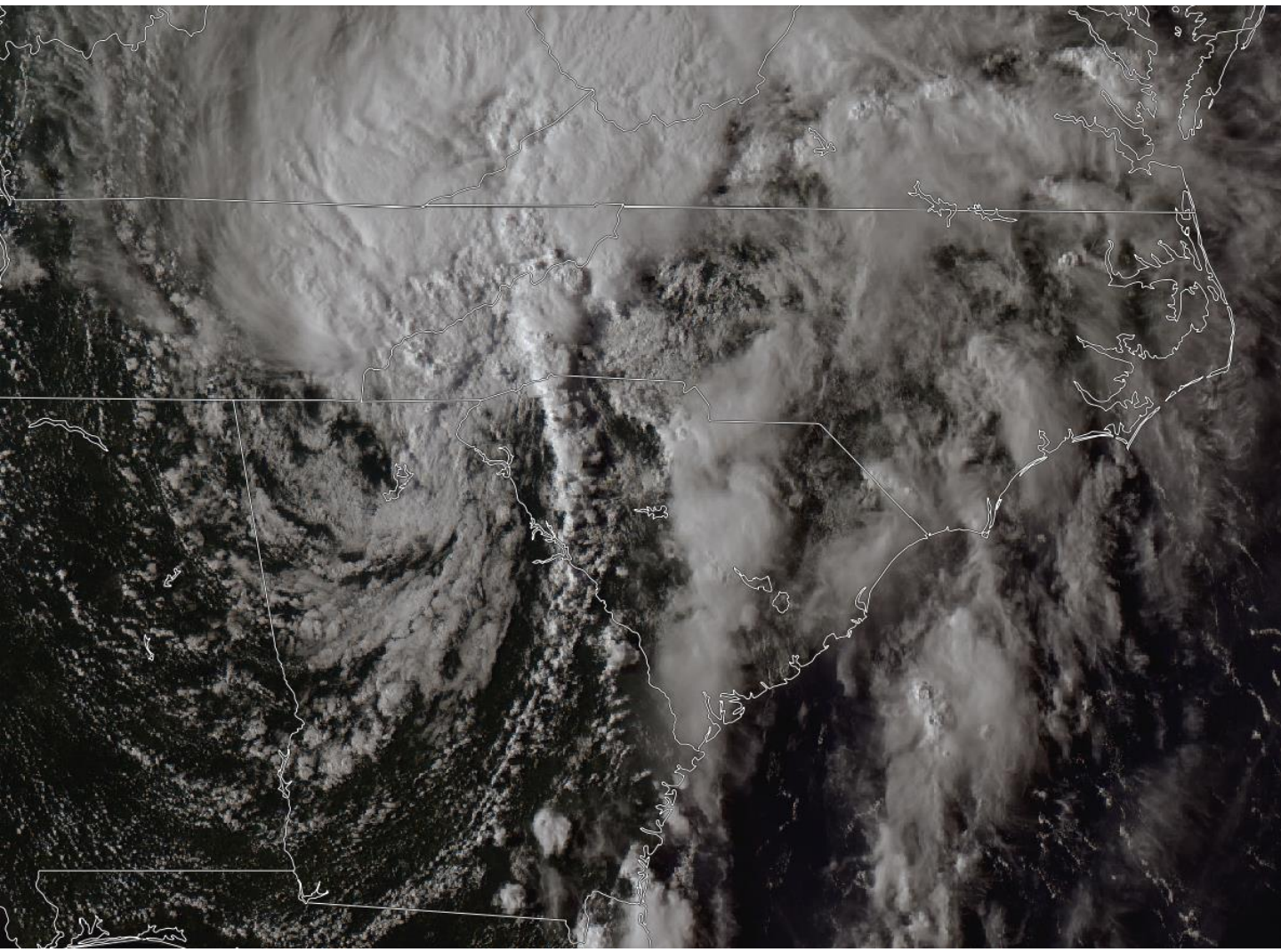
Tropical Storm Fred – Open File Report

South Carolina State Climatology Office
Report Date: September 3, 2021
Website: http://www.dnr.sc.gov/climate/sco



PRELIMINARY

Storm History and Impacts Report

August 17, 2021

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THIS REPORT SERVES AS A PRELIMINARY DISSEMINATION OF INFORMATION ON THE IMPACTS OF TROPICAL STORM FRED ON THE STATE OF SOUTH CAROLINA.

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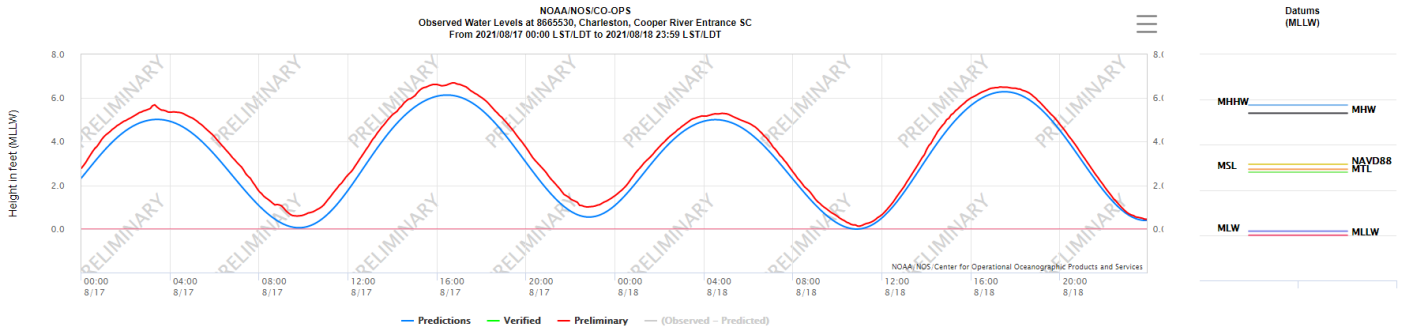
Cover Picture Credit
This is True Color RGB imagery generated by the University of Wisconsin's RealEarth website from GOES-16 satellite data of Tropical Storm Fred at 5:50 p.m. on August 17, 2021. At the time, several tornado warnings were in effect across South Carolina and the storm was centered near the Georgia-North Carolina state line. Additional figures and pictures used throughout this report were retrieved from the National Hurricane Center, University of Wisconsin, National Weather Service Damage Assessment Tool and WeatherBELL Analytics, LLC.

Storm Summary

Tropical Storm Fred formed on the evening of Tuesday, August 10, 2021, from a tropical wave that emerged from West Africa over the Atlantic around August 2. After passing through Hispaniola and Cuba, Fred briefly ceased to be a tropical cyclone but reformed quickly over the Gulf of Mexico and turned north. On Monday, August 16, it made landfall near Apalachicola, Florida, and passed by just to the west of South Carolina the following day on a north-northeastward track. The track took it through far western North Carolina, then northeastward through West Virginia, Pennsylvania, New York, and New England.

The primary impacts on South Carolina from Fred were heavy rainfall and tornadoes. The rainfall impacts in the Upstate were exacerbated by heavy rain in the days leading up to Fred's passage through the southeastern United States. Fred spawned a total of ten tornadoes across South Carolina; five of them were rated EF-1, and five were rated EF-0. Both the flooding potential and severe weather risk were well-forecast by public and private sector meteorologists, giving South Carolinians time to prepare.

Other tropical cyclone hazards were not significant with Fred. There was no notable storm surge along the South Carolina coast; none of the state's tidal gauges reported water levels more than one foot above forecast astronomical tides. Also, no high wind or tropical storm force gusts (35 mph or higher) with Fred's passage through the state, outside of the thunderstorms that spawned tornadoes.



Tidal gauge observations from the NOAA station located in Charleston at the Cooper River Entrance from 0000 UTC August 17 through 0000 UTC August 19 showing observed water levels only slightly above predicted astronomical tide levels during Fred's passage.
Other tidal gauges along the South Carolina coast reported similar departures from predicted levels.

Synoptic Analysis

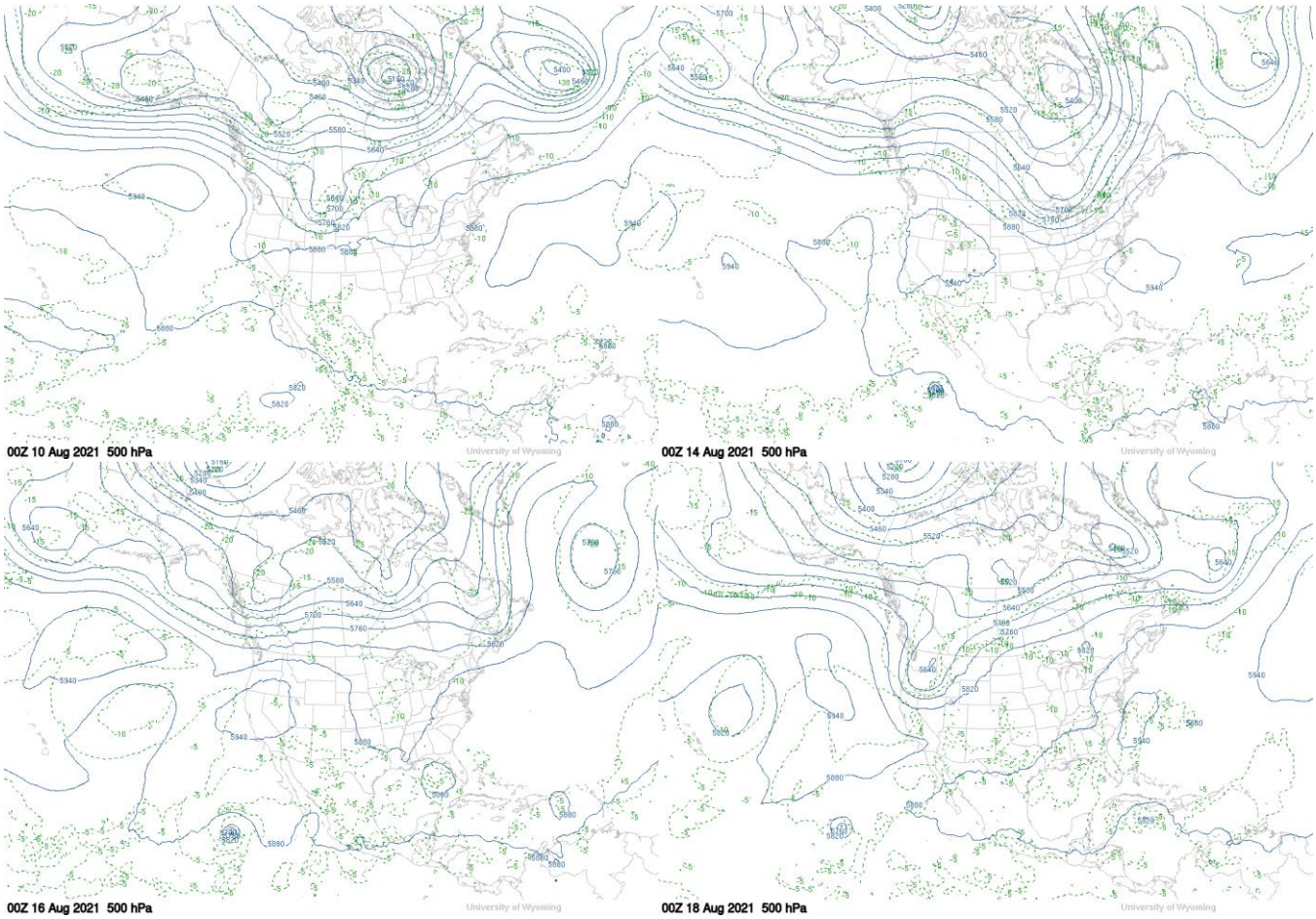
Tropical Storm Fred began as a tropical wave that moved over the Atlantic Ocean from West Africa around August 2, 2021. This tropical wave drifted westward through generally unfavorable conditions for development for nearly a week. Still, on August 4, forecasters at the National Hurricane Center (NHC) recognized that this tropical wave would reach a more favorable environment as it approached the Lesser Antilles and began highlighting the potential for tropical cyclone development from the wave in their outlook product. By 2:00 p.m. EDT on August 9, NHC forecasters saw a need to begin issuing advisory products for this disturbance even though it was not yet truly a tropical cyclone, so they designated it as Potential Tropical Cyclone Six.

Historical track of Tropical Storm Fred

They determined that this feature had become a tropical cyclone on the evening of August 10 and declared it to be Tropical Storm Fred as of the 11 p.m. EDT advisory. From August 11 to August 13, Fred passed over Hispaniola and Cuba. The interaction with those landmasses, along with shearing upper-level winds, took a toll on Fred's circulation and caused it to dissipate entirely by 11 a.m. on August 14. However, the NHC continued to issue advisory products for Fred because they expected it to regenerate once it emerged into the Gulf of Mexico. The storm regained strength by 11:00 a.m. on August 15, while Fred was over the eastern Gulf of Mexico around 200 miles west-southwest of Tampa, Florida. It intensified slowly but steadily, tracking northward and then made landfall just before 5:00 p.m. EDT on Monday, August 16. After landfall, Fred tracked across the Florida panhandle and Georgia near the Tennessee-North Carolina State line the following day as a tropical depression and through West Virginia and western Pennsylvania on August 18, transitioning into a post-tropical storm system.

Synoptic Analysis

Fred's track was in many ways like that of Elsa, which preceded Fred in affecting South Carolina just over a month earlier. The only notable exception was that rather than traveling through the state as Elsa did, Fred passed nearby to the west. As with Elsa, the primary steering influence on Fred was the Bermuda-Azores high-pressure area and upper-level ridge, which is generally prevalent during summertime in the Northern Hemisphere. A primary difference in the upper-level pattern with Fred's situation compared to Elsa's is that there was no strong shortwave trough arriving in the eastern part of North America to cause Fred to accelerate to the northeast. However, a weak upper-level trough was present over the Mississippi Valley to steer Fred to the north through and then away from South Carolina.

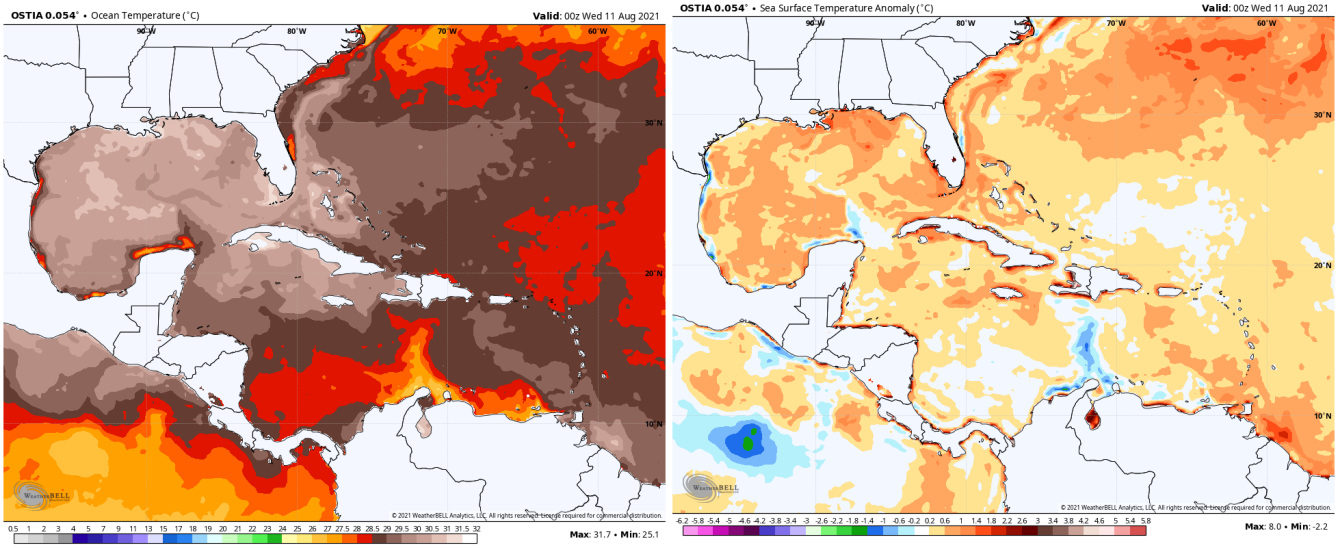


500 millibar height analyses from the University of Wyoming during Fred's life, showing the progression of the upper-level pattern.

Top Left: 00 UTC on August 10, 2021, as Fred was developing near the Leeward Islands
Top Right: 00 UTC on August 14, 2021, while Fred was passing over Cuba
Bottom Left: 00 UTC on August 16, 2021,while Fred was strengthening over the eastern Gulf of Mexico
Bottom Right: 00 UTC on August 18, 2021, when Fred was centered over western North Carolina

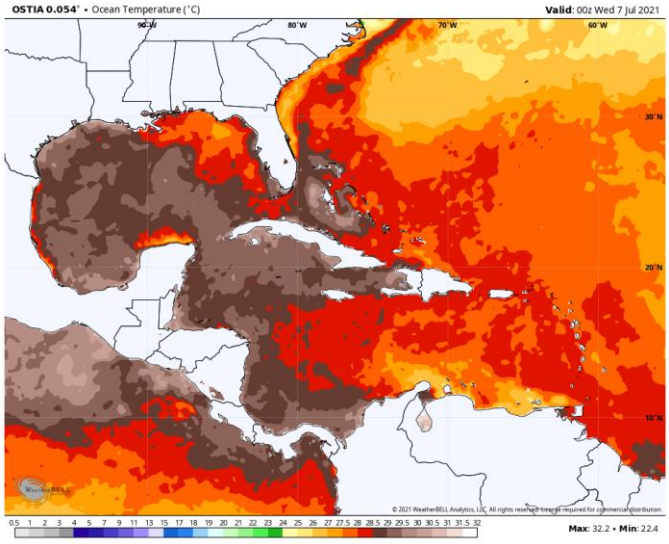
Synoptic Analysis

As is typical for August, very warm waters were present in the Caribbean, adjacent to the Atlantic and Gulf of Mexico, while Fred passed through this part of the Atlantic basin. Sea surface temperatures all along Fred's track were at least 28°C (82.4°F) and as warm as 31.5°C (88.7°F). These values are generally above average for the time of year, particularly over the eastern Gulf of Mexico, where sea surface temperatures were as much as 1.4°C (2.5°F) above average for the middle of August.



Left: OSTIA sea surface temperature plot for 0000 UTC on August 11, 2021 (image from WeatherBELL)
Right: OSTIA sea surface temperature anomaly plot for 0000 UTC August 11, 2021 (image from WeatherBELL)

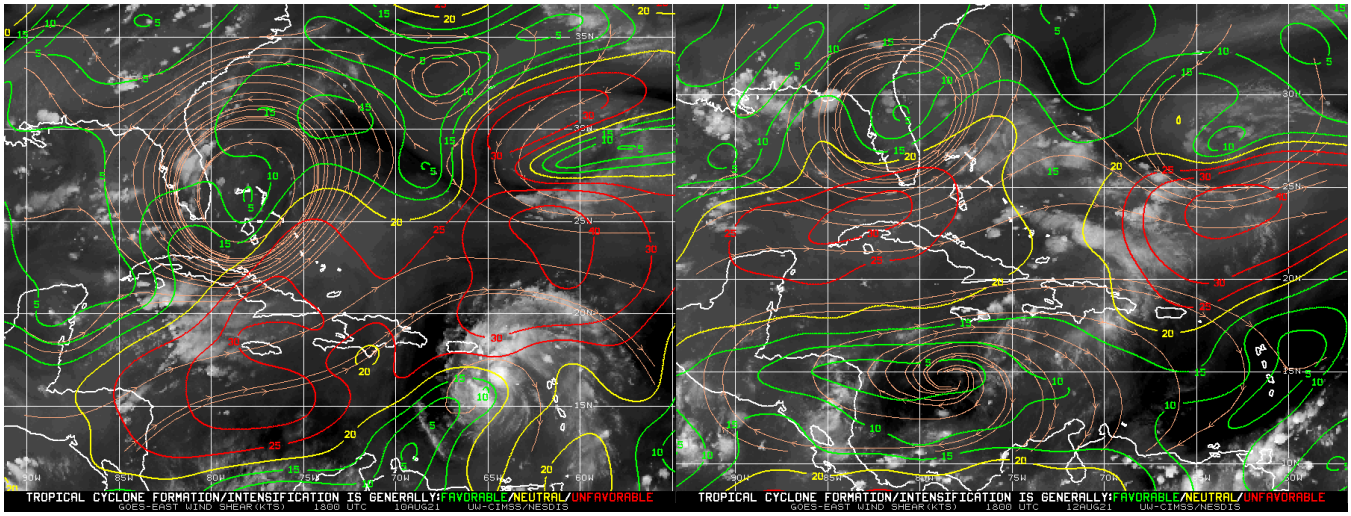
The sea surface temperatures had recovered fully over the eastern Gulf of Mexico after Elsa's passage a month earlier. In Elsa's wake, waters had cooled over the eastern Gulf of Mexico to 28-29°C (82.4-84.2°F), a change of about 1°C (1.8°F) from before Elsa's passage.



OSTIA sea surface temperature plot for 0000 UTC on August 7, 2021, just after Elsa made landfall in the Florida Panhandle. (image from WeatherBELL)

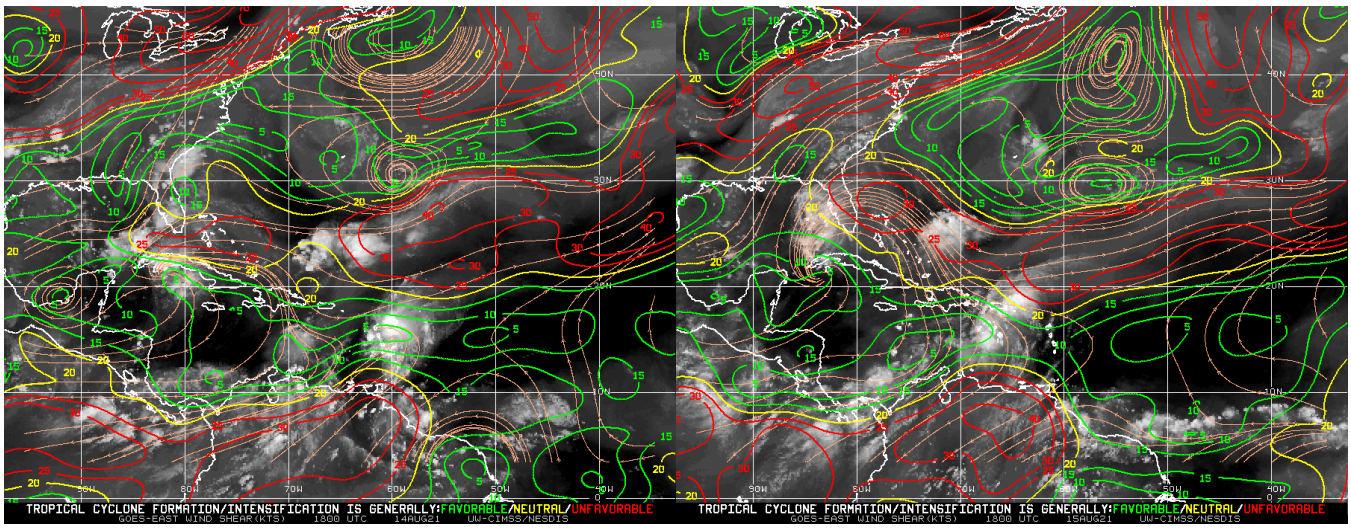
Synoptic Analysis

For much of its life, Fred was strongly affected by shear due to strong southwesterly winds aloft over the Caribbean. Fred was initially south of this band of upper-level winds when it formed but moved into the strong winds aloft at the same time it moved over Hispaniola.



Left: UW-CIMSS shear analysis at 1800 UTC August 10; Fred was a developing storm near Puerto Rico. Right: UW-CIMSS shear analysis for 1800 UTC August 12, while Fred was crossing Hispaniola

Fred was so seriously disrupted by passing over land and by the strong shear that it ceased to be a tropical cyclone at all by August 14. However, the NHC treated the system as a potential tropical cyclone and still issued advisories because their forecast was for Fred to regenerate over the Gulf of Mexico. A relaxation of the strong shear during August 15 combined with the warm waters present in this area led to Fred regenerating and then intensifying steadily until making landfall near Cape San Blas, Florida, on August 16.

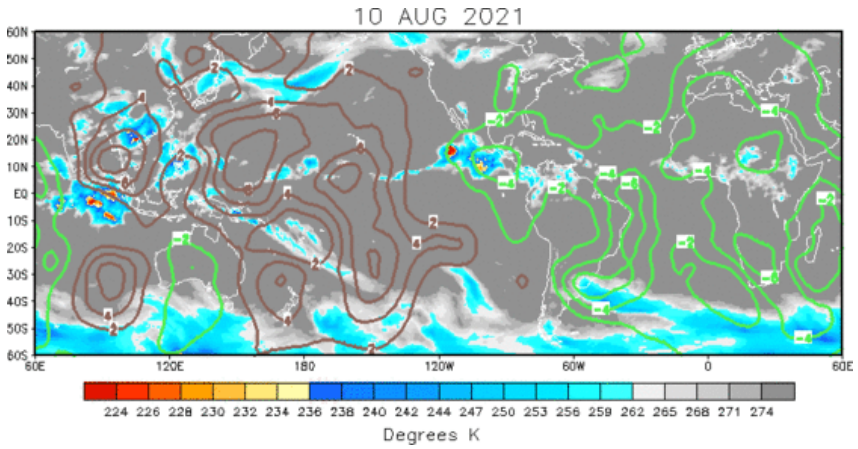


Left: UW-CIMSS shear analysis at 1800 UTC August 14; Fred's remnants were near the western tip of Cuba. Right: UW-CIMSS shear analysis at 1800 UTC August 15; Fred was intensifying in the eastern Gulf of Mexico.

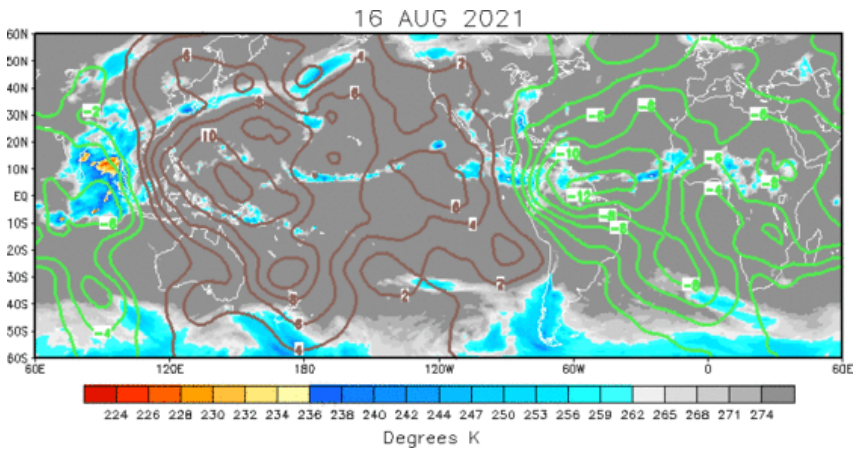
Synoptic Analysis

The Madden-Julian Oscillation (MJO), discovered in 1971 by researchers at the National Center for Atmospheric Research, is well-known to modulate thunderstorms and tropical cyclone activity in the world's tropics, as described in our Open-File Report on Elsa. The Atlantic basin is under favorable conditions for tropical thunderstorm activity and potential tropical cyclone formation when the MJO is in Phases 8, 1, and 2.

When the tropical wave that gave rise to Fred was crossing the Atlantic, the MJO weakly entered Phase 1 and entered Phase 2 while Fred was crossing the Greater Antilles. The MJO gained intensity while reaching Phase 2. The result was increasingly favorable upper divergence over the Gulf of Mexico, Caribbean Sea, and the southwestern Atlantic Ocean during Fred's life cycle and, in turn, a general tendency for rising motion. Such a situation enhances thunderstorm development and creates conditions more favorable for tropical cyclone development and intensification.



200 hPa (millibar) level Velocity Potential Anomaly plotted by the Climate Prediction Center on August 10, 2021, showing upper divergence (green contours), corresponding to general rising motion, over Africa and much of the Atlantic Ocean. Fred at the time was forming just east of the Windward Islands.

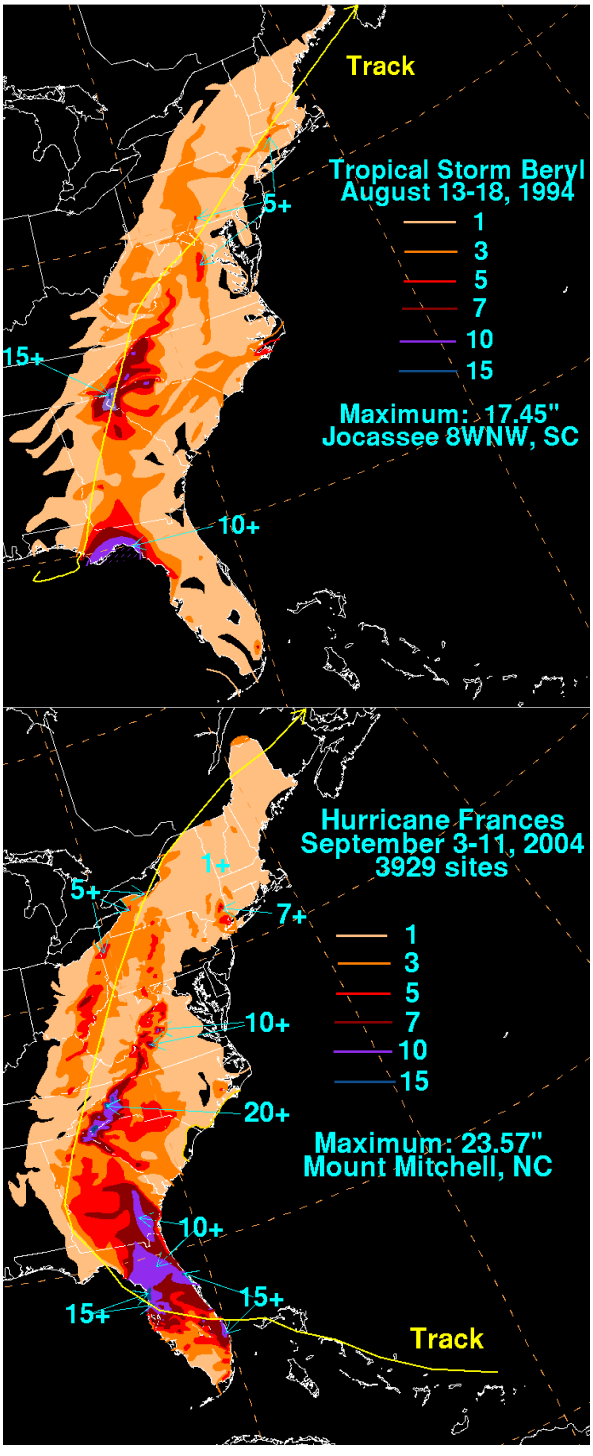


200 hPa (millibar) level Velocity Potential Anomaly plotted by the Climate Prediction Center on August 16, 2021, showing continued upper divergence (green contours) over most of the Atlantic Basin. Fred was located over the eastern Gulf of Mexico at the time, approaching landfall in Florida.

Synoptic Analysis

A tool that proved helpful in forecasting Fred's potential effects on South Carolina was a comparison to previous storms that followed a similar path, a technique called analog forecasting. This method compares the historical storm tracks with the path to date and forecast track of an ongoing storm along with surrounding weather features to previous events to find similarities. One such tool, Climatology-based Quantitative Rainfall (CLIQR), developed by the Weather Prediction Center, focuses on displaying the rainfall produced by storms found to be like an ongoing storm.

CLIQR found two storms to have a similar track to the one Fred had followed and was forecast by the NHC. The first was Tropical Storm Beryl of 1994, which formed in the Gulf of Mexico and tracked inland through Florida, Georgia, and the western Carolinas. The other was Hurricane Frances of 2004, a Cabo Verde storm and a major hurricane over the Atlantic, which weakened to a tropical storm while crossing The Bahamas and making landfall in Florida. After passing over the Gulf of Mexico, the center of Frances moved inland over the Florida Panhandle, through Georgia, and across western North Carolina. Both storms generated flooding rainfall in South Carolina and adjacent areas of North Carolina and Georgia.



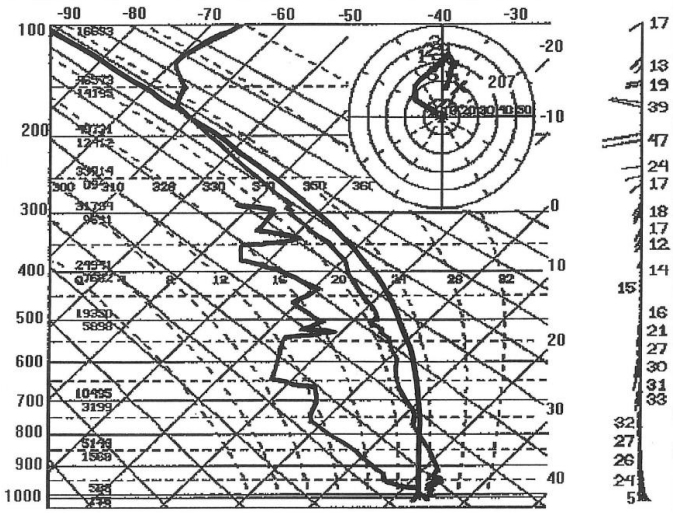
These comparisons were valuable to a forecaster because they validated a forecaster's concern about Fred's potential impacts. At the time, computer model guidance indicated the potential for enough rainfall to cause widespread flooding in Upstate South Carolina and isolated flash flooding elsewhere in the state. Also, both storms were prodigious tornado producers in South Carolina. Beryl caused 23 tornadoes in South Carolina, including a notable F-3 that struck Lexington. Frances caused 46 tornadoes in South Carolina; again, the strongest was an F-3 in Kershaw County.

Synoptic Analysis

Tropical cyclones are well-known to generate tornadoes, and they can do so long after landfall. However, some tropical cyclones produce more and stronger tornadoes than others. In 1996, National Weather Service meteorologists studied tornadoes spawned by Tropical Storm Beryl, which made landfall in Florida on August 16, 1994, before tracking through Georgia, the Carolinas, and Virginia.

Their research determined that sufficient low-level shear must be present for tornadoes to occur, and that dry air intrusion can enhance the potential for severe weather. In the case of Beryl, 0-3 km storm-relative helicity was measured at 207 m2/s2, and there was an intrusion of dry air aloft on the 1200 UTC (0800) on August 16, 1994, in the Charleston, SC sounding.

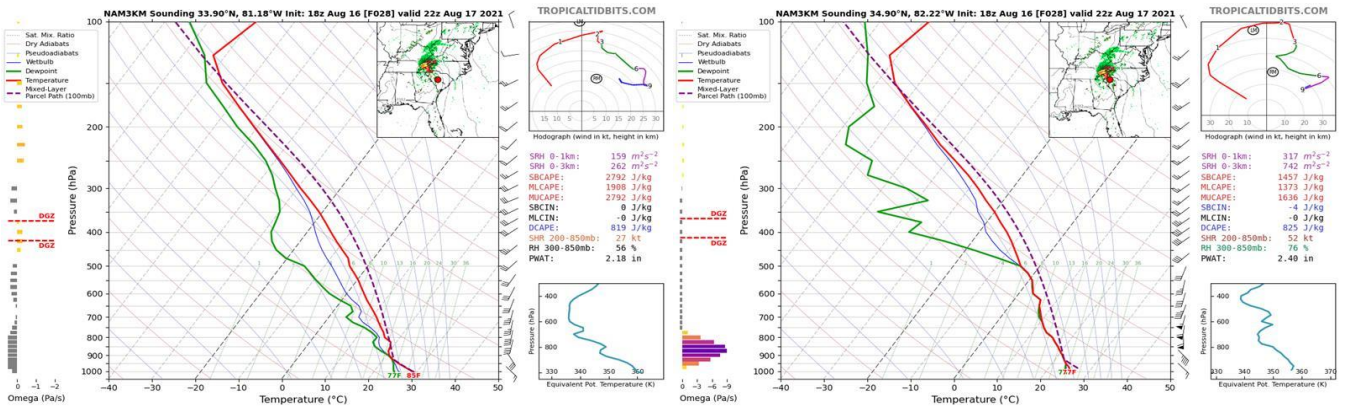
Fred's forecast model soundings from August 16, 2021, indicated that similar conditions, though not as conducive for tornadoes, would occur the next afternoon in South Carolina. Dry air could clearly be seen intruding into South Carolina aloft on these forecast soundings, particularly in the Midlands. This enhanced instability, though the dry air aloft was found only at higher altitudes (generally above 800 mb), whereas with Beryl, the dry air was found just above the surface. Ample low-level shear was forecast by the numerical models, particularly in the Upstate, where low-level shear was predicted to be extremely strong.



Left: the 1200 UTC, August 16, 1994, sounding from Charleston showing the presence of strong low-level shear (evident from the wind speed and direction plotted at right) and dry air (indicated by the spread between the temperature and dewpoint traces).

Bottom left: Forecast sounding for a point near Columbia from the 1800 UTC August 16, 2021, run of the NAM model 3km CONUS nest, valid at 6 p.m. EDT August 17, which showed strong low-level shear in an environment conducive for thunderstorms to occur with dry air present aloft.

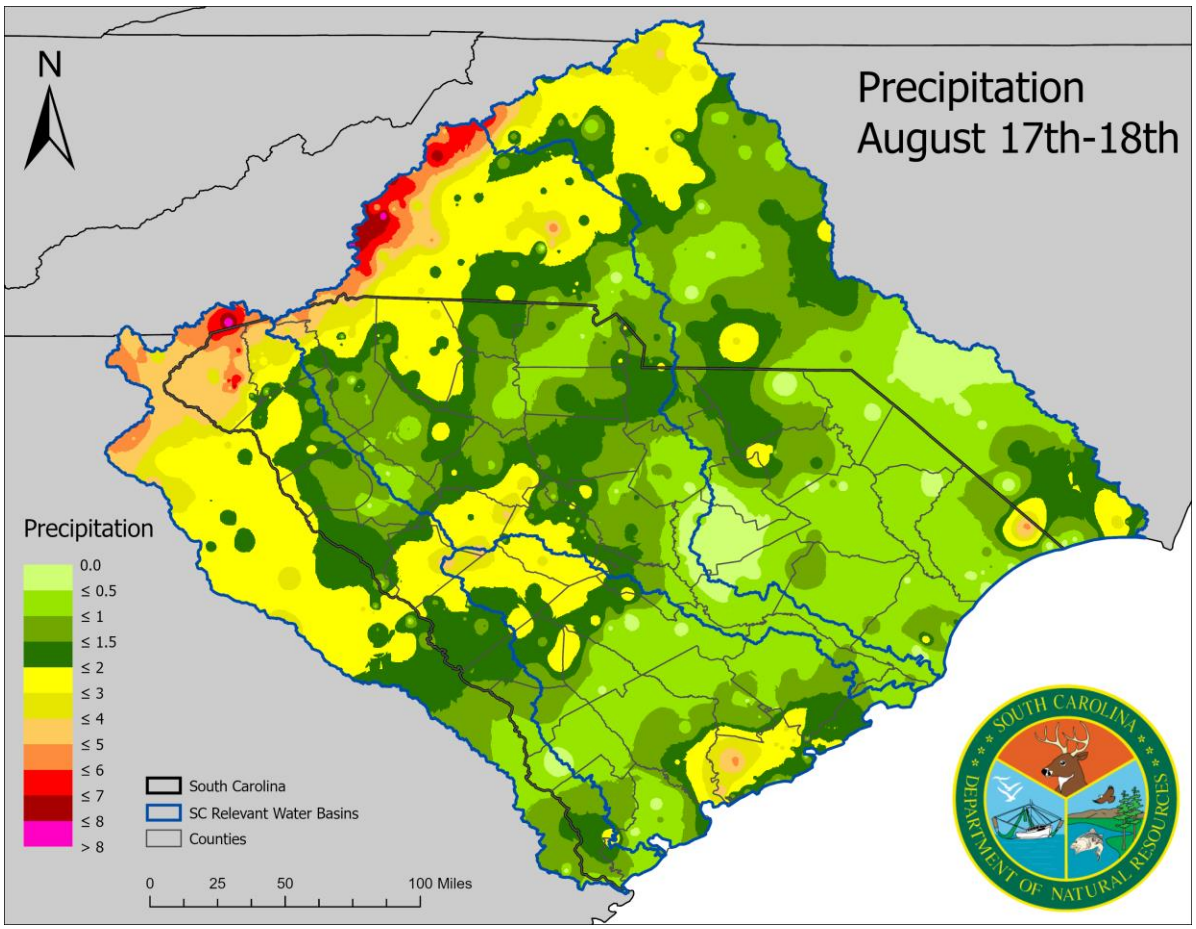
Bottom right: A forecast sounding from the same model, valid at the same time, for a point in Upstate SC. It indicates thunderstorms occurring in an environment with extremely strong low-level shear.



Rainfall Reports

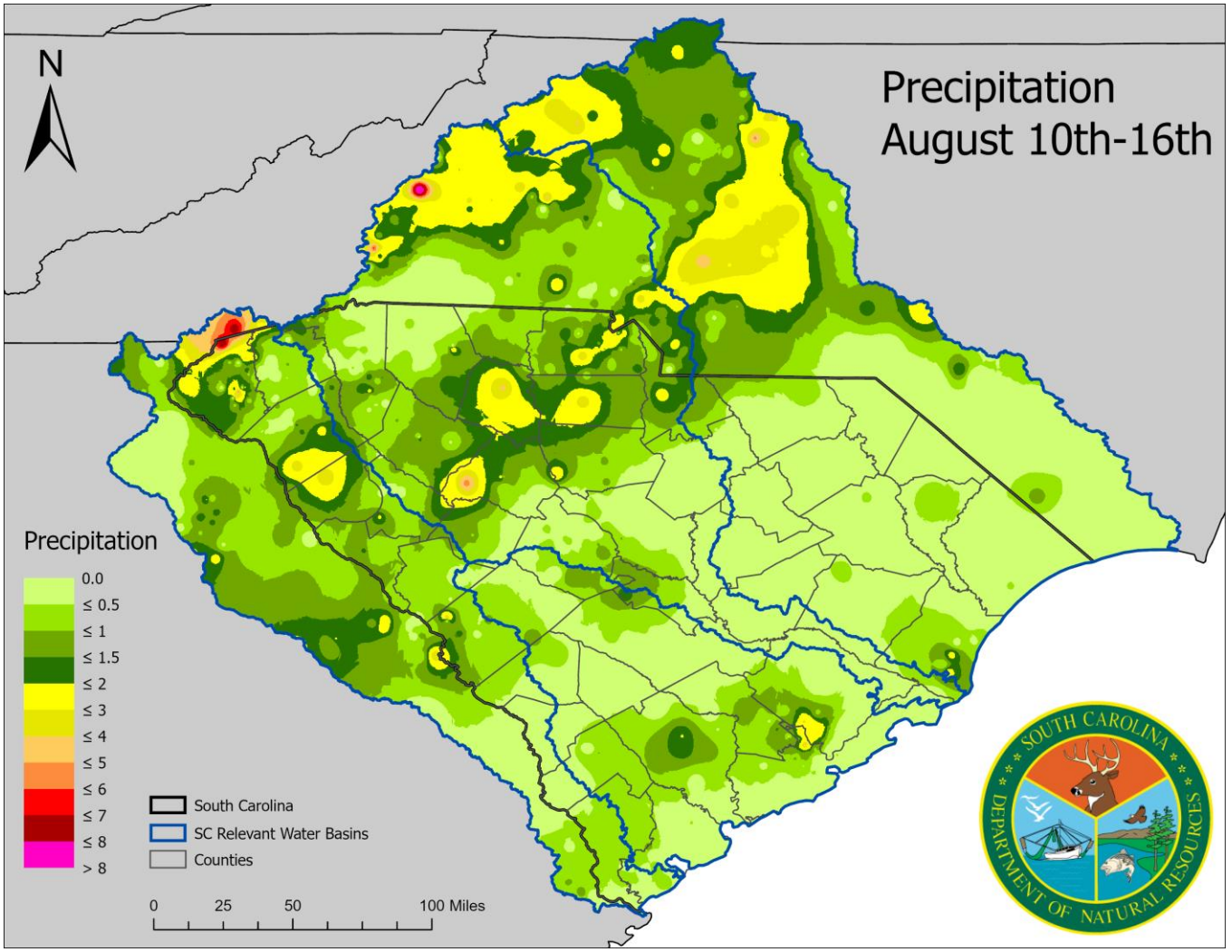
Fred's most significant impact on South Carolina was heavy rainfall. Most of the rain caused by Fred occurred on Tuesday, August 17, though some rain lingered over the Coastal Plain through much of the following day. For the two days combined, rainfall over two inches occurred over much of the Upstate, Midlands, and Central Savannah River Area (CSRA). A large portion of Charleston County and adjacent areas also received over two inches of rainfall. However, the Upstate saw the heaviest rain with locally over six inches along the North Carolina state line in Oconee, Pickens, and Greenville Counties.

Station	Station Type	Rainfall Total (in)
Sassafras Mountain	SC DNR	7.55
Seneca (SC-OC-53)	CoCoRaHS	4.68
Seneca (SC-OC-97)	CoCoRaHS	4.68
Seneca (SC-OC-7)	CoCoRaHS	4.39
Hollywood	CoCoRaHS	3.84
Sunset	CoCoRaHS	3.72
Salem	CoCoRaHS	3.35
Bluffton	CoCoRaHS	2.79
Seneca (SC-OC-98)	CoCoRaHS	2.71
Salem (SC-OC-40)	CoCoRaHS	2.42



Rainfall totals for August 17-18, 2021, for South Carolina and areas of adjacent states which drain into South Carolina rivers.

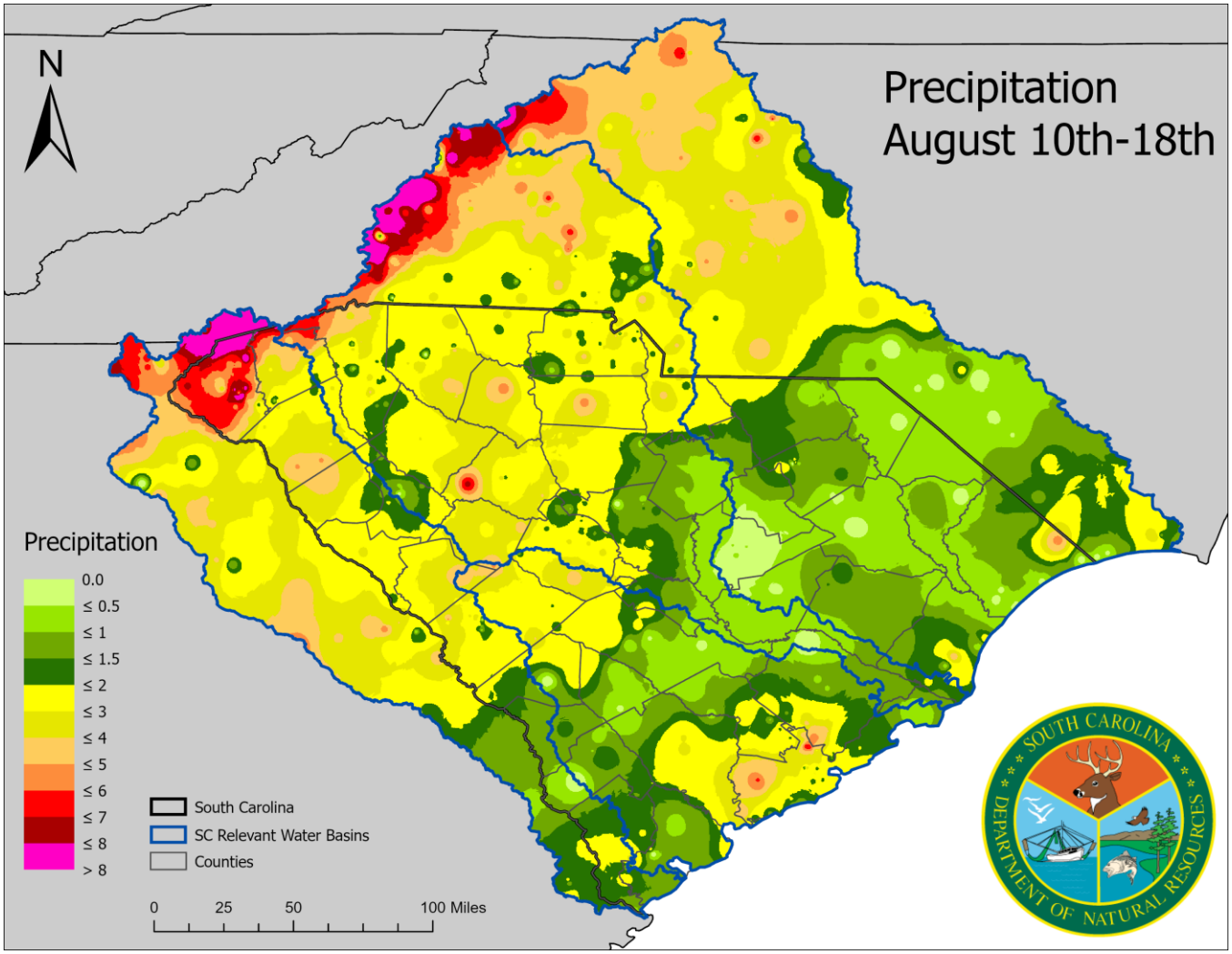
However, the rainfall that occurred with Fred's passage through South Carolina was only part of the story. The days leading up to Fred's rain were also quite wet in Upstate South Carolina and across parts of Georgia and North Carolina that drain into South Carolina's rivers. The precursor rain led to saturated soils and higher flow rates in South Carolina's rivers and smaller streams in advance of the storm and increased the risk of flooding from the heavy rainfall that Fred would bring.



Rainfall for South Carolina and the state's river's watersheds in other states for August 10-16, 2021

Rainfall Reports

The combined rainfall over the nine-day period that ended once Fred had moved out of the region exceeded two inches over more than half of South Carolina. Most of Oconee County and large parts of Pickens and Greenville Counties received more than a month worth of rainfall during these nine days. While the heaviest rain during this time fell in North Carolina, a significant portion of it fell in a part of this neighboring state which drains into a South Carolina river. The result was substantial rises and flooding along rivers and smaller streams in South Carolina.

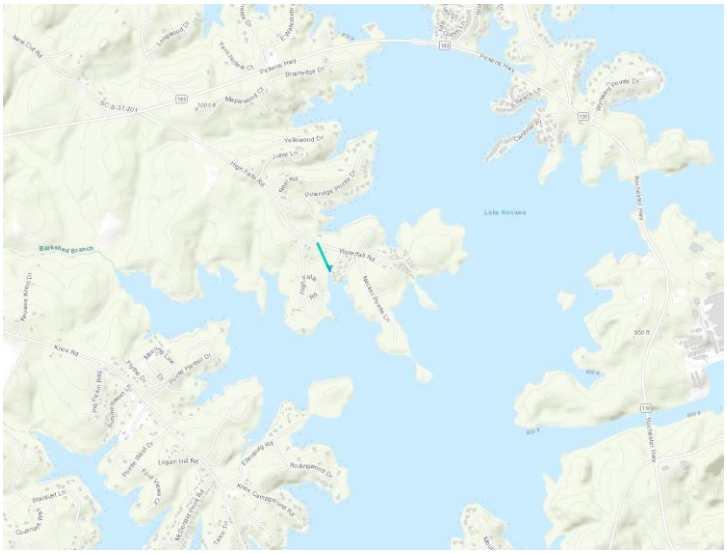


Rainfall for South Carolina and the state's river's watersheds in other states for August 10-18, 2021, which includes rainfall from Fred and the predecessor rain events

Tornadoes

Storm survey teams from the National Weather Service were able to confirm a total of ten tornadoes in South Carolina spawned by the remnants of Fred on August 17. Five of the tornadoes were rated EF-0, and five were rated EF-1 on the Enhanced Fujita (EF) Scale.

The first tornado occurred near the western shore of Lake Keowee in Oconee County at 12:50 p.m. EDT. The NWS storm survey team estimated the tornado only lasted one minute. The path width was about 50 yards, and the length was 0.136 miles, beginning about 6.2 miles west of Six Mile, or about nine miles north of Oconee County Regional Airport. This tornado was rated an EF-0 with peak winds near 75 mph. Damage in this area included several uprooted trees, with one tree falling on a home on Crowe Drive, about nine miles to the north-northwest Oconee County Regional Airport. No injuries nor deaths were reported.

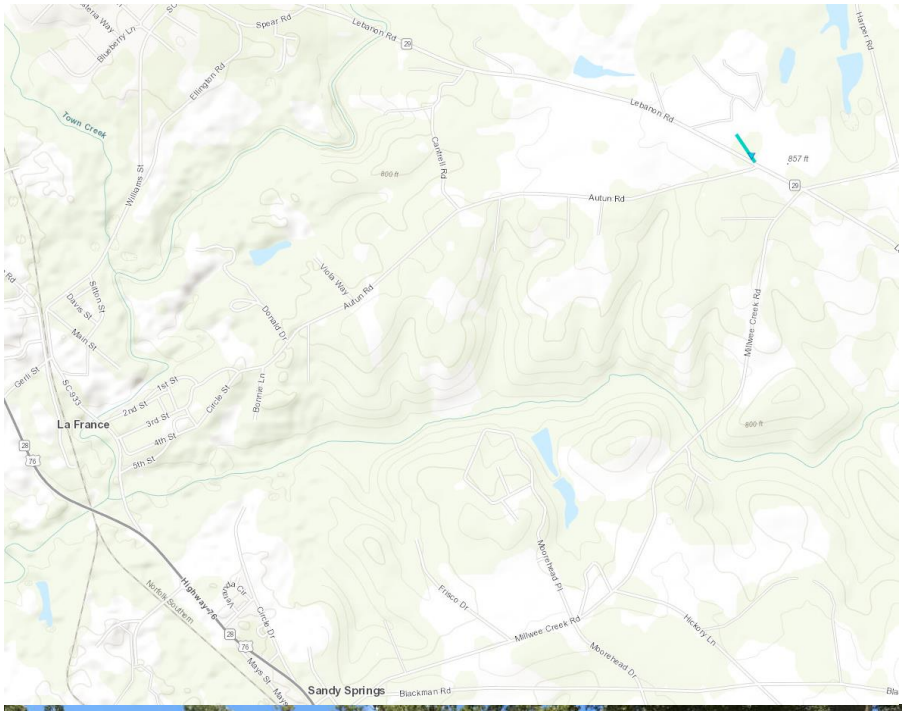


Damage path (blue line) of the Lake Keowee tornado of August 17, 2021.

A photo of one of the downed trees caused by the Lake Keowee Tornado of August 17, 2021

Tornadoes

The second tornado occurred at 12:59 p.m. in Anderson County on Lebanon Road near Sandy Springs, or about 8.8 miles north-northwest of Anderson Regional Airport. The tornado lasted for about one minute. The path was about 50 yards wide and approximately 0.1 miles in length. It was rated EF-0 by an NWS storm survey team with a peak wind of about 85 mph. The tornado uprooted several trees. No injuries nor deaths were reported.

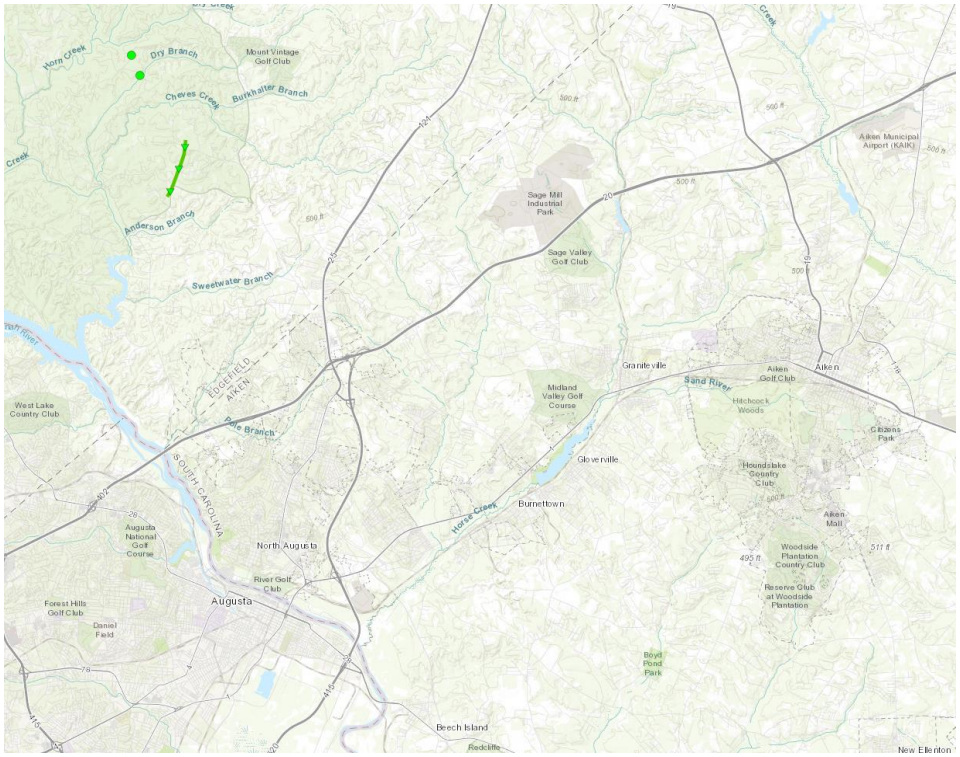


Damage path (green line at upper right) of the Sandy Springs tornado of August 17, 2021.

A photo of damage caused by the Sandy Springs tornado.

Tornadoes

The third tornado struck Edgefield County just northwest of Murphy's Estates, or about 19 miles west-southwest of Aiken Regional Airport. It touched down at 1:03 p.m. EDT and lasted for about four minutes. The tornado tracked on a path to the north-northeast that was as much as 100 yards wide and was 1.5 miles long. The damage path was up to 100 yards wide and 1.5 miles long, beginning about 4.5 miles northwest of Murphys Estates, or 18.9 miles west-southwest of Aiken Regional Airport. It was rated at EF-1 by an NWS storm survey team. The tornado destroyed a small shed and caused tree damage in the nearby area. No fatalities nor injuries were reported.



A map showing the path of the August 17 Edgefield County tornado and nearby tree damage found by a NWS survey team.

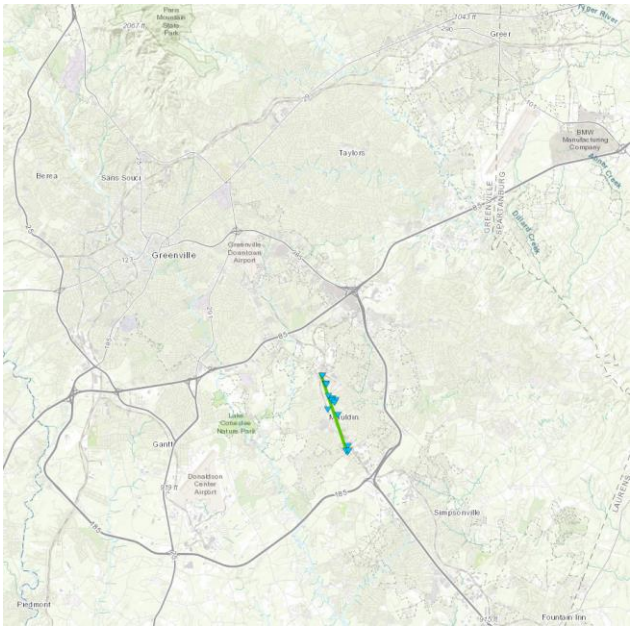
Tornado: green line near the top left of the map.

Tree damage: green dots just to the northwest of the tornado track

A photo of some of the tree damage caused by the August 17 Edgefield County tornado.

Tornadoes

The fourth tornado struck Mauldin in Greenville County. It was rated EF-1 by an NWS storm survey team with peak winds near 90 mph. It began at 2:53 p.m. and lasted four minutes. The path was up to 75 yards wide, and the tornado was on the ground for 2.38 miles, starting about 9.4 miles southwest of Greenville - Spartanburg International Airport. Considerable tree damage was reported along the tornado's path in Mauldin, along with some minor roof damage and some sliding structure damage. There were no injuries nor deaths reported.

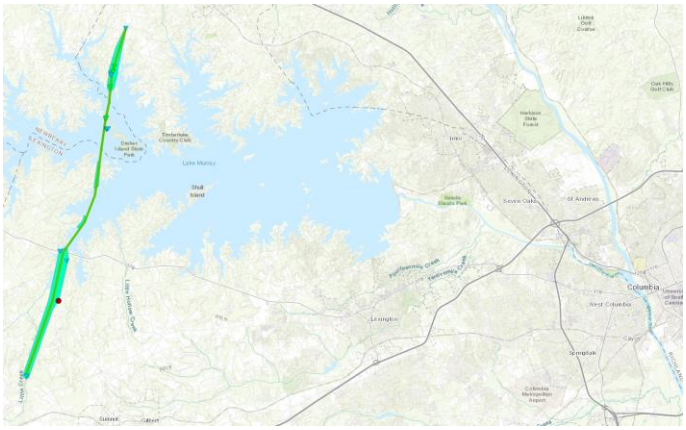


Right: A map showing the damage path (green line just below center) of the August 17 Mauldin tornado.

Photos of damage caused by the August 17 Mauldin tornado.

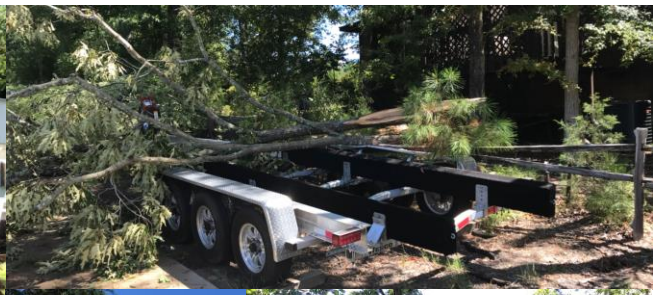
Tornadoes

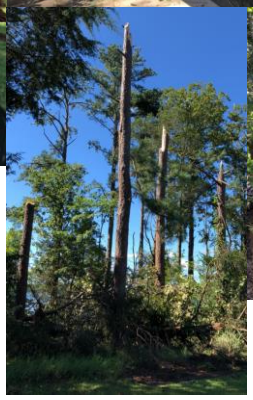
The fifth tornado affected parts of Lexington and Newberry Counties near the west side of Lake Murray and was initially believed to be two separate tornadoes until a video provided to the NWS indicated that it was one tornado. It began about 3 miles northwest of Summit in Lexington County, approximately 20.6 miles west of Columbia Metropolitan Airport, at 3:31 p.m. EDT. The tornado was on the ground for about seven minutes. The path was up to 50 yards wide and 5.19 miles long. It was rated EF-1 by an NWS storm survey team with peak winds near 95 mph. The tornado caused tree damaged along its path; one tree fell on a boat moored to a pier on Lake Murray near Dreher Island State Park. Farther north, tree, home, and boat damage was reported on or near RB Baker Drive in northwestern Lexington County. No injuries nor deaths were reported.



A map showing the path (green line at left) of the Lake Murray tornado of August 17, 2021.

A tree downed onto a boat on Lake Murray





More photos of damage from the August 17 Lake Murray tornado.

Tornadoes

Another tornado occurred simultaneously and just to the west of the Lake Murray tornado on August 17. It began at 3:33 p.m. EDT and lasted about 10 minutes. The damage path started about 4.4 miles northeast of Batesburg-Leesville, or 22.3 miles west of Columbia Metropolitan Airport. The tornado caused damage along its track up to 50 yards wide and 4.32 miles long, close to the Lexington-Saluda County Line and ending in Saluda County. It was rated EF-0 by an NWS storm survey team with peak winds near 75 mph. This tornado caused only minor and sporadic tree damage. No injuries nor deaths were reported.

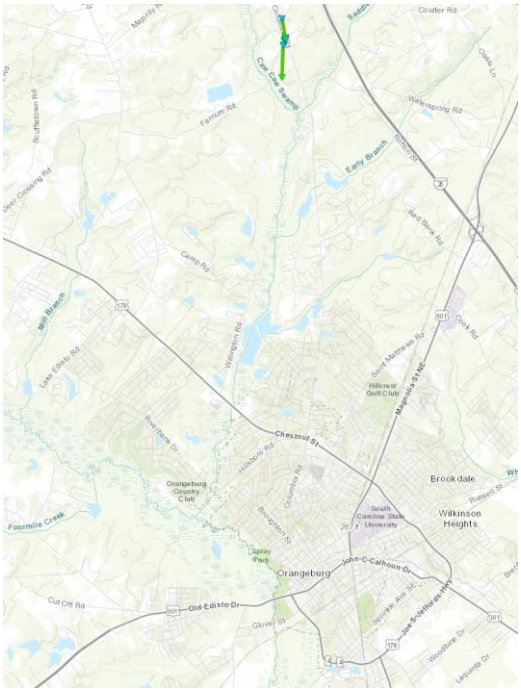
A map showing the path (blue-green line) of the far west Lexington County tornado of August 17, 2021.

A tree downed by the far west Lexington County tornado of August 17

More tree damage caused by the far west Lexington County tornado of August 17.

Tornadoes

South Carolina's seventh tornado spawned by Fred occurred in Orangeburg County, just north-northwest of Orangeburg. It touched down at 5:40 p.m. EDT and was on the ground for three minutes. The path began about 8 miles north of Orangeburg, or about 12.2 miles east of North Air Force Auxiliary Airfield. The damage path was 25-50 yards wide and 0.9 miles long. It was rated EF-1 by an NWS storm survey team with peak winds of 88 miles per hour. The tornado mainly caused tree damage, but some downed branches damaged a vinyl fence along Columbia Road and removed some shingles and flashing from Bethel Church along Columbia Road. There were no injuries nor deaths reported.



A map showing the path (green line near top center) of the Orangeburg County tornado of August 17, 2021.

Minor roof damage caused by the tornado to Bethel Church near Orangeburg.

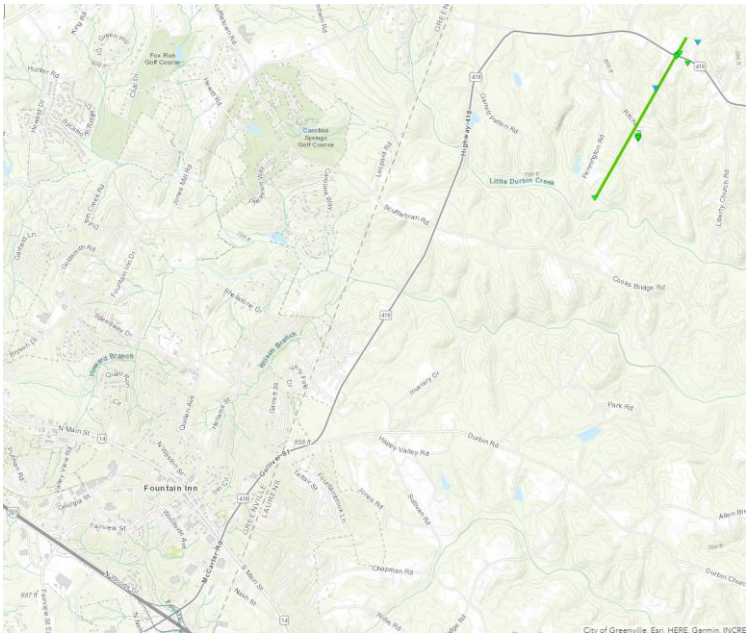
Damage to fencing along Columbia Road north of Orangeburg, where trees were downed by the tornado which landed on the fence.

Tornadoes

The eighth tornado occurred in far western Laurens County. It touched down briefly at 6:07 p.m. EDT, lasting at most one minute. The path was up to 30 yards wide and about 0.2 miles long. It began about 2.9 miles southeast of Fountain Inn, or 16.1 miles south-southeast of Greenville-Spartanburg International Airport. It was rated EF-0 by the NWS with peak winds of about 65 mph. A NWS storm survey team found no damage and no fatalities nor injuries were reported. The only video posted to social media by a storm chaser in the vicinity provided evidence that this weak and short-lived tornado occurred.

The path (short blue-green line near center) of the brief far western Laurens County tornado.

Tornadoes



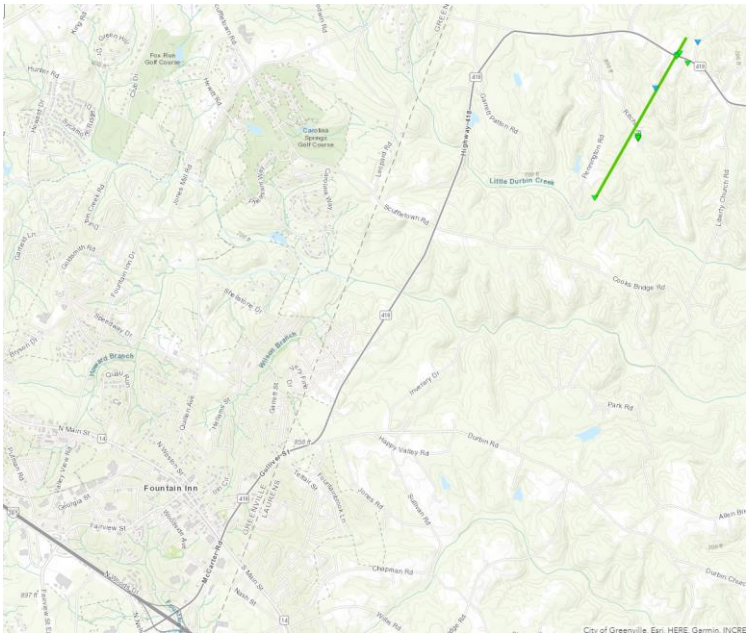
A map showing the damage path (green line at top right) of the Laurens County tornado of August 17.

The ninth tornado occurred in far northern Laurens County near the Greenville County line. The tornado began at 6:18 p.m. EDT and lasted three minutes. The damage path was up to 75 yards wide and 1.45 miles long, starting about 4 miles northeast of Fountain Inn or 11.7 miles southeast of Greenville-Spartanburg International Airport. Rated an EF-1, with peak winds of about 90 mph, the tornado caused Mostly this tornado caused tree damage, but one tree fell on a home along Ritchie Road. Also, a shed was destroyed, and a home sustained minor roof damage along Highway 418. No injuries nor fatalities were reported.

The Fountain Inn area tornado of August 17 damaged this shed and the roof of this home along Highway 418.

A tree uprooted by the Fountain Inn area tornado which landed on a home along Ritchie Road.

Tornadoes



A map showing the damage path (green line at top right) of the Laurens County tornado of August 17.

The tenth tornado caused by Fred occurred in Saluda County near Holton Crossroads. It began at 8:47 p.m. EDT and lasted for about one minute. The tornado's damage path was at most 25 yards wide and about 200 yards long. The track began about 5.3 miles northwest of Batesburg-Leesville or about 27 miles east-northeast of Columbia Metropolitan Airport. Damage was limited to a few snapped trees, and it was rated EF-0 by an NWS storm survey team. . No injuries nor deaths were reported.

Photos of tree damage caused by the August 17 Saluda County tornado