COMMON ENVIRONMENTAL PARAMETERS ASSOCIATED WITH HEAVY PRECIPITATION AND FLASH FLOOD EVENTS OVER SOUTHWEST ARKANSAS, EAST TEXAS, AND NORTH LOUISIANA

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1. INTRODUCTION

Located within a few hundred miles from the warm waters of the Gulf of Mexico, the Ark-La-Tex (consisting of Southwest Arkansas, North Louisiana, and Northeast Texas) is often the breeding ground for heavy rainfall and flash flooding. Its geographic location and proximity to the Gulf of Mexico allows for cold frontal systems and attendant upper level troughs to be greatly influenced by the sub-tropical climate. In addition, tropical systems occasionally affect the region during the summer months.

In this study, six heavy rainfall and flash flood events between 2006 and 2010 were analyzed, and the synoptic and mesoscale conditions that contributed to the excessive rainfall were identified in each case. Rainfall in these events ranged from 102-406 mm (4.00-16.00 in) in about 24 hours. The common environmental parameters identified during the analysis were used to create a Flash Flood Decision Flow Chart for use by meteorologists to assist in determining whether a Flash Flood Watch should be issued.

2. FLASH FLOOD CASE EVENTS

Six heavy rainfall/flash flood events were analyzed: 1) Widespread flash flooding across North-central Louisiana on 16 October 2006, where widespread rainfall totals ranged from 76-254 mm (3.00-10.00 in), with isolated amounts up to 406 mm (16.00 in); 2) Flash flooding across Shreveport and Bossier City, Louisiana on 13 May 2008, where 102-203 mm (4.00-8.00 in) of rain fell, with isolated amounts exceeding 254 mm (10.00 in); 3) Localized flash flooding in El Dorado, Arkansas on 19 August 2008, where rainfall totals of 76-127 mm (3.00-5.00 in) were observed; 4) Widespread flash flooding across North-central Louisiana resulting from Hurricane Gustav on 2 September 2008, where rainfall amounts of 102-254 mm (4.00-10.00 in), with isolated amounts exceeding 305 mm (12.00 in) were recorded; 5) Widespread flash flooding across extreme Eastern Texas, Northwest Louisiana, and Southwest Arkansas on 29 October 2009, where rainfall totals ranged from 102-203 mm (4.00-8.00 in), with isolated amounts near 254 mm (10.00 in); 6) Significant flash flooding across portions of Northeast Texas on 10 June 2010, where rainfall totals of 102-203 mm (4.00-8.00 in), with isolated amounts exceeding 254 mm (10.00 in) were observed.

The integration of the National Weather Service's (NWS) Weather Event Simulator (WES), which mirrors the displays and functionality of the NWS's Advanced Weather Interactive Processing System (AWIPS) software, allowed for meteorological events to be archived and analyzed by meteorologists for the purpose of producing improved forecasts and warnings in the future. The WES was used in the analysis of these six cases.

3. DISCUSSION OF COMMON PARAMETERS ASSOCIATED WITH HEAVY RAINFALL EVENTS

Each of these six flash flood events contained many of the same environmental characteristics, despite having differing synoptic scenarios. Each case contained high surface dewpoints and corresponding theta-e values in an area near a surface trough, outflow boundary, or cold front (non-tropical storm cases).

Regional raobs were extremely valuable in analyzing the pre-storm environment. High precipitable water values correlated to a very moist atmosphere, and were often noted to be where moderate to high surface and mixed-layer convectively available potential energy (CAPE) was present. The raobs also indicated a deep warm layer, where warm rain processes and high precipitation rates operate, from the lifting condensation level (LCL) to the freezing level (Davis, 2001) (Fig. 1).

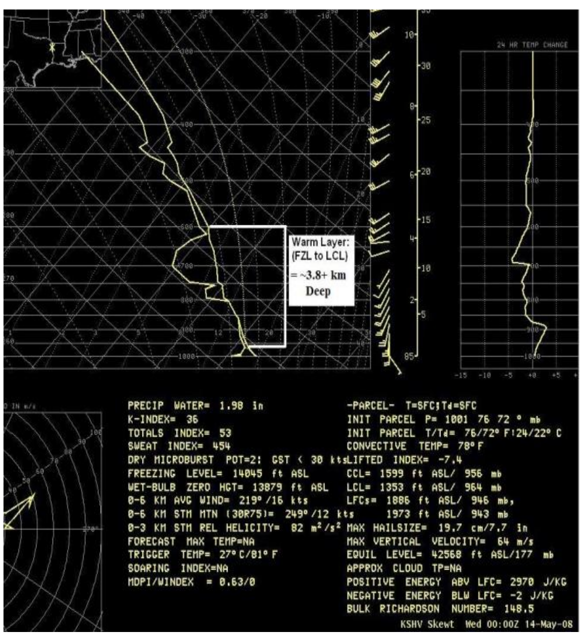

Fig. 1. *KSHV Raob at 00 UTC 14 May 2008, showing the depth of the warm cloud layer (3.8 km), and high precipitable water (1.98 in.) for the 13-14 May 2008 Flash Flood event over Shreveport, LA.*

A surface trough, outflow boundary, or cold front was present in each non-tropical storm case, with this boundary helping to focus enhanced moisture flux convergence, depending on the strength of the surrounding low level flow (Fig. 2). These surface boundaries often play a vital role in the initiation of subsequent convection, which in turn may develop into a slow moving mesoscale convective system, or MCS (Doswell et al., 1996). Specifically, surface and 850 hPa moisture flux convergence were analyzed, as well as the 0-2 km moisture flux convergence, where available. These areas of strong moisture flux convergence were all located near the maximum of positive 850 hPa theta-e advection, coupled with a southerly low level jet of 10 m/s (20 kts) or greater within the 850 hPa theta-e ridge (Moore et al., 2003).

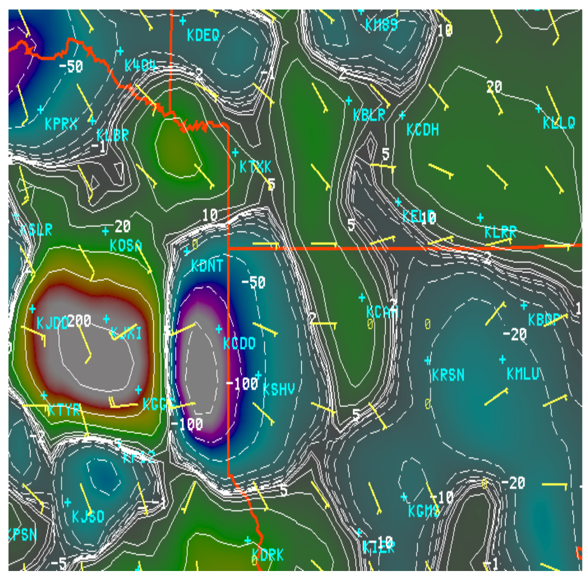

Fig. 2. *Surface moisture flux convergence in units of g/kg/12h during the 13-14 May 2008 Flash Flood event over Shreveport, LA (KSHV). Dashed lines indicate moisture flux convergence, while solid lines indicate moisture flux divergence. Wind barbs in knots.*

Vertical wind shear also played a vital role in the development of flash flood producing convection, as the higher wind shear contributed to large and well-organized convective systems. In most cases, the 850-300 hPa mean wind (Fig. 3) paralleled the surface boundary (Fig. 4). Junker et al. (1999) determined that when the 850-300 hPa mean winds nearly paralleled the low-level boundary/zone of enhanced moisture flux convergence, new cells may form and move with the mean wind, or train, over the same locations. Conversely, if the surface boundary was aligned perpendicular to the 850-300 hPa mean winds, the heavy rain would be oriented along the surface boundary, but could be of shorter duration.

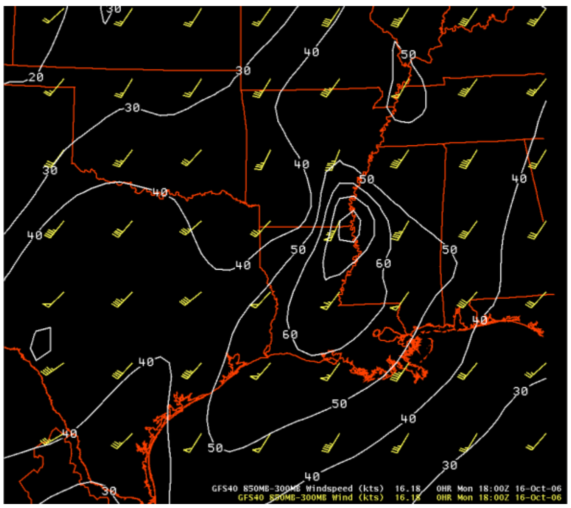

Fig. 3. *GFS 40km 850-300 hPa mean wind analysis for 19 UTC 16 October 2006 Flash Flood event over North-central Louisiana. Solid lines denote isotachs contoured every 10 knots. Wind barbs in knots.*

The upper air pattern during most of the events featured a 500 hPa trough over Arizona and New Mexico, with the organized and flash flood-producing convection developing near embedded shortwaves or mesoscale convective vorticies (MCVs) in the resultant southwest flow aloft (Fig. 5). The only exception was the 2 September 2008 flash flood event over North-central Louisiana, which was associated with Hurricane Gustav as it tracked northwest across Northwest Louisiana. Strong divergence and diffluence at 250 hPa also accompanied each of these events, with all but one having an additional moisture feed from the Eastern Pacific advecting northeast along the subtropical jet (Fig. 6).

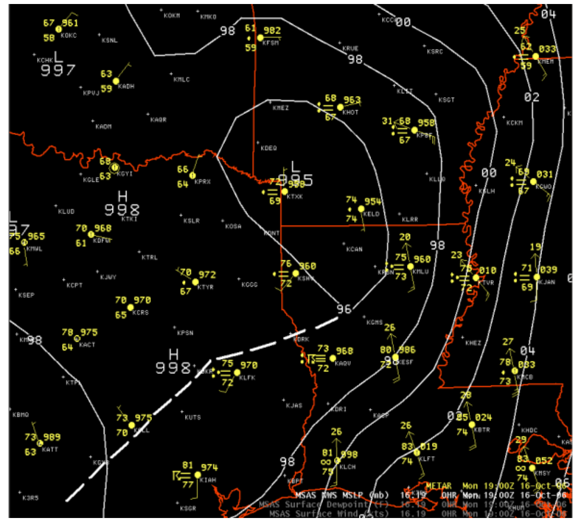

Fig. 4. *Surface analysis for 19 UTC 16 October 2006 Flash Flood event over North-central Louisiana. Solid lines denote isobars contoured every 2 hPa. Long dashed lines indicate a surface trough. Temperatures and dewpoints in °F, with wind barbs in knots.*

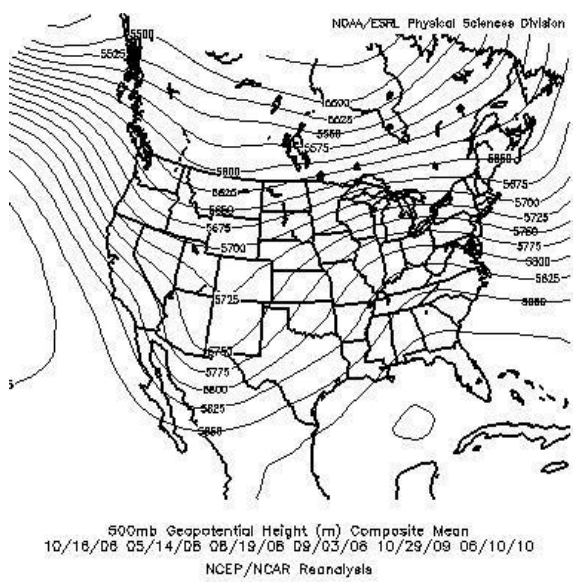

Fig. 5. *Composite 500 hPa chart from all six cases studied, showing a large trough over AZ/NM, with shortwaves ejecting northeast across the Ark-La-Tex.*

In addition to the synoptic and mesoscale features, saturated grounds from earlier rainfall acted to enhance the flash flood threat, which was the case during the 29-30 October 2009 flash flood event over East Texas, Northwest Louisiana, and Southwest Arkansas.

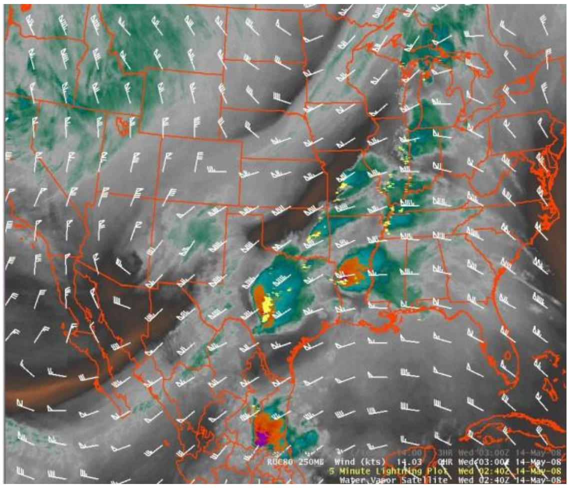

Fig. 6. *Water vapor satellite imagery and 250 hPa RUC winds (knots) at 0240 UTC 14 May 2008, showing Pacific middle and upper level moisture feed, upper level trough over Arizona / New Mexico border, and upper level diffluence over Northeast Texas and North Louisiana.*

The following environmental parameters were found to be common among the six heavy rainfall/flash flood cases:

Synoptic Scale Features

- One of these three types of synoptic systems should be present over the forecast area:
    - *Synoptic Continental* - Upper level longwave trough over Arizona / New Mexico, with shortwave troughs ejecting to the east in the resultant southwest flow.
    - *Tropical* - Tropical cyclone or remnants of a tropical cyclone
    - *Hybrid* - Synoptic systems enhanced by tropical moisture
- Upper level diffluence
- Deep atmospheric moisture from surface to 500 hPa with precipitable water values of 48 mm (1.90 in) or greater
- Elevated moisture source from the eastern Pacific advecting northeast along the subtropical jet.
- Warm cloud layer depth (LCL to freezing level) greater than or equal to 3.5 km (~11,500 ft)
- Moderate mixed-layer CAPE greater than or equal to 1000 J/kg

Low Level Features

- Southwest, south, or southeast winds at least 10 m/s (20 kts) at 850 hPa
- Surface or 850 hPa moisture flux convergence greater than or equal to 25 g/kg/12 hrs
- Surface dewpoints of 17° C (63° F) or greater
- Slow moving surface trough / cold front / outflow boundary oriented parallel to the 850-300 hPa mean wind (storm motion) suggests heavy rainfall would be along and in advance of the front in the form of train echoes. A surface trough/ cold front/ outflow boundary oriented perpendicular to the 850-300 hPa mean wind suggests heavy rain would be along the front, but could be of shorter duration
- Surface trough / cold front / outflow boundary parallels or intersects an 850 hPa theta-e ridge greater than 340K

4. FLASH FLOOD DECISION FLOW CHART

Based on these results, a Flash Flood Decision Flow Chart was developed for use by forecasters (Fig. 7). This flow chart can be instrumental in the prediction of extreme rainfall and potential flash flooding.

Flash Flood Decision Flow Chart

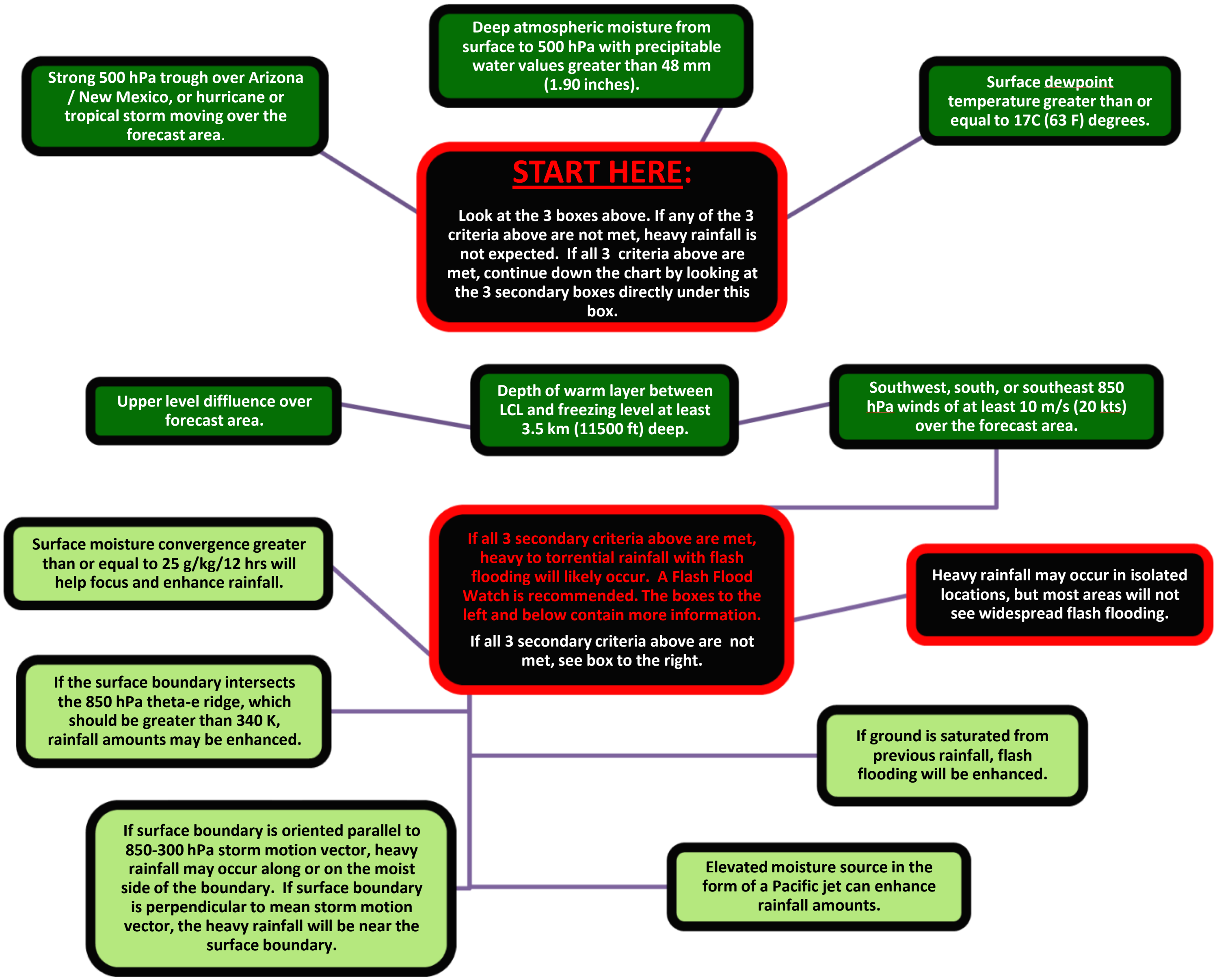

Fig. 7. *Flash Flood Decision Flow Chart - To use the flow chart, locate the box that says "Start Here" at the top center of the diagram. Begin with that box and follow the instructions and information in the flow chart boxes.*

5. ACKNOWLEDGEMENTS

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