6C.2 THE EVOLUTION OF A WARM SEASON SEVERE EASTERN KENTUCKY FLASH FLOOD

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1. INTRODUCTION

Flash floods cause more fatalities annually than any other convective storm event (Doswell *et al.*, 1996). Eastern Kentucky (Figure 1) commonly experiences flash flooding. However, there is a lack of scientific research concerning flash flooding in this region, and Appalachia, in general. Therefore, this paper examines the atmospheric conditions associated with one of eastern Kentucky's major flash flood events.

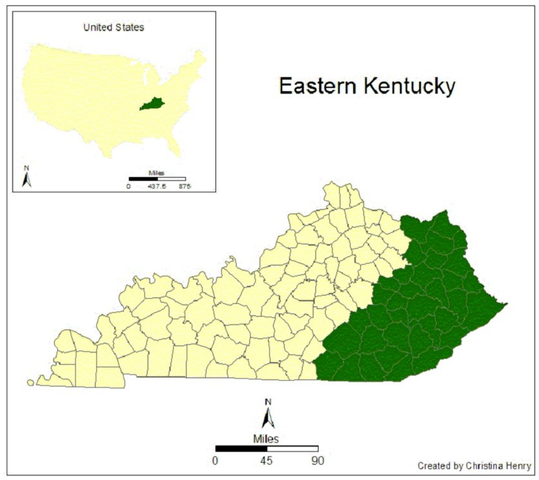

Figure 1: Eastern Kentucky Climate Division.

A number of studies demonstrate that the evolution of heavy rain and flash flood producing storms may not occur in a spectacular fashion. Therefore, they receive little attention, which creates a forecasting challenge (Read and Maddox, 1983; Schwartz *et al*, 1990; Maddox & Grice, 1986). In many occasions, other simultaneous severe weather conditions (e.g. tornados) overshadow the threat posed by heavy rainfall and potential flood conditions (Rogash and Smith, 2000; Rockwood & Maddox, 1988; Schwartz *et al*, 1990). In addition, assessment of prevailing local surface hydrology and its integration continues to be a difficult issue. The

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results presented here primarily focus on the assessment of the meteorological setting during the 3-4 August 2001 flash flood event. Due to the lack of local data, MM5 simulations are examined to further understand the meso-scale features of this event.

2. FLASH FLOOD CLIMATOLOGY OF EASTERN KENTUCKY

Eastern Kentucky receives an annual average of 1,192 mm of precipitation (Midwestern Regional Climate Center's climatological database, MICIS, 2004). Using the daily precipitation data obtained from MICIS for 1990-2002, seasonal maps were created to illustrate the temporal and spatial patterns of days receiving at least 25 mm of precipitation (Figure 2). The majority of these precipitation days occurred during the spring and summer, with the fewest occurring during the fall.

Flash flood records were obtained from the digitized U.S. Storm Events Database from the National Climatic Data Center (NCDC) for 1990-2002. Seasonal maps were also created to illustrate the spatial and temporal patterns of flash flood reports (Figure 3). The majority of flash flood reports, as with the precipitation days, occurred

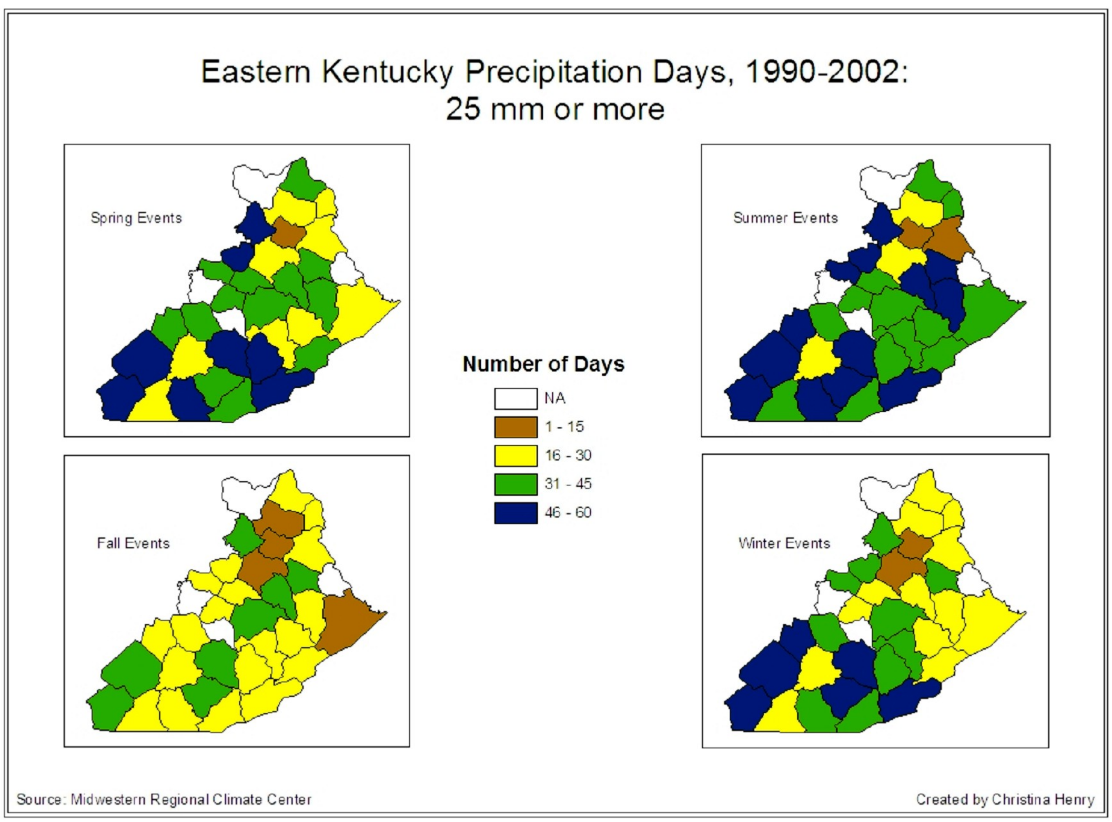


Figure 2: 1990-2002 climatology of precipitation days reporting 25 mm or more

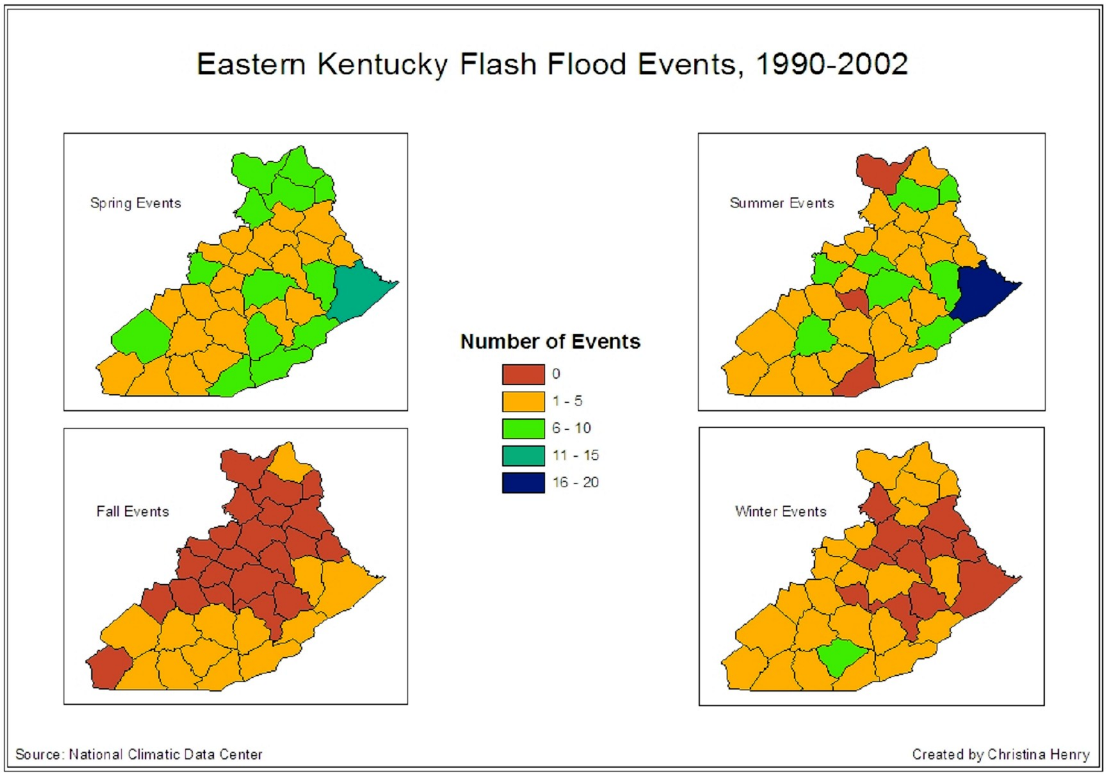


Figure 3: Climatology of reported flash flood events from 1990-2002.

during the spring and summer months, with the least number of events occurring during the fall.

3. FLASH FLOODING OF 3-4 AUGUST 2001

On 3-4 August 2001, a cold front moved through eastern Kentucky producing heavy rains and flash flooding. Eight counties in eastern Kentucky reported flash floods (Figure 4). The worst of the flash flooding occurred in Pike and Floyd counties resulting in a combined total of over $13 million dollars in property damage. Pike, Floyd, Knott, Letcher, and Perry counties were all declared disaster areas. Overall, this event resulted in four casualties, three of which resulted as raging water swept away the victims' vehicles (according to the Event Record Details obtained from NCDC, 2003).

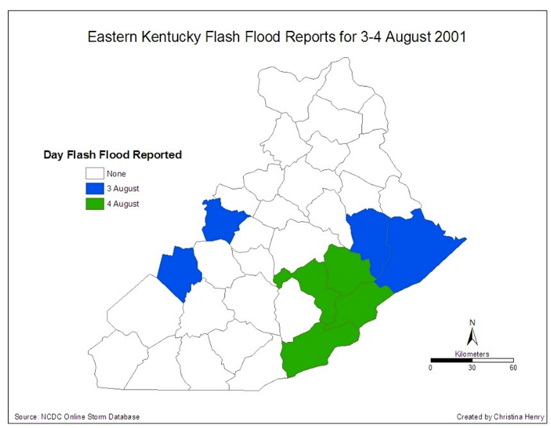


Figure 4: Eastern Kentucky counties reporting flash flooding.

4. METEOROLOGICAL CHARACTERISTICS

Though flash flooding is inherently a meso-scale event, it is embedded within a large-scale setting (e. g., Maddox et al., 1978; Schwartz et al., 1990; Pontrelli et al., 1999). Thus, we have used synoptic data, interpolated synoptic data, soundings, and MM5 simulations (section 5). The following discussion includes both meso- and large-scale conditions to recognize the evolution of the current flash flood event.

At 12Z on August 3rd, dense cloud cover and heavy precipitation accompanied a west-to-east oriented cold front that stretched across northern Ohio, Indiana, and Illinois. Heavy rains developed in eastern Kentucky ahead of a trough axis extending southwest along the Ohio River (Figure 5). Station reports at the meso-scale indicated saturated surface conditions, with equivalent dewpoint and air temperatures in the low 20's °C. Theta-e values around 340 K in this locality also indicated moist air over the flash flood region.

A deep, moist layer extended from the surface up through approximately 450 mb, especially in the Wilmington, OH region near the center of the surface low. A precipitable water value of 52 mm, more than double the normal value of 25 mm (Maddox et al., 1979), also indicated a high moisture content. The Lifted indices for Nashville and Wilmington both suggested the possibility of heavy precipitation and flash flooding (Table 1; Gaffin and Hotz, 2000). These values were also exemplified in other flash flood studies, such as the Big Thompson storm, Rapid City, and Madison County flash flood events (Caracena et al., 1979; Maddox et al., 1978, and Pontrelli, et al., 1999).

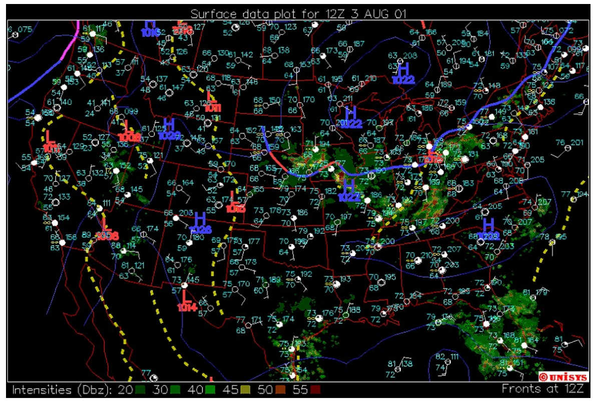


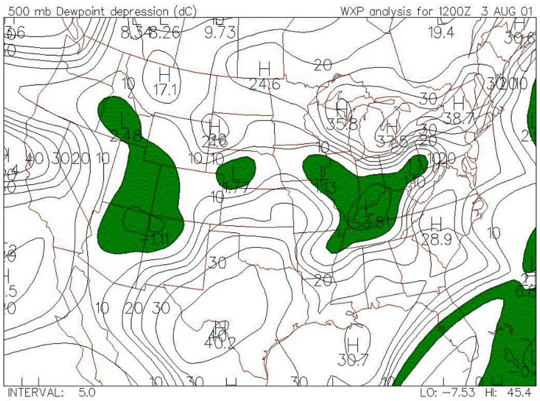
Figure 5: Synoptic conditions for 12Z, August 3, 2001

Table 1: Stability indices. PW=precipitable water (mm), LI=lifted index, KILN=Wilmington OH, KBNA=Nashville TN.

	PW	LI
00Z 3rd		
KILN	44	-3.3
KBNA	44	-2.6
12Z 3rd		
KILN	52	-0.2
KBNA	52	-4.2
00Z 4th		
KILN	43	-3.5
KBNA	49	-2.3

Similar moist conditions existed in eastern Kentucky and most of Tennessee at 12Z. Data suggested that at 850 mb, the dew point depression was less than 5 °C in these areas. At 700 mb, Nashville had larger dewpoint depressions between 5 and 10 ºC (Figure 6). In addition, Nashville also exhibited a precipitable water value of 52 mm. At 12Z Nashville seemed to best represent the conditions in eastern Kentucky. Wilmington seemed to best represent the future atmospheric conditions for eastern Kentucky.

By 00Z of August 4th, the cold front had stretched southwestward along the Ohio River. Around this time, locally, heavy precipitation was reported in the eastern most portions of eastern Kentucky. This sparked the major flash flooding in



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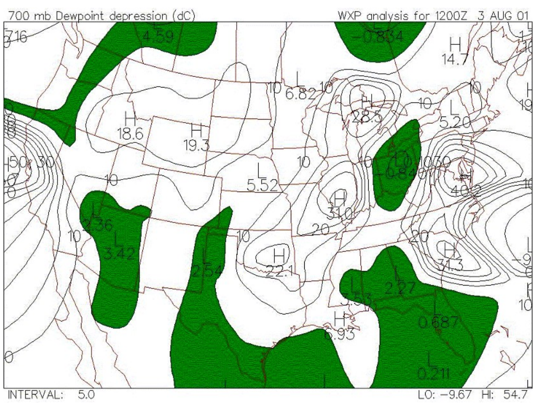

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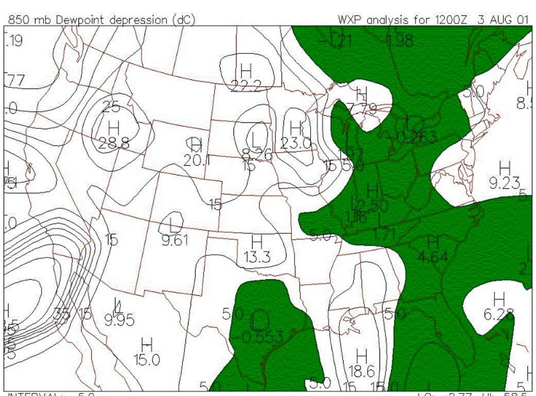

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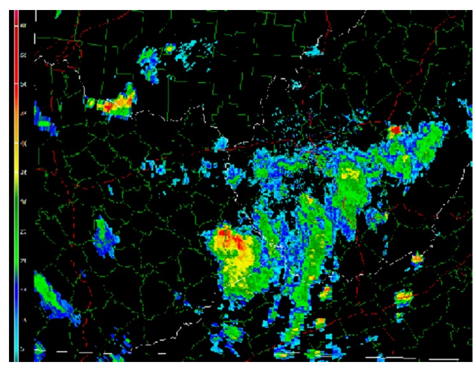
Figure 6: The shaded areas show dewpoint depressions 5ºC or less at 12Z, 3 August for a) 500mb, b) 700mb, and c) 850mb.



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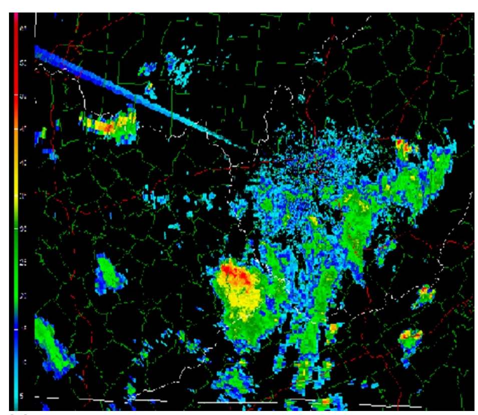

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Figure 7: Charleston, WV Level II radar data for a) 0015Z and b) 0030Z August 4th.

Pike and Floyd counties (Figure 7). The surface dewpoint depressions remained small (=5 °C). A theta-e ridge had developed over eastern Kentucky with values around 340 K. At the large-scale, lower atmospheric moisture remained very high for this time period (dew point depression was =5 °C). This was further verified by the high precipitable water value (50 mm) observed by the sounding at Nashville (Refer back to Table 1). The precipitable water value for Wilmington had dropped to 43 mm. However, it still suggested a significantly moist condition.

The data shows that the cold front had moved into eastern Kentucky by 12Z of August 4th. Precipitation continued to fall along the front and the dewpoint depressions remained small in the vicinity of the flash flooding. The data also suggested the presence of drier air behind the cold front. For example, precipitable water for Wilmington had dropped even further to 30 mm. The Nashville precipitable water value remained fairly high at 48 mm. Again, Nashville continued to best represent the current conditions in eastern Kentucky.

5. MM5 SIMULATIONS

5.1 *Model Setup*

The only observed meso-scale data available for eastern Kentucky was hourly surface data. However, forecasting flash flooding requires knowledge of the meso-scale upper air conditions as well. Therefore, MM5 simulations were conducted to provide high spatial-temporal data for both surface and upper air conditions to help clarify the meso-scale setting for the current flash flood event.

Four simulations were conducted, using four domains each (Figure 8). The first used the Grell parameterization scheme for all four domains (Grell et al, 1994). The second used the Grell parameterization scheme for only the first two

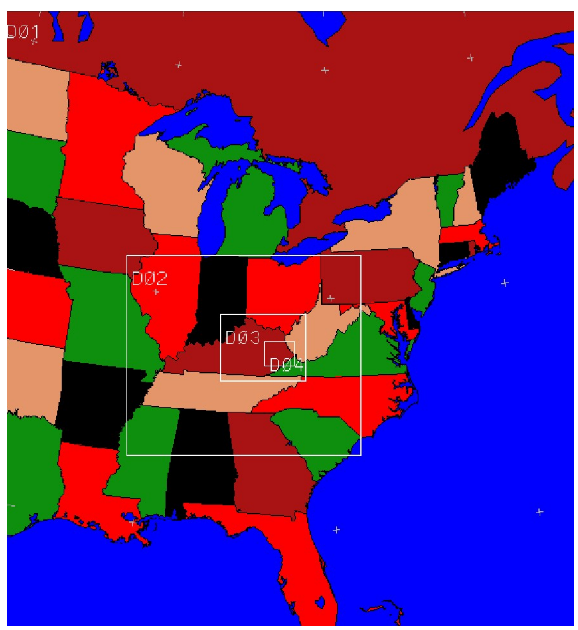


Figure 8: Four Domains were defined for the MM5 simulations. Domain 1 has a 27-km resolution. Domain 2 has a 9-km resolution. Domain 3 has a 3-km resolution. Domain 4 has a 1-km resolution.

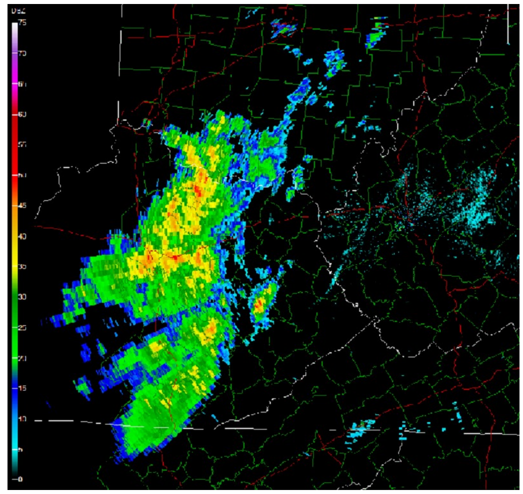
domains. The other two simulations were conducted the same as the first two, except they used the Kain-Fritsch cloud parameterization scheme (Kain & Fritsch, 1998).

Each simulation was initialized using NCEP-NCAR data and ran from 12Z August 2nd through 06Z August 5th. The simulations used thirty-eight sigma levels. A visual comparison was conducted for the simulated and the actual radar reflectivity. Recorded level II reflectivity data for Charleston, WV was obtained from the National Climatic Data Center (NCDC). A qualitative comparison was also made between observed and simulated soundings for Nashville, TN and Wilmington, OH.

All of these comparisons suggested that the application of the Grell parameterization scheme for all four domains provided comparatively satisfactory results. Therefore, the following analysis examines the atmospheric conditions for the simulation using the Grell parameterization scheme for all domains.

5.2 *Simulation Analysis*

Comparison of observed data and simulated radar reflectivity for 12Z, August 3rd, suggested precipitation over an area slightly west of the actual events (Figure 9). Simulated



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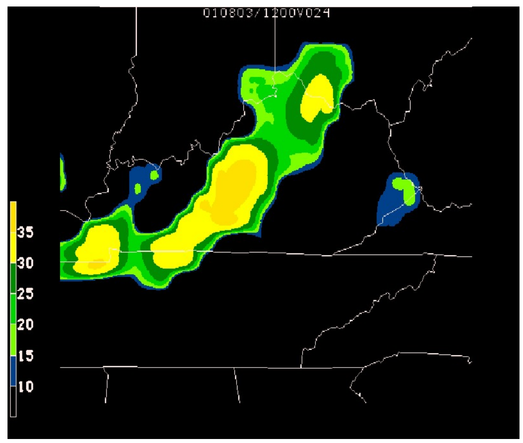

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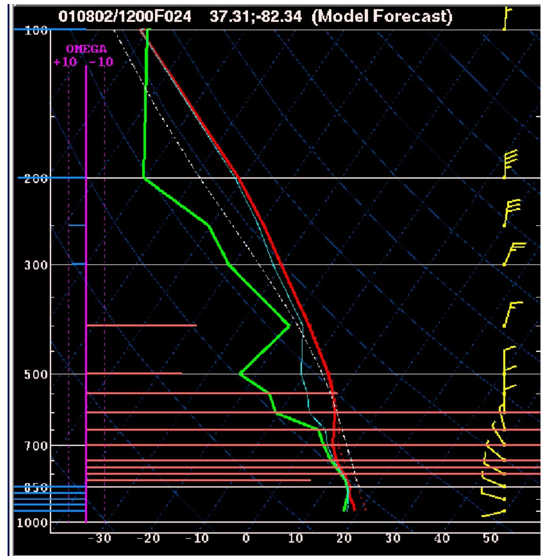
Figure 9: a) Observed and b) Simulated radar reflectivity for 12Z, August 3rd.

soundings for the same observation period indicated a very moist atmosphere at Wilmington and Nashville. The precipitable water values were 49 mm and 50 mm, respectively. Jackson, KY also had moist air, with a precipitable water value of 40 mm. Prestonsburg, KY and Pikeville, KY had progressively smaller precipitable water values, 38 mm and 37 mm respectively. The Lifted indices from the Nashville, Wilimington, and Jackson simulated soundings suggested the possibility of heavy precipitation. However, the lifted index for Prestonsburg and Pikeville indicated stable conditions (Figure 10). The simulated theta-e values between Louisville, KY and Jackson indicated an increase in moist air from 07Z and 12Z. At 12Z, there existed a relatively drier air mass, with values of 330 K and less above Jackson. The theta-e values for the flash flood region were between 330 K and 340 K.

The simulated theta-e values continued to indicate increasing moisture over Jackson and by 15Z, a band of precipitation entered eastern Kentucky. Precipitable water values remained in the upper 30's in the flash flood region, while Jackson experienced a slight increase to 43 mm.

The theta-e values continued to increase through 20Z. The precipitable water values had also increased. Jackson's precipitable water value had increased to 50 mm. Prestonsburg and Pikeville had values of 43 mm and 42 mm, respectively. The simulated radar reflectivity indicated moderate to heavy precipitation in the majority of eastern Kentucky.

By 21Z, the theta-e over Jackson had reached it's highest and began to decrease by 22Z. The 21Z local and regional theta-e values ranged from less than 350 K at 850-mb to less than 340 K at 700 mb and between 340 and 350 at 500mb. The precipitable water for Jackson at 21Z remained at 50 mm. Prestonsburg and Pikeville both had increased precipitable water values of 45 mm. According to both the modeled and observed radar reflectivity, heavy precipitation fell over Pike and Floyd counties.



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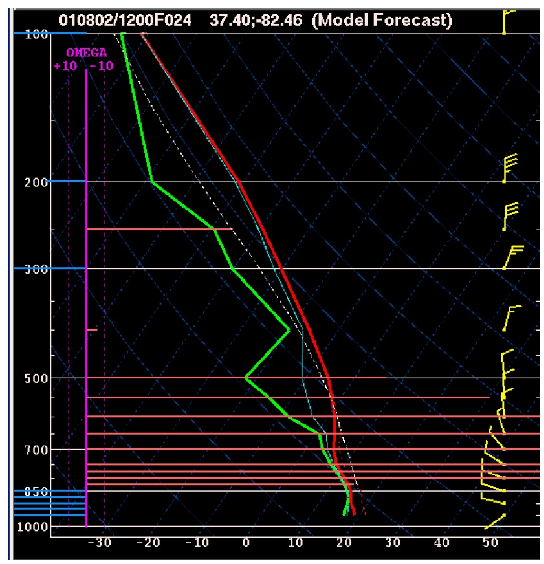

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Figure 10: Simulated soundings for a) Pikeville, KY and b) Prestonsburg, KY for 12Z August 3rd.

At 22Z, the theta-e over Jackson was greater than 340 K. Eastern Kentucky continued to receive moderately heavy precipitation. The precipitable water values in Jackson had decreased slightly to 49 mm, indicating the decrease in moisture already visible in the theta-e values. Prestonsburg and Pikeville both had slightly increased precipitable water values of 46 mm.

By 23Z, the simulated reflectivity over eastern Kentucky indicated moderate precipitation over the flash flood areas. The region of greater than 340 K theta-e values had decreased further. The precipitable water values continued to remain high at Jackson (47 mm), Prestonsburg (46 mm), and Pikeville (46 mm).

During the following hour (00Z, August 4th), the precipitable water values had dropped 1 mm at all three locations in the flash flood region. However, they were still very high compared to the normal values. The theta-e also demonstrated a similar pattern, with regional values between 330 K and 350 K at 500 mb and 700 mb and less than 340 at 850 mb. The radar reflectivity again indicated precipitation over Pike and Floyd counties. The NCDC Storm Database (NCDC, June 2003) reports flash flooding in Floyd County at 0015Z (refer back to Figure 9a). This area is located just south of Prestonsburg. At 0030Z, flash flooding was reported in Pike County, just west of Pikeville (refer back to Figure 9b).

6. SUMMARY AND FINAL REMARKS

Maddox *et al.* (1979) identified four types of flash flood events. Based on those categories, the 3-4 August 2001 flash flood event was classified as a frontal event. This type of event tends to occur during the night and is usually associated with a meso-a scale short wave trough (Maddox *et al.*, 1979), which, according to Read and Maddox (1983) and Hales (1978), contributes to the development of flash flooding.

The majority of the reported flash floods occurred during the evening and early morning hours and a short-wave trough appeared at 12Z on the 3rd. Gaffin and Hotz (2000) stated that frontal events are characterized by a quasi-stationary front that is oriented west to east. Doswell *et al.* (1996) and Hales (1978) attribute the slow motion of the quasi-stationary system to the production of flash flooding.

The slow motion of the eastern Kentucky frontal system certainly increased the amount of time eastern Kentucky experienced heavy rain. At 12Z on the 3rd of August, the cold front was oriented west to east and the northern portion of the front appeared to have stalled. Consequently, it became more southwest to northeast oriented by 00Z on the 4th. During this change in orientation, eastern Kentucky continually experienced heavy rains. In fact, the two major flash floods that developed during this event occurred a little after 00Z on the 4th, before the front resumed its eastward motion.

Gaffin and Hotz (2000) determined that certain atmospheric parameters provide valuable data concerning the development of flash flooding. These parameters include a surface dewpoint temperature greater than 16 °C and a negative lifted index (Gaffin & Hotz, 2000). According to the surface data and sounding data for the 3rd and 4th of August, all of these parameters were met. Throughout the event, the surface dewpoint temperatures remained above 16 °C, with the majority of the dewpoint temperatures in the lower 20s. The lifted indices were reported below zero for the majority of the flash flood event. Other sounding parameters that indicated an unstable or moist atmosphere were the high precipitable water values, the Showalter index, and the total totals index.

To better understand the meso-scale conditions and development of this event, the authors completed four MM5 simulations. Of these, two simulations used the Kain-Fritsch and two the Grell cloud parameterization scheme. Eventually, the simulation using the Grell parameterization scheme for all four domains was examined in detail because it performed satisfactorily. However, it should be noted that simulated atmospheric conditions did not completely agree with the actual account.

Again, extreme moist conditions with forcing of the front and (potentially) topography resulted in heavy precipitation and flash flooding. The development of this event was not spectacular and somewhat similar to the past episodes of flash floods in the western mountain region that occurred under relatively benign large and meso-scale settings (e. g., Maddox et al., 1978). These conditions presented a forecasting challenge in the past as well as in the present. The authors plan to continue further analyses of the data to better understand this flash flood event.

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