## 3A.4 AN ANALYSIS OF THE ELEVATED MIXED LAYER DURING THE SUPER TUESDAY OUTBREAK

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### 1. INTRODUCTION

#### 1.1. *Elevated Mixed Layer*

When those interested in severe weather analyze atmospheric conditions for impending events, one of their main focuses is on a capping inversion and layer of well mixed air above it. This layer is called the Elevated Mixed Layer (EML) and is a key to the successful development of severe weather over the Midwest and southeast United States.

The importance of the EML is due to two ingredients it provides to the storm environment. One is the capping inversion that is the lower bound of the mixed layer and the other is the dry air found in the layer. The capping inversion, or cap, limits storm development in the earlier stages of a systems life cycle. This allows for the building of energy in the lower levels of the environment until daytime heating or other events give parcels an extra little push that breaks through the cap. Above the cap, the mixed layer is a very unstable environment that allows for the continued explosive rising of the much warmer and energetic parcels (Carlson 1983). Strong convection can occur, therefore, and if the atmospheric shear is strong enough the storm can produce a strong rotating updraft and potentially tornados.

In addition to the capping inversion, the EML provides a dry layer of air at mid-levels, which can aid in the development and structure of airflows within a convective cell. By the juxtaposition of dry air near the developing moist updraft of a storm, dry entrainment occurs. This process aids in the propagation of storms systems in addition to the development of downdrafts within a cell. The second of these is most important in severe weather situations. By entraining dry air into the trailing edge of a storm, evaporative cooling takes place. This leads to negative buoyancy in that region of the storm and if combined with precipitation loading in the column, a very strong downdraft may develop. Strong downward momentum transfer increases outflow speed, which can cause severe wind damage and contribute to tornado development or strengthening in the form of a rear flank downdraft (Betts 1979).

The formation of the Elevated Mixed Layer is done in two common ways in the Midwest United States. A region of warm dry air can develop either in the desert southwest or Mexico or over the Rocky Mountains. Strong surface winds can push this air over moist regions that are at lower elevations further to the east. This layer can be seen in soundings and on weather maps as a dry intrusion of high theta air aloft, especially around 700mb, where it looks like a weak mid-level front. Where the layer intersects the ground a weak surface front is formed, called the dry line (Carlson 1983).

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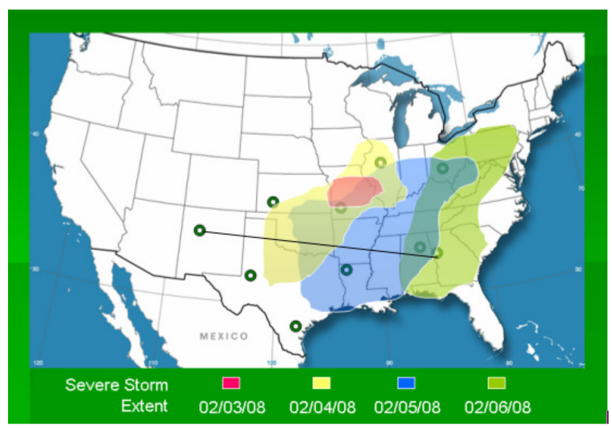


***Fig. 1.*** *Extent of Severe Weather Reports from 03-06 Feb 2008. Green circles represent sounding sites utilized. Black line indicates location of cross section used.*

#### 1.2 *February 5-6, 2008*

On 05-06 February 2008, an outbreak of severe weather occurred in the Midwest and southeast United States (Fig 1). This event was unusual in its timing, as severe weather in these regions does not tend to arise until mid-March through June. Unseasonably warm moist air lead to record high temperatures across much of the southeast on the days prior, providing energy to the storms usually not found until warmer months (NWS Huntsville 2008).

In addition to severe winds, hail and tornadoes reported across 20 states over the course of the two days, significant snow occurred from Oklahoma to Michigan. Snowfall totals in northern Missouri reached one foot and in Wisconsin and other areas around the lakes, totals were above 21 inches, with drifts up to 3 feet (NWS Kansas City 2008, NWS Milwaukee 2008).

As far as severe weather was concerned, 80 tornadoes touched down ranging in strength from EF-0 to EF-4, hail was reported in numerous states up to softball size, and wind damage from straight-line winds including downbursts and microbursts was estimated to be caused by winds with speeds up to 90 miles per hour in some regions (SPC 2008).

While some severe weather did occur on the 3rd and 4th, the large majority of and the strongest occurrences of severe weather occurred on the 5th and 6th of February.

## 2. DATA AND METHODOLOGY

As part of a larger investigation of this severe weather event, an analysis of the development and progression of the Elevated Mixed Layer was performed. To identify the coverage extent and motion of the EML, five different types of analysis were performed. All five types were investigated over a period from 02 February 2008, at 0000Z to 06 February 2008, at 1200Z. This time period was chosen in order to get a general idea of the background storm environment prior to the development of the system that spawned the severe weather and then following through the end of the most significant severe events spawned by the system.

The gridded data analyzed in the first four parts included the initializations of the NAM at 0000Z and 1200Z daily. Initializations were chosen to try and weed out and variations in the system brought about by model interpretation. The NAM was chosen over other models because of the extent of the gridded data. Information was desired for over and west of the Rockies and southward into the Mexican landmass for better identification of the origin of the mixed layer. The fifth analysis was performed with separate data, which will be discussed later.

## 3. RESULTS

### 3.1 ***Surface Dry Line***

The first analysis performed was that of mean sea level pressure in millibars plotted along with surface dewpoint temperatures in Celsius. This plot was used to identify the surface dryline, or the intersection of the EML and the ground. West of the dryline, the mixed layer is in contact with the ground, as evidenced by the low dewpoint values. East of the dryline, above the layer of moist, high dewpoint air, the EML will be found in vertical analyses.

From the analysis, the moist air can be seen pushing northward from the Gulf of Mexico ahead of the development of the low pressure system on the 2nd and 3rd of February. As the system gets organized and pushed eastward through the 5th and 6th, the dryline can be seen pushing east across Texas, Arkansas and Louisiana (Fig. 2). This line does not seem to fully infiltrate the southwest during this period possibly due to the relatively moister atmosphere over the area. As opposed to the dry and desert-like portions of western-Texas and Arizona, there is a much larger amount of moisture and vegetation over Mississippi, Tennessee and Alabama. Therefore, this analysis alone can not be used to determine the progression of the mixed layer over time.

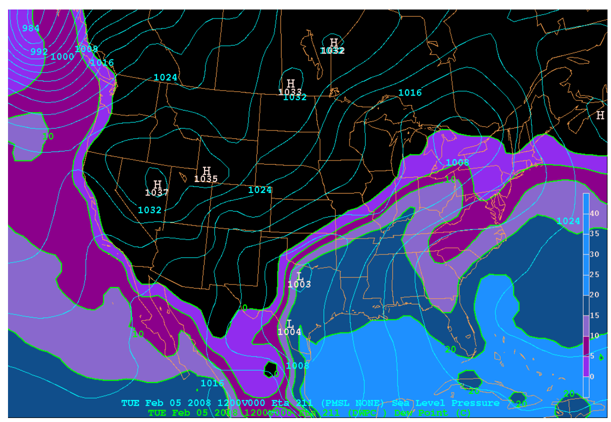

***Fig. 2.*** *Contours in blue of Mean Sea Level Pressure (mb) and shaded Surface Dewpoint values (°C) for NAM initialization at 12Z on 05 Feb 2008.*

### ***3.2 Elevated Dry Sector***

To better define the evolution of the EML over time, an analysis of the 700mb heights and dewpoint depression was performed. Since the EML can be described as a weak mid-level front, the 700mb analysis provides a useful tool for identifying the dry sector associated with the EML (Carlson 1998).

One dry sector can be seen propagating from northwest Mexico up into Kansas on the 2nd through the 4th. A second develops from mid-Texas across to the Gulf, intensifies on the 5th and works its way off the coast of South Carolina on the 6th (Fig 3). This second dry sector, which likely developed over southern portions of Mexico, is evidence of the Elevated Mixed Layer that was associated with the strong convection in the second half of the period investigated.

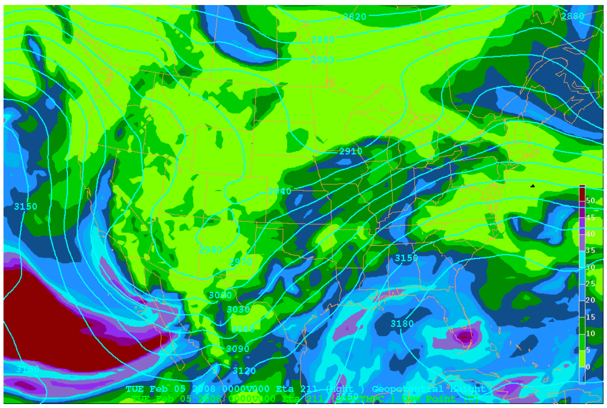

***Fig. 3.*** *Contours in blue of 700 mb Heights (km) and shaded 700mb Dewpoint Depressions (°C) for NAM initialization at 00Z on 05 Feb 2008.*

### 3.3 *Vertical Cross Section*

A vertical cross section of theta was then performed in order to identify the isentropic level that was contained within the EML. The western edge of the cross section was placed at Albuquerque, NM (ABQ) and the eastern edge at Peachtree City, GA (FFC) [denoted by line in Fig 1]. These widely separated points were chosen after analyzing the motion of the dryline in the surface plot, discussed above, in order to provide a clear continuous picture of the air masses on either side of this line.

In a cross section of theta, stable layers are found where theta contours are closely spaced and unstable layers where theta contours are spaced far apart. An EML can then be identified by a layer of unstable air over a shallower layer of stable air (Carlson 1983).

The two separate Elevated Mixed Layers described in the 700mb analysis can be seen to develop over the course of this period, the first centered around 306K on the 3rd and 4th and the second centered around 310K later in the period. The best view of this first EML over the course of the analysis can be found at 1200Z on 4 February, as can be seen in figure 4. A strong stable layer lies just below this on the 4th, which likely prevented significant convection at this time. On the 5th and 6th, as the second EML enters the region, the stable layer associated with the capping inversion is still evident but slightly weaker than that on the 4th (Fig 5). This may be indicative of why severe convection occurred later in the period rather than earlier.

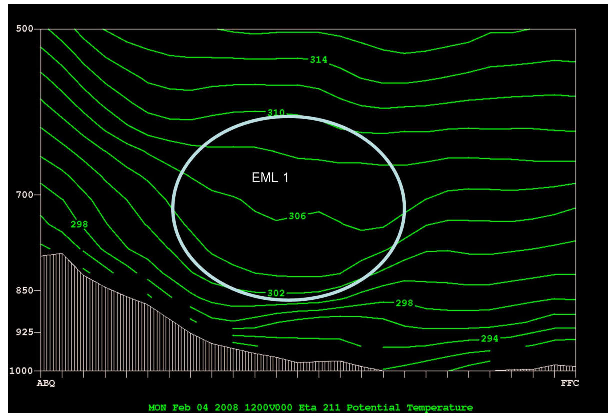


***Fig. 4.*** *Vertical cross section of theta (K, green contours) from ABQ to FFC (left to right) at 12Z on 04 Feb 2008.*

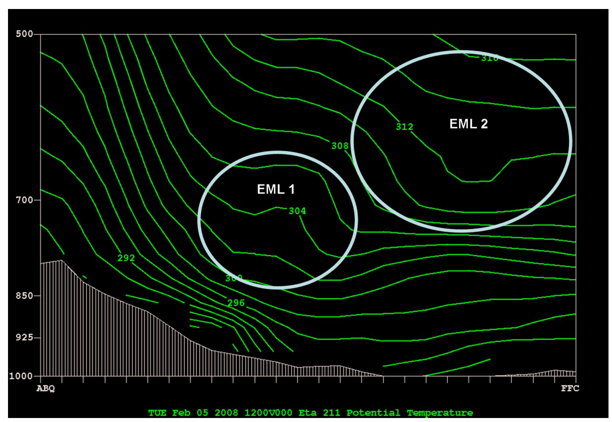


***Fig. 5.*** *Vertical cross section of theta (K, green contours) from ABQ to FFC (left to right) at 12Z on 05 Feb 2008.*

It should be noted that the 306K surface was chosen as representative of the EML streams as they progressed over time, but that during the later periods a surface of 310K would be more representative of the second EML. While multiple isentropic level analysis could be performed to create a more complete understanding of the EML, for the scope of this study, the single level analysis was determined as being a close enough representation of the EML when combined with the other types of analyses.

### 3.4 ***Isentropic Analysis***

After analyzing the cross section from above, the 306K isentrope was chosen as a representative surface for the motion of the Elevated Mixed Layer through time. On this isentropic surface were plotted pressure contours and filled contours of relative humidity.

On the 2nd and 3rd, the first EML can be found propagating across northern Mexico, New Mexico and into Kansas. Evidence of the source region of the second EML can found on the 4th as the isentropic surface begins to intersect the ground over the Mexican desert region (Fig. 6). Parcels that originate over this area were then carried aloft over Texas, Louisiana and the southeast over the next two days.

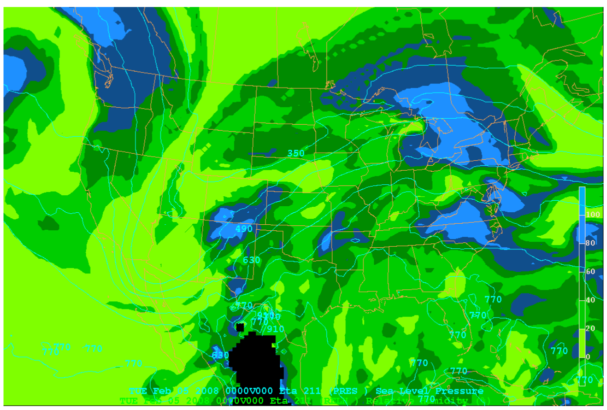

***Fig. 6.*** *Plot of pressure (mb, blue contours) and relative humidity (%, shaded) on the 306K isentropic surface at 00Z on 05 Feb 2008.*

### 3.5 ***Soundings***

In order to more fully identify the development of the EML, soundings were analyzed for the depth and height of the layer. These soundings were not pulled from model initializations, but rather from actual balloon soundings performed by various National Weather Service Offices. The data was procured from the University of Wyoming's soundings archive website.

The sounding sites that were chosen include: Albuquerque, NM (ABQ); Midland, TX (MAF); Corpus Christi, TX (CRP); Shreveport, LA (SHV); Dodge City, KS (DDC); Springfield, MO (SGF); Lincoln, IL (ILX); Wilmington, OH (ILN); Birmingham, AL (BMX); and Peachtree City, GA (FCC). These sites were chosen due to their proximity to reported severe weather in addition to their geographic spacing in order to cover the area of interest (the southern-Midwest/southeast) as evenly as possible. The sites are denoted by green circles in figure 1.

Once the soundings were collected, an analysis of the vertical structure of the environment at each site over time could be performed. Qualities of interest included the vertical extent (depth) and the height of the EMLs. This second value was equal to the average of the pressures of the top and bottom of the EML. After each site was analyzed, a map was then drawn to demonstrate the horizontal extent of the mixed layer at 0000Z and 1200Z on the four day period from 03-06 February 2008 (Fig 10).

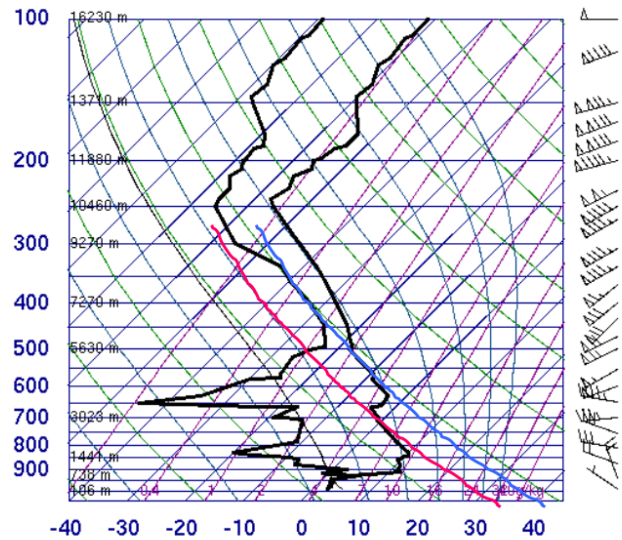


***Fig. 7.*** *Sounding from Lincoln, IL (ILX) at 12Z on 05 Feb 2008. The theta values of 306K (pink) and 310K (blue) are approximated with the curves. Courtesy University of Wyoming*

It was found that the two EMLs slowly progressed eastward over the period, with the 1st EML trending in a more northerly direction and at a lower level compared to the second. These two layers were differentiated in the soundings by identifying the theta value for the dry layer. For instance, at ILX on the 5th at 1200Z, both EMLs can be found, one with a theta value around 310K and the other around 306K (Fig 7). On this sounding, the 306K EML is centered at a lower level and thicker than the 310K EML. This trend continued through time and across the region, as can be seen in the comparison of the SGF and SHV soundings at 1200Z on the 4th and 5th, respectively (Figs 8 & 9).

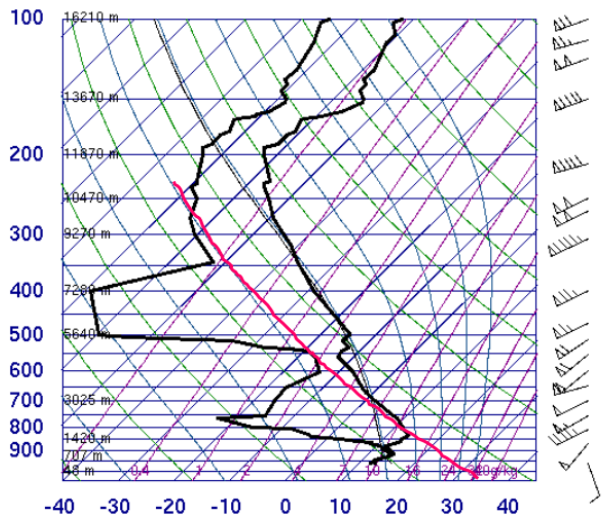


*Fig. 8.* *Sounding from Springfield, MO (SGF) at 12Z on 04 Feb 2008. The theta value of 306K (pink) is approximated with the curve. Courtesy University of Wyoming*

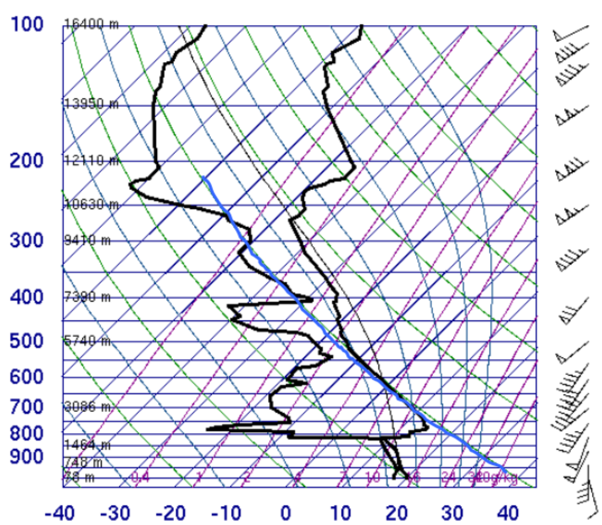


*Fig. 9.* *Sounding from Shreveport, LA (SHV) at 12Z on 05 Feb 2008. The theta value 310K (blue) is approximated with the curve. Courtesy University of Wyoming*

## 4. SUMMARY

The Super Tuesday Outbreak of severe weather was associated with two separate elevated mixed layers, each with their own distinct region of origin. The earlier developer originated over the southern Rockies in a region of lower theta air. The later developer originated further south over Mexico in a region of higher theta air and remained at a higher elevation over time compared to the other EML.

Variations in the stable inversion below the EMLs aided in capping convection until later on the fifth and sixth. The most significant severe weather that occurred late on the 5th into early on the 6th was well correlated with the extent of the second Elevated Mixed Layer.

While not a clear-cut and textbook example of the contribution of the EML in severe weather, this study does provide an interesting look at the interactions between two muddled EMLs from multiple synoptic perspectives: standard pressure surface analyses and isentropic analysis.

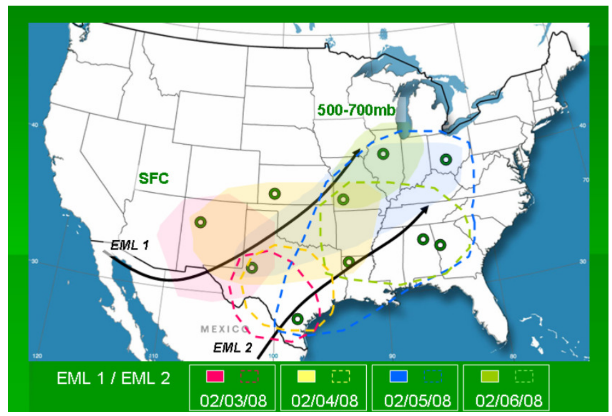


*Fig. 10.* *A plot of the extent of the two EMLs over the course of the event. The black lines indicate the direction of the progression of each EML. The height labels indicate the trend of the centered height of the EMLs as they progressed eastward.*

## 5. ACKNOWLEDGEMENTS

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## 6. RESOURCES

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