# Palm Sunday Tornado of March 27th 1994

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ABSTRACT

Through the years, residents of the US have endured numerous severe weather outbreaks. Overtime, improvements in technology and methodology in forecasting for these events have helped to decrease the loss of lives to these storms. However, the Palm Sunday Tornado Outbreak that occurred in 1994 seemed to negate these advancements by giving very few synoptic indicators to its formation. Upon closer examination, however, the interaction between a low level jet and a stationary front located over the northern portion of Alabama and Georgia caused the lift needed to get the storms going. This paper examines the factors that created this storm.

## INTRODUCTION

Supercells and tornadoes are not foreign terms to those residents of tornado alley. Every year hundreds of these storms develop across the middle of the United States, and not just by chance either. As shown by the conceptual model in Figure 1, certain characteristics unique to the central part of the country blend to form a hot bed for severe weather activity. In many cases the warm, moist gulf air flows north westward and converges with the dry air native to regions in the lee of the Rockies. As these air masses converge, an updraft of moist air is formed and flanked by rear and forward down drafts. Many of these structures form across the US each year varying in their strengths. One particularly strong supercell formed suddenly and spawned many tornadoes throughout the day.

On March 27th, 1994, many people across the country celebrated Palm Sunday. In the midst of such celebration at Goshen United Methodist Church in Alabama, an F4 tornado abruptly silenced the festivities as it destroyed the building, killing at least 20. This was no isolated incident for numerous tornadoes formed that day throughout northern Alabama and Georgia leaving great devastation in their wake. With the technology and forecasting that was available in the mid-1990s, the death toll caused from violent tornadoes had been decreasing from previous years. However, due to the lack of signs indicating severe weather, warnings were slow to reach those in the path of the storm. The delay of the warnings proved to have dire consequences as 26 recorded tornadoes killed 42 people and left over 300 others injured with over one hundred million dollars in damage. [Wikipedia]

This paper investigates the lack of synoptic precursors available for this event, after which a close examination of the mesoscale features is conducted. While a number of subtle mesoscale features helped to develop these storms, the key factor seemed to be a stationary just to the northwest of the region where the tornadoes occurred.

## DATA

A variety of sources were used in order to gather the data discussed in this paper. The University of Wyoming sounding web page provided the Skew-T profile and hodograph. NGM and Eta data were used to produce many of the

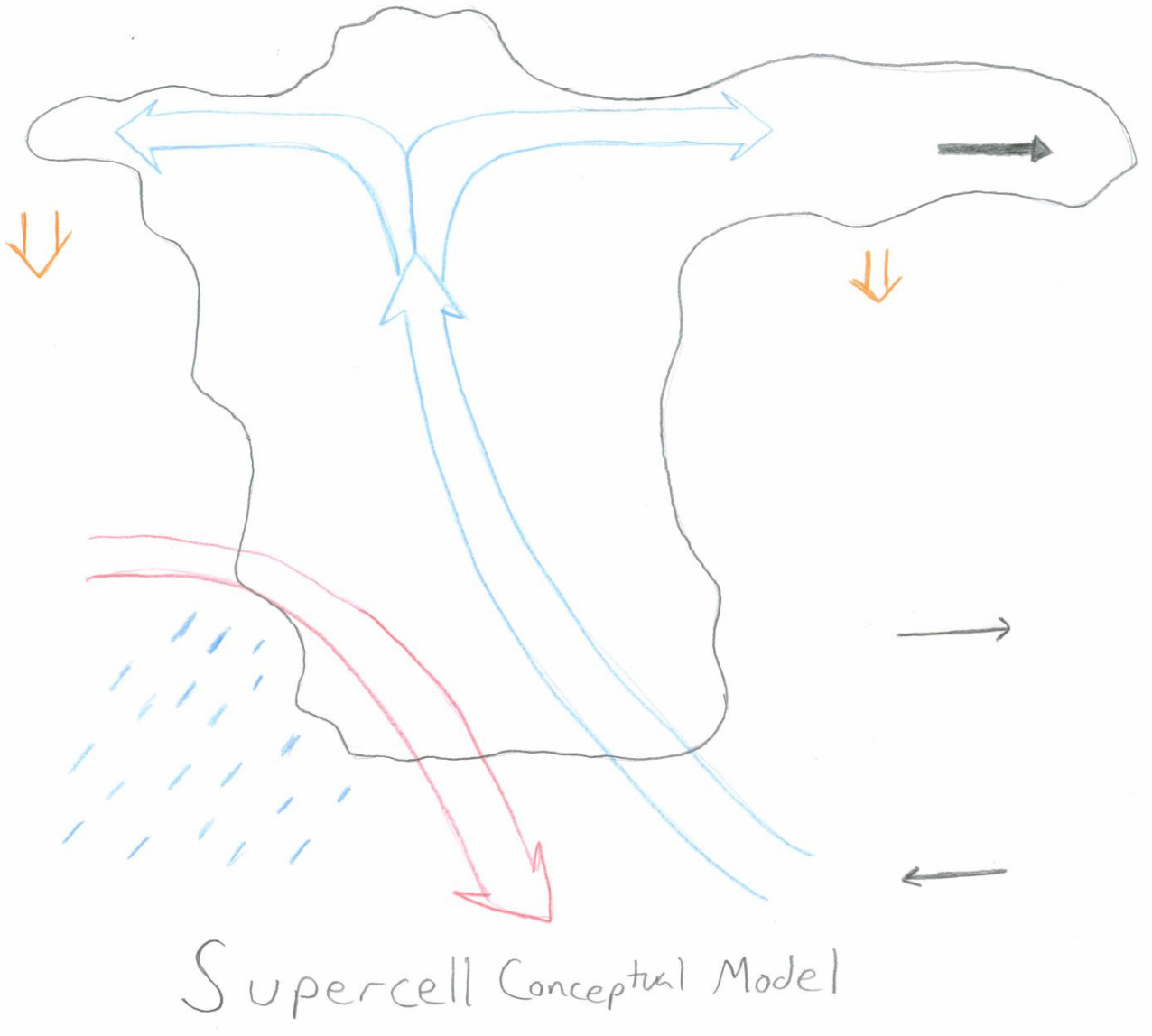


Figure 1: Conceptual Model of the mature stage of a super cell.

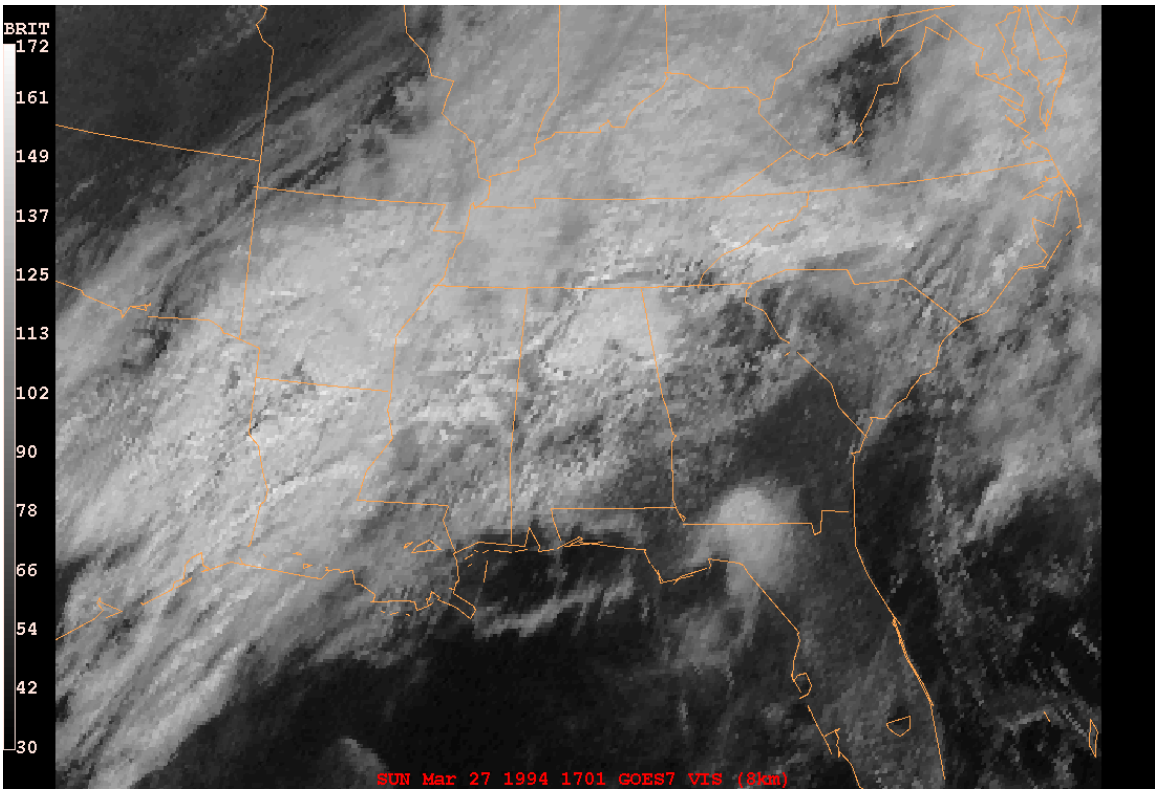


Figure 2: GOES visible satellite imagery of the Palm Sunday Tornado Outbreak taken at 17Z on the 27th of March 1994.

figures plotted by the GEMPAK and Garp programs. Further figures of synoptic upper air data were obtained from the Plymouth State Weather Center web site.

SYNOPTIC CONDITIONS

The synoptic conditions leading up to the massive outbreak of tornadoes on March 27th yielded no major indicators of the storm that was to form. The upper levels of the atmosphere appeared to be of little consequence to the Alabama and Georgia region with a 300mb jet positioned well to the west over Texas at 12Z. The exit region of the jet was weak and elongated to the north west of where the super cells would soon develop. Further plots of positive vorticity advection by the thermal wind and q-vector convergence produced similar results leaving the southeastern region of the United States in an absence of any synoptic aid in which to produce severe weather.

Although, the synoptic conditions for the most part did not seem to play a major role in creation of the storms, a couple of features proved to be essential. One element needed to produce deep convection concerns stability. It is near impossible for convection to occur in a very stable environment. Therefore, the Lifted Index of -2 to -4 that was present across

northern Alabama and Georgia definitely allowed for the possibility of severe weather provided a mechanism existed to kick off the event. Even though the synoptic conditions during the morning and afternoon of the 27th, for the most part, gave no indication of severe weather; a rather crude 8km visible GOES satellite image, as shown in Figure 2, taken over the southeast at 17Z on that day shows a storm hovering over northern Alabama. Therefore, given no synoptic conditions for ascent near Alabama or Georgia, mesoscale features must have been behind the lifting that started the storm.

MESOSCALE DISCUSSION

Indeed, the lack of synoptic conditions factoring into the creation and development of the storm, the mesoscale features were left to be the driving forces behind it. However, even these elements proved to be subtle in nature. Nonetheless, these features created a storm that ripped through the south.

One of the greatest tools used in analyzing mesoscale features to a storm is the Skew-T profile. Unfortunately, no detailed soundings were available for the immediate vicinity of northern Alabama or Georgia before, after or during the storm. However, an extra sounding released from Jackson, Mississippi at 18Z on the 27th as shown in Figure 3 was obtained as well as a rough sketch of the vertical profile for Centreville, Alabama as found in a paper written by Dr. Al Riordan. In order to get an in depth view of the conditions of the local and surrounding areas of the storm, an examination of both diagrams shall be conducted.

Given the fact that the Jackson sounding is fairly removed from where the storms occurred, it must be noted that the data is not accurate to the region being discussed. However, the fact that a special 18Z sounding was sent indicates that the possibility of severe weather near Jackson, Mississippi existed. In any matter, the use of the sounding together with comparing conditions between Jackson and the areas that experienced the storms is insightful. First of all, the indices will be taken into account. None of the indices on this sounding indicate favorable conditions for severe weather. The K, SWEAT and Total Totals indices of 24, 253, and 41 respectively all imply low to no convective activity. As a matter of a fact, only the Vertical Total index of 27 barely indicates a potential for thunderstorms. Even with the indices discouraging severe weather, the sounding does show a capping inversion between 850 and 900mb. Although, as shown in Figure, Jackson, MS shares the same LI as northern Alabama, it does not have a lifting mechanism in its vicinity. Such a feature would help to break the inversion and allow for convection. Yet, even with such a mechanism, the lack of CAPE in the sounding further discourages such development.

Even though the sounding from Jackson indicated a low threat of severe weather, some basic elements conducive of severe weather were present including a capping inversion and a relatively unstable, deep convective layer above it. Similar conditions were present in Alabama during 18Z with a more favorable sounding (Figure 4) added to the mix, which explained the severe weather outbreak that occurred. To explore this, a number of factors must be examined. To start, both the Lifted Index and K Index proved to be more favorable over northern Alabama than in Jackson, MS. The Lifted index was slightly more negative over Alabama

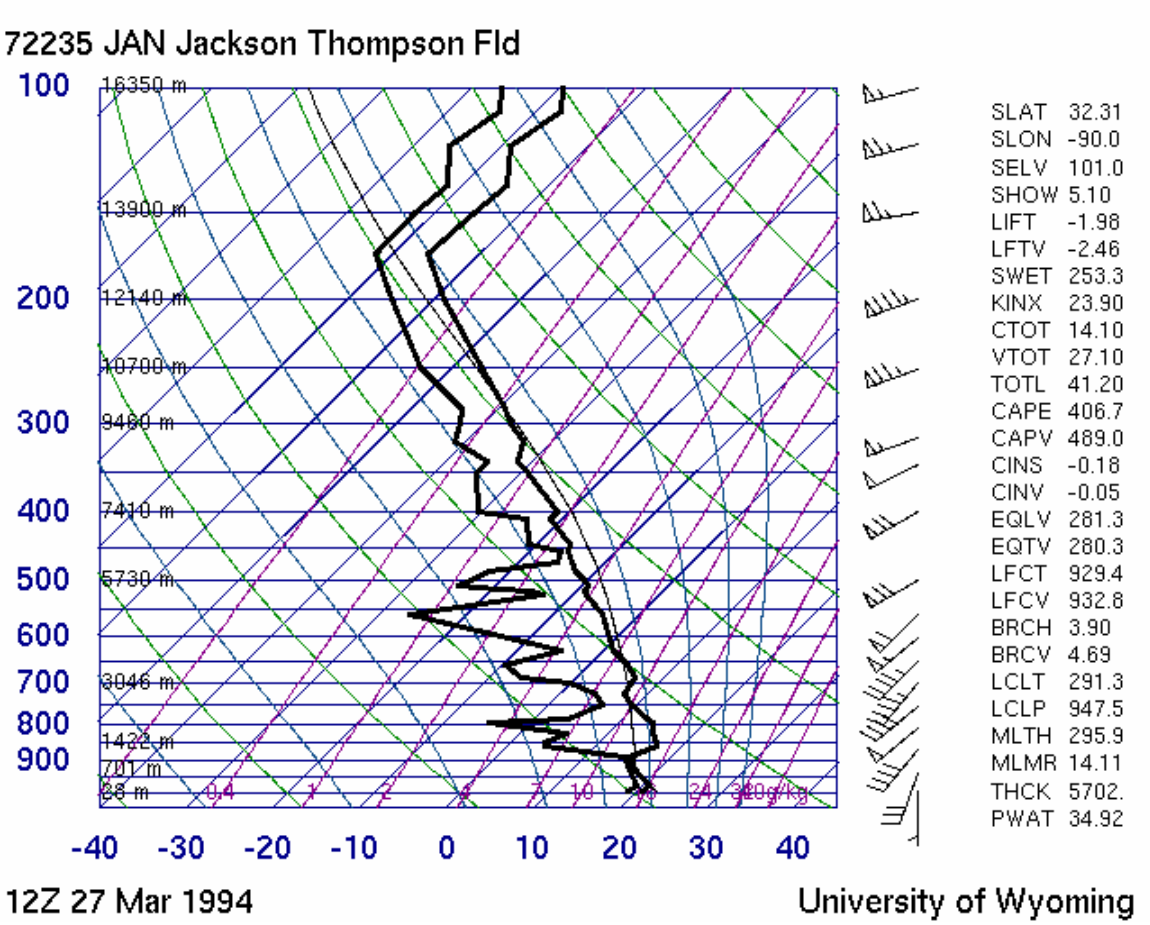


Figure 3: Skew-T Diagram of the 18Z sounding taken from Jackson, MS on March 27th 1994

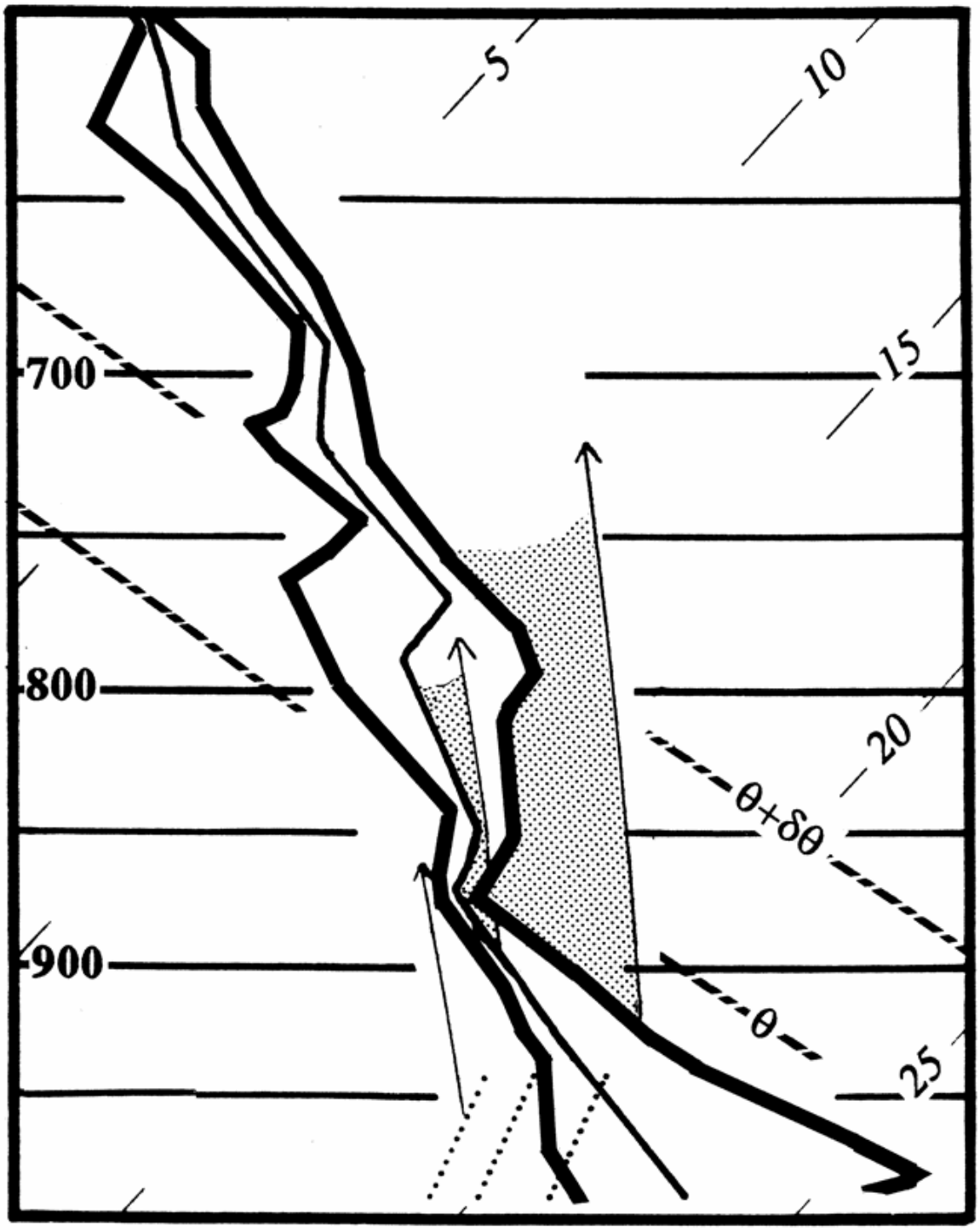


Figure 4: Sketch of a Skew-T diagram taken from Centreville, AL on the 27th of March 1994. Credit is given to Dr. Al Riorden.

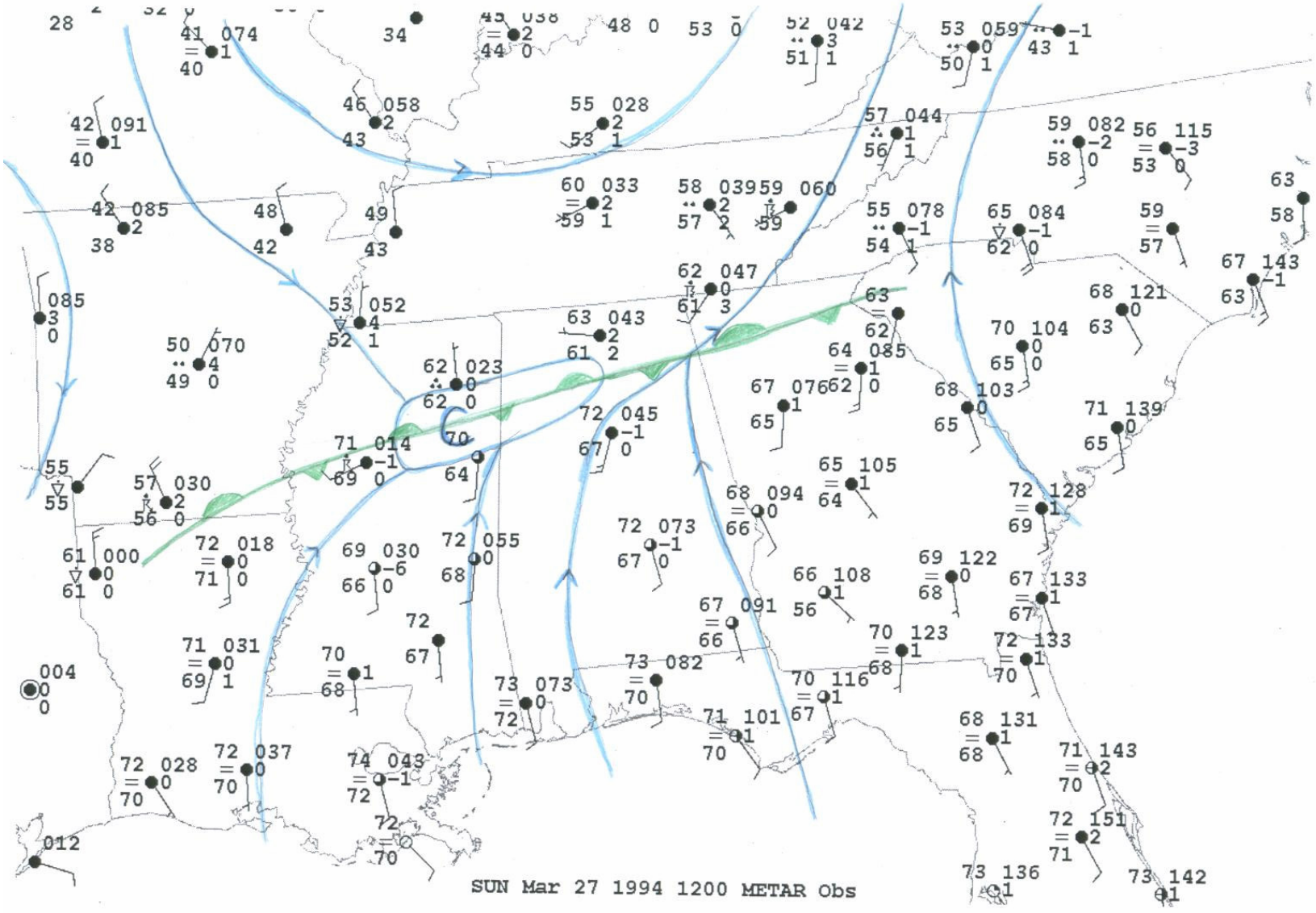


Figure 5: Mesoscale analysis of surface stationary front and streamlines for 12Z on the 27th.

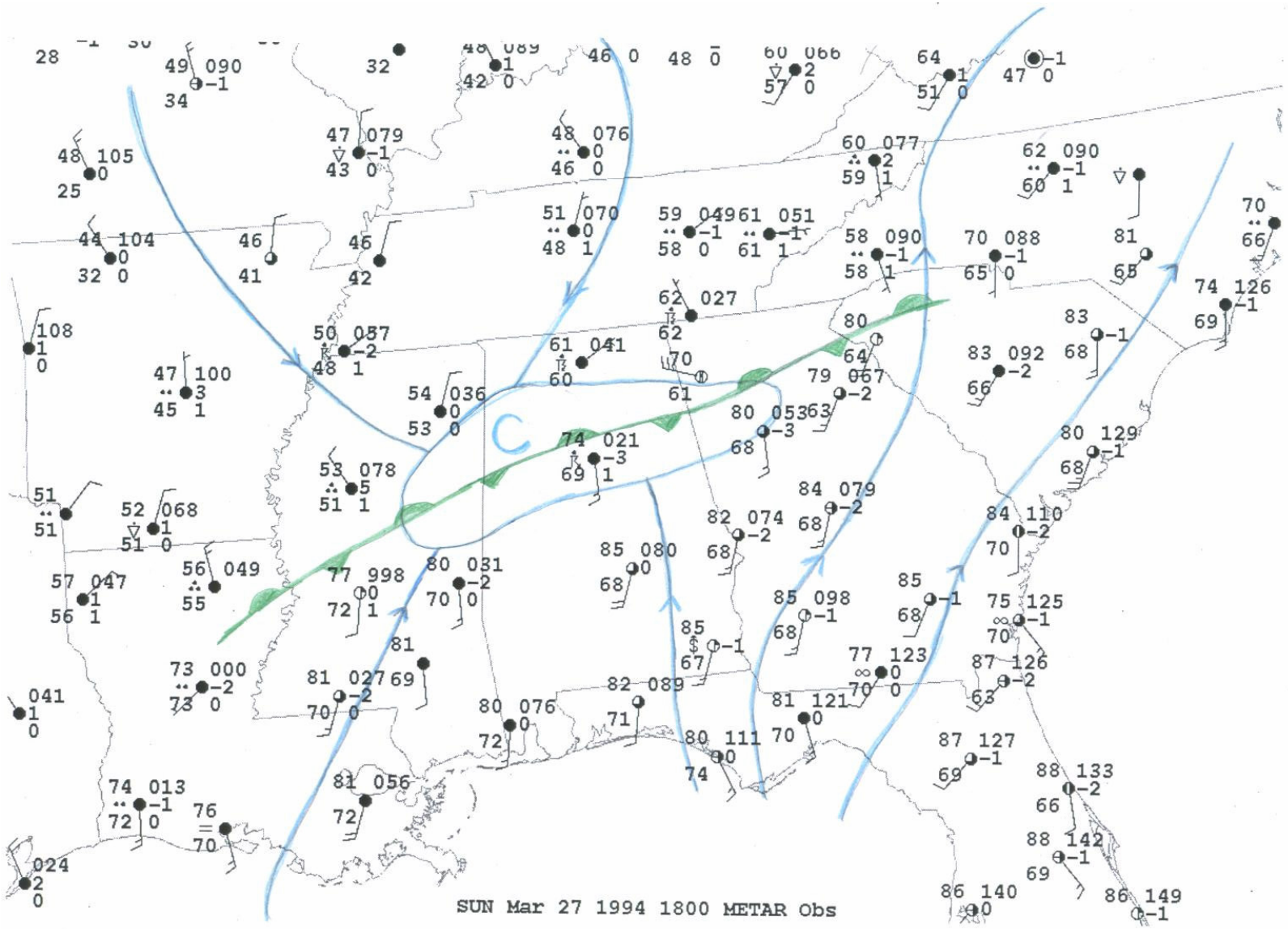


Figure 6: Mesoscale analysis of surface stationary front and streamlines for 18Z on the 27th.

with a value of -4 compared to Jackson's -2. A plot of the K Index was also higher with values in the mid to upper thirties compared to Jackson's value in the 20s. Another aspect that caused more favorable conditions for Alabama was the CAPE. The CAPE value of 407 and EL near the surface in the Jackson sounding does not match the CAPE value for the Centreville sounding, which indicates the EL to be somewhere above 700mb. With a descent CAPE value on top of favorable Lifted and K index values and a capping inversion building between the 750 and 800mb, a lifting mechanism is the last element needed to trigger the storm. With no such mechanism available on the synoptic scale, the investigation turns to the mesoscale level.

At first glace, it may seem that no such factors did exist. While no dry line was present to provide lift as often is the case for places such as Texas, other common lifting mechanisms did exist. These features interacted in a way that turned out to create and enhance this storm, and turned out to be a stationary front located in the northwest of Alabama. Figure 5 shows the surface convergence as a small cut off region spanning from northeast Mississippi to northwest Alabama at 12Z. With the small region did not seem significant at the time, the 18z convergence zone, as shown in Figure 6, grew to span from northwestern Mississippi, across northern Alabama and even into northwestern Georgia. As time progressed through the day, the front became more of a factor, acting as a lifting mechanism to the storm.

The most important factor that contributed to the storm was the interaction between a low level jet and the stationary front mentioned above. The other main mesoscale ingredients to this storm are depicted in the Miller Diagram displayed in Figure 7. In this figure, the red dash/dot line, brown-spiked line and red arrow show the dry tongue, 700mb moisture and low level jet respectively. As the diagram shows, high-speed, low-level winds feed into the stationary front, which acted as a cap across the northern section of the states. Together, these two features created significant lift as shown in Figure 8, which is a plot of the upward vertical motion at 18Z on the 27$^{th}$. Hence, a lifting mechanism was created to break the capping inversion. A third ingredient of low level moisture was also present along the convergence line. This moisture was taken up in the upward vertical motion and can be viewed from a cross section such as the one shown in Figure 9, which is taken from Shelby County Airport in Alabama to Peachtree, Georgia. As the figure displays, the updraft of the storm-caused by the lifting mechanisms mentioned previously-lifts the lines of constant theta-e high up into the atmosphere.

## CONCLUSION

On the 27$^{th}$ of March 1994, a series of deadly tornadoes ravaged northern Alabama and Georgia leaving a great deal of destruction in its wake. The lack of synoptic precursors to the event along with hidden mesoscale factors that contributed to the storms development created late warnings to reach out to those in the storm's path as well as a challenge to find the cause behind the start of the storm. After an in depth investigation, it was found that the interaction between a low level jet and a stationary front created the lift needed for the storm to form.

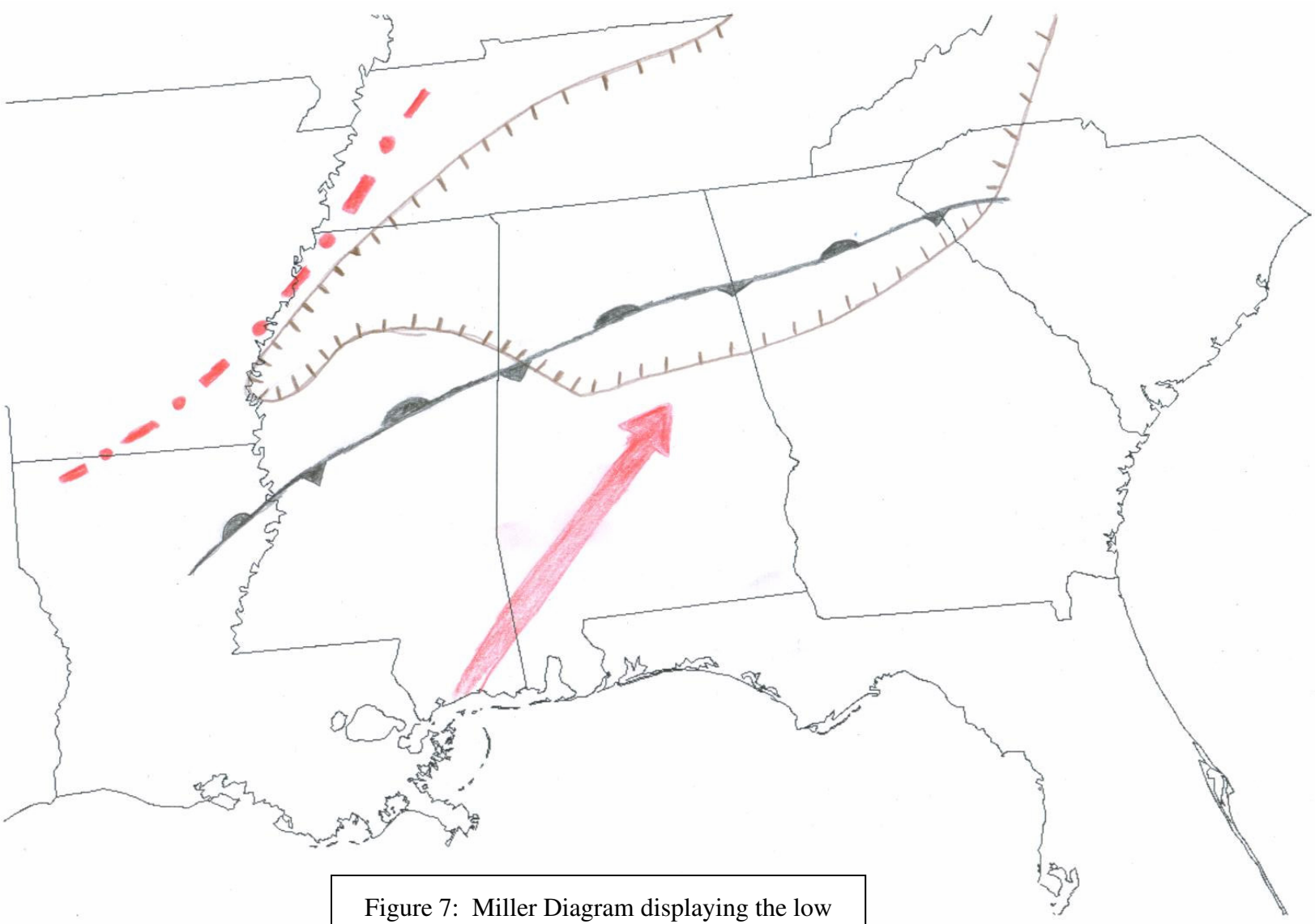

Figure 7: Miller Diagram displaying the low level jet, stationary front, low level dry tongue and mid-level moisture.

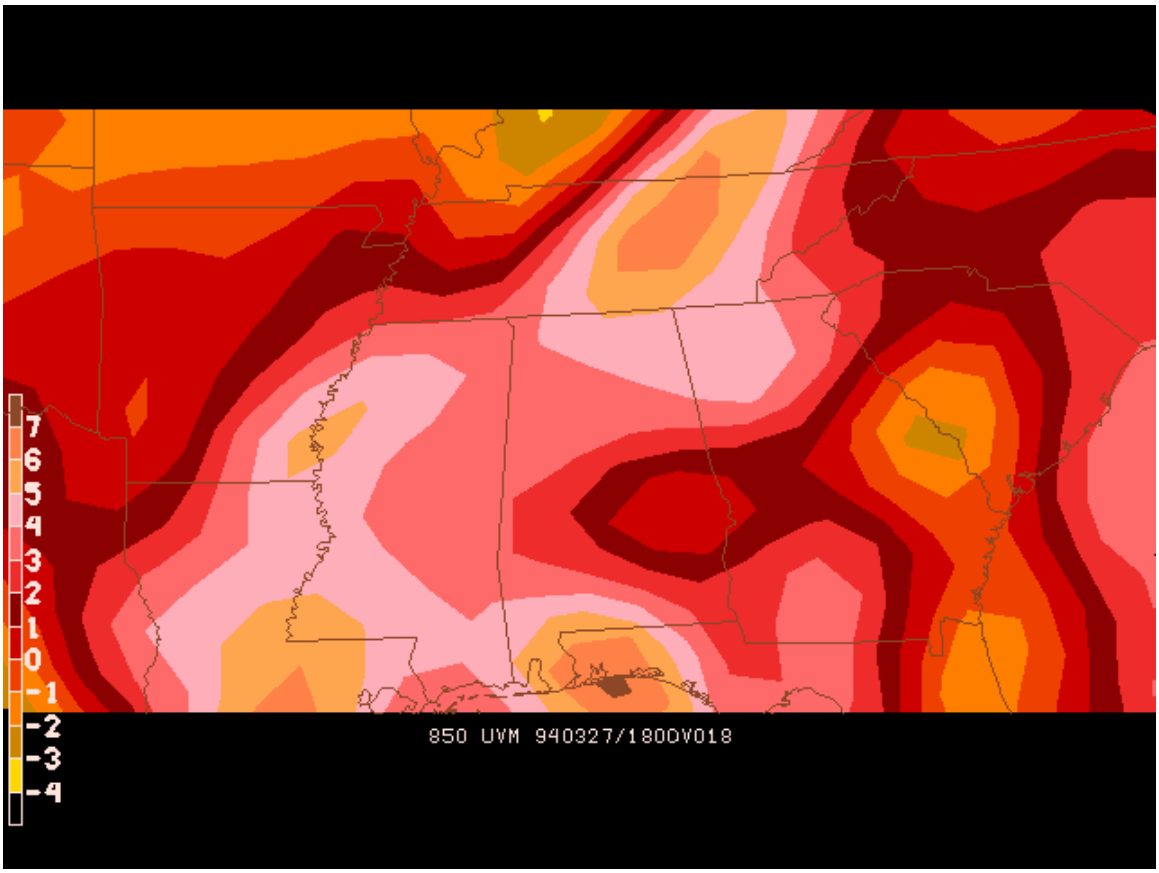


Figure 8: 18Z upward vertical motion at 850mb.

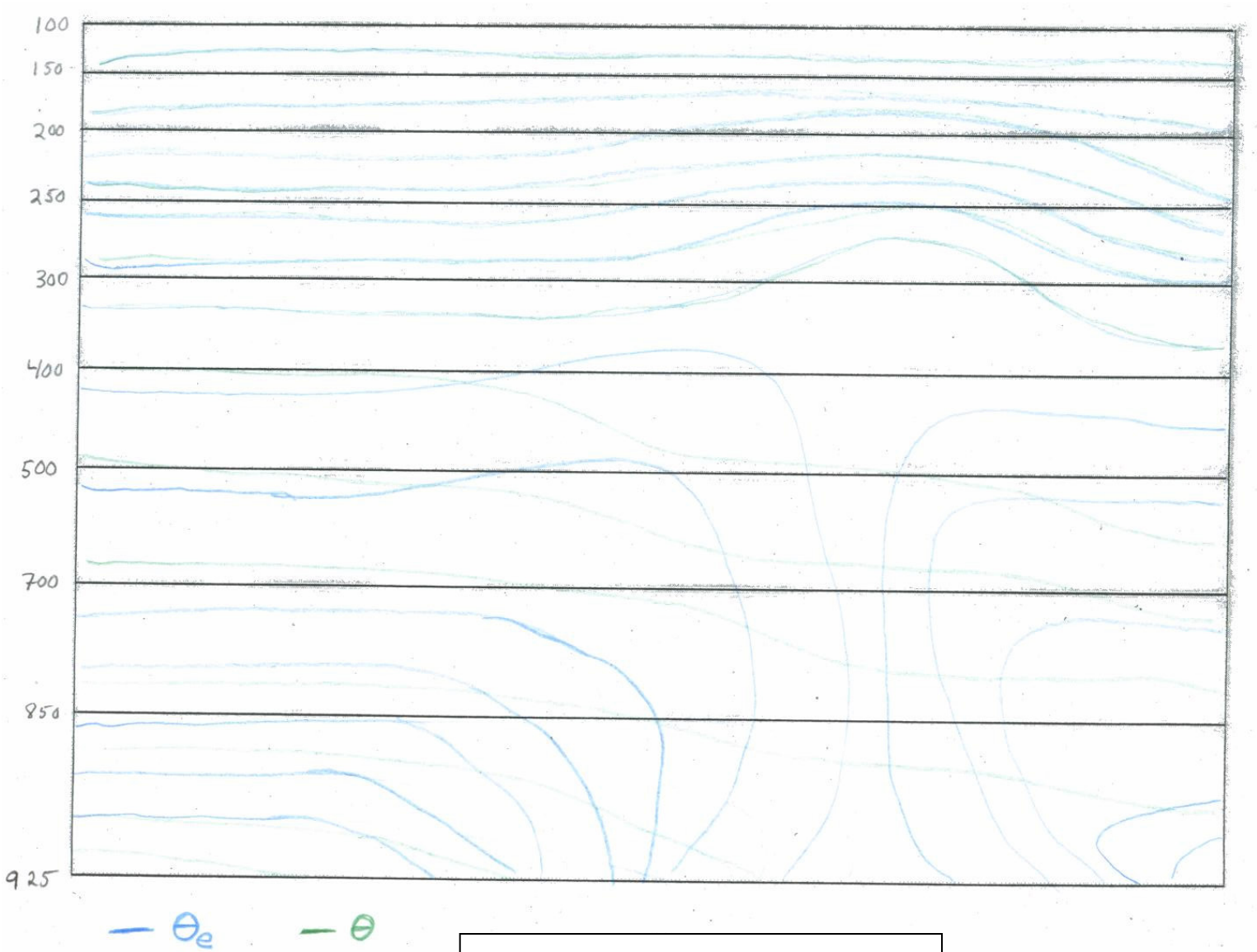


Figure 9: Cross Section of Theta and Theta-e contours taken from Shelby, AL to Peachtree, GA.

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