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MONITORING OF SHORT-FUSED FLOOD EVENTS BY THE NATIONAL WEATHER SERVICE HYDROLOGIC FORECAST SYSTEM

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1. INTRODUCTION

The Hydrology Program of the National Weather Service (NWS) provides forecasts, watches and warnings, and other services regarding the hydrologic conditions in the United States. Within the Advanced Weather Interactive Processing System (AWIPS) being deployed at NWS field offices is the Weather Forecast Office (WFO) Hydrologic Forecast System (WHFS). A recent release of the WHFS includes an initial delivery of the Flash Flood Monitoring (FFM) function to assist WFO forecasters in monitoring short-fused flood events. This function has been also referred to as the Area-Wide Hydrologic Prediction System; the alternate name of FFM reflects its implementation as a function integrated within the WHFS - instead of a stand-alone system, and which does not have a true predictive component.

It is well documented that floods, particularly flash floods, are the leading cause of weather-related fatalities in the United States. Unfortunately, short-fused flood events tend to be the most difficult to forecast, due in part to the extremely local characteristics of the rainfall causing these events. In addition, local features can cause different basins to respond uniquely to the same rainfall. By monitoring the rainfall data, the FFM function allows the forecaster to identify areas with a high potential for local flooding. It is designed to allow detection and monitoring of events that previously went undetected, and to increase warning lead time.

The flood monitoring function is described below, first in general terms, then in terms of its required data sets, then lastly in terms of the user interface. This paper then concludes with a general discussion.

2. FUNCTIONAL DESCRIPTION

The primary focus of the FFM function is to compare precipitation data with flash flood guidance (FFG) data. These two data sets are generated by external processes and then used by the function to derive comparison data sets that can be filtered and sorted. Although either data set can be viewed separately, in graphical or tabular form, the coupling of these data sets provides a much more valuable product because of the information inherent in the FFG value. An FFG value is defined as the amount of rain an area can receive for a given duration without flooding. Therefore, the higher the FFG value for an area, the more rain the area can receive before flooding. For example, the FFG value for a steep-sloped basin with hard, rocky soil would be much lower than the FFG value for a generally flat basin with porous, sandy soil. It is the comparison of FFG to observed and forecast precipitation data that allows the flood threat to be quantified.

The precipitation data sets that are monitored include observed and forecast precipitation for various durations. The data can be analyzed at different spatial resolutions, including gridded and areal modes, where the areas are either counties, NWS zones, or hydrologic basins. When comparing the precipitation data with FFG data, the comparisons can be performed by computing precipitation as either a percentage of FFG or as a difference from FFG. The precipitation can also be viewed as a rate value, independent of FFG.

3. DATA REQUIREMENTS

There are three primary input data sets:

(1) precipitation data;
(2) FFG data; and
(3) areal boundary data.

The characteristics of each of these data sets plays a crucial role in how effectively the flood threat is assessed. All data sets are stored in a relational database residing on the AWIPS workstation. This database serves the entire suite of WHFS applications that support the NWS Hydrology Program, and is referred to as the Integrated Hydrologic Forecast System (IHFS) database. It includes static parametric data, such as precipitation gage information and areal boundary data, and dynamic operational data, such as the precipitation and FFG data.

3.1 Precipitation Data

The precipitation data are the most important data set since rainfall amount and intensity are the primary cause of short-fused flood events. Even without FFG data, the precipitation data can be invaluable in identifying areas of high intensity, flood-causing rainfall. The function takes advantage of the two basic sources of precipitation data in AWIPS: gridded radar-based estimates, and point gage measurements.

The WSR-88D Digital Precipitation Array (DPA), or Stage I, product provides a 4 x 4 km grid of hourly estimates to a distance of 230 km from the radar. The Stage I product is a running one-hour accumulation updated every volume scan of the radar, or about every 5-6 minutes. Using precipitation gage data and Stage I grid data, two Stage II gridded products with the same spatial characteristics as the Stage I product are also generated locally in the WHFS. First, the Stage II "gage-radar" product merges the radar data with available point gage data. Second, the gage data are also used independent of the radar

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data to compute a Stage II "gage-only" product by performing an objective analysis of the point gage data.

Although the Stage I radar data are available throughout an hour period, the FFM function is currently not capable of handling multi-hour Stage I accumulations except for time periods ending at the top of the hour. Similarly, the Stage II analyses are only performed for hourly periods ending at the top of the hour, and the multi-hour Stage II accumulations are available at the top of the hour only. These are significant issues, as the up-to-the-minute availability of multi-hour accumulations is important for effective monitoring.

Forecast precipitation data are also available for display and comparison with the FFG values. Quantitative Precipitation Forecast (QPF) data are typically provided for hydrologic basins, using forecasts generated locally by the WFO, and quality-controlled by the River Forecast Center (RFC). Other QPF data sets can be supported provided that the data can be ingested into the IHFS database.

3.2 Flash Flood Guidance Data

The FFG values used in the comparisons of precipitation data are computed by the RFC(s) and then provided to the WFO. An FFG value is defined for a given area and for a given duration. The durations for which FFG values are given vary among the RFCs; typically, the 1-, 3-, and 6-hour durations are used; some RFCs also provide 12- and 24-hour duration FFG values. The areas for which values are given also vary among the RFCs. Some provide county-based values, while others use NWS zones. Additionally, some RFCs provide FFG values for headwater basin areas. A set of FFG values is usually computed once per day, while some RFCs compute them more often. These differences among RFCs can be an issue for WFOs served by more than one RFC.

Because the FFG values are the measure of the potential for flooding, they are of critical importance to the monitoring process. The RFC models which generate the FFG values are quite complex and try to account for all the characteristics which reflect the susceptibility of an area to flooding. Nonetheless, they do have limitations in terms of their spatial resolution and other factors. Ideally, an FFG value is computed for very small basins, since that is the resolution at which the hydrologic features being modeled are most uniform and at which the FFG is most meaningful. Since the values are computed using a lumped parameter approach in the RFC models, the data are not as applicable to small basins. Also, the values can not be updated as often as certain storm events occur. If there are two distinct events that occur before the FFG is updated, runoff from the first event may be long over but the soil moisture state is altered which then may not be reflected in a lower FFG value for the second event.

Efforts are underway in the NWS Office of Hydrology to improve the computations of FFG. The focus of these efforts is to use distributed modeling methods, by which the analysis is performed at much smaller spatial scales. Also, high resolution digital elevation data, soil cover/land use data, and other geophysical data sets will be used to more accurately quantify the hydrologic response of small basins. A grid resolution will be used for the improved data sets. Currently, the areal FFG data are internally converted to the grid resolution to allow the comparison of the FFG with other gridded data sets.

3.3 Areal Boundary Data

Each of the data sets have different spatial characteristics. While the raw precipitation data may be in point or gridded form, they are transformed between gridded form or different areal forms. FFG data are given as areas and are transformed to a grid, but are not transformed from one areal form to another. The comparison data are always available in gridded form, but for the areal form, they are only produced for the resolution for which FFG exists. All of these transformations are accomplished by use of areal boundary data stored in the IHFS database. Each area is defined by a collection of paired latitude-longitude values.

The most meaningful manner to present the comparison displays and the associated tabulations is in terms of the basins. Basin boundary data are available from the RFCs, which make use of the Integrated Hydrologic Automated Basin Boundary System (IHABBS) developed by the Office of Hydrology, to delineate basins. The RFC basin size tends to be larger than the typical basin size for flash flooding. Ideally, very small basins are defined to capture the local nature of the short-fused floods. Alternatively, basins can be defined using in-house methods or a commercial Geographic Information System (GIS). Within the WHFS, a utility exists to import basin or other areal data provided that it is in the simple text format supported by the WHFS. The FFM function does not distinguish the source of the boundary data once it is in the database.

4. USER INTERFACE

The FFM function is integrated into the comprehensive HydroView application, the primary data viewing application within the WHFS. The main window of HydroView contains a large geographic area shown in Figure 1 and a set of pull-down menus from which certain display options can be exercised or from which other windows can be displayed.

One of these other windows allows the user to control most of the overlays and display features of the geographic display. The user can pick the data mode, the precipitation data source, and the spatial resolution. Three available modes exist:

(1) Precipitation data;
(2) FFG data; and
(3) Compare precipitation and FFG data.

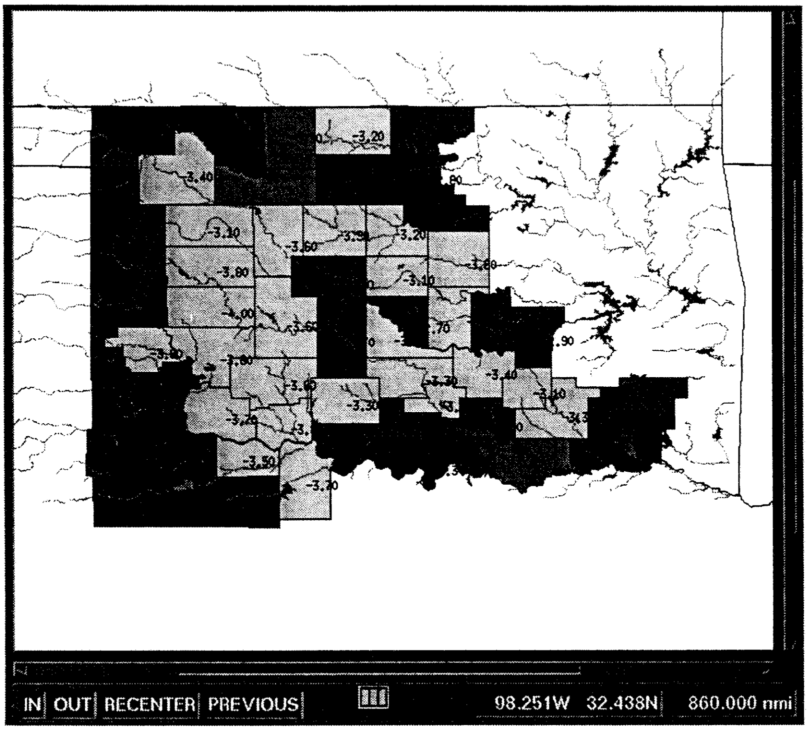

Figure 1. Sample Display of Difference Comparison by County

The comparison data mode is one of the two ways in which the FFM features are manifested. Four precipitation sources are available:

(1) Stage I radar estimates;
(2) Stage II gage-radar estimates;
(3) Stage II gage-only estimates; and
(4) QPF.

The data can be displayed for four resolutions:

(1) Grid;
(2) Basin;
(3) County; or
(4) NWS Zone.

Depending upon the chosen mode and precipitation source, the scrolled list of available products is loaded accordingly. The products include not only the one-hour products which are generated by the Stage I and Stage II processes, but also multi-hour products which the user can schedule.

Once a product is selected, it is overlaid on the geographic display for the specified resolution. If a non-gridded resolution (i.e. areal) is specified, then the options allow the name, identifier, and/or value to be annotated in the display, and the area to be colored according to a color scheme which the user can control. For the comparison mode, the comparison value can be given as either the difference or the ratio between the precipitation value and the FFG value.

The other manner in which the FFM features are manifested is by selecting the Summary button. This results in the window shown in Figure 2 which summarizes the precipitation monitoring in tabular form. The user can select the precipitation data source and radar area to consider. Upon doing so, the lists of available data sets are shown and the main scrolled list is updated to contain an entry for each area that meets the filter criteria. The main list is sorted in a manner that is controllable via the options. Areas can be filtered by their form (i.e. basin, zone, or county), or whether their most critical value is greater than or less than some user-defined value. The list can be sorted by value or alphanumerically, where the value sort is for either the area's precipitation rate, percent of FFG, or difference from FFG. The main list presents information for the duration that has the most critical value. When more information about a particular area is desired, the user can select the area from the list and the detailed information for all durations is given in the lower portion of the window. The intent of the summary window is to allow the user to quickly scan the data and note areas of concern. The area and time period in question can then be analyzed further by displaying the data in the geographic display.

Other HydroView options allow zooming and re-centering of the display, and also support the overlay of the following datasets: rivers, streams, cities, towns, highways, roads, counties, zones, and basins. Point rain gage data can be displayed with the gridded or areal overlays. Time-series of observed stages, rainfall, or other data sets can be plotted, as can parametric hydrologic data associated with stations.

5. DISCUSSION

This is the initial release of the FFM function. It contains powerful features for achieving its goal of allowing detection of short-fused flood events. To address limitations in its current implementation, enhancements will be made in a future release. These include the ability to compute running accumulations for any duration, using the expected Digital Hybrid-Scan Reflectivity (DHR) product. It also includes the use of nested basin layers and definition of urban areas, which are not currently supported - the issue of how to specify basin boundaries is considered external to this function.

Other planned features are the use of real-time projected precipitation data such as one-hour QPF, which can be summed with the observed data to obtain the expected storm rainfall. As improved, gridded FFG and gridded QPF data sets are made available, they will be incorporated. More search-and-identify monitoring can be

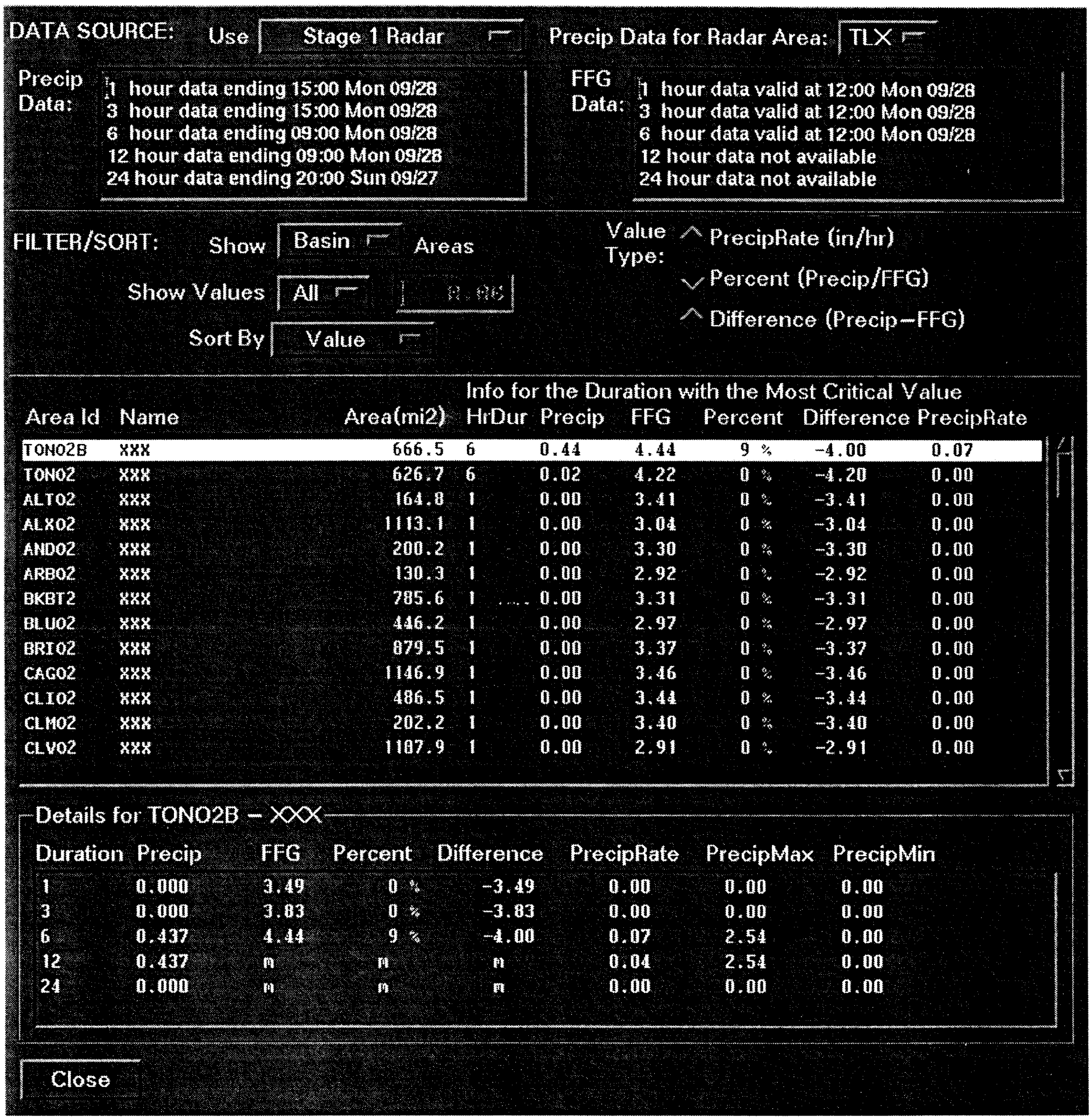

Figure 2. Summary Display for Current Precipitation and FFG Data

performed to further hasten the scanning and review of the voluminous data sets. Improved filter, sort, and time period specification tools for managing the product list can be added. The incorporation of additional geophysical data such as average basin slope, channel slope, soil cover/land-use would allow for better interpretation of the data. Providing a means for this and all other pertinent comparison data for a particular point when the mouse cursor is clicked on the screen would be informative. Ultimately, a local hydrologic model could be integrated to provide specific stream flow and discharge estimates. All of these features would add to the utility of the FFM function.

6. ACKNOWLEDGEMENT

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