2018 Heavy Rainfall Guidance Tool: Upgrades and Operations

for the Urban Drainage and Flood Control District

INTRODUCTION

The Urban Drainage & Flood Control District (hereafter, District) Heavy Rainfall Guidance Tool (hereafter, Tool) began operations in 2015. The Tool provides a quick, but comprehensive snapshot of the daily heavy rainfall risk across six Forecast Zones placed within and surrounding the District. The 2015 version of the Tool used raw Quantitative Precipitation Forecast (QPF) data from 12 high resolution weather models and showed encouraging results. The Tool was upgraded in 2016 to provide post-processing of raw data that was shown to increase the reliability of all forecasts. In 2017, the two main refinements were (i) to add the HRRR weather model to the model ensemble and (ii) to provide three daily updates, compared to 2016's two updates. This proposal outlines the scope of Tool upgrades and operations for the 2018 season.

WORK PLAN

Task 1 – Tool Upgrades

Task 1.1 – Reduce Tool to Five Forecasts Zones and Trim Existing Zones

Dewberry will reduce the number of forecasts zones from six to five. This includes eliminating Zone D (Plains) and extending the eastern boundary of Zones E and F (Northern and Central Metro) to the eastern boundary of Zone C (Palmer Divide). Dewberry will also cut the southern boundaries for forecast Zones B and C (Southern Foothills and Palmer Divide) at the Jefferson, Douglas and Elbert County lines. This is approximately the highest elevation of the Palmer Ridge and should eliminate storms on the south side of the Ridge that unnecessarily increase the probability of heavy rainfall output by the Tool. To keep all zones equal in area for consistent post-processing, the western boundary of Zone C (Palmer Divide) will follow the Douglas County line along the South Platte River Valley. There is a lull in rainfall climatology along the South Platte River Valley, which the new Zone C will now capture. Zones E and F (North and Central Metro) southern boundaries will be moved to the Arapahoe and Weld County lines. Lastly, Dewberry will change the name of Zone F (Central Metro) to Zone D for consistency. Using this smaller domain, Dewberry will update the post-processing equations, found in the 2016 Technical Memo, for all data during the 2015-2017 seasons.

Benefits

- Expected to hone in the Tool's capability for more reliable and accurate District probabilistic forecast.

Task 1.2 – Incorporation of New High Resolution Atmospheric Models

After the 2017 forecast season, the NCAR and NSSL ensembles were discontinued. Together, these ensembles contributed 18 of the 23 models used in the Tool during the past seasons. As with any weather model, each model represents one set of physics and assumptions out of countless configurations that can generate different forecasts; the reason for using a high number of models in the past was to allay this concern. The effect of excluding 18 models on the utility of the Tool will be in the form of a bias related to the increased weight of an individual model's forecast resulting from the use of fewer models. For example, the certainty of a forecast where two out of the five models predict a storm event is much different than a forecast where 10 out of 23 models predict the same storm event; a greater number of models is preferred and provides higher confidence in the overall reliability of the Tool forecasts. The overall result will be a decrease in the utility of the Tool during the 2018 forecast season. With that said, the models that are still in operation and will be used during the upcoming season are the most state-of-the-art with both high spatial and temporal resolutions and are constantly being improved. The newest version of the HRRR in

particular allows improved resolution of convective storms and clouds and less high-precipitation bias. In the case that there are days that have four or less contributing models to the Tool, Dewberry will issue a "use with caution" message at the top of the Tool. While it has not been an issue in the past, it is possible that the numerical models may produce no files for a run, or the entire day, due to errors outside Dewberry's control. A Dewberry meteorologist will provide daily quality control of the Tool.

To help increase the utility of the Tool and help alleviate the loss of the other models, Dewberry proposes the inclusion of the HRRR ensemble (HRRRE). This will allow for (i) increased ensemble size and (ii) more updates for the early and mid-afternoon updates similar to the High-Resolution Rapid Refresh (HRRR) model. The HRRRE is a deterministic model with 3km resolution and has 1-hour QPFs issued 2 times daily for 9 members. At this time, there are no other capable numerical models available to replace the discontinued ensembles; however, efforts have been made to reach out the Canadian research group that runs the High Resolution Deterministic Prediction System (HRDPS) group to extend their model domain to our region. Dewberry will continue to monitor the research and development of high resolution numerical models for additional ensemble models in future forecast seasons.

It is important to note, despite the setbacks, the Tool will still provide the best available objective flood warning system to the District by using the most updated versions of all high resolution models that are currently available. Dewberry's bias correction and post-processing of the ensemble data will provide additional utility to the District's QPF, which includes a commitment to the collection of past and future data to further enhance the Tool's output. The inclusion of early afternoon and mid-afternoon updates will continue to provide better awareness of rapidly evolving conditions and provide lead time to end-users.

Benefits

- Additional numerical models will improve probability forecasts and help alleviate the effects of the discontinued ensemble data.

Task 1.3 – Update Post-Processing Algorithms

To continue to refine Tool reliability and accuracy, Dewberry will update the post-processing equations to account for the 2017 data and incorporate the outcome of Task 1.1. Specifically, we will explore:

- Improvements to the post-processing techniques from (1) QPF based predictors, (2) non-QPF, atmospheric-based predictors and (3) possible other predictors such as seasonality and location (e.g. higher versus lower elevation zones).
- The probability of exceedance thresholds, in particular, for days with high and moderate threats. Dewberry will utilize past season data to pick a threshold for high threat days that has a 75% hit rate.
- Increasing the max 1-hour QPF used for bias correction. It is currently set at the 1 in 100-year rainfall event, which is 2.34 inches. Given that this threshold is frequently exceeded somewhere in the district at least once a season, an increase in max 1-hour QPF will help eliminate events where the "worst-case" scenario underestimates observed rainfall. To do this, Dewberry will use the max 1 hour QPF from ALERT gages over the past 3 seasons as guidance.

Benefits

- Continues to leverages already developed methods to improve Tool reliability and accuracy,
- Tool will produce more realistic estimates of "worst-case" scenario.

Deliverables:

- An updated processing method to be used by the Tool during the 2018 season. All changes will continue to be archived and are available upon request.

Task 2 – 2018 Operations

Task 2.1 – Daily Quality Assurance and Maintenance of Operations

Although the Tool is to a large extent automated, there are two aspects that still require manual quality control. First, in situations where very few atmospheric models successfully download, Dewberry will provide a warning message cautioning users that accuracy may be temporarily degraded. In practice, we foresee this only being an issue for the morning (i.e. first) update since more models are continuously added throughout the ensuing updates. Second, a Dewberry meteorologist and web developer will work together to provide daily quality assurance that Tool output makes physical sense and is properly visualized on the website.

Hosting and Computing Platform

Dewberry will host the Tool on our Amazon Web Services (AWS) platform, which ensures maximum uptime. The Tool's daily updates will be archived and available through the Tool's website ("Archives" link). All data will be backed up monthly. The collective cost for hosting and computing will be $200/month for the May-September period of the Tool's operations.

Deliverable:

1. All QC logs and manual messages have been, and will continue to be, archived and made available upon request.

Task 2.2 – Outreach/Education Contingency

A key purpose of the Tool is to effectively communicate the daily flood potential over the District to end-users, which include the Flash Flood Prediction Program (F2P2) meteorologists, area Emergency Managers and other decisions makers. Training during 2017 educated users on the Tool's methods and features. To continue this effort, Dewberry will put in a contingency for general outreach and education sessions that will be performed in coordination with the UDFCD project manager as agreeable by both parties prior to obtaining a notice to proceed for Task 2.2.

Benefits

- Communicating the features of the Tool to key end-users,
- Potentially use feedback for further refinement of the Tool.

Deliverable:

1. Dewberry meteorologists and/or hydrologists will develop and tailor presentations for each event,
2. Minutes of all outreach/education events will be available upon request.

Task 3 – Validation Report

The importance of properly validating the Tool's performance is critical in evaluating the Tool's overall value. For example, 2015's validation highlighted scientific issues that were later explored in 2016 and resulted in an increase in the Tool's reliability and accuracy. Dewberry recommends an end-of-season validation for 2018 using the UDFCD's ALERT data, gridded NOAA Stage IV estimates and CoCoRaHS data for quality control. Key aspects of the validation will investigate the Tool's performance in the following metrics:

- Was a flood threat realized (both across the full model domain and in each zone)?
- Was the timing reasonably forecasted?

- Was the forecasted QPFMAX consistent with observations?
- Was the probability forecast reliable? For example, if an event was forecasted 20% of the time, did it occur 20% of the time?

It is likely that the validation results will also provide insight on how and to what extent Tool performance can be further optimized.

Deliverable:

1. A final validation report that will include data and analysis for the 2018 operational season and, as warranted, recommendations for future enhancements.

Add Alternative

Add Alternative 1.1 – Conceptual Outline for Social Media Operations

Social media has been proven adept for quickly and simply delivering important messages to end-users. To further increase usage of the Tool, UDFCD has requested the development of a social media component to supplement the Tool's daily output. We believe there is an optimal frequency of tweets that balances providing important notices while not over-sharing, which can desensitize users and make Tool output less effective. The following topics will be explored:

- Determining the best platform(s) and account(s) to disseminate a message.
- Developing a protocol for what triggers a message, and as warranted, the need for updates. Preliminary ideas for such a protocol include:
    - A message could be triggered by a High or Very High threat issued in the Tool's morning update.
    - The message will include pre-determined text and an image that highlights the potential area of impact. Figure 1 shows an example message.
    - Another message could potentially be triggered later in the day if the Tool's output has substantially changed. For example, this could include both increases and decreases in threat level and/or spatial extent. A schematic of how a message could look, using the Twitter platform, is shown in Figure 1.

Figure 1. An example showing a proposed message design, using the Twitter platform.
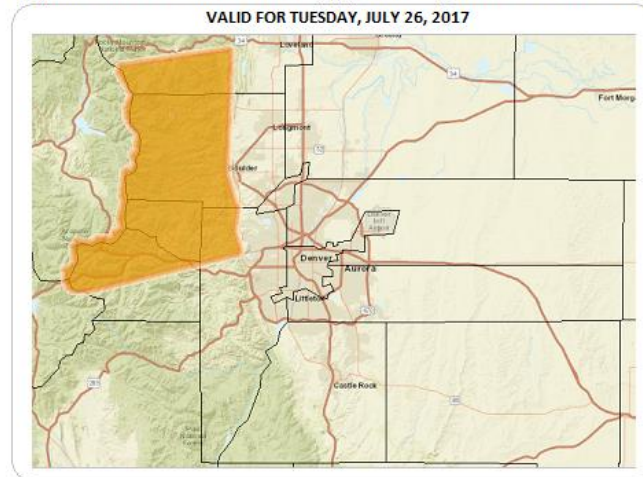
Deliverable:

1. Brief technical memo summarizing recommendations for social media operations to be approved by the UDFCD project manager.

Add Alternative 1.2 – Implementation and Daily Operations

Similar to Task 2.1, Dewberry initially recommends a human-based QC when a social media message is warranted during days heavy rainfall poses a potential risk to the District. The details and exact methodology will be set forth by Task 3.1 before the start of the 2018 season. While Dewberry will strive to make this a fully automated procedure, it is difficult to speculate how much operational testing will be needed to achieve this. However, given the stakes involved, it is clear that this should be done with caution.

Benefits

- Expands Tool's reach to a broader audience,
- Develops engagement between UDFCD and the community.

Deliverable:

1. Issuance of social media messages as warranted by the procedure developed in Task 3.1.

DAILY LOGISTICS

For 2018 Tool operations, Dewberry recommends 3 updates per day. The proposed update times are:

Update	Tool updated no later than:
Morning	8:30AM
Early afternoon	1PM
Mid afternoon	4PM

Since 2015, the operational season has been from May 1 to September 30 and we do not recommend any changes for 2018.

SCHEDULE

The following schedule assumes a notice to proceed date of March 1, 2018. Earlier or later dates will allow us to adjust the schedule accordingly.

Task	Completion Date
1. Tool Upgrades	May 14, 2018
2. 2018 Operations	May 14 - September 30, 2018
3. Validation Report	November 30, 2018

STAFF

Staff	Proposed Role
Danny Elsner *Project Manager*	Danny will provide final quality assurance and be the administrative point of contact for the client.
Dana McGlone *Meteorologist I*	Dana will serve as the technical point of contact for the client. She will be in charge of day to day quality control of Tool output. Dana will also work closely with Jason on Tool improvement before 2018 operations begin.
Jason Giovannettone, Ph.D. *Meteorologist II*	Jason will help implement and provide quality control of the Tool upgrades before the 2018 operations with Dana. He will also help monitor performance of the Tool throughout the season.
Ravi T. Pavuluri *Developer*	Ravi will provide application development for the Tool operations and help build the social media platform.