

**AN OVERVIEW OF THE LOWER MISSISSIPPI RIVER VALLEY SEVERE
WEATHER AND FLASH FLOOD EVENT OF 6-7 APRIL 2003**

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1. INTRODUCTION

An unusual mix of severe weather and excessive rainfall ravaged much of the Lower Mississippi River Valley Region during 6-7 April 2003, causing more than \$250 million in damage ([Figs. 1, 2](#)). In all, there were 98 reports of severe weather, 15 confirmed tornadoes, and 32 reports of flash flooding ([Table 1](#)). By the end of the event, Jackson International Airport reported 8.5 inches of rainfall, setting the all-time 24-hour rainfall record for the station. In addition, several NWS cooperative stations reported 24-hour rainfall accumulations greater than ten inches, with northeastern suburbs of Jackson, MS reporting up to 12.2 inches of rainfall. Such intense rainfall resulted in a top ten crest of 35.3 feet at the Pearl River at Jackson, MS, and record flooding on the Chickasawhay and Chunky Rivers in east Mississippi ([Fig. 3](#)). Widespread flash-flooding was reported across much of central Mississippi with several creeks and tributaries inundating populated urban and suburban regions of the Jackson metropolitan area. ([Fig. 4](#)).

The potent, early spring storm system, responsible for initiating the severe convection featured strong dynamical forcing, a very moist, moderately unstable atmosphere, and strong low-level wind shear. Two mesoscale convective systems (MCS) associated with the storm system produced the severe weather and flooding. The first MCS developed and moved over northeast Louisiana and central Mississippi during the late morning and early afternoon hours of 6 April 2003, resulting in numerous reports of large hail, wind damage, tornadoes and flash flooding. The second MCS developed in the late afternoon, and it moved across the same area during the evening and overnight hours. Heavy rainfall from the first MCS resulted in very moist soil conditions, and the focus gradually shifted from severe weather to flash flooding. Convective precipitation regenerated over northeast Louisiana and trained across central Mississippi during the overnight, leading to the record rainfall.

From an operational perspective, the 6-7 April 2003 event proved to be a most difficult forecast, largely because of strong mesoscale influences that led to a southward displacement of severe weather and flooding ([Fig. 5](#)). We will now delve into the synoptic and mesoscale environments, and discuss their roles in governing convective location, intensity, and duration.

2. CONVECTIVE INITIATION AND EVOLUTION

As a strong mid-tropospheric shortwave trough approached the Lower Mississippi Valley from the west on the morning of 6 April 2003, warm advection increased substantially. At 1200 UTC, the primary surface warm front was analyzed from just north of Monroe, LA to Meridian, MS, with several other diffuse boundaries in the region ([Fig. 6](#)). By mid morning, the warm front had shifted well to the north, as a strengthening baroclinic zone set up from central Arkansas into northern Mississippi ([Fig. 7](#)). However, a semblance of a surface boundary remained near the earlier warm front position. This particular boundary marked the northward extent of very rich boundary layer moisture ($T_d > 20$ C) that surged northward from the Gulf of Mexico. 1200 UTC upper air soundings from Lake Charles and Slidell, LA ([Fig. 8](#)) indicated that the broad warm sector south of the surface warm front was characterized by rich boundary layer moisture and a strong mid-level capping inversion (~ 3 C), above which steep lapse rates existed (~ 8 C/km). During the morning of 6 April 2003, elevated convective precipitation developed rapidly over Arkansas where frontal ascent strengthened under an increasingly favorable region of upper level divergence ([Fig. 9](#)). A cluster of surface-based HP supercells developed in the *warm sector* over northern Louisiana, south of the strengthening warm front, and eventually

evolved into a linear mesoscale convective system (MCS) that initially progressed to the east ([Fig. 10](#)).

The MCS motion deviated to the right of the mean 850mb-300mb flow as it moved into Mississippi ([Fig 11](#)). The slight southward propagation of the system was, in part, attributable to the strong positive low-level equivalent potential temperature advection in the Vicksburg to Jackson, MS area (12 deg K from 12 UTC to 16 UTC) ([Fig 12](#)). A classic line echo wave pattern (LEWP) developed with this MCS over west central Mississippi and was associated with numerous reports of wind damage ([Fig. 13](#)). In fact, inflow winds into the MCS were intense enough to cause minor structural damage in the Jackson area. The east-to-west orientation of the MCS promoted the training of the HP supercells, and rainfall rates of up to 3 inches per hour were observed along its path, resulting in localized flash flooding ([Fig. 14](#)).

After the passage of the first MCS, the airmass recovered quickly as stronger synoptic scale forcing developed with the approach of the primary shortwave trough axis ([Fig.15](#)). A lingering, nearly stationary boundary that stretched across northeast Louisiana and central Mississippi was reinforced by the earlier convection and became a focus for continued convective generation. Strong, diffluent flow aloft was characterized by a split upper-level jet (ULJ) formation. A strong southwesterly low-level jet (LLJ) combined with this diffluent upper-level pattern to provide a continuous feed of rich low-level moisture to the region ([Fig. 16](#)). A second, more persistent MCS ([Fig.17](#)) moved slowly across the region during the overnight hours of 6-7 April, from about 2300 UTC to 1000 UTC. It was this second MCS that produced the bulk of excessive rainfall during this event. Remarkably, the axis of heaviest rainfall from the second MCS was nearly coincident with the area of heavy rainfall from the first MCS. Ultimately, this led to the flash flooding and record river flooding.

3. MESOSCALE INFLUENCES AND SEVERE WEATHER

The atmosphere over the lower Mississippi valley region was prime for a major severe weather event on the morning of 6 April, 2003. Strong deep layer shear (0-6 km shear > 20 m/s) and very unstable air (850mb - 500mb lapse rates near 7.5 deg C/km) were more than sufficient for the development of supercells and organized severe thunderstorms ([Fig. 18](#)). The strong capping inversion noted on the 12 UTC KLIX sounding (refer to [Fig. 8](#)) permitted a deep, moist, and well-mixed boundary layer to reach the previously discussed surface boundary that extended across northeast Louisiana and central Mississippi. (refer to [Fig. 7](#)). This allowed storms along and just north of the surface boundary to receive uninhibited low-level inflow from very rich air. Furthermore, the near-storm environment became favorable for tornadoes. Baroclinicity associated with the boundary enhanced the effective low-level storm-relative helicity (0-1 km srh 252 m²/s²) along and just north of the boundary (Markowski et al. 1998), and a low mixed layer LCL height (~352 m) indicated a very moist boundary layer, a favorable characteristic of observed tornadic environments (Craven et. al 2002). Tornadoes turned out to be quite numerous during the afternoon and early evening hours (refer to [Figs. 1,2](#)). Marginal mid level storm relative flow (8 m/s) resulted in the HP nature of supercells. So despite the relatively high tornado frequency, tornadoes tended to be short-lived, and never became strong along and north of the mesoscale boundary. In addition, the strengthening large-scale upward forcing associated with improving jet structure caused convection to become widespread, further lessening the risk for long-lived strong tornadoes.

In contrast, the area south of the boundary was still under the influence of a strong capping inversion, and the airmass there could be best described as a "loaded gun." A discrete cell developed in this airmass

over southeast Louisiana, and moved into southwest Mississippi during the early evening hours of 6 April 2003. It managed to break through the cap, and quickly took on supercell characteristics. The storm went on to produce the event's strongest tornado ([Fig. 19](#)), an F2 that tracked for 10 miles across northern Lincoln County. Somewhat of a surprise is that the supercell did not produce evidence of another tornado as it tracked across the remainder of south central Mississippi.

4 . RECIPE FOR FLASH FLOODING

While this spring storm exhibited classic severe thunderstorm characteristics, it is likely to be most remembered for its anomalous rainfall production and subsequent record flooding. It is of great operational significance to determine the meteorological factors that led to the intensification of an apparent low-level meso-beta scale boundary, responsible for focusing intense convective rainfall in a relatively narrow corridor (< 45 km wide) from near Tallulah, LA to Jackson and Meridian, MS. ([Figs. 20a,b](#)).

A weak surface boundary lingered across northeast Louisiana and central Mississippi after the surface warm front shifted north of the region (refer to [Fig. 7](#)). The observed data implies this boundary strengthened and served as a focus for the first MCS. It is apparent that the convective pattern was governed by subsidence underneath the ULJ that was present south of the surface boundary. A strong mid level capping inversion associated with this subsidence resulted in a sharp cut-off in precipitation to the south, indicated by visible satellite imagery ([Fig. 21](#)). Observed surface data suggests that an increase in the surface thermal gradient developed along the southern edge of the anvil shield during the late morning and early afternoon ([Fig. 22](#)). Although a limited amount of surface data exists for sampling along this boundary, one can hypothesize that differential heating along the anvil edge helped to intensify the thermal gradient. Actual observations of anvil shadow induced boundaries were made during the VORTEX field program (Markowski et. al. 1997).

After the first MCS exited the region, the boundary remained in tact. As the primary shortwave trough axis approached during the late afternoon hours, surface winds backed and a second MCS erupted over northeast Louisiana near the western edge of this boundary ([Fig. 23](#)). This MCS moved slowly east along the boundary during the night, and was responsible for producing the bulk of the heavy rainfall. Two elements played vital roles in the evolution of this regenerative heavy rainfall event. First, the wind fields throughout the depth of the troposphere became increasingly unidirectional with time as the primary shortwave trough axis approached the Lower Mississippi River Valley ([Fig. 24](#)). Second, instability and moisture parameters were consistently maximized coincident or just to the west of the region of heavy rainfall (LIs ~ -5 , surface-based CAPE near 2000 J kg⁻¹, precipitable water near 5 cm, and K-indices near 40) ([Fig. 25](#)).

As the flow aloft became increasingly unidirectional with time, regeneration became the preferred mode of MCS propagation. The Vector Method (Corfidi et. al. 1996) indicates that regeneration or back-building MCS propagation results when the propagation vector (i.e. the vector opposite the LLJ) opposes the 850-300 mb mean wind vector (i.e. cell motion). The Vector Method plot from 0600 UTC 7 April 2003 exemplifies the opposition of the propagation and cell motion vectors ([Fig. 26](#)).

Gagan (2001) used the Vector Method to study all types of MCS propagation and found that the propagation of a MCS depends not only on the location and interaction of the LLJ and 850-300 mb mean

wind, but also the low-level moisture transport, low-level moisture convergence, and unstable air. If these parameters are maximized on the rear-flank of the MCS, then regenerative propagation will occur. In this case, we found that the greatest moisture and instability were focused on the western flank of the surface boundary. The west-to-east orientation of the surface boundary, the strongly capped air to the south of the boundary, and the convective regeneration along the boundary account for the meso-beta scale length of the heavy rainfall band (about 175 km) and the sharp north-south gradient of rainfall accumulation (about 40 km between the maximum rainfall of >12 inches to almost no rainfall).

5. CONCLUSION

On 6-7 April 2003, a strong shortwave trough, a strong ULJ pattern, and plenty of moisture and instability combined to produce a major severe weather and flood event over portions of northeast Louisiana and central Mississippi. The synoptic scale environment was favorable for excessive rainfall, but the location of heaviest rainfall was determined on the meso-beta scale, as two separate MCSs moved across the region. Regenerative convection along a strong, persistent meso-beta scale boundary led to anomalous rainfall and widespread flash flooding. This boundary proved to be an excellent focus for a long duration of convective development.

While a strong mid level capping inversion under the ULJ shaped the convective pattern, the sharp edge of the anvil from the first MCS was determined to be a source of significant differential heating. This differential heating helped strengthen the pre-existing low-level boundary across northeast Louisiana and central Mississippi. This boundary was further enhanced by rain-cooled air, and it was in place for the second longer-lived MCS.

The boundary proved effective in focusing a multitude of severe wind and hail events, and further enhanced tornado potential as evident by the numerous tornadoes. The longer duration (nearly 12 hours) of the second MCS was owed to an increasingly unidirectional wind field and favorable upstream positioning of the greatest moisture and instability. This resulted in back-building propagation of the MCS and torrential rainfall along the boundary.

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