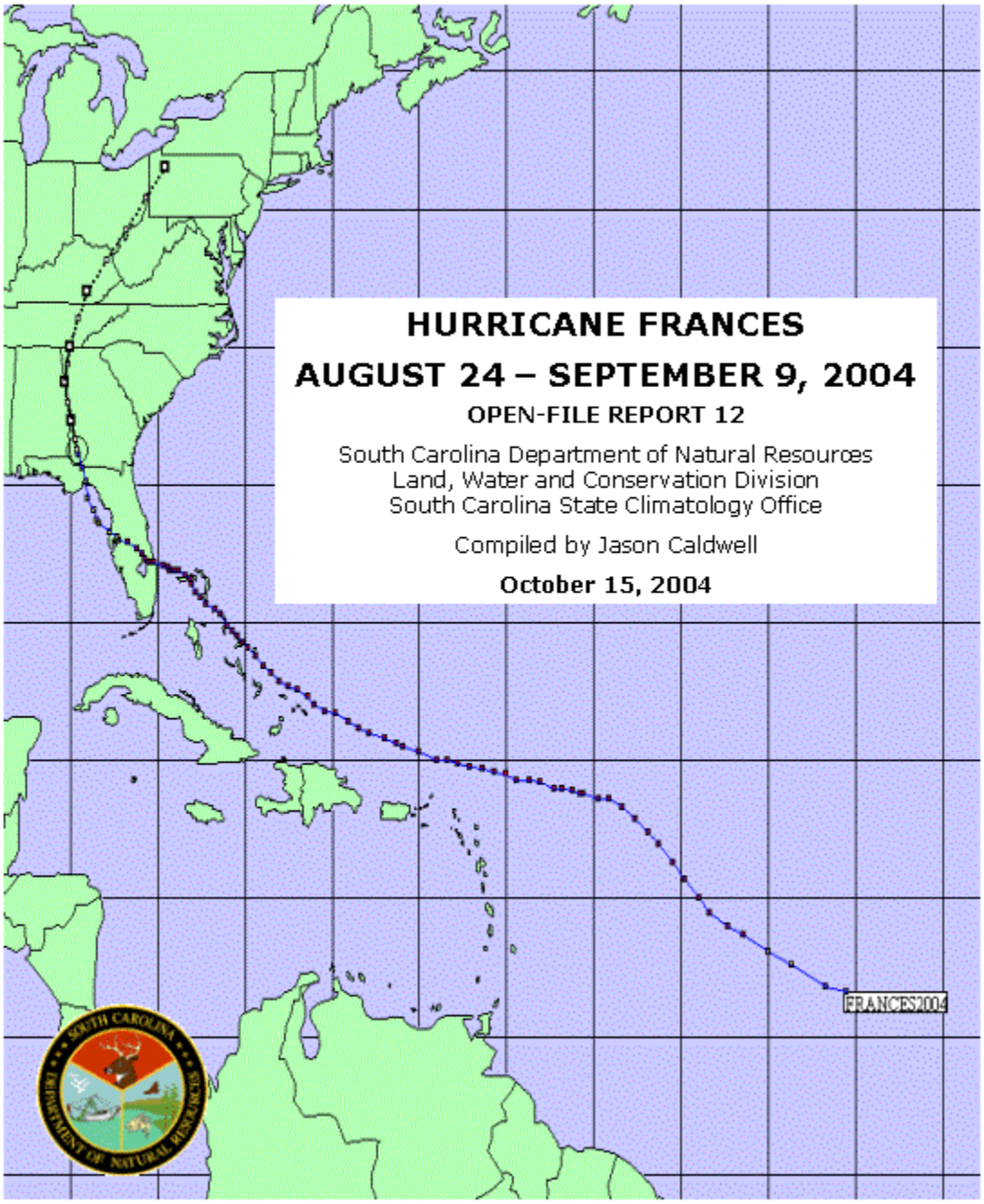
Hurricane Frances



Publication of the South Carolina State Climatology Office

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HURRICANE FRANCES

August 24-September 9, 2004

EVENT SUMMARY

On August 24, 2004, a strong tropical disturbance moved into the far eastern Atlantic Ocean (Figure 1) and strengthened to become Frances, the sixth named tropical storm of the 2004 Atlantic Basin Hurricane Season, on the following day (Figure 2). Wasting no time, Frances achieved hurricane status on August 26 (Figure 3) as the storm moved west-northwestward across the central portions of the Atlantic Basin.

By August 27, Hurricane Frances was approaching category 3 (Figure 4) on the Saffir-Simpson scale as the storm headed westward toward Puerto Rico (Figure 5) where the storm passed just north of the island nation on the last day of August with sustained winds of 140 mph, a category 4 storm.

The Turks and Caicos Islands then braced for the storm as Frances moved northwestward toward the southeastern Bahamas (Figure 6) with the storm passing over San Salvador Island late in the day on September 2 as a weaker category 3 storm.

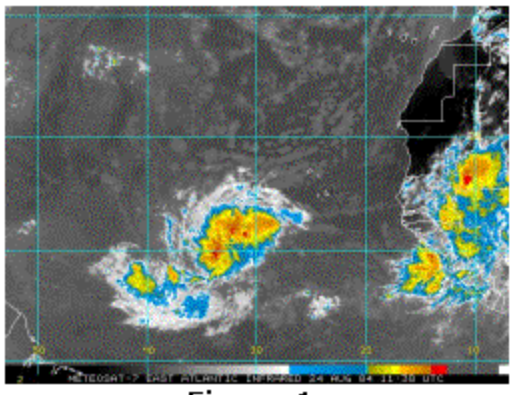


Figure 1

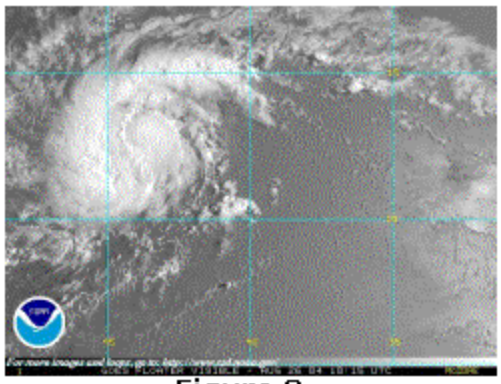


Figure 2

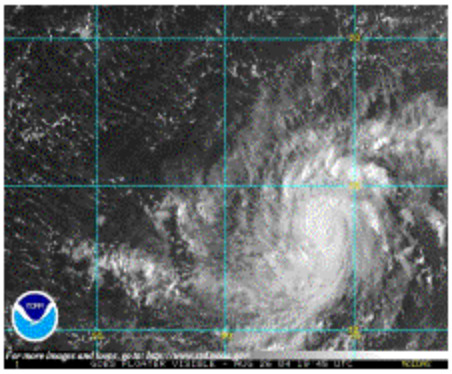


Figure 3

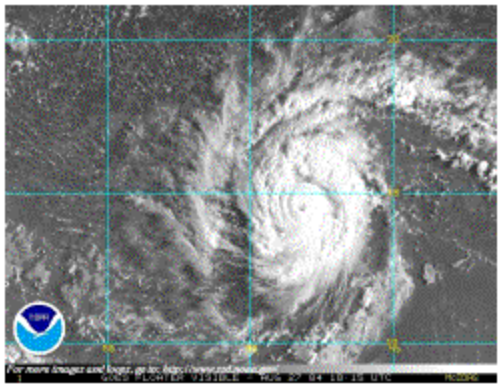


Figure 4

EVENT SUMMARY (cont.)

Hurricane Frances was the second major hurricane to threaten the Florida coast in 2004; however, in the hours before landfall on September 5, the hurricane weakened from a category 3 to a formidable category 2 with sustained winds of 105 mph with gusts to 125 mph (Figure 7). Frances made landfall near Sewall's Point on the east-central coast of Florida (Figure 8) before tracking across the peninsula and into the northeastern Gulf of Mexico during the day on September 6, making a second landfall near St. Marks in the Florida panhandle as a tropical storm.

Frances then moved northward along the East Coast of the United States before dissipating in eastern Canada on September 9, 2004, leaving at least 23 deaths along the path.

Figure 5

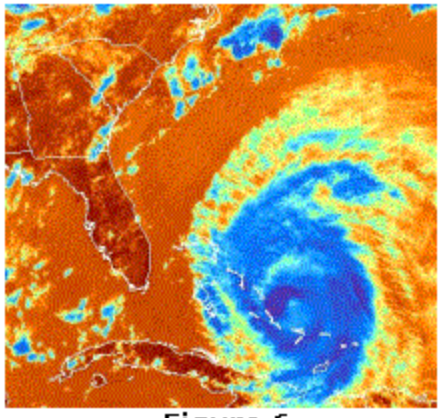


Figure 6

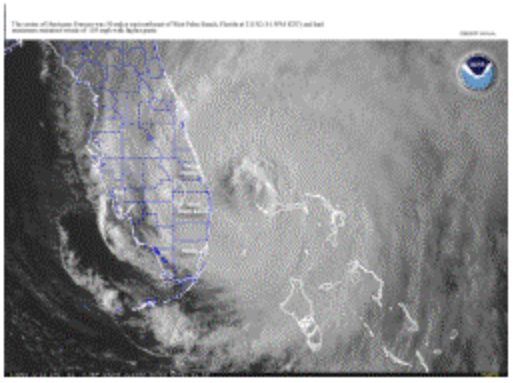


Figure 7

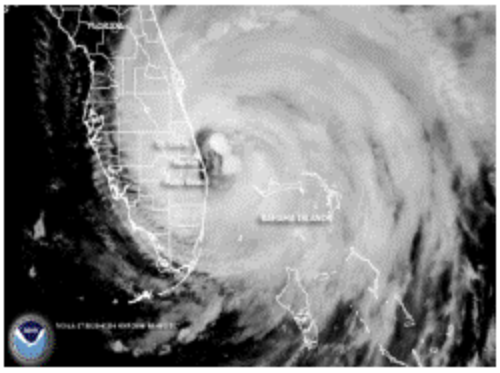


Figure 8

FORECAST CONSIDERATIONS

Model forecasts for the eventual track of Frances were in relatively good agreement from early in the period on August 26, 2004 (Figure 9). The Global Forecast System (GFS) model predicted a landfall along the Southeast coast even with lead times of up to 14 days, although the storm was predicted to track farther to the north than the eventual path.

In the days prior to landfall along the Florida East Coast, Frances had traveled along the southern periphery of the Bermuda High positioned to the north of the storm. The dynamical models consistently showed a weakening of the ridge over the East Coast until 48 hours before landfall and turned Frances to the north several hundred miles to the east of Florida with the potential for a landfall farther north along the Georgia or South Carolina coastline.

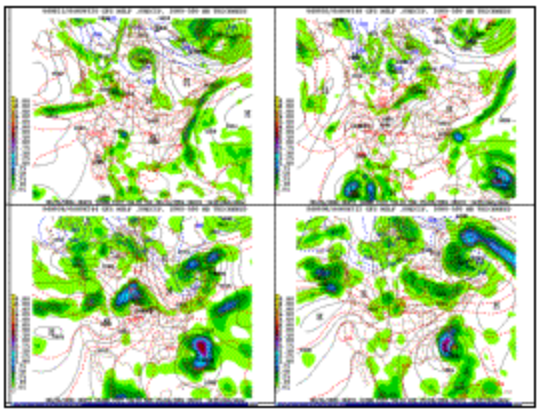


Figure 9

The Global Forecast Model (GFS) model forecasts from August 26, 2004, indicating the eventual path of Frances to impact the southeast coast of the United States during the period from September 5 to September 10, 2004.

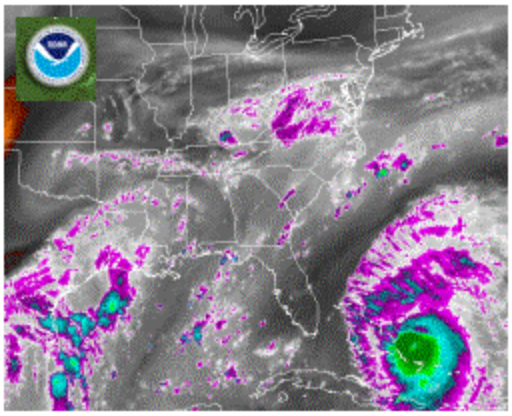


Figure 10

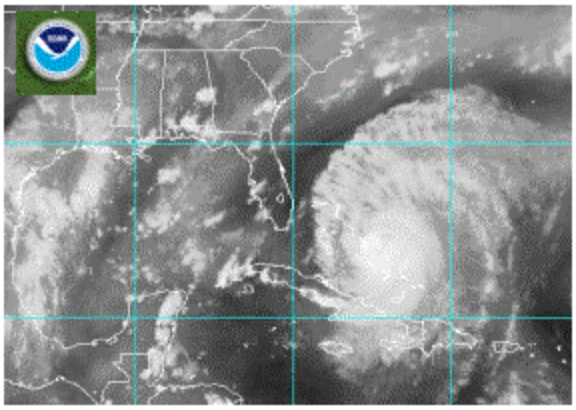


Figure 11

FORECAST CONSIDERATIONS (cont.)

Figures 10 (color enhanced) and 11 show the water vapor imagery, prior to landfall in Florida as Frances traveled slowly across the Bahamas under weak steering conditions with a trough located to the west over Texas and the western Gulf of Mexico. The timing of the eastward progression of this trough and associated southwesterly flow aloft were the primary consideration by meteorologists in determining the turn to the north projected by the models forecasts.

For South Carolina, the delayed turn to the north until over western Florida and the northeast Gulf of Mexico provided decreased likelihood of a direct landfall in the State. However, the track of the storm across the western Carolinas and Georgia did provide increased probability of tornadoes, high winds primarily associated with thunderstorms, and flooding rainfall as indicated by the Hydrometeorological Prediction Center forecast for 5-day total precipitation on September 3, 2004 (Figure 12).

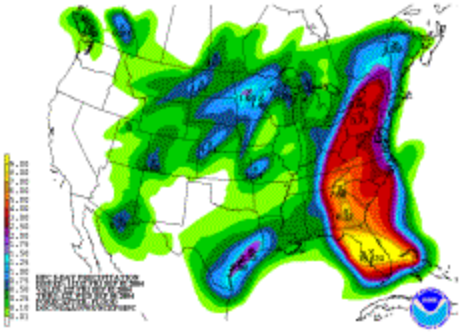


Figure 12

The official forecast from the Hydrometeorological Prediction Center (HPC) on September 3, 2004, for the 5-day period ending September 8, 2004. Red, orange, and yellow shaded contours indicate amounts from three to eight inches across South Carolina.

CONTRIBUTING FACTORS:
TD FRANCES TORNADO OUTBREAK
SEPTEMBER 6 – 7, 2004

Southeasterly flow (blue arrow) of warm, moist air (green shading) in the lower troposphere became increasingly unstable as dry air aloft (tan shading) moved over South Carolina at mid-levels (yellow arrow). The change in wind direction and speed with height (wind shear) allowed rotation to develop in thunderstorms as they developed in the outer bands of Frances.

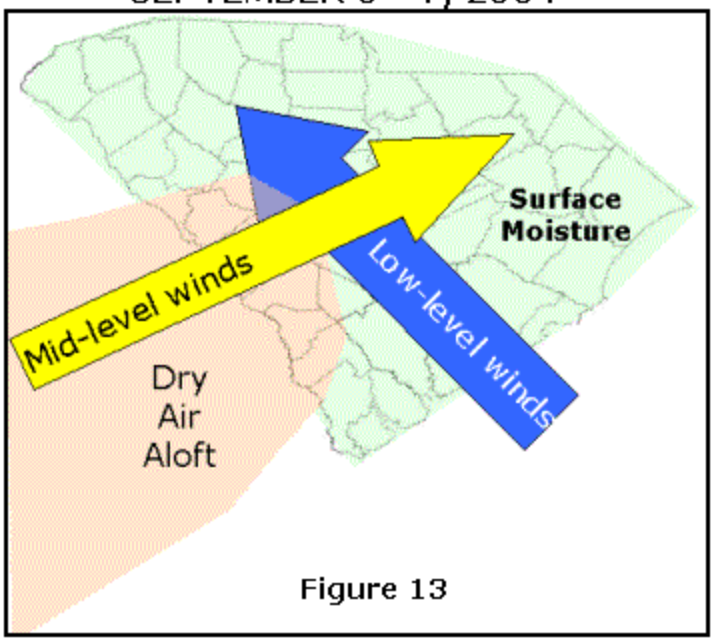


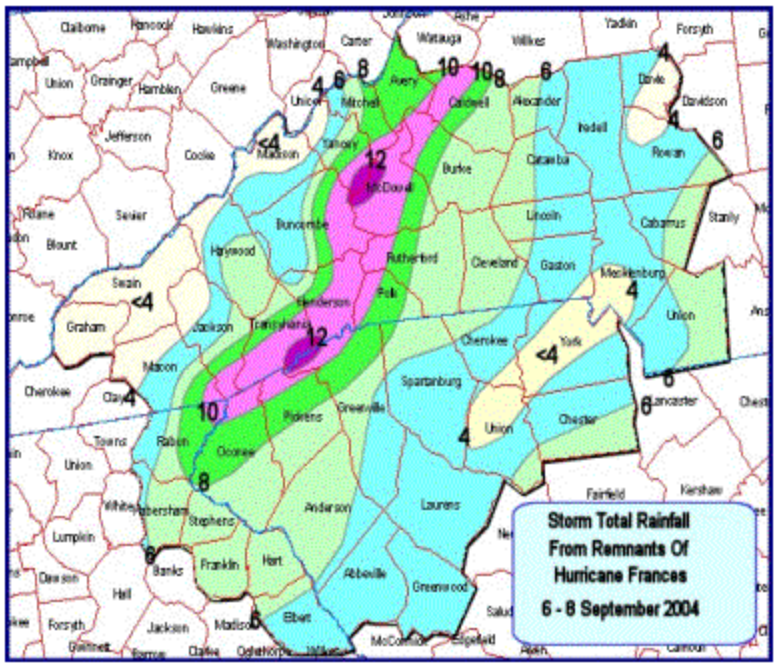
Figure 13

FORECAST CONSIDERATIONS (cont.)

In the Upstate of South Carolina, forecasters were concerned with the potential for orographically-enhanced rainfall along the windward slopes of the Appalachian Mountains. With Frances, the surface to 850 mb winds were from the southeast at 10 – 20 mph. This creates the most favorable atmospheric conditions for orographic lift and convergence as the winds are perpendicular to the axis of the mountain barrier. At mid- and upper-levels, the winds were 40 – 50 mph from the southwest and assisted in the development of rainfall by promoting divergence aloft.

These conditions also predisposed the region to the development of tornadoes (Figure 13) due to the increased risk of thunderstorms and the influence of vorticity (or spin) of the air associated with the circulation center of Frances.

Figure 14



Source: National Weather Service – Greenville-Spartanburg

SOUTH CAROLINA EFFECTS

Although Hurricane Frances made final landfall along the north-central coast of Florida, the storm track up the spine of the Appalachians supplied additional lift to the already buoyant air. As a result, the impact from the storm in South Carolina was quite severe. Being in the right front quadrant of the storm allowed vorticity- and moisture-rich tropical air to invade the state from the south, bringing with it the enhanced chance for tornadoes and heavy rainfall across the entire state. Rainfall totals averaged 3.80 inches in a post-storm survey of total accumulated precipitation from the 4-day period of September 6 through 9 (Table 1). The heaviest rains fell over the Upstate where totals over ten inches occurred during the 72 hour period with 12.17" and 10.89" at Caesars Head and Travelers Rest, respectively. Travelers Rest recorded the highest 24-hour rainfall total with 9.62." The National Weather Service in Greenville-Spartanburg provided an excellent graphic depicting the distribution of rainfall across their county warning area (Figure 14).

Table 1

Tropical Depression Frances SC 4-Day Rainfall Totals

September 6 - 9, 2004

Location	9/6/04 7am	9/7/04 7am	9/8/04 7am	9/9/04 7am	Totals 4-Day
NWS Columbia					
Sumter	0.03	0.25	3.05	mm	3.33
Columbia Metro	t	0.95	2.18	0.56	3.69
Columbia Owens	t	1.83	1.60	0.03	3.46
Orangeburg AP	t	1.66	0.43	0.06	2.15
Sandhill	0.00	2.00	1.75	0.08	3.83
Sandy Run	0.00	2.80	0.60	0.00	3.40
Aiken	0.00	1.79	2.26	0.16	4.21
Johnston	0.00	1.94	2.82	0.05	4.81
Lake Murray	mm	0.54	2.78	0.08	3.40
Pelion	mm	0.82	1.75	0.25	2.82
Saluda Rtr Plt	0.00	1.22	2.69	0.04	3.95
Chappells	0.00	0.59	2.96	0.03	3.58
Lake Greenwood	mm	0.11	1.80	2.52	4.43
Lake Wateree	mm	0.41	2.12	1.08	3.61
Neal Shoals	mm	0.30	7.53	mm	7.83
Lake Marion	mm	0.71	1.50	0.05	2.26
4 Day Average					*3.80*
NWS Greer					
Caesars Head	0.03	1.10	8.42	2.62	12.17
Long Creek	0.00	1.04	8.41	0.40	9.85
Table Rock	mm	1.21	8.07	0.74	10.02
Walhalla	0.00	0.86	8.13	0.40	9.39
Anderson AP	0.00	1.06	5.08	0.06	6.20
Anderson	mm	1.38	4.50	mm	5.88
Clemson	mm	1.16	5.73	0.11	7.00
Greenville	0.00	0.62	3.51	0.06	4.19
Greer	t	0.77	4.51	0.14	5.42
Hunts Bridge	0.00	0.53	4.41	0.42	5.36
Lake Bowen	0.00	0.45	5.88	0.25	6.58
Pickens	0.00	0.53	8.02	0.39	8.94
Sandy Springs	0.00	0.77	5.92	0.21	6.90
West Pelzer	0.00	0.60	2.72	0.76	4.08
Chester	0.00	0.44	5.72	0.06	6.22
Rock Hill	0.00	0.27	3.26	0.04	3.57
Clinton	0.00	0.55	3.72	0.02	4.29
Greenwood AP	t	1.21	3.36	0.04	4.61
Laurens	0.00	0.71	3.39	0.04	4.14
Antreville	mm	1.39	3.98	0.07	5.44
Clemson AP	0.00	1.43	4.82	0.07	6.32
Fountain Inn	0.00	0.26	4.33	0.08	4.67
Gray Court	0.00	0.94	4.67	0.13	5.74
Lockhart	0.00	0.28	4	mm	4.28
Abbeville	0.00	1.14	3.93	0.11	5.18
Gaffney	0.00	0.07	6.47	0.07	6.61
Travelers Rest	0.00	0.82	9.62	0.46	10.89
4 Day Average					6.44

Location	9/6/04 7am	9/7/04 7am	9/8/04 7am	9/9/04 7am	Totals 4-Day
NWS Charleston					
Charleston AP	0.12	1.60	0.21	0.13	2.06
Charleston City	0.10	1.82	0.00	0.20	2.12
Fort Moultrie	0.20	2.35	mm	0.15	2.70
Edisto Beach	mm	3.20	0.10	0.00	3.30
Beaufort	0.59	1.20	0.11	0.00	1.90
Jamestown	0.19	0.55	0.08	0.19	1.01
Givhans	mm	1.60	0.73	mm	2.33
Ridgeville	0.14	1.45	mm	0.26	1.85
Allendale	0.00	3.10	1.10	0.00	4.20
4 Day Average					*2.39*
NWS Wilmington					
Florence	0.00	0.05	2.13	0.15	2.33
Darlington	0.00	0.03	4.25	0.36	4.64
Mullins	0.00	t	1.27	mm	1.27
Pee Dee	mm	0.02	3.31	mm	3.33
Bennettsville	0.00	0.24	4.75	0.18	5.17
Dillon	0.00	0.25	1.60	1.20	3.05
Cades	0.05	0.13	1.66	0.28	2.12
Kingstree	mm	0.26	0.95	0.89	2.10
Herringway	0.04	0.13	1.03	0.44	1.64
Conway	0.05	0.12	0.15	0.25	0.57
Loris	0.04	0.03	0.35	0.37	0.79
N Myrtle Beach	0.04	0.17	0.03	0.47	0.71
Hartsville pcp-only	0.00	0.10	6.21	0.02	6.33
Effingham	t	0.11	1.79	0.09	1.99
4 Day Average					*2.57*

AVERAGES	
NWS CAE	3.80
NWS GSP	6.44
NWS CHS	2.39
NWS ILM	2.57
STATE	***3.80***

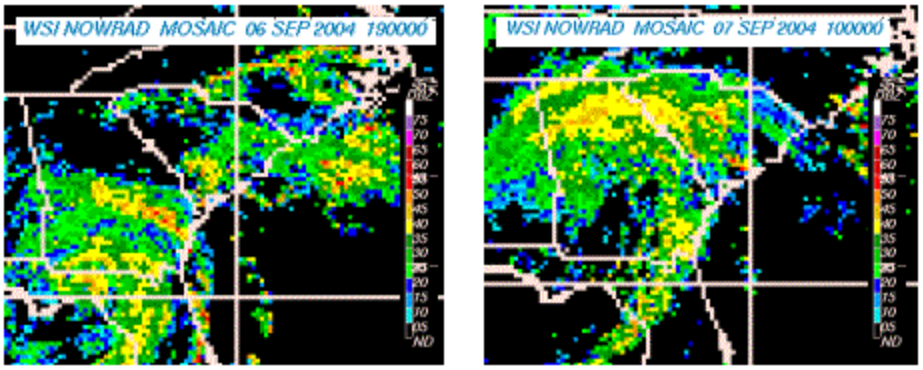
	> 8.00 inches
	4.00-7.99 inches
	0.00-3.99 inches

Compiled by the South Carolina State Climatology Office

SOUTH CAROLINA EFFECTS (cont.)

Flooding and heavy rains were not the only impacts from Frances, however, as conditions were also favorable for tornadoes. Feeder bands from Frances began entering the state on September 6, 2004, (Figure 15) and continued through the next day when the most significant outbreak of tornadoes occurred. Preliminary storm reports from the Storm Prediction Center in Norman, Oklahoma, indicated an initial count of 37 tornadoes on September 6 and 7 with the majority of the storms impacting South Carolina on the second day (Figure 16).

Figure 15



Locations of Preliminary Storm Reports

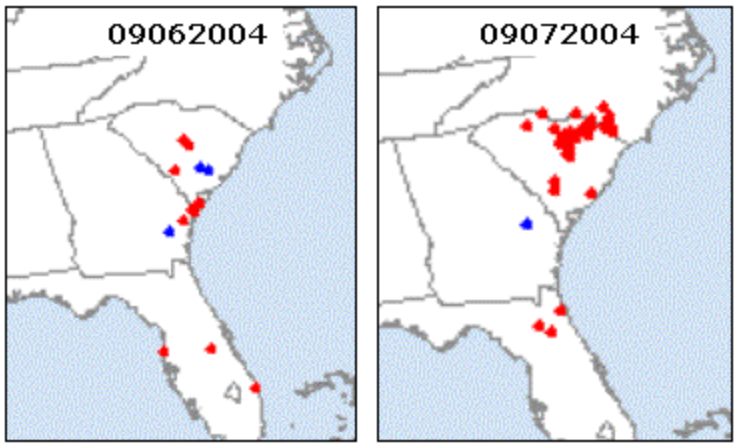


Figure 16

National Weather Service
Storm Prediction Center

▪ High Wind Report (65KT +)
▲ Large Hail Report (2" dia. +)

TORNADO REPORTS
WIND REPORTS/HI....
HAIL REPORTS/LG....

FRANCES

SOUTH CAROLINA EFFECTS (CONT.)

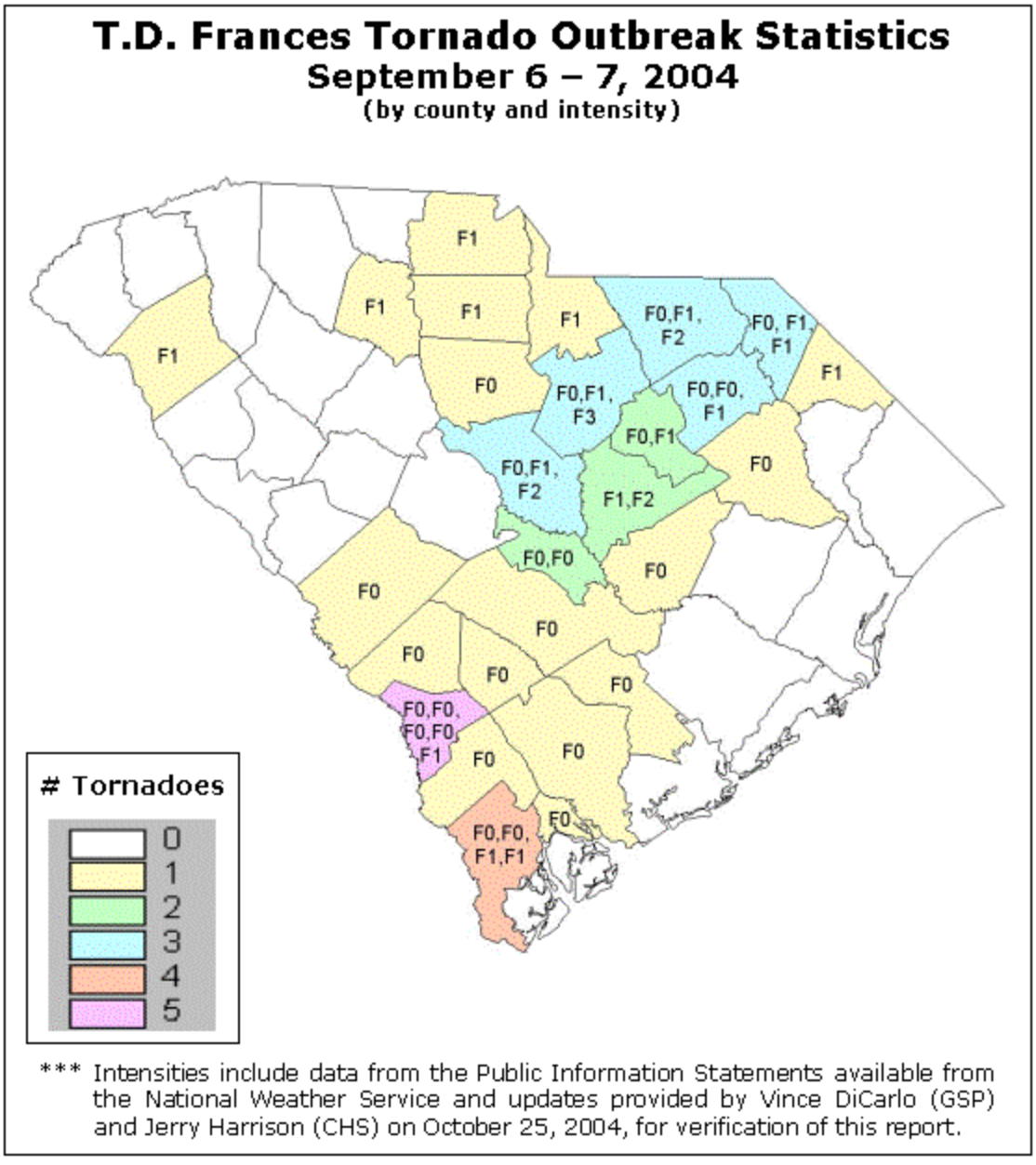
In reality, a total of 47 tornadoes touched down across the State as Frances moved northward toward the Carolinas. The hardest hit area stretched from south coastal region northward through the eastern and northern Midlands, and into the Pee Dee. Based on the Fujita intensity scale, which ranges from F0 to F5, the distribution of tornadoes included 26 at F0, 17 at F1, 3 at F2, and 1 at F3. Of these storms, only four occurred on September 6 in the Charleston NWS service area. The remaining 43 storms broke the record for the number of tornadoes to occur in a single day set on August 16, 1994, with Tropical Storm Beryl. A complete overview of the number of tornadoes and intensity by county is provided in Figure 17.

The primary result from the damages were uprooted trees, downed power lines, and mobile homes, particularly in the F0 tornadoes. Homes were completely destroyed or heavily damaged in regions that saw stronger tornadoes. In Chesterfield County, an F1 and F2 tornado led to damages to businesses, a school, and many homes with 2 mobile homes completely destroyed and five people injured. Kershaw County saw the power of an F3 tornado, the only one reported in the state, due to the destruction of brick homes, stables, and storage buildings. In Richland County, the storms ripped through locations near Fort Jackson with moderate damage to 22 homes, three mobile homes destroyed, and three injuries.

Sumter County remained under tornado warnings consistently through the morning on September 7 with perhaps the most widespread damage of all the counties as an F2 tornado damaged 55 homes, destroyed nine, and created an estimated 1.7 million dollars in damages.

Farther north in the Pee Dee region, most damage was limited to uprooted and snapped trees falling onto homes. In Marlboro County, a mobile home was completely demolished by a tornado from the same storm that downed trees over three feet in diameter in Clio. The most significant damage was in Dillon County where a brick home was heavily damaged, a barn was flattened, and several other homes sustained minor damage.

Figure 17



*** Intensities include data from the Public Information Statements available from the National Weather Service and updates provided by Vince DiCarlo (GSP) and Jerry Harrison (CHS) on October 25, 2004, for verification of this report.

SOUTH CAROLINA EFFECTS (CONT.)

Across the state, these counties had confirmed tornado damage:

Aiken	Allendale	Anderson	Bamberg
Barnwell	Beaufort	Calhoun	Charleston
Cherokee	Chesterfield	Clarendon	Colleton
Darlington	Dillon	Dorchester	Fairfield
Florence	Hampton	Jasper	Kershaw
Lancaster	Lee	Marlboro	Orangeburg
Richland	Sumter	Union	York

As of October 2004, a gallery of damage photographs is available from the National Weather Service at the following links:

http://www.erh.noaa.gov/cae/tornado_damage2.htm
http://www.erh.noaa.gov/ilm/archive/09-07-04/

Since online data will likely be moved to archives in the future, the essential graphics and text relative to tornadoes in South Carolina follows the main report in Appendix A.

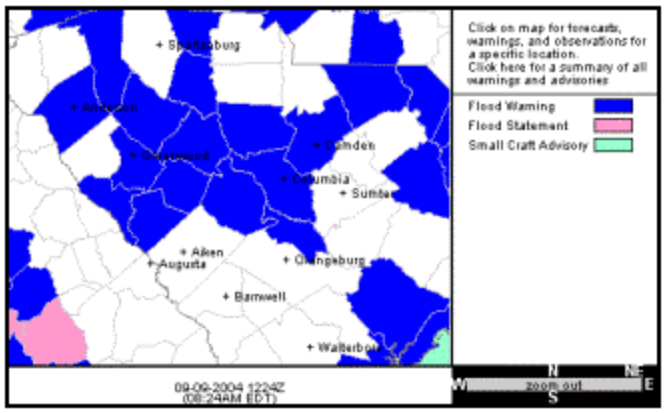


Figure 18

Current warnings, advisories, and statements from 0824 EDT on September 9, 2004, indicated on the National Weather Service in Columbia homepage found at: *http://www.erh.noaa.gov/cae/*

In the wake of the heavy rains and tornadoes, numerous rivers exceeded flood stage on September 9, 2004, (Figure 18) including the Wateree, Congaree, Pee Dee, Broad, Saluda, and Enoree Rivers.

SOUTH CAROLINA RESPONSE

Frances did not mandate an evacuation in South Carolina. Some initial planning stages were conducted due to a potential northwestward shift in the path toward the Georgia or South Carolina coast. The State did continuously monitor the situation for the potential of severe weather conditions associated with flooding and tornadoes.

CLIMATOLOGICAL PERSPECTIVE

Frances became the third tropical system to affect South Carolina this year. The most notable weather event during Frances will be the tornado outbreak on September 6 and 7 when the most tornadoes to ever occur in a single day pounded the entire state with a total of 28 of 46 counties reporting at least one tornado.

ACKNOWLEDGMENTS

*A special thanks to the National Oceanic and Atmospheric Administration (NOAA) and its many divisions for the wealth of weather and climate data made available to prepare this report. (**http://www.noaa.gov**)*

IN PARTICULAR, WE APPRECIATE THE HELP OF LOCAL NATIONAL WEATHER SERVICE OFFICES COVERING SOUTH CAROLINA.

Additional information is found on their websites at the following links:

National Weather Service Forecast Office – Wilmington, NC
http://www.erh.noaa.gov/er/ilm/

National Weather Service Forecast Office – Charleston, SC
http://wchs.csc.noaa.gov/

National Weather Service Forecast Office – Columbia, SC
http://www.erh.noaa.gov/cae/

National Weather Service Forecast Office – Greenville-Spartanburg, SC
http://www.erh.noaa.gov/gsp/

The State Climatology Office website is
http://www.dnr.state.sc.us/climate/sco

APPENDIX A:
NATIONAL WEATHER SERVICE POST-FRANCES CASE EVENT-GRAPHICS AND ASSOCIATED TEXT

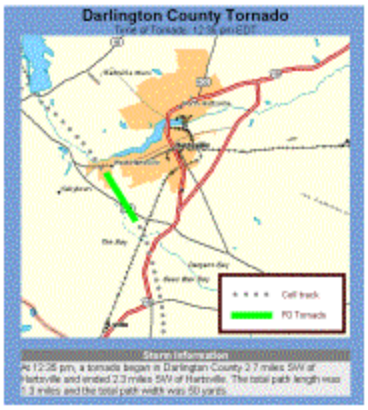
FROM THE COLUMBIA NATIONAL WEATHER SERVICE

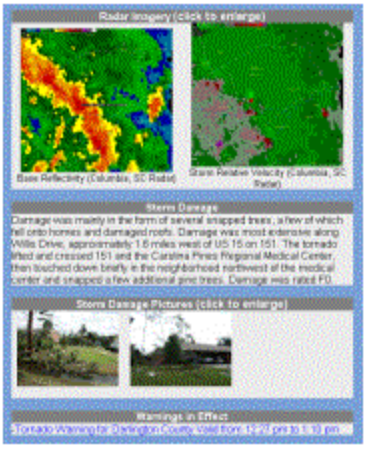
Summary:

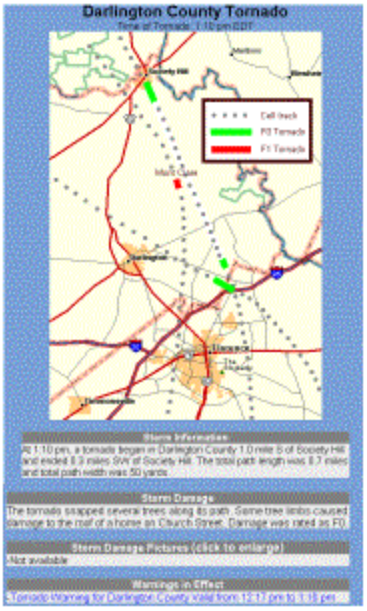
Tornado

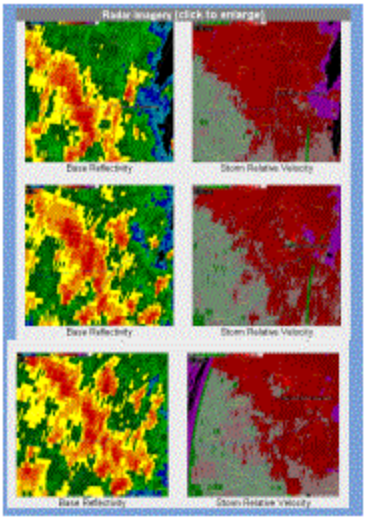
Rainfall

FROM THE WILMINGTON NATIONAL WEATHER SERVICE









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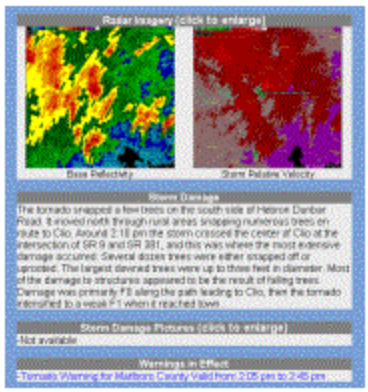

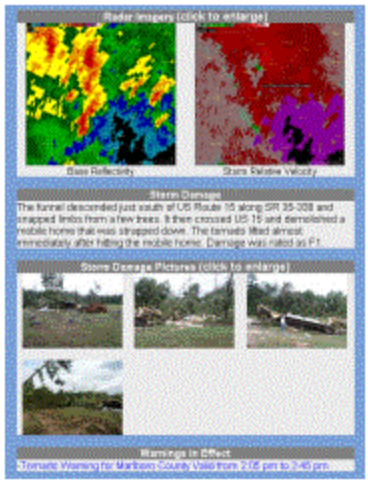

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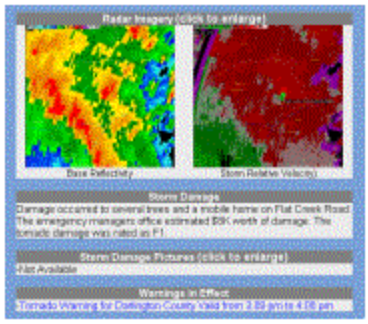

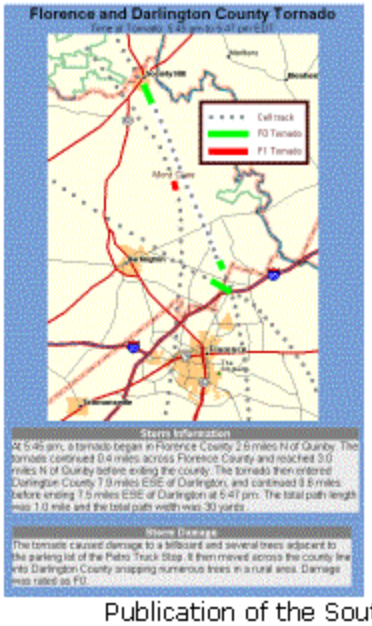

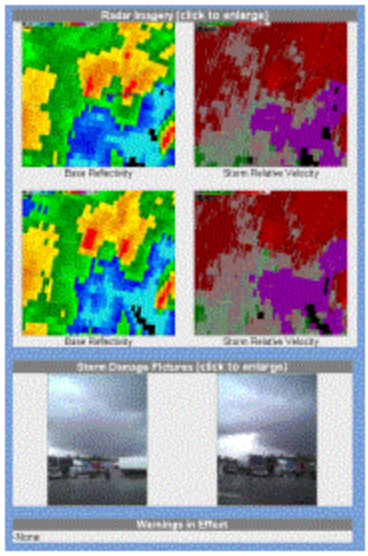

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