Service Assessment

Southeast United States Floods, September 18-23, 2009

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
Silver Spring, Maryland

Cover Photograph: Sweetwater Creek at Veterans Memorial Highway, Austell, Georgia, September 23, 2009, after waters started to recede. Photo courtesy of Melissa Tuttle Carr, CNN.

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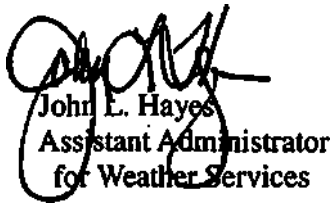
May 2010

National Weather Service
John L. Hayes, Assistant Administrator

Preface

Copious moisture drawn into the southeastern United States from the Atlantic and Gulf of Mexico produced showers and thunderstorms from Friday, September 18, through Monday, September 21, 2009. Rainfall amounts across the region totaled 5-7 inches, with locally higher amounts near 20 inches. The northern two-thirds of Georgia, Alabama, and southeastern Tennessee were hardest hit with the southeasterly low-level winds providing favorable upslope flow. Flash flood and areal flooding were widespread with significant impacts continuing through Wednesday, September 23, 2009. Eleven fatalities were directly attributed to this flooding.

Due to the significant effects of the event, the National Oceanic and Atmospheric Administration's National Weather Service formed a service assessment team to evaluate the National Weather Service's performance before and during the record flooding. The findings and recommendations from this assessment will improve the quality of National Weather Service products and services and enhance the ability of the Weather Service to provide an increase in public education and awareness materials relating to flash flooding, areal flooding, and river flooding. The ultimate goal of this report is to help the National Weather Service meet its mission of protecting lives and property and enhancing the national economy.



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Executive Summary

The mission of the National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service (NWS) is to protect life and property by providing weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas. The NWS disseminates centrally produced data, weather products and guidance to 135 regional and local Weather Forecast Offices (WFOs) and River Forecast Centers (RFCs). Forecasters at the WFOs issue all local forecasts and warnings to the public. The National Centers for Environmental Prediction (NCEP), consisting of nine prediction centers, provides central guidance, outlooks, and hazardous weather watches and warnings to the NWS organization and the public.

Extreme to catastrophic flooding occurred across northern Georgia, northern Alabama, southeastern Tennessee, upstate South Carolina and extreme southwestern North Carolina September 18–23, 2009. Eleven people lost their lives. All 11 fatalities in the assessment area were attributed to flash flooding and areal flooding[1]. Ten of those fatalities occurred at night. Eight deaths were a result of people driving vehicles across flooded roads in poor visibility conditions due to heavy rain, occurring in a 7-hour period in a two-county area. Property damage in Georgia alone exceeded $250 million. A stationary frontal boundary stretched from North Carolina across Tennessee, down through southeastern Arkansas into Louisiana for many days.

A combination of moist southeast flow from the Atlantic in the lower levels, moist southwest flow above that from the Gulf of Mexico, and terrain enhancement helped bring heavy rains to the affected area over multiple days. An estimated 10-20 inches of rain occurred in less than 24 hours September 20-21, 2009. Thunderstorms brought intense rainfall, initially resulting in flash flooding, and eventually headwater and main stem river flooding. Numerous record flood levels were set, with some river flooding exceeding the expected 500-year flood level, or less than the 0.2 percent annual chance of occurrence.

Thunderstorms that caused the heaviest rains developed rapidly on a Sunday night. From a preparedness standpoint, emergency managers (EM) noted the event occurred at the worst possible time. It was also a time with minimal media staffing and monitoring of weather developments. Numerous timely flash flood and flood warnings were issued prior to the onset of flooding. Forecasters, EMs, and residents, however, underestimated the magnitude of the flooding. Warning statements at the onset of the event did not convey the severity of these life-threatening events. Flash flood warnings had already been issued in the assessment area on days leading up to the most severe flash flooding. Residents became desensitized to flash flood warnings due to widespread dissemination of warnings on prior days that they perceived did not directly affect them. The large number of warnings issued at the height of flooding made it

[1] NWS Instruction 10-1605, Storm Data Preparation, defines a flood as, "Any high flow, overflow, or inundation by water which causes or threatens damage. In general, this would mean the inundation of a normally dry area caused by an increased water level in an established watercourse, or ponding of water, generally occurring more than 6 hours after the causative event." All 11 fatalities were caused by heavy rain induced rapid rises in water levels; however, three of the fatalities were beyond 6 hours of the causative event.

difficult for EMs and the media to stay current and glean new, important information from the statements.

WFOs issued numerous flash flood, areal flood, and river flood warnings in advance of the flooding. Three of the seven NWS official river forecast points had forecasts of major flood issued with at least 36 hours of lead time, which is significant for this fast response event. WFOs utilized the Site Specific Hydrologic Prediction System to issue very skillful headwater flood forecasts. The inability of numerical prediction models, the Hydrometeorological Prediction Center, Southeast River Forecast Center, Lower Mississippi River Forecast Center, and WFOs to predict the location and magnitude of the heavy, mesoscale precipitation that caused the flash flooding/flooding resulted in forecast river hydrographs that were significantly under forecast for the two headwater river floods that caused most of the damage. Loss of United States Geological Survey (USGS) river gages by flooding, and river flows exceeding that depicted on rating tables (river flow vs. gage height relationship), also made it difficult to predict the magnitude of the floods.

Performance measures indicate that flash flood warnings issued by the three offices that experienced most of the flash flooding during these events exceeded NWS Government Performance and Results Act (GPRA) goals in probability of detection (90 percent) and lead time (49 minutes), with WFO Peachtree City average lead time of 103 minutes far exceeding the goal (see **Appendix F**). The lead time provided for major flood on three of the rivers (36 hours) was significant for such a small scale, rapidly developing event. Interviews with EMs and other decision makers indicated that the RFCs and WFOs have developed an overall excellent working relationship with these partners, and there is high satisfaction with services provided. Despite the above, 11 persons died, each while a warning was in effect. Communications with partners and users was time constrained. With a desire to improve operations and services for future such challenging events, the team has identified a series of facts, findings and recommendations that are presented in this report.

The following are major facts of the assessment:

- ✓ Forecasters, EMs, and residents did not recognize the magnitude or severity of the flash flood/flood events until the event was well underway. There was a general misconception that “the usual” flood-prone areas would have a problem, with “the usual” flood impacts.

- ✓ This event posed an extreme operational challenge for the RFCs to produce specific flood crest forecasts with much lead time. This highly localized rainfall exceeding the 100-year recurrence interval, over headwater basins with crests well over existing rating curves, stretched the current state of hydrologic science predictability to its limit.

- ✓ When the heaviest rains, flash flooding, and fatalities occurred in northwestern Georgia, the Hydrometeorological Prediction Center 24-hour Quantitative Precipitation Forecasts (QPF) covering the period 1200 Coordinated Universal Time Sunday, September 20–1200 Coordinated Universal Time, Monday, September 21, were for rainfall amounts between 0.5 and 1.0 inches. The Excessive Rainfall Potential Outlook did not identify any portion of the country for excessive rainfall.

- ✓ The NWS WFOs issued timely flash flood/flood watches, warnings, and statements in the assessment area before and during the period of heaviest rain and flooding. Each of the fatalities occurred in an area encompassed by an NWS Warning: two during areal flood warnings and nine during flash flood warnings.

- ✓ A major flood forecast was made for Austell, GA on Sweetwater Creek with 36 hour lead time, and a major flood forecast crest for Whitesburg, GA on the Chattahoochee River was forecast within a foot of observed with 36 hour lead time. RFC forecast hydrographs and crest forecasts for the two rivers where the greatest property damage occurred were considerably under forecast, with subsequent forecasts each nudging closer to the conditions eventually observed.

- ✓ Even though there were significant flood impacts, including water rescues, no city, county or other EMs or first responders called WFO Peachtree City on Sunday night, September 20-21, to report the severity of impacts.

- ✓ NOAA Weather Radio (NWR) broadcast cycles at WFO Peachtree City became excessively long (more than 20 minutes in length) due to the number and length of warnings in effect. Many residents said they owned an NWR receiver but did not have it turned on during the flood event. When asked why, the majority stated, "It goes off too often."

A summary of major findings of the assessment are:

- ✓ The lack of real-time feedback to WFO Peachtree City contributed to NWS forecasters, the media and residents underestimating the magnitude of flash flooding. Forecasters had little time to solicit feedback from affected counties. The few efforts made by forecasters to call 911 centers were unproductive, with the 911 centers' response being, "We're too busy to talk to you."

- ✓ WFO-initiated decision-support phone calls, briefings, email alerts, etc., are very popular with the emergency management and media communities. These briefings are typically conducted during normal business hours before significant weather events. Due to the rapid development and night and weekend timing of this event, no such coordination efforts were conducted prior to the flash flood-producing rains.

- ✓ There is no WFO Operations directive or mandate for WFOs to document major decisions and coordination efforts made on shift, nor to document the many decision-support activities that take place.

- ✓ WFO flash flood warnings and statements generally contained standard Warning Generation Software (WarnGen) call-to-action statements and generic impact information. These generic statements failed to convey the severity of the flash flood/flood events. Emergency management and media representatives wanted more specific impact information in statements, despite having difficulty with the long length and large number of warnings issued. These users would like more strongly worded impact information at the top of the statement where it would be readily noticed.

- ✓ EMs expressed concern about NWS river warning credibility when some current river gage readings exceeded forecast expectations in warnings/forecast hydrographs that had been recently issued.

- ✓ WFO staffing levels during the weekend and nights of many of these heavy rain events were augmented and adequate for issuing basic forecast and warning services, but not for aggressively soliciting feedback reports and providing coordination and other decision-support activities. EMs in Georgia believe WFO Peachtree City provides a reduced level of service during weekend events, which they attribute to reduced weekend staffing.

- ✓ The loss of river gage data played a significant role in underestimating the river forecast for Sweetwater Creek near Austell, GA (AUSG1). The Southeast River Forecast Center and WFO Peachtree City did not exhaust alternative means to infer reference river stage at Austell along Sweetwater Creek once gages became inoperable.

- ✓ Residents responded better to warnings communicated down to a personal level (e.g., evacuation notice, reverse-911call) than from mass communication methods. Few residents took action solely on warnings received via mass communications systems (media, NWR). Warnings heightened residents' awareness, which led to subsequent personal validation of the warning threat before precautionary measures were taken.

- ✓ Residents have a low tolerance for missed warnings or false alarms when communications get down to a personal level. People quickly become disenchanted with telephone warnings and evacuation messages when no threat materializes.

- ✓ Many of the fatalities occurred at night, in heavy rain, when visibility was minimal. It was not evident that the victims intentionally attempted to drive through water on the roadway; rather, they were blinded by the heavy rain. Drivers did not seem aware of the danger of driving at night, even though flash flood warnings had been issued.

A summary of the team's major recommendations are:

- ✓ The NWS should improve hydrometeorological monitoring and situational awareness tools to help forecasters recognize the extreme nature of unusual events.

- ✓ The Duties Priority statement (Appendix C) should incorporate decision support as a top priority along with warning responsibility. NWS should conduct a comprehensive communication effort and training program to help employees make the culture change from a product-oriented organization to a high impact and decision-support agency.

- ✓ Warning statements should be as specific as possible regarding area and severity of impact. Statements should include severity wording, i.e., flood emergency, life threatening, etc., when extreme events are anticipated or are occurring. Statements should reference commonly known benchmarks to better convey severity, i.e., higher levels than the 100-year flooding from Hurricane Dennis in 2005. Flash flood statements should be updated often to include reports of flooding and the latest impact information.

- ✓ RFCs should implement automated procedures to perform a cursory check of forecast hydrographs against observed conditions and flag questionable forecasts before they are posted on the Advanced Hydrologic Prediction Service.

- ✓ The NWS should address archival and documentation requirements for operational shift decisions made and for decision-support activities such as phone calls, Webinars, graphical weather stories, narrated graphic-casts, chats, etc.

- ✓ WFO staffing levels for flash flood events should be similar to those for severe weather events, including use of a Warning Coordinator position. A similar level of effort should be made to solicit feedback reports, including activation of HAM radio networks, and provision of briefings and other decision-support services.

- ✓ The RFC and WFO should make a concerted effort to assess river stage when automated gages fail. This assessment should include gathering onsite readings from the U.S. Geological Survey, inferring stages from emergency officials or news reports of impacts (e.g., I-20 bridge closed due to the river rising to 27 feet), webcam images, etc., and cross referencing them to NWS Form E-19, Reports on River Gage Stations.

- ✓ Installation of low cost staff gages may be a means to obtain backup river stage readings.

- ✓ Improvements in QPF and mesoscale rainfall prediction need to be a top NWS research and training priority. WFO forecasters should use short-term mesoscale precipitation estimation techniques to update WFO QPF forecasts for flash flood forecasting and for RFCs to use in making short-term headwater river forecasts.

- ✓ NWS should explore use of public information systems, (e.g., Nixle, emergency management networks), commercial or other electronic news sources, and mine information from social media sources such as Facebook and Twitter to infer weather, flood, and societal impact information needed by forecasters in real-time.

- ✓ A variety of dissemination methods should be employed for a most effective warning notification system, with warnings in a format suitable for the dissemination means.

- ✓ In addition to Turn Around, Don't Drown, outreach efforts must emphasize the danger of driving at night when limited visibility makes it difficult to discern a section of a roadway under water. The NWS message should be, "If you can't see the road due to intense night rainfall, you should not drive." NWS should work with the Departments of Transportation and Education to include the hazards of driving in heavy rain as part of driver training curriculums and licensing examinations.

Service Assessment Report

1. Introduction

1.1. NWS Mission

The mission of the NWS is to protect life and property by providing weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas. The NWS disseminates centrally produced data, weather products, and guidance to 135 regional and local WFOs and RFCs. Forecasters at the WFOs issue all local forecasts and warnings to the public and interface with local emergency managers (EM) and state and local government to promote community awareness and understanding of local climates, forecasts, and weather events.

The NWS is organized into six regional headquarters and one national headquarters, which provide policy and guidance to the WFOs and RFCs. The National Centers for Environmental Prediction (NCEP), consisting of nine centers, provide central guidance, outlooks, and hazardous weather watches and warnings to the NWS organization and the public.

1.2. Purpose of Assessment Report

The NWS conducts Service Assessments of significant weather-related events that result in at least one fatality, numerous injuries requiring hospitalization, extensive property damage, widespread media interest, or an unusual level of scrutiny of NWS operations by the media, Emergency Management (EM) community, or elected officials. Service Assessments evaluate the NWS performance and ensure the effectiveness of NWS products and services in meeting the mission. The goal of Service Assessments is to improve the ability of the NWS to protect life and property by implementing recommendations and best practices that improve products and services.

This document presents findings and recommendations resulting from the evaluation of NWS performance during the heavy rains and flash flooding/flooding from September 18 to September 23, 2009, in northern Alabama and Georgia, southeastern Tennessee, upstate South Carolina, and extreme southwestern North Carolina. Showers and thunderstorms brought copious rainfall that produced flash flooding, areal, and river flooding that resulted in 11 fatalities, considerable property loss, and significantly affected transportation and commerce.

The objectives of this assessment are to identify significant findings, and issue recommendations and best practices related to the following key areas:

- Timeliness, quality, accuracy, and usefulness of NWS forecasts and warnings
- Effectiveness of NWS internal and external coordination and collaboration
- Effectiveness of NWS data dissemination, uncertainty communication, and flood risk
- Effectiveness of hydrologic forecasting and warning procedures at NWS offices
- Identification and evaluation of opportunities for improved collaboration among other federal, state, and local agencies

1.3. Methodology

The NWS formed an assessment team on October 2, 2009, consisting of employees from NWS field offices, the Office of Climate, Weather and Water Services (OCWWS) in NWS Headquarters, a private sector meteorologist, and a county emergency manager. The nine-member team did the following:

- Performed an on-scene evaluation from October 12–17, 2009.
- Conducted interviews with staff from WFOs in Peachtree City, Georgia; Birmingham and Huntsville, Alabama; Morristown, Tennessee; and Greenville-Spartanburg, South Carolina; and with the Southeast River Forecast Center (SERFC) and Lower Mississippi River Forecast Center (LMRFC). These offices had primary responsibility for providing forecasts, warnings and decision support to the residents and EMs of the affected areas.
- Interviewed EMs, the media, and the public, as well as other government agency representatives and assessed the damaged areas.
- Evaluated products and services issued by the WFOs, SERFC, LMRFC, as well as national guidance issued from the Hydrometeorological Prediction Center (HPC).
- Came to agreement on the significant findings and recommendations to improve the effectiveness of NWS products and services.

After a series of internal reviews, the Service Assessment was approved and signed by the NOAA Assistant Administrator for Weather Services and issued to the American public.

2. Hydrometeorological Summary

Extreme to catastrophic flooding occurred across northern Georgia, northern Alabama, southeastern Tennessee, upstate South Carolina and extreme southwestern North Carolina from September 18 to September 23, 2009. Eleven people lost their lives; damages were over $250 million in Georgia alone. The worst flooding occurred in and around metropolitan Atlanta.

2.1. Antecedent and Event Conditions

Wetter than normal conditions characterized the impacted area from August into early September (**Figure 1**). The South experienced its 6th wettest September on record in 2009. Rainfall in the impacted area was 300 percent to more than 600 percent of normal for September (**Figure 2**). Statewide-average rainfall was among the 10 wettest for two states affected by the floods: Tennessee (5th) and Alabama (6th) according to the NOAA's National Climatic Data Center (NCDC).

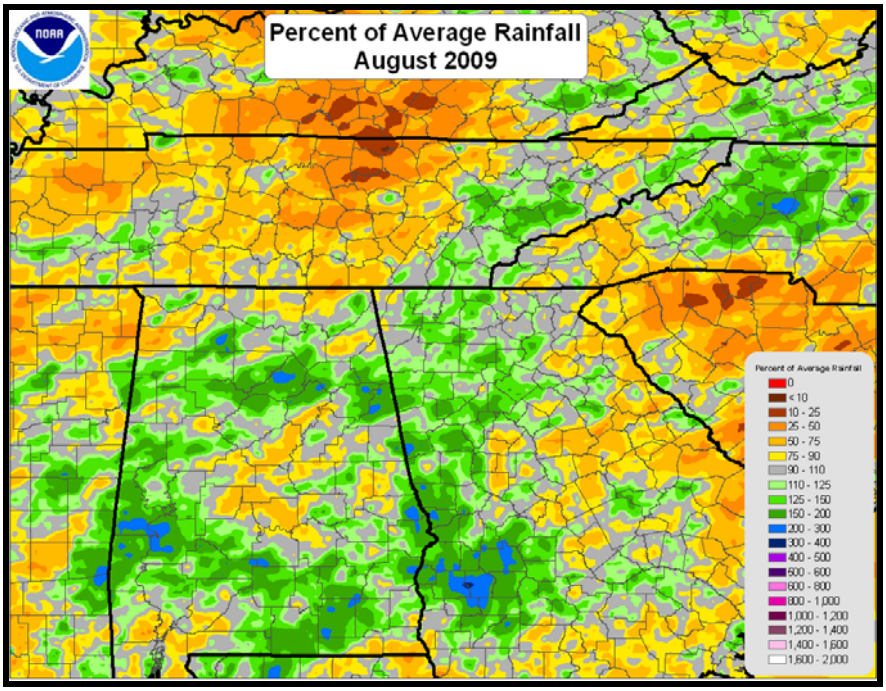


Figure 1. Percent of Normal Precipitation from Multi-Sensor Precipitation Estimates, August 2009.

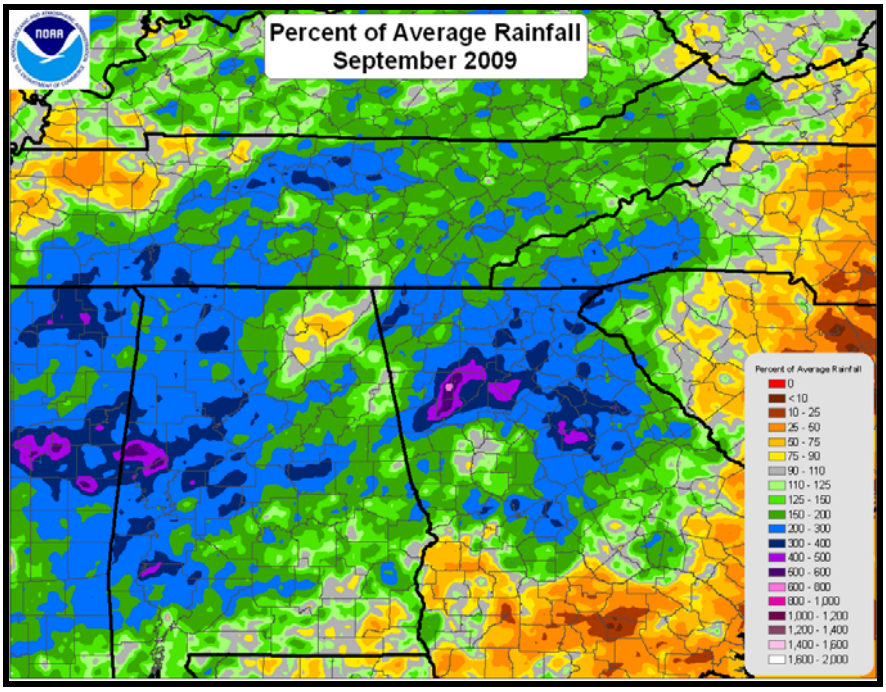


Figure 2. Percent of Normal Precipitation from Multi-Sensor Precipitation Estimates, September 2009.

By mid-September, lower levels of the atmosphere were saturated with moisture from the Atlantic Ocean and the Gulf of Mexico, feeding an area south of a nearly stationary front (**Figure 3**). In the upper atmosphere, a low pressure area, stalled over the southern Plains and lower Mississippi Valley, began to lift out on Sunday, September 20, 2009 (**Figure 4**). Weather disturbances in the mid- and upper-level flow periodically moved over the region, aiding the development of widespread showers and thunderstorms. The upper level atmospheric flow (**Figure 4**) was nearly parallel to the terrain, while the low-level flow (**Figure 5**) was nearly perpendicular. The peak flooding occurred late on September 20-21, 2009, when the upper level low pressure system began to lift out and strong low-level winds of nearly 40 knots (**Figure 5**) moved across the affected area. Precipitable water (PW) values (**Figure 6**) were in excess of 2 inches during the peak event—at least two standard deviations above normal. These ingredients set the stage for torrential downpours where terrain and small-scale boundaries anchored storms or led to training of storms over a particular area. The result was 10-20 inches of rain in less than 24 hours, with isolated totals even higher, yielding a significant and deadly flood event (the maximum 24-hour rainfall reported was 21.03 inches at the Douglas County Water and Sewer Authority near Douglasville, GA from Sunday, September 20, through Monday, September 21). The effects of flooding were exacerbated because some of the heaviest rains fell over highly urbanized areas.

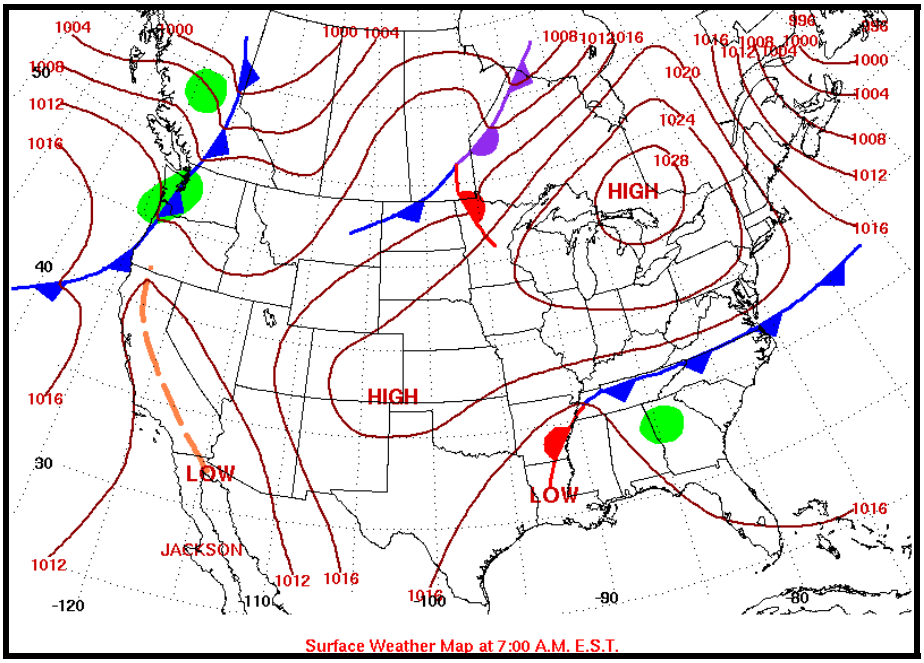


Figure 3. Surface Weather Map, September 19, 2009, 1200 UTC.

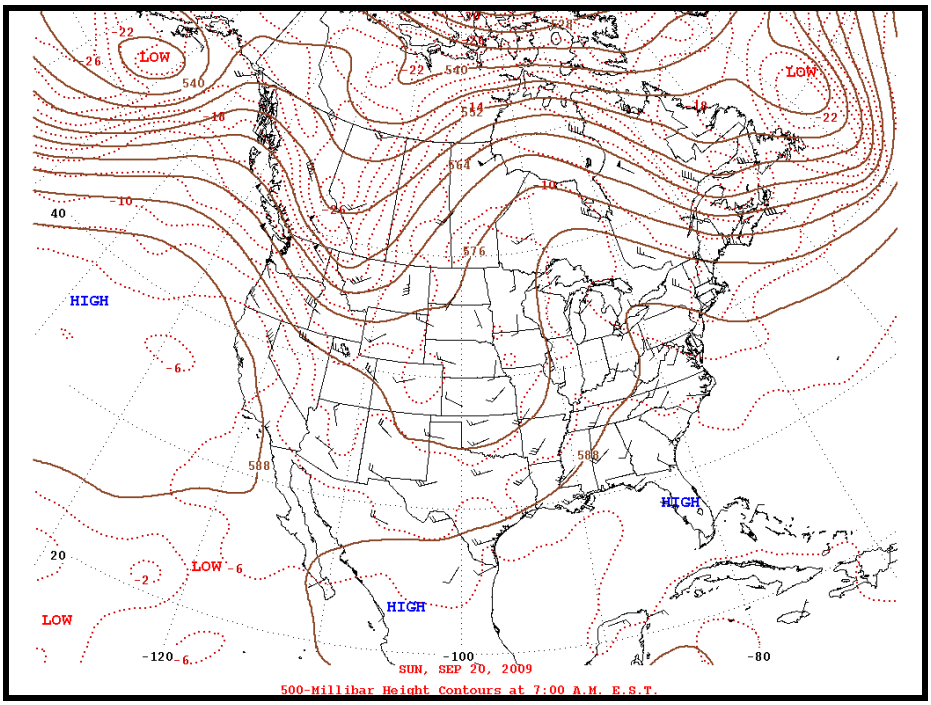


Figure 4. 500 mb Upper Level Map September 20, 2009, 1200 UTC.

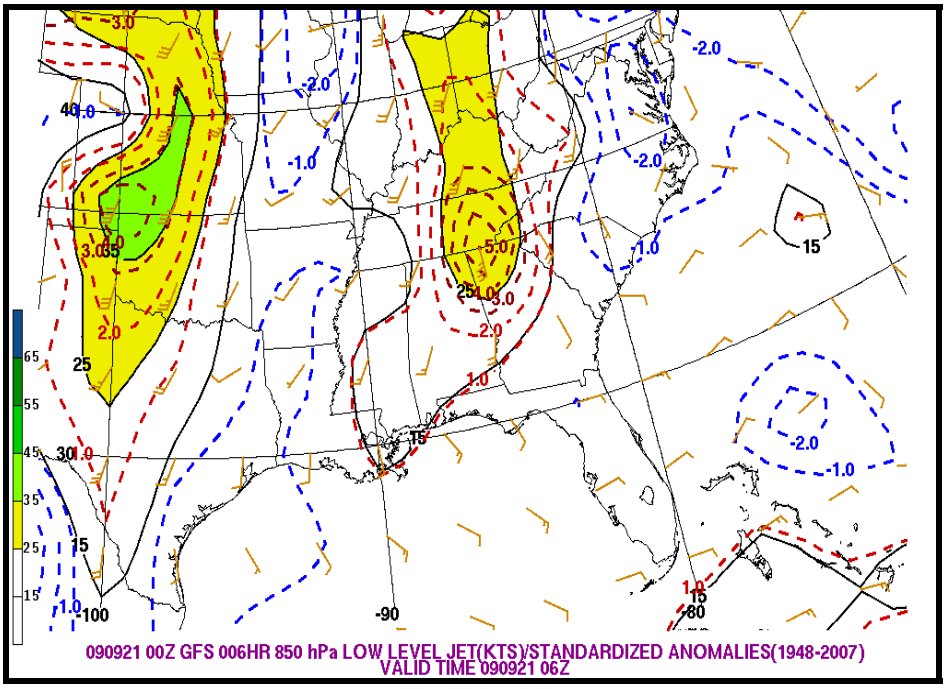


Figure 5. 850 mb Winds and Standardized Anomalies, September 21, 2009, 0600 UTC.

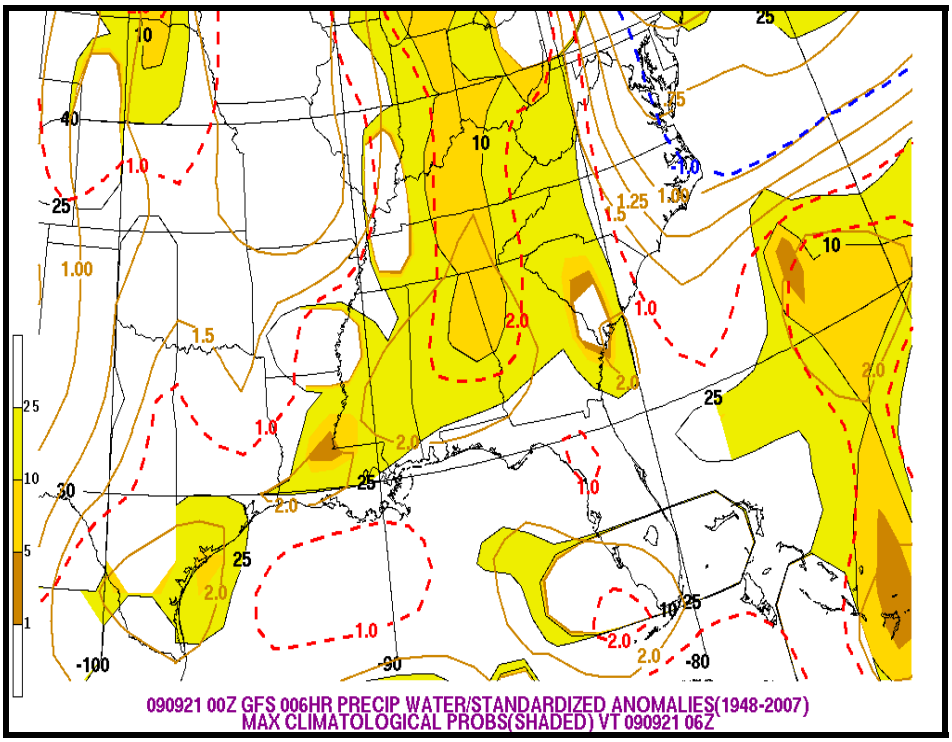


Figure 6. Precipitable Water and Standardized Anomalies, September 21, 2009, 0600 UTC.

Rain began falling across the region on September 15, 2009. Heavy rainfall began on September 17, 2009. Rainfall was nearly continuous across the region for six days, with periods of heavier rainfall interspersed. Heavy rainfall produced localized flash flooding from September 18 to September 23 and several weeks of river flooding across the area. The worst flooding occurred in the western and northeastern suburbs of metropolitan Atlanta, including

Douglas, Cobb, Paulding, Carroll, and Gwinnett counties. Rainfall estimates from the SERFC indicated a narrow band of extreme rainfall totals around 20 inches from September 18-23 in and near Atlanta (**Figure 7**). The heaviest rain fell from 8 p.m., September 20, through 8 p.m., September 21 (**Figure 8**).

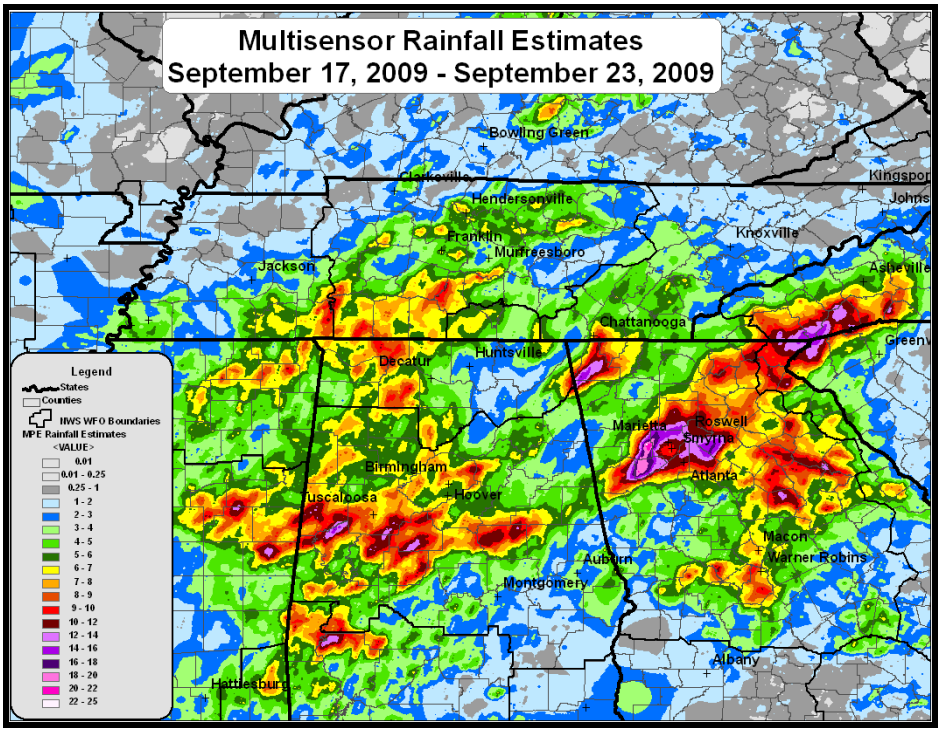


Figure 7. Multi-Sensor Precipitation Total for September 18-23, 2009

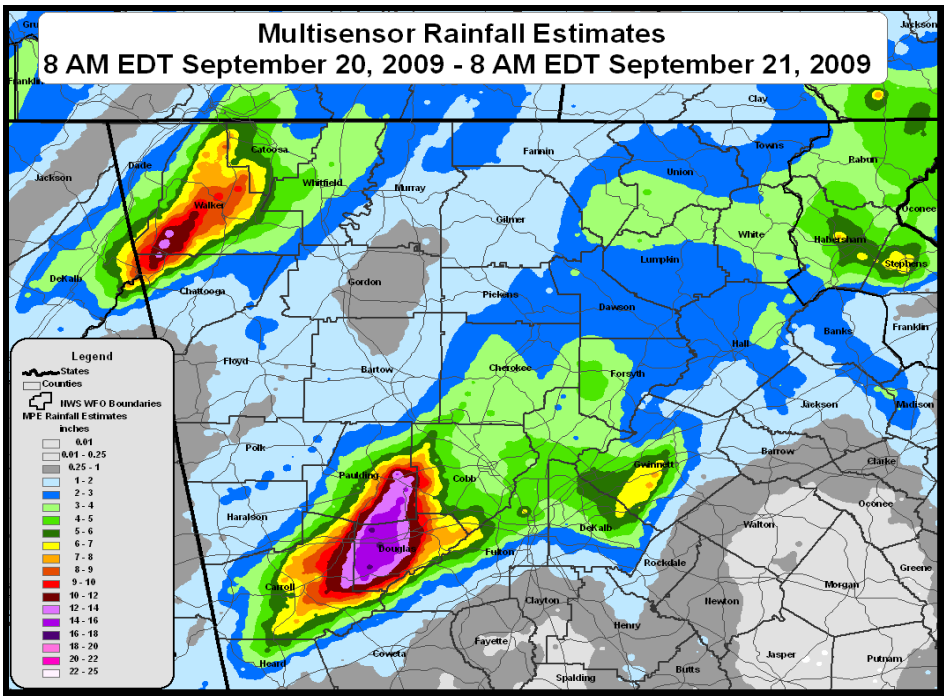


Figure 8. Multi-Sensor Precip. Total for 8 a.m. EDT, Sep. 20, to 8 a.m. EDT, Sep. 21, 2009.

Terrain was also a factor in this event. During the height of the event, September 20-21, southeast winds near the ground combined with moderately strong south to southwest flow 5,000 to 10,000 ft. in the atmosphere to maximize convergence along higher elevations in the western suburbs of Atlanta and in northwestern Georgia near Lookout Mountain. The heaviest rain, in northern Georgia, was closely associated with the elevation rise on the upslope side of the terrain (**Figures 9a and 9b**).

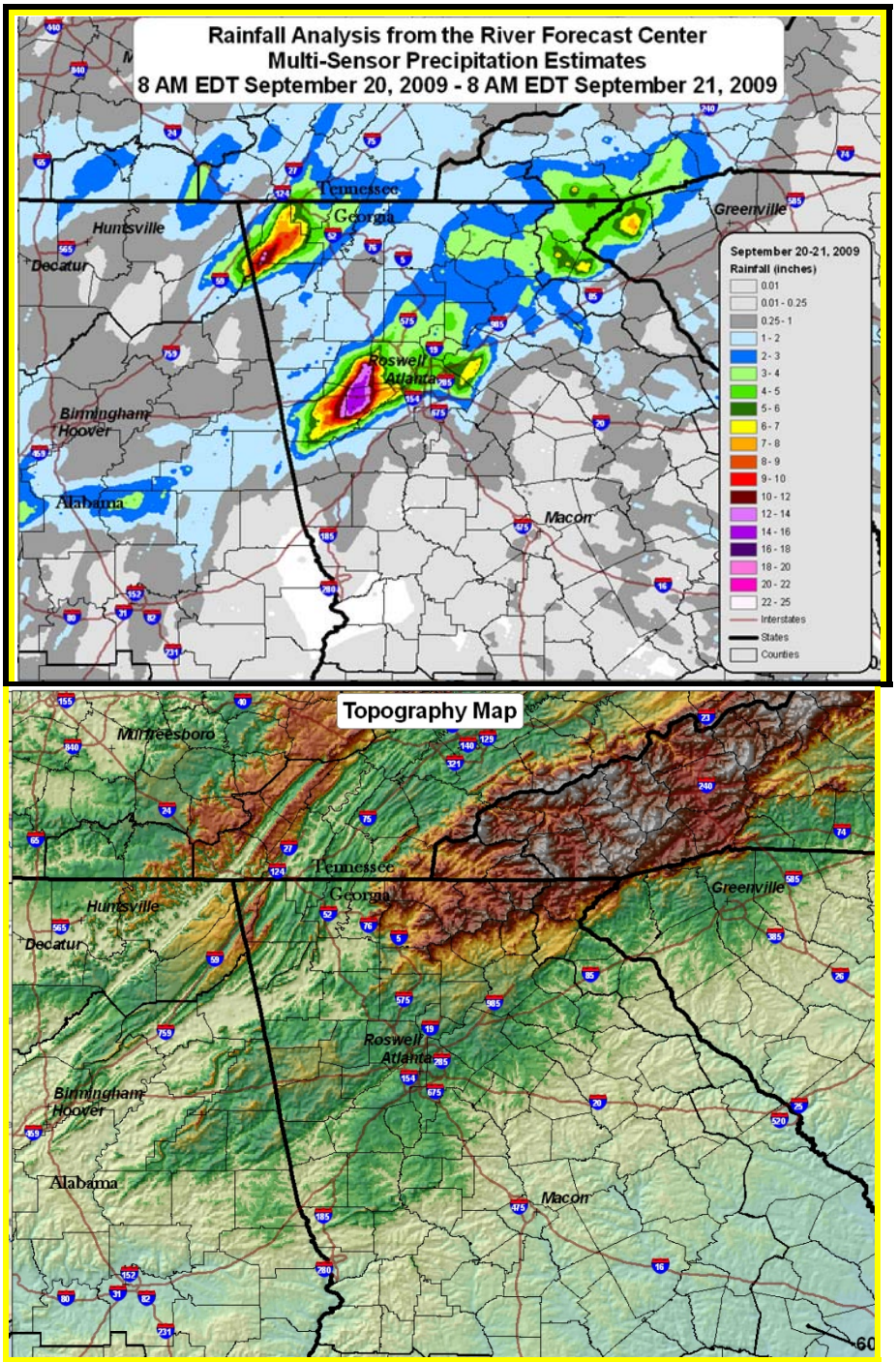
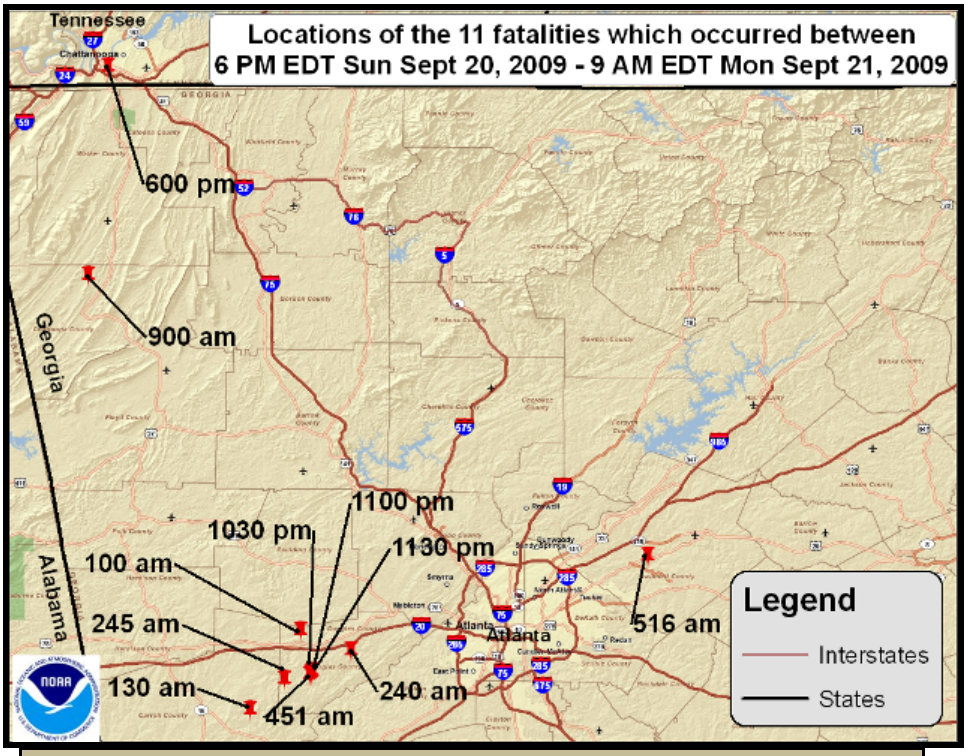


Figure 9a/b. Multi-Sensor 24-Hour Precipitation Total ending 9 a.m. EDT, September 21, 2009 compared with topography, below.

2.2. Impacts

All of the fatalities were caused by flash flooding and areal flooding. Most of the flash flooding occurred during the night of September 20, 2009, into the early morning hours of September 21, 2009. There were 10 fatalities reported in the Atlanta area. An additional fatality occurred near Chattanooga, TN, bringing the total count to 11 (**Figure 10**).



Flood Fatalities		
600 p.m. EDT	14th St. City Culvert-Chattanooga	Attempted swim
1030 p.m. EDT	Mobley Creek	Vehicle
1100 p.m. EDT	Pool Creek	Vehicle
1130 p.m. EDT	Mobley Creek	Vehicle
100 a.m. EDT	Town Branch	Vehicle
130 a.m. EDT	Snake Creek	In mobile home
240 a.m. EDT	Annewakee Creek	Vehicle
245 a.m. EDT	West Billy Creek	Vehicle
451 a.m. EDT	Dog River	Vehicle
516 a.m. EDT	Small Tributary of Yellow River	Vehicle
900 a.m. EDT	Chattooga River	Rescue attempt

Figure 10. Flood Fatalities across Southeastern Tennessee, Northern Georgia, and the Atlanta Metropolitan Area.

In addition to the fatalities, the most significant impacts included:

- Major flooding in Austell, GA, where 40 percent of the homes were damaged or destroyed, including pushing numerous homes off their foundations.
- Flash flood waters washed out a portion of train tracks near Mortar Creek in Autauga County, AL, resulting in a derailment of over 40 train cars causing around $1 million in damage.

- More than two dozen persons had to be rescued from their homes during early morning flash flooding in Brent, AL (Bibb County).
- Approximately 300 homes were damaged by flash floods in Stephens County, GA causing approximately $4.5 million in damages.
- Several residents required evacuation in Polk County, NC during the morning of September 20, 2009, as floodwaters rose. A motorist who drove into a flooded area needed to be rescued in Macon County, NC, during the evening of September 21, 2009.
- Widespread flooding around the South and West Chickamauga Creeks, TN damaged numerous businesses and necessitated rescues of several drivers after driving onto flooded roadways. Damages were estimated at $455,000.
- Road infrastructure was severely damaged in Catoosa, Douglas, and Walker counties, GA with estimates of over a year for road repairs. More than 40 roads in Douglas County, GA had sections that were completely washed out.
- Rescue personnel in Douglas and Paulding counties, GA had to rescue individuals from their vehicles stuck in flash flood waters. In addition to those vehicle rescues, in Catoosa, Douglas, Lumpkin, emergency personnel had to rescue individuals from their homes.
- Emergency response personnel were called in to perform rescues of people trapped in flooded cars in Baldwin, Carroll, and Paulding counties.

Broad portions of Alabama, northern Georgia, and western North Carolina recorded much above normal precipitation totals during the month of September in contrast with the remainder of the region, which was relatively dry. Numerous locations in northern Georgia registered the wettest September on record.

Initial property damage in Georgia was estimated at $250 million. This figure is expected to rise. Some 20,000 homes, businesses, and other buildings received major damage and 17 Georgia counties were declared Federal Disaster Areas. Of the 11 fatalities in the assessment area, the majority were a result of driving vehicles across flooded roads. Hundreds of people were rescued by boat from their homes and neighborhoods. The floodwaters posed significant impacts to transportation throughout the region. Hundreds of federal, state, and local roads were closed, including Interstates 20, 285, and 575.

These floods were historic, breaking records that go back as far as 1919. The area experienced 30 new record high flood levels. Nine additional sites reached crests in the top five of their highest recorded water levels. Many crests exceeded the 100 and even 500-year flood levels. Those levels have a 1 and 0.2 percent chance of exceedance in any given year (**Table 1**). Seven official NWS forecast points experienced major to record crests. Twenty U.S. Geological Survey (USGS) gages were inundated or damaged by flood waters during this event.

High water marks showed a peak stage at Sweetwater Creek near Austell, Georgia, more than 20 feet above flood stage and nearly nine feet above the previous recorded crest. The peak flow was more than double the previous flow record at this site. In Douglas County, the Dog River near Fairplay overtopped the USGS stream gage by 12 feet.

In the southwestern corner of North Carolina, rain caused 31 mud slides and debris flows and some localized flash flooding. The French Broad River at Blantyre began rising on the 20th,

flooding local roads as well as Highway 64. In Tennessee, South Chickamauga Creek began rising on the 21st and crested two days later, prompting evacuations and flooding homes and businesses. In Alabama, a 4-6 inch deluge on September 17-18 resulted in high water rescues and flooded streets, businesses, and homes in Birmingham. Another 4-6 inch event on September 18-19 in Tuscaloosa closed and washed out roads and overflowed culverts. DeKalb County, Alabama, recorded 5.5 inches of rain in a 3-hour period, resulting in closed roads and flooding in the city hall building.

Some comments on the flooding were noted by the assessment team. "The annual chance of a flood of this magnitude was so significantly less than 1 in 500 that, given the relatively short length of stream gauging records (well under 100 years), the USGS cannot accurately characterize the probability due to its extreme rarity," said Robert Holmes, USGS National Flood Program Coordinator. "If a 0.2 percent [500-year] flood was a cup of coffee, this one brewed a full pot," said Brian McCallum, Assistant Director for the USGS Georgia Water Science Center in Atlanta. "This flood overtopped 20 USGS stream gages–one by 12 feet. The closest numbers we have seen like these in Georgia were from Tropical Storm Alberto in 1994." "The flooding in Atlanta is certainly near the top of the list of the worst floods in the United States during the past 100 years," said Holmes. "For comparable drainage areas, the magnitude of this flood was worse than the 1977 Kansas City flood, which caused tremendous destruction and loss of life. It is a testament to the diligence of county officials and emergency management teams that more lives were not lost in Georgia."

2.3. River Flood Warnings and Forecasts for Major Flood Stage and Above

This event generated six major flood forecasts at NWS river forecast points in (or near) Atlanta and one near Chattanooga. The focus of the major river flooding was in the headwaters of the Chattahoochee and Etowah River basins and South Chickamauga Creek. The sites that reached major flood levels include Sweetwater Creek near Austell (AUSG1), Chattahoochee River at Vinings/Atlanta (VING1), Chattahoochee River at Whitesburg (WHTG1), Suwanee Creek near Suwanee (SWEG1), Etowah River near Cartersville (CTVG1), and Yellow River near Milstead (MYRG1) in Georgia and South Chickamauga Creek near Chattanooga, Tennessee (CHKT1) (**Figure 11**).

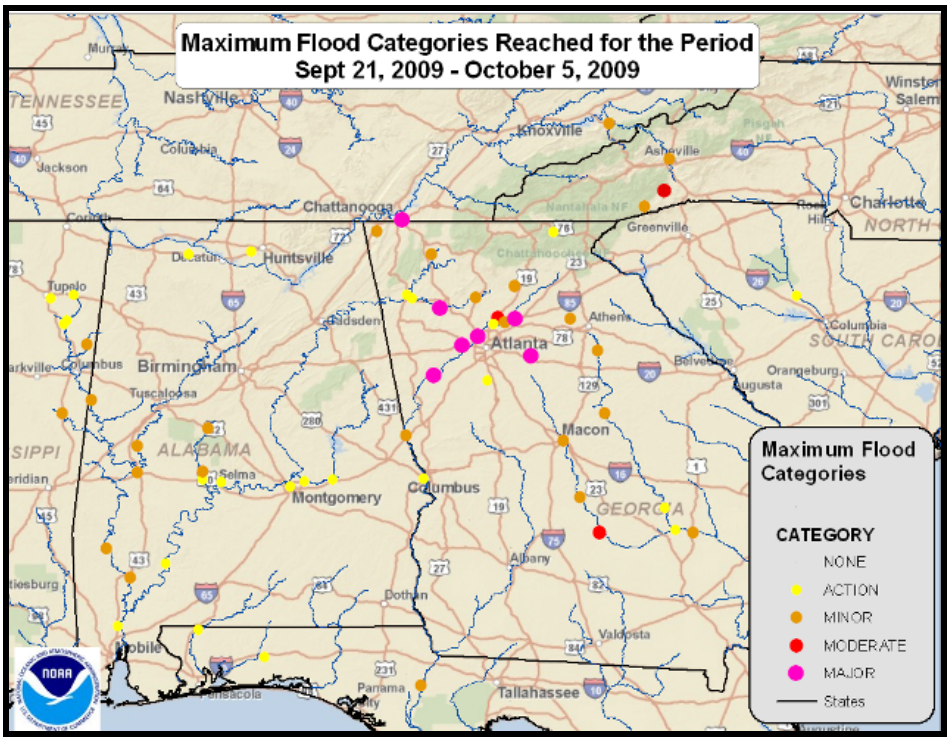


Figure 11. Forecast Points and Maximum Flood Categories Reached Due to Flooding During the Period September 21 – October 5, 2009.

Initial guidance, based on QPF valid from 1200 UTC, September 20, did not generate flood forecasts at these points. Initial guidance forecasts based on a combination of Quantitative Precipitation Estimates (QPE) and QPF between 0000-1200 UTC September 21 generated a major flood forecast of 18.6 feet on Sweetwater Creek at Austell where flood stage is 10 feet. Due to the flashy and headwater nature of many of these points, forecast lead time to major flood was about 24 hours (see Table 1). In the case of Sweetwater Creek near Austell, Georgia, where some of the worst river flooding occurred, SERFC was able to forecast a major flood in excess of 36 hours prior to crest; however, three forecast points had significant crest magnitude errors within 6 hours of the observed crest. The forecast for Austell was too low by almost 10 feet. This error partly was due to the absence of data. For Vinings, the crest was under forecast by 8 feet and for Suwanee Creek near Suwanee, the crest was under forecast by about 5 feet.

Forecast Point	Flood Stage (feet)	Major Flood Stage (feet)	36-Hour Forecast	24-Hour Forecast	12-Hour Forecast	6-Hour Forecast	3-Hour Forecast	Observed Crest
CHKT1	18.0	27.0	19.0	23.5	26.5	28.5	28.5	28.50
AUSG1	10.0	17.0	18.7	21.2	21.2	21.2	21.2	30.80
VING1	14.0	18.0	N/A	N/A	20.1	20.1	27.5	28.12
WHTG1	15.0	26.0	30.1	29.3	29.4	29.8	29.8	29.84
SWEG1	8.0	14.0	N/A	N/A	N/A	9.4	11.5	14.30
MYRG1	11.0	20.0	11.4	20.0	21.4	21.7	21.7	22.54
CTVG1	18.0	20.0	N/A	N/A	N/A	N/A	21.2	20.73

Table 1. Major Flood Forecasts and Official Crests for NWS RFC/WFO Forecast Points.

In addition, there were three WFO Peachtree City Site Specific Hydrologic Prediction System points (SSHPS) that reached major flood level. At Peachtree Creek in Atlanta, the maximum forecast was 25.0 feet, with a maximum observed crest of 23.89 feet. At Nancy Creek in Atlanta, the maximum forecast was 16.3 feet with the maximum observed crest of 14.69 feet; at Sope Creek in Marietta, the maximum forecast was 18.9 feet with the maximum observed crest of 18.35 feet. The time between the warning issuance and the time the three SSHPS points in the WFO Peachtree City area of responsibility reached major flood level was 4 hours for Peachtree Creek and Nancy Creek and about 1 hour for Sope Creek. These creeks usually crest within 6 hours of the end of heavy rainfall. SSHPS, utilized by WFO Peachtree City, performed well for these major to near record flood events.

Forecast Point	Flood Stage (feet)	Major Flood Stage (feet)	6-Hour Forecast	4-Hour Forecast	2-Hour Forecast	1-Hour Forecast	Observed Crest
AANG1	17.0	20.0	N/A	25.0	25.0	25.0	23.89
NCKG1	11.0	13.0	N/A	16.3	16.3	16.3	14.69
MARG1	12.0	18.0	N/A	13.2	16.5	18.9	18.35

Table 2. Major Flash Flood Forecasts/Official Crests for NWS WFO SSHP Forecast Points.

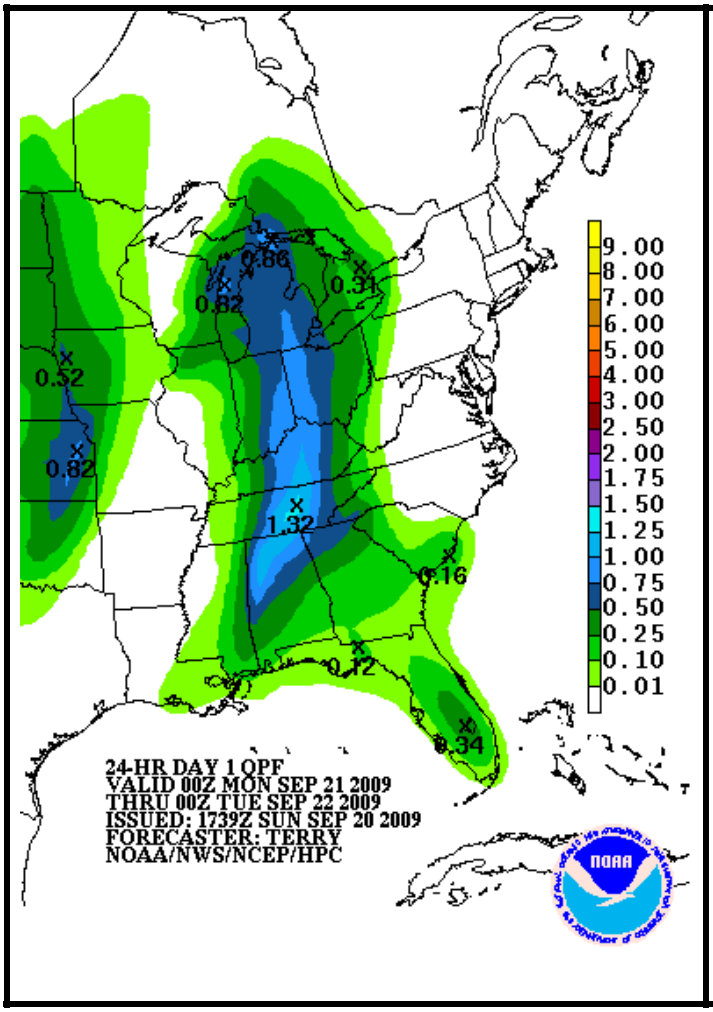
QPF was only somewhat helpful during these historic floods. QPE, especially the high resolution 4km data used at SERFC, offered significant help in forecasting these major floods. In addition, the SSHPS application played an important role in producing crest forecasts for critical hydrologic headwater points.

3. Facts, Findings, Recommendations, and Best Practices

3.1. Situational Awareness

Warning services, EM preparations, initial media coverage, and citizen response were all less than expected for an extreme, catastrophic flash flood and flood event. The rapid development of heavy rains over the affected areas was not anticipated in advance, resulting in reactive, rather than proactive, response. Flash flood/flood watches and warnings were issued in advance of flooding in almost all areas; however, all entities were unable to perceive the magnitude of the events until the flooding itself occurred.

Fact: When the heaviest rains, flash flooding, and fatalities occurred in northwestern Georgia, the HPC 24-hour QPFs covering the period 1200 Coordinated Universal Time (UTC) Sunday, September 20, through 1200 UTC, Monday, September 21, were for rainfall amounts between 0.5 and 1.0 inches. The Excessive Rainfall Potential Outlook did not identify any section of the country for excessive rainfall.



Excessive Rainfall Discussion issued 1833z
Sunday, September 20, 2009

...CNTRL GULF CST STATES INTO THE TN AND PTNS OF THE OH VLY...
NOT A LOT OF CHG IN THE SYNOPTIC PATN IS FCST FOR THIS PART OF THE COUNTRY THIS PD..AS MID/UPR LVL TROF OVR THE CNTRL STATES GETS RELOADED..RESULTING IN A CONTD SSWLY DEEP FLO REGIME DOWNSTREAM FM THE GULF CST STATES INTO THE GTLKS. IN THIS REGIME..VRY HI PWS WL PERSIST OVR THE GULF CST STATES AND TN VLY AND EXPAND NNEWD INTO PTNS OF THE OH VLY DURG THE PD ON BROAD AREA OF 20+ KTS OF SSWLY H85 FLO. MDL MASS FIELD SOLNS RMN IN GOOD AGREEMENT ON THIS SCENARIO..HOWEVER **CONFIDENCE STILL NOT REAL HI WITH THE QPF DETAILS GIVEN RECENT RATHER POOR MDL QPF PERFORMANCE AND CONTD DIFFS IN LATEST QPF SOLNS.** ALTHO PLENTY OF MSTR WL BE IN PLACE TO SUPPORT RNFL/CNVCTV DVLPMNT..LACK OF STG FORCING ESP ALOFT AND ONLY VRY WK BNDRYS TO FOCUS ACTIVITY AT THE SFC MAKE IT TOUGH TO PINPOINT WHERE THE HVIEST RAINS WL OCCUR. THERE IS A WK SFC LOW AND ACCOMPANYING WRMFNT THAT LIFT THRU THE TN VLY..OH VLY AND INTO THE GTLKS..SO WL TRY AND AT LEAST FOCUS AN AXIS OF HVIER RNFL WITH THEM..BUT WITH THE AXIS OF HVIER RNFL STILL EXTENDING SWD INTO AL IN HIEST PW BAND. **LACK OF CONFIDENCE IN WHERE THE HVIEST RAINS WL OCCUR IS PART OF THE REASON FOR NOT OUTLOOKING AN AREA**..BUT THREAT STILL EXISTS FOR SOME HVY TO VRY HVY RAINS IN AN AXIS FM CNTRL/NRN AL NNEWD INTO THE MID OH VLY. SOME 1-2 INCH RNFL AMTS IN A COUPLE OF HRS PSBL..WITH SOME ISOLD GTR THAN 2 INCH TOTALS PSBL THIS ENTIRE PD.

Figure 12. Excessive Rainfall Discussion issued 1833Z (2:33 p.m. EDT), Sunday, September 20, 2009.

Fact: Emergency managers received and acted upon NWS flash flood and flood warnings, per their local flood plans; however, they assumed "the usual" flood prone areas would be a problem, with "the usual" flood impacts. Initial NWS flash flood warnings and statements, using boilerplate warning format and generic call-to-action statements, gave no indication that these flash flood events would be much greater than usual. Webinar briefings have become very popular in Georgia, with EMs accustomed to receiving them prior to major weather events. The absence of phone call notifications from the NWS or conference call briefings in advance of the heavy rain led users to assume that nothing out of the ordinary was expected. Comments by Georgia County EMs include, "I don't think anybody expected to have the amount of rain we had. I think that caught all of us off guard," and "We're creatures of habit. We look back and we go, okay, if there's not a conference call, it must not be that bad."

Fact: Media representatives relayed the usual forecast and warning information, as had been done with flash flood and flood warnings issued on days prior to the heaviest rains. No extended news coverage was initiated until after fatalities were reported early Monday morning, September 21. The Sunday night fatalities were not reported by the media until early Monday morning.

Fact: Residents were largely aware of flash flood and flood warnings, but did not perceive any immediate danger to themselves or take extra precautionary measures. Some were desensitized to the threat by the numerous flash flood and flood warnings they had heard in the broadcast media during the days prior to the heaviest rain and flash flooding. One first responder performing rescue operations Sunday night (September 20-21) commented, "I could not believe the traffic … people got out in it for whatever reason."

Fact: Even when flash flooding and flooding began, and the public's perception of its severity increased, residents failed to realize the magnitude of the threat. EMs and residents seemed to have a mental model of what the worst-case scenario would be, which was far exceeded by this event. Many EMs based their assessment on their experience in 2005 with Hurricane Dennis, which was categorized in most areas as a 100-year event. One Austell, Georgia, business owner, whose business escaped flooding in 2005 and is above the high water mark from the 100-year Hurricane Dennis flood, commented, "It's not that I blew it off, I just didn't think it would affect us."

Finding 1: Forecasters effectively used flash flood guidance (FFG), radar precipitation estimates, and Flash Flood Monitoring and Prediction (FFMP) software to issue warnings in advance of flash flooding. Radar precipitation estimates indicated heavy rainfall rates, and some FFG was eventually exceeded by as much as 900 percent, but forecasters had limited historical context or tools to utilize to help put this information into impact perspective. Forecasters, therefore, did not initially recognize the extreme magnitude of the flash flooding.

Recommendation 1: The NWS should develop enhanced hydrometeorological monitoring and situational awareness tools to help forecasters recognize the extreme nature of unusual events by providing comparisons against critical values, historical events, and climatology, sending alerts when user-selected thresholds are reached. The system would be comparable to the way FFMP compares precipitation amounts to flash flood guidance and the River Gage Alert and Alarm program compares observed river stages to locally determined stage thresholds.

3.2. Decision Support

NWS is engaged in an aggressive effort to provide enhanced services beyond issuing forecast and warning products during high impact events. In partnership with EMs, other public safety officials, and government entities, NWS can provide weather information and consultation to help decision makers with preparedness and mitigation efforts.

Fact: Webinar briefing calls, provided by WFO Peachtree City, have become very popular with the EM community in Georgia. These event-driven calls and presentations are effective in circulating a consistent message about significant weather and flood events, and conveying the level of severity expected. WFO Morristown uses a combination of Webinar briefing calls and conference calls for collaboration.

Fact: WFOs Huntsville and Birmingham, Alabama, use the 800 MHz EM radio network in Alabama as a briefing tool in much the same way Webinar briefings are used in Georgia. WFO staff has tried Webinar briefings in Alabama but found the radio briefings were much preferred by the Alabama EM community.

Fact: WFO Greenville-Spartanburg does not conduct Webinar briefing calls in its County Warning Area (CWA). Georgia Counties in the Greenville-Spartanburg CWA participate in Georgia Emergency Management Agency (GEMA) briefing calls conducted by WFO Peachtree City, and find the briefings very helpful.

Fact: SERFC issued the first SERFC Alert! email product on Sunday, September 20, 2009. A briefing call regarding flood expectations, including a major flood at Austell, was conducted on Monday, September 21, with GEMA. Webinar briefings with an extensive group of partners/users commenced on Tuesday, September 22.

Finding 2: Decision-support activities were minimal at the onset of this mesoscale event, due to the heavy rain not being well forecast and significant flooding not anticipated. WFO-initiated decision-support phone calls, briefings, email alerts, etc., are typically conducted by members of the WFO management team during normal business hours. Few efforts were made to initiate these services during the weekend and night hours. SERFC and WFO staffing was augmented to handle the highest priority services (warnings) as described on the NWS Duty Priorities (see **Appendix C**) by holding over persons from a previous shift or calling in additional help.

Recommendation 2: The NWS Duty Priorities statement (**Appendix C**) should incorporate decision support as a top priority along with warning responsibility. NWS should conduct a comprehensive communication effort and training program to help employees make the transition from a product-oriented organization to a high impact and decision-support agency.

Best Practice 1: The SERFC is a leader in the development of innovative decision-support products. They issue the *SERFC Journal* email to interested subscribers two or three times per week. This publication conveys "the story behind the forecast," with discussions on flood climatology for the specific time of year, a description of a weather pattern change, and other topics of interest. SERFC also issues an event-driven *SERFC Alert!* email that describes rapidly developing hydrometeorological conditions, typically when flood conditions are forecast or severity level is upgraded. The GovDelivery subscriber service is used to manage distribution of the products. At the time of the assessment, the system had 1200 subscribers for the services.

Best Practice 2: In collaboration with WFO Peachtree City, which was providing full service backup for WFO Birmingham on Saturday, September 19, critical decision support was provided

prior to an Auburn football game on Saturday, September 19. Forecast information played a key role in the decision to delay the start of the televised football game by 30 minutes due to lightning and heavy rain.

Finding 3: Decision-support phone calls, briefings, graphical weather stories, email alerts, etc., are becoming an increasing part of the NWS suite of services. Because there is no NWS mandate to log or archive these important services, the local WFOs could provide minimal documentation of these decision-support services for this assessment area.

Recommendation 3: The NWS should address archival and documentation requirements for decision-support activities, which include phone calls, Webinars, graphical weather stories, narrated graphic-casts, chats, etc.

3.3. Products

HPC QPF products are prepared on a coarser resolution than that of the mesoscale heavy rain features that were involved in the assessment. Numerous WFO products were issued during the series of events according to NWS policies and product specifications.

Fact: Timely flash flood/flood watches, warnings, and statements were issued by WFOs in the assessment area before and during the period of heaviest rain and flooding. Performance measures indicate that flash flood warnings issued by the three offices that experienced most of the flash flooding during these events exceeded NWS Government Performance and Results Act (GPRA) goals in probability of detection (.90 goal) and lead time (49 minutes), with WFO Peachtree City average lead time of 103 minutes far exceeding the goal (see **Appendix F**). Each of the fatalities occurred in an area encompassed by an NWS Warning—two during areal flood warnings and 9 during flash flood warnings.

Fact: Observed precipitation was considerably greater than depicted in HPC QPF forecasts for the assessment area. Areas of heaviest rain associated with the flooding and fatalities were not depicted as areas of Slight (5 percent-10 percent) or greater risk of rainfall exceeding flash flood guidance on HPC Flash Flood Potential Outlooks.

Fact: Under routine operations, SERFC would have issued a total of 146 river forecasts in the WFOs Greenville-Spartanburg, Birmingham, and Peachtree City areas during the September 18-23 period. During this event for the three offices, SERFC issued 438 river forecasts. If LMRFC had been conducting routine operations, LMRFC would have issued a total of 84 river forecasts in the WFOs Huntsville, Greenville-Spartanburg, and Morristown areas during the September 18-23 period. During this event for the three offices, LMRFC issued 149 river forecasts.

Fact: NWS Instruction 10-922, *WFO Hydrologic Products Specification***,** dated August 17, 2009, authorizes use of a Flash Flood Emergency headline in Flash Flood Statements (FFS) when there is "clear evidence that people have been placed in life-threatening situations by rapidly rising floodwaters."

Fact: There was considerable confusion within the media and the public regarding the differences between areal flood, river flood, and flash flood. There was also confusion regarding the differences in content, format, and dissemination for products issued for different types of flooding. There was a general belief, however, that flash flooding was the most dangerous and life threatening.

Finding 4a: WFO warnings and statements generally contained standard Warngen template call-to-action statements and generic impact information that failed to convey the severity of the flash flood/flood events. EMs and media representatives wanted more specific impact information in statements, despite having difficulty with the long length and large number of the warnings issued. There was a strong desire to have more strongly worded impact information at the top of the statement where it would be more quickly noticed (see **Appendix D** as an example of a strongly worded statement issued by WFO Morristown, on Monday, September 21).

Finding 4b: Flash Flood Emergency headlines were not used by WFOs within the assessment area. WFO Louisville, Kentucky, a WFO outside this assessment area, effectively headlined a Flash Flood Statement with "Flash Flooding Emergency" on August 4, 2009 (see **Appendix E**).

Finding 4c: In a poll of some Central, Southern, and Eastern Region WFOs, few offices were aware of the NWS Instruction 10-922 authorizing use of a Flash Flood Emergency.

Recommendation 4: Warning statements should be as specific as possible regarding area and severity of impact. Warning polygons should be drawn with as many vertices as possible to encompass only the area truly affected. Warnings should not encompass an entire county if only a portion of the county will be impacted. Statements should include severity wording, i.e., flash flood emergency, life threatening, etc., when extreme events are anticipated or are occurring. Statements should reference commonly known benchmarks to better convey severity, i.e., higher levels than the 100-year flooding from Hurricane Dennis in 2005. Statements should be updated often to include reports of flooding and latest impact information.

Best Practice 3: WFO Huntsville meticulously outlined the flash flood warning polygon boundaries, adding extra polygon points to depict the precise warned area. This level of detail allowed DeKalb County, Alabama, EMs to limit the area alerted through reverse 911 notification calls.

Best Practice 4: Flash Flood Catalogue. WFO Greenville-Spartanburg has catalogued all flash flood events over the past 11 years into an easily accessible database in AWIPS and in operations area computers. The AWIPS data can be displayed as an overlay with context sensitive pop-up information depicting past rainfall rates and resulting impacts by small basins. These data also can be accessed as an AWIPS text file for easy inclusion in Warngen statements. WFO Birmingham has a binder with a section for each county depicting known flash flood locations along with information on rainfall rates that caused the flooding and the known impacts. (Note: Outside of this assessment area, WFO Salt Lake City is developing a flash flood database in Google Earth, which includes radar reflectivity and precipitation estimate loops associated with the flooding.)

Finding 5a: Media representatives in the WFO Peachtree City CWA noted that there were so many flash flood and flood (areal and river) warnings issued, and the statements so long, that during the peak of the event, there was too much information to convey via TV crawler messages. EMs and media, some of whom were receiving warning messages from multiple sources, noted it was difficult to sift through so many products to find essential impact information.

Finding 5b: WFO Peachtree City allowed flash flood warnings to expire and issued areal flood warnings on Monday, September 21, because flooding was persisting more than 6 hours beyond the causative event. Areal flood warnings are not sent with the NWR Specific Area Message Encoding (NWR-SAME) 1050Hz warning tone. The lack of tone alarm, and use of a product

that residents and EMs viewed as less life threatening than a flash flood warning, led some to believe the situation had decreased in severity.

Recommendation 5: A review of the current suite of NWS flash flood and flood products should be conducted. The review should consider: 1) how best to handle flash flooding that is expected to last more than 6 hours beyond the causative event, taking into account public perceptions of the severity of flash flooding vs. areal flooding, 2) the best use of Flash Flood Emergency, as a flash flood statement, as a separate flash flood product, or as a new emergency product that could be used for any type of weather emergency, and 3) changes to the text watch/warning product paradigm to serve customers more effectively, including possible separate "public" and "emergency professional" products, and products in a concise format for Smartphones. New methods and technology for warning dissemination must be considered, including Common Alerting Protocol (CAP) and Extensible Markup Language (XML) feeds.

Fact: Many national and local media outlets stated they were looking for Local Storm Reports (LSR) overnight September 20-21. WFOs did not send LSR products because they were unaware of the extent of the impacts—flooding, water rescues, and fatalities. One media representative stated, "I was kind of disappointed because we really didn't get any storm reports until later in the day, and that's what we monitor a lot."

Fact: This event posed an extreme operational challenge for the RFCs to produce specific flood crest forecasts with much lead time. This highly localized rainfall exceeding the 100 year recurrence interval, over headwater basins with crests well above existing rating curves, stretched the current state of hydrologic science predictability to its limit.

Fact: Sweetwater Creek at Austell, Georgia, (AUSG1) reached a record crest of 30.80 feet, 8.99 feet above the previous record of 21.81 feet and 9.6 feet above the forecast crest of 21.20 feet. Sweetwater Creek normally runs below 3 feet, with flood stage at 10 feet. Sweetwater Creek flooding caused extreme damage, damaging or destroying an estimated 40 percent of the homes in Austell and pushing numerous homes off their foundations.

Fact: Major flood forecasts were made for Austell, GA on Sweetwater Creek, and for Whitesburg, GA on the Chattahoochee River with 36 hour lead times, and a major flood forecast crest for Whitesburg, GA on the Chattahoochee River was forecast within a foot of observed with 36 hour lead time. Site Specific Hydrologic Prediction System forecasts issued by the WFOs provided skillful short-term headwater flood forecasts. RFC forecast hydrographs and crest forecasts for the two rivers where the greatest property damage occurred were considerably under forecast, with subsequent forecasts each nudging closer to the conditions eventually observed (see hydrographs, below).

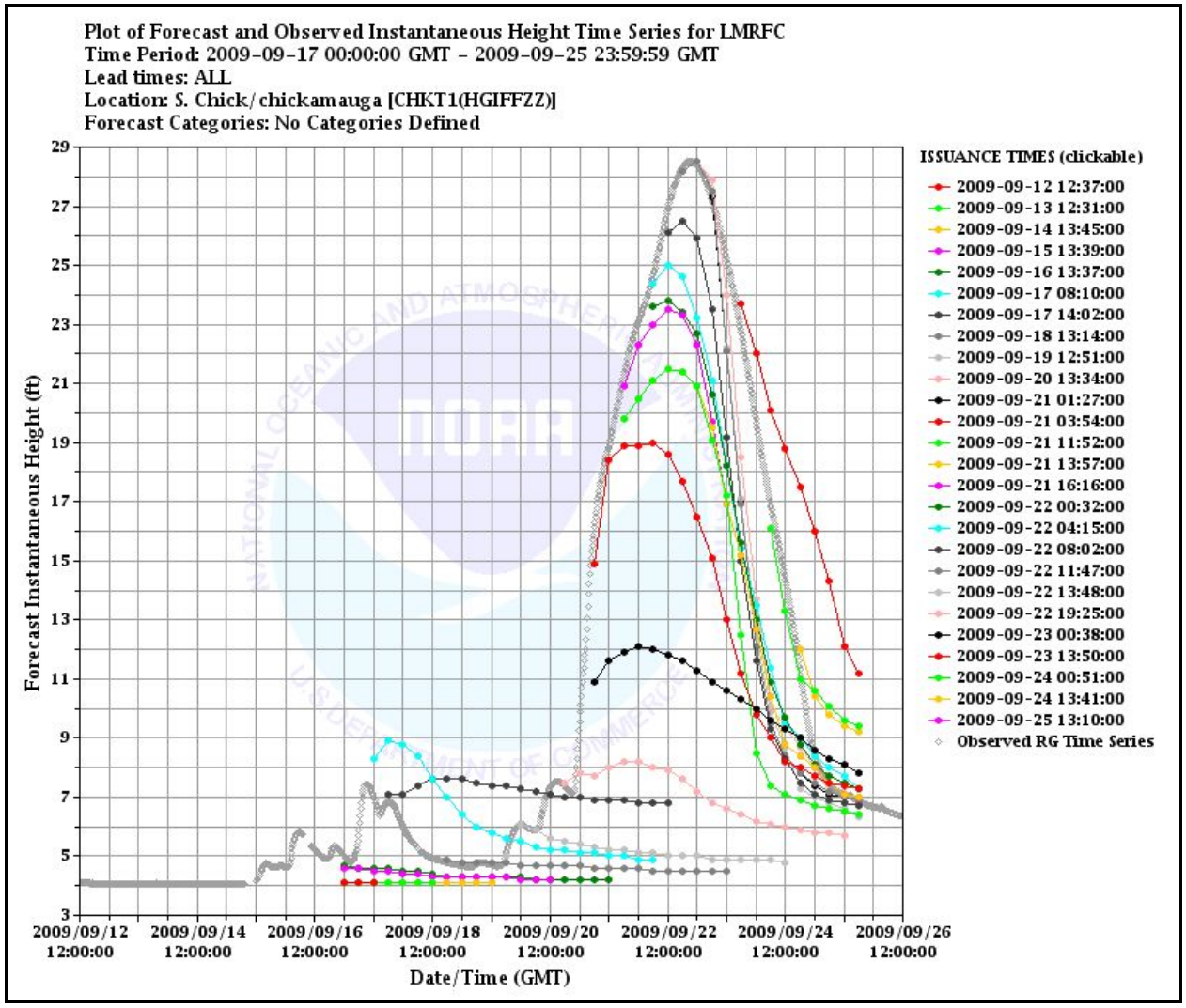


Figure 13. Plot of Forecast and Observed Instantaneous Height Time Series for Forecast Point CHKT1, South Chickamauga River near Chattanooga, TN.

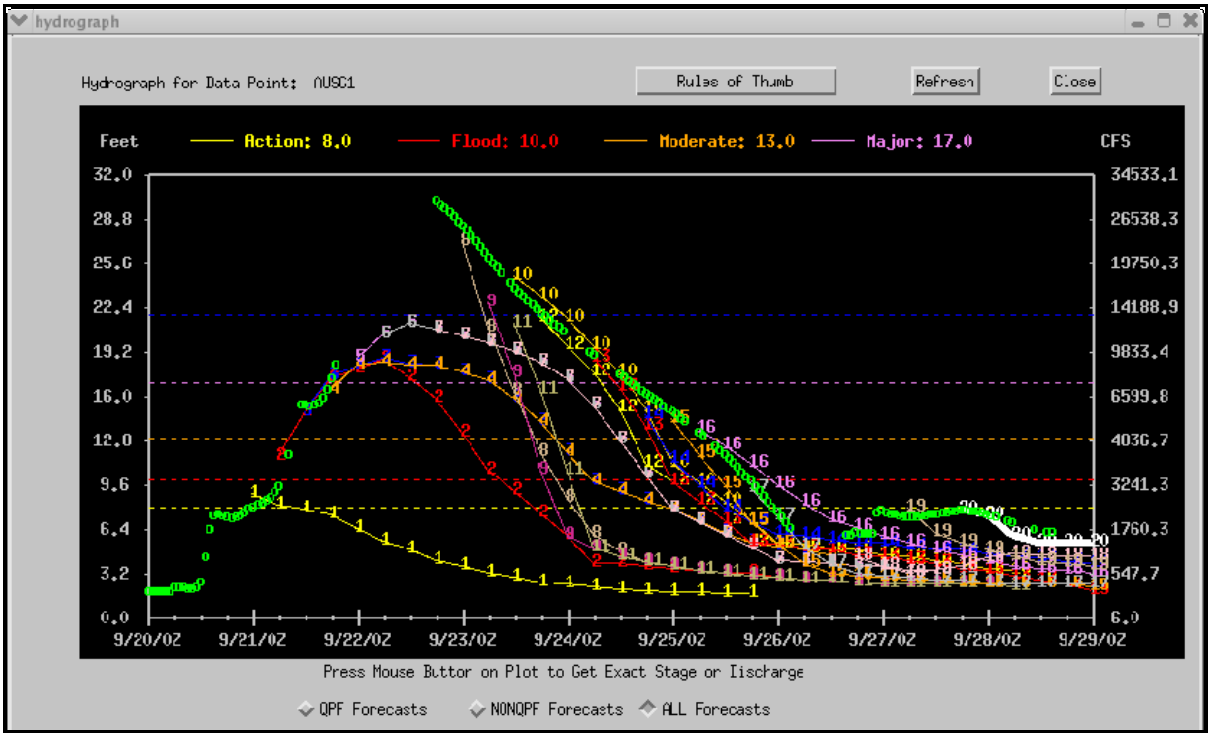


Figure 14. Plot of Forecast and Observed Instantaneous Height Time Series for Forecast Point AUSG1, Sweetwater Creek at Austell, GA.

Fact: The South Chickamauga Creek near Chattanooga, TN (CHKT1), reached its 2nd highest crest ever on September 22, causing major flooding. The crest of 28.54 feet at CHKT1 was under forecast by about 5 feet even within 18 hours of the observed crest.

Finding 6: Because the CHKT1 crest was under forecast, local government officials and residents were not prepared for the flooding. The EM community believes an additional river gage upstream of Chickamauga, as well as additional rainfall observation sites for the Chickamauga basin in northwestern Georgia, would lead to improved situational awareness and forecast quality at CHKT1.

Recommendation 6: WFO Morristown, Tennessee, LMRFC, and EMs should examine river and rainfall data needs for the South Chickamauga Creek in northern Georgia.

Fact: Even though there is a general definition of a flash flood in NWS Directives, NWS regions and WFOs differ in their local definitions. WFO Peachtree City issues a flash flood warning (FFW) for 6 inches or more of water flowing, caused by a stream or creek that must crest in 6 hours or less. WFO Peachtree City issues an areal flood warning (FLW) for the same criteria as a flash flood warning, except that areal flood warnings are issued for durations longer than 6 hours. WFO Birmingham defines an FFW as 6 inches or more of flowing water without any other criteria.

Finding 7: WFO Peachtree City issued a Public Information Statement stating that the September 2009 rainfall event was a 10,000 year event while the USGS stated the flood event was in excess of a 500 year event. The USGS policy is to not issue numbers in excess of 500-year events due to the limited amount of data.

Recommendation 7: The NWS should evaluate policy regarding terminology used to describe rare events to insure the information conveyed is statistically sound, and meaningful to partners and users. This should include an evaluation of the effectiveness of using probability of occurrence information (1 percent chance of occurrence) vs. expected return frequency information (100-year event).

Finding 8a: EMs expressed a concern about NWS warning credibility when some river stage readings exceeded forecast expectations in recently issued warnings.

Finding 8b: WFO Peachtree City forecasters delayed issuing some flood warnings until they had performed a quality assurance review of observed vs. predicted hydrographs and found 6-hour forecasts at or only a few tenths of a foot higher than current conditions. Forecasts were rerun by the SERFC before warnings were issued.

Recommendation 8: RFCs should implement automated quality assurance procedures to perform a cursory check of forecast hydrographs against observed conditions, flagging questionable forecasts before the forecasts are issued and posted on the Advanced Hydrologic Prediction Service (AHPS) Web pages.

3.4. Operational Practices

The prolonged period of heavy rains and flooding increased operational workloads at the RFCs and WFOs in the assessment area. The mesoscale nature of the rains limited predictability, resulting in a quick transition into warning mode. The onset of the heaviest rains and flooding occurred over a weekend and at night, further impacting operations.

Fact: RFCs across the country use anywhere from 6 hours to 10 days of QPF in routine river model runs. SERFC and LMRFC use 24 hours of QPF in river model runs, which sometimes results in hydrographs with receding trends when heavy rain is forecast 2 or 3 days out. For this reason, WFO Greenville-Spartanburg was displaying AHPS forecast hydrographs only out to 24 hours.

Finding 9a: Observed river stage information was 2 to 2.5 hours old on the AHPS Web page due to AHPS system posting delays.

Finding 9b: River forecasts are color-coded on WFO AHPS Web pages and the national Web site (water.weather.gov) at different time-scales than those on RFC Web pages. For example, RFCs color-code their forecast points for action through major flood stage to the length of their River Forecast products; however, the national Web page and WFO pages are color-coded to 48-hours. However, WFO Peachtree City AHPS pages display hydrographs out to 5 days, while WFO Greenville-Spartanburg was only displaying forecast hydrographs out to 24-hours, which is inconsistent with what the national page states: 48 hours.

Recommendation 9: NWS should review AHPS and all other Web displays of river forecast information to ensure forecasts are consistently depicted in terms of length of forecast projection and color coding of categories and stages from all weather.gov sources. NWS should ensure timely posting of observed river stage information to all weather.gov sources in concert with data updates from the USGS and other data providers.

Finding 10: There is no NWS Operations Directive or mandate requiring field offices to document shift leader decisions such as calling in extra staff, logging equipment problems, tracking coordination calls to other NWS centers or offices, etc., or tracking decision-support

services provided. The only suggestion for any such record keeping is in the Appendix of NWS Instruction (NWSI) 10-1607, *Office Evaluation*, dated June 27, 2008, which includes the following in the sample office evaluation checklist:

C. SHIFT LOGS

1. Are shift logs generated for each operational shift?
2. Are shift logs archived for 5 years?
3. Is an equipment Status board maintained in the operational area?

Recommendation 10: An appropriate NWS procedural directive needs to mandate whether a Shift Leader Log must be maintained, and what types of decisions/activities must be documented. If a log is required, the directive should mandate how long the office should keep the log as part of station records.

Fact: WFO Peachtree City had two staff members on extended sick leave during the period of heavy rains and flash flooding examined by this assessment.

Fact: WFO Peachtree City provided full service backup on Saturday, September 19, for WFO Birmingham, which experienced a major communication outage. WFO Peachtree City effectively issued several flash flood warnings, one severe thunderstorm warning, and the afternoon forecast grid package. Radar interpretation was provided to WFO Birmingham, which led to decision-support assistance noted in Best Practice 2.

Finding 11: Station Duty Manuals provided WFOs and the RFC with staffing level guidance. Shift Leaders augmented staffing to cover increased operational workload by holding over staff from the previous shift and bringing in additional help (see **Table 3** below for overtime used during the pay period encompassing the flash/flood event). The augmented night and weekend WFO staffing levels were adequate for providing basic forecast and warning services, but not for aggressively soliciting feedback reports on rain/flood impacts. There were an insufficient number of staff members to provide the full level of decision-support services typically available for a high impact event during normal weekday business hours when other administrative personnel would have been pressed into duty. EMs in Georgia feel they receive less service (fewer phone calls and timely data/updates) from WFO Peachtree City on weekends, which they attributed to the lower weekend staffing. The Mother's Day Tornadoes of May 11, 2008, and this flood event were cited as examples.

WFO Morristown	2.00 hours
WFO Huntsville	2.50 hours
WFO Birmingham	43.00 hours
WFO Peachtree City	117.00 hours
WFO Greenville-Spartanburg	62.75 hours
Southeast RFC	80.75 hours
Lower Mississippi RFC	44.50 hours

Table 3. Overtime Worked during Pay Period 19, 2009 at WFOs in the assessment area.

Recommendation 11: WFO staffing levels for significant flash flood events should be similar to those for severe weather events, including use of a Warning Coordinator position. A similar level of effort should be made to solicit feedback reports, including activation of HAM radio networks and provision of briefings and other decision-support services.

Best Practice 5: Since 2005, WFO Peachtree City has (re)surveyed every river gage in the CWA, including all non-forecast points, noting impacts for various river levels. WFO staff members accompanied the Service Hydrologist on many of these river gage site surveys for familiarization.

Fact: WFO Peachtree City has 17 SSHPS forecast points. In this event, three points were impacted including Peachtree Creek at Atlanta, Nancy Creek at Wesley Rd near Atlanta, and Sope Creek near Marietta. This tool assisted the WFO in generating specific flood warnings with greater lead time than if no model had been available; however, it would have helped to have multiple unit hydrographs available for various durations to allow for better timing of significant convective flood events. In addition, WFO Peachtree City uses SSHPS and RiverMonitor, but has not integrated SSHPS into RiverMonitor.

Finding 12: The loss of river gage data played a significant role in underestimating the river crest forecast for Sweetwater Creek near Austell (AUSG1). SERFC and WFO Peachtree City did not exhaust alternate means to infer reference river stage at Austell along Sweetwater Creek once the gage became inoperable.

Recommendation 12: The RFC and WFO should use alternate methods to assess river stage when automated gages fail. These methods include gathering on-site readings from the USGS, inferring stages from EMs, news reports of impacts (e.g., I-20 bridge closed due to the river rising to 27 feet), and webcam images, cross referencing them to NWS E-19s. Installation of low-cost staff gages may be a means to obtain backup river stage readings.

Fact: A high intensity Community Collaborative Rain, Hail, and Snow (CoCoRaHS) network report received during the night via an AWIPS alerted product helped a WFO Greenville-Spartanburg forecaster assess radar precipitation estimates, increasing confidence to issue a flash flood warning.

Fact: WFO Peachtree City did not call EMs to coordinate issuing a warning for a major flood at Austell (AUSG1), which was issued shortly after the onset of the rainfall event, based partly on QPF and SERFC forecaster assessment.

Fact: The Precipitation Potential Placement parameter available on AWIPS Display Two Dimensional (D2D) Volume Browser Supplemental assisted WFO Peachtree City in predicting areas and timing of heaviest rainfall and in issuing flood watches.

Fact: FFMP is routinely run by the WFOs in the assessment area and was effectively used during this event. Gridded Flash Flood Guidance is not updated at 06Z when RFCs are not in 24 -hour operations. SERFC staff stayed on duty Sunday night, September 20-21, 2009, and was able to provide updated Flash Flood Guidance (FFG). Increased reliance on FFMP and Gridded FFG has increased the need for updated Gridded FFG overnight during significant rain events.

Fact: SERFC found the new Next Generation MultiSensor QPE (Q2) Multi-sensor Precipitation Estimator (MPE) tool helpful in its effort to produce good MPE amounts.

Finding 13: Inability of numerical weather prediction, HPC, RFCs and WFOs to predict the location and magnitude of the heavy, mesoscale precipitation causing the flash flooding and flooding during this series of events, resulted in some significantly under forecast river hydrographs, and forecast crests and receding trends occurring well before the observed river crest.

Recommendation 13: Improving QPF and mesoscale rainfall prediction needs to be a top NWS research and training priority. WFO forecasters should use short-term, mesoscale precipitation estimation techniques to update QPF forecasts for flash flood forecasting and for RFCs to use when making short-term headwater river forecasts.

3.5. Warning Feedback

An important part of situational awareness for NWS forecasters during a weather event is to understand the severity of observed weather and flood conditions, and the societal impacts of those conditions. Such awareness helps a forecaster make forecast and warning adjustments, improves decision-support assistance, and provides essential impact information for follow-up statements that help residents validate the warning threat. When the NWS conveys this information, it improves the situational awareness of the entire user community.

Fact: Even though there were significant flood impacts, including water rescues, no city or county officials, or other EMs or first responders called WFO Peachtree City during the flash flooding on Sunday night, September 20-21, to report the severity of the impacts.

Fact: While Georgia county EMs did not relay flood impact to WFO Peachtree City on the night of September 20-21, some information was relayed to GEMA. This information included the flooding of water treatment plants and flooded and damaged roadways.

Fact: WFO Peachtree City first learned of a flash flood fatality about 8 hours after it occurred via a crawler on an early Monday morning TV newscast on its Situational Awareness Display.

Finding 14a: The lack of real-time feedback to WFO Peachtree City contributed to NWS forecasters, the media, and residents underestimating the magnitude of flash flooding. As one local TV meteorologist stated, “I would think if there had been one report from one county of a car being swept away and a drowning, then it would have changed the complexion of the whole night. The news media would have been on the alert from that point on.”

Finding 14b: Despite WFO Peachtree City outreach efforts and table top exercise participations where communications with the NWS offices was stressed, EMs generally were unaware of the NWS need for real-time feedback information during a major flood event. After a post-event meeting with the Service Assessment team, one EM summed up what he learned by saying, “One thing that I’m going to take away from this meeting, that I didn’t realize, is that you guys at the National Weather Service are looking for information coming back in to you guys. I don’t really know that we really realized that [information] is as critical as it is.”

Finding 14c: With the rapidly developing heavy rain and flash flooding in the assessment area, and with the event occurring at night, forecasters had little time to solicit feedback from affected counties. The calls to 911 centers were unproductive: “We’re too busy to talk to you.” EMs stated that 911 centers would normally not be good sources of feedback information due to their workload and concerns for confidentiality. Direct contact with the EMs, or an Emergency Operations Centers (EOC), where established, would be a better way to obtain information.

Best Practice 6: NWS offices in Alabama use the state 800 MHz radio system to interact with the EM community – a system that was already in place and widely accepted by the EM community. This system is effectively used to provide weather briefings, interaction with EMs, warning dissemination, and to solicit real-time reports on weather/flood impacts.

Fact: HAM radio networks were not used to solicit flood impact information during the flash flood/flood events of this assessment period.

Finding 14d: Flood severity and impact information was available on law enforcement radio (scanner traffic), Nixle community information service, HAM radio traffic, on Twitter and Facebook postings, and on the GEMAnet system.

Recommendation 14: The NWS has long used newspaper clipping services to obtain storm report information from print media. In a similar way, the NWS should explore use of public information systems (e.g., Nixle, EM networks), commercial or other electronic news sources for information. NWS should also use information automatically mined from social media sources such as Facebook and Twitter to infer real-time weather, flood, and societal impact information needed by forecasters. Such information would improve forecaster awareness and free time for decision-support activities.

Fact: NWS Internet based chat software (NWSChat) was effectively used in the Birmingham and Huntsville WFO areas during the heavy rain/flash flood events. NWSChat was running on forecaster computers in WFOs Peachtree City, Greenville-Spartanburg and Morristown during the flash flood events, but no communications were initiated by users/partners in these areas. These WFOs have promoted NWSChat, but it has not received the same acceptance as it has in Alabama. Some users access NWSChat to see warnings and information provided by the Bot (a computer program that interacts with each NWS WFO's chat room by routing brief summary messages containing links to complete NWS text products to each room on an as-needed basis), but not for individual communications. Many partners said they signed up for NWSChat after WFO outreach visits, but dropped off when their 60-day password expired.

Fact: Some NWSChat national partners, such as The Weather Channel, can observe NWSChat comments by others, but are blocked from inputting information to WFOs.

3.6. Warning Dissemination

Warning dissemination systems functioned properly during the period covered by this assessment.

Fact: NWR broadcast cycles at WFO Peachtree City became excessively long (more than 20 minutes) due to the number and length of warnings in effect. WFO personnel shortened the broadcast version of some warning statements to reduce program length.

Fact: Many residents said they owned an NWR receiver but did not have it turned on during the flood event. When asked why, the majority stated, “It goes off too often.”

Fact: Power and cable TV outages were common in significantly flooded areas. Users turned to Smartphones as an alternative method of receiving weather/flood information and warnings.

Fact: DeKalb County, Alabama, Emergency Management Agency (EMA) noted that WFO Huntsville stopped providing paging and text message notifications of warning information. This service was halted due to NOAANet security restrictions. EMA staff commented that the service had been very helpful and asked that NWS reinstate this service.

Fact: Community siren warning systems are typically used for tornado warnings only, not for other life threatening events such as flash flooding. This practice is to ensure siren warnings convey a single, consistent message to residents.

Finding 15a: Residents received warnings by a variety of methods, depending on their circumstances. Dissemination means varied from mass communications systems (media and NWR), to county warning systems (reverse-911 and personal notifications by law enforcement personnel), to personal communications methods (cell phone, Web access, text messages, and social media communications).

Finding 15b: Residents responded better to warnings communicated down to a personal level (e.g., evacuation notice, reverse-911call) than from mass communication methods. Few residents took action solely on warnings received via mass communications systems such as media and NWR. Warnings heightened citizen awareness, which led to subsequent personal validation of the warning threat before precautionary measures were taken.

Finding 15c: Residents have a low tolerance for missed warnings or false alarms when communications get down to a personal level. People quickly become disenchanted with telephone warnings and evacuation messages if no threat materializes. A DeKalb County staff person noted that 5,000 persons of the 65,000 county population had signed up for reverse 911 notifications. Of the 800 people that signed up for the service on one day, only four opted to be notified of flash flood warnings. An EM believes people did not sign up for flash flood warnings because flash flood warnings are issued more frequently than tornado warnings and most people do not believe they are directly threatened by flash flooding.

Fact: Social media, such as Facebook and Twitter, have become common means of information exchange among a growing segment of the population. Some residents first became aware of observed flooding and flood impacts from postings they received via these sources.

Finding 15d: Use of existing and emerging technologies and communication means (e.g., Facebook and Twitter), cell phone text messaging, and Interactive NWS (iNWS), could have improved the flow of information during this event.

Recommendation 15a: A variety of dissemination methods should be employed to provide the most effective warning notification system, with warnings in a format suitable for the dissemination means. No single dissemination method reaches everyone.

Recommendation 15b: The NWS needs to ensure new technologies and communications methods are more efficiently reviewed for potential NWS use, with suitable application promptly implemented.

3.7. Outreach

All WFOs in the assessment area have conducted aggressive outreach, in conjunction with the EM community, to educate residents on the usefulness of NWR and of the hazards of flash flooding. All county EMs contacted knew members of the local WFO by name, indicative of the strong outreach efforts by the WFOs.

Fact: WFO Morristown has a highly proactive outreach educational program. The WFO conducted nearly 40 outreach educational hydrology events and programs in 2009. The WFO also has a very active Turn around, Don't Drown (TADD) program and was assisting the EM community in applying for Walmart and State Farm grants to help purchase and place TADD signs in its CWA. Walmart has also helped with grants to purchase NWR receivers. WFO Huntsville has worked with all of its counties to acquire and place TADD signs that highlight flood prone areas.

Fact: WFO Peachtree City has 96 counties in its CWA. A close working relationship has been formed with the county emergency managers, despite the high number of those important partners.

Fact: NWR has been heavily promoted by the WFOs in the assessment areas and by EMs. As one EM expressed, "A NOAA Weather Radio is as essential as a smoke detector." Promotional efforts have been primarily directed toward severe weather notifications, where NWR use has gained its greatest acceptance.

Best Practice 7: A new Tennessee law adds driver license violation points for anyone who drives through a barricaded road. If a rescue has to be made, or the violation is in a commercial vehicle, additional points are added. New warning Call-to-Action statements were developed by the WFO Morristown's Senior Service Hydrologist to incorporate language from this law.

Fact: Public education efforts related to flash flood driving risks reduce the danger to drivers from flood related hazards. The TADD message seems to be reaching many residents.

Finding 16: Many of the fatalities occurred at night, in heavy rain, when visibility was poor. It was not evident that the victims were intentionally attempting to drive through water on the roadway; rather, they were likely blinded by the heavy rain. Drivers did not seem aware of the danger of driving at night, even though NWS had issued Flash Flood Warnings. One flood victim exclaimed in her 911 call as her car was being swept away in flash flood waters, "I didn't see the road, and my car stopped." An EM stated in an interview, "There were a lot of cars on the road. A lot of cars. And I was wondering why I wasn't the only car on the road. The only way I could see the road at 20 miles per hour was [because] my bright lights would catch the reflectors that were under water on Highway 5 going north. Flood warnings had been out all day—didn't make a bit of difference."

Recommendation 16: In addition to TADD, outreach must emphasize the danger of driving at night when limited visibility makes it difficult to discern a section of a roadway under water. The message is: If you can't see the road due to intense night rainfall, you should not drive. NWS should work with the Departments of Transportation and Education to include the hazards of driving in heavy rain as part of the driver training curriculum. Driver's license exams should include a question on driving and car buoyancy, and emphasize the dangers of driving at night in heavy rain where reduced visibility hinders a driver's ability to see the road and related road hazards.

Finding 17a: There is a perception by the EMs responsible for six Georgia counties within the Greenville-Spartanburg CWA that neighboring Georgia counties to their west, serviced by WFO Peachtree City, were given a higher quality of service. In addition, when considering all warnings issued by WFO Greenville-Spartanburg, one EM commented that warnings issued for South Carolina counties seemed to receive greater lead time for events than the six Georgia counties. An examination of warning statistics, by state, within the Greenville-Spartanburg CWA for the past 3 1/2 years (**Table 4**), however, did not support that perception. Lead times for tornadoes were actually higher for the six Georgia Counties than any other counties serviced by WFO Greenville-Spartanburg.

Counties	Combined Severe Events		Tornado Events		Flash Flood Events	
	POD	Lead Time	POD	Lead Time	POD	Lead Time
Georgia counties (6)	0.90	17.2 min	1.00	26.8 min	1.00	92.3 min
Number of events	154		4		3	
South Carolina counties (28)	0.90	17.7 min	0.95	13.6 min	0.85	22.6 min
Number of events	775		22		7	
North Carolina counties (12)	0.89	15.4 min	0.55	6.5 min	0.86	42.5 min
Number of events	1149		20		55	

Table 4. Warning Statistics by State within the Greenville-Spartanburg, SC CWA.

Finding 17b: Policy and practice differences between WFO Peachtree City and WFO Greenville-Spartanburg contributed to the service perception difference noted by the Georgia counties serviced by Greenville-Spartanburg. Popular Webinar briefings are provided by WFO Peachtree City but not by Greenville-Spartanburg. WFO Peachtree City issues Special Weather Advisories (Special Weather Statements) for sub-severe convection that Greenville-Spartanburg does not issue. NWS Eastern Region has not implemented the Significant Weather Advisory practice. Much of the service difference perception seemed to be a holdover of NWS Modernization and Associated Restructuring service changes, where these six Georgia Counties moved from the Atlanta Weather Service Forecast Office to Greenville-Spartanburg WFO.

Finding 17c: NWS Southern Region has adopted the practice of issuing Significant Weather Advisories for significant, non-severe convection, while NWS Eastern Region does not issue such advisories. This difference in practices contributed to the perception that Georgia counties serviced by Greenville-Spartanburg are not given the same level of service as adjacent counties in the Peachtree City CWA.

Finding 17d: EMs from North Carolina served by WFO Greenville-Spartanburg were pleased with their weather services. The EMs did not perceive any service difference compared to their neighboring South Carolina counties serviced by WFO Greenville-Spartanburg, even though recent verification statistics showed less skill for that area.

Recommendation 17a: WFO Greenville-Spartanburg should increase outreach efforts to the six Georgia Counties in its CWA. EMs viewed both the Service Assessment team's interest in visiting them, and interest by WFO Greenville-Spartanburg's new Warning Coordination Meteorologist, as positive developments, creating an opportunity to strengthen working relationships. Webinar briefings should be considered as a means of forecast coordination prior to significant weather events. WFO Peachtree City should invite WFO Greenville-Spartanburg to help prepare and conduct briefing calls in Georgia when an event may affect any of WFO Greenville-Spartanburg's Georgia counties.

Recommendation 17b: NWS Eastern Region should consider Significant Weather Advisories as a service option, especially for the portion of its service area that crosses into states served by NWS Southern Region.

Appendix A: Acronyms

AHPS	Advanced Hydrologic Prediction Service
AWIPS	Advanced Weather Interactive Processing System
BMX	Identifier for WFO Birmingham
cfs	Cubic Feet per Second
CAP	Common Alerting Protocol
CoCoRaHS	Community Collaborative Rain, Hail, and Snow Network
CWA	County Warning Area
D2D	Display Two Dimensions
EM	Emergency Management/Manager
EMA	Emergency Management Agency
EOC	Emergency Operations Center
ER	Eastern Region
FFC	Identifier for WFO Peachtree City
FFG	Flash Flood Guidance
FFMP	Flash Flood Monitoring and Prediction
FFS	Flash Flood Statement
FFW	Flash Flood Warning
FLS	Flood Statement
FLW	Flood Warning
GEMA	Georgia Emergency Management Agency
GPRA	Government Performance and Results Act
HPC	Hydrometeorological Prediction Center
HUN	Identifier for WFO Huntsville
Hz	hertz
iNWS	Interactive NWS, mobile weather service delivery
LMK	Identifier for WFO Louisville
LMRFC	Lower Mississippi River Forecast Center
LSR	Local Storm Report
mb	Millibar
MPE	Multisensor Precipitation Estimator
MSL	Mean Sea Level
MRX	Identifier for WFO Morristown
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
NWR	NOAA Weather Radio All Hazards
NWS	National Weather Service
NWSChat	NWS Chat - Internet based chat software
NWSI	National Weather Service Instruction
OCWWS	Office of Climate, Water and Weather Services
POD	Percentage of Detection
PW	Precipitable water
Q2	Next Generation Multisensor QPE
QPE	Quantitative Precipitation Estimation

QPF	Quantitative Precipitation Forecast
RFC	River Forecast Center
SAME	Specific Area Message Encoding
SERFC	Southeast River Forecast Center
SRH	Southern Region Headquarters
SSHPS	Site Specific Hydrologic Prediction System
TADD	Turn Around, Don’t Drown
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
UTC	Coordinated Universal Time
WarnGen	Warning Generation Software
WFO	Weather Forecast Office
XML	Extensible Markup Language

Appendix B: Recommendations, Findings and Best Practices

Definitions

Best Practice—An activity or procedure that has produced outstanding results during a particular situation that could be used to improve effectiveness and/or efficiency throughout the organization in similar situations. No action is required.

Fact—A statement that describes something important learned from the assessment for which no action is necessary. Facts are not numbered, but often lead to recommendations.

Finding—A statement that describes something important learned from the assessment for which an action may be necessary. Findings are numbered in ascending order and are associated with a specific recommendation or action.

Recommendation—A specific course of action, which should improve NWS operations and services, based on an associated finding. Not all recommendations may be achievable but they are important to document. If the affected office(s) and OCWWS determine a recommendation will improve NWS operations and/or services, and it is achievable, the recommendation will likely become an action. Recommendations should be clear, specific, and measurable.

Findings and Recommendations

Finding 1: Forecasters effectively used flash flood guidance (FFG), radar precipitation estimates, and Flash Flood Monitoring and Prediction (FFMP) software to issue warnings in advance of flash flooding. Radar precipitation estimates indicated heavy rainfall rates, and some FFG was eventually exceeded by as much as 900 percent, but forecasters had limited historical context or tools to utilize to help put this information into impact perspective. Forecasters, therefore, did not initially recognize the extreme magnitude of the flash flooding.

Recommendation 1: The NWS should develop enhanced hydrometeorological monitoring and situational awareness tools to help forecasters recognize the extreme nature of unusual events by providing comparisons against critical values, historical events, and climatology, sending alerts when user-selected thresholds are reached. The system would be comparable to the way FFMP compares precipitation amounts to flash flood guidance and the River Gage Alert and Alarm program compares observed river stages to locally determined stage thresholds.

Finding 2: Decision-support activities were minimal at the onset of this mesoscale event, due to the heavy rain not being well forecast and significant flooding not anticipated. WFO-initiated decision-support phone calls, briefings, email alerts, etc., are typically conducted by members of the WFO management team during normal business hours. Few efforts were made to initiate these services during the weekend and night hours. SERFC and WFO staffing was augmented to handle the highest priority services (warnings) as described on the NWS Duty Priorities (see **Appendix C**) by holding over persons from a previous shift or calling in additional help.

Recommendation 2: The NWS Duty Priorities statement (**Appendix C**) should incorporate decision support as a top priority along with warning responsibility. NWS should conduct a comprehensive communication effort and training program to help employees make the transition from a product-oriented organization to a high impact and decision-support agency.

Finding 3: Decision-support phone calls, briefings, graphical weather stories, email alerts, etc., are becoming an increasing part of the NWS suite of services. Because there is no NWS mandate to log or archive these important services, the local WFOs could provide minimal documentation of these decision-support services for this assessment area.

Recommendation 3: The NWS should address archival and documentation requirements for decision-support activities, which include phone calls, Webinars, graphical weather stories, narrated graphic-casts, chats, etc.

Finding 4a: WFO warnings and statements generally contained standard Warngen template call-to-action statements and generic impact information that failed to convey the severity of the flash flood/flood events. EMs and media representatives wanted more specific impact information in statements, despite having difficulty with the long length and large number of the warnings issued. There was a strong desire to have more strongly worded impact information at the top of the statement where it would be more quickly noticed (see **Appendix D** as an example of a strongly worded statement issued by WFO Morristown, on Monday, September 21).

Finding 4b: Flash Flood Emergency headlines were not used by WFOs within the assessment area. WFO Louisville, Kentucky, a WFO outside this assessment area, effectively headlined a Flash Flood Statement with "Flash Flooding Emergency" on August 4, 2009 (see **Appendix E**).

Finding 4c: In a poll of some Central, Southern and Eastern Region WFOs, few offices were aware of the NWS Instruction 10-922 authorizing use of a Flash Flood Emergency.

Recommendation 4: Warning statements should be as specific as possible regarding area and severity of impact. Warning polygons should be drawn with as many vertices as possible to encompass only the area truly affected. Warnings should not encompass an entire county if only a portion of the county will be impacted. Statements should include severity wording, i.e., flash flood emergency, life threatening, etc., when extreme events are anticipated or are occurring. Statements should reference commonly known benchmarks to better convey severity, i.e., higher levels than the 100-year flooding from Hurricane Dennis in 2005. Statements should be updated often to include reports of flooding and latest impact information.

Finding 5a: Media representatives in the WFO Peachtree City CWA noted that there were so many flash flood and flood (areal and river) warnings issued, and the statements so long, that during the peak of the event, there was too much information to convey via TV crawler messages. EMs and media, some of whom were receiving warning messages from multiple sources, noted it was difficult to sift through so many products to find essential impact information.

Finding 5b: WFO Peachtree City allowed flash flood warnings to expire and issued areal flood warnings on Monday, September 21, because flooding was persisting more than 6 hours beyond the causative event. Areal flood warnings are not sent with the NWR Specific Area Message Encoding (NWR-SAME) 1050Hz warning tone. The lack of tone alarm, and use of a product that residents and EMs viewed as less life threatening than a flash flood warning, led some to believe the situation had decreased in severity.

Recommendation 5: A review of the current suite of NWS flash flood and flood products should be conducted. The review should consider 1) how best to handle flash flooding that is expected to last more than 6 hours beyond the causative event, taking into account public perceptions of the severity of flash flooding vs. areal flooding: 2) the best use of Flash Flood Emergency, as a flash flood statement, as a separate flash flood product, or as a new emergency product that could be used for any type of weather emergency: and 3) changes to the text watch/warning product paradigm to serve customers more effectively, including possible separate "public" and "emergency professional" products, and products in a concise format for Smartphones. New methods and technology for warning dissemination must be considered, including Common Alerting Protocol (CAP), and Extensible Markup Language (XML) feeds.

Finding 6: Because the CHKT1 crest was under forecast, local government officials and residents were not prepared for the flooding. The EM community believes an additional river gage upstream of Chickamauga, as well as additional rainfall observation sites for the Chickamauga basin in northwestern Georgia, would lead to improved situational awareness and forecast quality at CHKT1.

Recommendation 6: WFO Morristown, Tennessee, LMRFC, and EMs should examine river and rainfall data needs for the South Chickamauga Creek in northern Georgia.

Finding 7: WFO Peachtree City issued a Public Information Statement stating that the September 2009 rainfall event was a 10,000 year event while the USGS stated the flood event was in excess of a 500 year event. The USGS policy is to not issue numbers in excess of 500-year events due to the limited amount of data.

Recommendation 7: The NWS should evaluate policy regarding terminology used to describe rare events to insure the information conveyed is statistically sound, and meaningful to partners and users. This should include an evaluation of the effectiveness of using probability of occurrence information (1% chance of occurrence) vs. expected return frequency information (100-year event).

Finding 8a: EMs expressed a concern about NWS warning credibility when some river stage readings exceeded forecast expectations in recently issued warnings.

Finding 8b: WFO Peachtree City forecasters delayed issuing some flood warnings until they had performed a quality assurance review of observed vs. predicted hydrographs and found 6-hour forecasts at or only a few tenths of a foot higher than current conditions. Forecasts were rerun by the SERFC before warnings were issued.

Recommendation 8: RFCs should implement automated quality assurance procedures to perform a cursory check of forecast hydrographs against observed conditions, flagging questionable forecasts before the forecasts are issued and posted on the Advanced Hydrologic Prediction Service (AHPS) Web pages.

Finding 9a: Observed river stage information was 2 to 2.5 hours old on the AHPS Web page due to AHPS system posting delays.

Finding 9b: River forecasts are color-coded on WFO AHPS Web pages and the national Web site (water.weather.gov) at different time-scales than those on RFC Web pages. For example, RFCs color-code their forecast points for action through major flood stage to the length of their River Forecast products; however, the national Web page and WFO pages are color-coded to 48-hours. However, WFO Peachtree City AHPS pages display hydrographs out to five days,

while WFO Greenville-Spartanburg was only displaying forecast hydrographs out to 24-hours, which is inconsistent with what the national page states: 48 hours.

Recommendation 9: NWS should review AHPS and all other Web displays of river forecast information to ensure forecasts are consistently depicted in terms of length of forecast projection and color coding of categories and stages from all weather.gov sources. NWS should ensure timely posting of observed river stage information to all weather.gov sources in concert with data updates from the USGS and other data providers.

Finding 10: There is no NWS Operations Directive or mandate requiring field offices to document shift leader decisions such as calling in extra staff, logging equipment problems, tracking coordination calls to other NWS centers or offices, etc., or tracking decision-support services provided. The only suggestion for any such record keeping is in the Appendix of NWS Instruction (NWSI) 10-1607, *Office Evaluation*, dated June 27, 2008, which includes the following in the sample office evaluation checklist:

C. SHIFT LOGS

1. Are shift logs generated for each operational shift?
2. Are shift logs archived for 5 years?
3. Is an equipment Status board maintained in the operational area?

Recommendation 10: An appropriate NWS procedural directive needs to mandate whether a Shift Leader Log must be maintained, and what types of decisions/activities must be documented. If a log is required, the directive should mandate how long the office should keep the log as part of station records.

Finding 11: Station Duty Manuals provided WFOs and the RFC with staffing level guidance. Shift Leaders augmented staffing to cover increased operational workload by holding over staff from the previous shift and bringing in additional help (see **Table 3** for overtime used during the pay period encompassing the flash/flood event). The augmented night and weekend WFO staffing levels were adequate for providing basic forecast and warning services but not for aggressively soliciting feedback reports on rain/flood impacts. There were an insufficient number of staff members to provide the full level of decision-support services typically available for a high impact event during normal weekday business hours when other administrative personnel would have been pressed into duty. EMs in Georgia feel they receive less service (fewer phone calls and timely data/updates) from WFO Peachtree City on weekends, which they attributed to the lower weekend staffing. The Mother's Day Tornadoes of May 11, 2008, and this flood event were cited as examples.

Recommendation 11: WFO staffing levels for significant flash flood events should be similar to those for severe weather events, including use of a Warning Coordinator position. A similar level of effort should be made to solicit feedback reports, including activation of HAM radio networks and provision of briefings and other decision-support services.

Finding 12: The loss of river gage data played a significant role in underestimating the river crest forecast for Sweetwater Creek near Austell (AUSG1). SERFC and WFO Peachtree City did not exhaust alternate means to infer reference river stage at Austell along Sweetwater Creek once the gage became inoperable.

Recommendation 12: The RFC and WFO should use alternate methods to assess river stage when automated gages fail. These methods include gathering on-site readings from the USGS, inferring stages from EMs, news reports of impacts (e.g., I-20 bridge closed due to the river rising to 27 feet), and webcam images, cross referencing them to NWS E-19s. Installation of low-cost staff gages may be a means to obtain backup river stage readings.

Finding 13: Inability of numerical weather prediction, HPC, RFCs and WFOs to predict the location and magnitude of the heavy, mesoscale precipitation causing the flash flooding and flooding during this series of events, resulted in some significantly under forecast river hydrographs, and forecast crests and receding trends occurring well before the observed river crest.

Recommendation 13: Improving QPF and mesoscale rainfall prediction needs to be a top NWS research and training priority. WFO forecasters should use short-term, mesoscale precipitation estimation techniques to update QPF forecasts for flash flood forecasting and for RFCs to use when making short-term headwater river forecasts.

Finding 14a: The lack of real-time feedback to WFO Peachtree City contributed to NWS forecasters, the media, and residents underestimating the magnitude of flash flooding. As one local TV meteorologist stated, “I would think if there had been one report from one county of a car being swept away and a drowning, then it would have changed the complexion of the whole night. The news media would have been on the alert from that point on.”

Finding 14b: Despite WFO Peachtree City outreach efforts and table top exercise participations where communications with the NWS offices was stressed, EMs generally were unaware of the NWS need for real-time feedback information during a major flood event. After a post-event meeting with the Service Assessment team, one EM summed up what he learned by saying, “One thing that I’m going to take away from this meeting, that I didn’t realize, is that you guys at the National Weather Service are looking for information coming back in to you guys. I don’t really know that we really realized that [information] is as critical as it is.”

Finding 14c: With the rapidly developing heavy rain and flash flooding in the assessment area, and with the event occurring at night, forecasters had little time to solicit feedback from affected counties. The efforts made to call 911 centers were unproductive: “We’re too busy to talk to you.” EMs stated that 911 centers would normally not be good sources of feedback information due to their workload and concerns for confidentiality. Direct contact with the EMs, or an Emergency Operations Centers (EOC), where established, would be a better way to obtain information.

Finding 14d: Flood severity and impact information was available on law enforcement radio (scanner traffic), Nixle community information service, HAM radio traffic, on Twitter and Facebook postings, and on the GEMAnet system.

Recommendation 14: The NWS has long used newspaper clipping services to obtain storm report information from print media. In a similar way, the NWS should explore use of public information systems (e.g., Nixle, EM networks), commercial or other electronic news sources for information. NWS should also use information automatically mined from social media sources such as Facebook and Twitter to infer real-time weather, flood and societal impact information needed by forecasters. Such information would improve forecaster awareness and free time for decision-support activities.

Finding 15a: Residents received warnings by a variety of methods, depending on their circumstances. Dissemination means varied from mass communications systems (media and NWR), to county warning systems (reverse-911 and personal notifications by law enforcement personnel), to personal communications methods (cell phone, Web access, text messages, and social media communications).

Finding 15b: Residents responded better to warnings communicated down to a personal level (e.g., evacuation notice, reverse-911call) than from mass communication methods. Few residents took action solely on warnings received via mass communications systems such as media and NWR. Warnings heightened citizen awareness, which led to subsequent personal validation of the warning threat before precautionary measures were taken.

Finding 15c: Residents have a low tolerance for missed warnings or false alarms when communications get down to a personal level. People quickly become disenchanted with telephone warnings and evacuation messages if no threat materializes. A DeKalb County staff person noted that 5000 persons of the 65,000 county population had signed up for reverse 911 notifications. Of the 800 people that signed up for the service on one day, only four opted to be notified of flash flood warnings. An EM believes people did not sign up for flash flood warnings because flash flood warnings are issued more frequently than tornado warnings and most people do not believe they are directly threatened by flash flooding.

Finding 15d: Use of existing and emerging technologies, and communication means (e.g., Facebook and Twitter), cell phone text messaging, and Interactive NWS (iNWS), could have improved the flow of information during this event.

Recommendation 15a: A variety of dissemination methods should be employed to provide the most effective warning notification system, with warnings in a format suitable for the dissemination means. No single dissemination method reaches everyone.

Recommendation 15b: The NWS needs to ensure new technologies and communications methods are more efficiently reviewed for potential NWS use, with suitable application promptly implemented.

Finding 16: Many of the fatalities occurred at night, in heavy rain, when visibility was poor. It was not evident that the victims were intentionally attempting to drive through water on the roadway; rather, they were blinded by the heavy rain. Drivers did not seem aware of the danger of driving at night, even though NWS had issued Flash Flood Warnings. One flood victim exclaimed in her 911 call as her car was being swept away in flash flood waters, “I didn’t see the road, and my car stopped.” An EM stated in an interview, “There were a lot of cars on the road. A lot of cars. And I was wondering why I wasn’t the only car on the road. The only way I could see the road at 20 miles per hour was [because] my bright lights would catch the reflectors that were under water on Highway 5 going north. Flood warnings had been out all day—didn’t make a bit of difference.”

Recommendation 16: In addition to TADD, outreach must emphasize the danger of driving at night when limited visibility makes it difficult to discern a section of a roadway under water. The message is: If you can't see the road due to intense night rainfall, you should not drive. NWS should work with the Departments of Transportation and Education to include the hazards of driving in heavy rain as part of the driver training curriculum. Driver's license exams should include a question on driving and car buoyancy, and emphasize the dangers of driving at night in heavy rain where reduced visibility hinders a driver's ability to see the road and related road hazards.

Finding 17a: There is a perception by the EMs responsible for six Georgia counties within the Greenville-Spartanburg CWA that neighboring Georgia counties to their west, serviced by WFO Peachtree City, were given a higher quality of service. In addition, when considering all warnings issued by WFO Greenville-Spartanburg, one EM commented that warnings issued for South Carolina counties seemed to receive greater lead time for events than the six Georgia counties. An examination of warning statistics, by state, within the Greenville-Spartanburg CWA for the past 3 1/2 years (**Table 4**), however, did not support that perception. Lead times for tornadoes were actually higher for the six Georgia Counties than any other counties serviced by WFO Greenville-Spartanburg.

Finding 17b: Policy and practice differences between WFO Peachtree City and WFO Greenville-Spartanburg contributed to the service perception difference noted by the Georgia counties serviced by Greenville-Spartanburg. Popular Webinar briefings are provided by WFO Peachtree City but not by Greenville-Spartanburg. WFO Peachtree City issues Special Weather Advisories (Special Weather Statements) for sub-severe convection that Greenville-Spartanburg does not issue. NWS Eastern Region has not implemented the Significant Weather Advisory practice. Much of the service difference perception seemed to be a hold over of NWS Modernization and Associated Restructuring service changes, where these six Georgia Counties moved from the Atlanta Weather Service Forecast Office to Greenville-Spartanburg WFO.

Finding 17c: NWS Southern Region has adopted the practice of issuing Significant Weather Advisories for significant, non-severe convection, while NWS Eastern Region does not issue such advisories. This difference in practices contributed to the perception that Georgia counties serviced by Greenville-Spartanburg are not given the same level of service as adjacent counties in the Peachtree City CWA.

Finding 17d: EMs from North Carolina served by WFO Greenville-Spartanburg were pleased with their weather services. The EMs did not perceive any service difference compared to their neighboring South Carolina counties serviced by WFO Greenville-Spartanburg, even though recent verification statistics showed less skill for that area.

Recommendation 17a: WFO Greenville-Spartanburg should increase outreach efforts to the six Georgia Counties in its CWA. EMs viewed both the Service Assessment team's interest in visiting them, and interest by WFO Greenville-Spartanburg's new Warning Coordination Meteorologist as positive developments, creating an opportunity to strengthen working relationships. Webinar briefings should be considered as a means of forecast coordination prior to significant weather events. WFO Peachtree City should invite WFO Greenville-Spartanburg to help prepare and conduct briefing calls in Georgia when an event may affect any of WFO Greenville-Spartanburg's Georgia counties.

Recommendation 17b: NWS Eastern Region should consider Significant Weather Advisories as a service option, especially for the portion of its service area that crosses into states served by

NWS Southern Region.

Best Practices

Best Practice 1: The SERFC is a leader in the development of innovative decision-support products. They issue the *SERFC Journal* email to interested subscribers two or three times per week. This publication conveys "the story behind the forecast," with discussions on flood climatology for the specific time of year, a description of a weather pattern change, and other topics of interest. SERFC also issues an event-driven *SERFC Alert!* email that describes rapidly developing hydrometeorological conditions, typically when flood conditions are forecast or severity level is upgraded. The GovDelivery subscriber service is used to manage distribution of the products. At the time of the assessment, the system had 1200 subscribers for the services.

Best Practice 2: In collaboration with WFO Peachtree City which was providing full service backup for WFO Birmingham on Saturday, September 19, critical decision support was provided prior to an Auburn football game on Saturday, September 19. Forecast information played a key role in the decision to delay the start of the televised football game by 30 minutes due to lightning and heavy rain.

Best Practice 3: WFO Huntsville meticulously outlined the flash flood warning polygon boundaries, adding extra polygon points to depict the precise warned area. This level of detail allowed DeKalb County, Alabama, EMs to limit the area alerted through reverse 911 notification calls.

Best Practice 4: Flash Flood Catalogue. WFO Greenville-Spartanburg has catalogued all flash flood events over the past 11 years into an easily accessible database in AWIPS and in operations area computers. The AWIPS data can be displayed as an overlay with context sensitive pop-up information depicting past rainfall rates and resulting impacts by small basins. These data also can be accessed as an AWIPS text file for easy inclusion in Warngen statements. WFO Birmingham has a binder with a section for each county depicting known flash flood locations along with information on rainfall rates that caused the flooding and the known impacts. Note: Outside of this assessment area, WFO Salt Lake City is developing a flash flood database in Google Earth, which includes radar reflectivity and precipitation estimate loops associated with the flooding.)

Best Practice 5: Since 2005, WFO Peachtree City has (re)surveyed every river gage in the CWA, including all non-forecast points, noting impacts for various river levels. WFO staff members accompanied the Service Hydrologist on many of these river gage site surveys for familiarization.

Best Practice 6: NWS offices in Alabama use the state 800 MHz radio system to interact with the EM community – a system that was already in place and widely accepted by the EM community. This system is effectively used to provide weather briefings, interaction with EMs, warning dissemination, and to solicit real-time reports on weather/flood impacts.

Best Practice 7: A new Tennessee law adds driver license violation points for anyone who drives through a barricaded road. If a rescue has to be made, or the violation is in a commercial vehicle, additional points are added. New warning Call-to-Action statements were developed by the WFO Morristown's Senior Service Hydrologist to incorporate language from this law.

Appendix C: NWS Duty Priorities

The mission of the National Weather Service, in part, is "to provide weather and flood warnings, public forecasts and advisories for all the United States, its territories, adjacent waters and ocean areas, primarily for the protection of life and property."

Therefore, when the workload in any office exceeds the capability of the staff, weather and flood warnings are to be given top priority over all other duties. The following prioritized list provides guidance under these difficult circumstances but does not replace the exercise of professional judgment:

1. WARNINGS, WATCHES, and ADVISORIES

2. MISSION CRITICAL OBSERVATIONS

3. FORECASTS, OBSERVATIONS, and BASIC WEATHER WATCH

4. NON-CRITICAL PUBLIC SERVICE

5. TRAINING, DEVELOPMENT, and FOCAL POINT DUTIES

Appendix D: Flash Flood Statement, Morristown, Tennessee

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WGUS84 KMRX 211330
FLSMRX

FLOOD STATEMENT
NATIONAL WEATHER SERVICE MORRISTOWN TN
930 AM EDT MON SEP 21 2009

NCC039-043-TNC007-011-065-107-115-121-123-139-143-153-220100-
/O.CON.KMRX.FA.W.0011.000000T0000Z-090922T0100Z/
/00000.0.ER.000000T0000Z.000000T0000Z.000000T0000Z.OO/
CHEROKEE NC-CLAY NC-RHEA TN-BLEDSOE TN-MEIGS TN-MCMINN TN-
SEQUATCHIE TN-HAMILTON TN-BRADLEY TN-MARION TN-MONROE TN-POLK TN-
930 AM EDT MON SEP 21 2009

...THE FLOOD WARNING REMAINS IN EFFECT UNTIL 900 PM EDT MONDAY/800 PM
CDT MONDAY/ FOR POLK...MONROE...MARION...BRADLEY...HAMILTON...
SEQUATCHIE...MCMINN...MEIGS...BLEDSOE...RHEA...CLAY AND CHEROKEE
COUNTIES...

AT 924 AM EDT/824 AM CDT/ FLOODING CONTINUES ACROSS PORTIONS OF
SOUTHEAST TENNESSEE AND EXTREME SOUTHWEST NORTH CAROLINA. HAMILTON
COUNTY AND THE AREAS AROUND BRAINERD AND EAST RIDGE HAVE BEEN
ESPECIALLY HARD HIT. THERE HAVE BEEN NUMEROUS RESCUES OF PEOPLE
HAVING DRIVEN INTO WATER.

NEWS REPORTS ALSO SHOW PICTURES OF STRANDED CARS. ONE PERSON HAS DIED
AND AT LEAST ONE PERSON INJURED.

IF YOU DRIVE INTO FLOODED WATERS, YOU WILL BE STRANDED. YOU WILL
THEN HAVE TO BE RESCUED. THIS PUTS RESCUE WORKERS LIVES AT RISK. IN
TENNESSEE...IF YOU DRIVE AROUND A BARRICADE...YOU HAVE COMMITTED
RECKLESS DRIVING.

THINK ABOUT THE PEOPLE IN YOUR CAR AND THE EMERGENCY PERSONNEL WHO
HAVE TO DEAL WITH THIS SITUATION. DO NOT END UP ON THE NEWS THIS WAY.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

IF YOU COME TO A FLOODED OR CLOSED ROAD...TURN AROUND...DONT DROWN.

&&

LAT...LON 3526 8583 3523 8574 3537 8551 3553 8561
      3557 8543 3578 8525 3576 8500 3583 8479
      3564 8457 3567 8432 3555 8399 3548 8393
      3542 8401 3524 8399 3526 8370 3515 8373
      3515 8365 3499 8351 3499 8588 3518 8588

$$

BB
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Appendix E: Flash Flood Statement, Louisville, Kentucky

Flash Flood Statement

WGUS73 KLMK 041340
FFSLMK

FLASH FLOOD STATEMENT
NATIONAL WEATHER SERVICE LOUISVILLE KY
940 AM EDT TUE AUG 4 2009

INC019-KYC111-185-041700-
/O.CON.KLMK.FF.W.0034.000000T0000Z-090804T1700Z/
/00000.0.ER.000000T0000Z.000000T0000Z.000000T0000Z.OO/
CLARK IN-OLDHAM KY-JEFFERSON KY-
940 AM EDT TUE AUG 4 2009

...FLOOD EMERGENCY FOR METRO LOUISVILLE...JEFFERSONVILLE AND
CLARKSVILLE...

...A FLASH FLOOD WARNING REMAINS IN EFFECT UNTIL 100 PM EDT FOR
NORTHEASTERN JEFFERSON...WESTERN OLDHAM AND CLARK COUNTIES...

AT 936 AM EDT...THE PUBLIC REPORTED A THUNDERSTORM PRODUCING FLASH
FLOODING OVER THE WARNED AREA.

LOCATIONS IN THE WARNING INCLUDE BUT ARE NOT LIMITED TO CLARK
REGIONAL AIRPORT...WILSON...WATSON...UTICA AND SPEED.

MAJOR FLASH FLOODING HAS BEEN REPORTED IN THE METRO LOUISVILLE AREA
AND ACROSS THE RIVER IN SOUTHERN INDIANA. REPORTS OF WATER SEVERAL
FEET DEEP WITH CARS STRANDED HAVE BEEN REPORTED. WATER RESCUE TEAMS
HAVE BEEN DEPLOYED ACROSS THE METRO AREA. THIS IS A LIFE THREATENING
AND DANGEROUS SITUATION! TAKE PRECAUTIONS NOW TO MOVE TO HIGHER
GROUND AND DO NOT ATTEMPT TO CROSS FLOODED AREAS IN VEHICLES OR ON
FOOT.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

EXCESSIVE RUNOFF FROM HEAVY RAINFALL WILL CAUSE FLOODING OF SMALL
CREEKS AND STREAMS...URBAN AREAS...HIGHWAYS...STREETS AND UNDERPASSES
AS WELL AS OTHER DRAINAGE AREAS AND LOW LYING SPOTS.

DO NOT DRIVE YOUR VEHICLE INTO AREAS WHERE THE WATER COVERS THE
ROADWAY. THE WATER DEPTH MAY BE TOO GREAT TO ALLOW YOUR CAR TO CROSS
SAFELY. MOVE TO HIGHER GROUND.

FLOODING IS OCCURRING OR IS IMMINENT. MOST FLOOD RELATED DEATHS OCCUR
IN AUTOMOBILES. DO NOT ATTEMPT TO CROSS WATER COVERED BRIDGES...
DIPS...OR LOW WATER CROSSINGS. NEVER TRY TO CROSS A FLOWING STREAM...
EVEN A SMALL ONE...ON FOOT. TO ESCAPE RISING WATER MOVE TO HIGHER
GROUND.

```
&&

LAT...LON 3858 8546 3830 8543 3830 8545 3830 8547
      3828 8542 3822 8542 3816 8573 3835 8578
      3835 8577 3845 8588
$$
```

Appendix F: Flash Flood Warning Verification

(Storm-based Method) September 17 – 23, 2009

Warning Statistics

Forecast Office	# of Warnings	# of Warnings Verified	# of Warnings Unverified	False Alarm Ratio	Average Warning Size (sq. mi.)
Birmingham, AL (BMX)	54	33	21	38.9%	1155.4
Peachtree City, GA (FFC)	27	22	5	18.5%	598.8
Greenville-Spartanburg, SC (GSP)	5	4	1	20.0%	365.0
Huntsville, AL (HUN)	19	15	4	21.1%	759.7
Morristown, TN (MRX)	3	3	0	0.0%	182.3
Total	108	77	31	28.7%	883.0

Event Statistics

Forecast Office	# of Events	# of Warned Events	# of Partially Warned Events	# of Unwarned Events	Probability of Detection	Average Lead Time (min)
Birmingham, AL (BMX)	42	18	22	2	91.2%	54.7
Peachtree City, GA (FFC)	45	17	28	0	93.3%	103.2
Greenville-Spartanburg, SC (GSP)	6	1	4	1	59.3%	40.5
Huntsville, AL (HUN)	24	9	14	1	91.6%	51.3
Morristown, TN (MRX)	5	1	3	1	54.4%	29.6
Total	122	46	71	5	89.0%	70.2

Appendix G: River Crests—NWS Forecast Points

River Crests NWS Forecast Points September 2009				
Forecast Point	Flood Stage (Feet)	Above Flood Stage Date / EDT	Crest Stage (Feet)	Crest Date
WFO Peach Tree City Hydrologic Service Area				
Tennessee River Basin				
New England | Lookout Creek	12	9/21 8:10am – 9/22 12:50pm	15.01	9/22 3:15am
Conasauga River Basin				
Tilton	18	9/26 8:30pm – 9/26 10:39pm 9/28 7:10am – 9/30 4:00am	18.05 19.63	9/26 9:45pm 9/29 10:00am
Etowah River Basin				
Dawsonville	13	9/20 8:37pm – 9/20 9:46pm 9/21 2:40pm – 9/22 6:59am	13.01 14.56	9/20 8:45pm 9/21 7:45pm
Canton	16	9/21 12:03pm – 9/23 2:55am	20.73	9/22 8:30am
Cartersville	18	9/21 7:20pm – 9/22 9:24am	20.73	9/22 2:00am
Chattahoochee River Basin				
Suwanee | Suwanee Creek	8	9/21 7:33am – 9/22 4:16pm	14.30	9/21 6:45pm
Norcross	12	9/21 5:21pm – 9/22 4:34am	14.51	9/21 10:00pm
Marietta | Sope Creek	12	9/21 2:38am – 9/21 9:26am 9/21 2:08pm – 9/21 10:17pm	15.33 18.35	9/21 7:00am 9/21 6:15pm
Alpharetta | Big Creek	7	9/20 4:30 pm – 9/23 6:26pm	Missing	Missing
Atlanta | Peachtree Creek	17	9/21 3:53am –	23.89	9/21 9:15pm

		9/22 6:02am		
Atlanta | Nancy Creek Rickenbacker Drive	11	9/21 4:44am – 9/21 12:12pm 9/21 4:08pm – 9/22 12:32am	13.03 14.69	9/21 9:45am 9/21 9:30pm
Vinings at Paces Ferry Road	14	9/21 5:01am – 9/23 10:09am	28.10	9/21 10:30pm
Whitesburg	15	9/21 3:15am – 9/25 7:23am	29.84	9/23 8:30pm
West Point	17	9/23 2:00pm – 9/26 6:11am	18.92	9/25 9:15am
Austell | Sweet Water Creek	10	9/21 2:57am – 9/25 1:28pm	30.80	9/22 Unknown
Ocmulgee River Basin				
Conyers Below Milstead	11	9/18 12:45pm – 9/18 2:12pm 9/18 8:00pm – 9/20 10:35am 9/21 11:17am – 9/24 8:10am	11.08 11.47 22.54	9/18 2:00pm 9/19 2:15am 9/22 5:30pm
Macon	18	9/21 11:06pm – 9/26 6:52am	22.47	9/24 11:15am
Hawkinsville	20	9/26 5:15pm – 9/29 8:05pm	21.85	9/28 6:30am
Abbeville	12	9/25 5:15pm – 10/03 7:26pm	14.30	9/30 8:30am
Oconee River Basin				
Arcade | Middle Oconee River	16	9/22 10:10am – 9/22 9:06pm	16.51	9/22 3:45pm
Penfield	11	9/20 6:30pm – 9/24 9:47pm 9/27 8:51pm – 9/28 4:21pm	17.00 11.78	9/22 4:30pm 9/28 7:15am
Milledgeville	27	9/22 3:02am – 9/22 3:50pm	30.83	9/22 10:30am
Oconee	17	9/23 5:12pm – 9/26 4:37pm	20.20	9/24 2:00pm
WFO Greenville / Spartanburg Hydrologic Service Area				
French Broad River Basin				
French Broad River | Blantyre	16	9/20 3:15 pm –	21.08	9/23 12:30

		9/24 3:45 pm		am
French Broad River | Asheville	8	9/22 1:00 am – 9/22 3:00 am	8.11	9/22 2:00 am
WFO Morristown Hydrologic Service Area				
South Chickamauga Creek Basin				
South Chickamauga Creek | Chickamauga	18	9/21 4:30 am – 9/24 10:30 pm	28.54	9/22 4:30pm
Pigeon River Basin				
Pigeon River | Newport	8	9/22 – 9/22	9.31	9/22 Unknown
Little Pigeon River | Sevierville	11	9/26 – 9/27	11.49	9/26 Unknown
WFO Huntsville Hydrologic Service Area **Coosa River Basin**				
Big Wills Creek | Fort Payne	11	9/21 – 9/21	12.17	9/21 Unknown
WFO Birmingham Hydrologic Service Area				
Cahaba River Basin				
Cahaba River | Cahaba Heights	14		19.53 14.44	9/18 Unknown 9/19 Unknown
Cahaba River | Centreville	23		28.22	9/21 Unknown
Cahaba River | Suttle	32		35.82	9/24 Unknown
Tombigbee River Basin				
Tombigbee River | Demopolis	68		70.07	9/23 Unknown

Appendix H: Flash Flood Impacts

WFO	County	State	Fatality	Injury	Property
BMX	AUTAUGA	AL	0	0	$1,000,000
	BIBB	AL	0	0	$176,000
	CALHOUN	AL	0	0	$5,000
	CHAMBERS	AL	0	0	$0
	CHILTON	AL	0	0	$50,000
	CLAY	AL	0	0	$2,000
	COOSA	AL	0	0	$5,000
	ELMORE	AL	0	0	$2,000
	FAYETTE	AL	0	0	$10,000
	GREENE	AL	0	0	$20,000
	HALE	AL	0	0	$25,000
	JEFFERSON	AL	0	0	$75,000
	LAMAR	AL	0	0	$7,000
	LEE	AL	0	0	$0
	MARION	AL	0	0	$0
	PERRY	AL	0	0	$0
	PICKENS	AL	0	0	$10,000
	RUSSELL	AL	0	0	$0
	SHELBY	AL	0	0	$48,000
	ST. CLAIR	AL	0	0	$55,000
	SUMTER	AL	0	0	$10,000
	TALLAPOOSA	AL	0	0	$5,000
	TUSCALOOSA	AL	0	0	$12,000
	WALKER	AL	0	0	$5,000
	Total		**0**	**0**	**$1,522,000**
FFC	BIBB	GA	0	0	$10,000
	CARROLL	GA	1	0	$1,330,000
	CATOOSA	GA	0	0	$500,000
	CHATTOOGA	GA	0	0	$60,000
	CHEROKEE	GA	0	0	$42,400
	CLARKE	GA	0	0	$5,000
	CLAYTON	GA	0	0	$5,000
	COBB	GA	0	0	$252,000
	CRAWFORD	GA	0	0	$10,000
	DE KALB	GA	0	0	$762,000
	DOUGLAS	GA	6	0	$870,000
	FORSYTH	GA	0	0	$1,820
	FULTON	GA	0	0	$4,576,000
	GREENE	GA	0	0	$10,000
	GWINNETT	GA	1	0	$1,260,000
	HALL	GA	0	0	$3,000
	HOUSTON	GA	0	0	$100,000

WFO	County	State	Fatality	Injury	Property
	JACKSON	GA	0	0	$30,000
	LUMPKIN	GA	0	0	$5,000
	MADISON	GA	0	0	$5,000
	MORGAN	GA	0	0	$250,000
	OCONEE	GA	0	0	$5,000
	PAULDING	GA	0	0	$240,000
	PUTNAM	GA	0	0	$12,000
	TAYLOR	GA	0	0	$150,000
	UNION	GA	0	0	$1,000
	WALKER	GA	0	0	$1,440,000
	WALTON	GA	0	0	$3,000
	WHITFIELD	GA	0	0	$15,000
	WILKES	GA	0	0	$5,000
	Total		**8**	**0**	**$11,958,220**
GSP	HENDERSON	NC	0	0	$20,000
	OCONEE	SC	0	0	$10,000
	POLK	NC	0	0	$50,000
	STEPHENS	GA	0	0	$4,500,000
	TRANSYLVANIA	NC	0	0	$10,000
	Total		**0**	**0**	**$4,590,000**
HUN	COLBERT	AL	0	0	$5,000
	DEKALB	AL	0	0	$60,000
	LAUDERDALE	AL	0	0	$0
	LAWRENCE	AL	0	0	$0
	LINCOLN	TN	0	0	$0
	MOORE	TN	0	0	$0
	Total		**0**	**0**	**$65,000**
MRX	ANDERSON	TN	0	0	$0
	LOUDON	TN	0	0	$0
	MCMINN	**TN**	**0**	**0**	**$0**
	MONROE	**TN**	**0**	**0**	**$0**
	Total		**0**	**0**	**$0**

Total Flash Flood Fatalities **8**
Total Flash Flood Damage **$18,135,220**

Appendix I: Flood Impacts

WFO	County	State	Fatality	Injury	Property
BMX	JEFFERSON	AL	0	0	$20,000
	Total		**0**	**0**	**$20,000**
FFC	BALDWIN	GA	0	0	$10,000
	BARROW	GA	0	0	$100,000
	BARTOW	GA	0	0	$6,000
	BIBB	GA	0	0	$10,000
	CARROLL	GA	0	0	$21,620,000
	CATOOSA	GA	0	0	$1,500,000
	CHATTOOGA	GA	1	0	$11,920,000
	CHEROKEE	GA	0	0	$53,000,000
	CLAYTON	GA	0	0	$55,000
	COBB	GA	0	0	$29,700,000
	COWETA	GA	0	0	$10,000
	CRAWFORD	GA	0	0	$10,000
	DAWSON	GA	0	0	$10,000
	DE KALB	GA	0	0	$9,280,000
	DOOLY	GA	0	0	$5,000
	DOUGLAS	GA	1	0	$19,140,000
	FLOYD	GA	0	1	$15,000
	FORSYTH	GA	0	0	$594,000
	FULTON	GA	0	0	$69,800,000
	GWINNETT	GA	0	0	$23,760,000
	HALL	GA	0	0	$50,000
	HEARD	GA	0	0	$15,000
	HENRY	GA	0	0	$250,000
	LUMPKIN	GA	0	0	$5,000
	MORGAN	GA	0	0	$5,000
	MURRAY	GA	0	0	$2,000
	NEWTON	GA	0	0	$700,000
	PAULDING	GA	0	0	$3,760,000
	PEACH	GA	0	0	$25,000
	PICKENS	GA	0	0	$5,000
	POLK	GA	0	0	$15,000
	PUTNAM	GA	0	0	$3,000
	ROCKDALE	GA	0	0	$2,999,999
	TAYLOR	GA	0	0	$150,000
	UNION	GA	0	0	$5,000
	WALKER	GA	0	0	$7,560,000
	WALTON	GA	0	0	$5,000
	WHITFIELD	GA	0	0	$950,000
	Total		**2**	**1**	**$257,049,999**

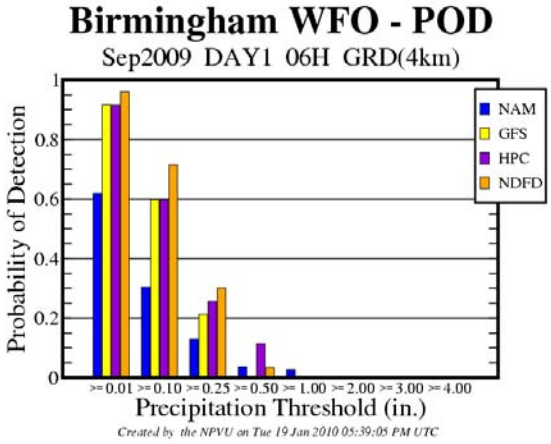
GSP	HABERSHAM	GA	0	0	$10,000
	HENDERSON	NC	0	0	$0
	JACKSON	NC	0	0	$0
	MACON	NC	0	0	$100,000
	OCONEE	SC	0	0	$0
	POLK	NC	0	0	$10,000
	STEPHENS	GA	0	0	$0
	TRANSYLVANIA	NC	0	0	$10,000
	Total		**0**	**0**	**$130,000**
HUN	DEKALB	AL	0	0	$0
	LIMESTONE	AL	0	0	$0
	Total		**0**	**0**	**$0**
MRX	BLEDSOE	TN	0	0	$0
	BRADLEY	TN	0	0	$0
	CHEROKEE	NC	0	0	$0
	CLAY	NC	0	0	$0
	HAMILTON	TN	1	1	$455,000
	MARION	TN	0	0	$0
	MCMINN	TN	0	0	$0
	MEIGS	TN	0	0	$0
	MONROE	TN	0	0	$0
	POLK	TN	0	0	$0
	RHEA	TN	0	0	$0
	SEQUATCHIE	TN	0	0	$0
	Total		**1**	**1**	**$455,000**

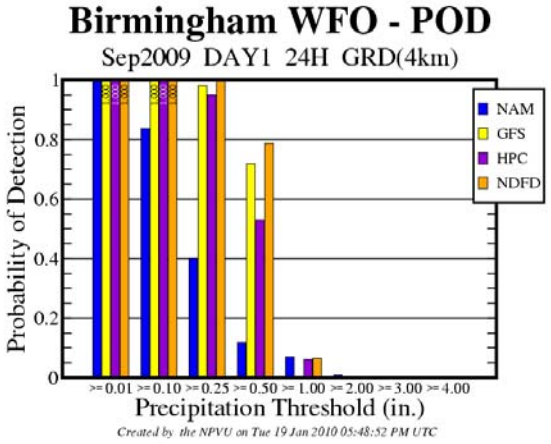
Total Flood Fatalities **3**
Total Flood Damages **$257,654,999**

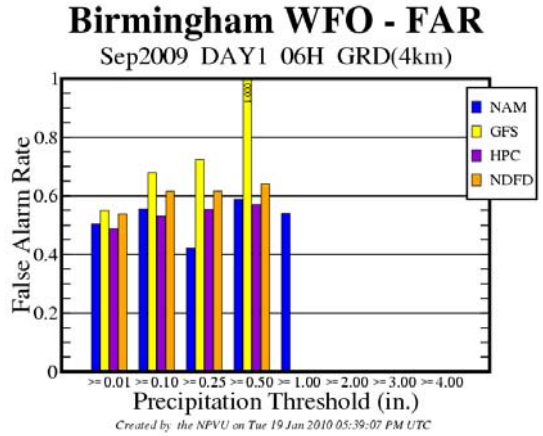
Appendix J: Quantitative Precipitation Forecast (QPF) Verification

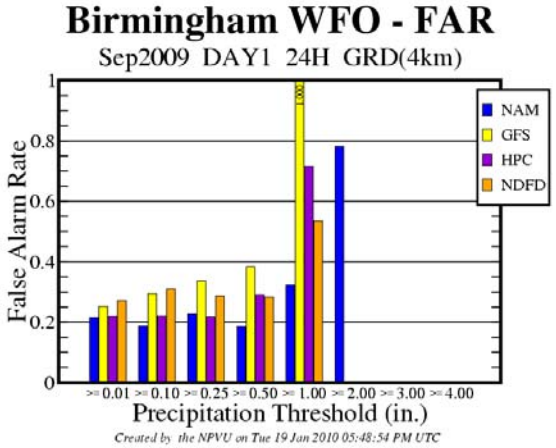
September 17-23, 2009

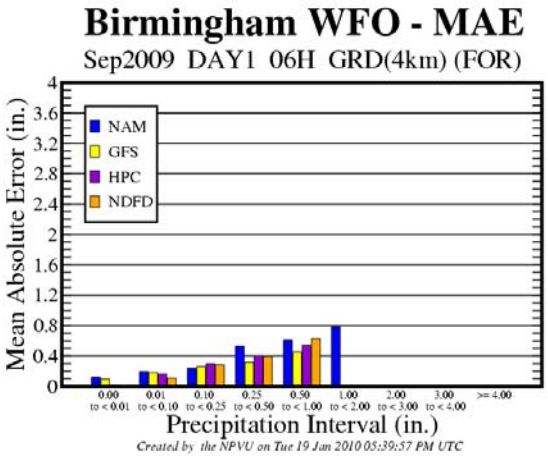
POD – Probability of Detection, FAR – False Alarm Ratio, MAE – Mean Absolute Error

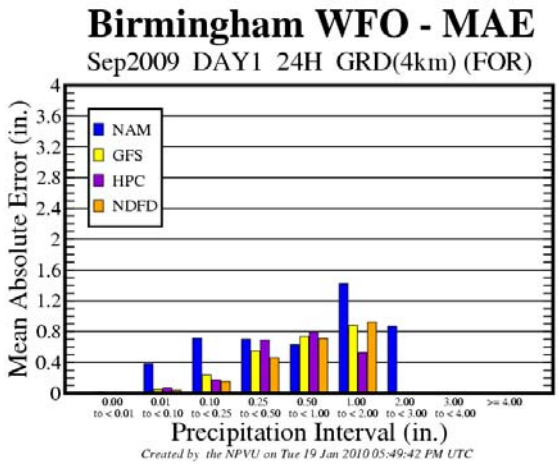






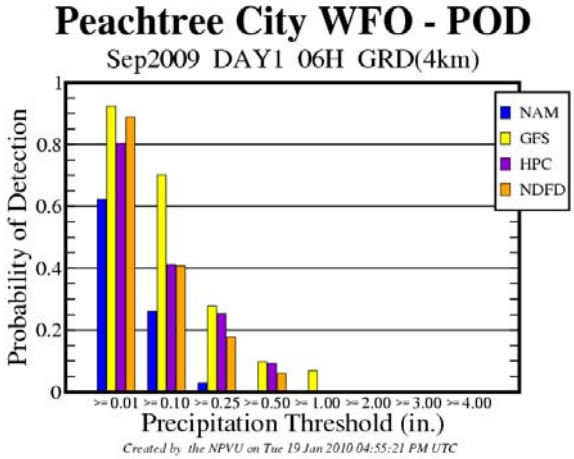


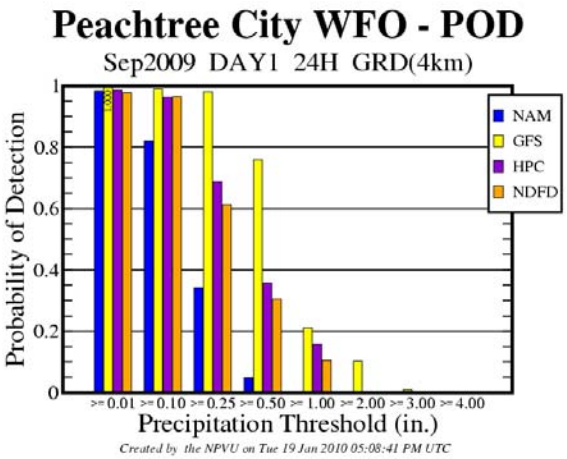


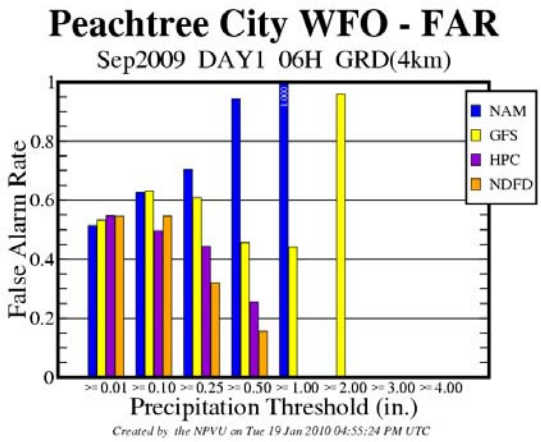


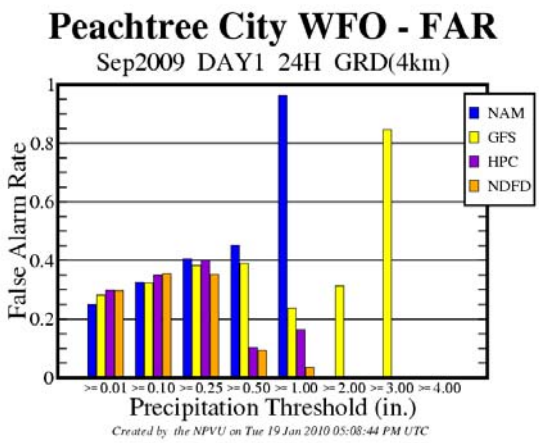
Quantitative Precipitation Forecast (QPF) Verification
September 17-23, 2009

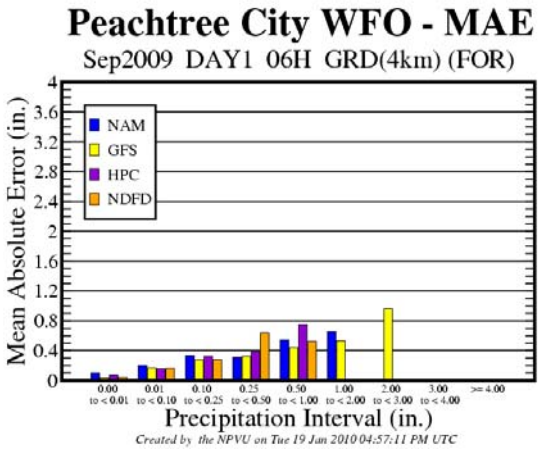
POD – Probability of Detection, FAR – False Alarm Ratio, MAE – Mean Absolute Error

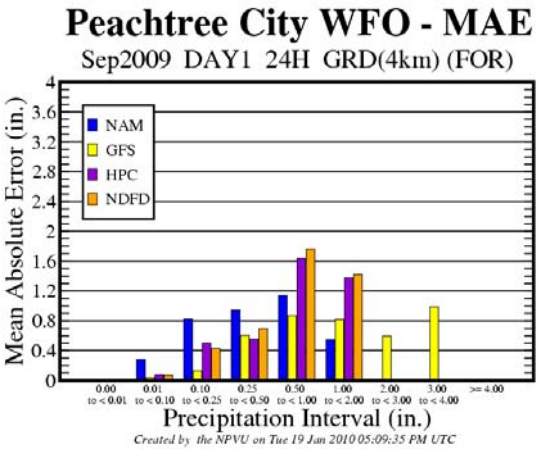












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September 17-23, 2009

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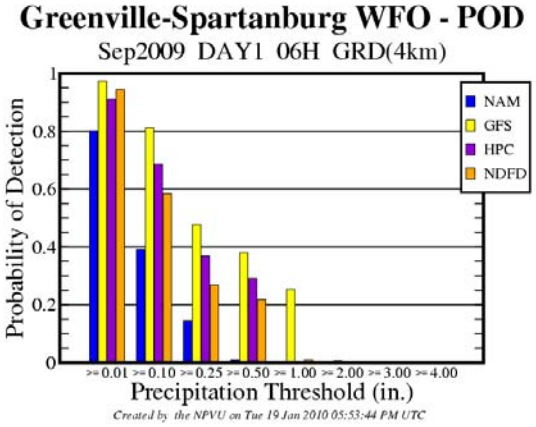

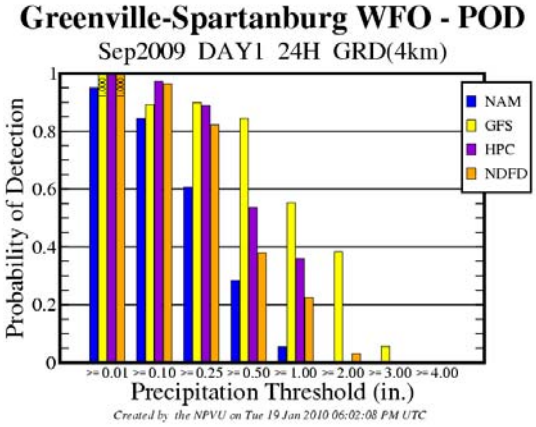

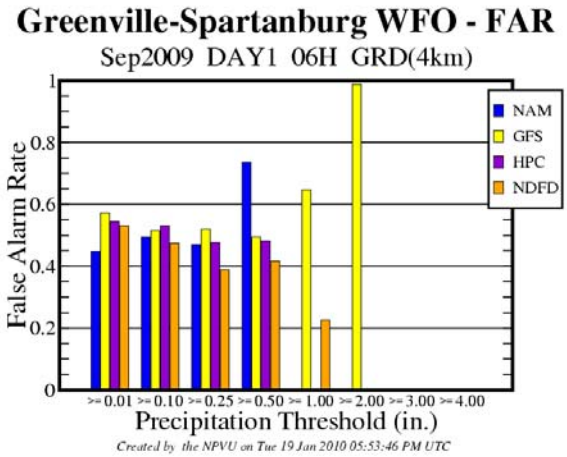

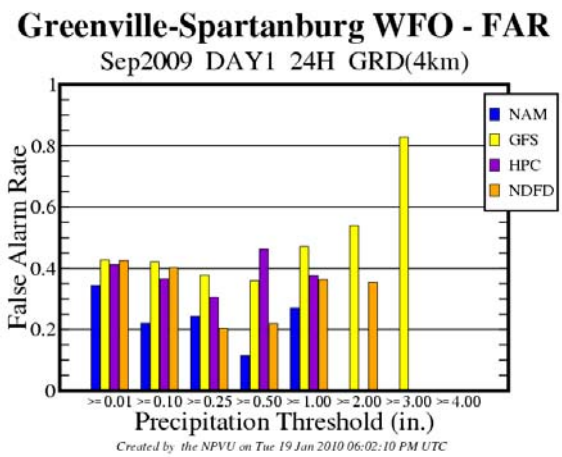

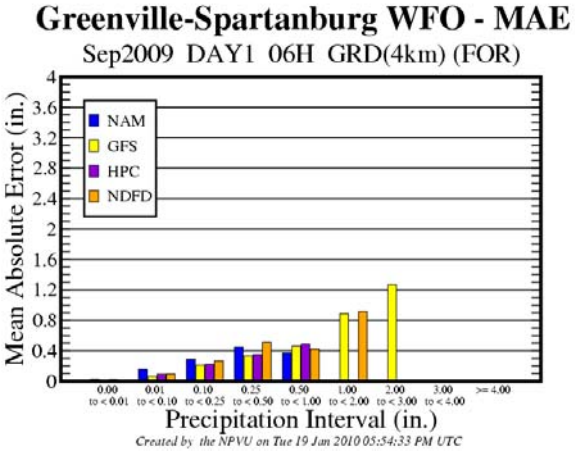

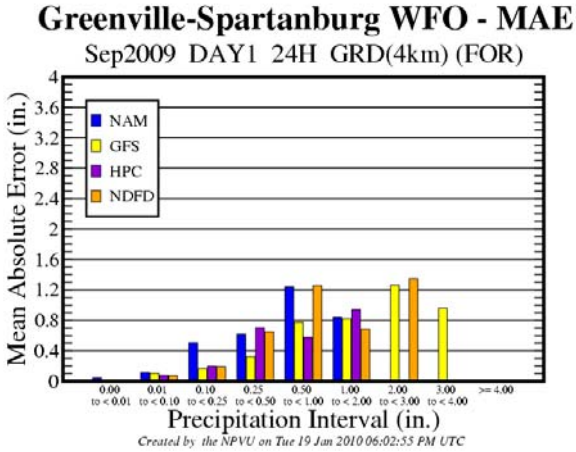

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September 17-23, 2009

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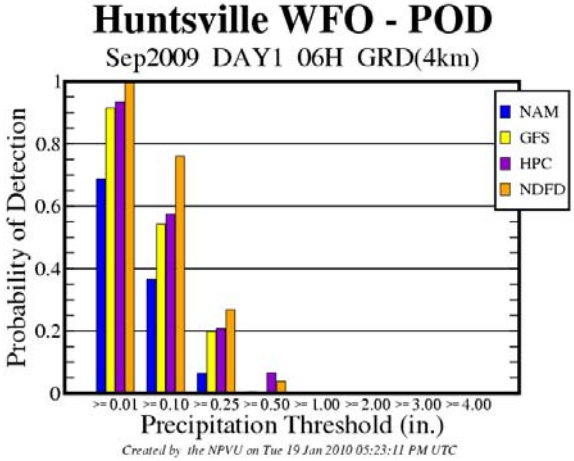

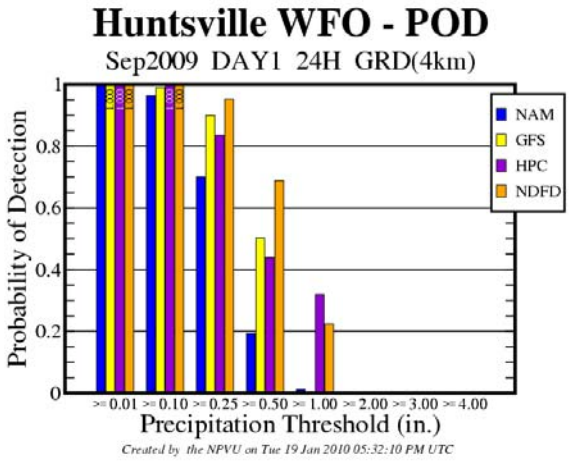

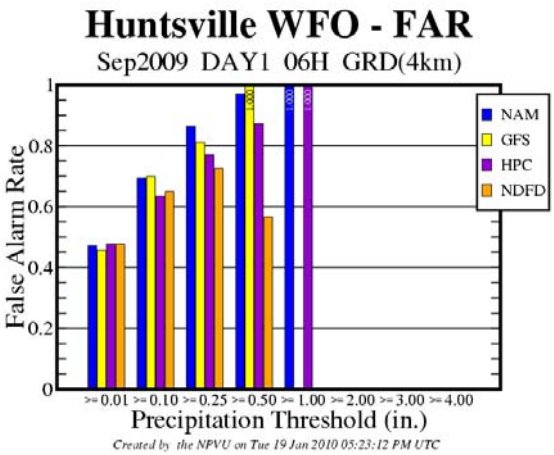

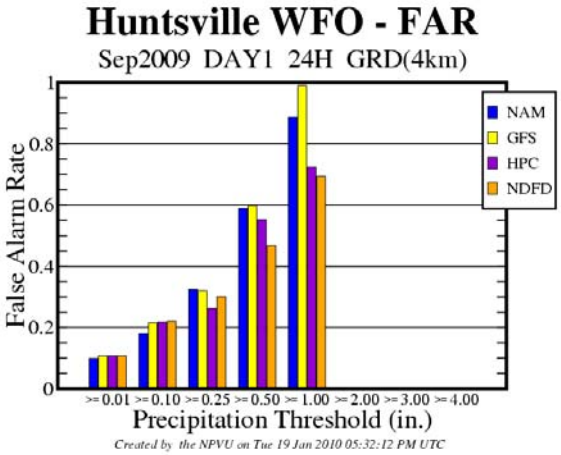

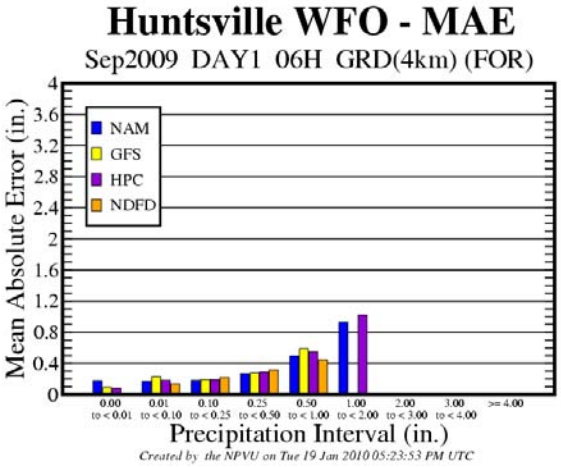

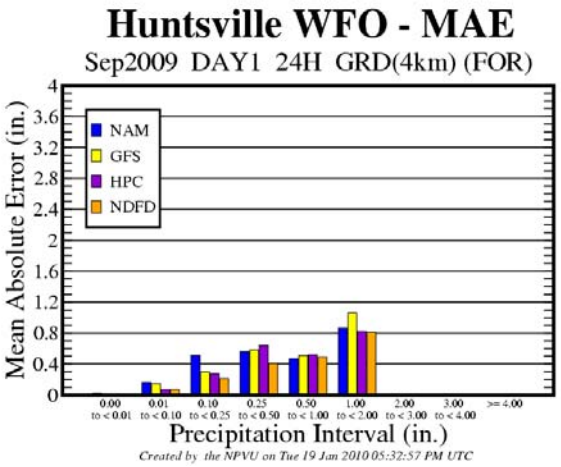

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September 17-23, 2009

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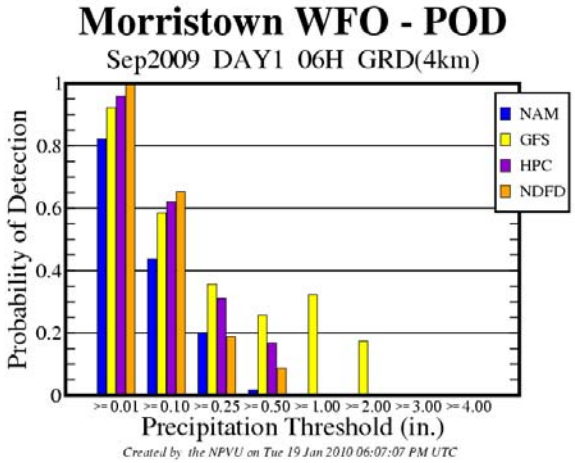

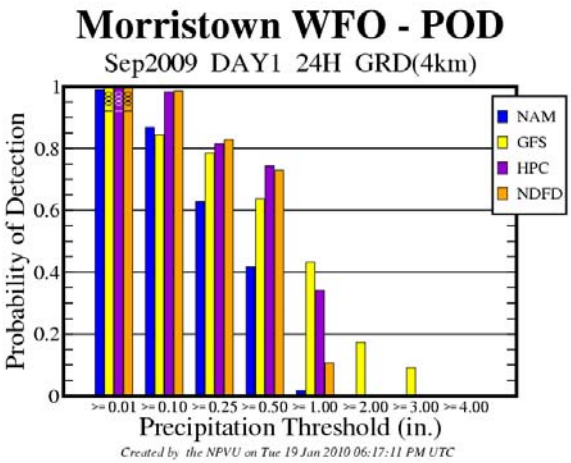

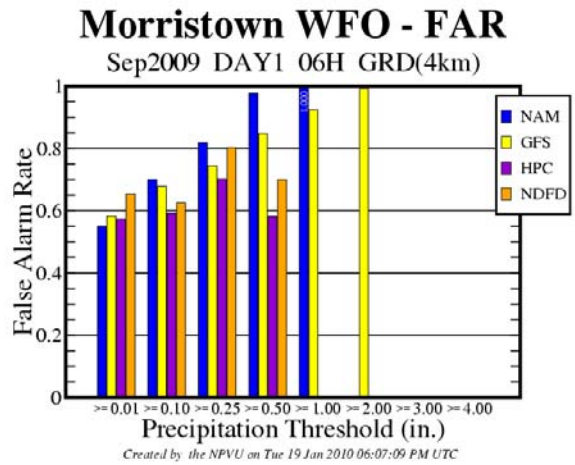

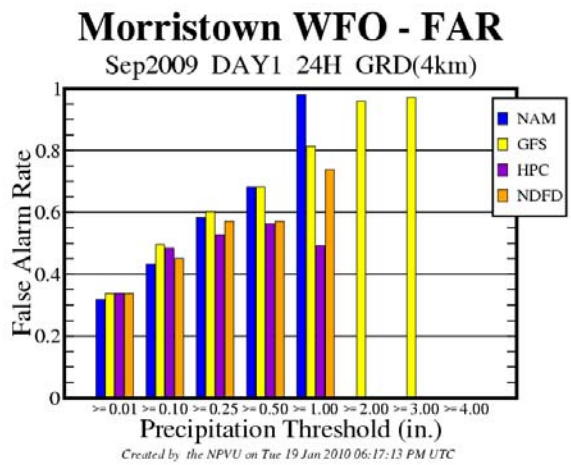

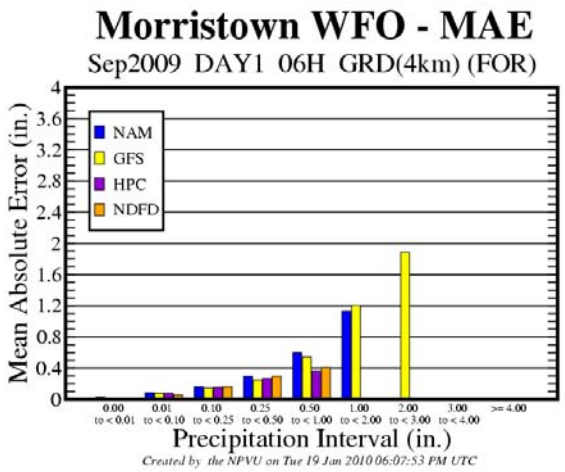

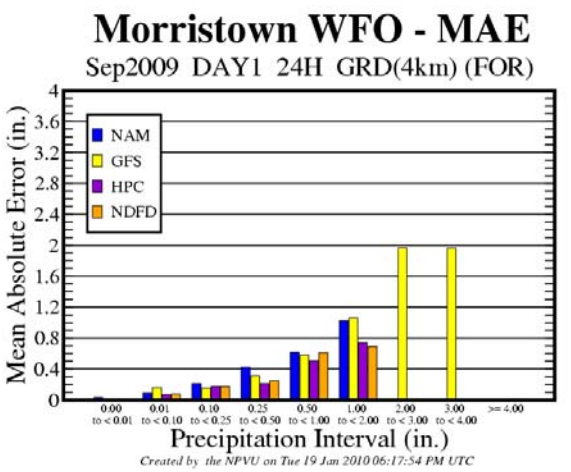

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September 17-23, 2009

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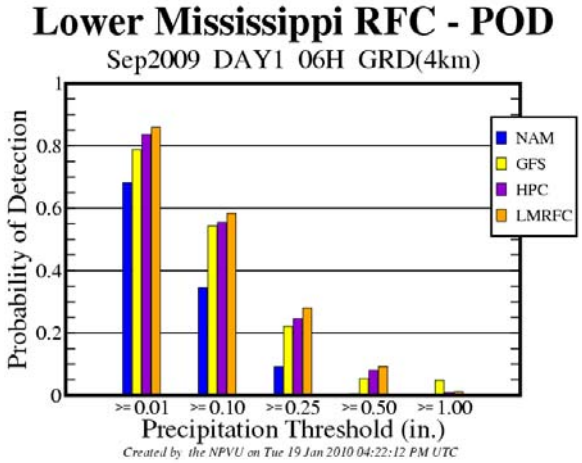

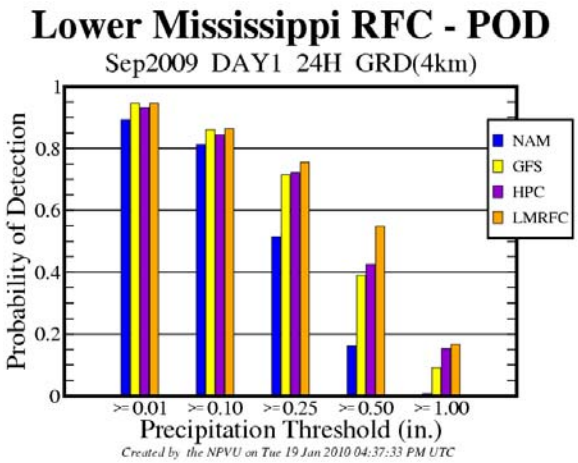

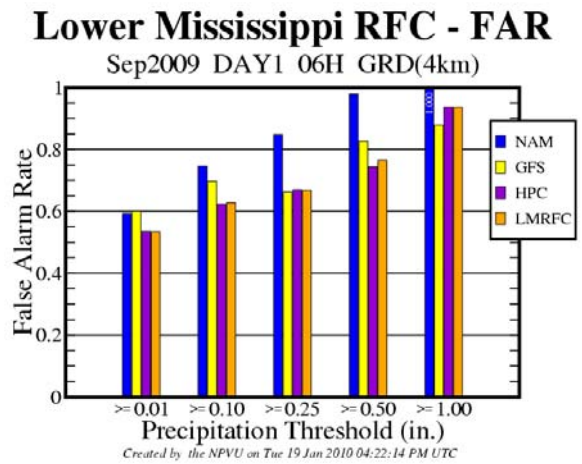

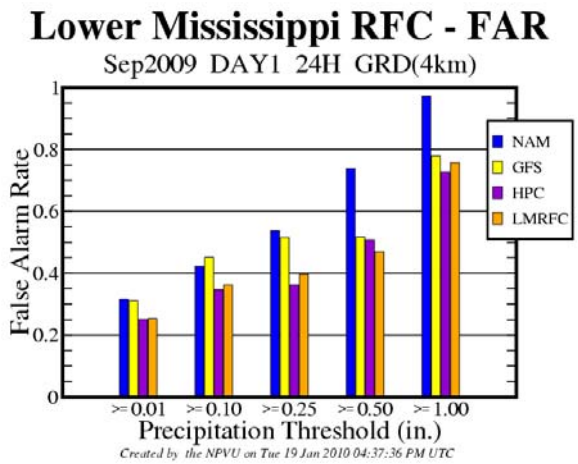

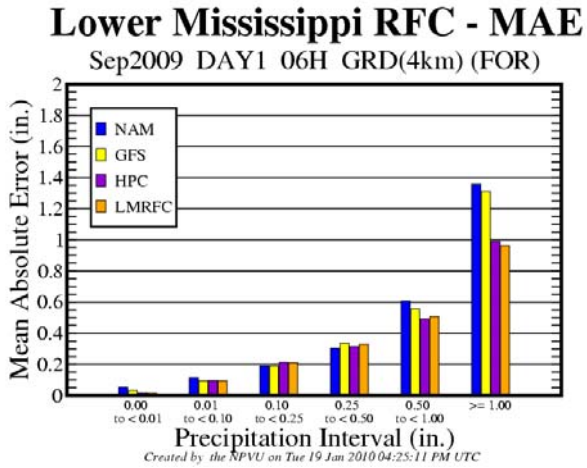

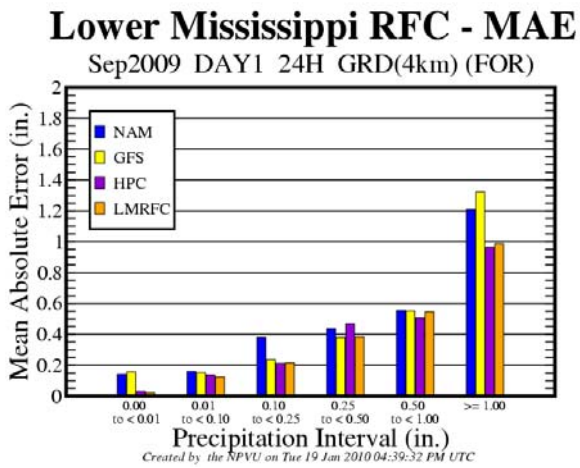

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September 17-23, 2009

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