2014 Colorado Flood Threat Bulletin

Colorado Water Conservation Board

Final Report

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Contents

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Submitted To:

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

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INTRODUCTION

Colorado is threatened seasonally by different forms of flooding including ice jams, flash floods, spring snowmelt and river flooding. Causes of this flooding vary with the season and include abnormal periods of hot weather during the spring snowmelt, severe thunderstorms and general storms during the spring and monsoon thunderstorms during the summer and early fall. This project is design to provide Colorado emergency managers and first responders with a daily county-specific assessment of flood and flash flooding threat in their county.

In 2012, another competitive award was made to Dewberry. As in previous years, the program runs from May 1 through September 30 and requires the daily issuance of flood threat bulletin describing the flood threat in Colorado and the issuance of a 15-day Flood Threat Outlook (FTO) to identify periods of locally heavy rainfall and conversely the development of drought conditions due to lack of precipitation. Meteorologists Brad Workman (FTB, FTO), Dmitry Smirnov (FTB, FTO), John Henz (FTB, FTO) and Robert Rahrs (FTB) developed all of the forecasts. The forecasts were made available on the FTB web page at www.coloradofloodthreat.com.

Daily Flood Threat Bulletin (FTB)

The Daily Flood Threat Bulletin (FTB) is designed for daily issuance during the contract period by 11:00 AM. The FTB outlines the daily threat of flooding across the State, the nature of the threat and the time period in which the threat of flooding would be the greatest in County-specific manner. Additional information includes a characterization of the threat of attendant severe weather (tornadoes, high winds, hail) and the probability of thunderstorm hourly rainfall rates and/or amounts.

The threat of flooding is conveyed to the user community through the use of graphics and text. The graphical component to the product includes a map of the State of Colorado with county boundaries and a color coded threat to succinctly illustrate the range of flooding threats across Colorado. The evolution of this presentation to a more communicative graphical form enhanced the spatial and temporal threat areas visualization.

The spatial coverage of the threat was available by clicking on a threat icon at the top of the page. The resulting graphic showed the areas of highest threat and a forecasted approximation of the temporal distribution associated with the type of thunderstorm/general storm system forecast. The spatial threat graphic is issued to users on days of high threat or when the National Weather Service issues either Flash Flood or Flood Watches.

Flood Threat Outlook (FTO)

The second product is a bi-weekly FTO issued to address the 7 to 15 day threat of flooding across the state on Mondays and Thursdays by 300PM. This product addresses both the extended threat of flooding and a precipitation outlook by river basin.

Storm Total Precipitation (STP)

For 2014, Dewberry provided a continuation of the STP service through use of MapBox web mapping tools and a website based in Google Sites. The STP product was updated this year to use gridded Stage 2 precipitation obtained by merging NWS WSR-88D Storm Total Precipitation products from Boulder, Grand Junction, Pueblo, Cheyenne and Goodand sites so that point-by-point comparisons of the STP/observed data can be assessed.

Additionally, Dewberry forecasters often used CoCoRaHS and NWS reports to supplement textual discussion with any notable weather events, such as extreme rainfall, flooding, debris slides, hail, wind and tornadoes.

FTB PERFORMANCE METRICS

Dewberry provides several performance metrics related to both the forecasting of the flood threat and the delivery of the forecasts. Table 1 shows both the final year to date number of Flood Threat Bulletins provided, the percent of FTB's provided by meteorologists (Brad Workman, Dmitry Smirnov, John Henz and Rob Rahrs) and the number of all products, FTB's, FTO's and STP's provided on time. In each case Dewberry met the CWCB-established metrics.

VERIFICATION METRICS

The daily FTB flood threat forecasts were verified on their ability to both identify days when flood threats were realized and the approximate location of the predicted flooding. This year, Dewberry placed substantially more effort on data collection to increase validation and verification robustness. Here are the information sources and methodology used to verify this year's forecast:

TABLE 1: PRODUCT DELIVERY PERFORMANCE FOR 2014 FLOOD THREAT BULLETIN PRODUCTS.

Product	Total Products	Products on Time	Percent on Time
STP	153	152	99%
FTB	153	149	97%
FTO	44	31	71%
Total	**350**	**332**	**95%**

Information sources

1. 24-hour accumulated precipitation reports from roughly 850 CoCoRaHS observers across Colorado
2. Gauge-adjusted radar estimated gridded precipitation data (4 kilometer grid) prepared daily by NWS's River Forecast Centers (RFC). This is very similar to the quality controlled Stage 4 product provided by NOAA.
3. Storm reports obtained daily from the Boulder, Pueblo, Goodland (KS) and Grand Junction NWS offices. Reports were only included if they contained the following phrases: "heavy rain", "flash flood", "flood" or "debris slide". Reports involving the term "heavy rain" are retained only when the magnitude of rainfall exceeds 0.75 in.

Verification methodology

A "flood day" is hereby defined when <u>any one of the following</u> criteria is met:

1. Gridded or CoCoRaHS rainfall exceeds:
    a) 1.00 in. west of 104˚W
    b) 1.50 in. east of 104 ˚W
2. An NWS storm report described in (3) above is received that day
3. If a "flood day" is based solely on CoCoRaHS reports, at least 2 reports satisfying the criterion (1) above must be received. This eliminates days with localized, marginal rainfall that is unlikely to cause flooding. Note that this kind of situation rarely occurs. Additionally, subjective analysis of a "flood day" may overwrite the objective procedure above based on:
    a) a day with significant snowfall that results in "flood day" precipitation totals, but is not an actual flood threat, and/or:
    b) a day where no rainfall occurs but flooding occurs due to strong snowpack melt.

In all, these corrections are applied on 10 days in May through early June (see worksheet in Appendix A).

TABLE 2: FORECAST METRICS BY MONTH FOR THE 2014 FORECASTING PERIOD.						
Forecast / Observed	May	June	July	August	September	Total
No Flood / No Flood	16	8	5	8	18	**55**
No Flood / Flood	1	7	5	7	3	**23**
Flood / Flood	13	14	16	11	7	**61**
Flood / No Flood	1	1	5	5	2	**14**
Total	**31**	**30**	**31**	**31**	**30**	**153**

Appendix A contains the daily forecast observations used for verification, while Appendix B shows all NWS storm reports according to the FTB threat level during their occurrence. Tables 2 and 3 shows a breakdown of the daily forecasts made for the 2014 FTB season. Four categories of daily forecast verification are presented:

1. No flood forecast and no flood observed
2. No flood forecast and flooding observed
3. Flooding forecast/flooding observed
4. Flooding forecast and no flooding observed

Each category is self-explanatory and is used to discuss the forecast accuracy.

The overall FTB accuracy can be calculated by adding the number of correct forecasts (a + d = 116) and dividing by number of forecasts (153) resulting in a 76% "hit rate", slightly lower than 2013's 84% and 2012's 86%. This decrease is attributed to a more robust validation effort, compared to previous years, including using statewide gridded precipitation estimates. The probability that a flooding day was forecasted correctly is determined by dividing the number of correct flood days forecast (61) by the number of flood days observed (84) or 73%, which is lower than last year's 84%. Despite the decrease, these accuracy values remain above the program's goal of 70%.

The false alarm rate of flood day forecasts is found by the number of incorrect flood day forecasts by the total number of non-flood days, or 18% (14/75), comparable to previous years and below the program's goal of 25%.

TABLE 3: FORECAST METRICS BY TYPE OF FORECAST FOR THE 2014 FORECASTING PERIOD.			
	Forecast Flood Day	Forecast No Flood Day	Total
Observed Flood Day	61 (a)	23 (b)	**84**
Observed No Flood Day	14 (c)	55 (d)	**69**
Total	**75**	**78**	**153**

Finally, the miss rate can be found by dividing the number of unforecasted flood days by the total number of flood days, or 27% (23/84). However, of these 23 miss days, only 2 had more 6 CoCoRaHS stations reporting "flood day" precipitation. Thus most "miss days" involved very localized heavy rainfall. It is also interesting to note that 9 of the 23 "miss" days did not even record a CoCoRaHS "flood day" report, instead relying on the RFC gridded precipitation product for diagnosis. This would not have been analyzed last year, and shows how much more robust this year's validation is.

CHARACTERIZATION OF FORECAST PERIOD WEATHER

Compared to the historic 2013 warm season that featured the state's worst flood since the Big Thompson event in 1976, 2014 was much less impactful. Nonetheless, this year was quite active from a statistical standpoint. Figure 1 shows the number of daily CoCoRaHS reports exceeding 1 inch, 2inches as well as the spatial area of precipitation exceeding the "flood day" standards established in the previous section. Of the 153 days of the FTB season, 101 (66%) experienced at least 1 inch of rainfall somewhere in the state. An equally impressive 50 days (33%) saw a location experience rainfall of 2 inches or more.

The season began with a heavy snowfall on Mother's Day (May 11-12) that impacted mainly the northern half of the state, including the heavily populated I-25 urban region. Total liquid equivalent precipitation with this event exceeded 4 inches in isolated areas, and added up to 40 inches of snow in the higher elevations of Grand, Jackson and Larimer counties. However, due to the cold temperatures, only nuisance street ponding and flooding occurred, mainly limited to urban areas.

Due in part to the Mother's Day snowstorm, many high elevation regions found themselves with significant positive anomalies in snow water equivalent (SWE). Parts of the North Platte and South Platte basins experienced SWE up to 200% of average. This led to a prolonged, and periodically strong, melt-off season at the end of May through mid June as several early heat waves pushed temperatures well into the 90s over the Plains and 70s and 80s over the mountains. During this period, there were also several heavy precipitation days with May 30 and June 8 seeing relatively high coverage of heavy rainfall, with 24-hour rainfalls up to 3.6 inches noted. By mid to late June, the State was able to skirt through the dreaded "heavy rain-on-snow" season and the snowpack melted off in a generally tame fashion. This relatively slow melt off of remaining snow was beneficial to ongoing recovery efforts from the 2013 floods.

July was an active month with 21 "flood days". Several days stood out from the rest including July 12, which reocrded 87 "flood day" CoCoRaHS reports and a max 24-hr rainfall of 3.93 inches, and July 29-30 was perhaps the most threatening day of the entire season. Moderate and High flood threats were issued during this period with nearly 20% of the state experiencing "flood day" criteria rainfall. On July 29, several areas reported rainfall exceeding 6 inches. Luckily, these amounts were localized and in fact, short-duration (1hr, 3hr) rain-rates during the event were not overly impressive. Instead, the rainfall was spread out over a long period of 24-36 hours, tempering runoff and preventing a much more dangerous situation.

August was quieter than July, and September was even quieter than August, perfectly in-step with climatological march of the seasons. Nonetheless, these two months did experience a few higher risk days as the Southwest Monsoon began to deliver plumes of moisture mainly over the western half of the state, where less rainfall is required to cause flooding issues. Notable events occurred on 8/13-8/14, 8/22, 8/25, 8/27, and then on 9/9, 9/20 and 9/29. The last event occurred with the passage of a very deep upper-level cut-off low pressure and resulted in several strong to severe thunderstorms across large swaths of the state.

In summary, 2014 can be characterized as eventful from a rainfall perspective, but relatively calm in the face of flood impacts, allowing the most severely affected regions to continue recovery efforts from last year's historic flooding.

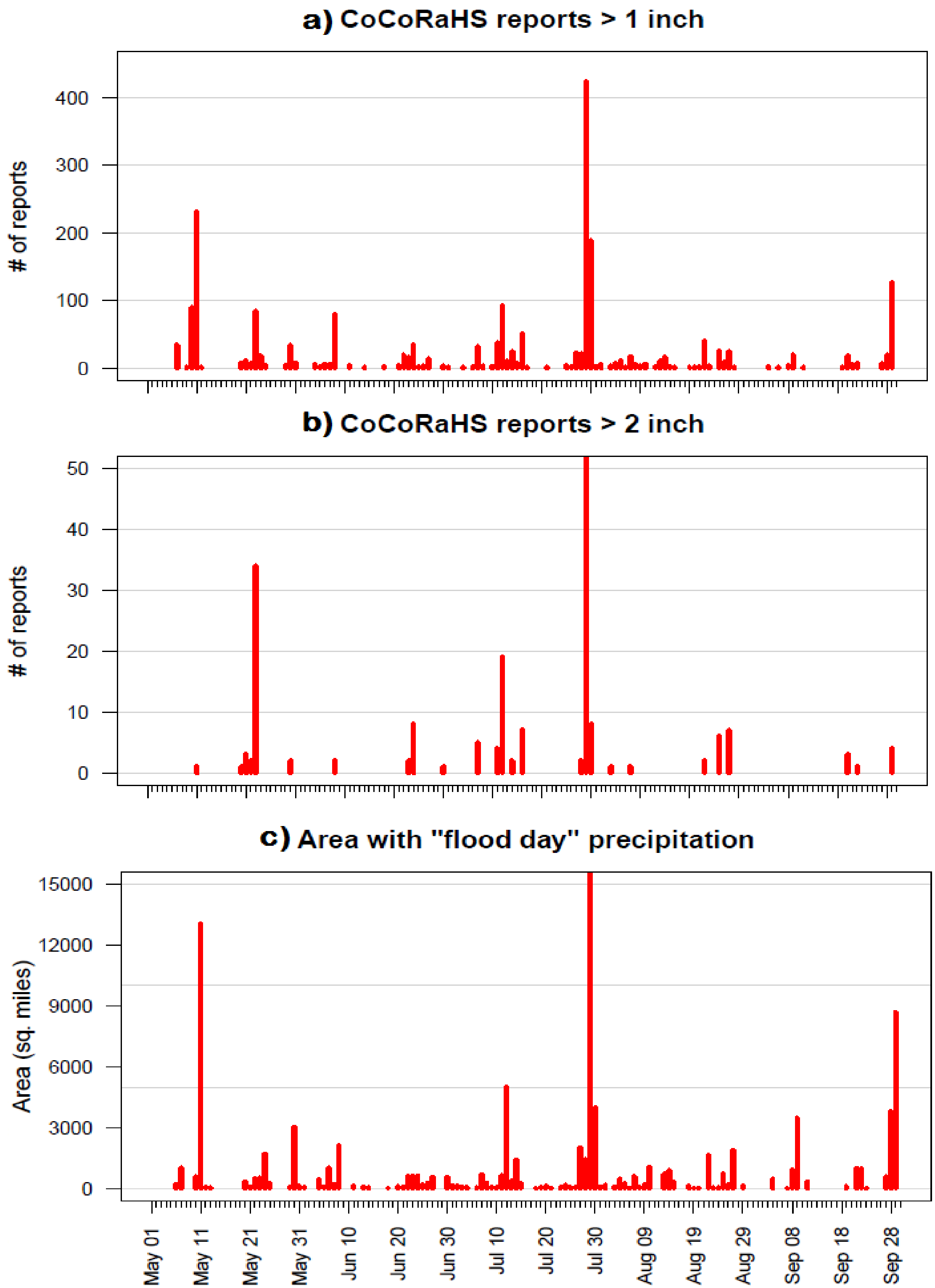


Figure 1 – The number of daily CoCoRaHS reports exceeding 1 in. and 2 in. is shown in panels (a) and (b), respectively. Panel (c) shows the coverage of "flood day" precipitation, in sq. miles, from the gridded precipitation product. For reference in (c), the total area of Colorado is about 104,000 sq. miles.

INVESTIGATION OF QPF TOOLS

During the 2014 FTB season, Dewberry undertook an applied investigation in an effort to incorporate more objective quantitative precipitation forecast (QPF) guidance into daily FTB operations. The result was the development of a 23-member weather model ensemble, producing a range of value-added QPF tools, such as two shown below. The 2014 forecast season provided an excellent opportunity to test and validate these tools with the objective of being able to improve the spatial, temporal and quantitative skill of the FTB threat forecasts. The results of the QPF validation was presented and well received at the 2014 CASFM conference in Vail, Colorado. The key results are also briefly described here. Please note that these results are for the time period of May 1 – August 31.

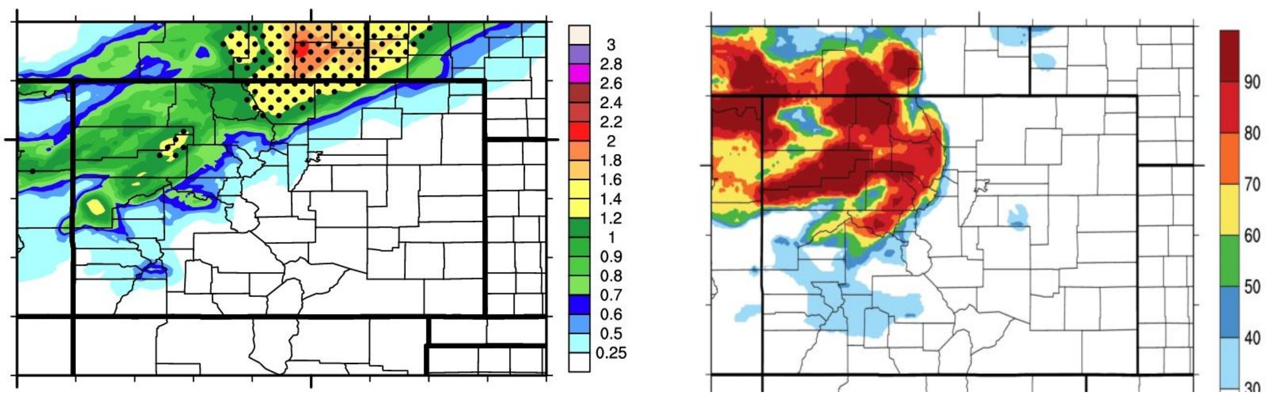


Figure 2 – Example products produced by the QPF Applied Investigation carried out during the 2014 FTB. On the left is the QPF-MAX product, showing maximum expected rainfall for the State in a given 24-hr period, and on the right is the percent chance of precipitation map.

Storm report validation

Figure 3 shows the results of a storm report-based validation where individual storm reports are categorized as either being successfully forecasted or not. This requirement is met when the storm report fell within a threat area. It is quite clearly seen that none of the four objective methodologies outperformed, or even came close to matching, the forecast accuracy of the FTB, which successfully forecasted 74% of all storm reports (81% if "heavy rain" reports are excluded). However, it is seen that that QPFMAX method, which chose the highest QPF values daily across all models, had by far the highest accuracy of the objective methods. Since QPFMAX was used daily by forecasters as guidance, it is possible that it augmented the FTB threat area, though the extent of this is difficult to quantify.

Assessing area of heavy precipitation

One particularly challenging aspect of rainfall (and flood) forecasting is correctly anticipating the spatial extent of the threat area. On the one hand, frequently issuing large threat areas will necessarily correctly forecast more flood events. On the other hand, this comes at the expense of increasingly large "false alarm" areas that could potentially undermine the end-user's confidence in the FTB. *It is important to note that the term "false alarm" is used here to describe area under a threat that did not materialize into a flooding situation. However, due to the nature of the FTB forecast, this sharply contrasts with a more conventional measure of a "false alarm" that applies to shorter-term forecasts such as NWS severe storm warnings. Clearly, we expect the latter to contain more skill (accuracy), hence the usage of different terminology (i.e. "threat" versus "warning"). For this report,* *we use the term "false alarm" to specifically illustrate the findings relevant for the FTB program and as a resykt may not be comparable with other "false alarm" validation metrics.*

Table 4 below shows the average spatial area that meets the "flood day" guidelines, measured by accumulated precipitation. It is clear that the FTB has, by far, the largest threat area. As seen previously in Figure 2, this is required to accurately capture a high percentage of flood reports and is thus an acceptable part of the FTB forecast. Another interesting finding in Table 4 is that the high-resolution NSSL4 model is the closest to capturing the typical "flood day" area (compare NSSL4 with Observed in Table 4), even though previously it was shown that this area poorly overlaps with exact position of the observed flooding area. This suggests future QPF tool development should employ more ensemble members with higher resolution.

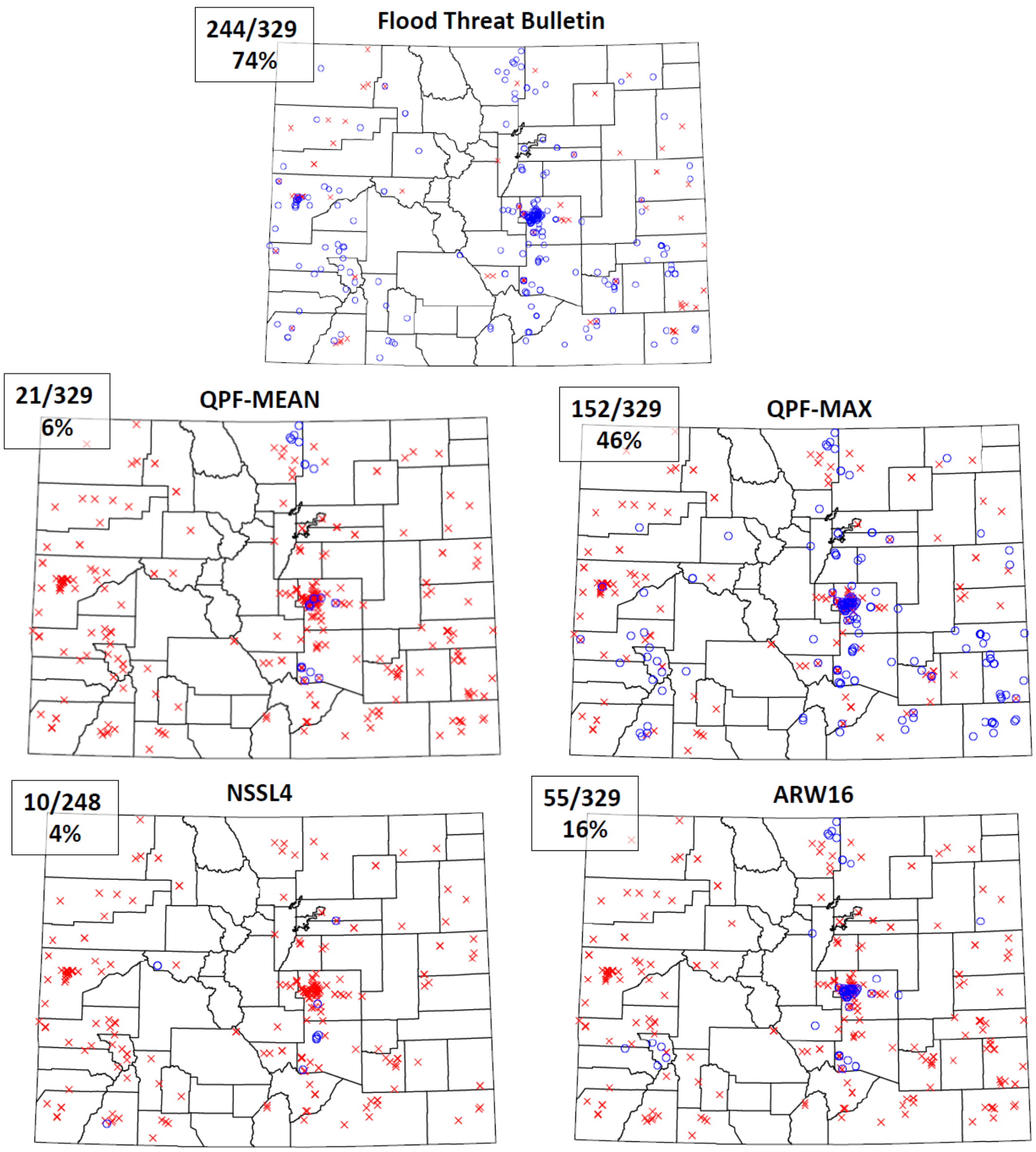


Figure 3: Verification of NWS storm reports using the FTB threat map (tool), compared to five differently purely objective methods developed from the QPF ensemble. Blue circle indicates a hit, red x indicates a miss.

Spatial area (in square miles) on an average "Flood Day"

Observed	QFPMAX	QPFMEAN	NSSL4	ARW16	FTB
883	10,030	304	1096	2343	25,398

Table 4: Average extent (in square miles) of area satisfying the "flood day" threshold (n = 83). Observed value is obtained from the gridded precipitation analysis. QPFMAX and QPFMEAN are the ensemble maximum and mean, respectively. NSSL4 and ARW16 are results from individual representative high-resolution and low-resolution models, respectively. The FTB value is simply the area covered by the FTB threat.

Next, Table 5 breaks down the areas shown in Table 4 into the following areas: hit, miss, and false alarm. These areas can be conceptualized using Figure 4, where the forecast is provided by one of the five forecast methods in Table 5. As alluded to earlier, the FTB and QPFMAX have the highest "hit" areas, but also the highest false alarm areas. It is interesting to note that QPFMAX's hit/false alarm ratio is better than FTB's and this will need to be further explored in subsequent QPF tool refinement, as it is somewhat at odds with the findings of Figure 2. All other methods have very low hit areas due the model's general underestimation of heavy rainfall events.

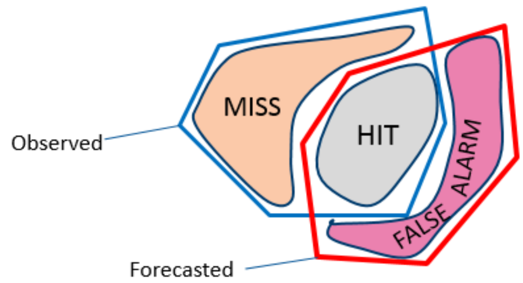


Figure 4 – Measures of spatial forecast skill.

Components of "flood day" area: hit, false alarm and miss

	QFPMAX	QPFMEAN	NSSL4	ARW16	FTB
HIT	556	136	120	221	464
FALSE ALARM	9,473	169	977	2122	24,934
MISS	569	375	266	434	494

Table 5: Average extent (in square miles) of area satisfying the "flood day" threshold (n =83). Observed value is obtained from the gridded precipitation analysis. QPFMAX and QPFMEAN are the ensemble maximum and mean, respectively. NSSL4 and ARW16 are results from individual representative high-resolution and low-resolution models, respectively. The FTB value is simply the area covered by the FTB threat.

WEBSITE AND SOCIAL MEDIA

During the historic floods of September 2013, we identified an opportunity to expand the outreach of the Colorado FTB and inform the public at large regarding ongoing flood threats. This unique opportunity was identified as a Twitter account with which to provide updates on meteorological conditions. The Twitter account was a great success during the September floods, so it was installed as a season-long tool this year to provide meteorological information in the form of links to our forecast products (FTB and FTO), "nowcasts," and the most current heavy rain/flooding reports from the public and National Weather Service offices.

The Twitter account, @COFloodUpdates, gained followers as the season progressed, more than doubling followers in the month of May. This can be attributed to the amount of retweets a few of our tweets received, especially from accounts like Colorado Emergency Management's Twitter feed, which has over 26,000 followers. This exponential increase of viewership of our tweets played a large role in expanding our outreach to those who may not have known about the @COFloodUpdates account and the FTB website otherwise. The use of specific hashtags also played a large role in expanding viewership; hashtags are searchable through Twitter, and using relevant hashtags such as #COwx or #COFlood allows people looking for specific information to be directed to our tweets. The following is a bullet point summary on how our season progressed in terms of followers:

- **May**: 377 followers (more than doubled throughout the course of the month)
- **June**: 395 followers
- **July**: 500 followers
- **August**: 542 followers
- **September**: 553 followers

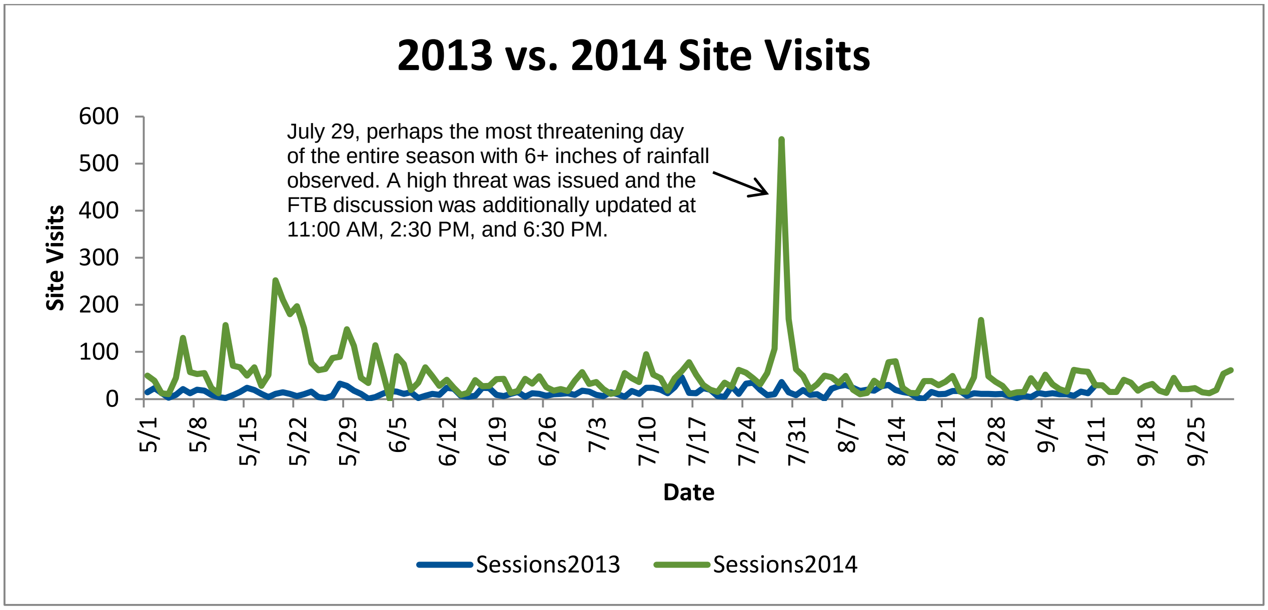


Figure 3 – Visits to the ColoradoFloodThreat.com site in 2013 vs. 2014. Note that September 1-30, 2013 has been removed to show a comparable relationship for the time period before and after the introduction of the Twitter service.

A graphical representation of site viewership shows the stark difference between last year and this year's site visits, with the primary catalyst being the use of the Twitter Account. In the graph above, September 12, 2013 – September 30, 2013 has been removed due to the fact that the Twitter account had been established and the historic flooding event drowned out the overall effectiveness of the Twitter account in 2014 vs. the lack of a Twitter account in 2013. Site visits between May 1, 2013 and Sept. 11, 2013 (once again removing the September 2013 floods and Twitter usage) were 1,845. Comparatively, for the same time period this year, May 1, 2014 – September 11, 2014, site visits were up to 7,358. The Flood Threat Bulletin site in 2014 received 3.99 times more visits over last year during that period.

Mentioned previously, the use of hashtags played a large role in expanding the outreach of our Flood Threat Bulletin products. The following bullet points show a list of common tags that were used, as well as unique tags that were used to target specific events with large audiences.

- Common hashtags: #FTB, #FTO, #STP, #Flood, #Threat, #COwx, #COFlood, #Colorado, #Weather, #Monsoon, #Summer, #Fire, #Severe

- Unique hashtags: #Broncos, #LaborDay, #FrontRange, #WaldoCanyon, #BlackForest, #HighPark, #IndependenceDay, #Arthur (for Tropical Storm Arthur), #July4th, #MemorialDay, #WinterStorm

Twitter has recently unveiled a new Analytics website for all public Twitter accounts. Arguably the most useful data variable is "impressions." Impressions are defined as the number of times Twitter users saw a particular tweet and demonstrates the effectiveness of the use of specific hashtags and interactions (retweets) from other accounts that may have more followers. Average tweets received between 300-500 impressions, as this represents the base follower group of our account. The more engaging or important the content, the more impressions a tweet received as more people retweeted it. During the season, 39% of Tweets (90 out of 231 tweets) made over 1,000 impressions, with the best tweet making 4,543 impressions. That particular tweet was an image of the day's Flood Threat Map with a link to the Flood Threat Bulletin website is shown in Figure 4. It was retweeted 14 times, most notably by Red Cross Denver, Daryl Orr (Weather Tracker/Weather Producer for FOX 31 KDVR and KWGN CW2), Colorado Springs Gazette, Jeff Gurney (CBS4 Senior Executive Producer), Colorado Emergency Management, and Lisa Hidalgo (7News Meteorologist).

In total, the FTB Twitter handle produced 220,842 impressions over the course of the 2014 season. The relationship between retweets and total impressions is illustrated in Figure 5 below.

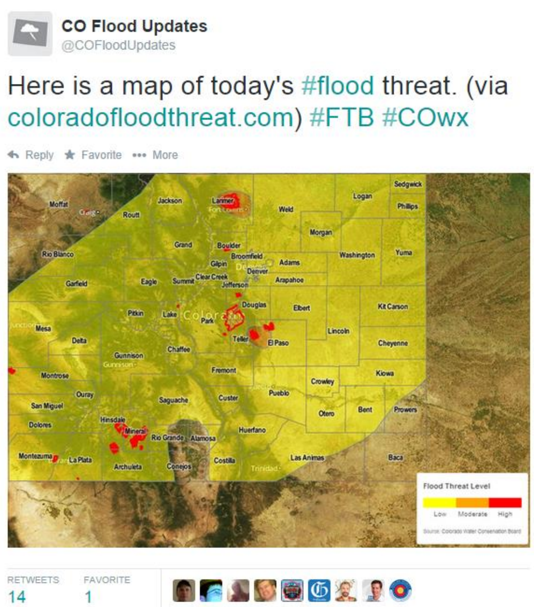


Figure 4 – Tweet with greatest amount of Twitter impressions (retweeted 14 times). August 22, 2014.

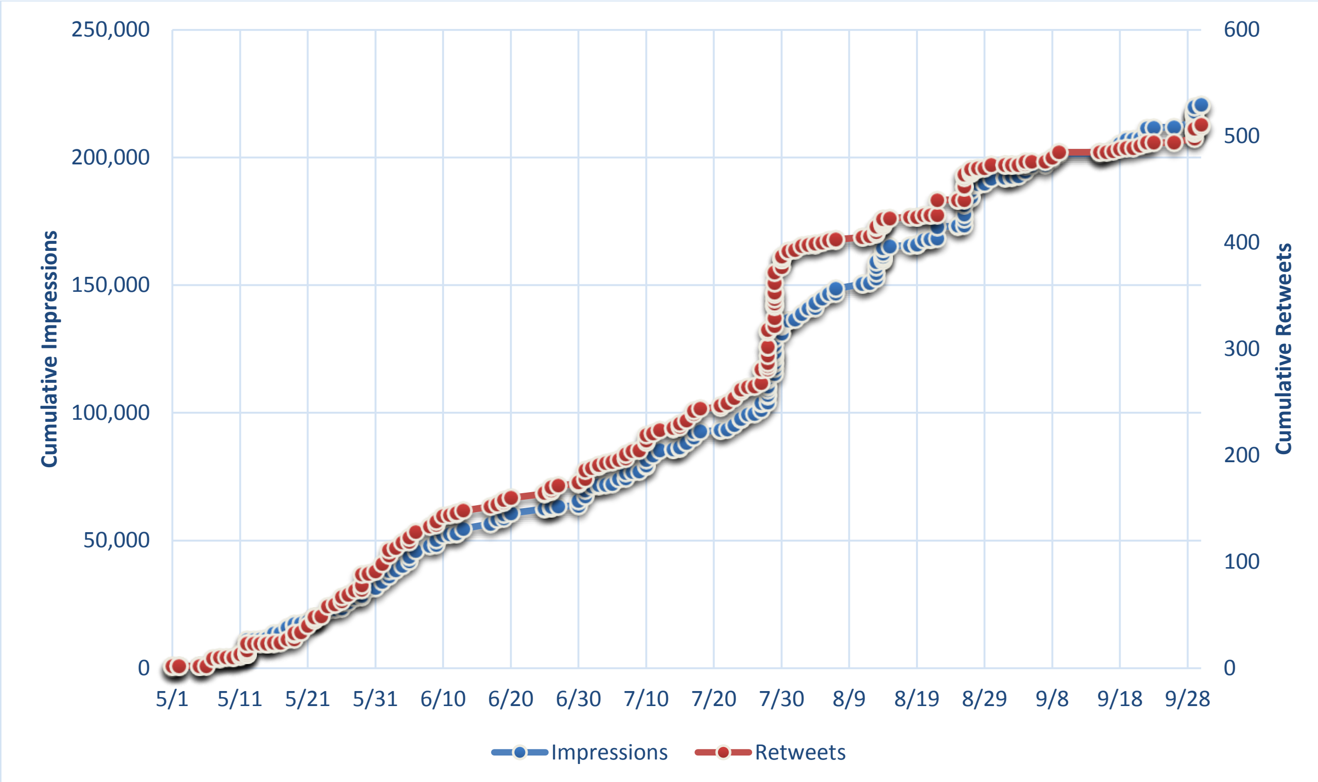


Figure 5 – Relationship between cumulative retweets and impressions from Twitter Analytics. Note that in general, the pattern of impressions closely follows the pattern of retweets, showing the direct relationship between the two measures.

Currently, the most notable followers (and interactions) are the following: Colorado Emergency Management, READY Colorado, AAA Colorado, Red Cross Denver, Colorado State Patrol Troop 1E, Colorado Wildfire Info, Dave Aguilera – CBS4 Meteorologist, Forest Service, ARP, KDVR FOX31 Denver, FOX31/CW Pinpoint Weather, CASFM, Pikes Peak Red Cross, Northern Colorado Red Cross, and Colorado Springs Gazette.

Various police precincts, city government offices, TV/newspaper reporters/meteorologists from across the state, academia meteorologists, individual citizens of Colorado, private meteorologists, fire and rescue units, etc. also follow the Twitter account.

CONCLUSIONS/RECOMMENDATIONS

1. Overall, the 2014 warm season in Colorado featured an active precipitation pattern, with 66% of all FTB service days seeing at least 1" of rain somewhere in the State. Overall, the FTB had a success rate of 76%, and correctly identified threat areas to include 74% of qualifying storm reports that mean flood criteria.

2. While a concerted effort was made this year to use objective tools for flood threat threat identification, the performance of those tools alone would not have produced a favorable forecast success rate. This demonstrates the continued effectiveness of having a qualified meteorologist reviewing the output information as part of a robust forecast process.

3. The Twitter program was immensely successful, resulting in the addition of nearly 500 followers to our Twitter handle and resulting in approximately 220,000 views of FTB flood threat information. We found that interaction was most significant when we posted the threat map inside the Tweet, which overall expanded our view. This is consistent with online marketing trends that have clearly identified Twitter and other Social Media users as “content thirsty”. More people are drawn to images and are likely to review this information when it presented to them in their Twitter feed. As a result, it leads to more impressions and greater overall awareness. This program has provided immense value to the State of Colorado and we recommend that it is continued during next year’s FTB.

4. We propose that CWCB and Dewberry review the current system of flood threat classification during the 2014-2015 cool season. One item that is of interest is the possibility of switching from the current three tier system (low, moderate, and high) to a four-tier system. A primary reason for this discussion is that currently, there is no clearly defined system as to what a low, moderate, and high threat mean to the EM community. Additionally, the moderate threat allows a meteorologist to be somewhat vague in their characterization of the flood threat on a particular day. Rather, a four tier system would be able to characterize both very high and very low threat days, with some amount of moderate threat in between. This discussion would help the FTB be more specific in its daily threat outlook as well as provide a standard definition of threat to users.

5. Further quantitative tool development should be a given for the program, as significant progress was made this year. We believe that these tools and their ability to forecast precipitation will continue to evolve over time and that the outputs will continue to be a benefit to both the flood protection and water supply missions of the Colorado Water Conservation Board, and the FTB is the ideal place to test this technology. Some items to consider are:

    a. Running a Colorado-specific Weather Research and Forecasting model, tailored to the unique topography and initial conditions found in the State. Some testing of this approach has yielded intriguing but as to date unanswered questions. More research is needed.

    b. Identifying additional high-resolution model members to be included in the QPF-MAX product.

    c. Developing objective flood threat level guidance using model output to act as a base product for the daily FTB, in turn allowing the meteorologist the opportunity to save time in developing flood threat polygons by focusing on the most problematic areas for the given day.

APPENDIX A – VERIFICATION WORKSHEETS

Column descriptions:

cocomax:

Maximum daily precipitation (in inches) from all available CoCoRaHS reports.

nstats:

Number of CoCoRaHS stations exceeding 1.00 in. (west of 104˚W) and 1.50 in. (east of 104˚W)

rfcmax:

Maximum daily precipitation from gridded River Forecast Center precipitation analysis

area:

Area of precipitation (in square miles) exceed 1.00 in. (west of 104˚W) and 1.50 in. (east of 104˚W) based on the River Forecast Center gridded precipitation analysis

obs:

Whether (1) or not (0) a "flood day" was observed (see page 3 for description of "flood day")

threat:

Maximum threat in Flood Threat Bulletin (0=None, 1=Low, 2=Moderate, 3=High)

remarks:

Indicates days where manual adjustment of observations was required, for one of the following reasons:
"SN": Snowfall resulted in precipitation exceeding "flood day" standards, but no flooding observed.
"MELT": Snowmelt induced flooding was noted despite no precipitation.

Date	cocomax	nstats	rfcmax	area	obs	threat	remarks
5/1/2014	0.77	0	0.16	0	0	0	
5/2/2014	0.02	0	0.21	0	0	0	
5/3/2014	0	0	0.07	0	0	0	
5/4/2014	0	0	0.00	0	0	0	
5/5/2014	0.6	0	0.00	0	0	0	
5/6/2014	0.63	0	1.68	201	1	1	
5/7/2014	1.6	20	2.30	1009	1	2	
5/8/2014	0.84	0	0.48	0	0	0	
5/9/2014	1.26	1	0.65	0	0	0	
5/10/2014	1.74	84	1.66	572	0	0	SN
5/11/2014	2.25	210	2.83	13036	0	0	SN
5/12/2014	1.14	1	1.11	41	0	0	
5/13/2014	0.19	0	3.76	47	0	0	
5/14/2014	0.25	0	0.29	0	0	0	
5/15/2014	0.23	0	0.31	0	0	0	
5/16/2014	0.78	0	0.54	0	0	0	
5/17/2014	0.25	0	0.51	0	0	0	
5/18/2014	0.11	0	0.56	0	0	0	
5/19/2014	0.85	0	0.82	0	0	1	
5/20/2014	2.19	5	2.22	307	1	0	
5/21/2014	2.22	8	2.04	77	1	1	
5/22/2014	2.88	5	2.50	484	1	1	
5/23/2014	5.38	82	3.06	513	1	1	
5/24/2014	1.65	17	2.18	1711	1	2	

Date	cocomax	nstats	rfcmax	area	obs	threat	remarks
5/25/2014	1.63	4	2.26	242	1	1	
5/26/2014	0.97	0	1.32	0	1	3	MELT
5/27/2014	0.61	0	0.93	0	1	3	MELT
5/28/2014	0.95	0	0.65	0	1	1	MELT
5/29/2014	1.6	2	1.54	77	1	3	
5/30/2014	3.61	20	3.00	3020	1	2	
5/31/2014	1.16	1	1.93	112	1	2	
6/1/2014	0.71	0	1.17	41	1	2	MELT
6/2/2014	0.03	0	0.00	0	1	2	MELT
6/3/2014	0.34	0	0.10	0	0	0	
6/4/2014	1.71	2	1.96	436	1	2	
6/5/2014	1.27	1	1.56	83	1	2	
6/6/2014	1.65	3	4.69	1009	1	2	
6/7/2014	1.6	3	3.42	201	1	0	
6/8/2014	2.2	37	2.98	2106	1	0	
6/9/2014	0.17	0	0.41	0	1	2	MELT
6/10/2014	0.13	0	0.47	0	1	1	MELT
6/11/2014	1.83	2	2.01	124	1	1	
6/12/2014	0.22	0	0.65	0	1	1	MELT
6/13/2014	0.53	0	2.14	71	1	0	
6/14/2014	1.1	0	1.83	41	0	1	
6/15/2014	0.41	0	0.00	0	0	0	
6/16/2014	0.05	0	0.05	0	0	0	
6/17/2014	0.77	0	0.27	0	0	0	
6/18/2014	1.01	1	1.64	12	0	0	
6/19/2014	0.29	0	N/A	0	0	0	
6/20/2014	0.73	0	2.22	112	1	0	
6/21/2014	1.82	1	1.99	88	1	1	
6/22/2014	1.95	5	2.43	578	1	1	
6/23/2014	2.04	8	2.38	613	1	1	
6/24/2014	2.89	32	2.55	619	1	0	
6/25/2014	1.1	0	2.65	189	1	1	
6/26/2014	1.23	0	2.12	254	1	1	
6/27/2014	1.66	6	2.24	554	1	0	
6/28/2014	0.28	0	0.63	0	0	0	
6/29/2014	0.82	0	0.24	0	0	0	
6/30/2014	2.54	1	3.33	566	1	0	
7/1/2014	1.1	1	1.63	147	1	0	
7/2/2014	0.86	0	1.94	136	1	0	
7/3/2014	0.7	0	1.54	88	1	1	
7/4/2014	1.08	1	1.79	59	1	0	
7/5/2014	0.75	0	0.61	0	0	0	
7/6/2014	1.24	2	1.62	41	0	0	
7/7/2014	2.89	24	2.35	684	1	1	

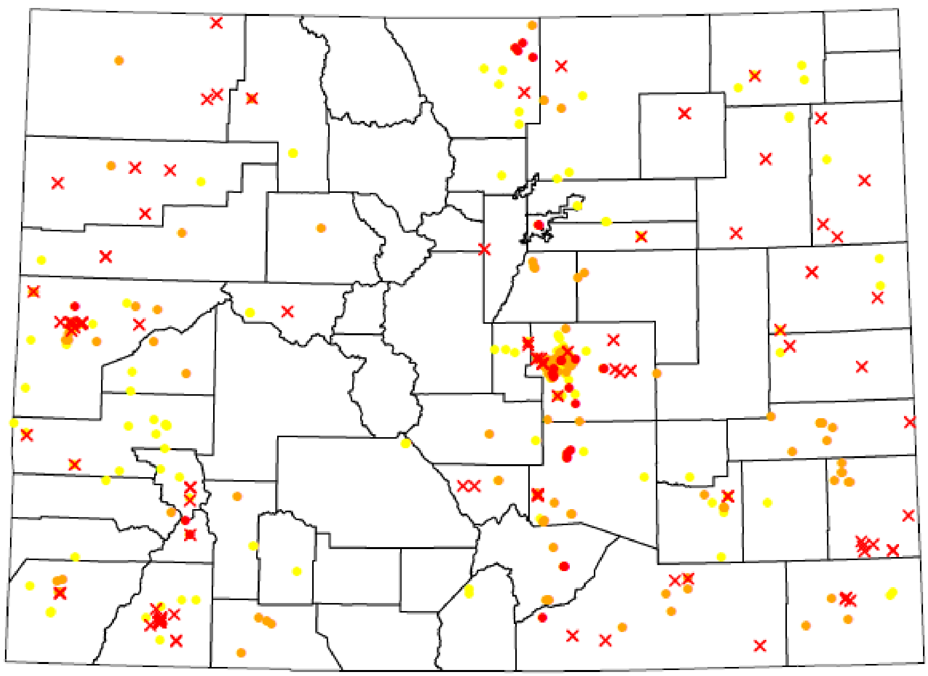
Date	cocomax	nstats	rfcmax	area	obs	threat	remarks
7/8/2014	1.87	2	1.92	265	1	0	
7/9/2014	0.84	0	4.05	71	1	1	
7/10/2014	1.08	2	1.59	59	1	2	
7/11/2014	2.54	32	4.89	631	1	2	
7/12/2014	3.93	87	3.90	4990	1	2	
7/13/2014	1.6	6	2.19	366	1	2	
7/14/2014	2.05	24	2.27	1392	1	2	
7/15/2014	1.71	7	1.86	236	1	3	
7/16/2014	2.34	48	N/A	0	0	2	
7/17/2014	1.06	1	0.53	0	0	2	
7/18/2014	0.51	0	1.37	6	0	2	
7/19/2014	0.97	0	2.20	41	0	0	
7/20/2014	0.73	0	3.55	118	1	0	
7/21/2014	1.1	0	2.36	24	0	0	
7/22/2014	0.56	0	1.48	0	0	0	
7/23/2014	0.64	0	1.44	47	0	1	
7/24/2014	0.82	0	1.56	153	1	1	
7/25/2014	1.72	4	1.19	47	0	1	
7/26/2014	1.16	1	1.57	53	1	1	
7/27/2014	1.86	22	2.93	1994	1	3	
7/28/2014	3.05	19	1.69	1422	1	2	
7/29/2014	6.31	380	6.71	17330	1	3	
7/30/2014	2.53	182	1.94	3976	1	2	
7/31/2014	1.05	2	1.33	88	1	2	
8/1/2014	1.96	5	1.93	159	1	2	
8/2/2014	0.94	0	0.90	0	0	1	
8/3/2014	2.5	3	1.54	88	1	1	
8/4/2014	1.51	7	2.37	454	1	1	
8/5/2014	1.89	4	1.68	218	1	0	
8/6/2014	1.5	0	1.09	12	0	1	
8/7/2014	3	14	2.52	596	1	1	
8/8/2014	1.43	0	2.27	71	1	0	
8/9/2014	1.36	3	1.85	171	1	0	
8/10/2014	1.58	6	3.28	1044	1	1	
8/11/2014	0.86	0	0.96	0	0	0	
8/12/2014	1	0	N/A	0	0	1	
8/13/2014	1.44	10	1.62	726	1	3	
8/14/2014	1.98	11	3.30	873	1	2	
8/15/2014	1.2	1	2.51	295	1	0	
8/16/2014	1.34	0	0.93	0	0	0	
8/17/2014	0.42	0	0.96	0	0	0	
8/18/2014	0.73	0	1.62	106	1	0	
8/19/2014	1.26	0	1.11	12	0	1	
8/20/2014	1.16	0	1.59	29	0	0	

Date	cocomax	nstats	rfcmax	area	obs	threat	remarks
8/21/2014	1.68	1	0.91	0	0	0	
8/22/2014	2.54	17	2.71	1628	1	1	
8/23/2014	1.09	3	1.42	35	0	1	
8/24/2014	0.94	0	1.71	53	1	0	
8/25/2014	2.56	20	1.99	708	1	1	
8/26/2014	1.6	5	2.35	159	1	3	
8/27/2014	3.92	14	3.63	1888	1	1	
8/28/2014	1.1	1	0.85	0	0	0	
8/29/2014	0.95	0	1.53	112	1	0	
8/30/2014	0.46	0	0.55	0	0	0	
8/31/2014	0.4	0	0.98	0	0	0	
9/1/2014	0.09	0	0.14	0	0	0	
9/2/2014	0.16	0	0.09	0	0	0	
9/3/2014	0.38	0	0.57	0	0	0	
9/4/2014	1.07	0	3.21	454	1	1	
9/5/2014	0.9	0	1.31	0	0	1	
9/6/2014	1.08	1	0.72	0	0	1	
9/7/2014	0.76	0	1.03	6	0	0	
9/8/2014	1.7	3	2.15	885	1	3	
9/9/2014	1.44	17	1.82	3468	1	3	
9/10/2014	0.46	0	0.37	0	0	0	
9/11/2014	1.1	0	3.80	324	1	0	
9/12/2014	0.73	0	0.05	0	0	0	
9/13/2014	0.05	0	0.06	0	0	0	
9/14/2014	0.25	0	0.64	0	0	0	
9/15/2014	0.8	0	0.58	0	0	0	
9/16/2014	0.43	0	1.31	0	0	0	
9/17/2014	0.57	0	0.48	0	0	0	
9/18/2014	0.09	0	0.00	0	0	0	
9/19/2014	1.09	1	2.09	100	1	0	
9/20/2014	2.26	18	N/A	0	0	0	
9/21/2014	1.72	5	1.69	985	1	0	
9/22/2014	2.45	2	2.93	938	1	1	
9/23/2014	0.78	0	1.61	6	0	0	
9/24/2014	0.04	0	0.21	0	0	0	
9/25/2014	0.18	0	0.29	0	0	0	
9/26/2014	0.64	0	0.44	0	0	0	
9/27/2014	1.43	6	1.36	596	1	1	
9/28/2014	1.43	18	2.00	3781	1	1	
9/29/2014	2.64	105	5.11	8688	1	1	
9/30/2014	0.81	0	0.55	0	0	0	

APPENDIX B – NWS REPORT VERIFICATION

The figure below shows all NWS storm reports received from May 1 – September 30 color coded according to the threat issued in the day's FTB. Yellow, orange, and red dots indicate low, moderate and high threats, respectively. Red crosses indicate the report did not fall into a threat region. Of the 372 qualifying reports (see page 3 for description), 267 (72%) were accurately anticipated by the FTB. However, excluding "heavy rain" reports, which often times did not result in flooding, increased the accuracy rate to over 80%.

NWS Report Verification



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