P9.8 LOW-LEVEL BOUNDARY INTENSIFICATION AND CONVECTIVE REGENERATION IN THE LOWER MISSISSIPPI RIVER VALLEY REGION SEVERE WEATHER AND FLASH FLOOD EVENT OF APRIL 6-7 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. The potent, early spring storm system responsible for instigating the severe convection featured strong dynamical forcing, a very moist, moderately unstable atmosphere (K-Index in the low 40s, precipitable water values approaching 50 mm (2 in.), lifted index between -5 and -8 and MUCAPE greater than 3000 J kg^{-1}) and strong low-level wind shear (0-1 km storm-relative helicity greater than 300 m^2 s^{-2}). Several high precipitation (HP) supercell thunderstorms developed over northeast Louisiana and central and southern 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. In all, 11 confirmed tornadoes touched down across the region: 8 F0s, 2 F1s and 1 F2.

As the event unfolded through the evening hours of 6 April 2003, focus shifted from severe weather to flash flooding. Rainfall from earlier in the day measured between 2.5 cm (1 in.) and 10 cm (4 in.) over central Mississippi, and soil conditions had become increasingly moist. A lingering, nearly stationary boundary that stretched across northeast Louisiana and central Mississippi was reinforced by the earlier convection and became a strong focus for continued convective generation. Strong, flow aloft was characterized by a split upper-level jet (ULJ) formation. A strong southwesterly low-level jet (LLJ) combined with this difluent upper-level pattern to provide a continuous feed of rich low-level moisture to the region.

During the evening of 6 April 2003 and early morning hours of 7 April 2003, convection

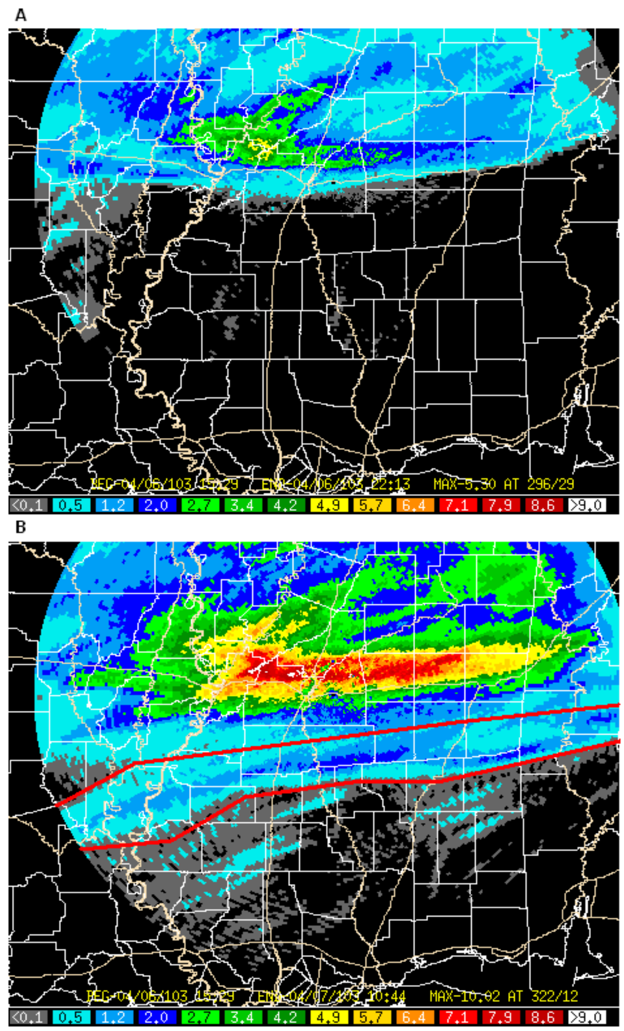

Fig. 1. (A) STP after passage of first MCS ending at 2213 UTC 6 April 2003 from the Brandon, MS WSR-88D (KDGX).
(B) Final STP after passage of second MCS ending at 1044 UTC 7 April 2003. A comparison to guage rainfall totals indicates radar was underestimating rainfall by up to two inches. The outlined area represents rainfall that was produced by an isolated supercell. Otherwise, very little rain fell over east central LA and south MS.

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continually regenerated over northeast Louisiana and trained over central Mississippi. In excess of 10 cm (4 in.) of rainfall was observed along and just north of Interstate 20 from Tallulah, LA to Jackson and Meridian, MS. By the end of the event, Jackson International Airport reported 21.6 cm (8.5 in) 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 25.4 cm (10 in.), with northeastern suburbs of Jackson, MS reporting up to 31 cm (12.2 in.) of rainfall. Such intense rainfall resulted in a top ten crest of 10.8 m (35.3 ft) at the Pearl River at Jackson, MS, and record flooding on the Chickasawhay and Chunky Rivers in east Mississippi. 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.

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 Tallulah, LA to Jackson and Meridian, MS. (Figs. 1a,b).

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. 1200 UTC upper air soundings from Lake Charles and Slidell, LA (not shown) 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).

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. 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. 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 (Td

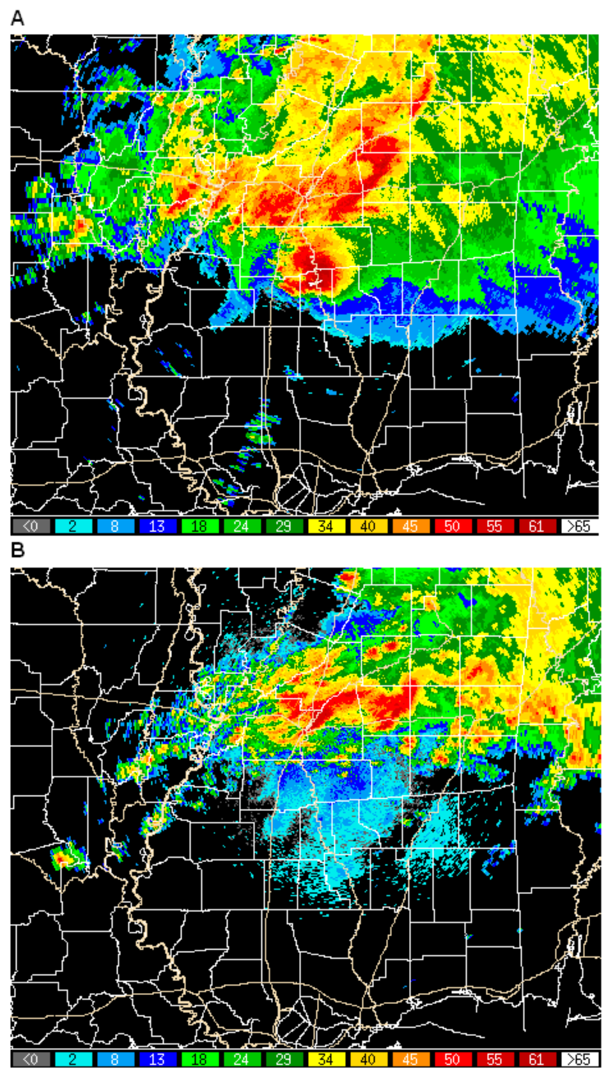

Fig 2. (A) Composite Reflectivity (CR) product at 0142 UTC 7 April 2003 from Brandon, MS, WSR-88D during the second MCS. (B) Another CR product about 4 hours later. Cell regeneration continued over central MS for several more hours.

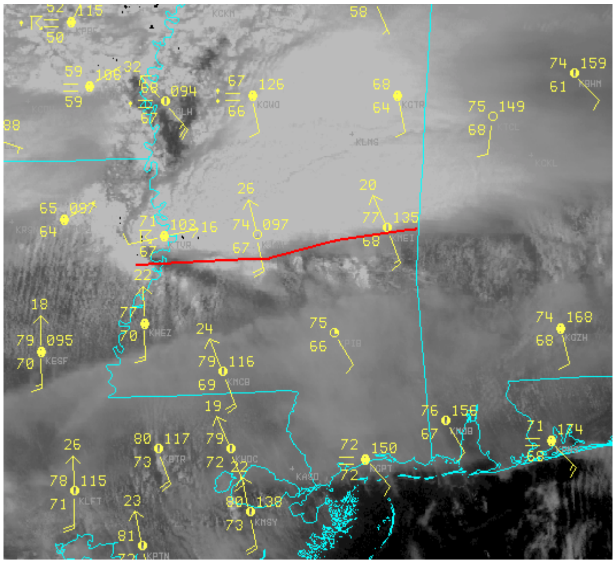

Fig. 3 GOES visible satellite image of first MCS at 1725 UTC 6 April 2003. The red line along the southern edge of the anvil represents the southward extent of heavier rainfall > 2 inches.

> 20 C) that surged northward from the Gulf of Mexico. Elevated convective precipitation developed rapidly over Arkansas where frontal ascent strengthened under an increasingly favorable region of upper level divergence. 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-northeast.

The MCS motion deviated to the right of the mean 850mb-300mb flow as it moved into Mississippi. The slight southward turn of the propagation of the system was, in part, attributable to the strong positive low-level θ_e advection in the Vicksburg to Jackson, MS area (12 deg K from 12 UTC to 16 UTC). Inflow winds into the MCS were intense enough to cause minor damage in Jackson. Rainfall rates of up to 7.6 cm (3 in.) per hour were observed along the path of this MCS, and its east-to-west orientation promoted the training of the HP supercells, resulting in localized flash flooding.

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. A second, more persistent MCS (Figs. 2a,b) 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. The goal of this paper is to offer an explanation as to why rainfall from two separate MCSs focused and persisted in the same area.

3. BOUNDARY INTENSIFICATION AND CONVECTIVE REGENERATION

A weak surface boundary lingered across northeast Louisiana and central Mississippi after the surface warm front shifted north of the region. Two factors led to the strengthening of this boundary: the strong, westerly ULJ observed just to the south of the region of heavy rainfall, and the sharp anvil boundary born from the first MCS.

In studying the first MCS, it is apparent that the convective pattern was governed by subsidence underneath the ULJ. A strong mid level capping inversion associated with this subsidence resulted in a sharp cut-off in precipitation to the south. Satellite imagery indicates a sharp edge to the southern flank of the anvil cirrus shield (Fig. 3).

Observed surface and satellite data suggest that an increase in the surface thermal gradient developed along the southern edge of the anvil during the late morning and early afternoon. There is enough evidence in the surface data to imply reduced insolation under the expanding anvil, and strong insolation south of the anvil deck. This resulted in significant differential heating that reinforced the pre-existing low-level boundary. Recent research from Markowski et al. (1997) discusses similar observations of anvil-induced low-level baroclinicity. In addition, rainfall associated with the convection underneath the anvil shield acted to cool the air over northeast Louisiana and central Mississippi and further intensified the boundary.

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. 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. Second, instability and moisture parameters were consistently maximized coincident or just to the west of the region of heavy rainfall (LI ~ -5 , MUCAPE near 2000 J kg^{-1}, precipitable water near 42 mm (1.65 in.), and K-Index near 40).

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 backbuilding 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 (Fig. 4) exemplifies the opposition of the propagation and cell motion vectors.

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 increasingly 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 > 30.5 cm (12 in.) to almost no rainfall).

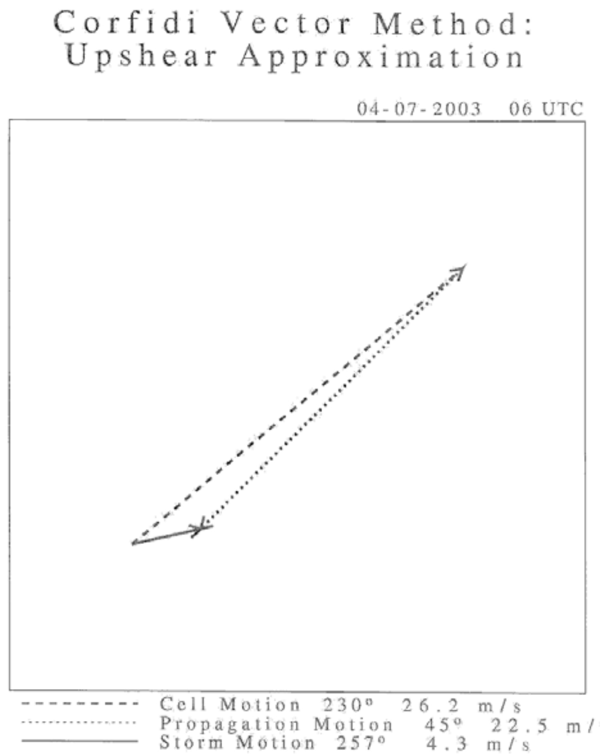

Fig. 4

4. CONCLUSION

On 6-7 April 2003, a strong shortwave trough, a strong ULJ pattern, and plenty of moisture and instability came together to produce a major flash flood and river 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 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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