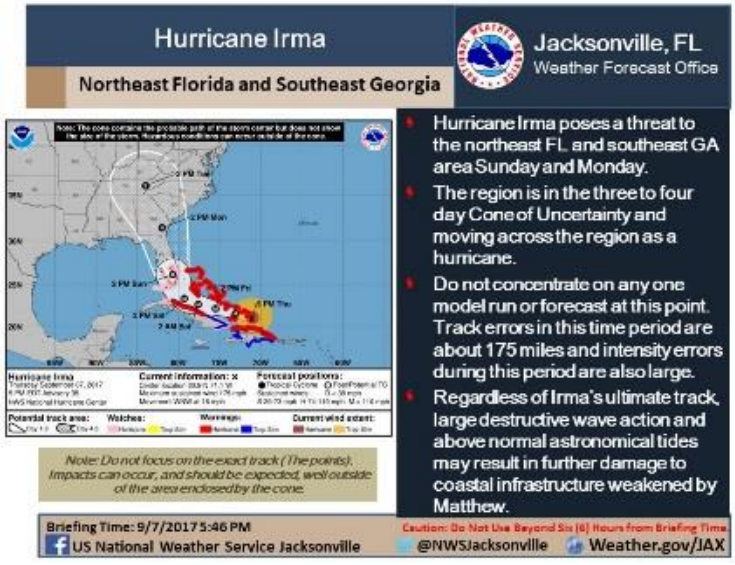
Appendix 3. Examples of Infographics created and posted by NWS Melbourne. Infographics are from 5-days, 3-days, and 1-day before Irma's landfall





Appendix 4. Examples of Infographics created and posted by NWS Tampa Bay. Infographics are from 5-days and 3-days before Irma's landfall. No infographic was posted 1-day before landfall. Tampa Bay graphics contained gifs of satellite imagery.





Appendix 5. Examples of Infographics created and posted by NWS Jacksonville. Infographics are from 5-days and 3-days before Irma's landfall. There was no infographic posted 1-day before Irma landfall.