

by Joseph T. Rubino (1) and James T. Moore (2)
Department of Earth and Atmospheric Sciences
Saint Louis University, Saint Louis, Missouri

An unusual period of severe winter weather struck the southeast Gulf coast during January 31 - February 2, 1983 as a low pressure system moving east-northeastward from Texas produced heavy rain and fourteen tornadoes. Several kinematic fields were computed for this case using synoptic scale surface and upper air data and a Barnes interpolation scheme. Skew-t analyses were also utilized to measure the stability of the atmosphere for key time periods. Fields of divergence, temperature advection, moisture convergence, and lifted index displayed spatial and temporal continuity with the observed synoptic features as the severe weather moved from west to east. Jet streak dynamics also exerted an influence on the convection which was sustained for a period of 48 hours.

An unusual two day outbreak of severe weather occurred along the southeast Gulf coast during the winter of 1983. Heavy thunderstorm activity commenced during the evening of 31 January and lasted well into the night of 1 February. In addition to the severe thunderstorms, widespread flash flooding occurred in eastern Texas. Fourteen tornadoes were reported, ranging up to F3 (3) in intensity, with the strongest tornadoes occurring in southern Louisiana. By the conclusion of this two day period, 10 people were killed, 89 injured, and damage estimates exceeded the 50 million dollar mark (4). The severe weather continued an eastward progression into Florida on 2 February, with the activity gradually becoming less violent.

2. DATA AND ANALYTICAL PROCEDURES

locations in the northern Gulf of Mexico and off the South Carolina-Georgia coastline were added to the surface observational network. At these locations, in the absence of ship data, extreme care was taken in subjectively interpolating temperature, pressure, dewpoint, pressure tendency, (over 3 hours) and wind direction and speed for all times. The interpolated values of these non-derived parameters were based on surrounding observations and temporal continuity of the station data. The authors made sure that the assigned magnitudes displayed little variation with respect to what was observed so that no erroneous gradients of temperature, pressure, etc. were created along the grid borders. Using a similar procedure, several stations (DAN, RDU, CMI, LOZ, EMP, STL, TYR) had missing data interpolated for some of the time periods to keep the station density constant. Twelve-hourly upper air observations at 17 stations were recorded for the same period. Fifteen upper air sites had similar variables subjectively interpolated to the location for 0000 and 1200 GMT 1 February. These included four stations in the northern Gulf of Mexico in addition to COU, MGM, JAX, CGI, TRI, SHV, IND, LEX, TUL, HOU, and MEM. Fig. 1 shows the surface and upper air network in addition to the severe weather reports between 0200 GMT and 1600 GMT 1 February 1983. Meso-alpha scale resolution of phenomena was obtained at the surface for a region centered over northwest Alabama

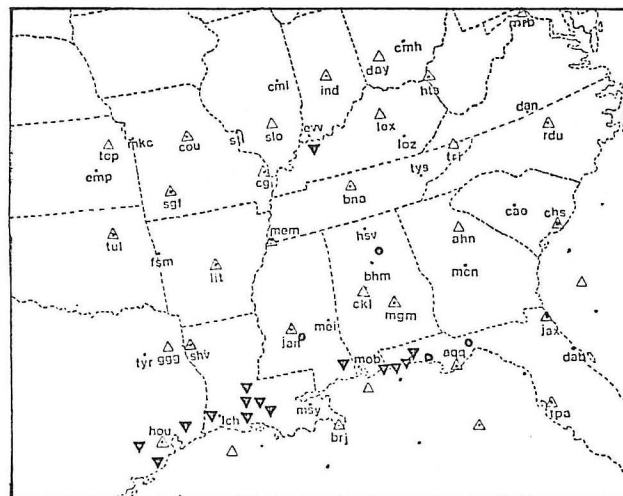


Fig. 1. Surface and upper air station network. Dot indicates surface station. Triangle indicates upper air station. Both symbols for combined sites. Severe weather reports between 0200 GMT and 1600 GMT 1 February 1983.

At 850 mb (Fig. 3c), a closed low was located over north central Texas, with a ridge centered in the Atlantic Ocean off the Florida coast. This height pattern allowed the Gulf coast to be influenced by a warm, moist southerly flow, closely resembling surface conditions. These features also existed at 700 mb (Fig. 3d), however the 700 mb closed low was displaced to the west over the Oklahoma-Texas panhandles. Unlike characteristic outbreaks of severe weather, this case did not exhibit an intrusion of dry air around 700 mb. The dry air was located at approximately 600 mb and above. Doswell (6) has noted that the threat of severe weather is downplayed when a deeper layer of moisture is present. The deeper moist layer typically acts to decrease instability, consequently causing traditional stability indices to be less impressive as severe convection forecast tools.

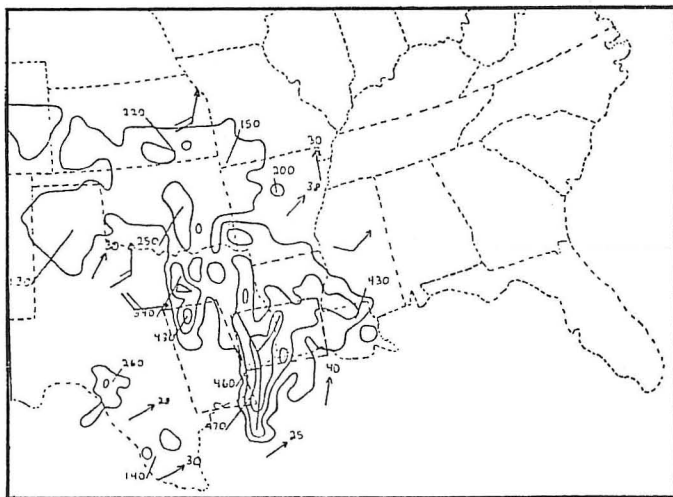


Fig. 3b. NMC radar summary for 2335 GMT 31 January 1983.

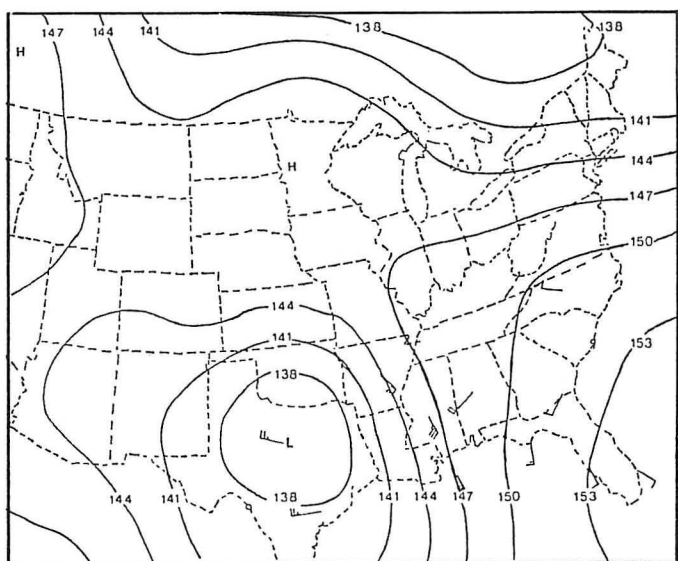


Fig. 3c. 850 mb analysis for 0000 GMT 1 February 1983.

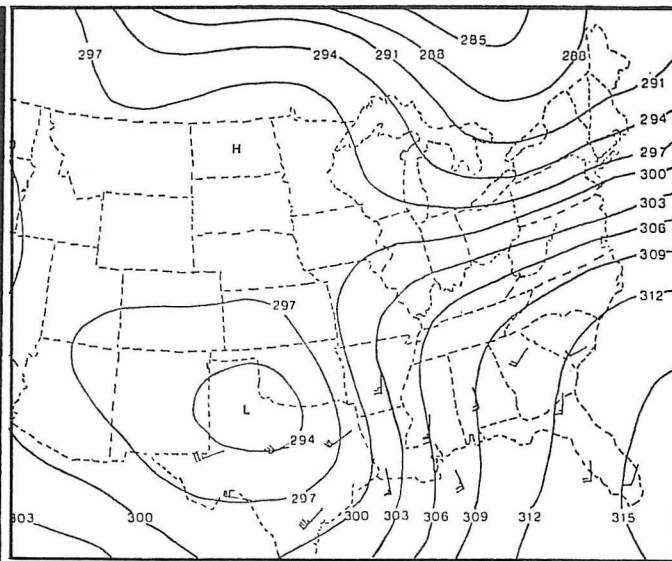


Fig. 3d. 700 mb analysis for 0000 GMT 1 February 1983. Height contours at 850 mb and 700 mb are in 30 gpm intervals.

The 300 mb analysis

(Fig. 3e) shows a wind minimum extended from extreme eastern Texas, through central Louisiana, southern Mississippi, into southern Alabama. There was strong diffluence eastward from central Oklahoma with a wind maximum located from northeast Texas into Arkansas. This jet streak was separated from the main jet stream located in extreme southern Texas, around the base of the trough. In addition to the diffluence,

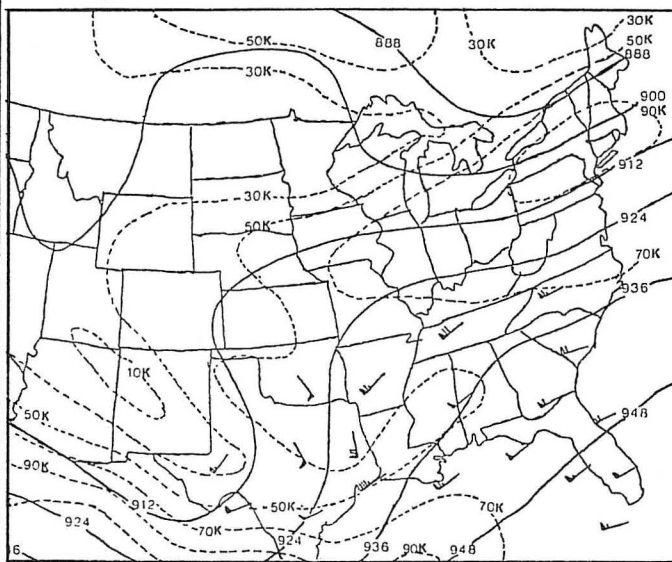


Fig. 3e. 300 mb analysis for 0000 GMT 1 February 1983. Height contours in 120 gpm intervals. Dashed lines are isotachs in 10 m s⁻¹ intervals. Wind barbs at 850 mb, 700 mb and 300 mb are in knots.

that extended north to Illinois, east to Georgia, south to the Gulf of Mexico, and west to the Red River Valley of Texas and Oklahoma. Macro-beta scale resolution was obtained for the same region at the upper levels. National Meteorological Center (NMC) surface, 850 mb, 700 mb and 300 mb analyses were obtained through the National Facsimile circuit. The sounding data were acquired from the National Climatic Center, North Carolina.

Objective analysis of u , v wind components, temperature and mixing ratio were done through a Barnes (5) scheme. All variables were interpolated to a 19 row by 20 column grid having a grid distance of 95.23 km at the surface and upper levels. Although the authors did not use stations outside the grid but still within the scan radius, adequate representation of the aforementioned variables along the grid borders was still achieved due to a uniform data distribution. Barnes (5) demonstrated that in the absence of data over water, an objective analysis of 500 mb heights agreed quite well with the reported heights in addition to an adequate fit around the boundaries. Divergence, temperature advection and moisture convergence were computed using standard, second order centered finite differencing. At the surface, this scheme (Fig. 2a) resolved no more than 15% of the amplitude of the 2 delta waves (approximately 400 kilometers). A lower resolution was found at upper levels with 25% of the amplitude of 800 kilometer waves being resolved (see Fig. 2b).

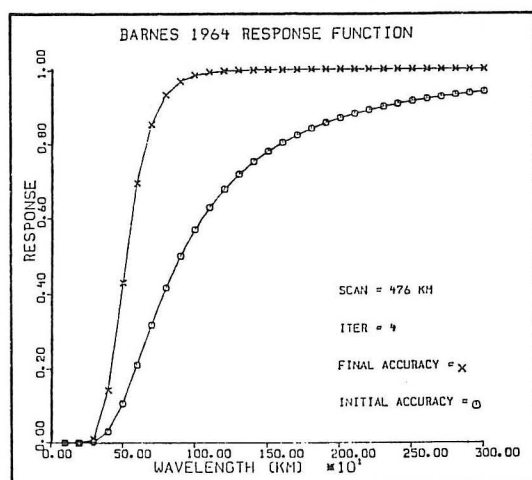


Fig. 2a. Barnes (5) response curve corresponding to the objective analysis parameters used with the surface and upper air data.

Lifted Indices were calculated from Skew- t analyses of rawinsonde data at 0000 and 1200 GMT 1 February to evaluate stability. The mean mixing ratio and potential temperature of the lower 100 mb of the sounding were utilized to define a boundary layer lifting condensation level (LCL). From the LCL, the parcel was lifted pseudo-adiabatically to 500 mb. The Lifted Index was computed by subtracting the parcel temperature at 500 mb from the environmental temperature at the same level.

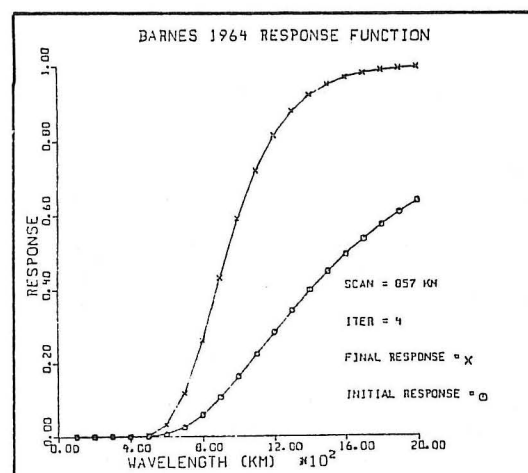


Fig. 2b. Barnes (5) response curve corresponding to the objective analysis parameters used with the surface and upper air data.

3. SYNOPTIC ANALYSES

a. Initial Conditions

On 31 January 1983, a low pressure system formed in west central Texas. By 0000 GMT 1 February, the cyclone had a central pressure of 997 mb as it moved into northeast Texas. A cold front extended southward from the low along the Texas Gulf coast with a warm front stretching eastward along the southeast Gulf coast (Fig. 3a). Radar reports at 2335 GMT 31 January indicated a solid line of thunderstorms extending through eastern Texas into the Gulf with movement to the east-northeast at approximately 10 knots (Fig. 3b). Maximum echo tops associated with this line were 47,000 feet. Ahead of the cold front, a southeasterly flow from the Gulf of Mexico was transporting warm, moist air inland as reporting stations observed dewpoints in the upper 50's and 60's (F). In contrast, dewpoints were in the 40's behind the cold front as northwesterly winds were ushering in drier air.

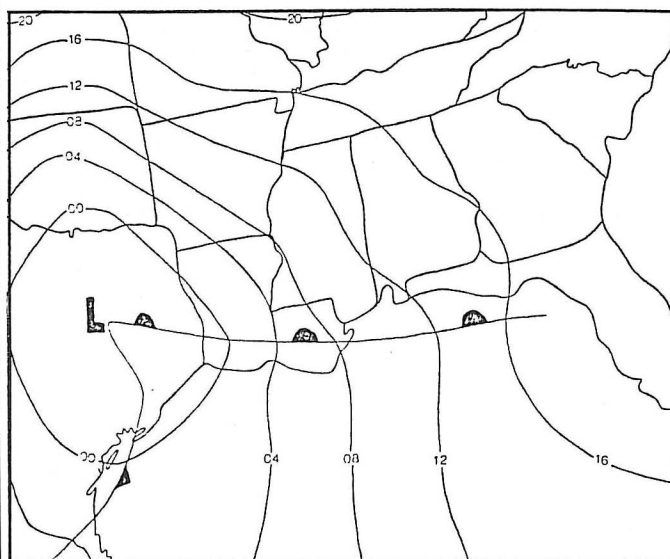


Fig. 3a. Surface analysis for 0000 GMT 1 February 1983. Pressure field in millibars with last 2 digits reported (e.g., 04=1004 mb).

Fig. 3f shows an area of strong divergence extended from eastern Texas into western Louisiana with a maximum value of $7.7 \times 10^{-5}/s$ extreme northeast Texas. This divergence occurred on the cyclonic side of the main jet stream and was centered within the diffluent zone along the Texas-Louisiana border. The jet streak and diffluence can create patterns of convergence/divergence in the upper levels. These patterns will not always follow the straight line jet streak model, described by Beebe and Bates (7), due to the cyclonic curvature of the jet. However, the divergence patterns associated with the upper level jet can contribute to the development of upward vertical motion. This vertical motion will decrease the static stability of a column of air while transporting moisture to a higher level. Beebe and Bates (7) have documented jet streaks as mechanisms which can aid in the release of convective instability.

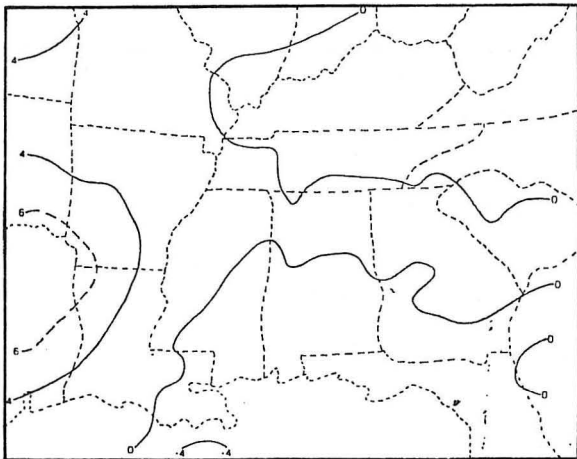


Fig. 3f. 300 mb horizontal divergence ($\times 10^{-5}/s$) for 0000 GMT 1 February 1983.

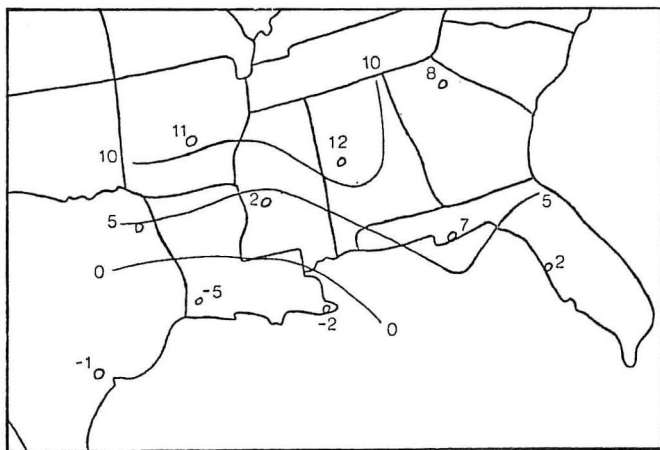


Fig. 3g. Lifted Index Analysis for 0000 GMT 1 February 1983.

An analysis of Lifted Index (LI) at 0000 GMT (Fig. 3g) shows an area of negative values in southern Louisiana. Values of -5 or less are quite unusual for late January. The LI analysis from 12 hours earlier (not shown) depicted values of -5 and less over southeast Texas. Based on this finding, one concludes that southern Louisiana was undergoing a decrease in stability most likely in response to the advection of warm, moist air at the surface and lower levels. Miller (8) has noted that the LI is a good indicator of instability under these conditions. A tornado watch, effective until 0400 GMT, 1 February for southwest Louisiana, was located in the area of negative LI's (Fig. 3b).

b. Surface Variability

The occluded wave cyclone moved to the east-northeast early on 1 February, while an associated area of showers and thunderstorms also propagated in a similar direction (Fig. 4a). By 0300 GMT 1 February, a squall line had translated into south-central Louisiana, extending into the Gulf of Mexico. The position of the squall line was aligned with the region of maximum surface moisture convergence in central Louisiana. The highest value associated with this maximum was 2.35 gm (kg-hr) (Fig. 4b). This moisture convergence contributed to the uplift needed in low levels to produce the severe convection, and provided a significant amount of moisture transport into Louisiana.

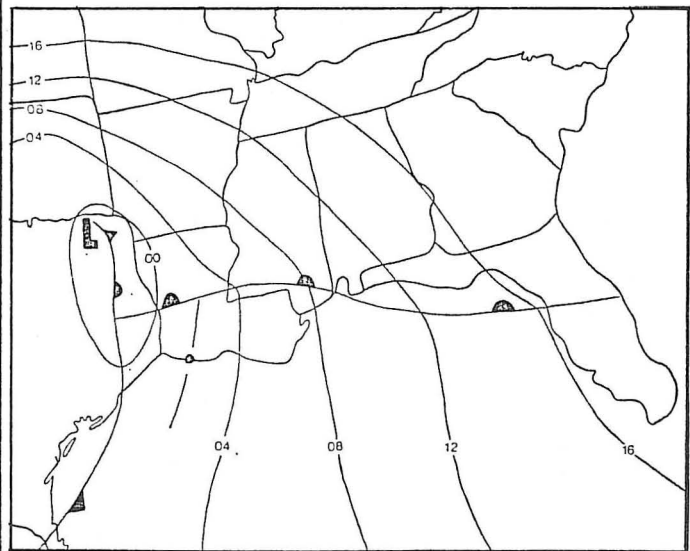


Fig. 4a. Surface pressure field (mb) for 0300 GMT 1 February 1983. Dash-dot line on pressure analysis represents squall line position.

By 0900 GMT, the squall line moved into extreme eastern Louisiana and southern Mississippi, while the surface low was centered on the northeast Texas-Oklahoma border (Fig. 5a). Once again, there was a strong correlation between the surface features and the computed kinematic fields. Surface

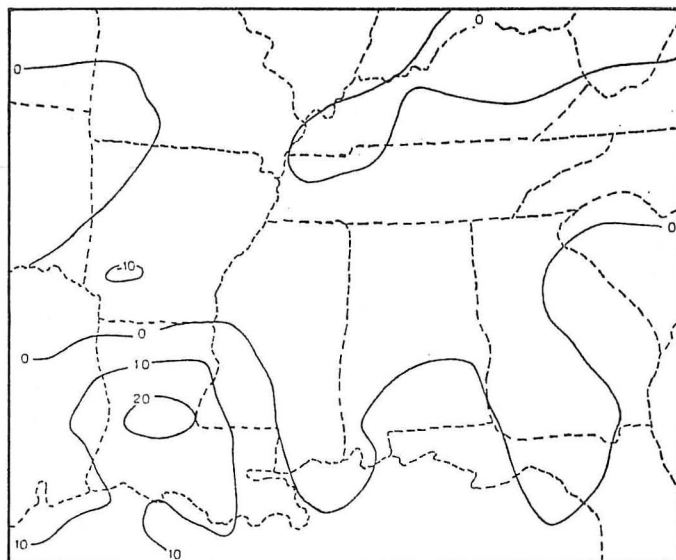


Fig. 4b. Moisture convergence ($\times 10 \text{ gm (kg-h)}^{-1}$) for 0300 GMT 1 February 1983.

moisture convergence showed strong values aligned with the position of the squall line, with a maximum value of 3.64 gm/(kg-hr) (Fig. 5b). In addition, Fig. 5b shows moisture divergence moved into western Louisiana, which helped to bring the precipitation to an end in this region. Another significant parameter was temperature advection (Fig. 5c). Strong warm air advection was located just to the east of the squall line off the coasts of Mississippi and Alabama. The highest value associated with this advection was $.79^\circ\text{K/hr}$. One can also see the advance of cold air advection into eastern Texas behind the cold front. The combination of cold air advection and low-level moisture divergence could be related to the cessation of precipitation over eastern Texas and western Louisiana which was observed on the 0835 GMT 1 February radar summary (not shown).

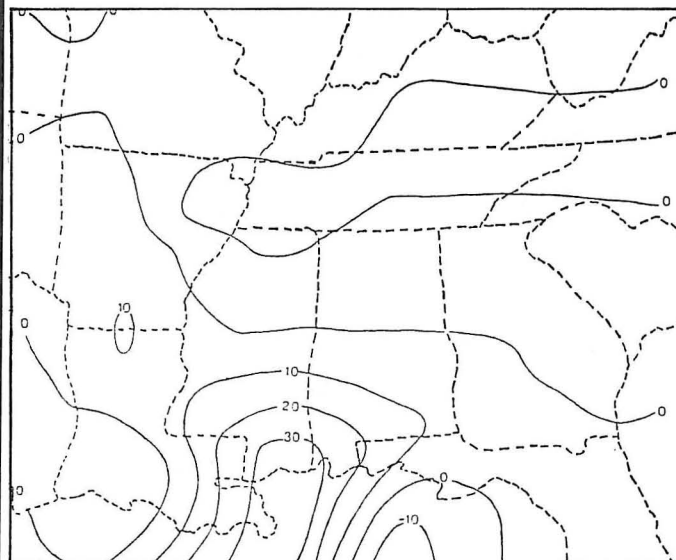


Fig. 5b.

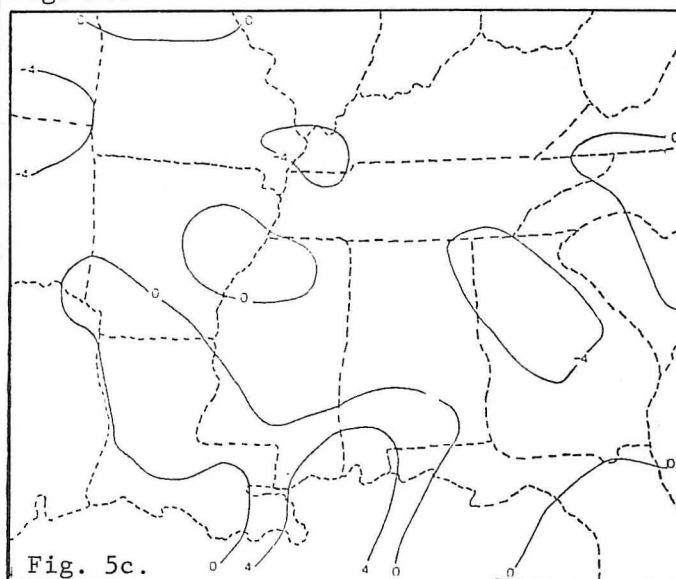


Fig. 5c.

Fig. 5. Surface pressure field (mb), moisture convergence, ($\times 10 \text{ gm (kg-h)}^{-1}$) and temperature advection ($\times 10 \text{ K(h)}^{-1}$) for 0900 GMT 1 February 1983. Dash-dot line on pressure analysis represents squall line position.

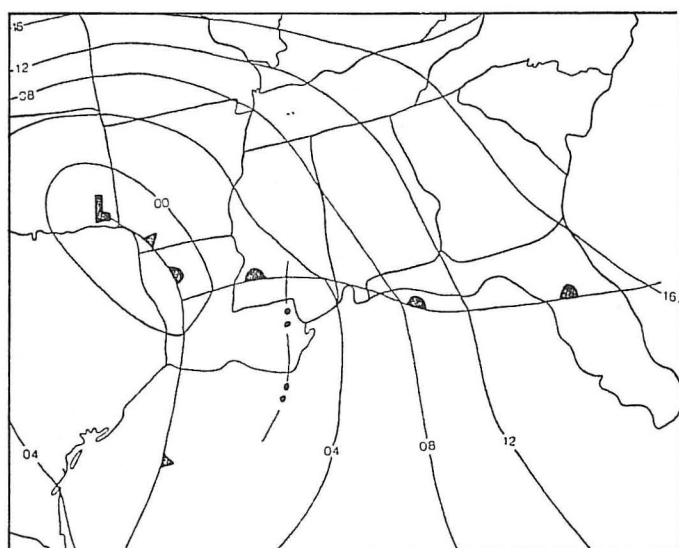


Fig. 5a.

Conditions at 1200 GMT 1 February did not exhibit significant changes as the squall line moved into the Florida panhandle and adjacent Gulf waters. The occluded wave cyclone was in southeast Oklahoma with the cold front extending through central Louisiana and into the Gulf of Mexico (Fig. 6a). Figure 6b shows that the strong axis of moisture convergence noted earlier had become elongated in a west-east direction, with a maximum value of 3.03 gm/(kg-hr) off the southeast Louisiana coast. Weaker values of moisture convergence were moving into the extreme eastern half of Louisiana as the squall line shifted eastward towards the Florida panhandle. Two maximum areas

patterned the surface features also. A maximum value of $2.26 \text{ gm}/(\text{kg}\cdot\text{hr})$ was located near the triple point position of the occluded cyclone in northeast Louisiana. The $1.44 \text{ gm}/(\text{kg}\cdot\text{hr})$ value in southwest Georgia could have been in response to the weak surface wave which developed along the warm front in southeast Alabama by 1500 GMT 1 February.

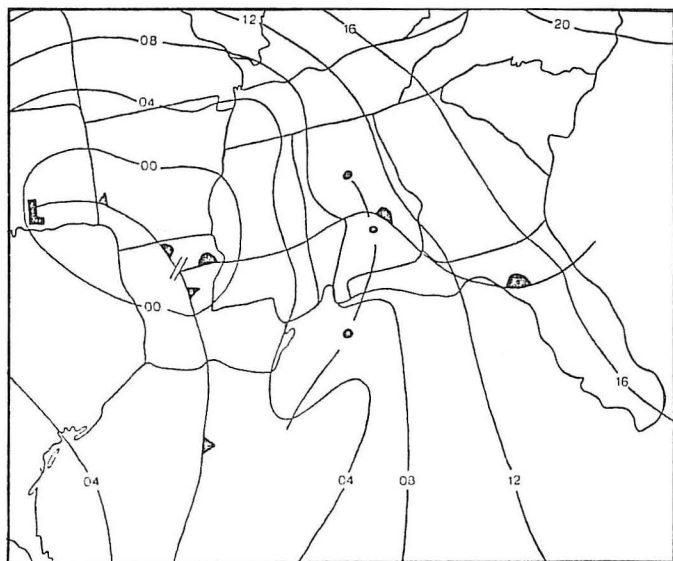


Fig. 6a.

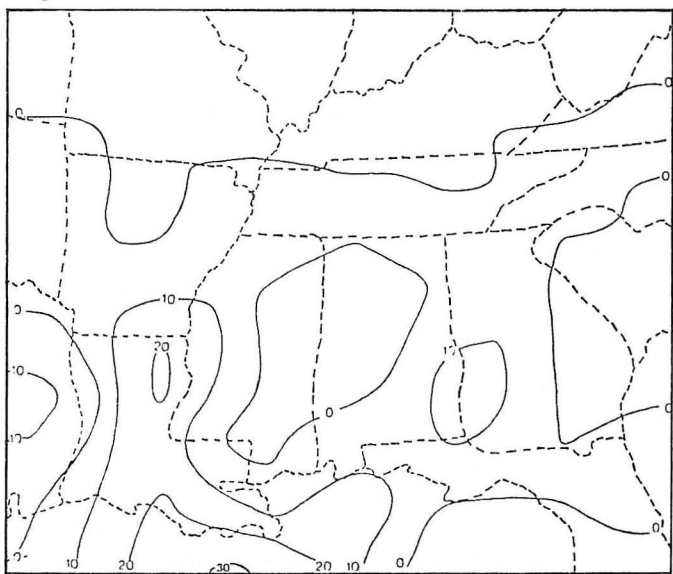


Fig. 6b.

Temperature advection at this time (Fig. 6c) revealed warm air advection shifting to the southeast, paralleling the movement of the squall line. The cold air advection had strengthened in extreme eastern Texas which was reflected in surface temperatures dropping into the 40's. The zero advection isopleth running through Louisiana was in very good agreement with the position of the cold front. A small area of cold air advection centered over southern Mississippi was probably induced by rain-cooled air behind the squall line. A mesoanalysis of surface temperatures and winds (not shown) does reflect a weak circulation that could support this advection pattern. In addition, the smoothing effect of the Barnes Scheme probably increased the spatial extent of this feature.

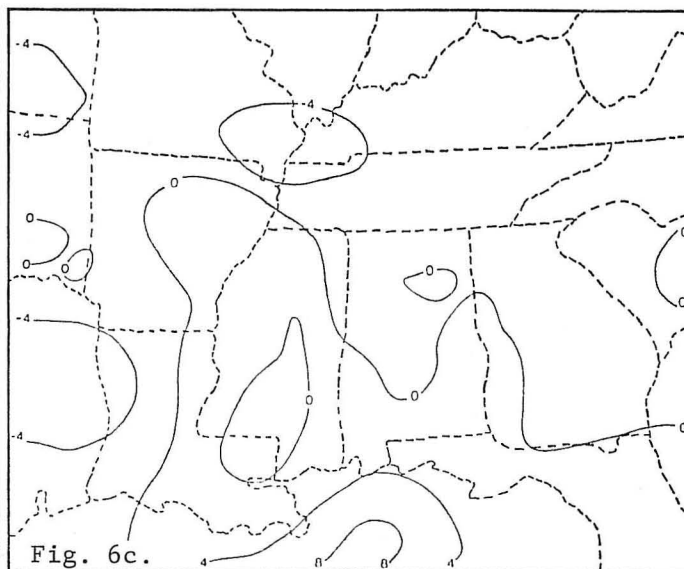


Fig. 6. Surface pressure field (mb), moisture convergence ($\times 10 \text{ gm}/(\text{kg}\cdot\text{h})^{-1}$), and temperature advection ($\times 10 \text{ K}/\text{h}$) for 1200 GMT 1 February 1983. Dash-dot line on pressure analysis represents squall line position.

c. Upper Air Variability

Unlike the special three-hourly rawinsonde data sets available for the Atmospheric Variability Experiment - Severe Environmental Storms and Mesoscale Experiment (AVE-SESAME) case studies, the authors could only utilize 12-hour observations from NMC analyses for an investigation of upper air features. Despite this long time interval, little change on the synoptic scale took place at 850 mb between 0000 and 1200 GMT on 1 February. The closed low (not shown) at 1200 GMT was located over southeast Oklahoma with height falls over a 12 hour period of -50 , -70 and -90 gpm extending to the east. Winds in the region to the east of the low were primarily from the south-southeast, ranging in speeds from 30 to 50 knots. They continued to transport warm, moist air across the Gulf coast states. A noticeable feature was a westerly wind at Centreville, Alabama. Two factors contributed to rejecting this direction. First, the authors considered its position in relation to the low center. East of the center one would typically expect a southerly component which was characteristic of the other wind observations. The second consideration was that at this time, there were heavy thunderstorms in the area. This mesoscale influence could have affected the wind direction temporarily. These factors prompted the authors to change the direction to a south-southwesterly component. Despite questioning the wind direction, the entire observation was not deleted, out of a necessity to maintain station density. The ability of the 1964 Barnes scheme to resolve synoptic features depends largely on the number of stations in the scan radius. Therefore, the authors felt compelled to at least keep the wind speed which was supported by the height analysis. Losing this observation, which was in close proximity to the squall line, might have negatively affected our results.

Temperature advection correlated fairly well with the upper air pattern. At 0000 GMT (Fig. 7a), strong warm air advection was located in extreme northeast Texas, eastern Oklahoma, and western Arkansas, just to the northeast of the 850 mb closed low. By 1200 GMT (Fig. 7b), the center of warm air advection had shifted to central Mississippi as the closed low moved into Oklahoma. Also, cold air advection was diagnosed in eastern Texas and extreme southwest Louisiana due to strong westerly winds at 850 mb.

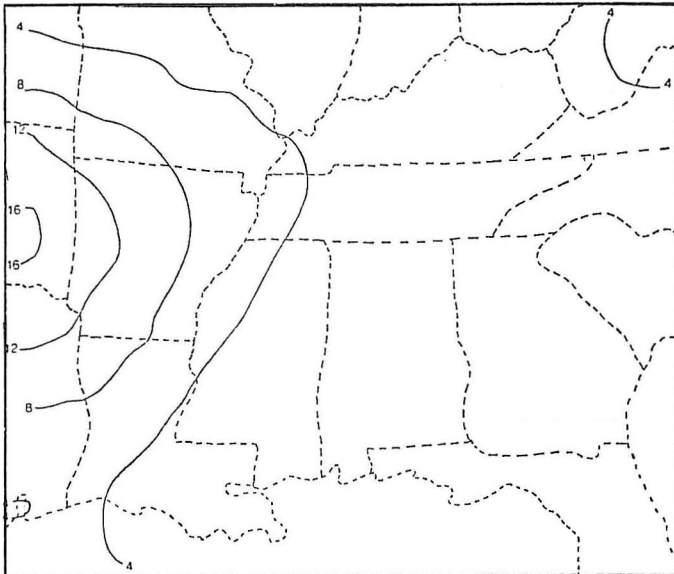


Fig. 7a.

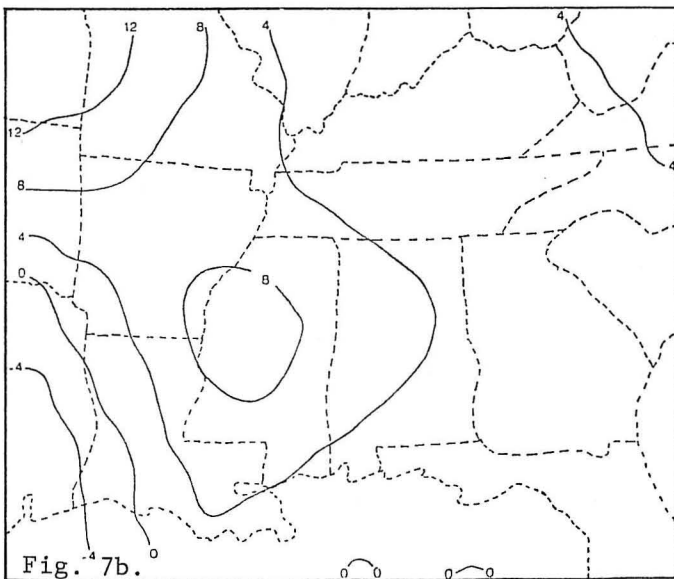


Fig. 7b.

Fig. 7. 850 mb temperature advection ($\times 10K(h)^{-1}$) for 0000 GMT and 1200 GMT 1 February 1983.

Moisture convergence at 850 mb over the 12-hour period did not show as much consistency with the thunderstorm activity as did the surface fields. At 0000 GMT (Fig. 8a), an axis of moisture convergence extended through eastern Texas along the Gulf Coast, with values reaching $1.45 \text{ gm} \cdot (\text{kg} \cdot \text{hr})^{-1}$

just off the Texas coast. This axis was located parallel to, and just to the east, of the heavy line of thunderstorms in extreme eastern Texas. By 1200 GMT, however, the axis of moisture convergence had shifted to the northeast and was centered over Mississippi (Fig. 8b). This area was well to the west of the squall line, and was probably associated with the closed low and frontal system over Louisiana and Arkansas. Despite moving into an area of moisture divergence at 850 mb over the Florida panhandle and adjacent waters by 1200 GMT, the squall line did retain an organized configuration well into the afternoon of 1 February. For both times, values were not as large as the surface values, but they were still impressive, especially considering the time of year.

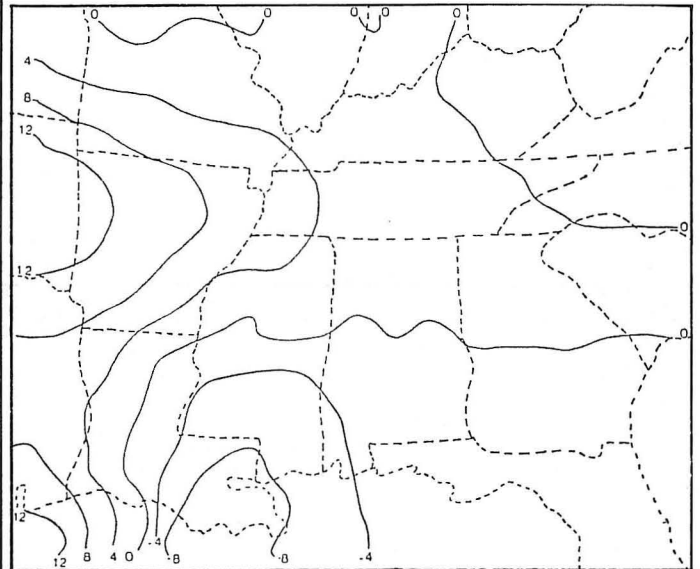


Fig. 8a.

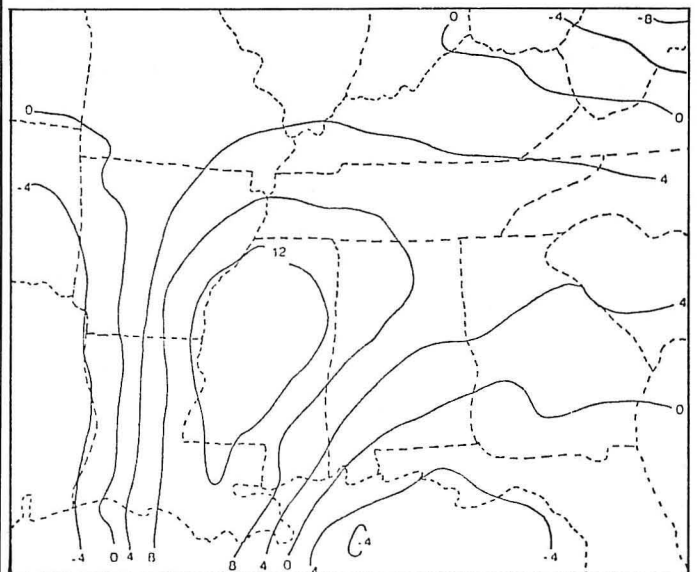
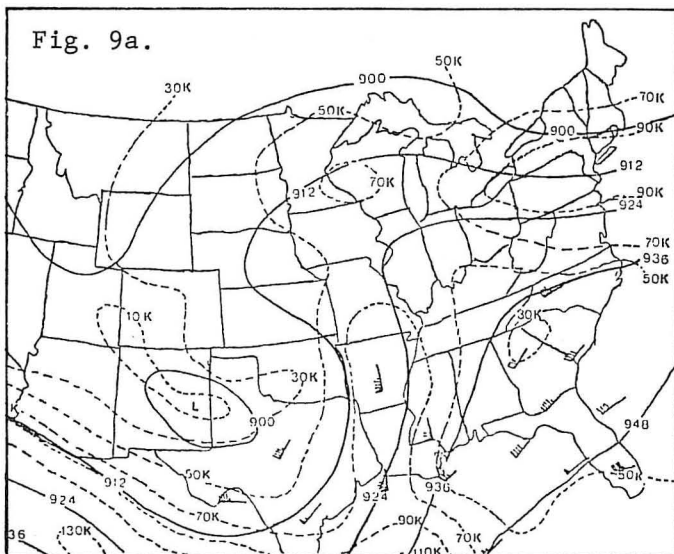


Fig. 8b.

Fig. 8. 850 mb moisture convergence ($\times 10 \text{ gm} \cdot (\text{kg} \cdot \text{h})^{-1}$) for 0000 GMT and 1200 GMT 1 February 1983.

The major feature worth noting at 300 mb was the jet maximum located to the south of the low center. This jet underwent noticeable changes in its structure over the 12-hour period. At 0000 GMT, 1 February (Fig. 3e), the jet extended across Mexico and into the Gulf of Mexico. However, by 1200 GMT (Fig. 9a), the jet had split near the Louisiana coast with part of it extending into Arkansas and



Missouri, and the other branch southwestward toward Mexico. Speeds within the jet were as high as 85 knots. Just to the east of where it splits, some of the most intense convection occurred. Once again the divergence field (Fig. 9b) shows consistency with the 300 mb patterns. The divergence maximum, which had weakened slightly (to $7.5 \times 10^{-5}/s$) in central Mississippi, still remained on the cyclonic side of the main jet stream in the Gulf of Mexico. This strong divergence could be linked to the right rear quadrant of the jetlet over Arkansas which other investigators (7, 9) have observed in jet

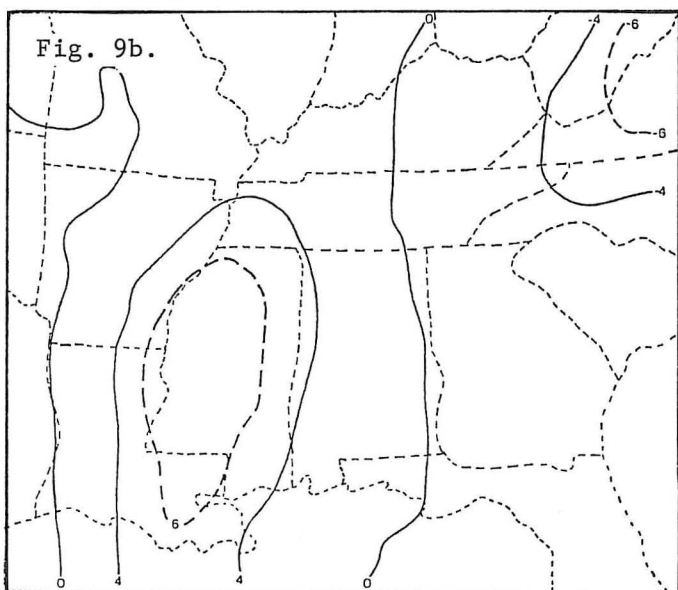


Fig. 9. 300 mb height analysis for 1200 GMT 1 February 1983. Horizontal divergence ($\times 10^{-5}/s$) for 1200 GMT 1 February 1983. Isotachs are in 10 m s^{-1} intervals. Heights are in 120 gpm intervals. Wind barbs are in knots.

streaks. A broad area of divergence extended from western Louisiana to eastern Alabama and covered the region occupied by the squall line. This divergence could have enhanced the vertical motion field, which is of prime importance to sustaining the squall line convection. In addition, the area of maximum divergence had become oriented in a north-south axis through western Mississippi into eastern Louisiana. This axis was just to the east of the jetlet protruding northward into Missouri and paralleled the strong diffluent zone associated with the split jet stream.

Changes in stability from 0000 to 1200 GMT showed that the negative region of LI values noted earlier across southern Louisiana had shifted eastward (Fig. 10). The area had become oriented into a well-defined north-south axis centered in extreme southeast Louisiana. The southern half of the squall line was located in the region of negative LI values; however, the northern half had moved into values as stable as +8. It is possible that because the northern portion of the squall line was located to the north of the warm front, cooler surface temperatures may have caused the lifted parcel temperatures to be less than the environmental temperatures, yielding positive LI values. This suggests that the convection may have been based aloft, above the warm frontal zone.

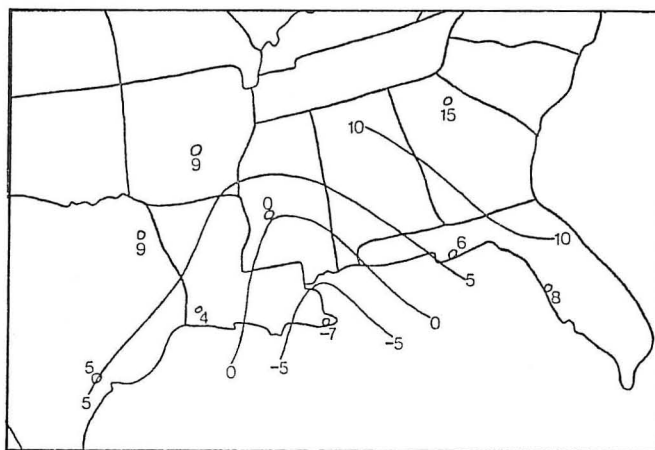


Fig. 10. Lifted Index Analysis for 1200 GMT 1 February 1983.

d. Soundings

To show a comparison of environmental conditions before and after the passage of the squall line, the authors analyzed skew-t plots of rawinsonde data. The pre-storm environment was characterized by the Boothville sounding at 0000 GMT, 1 February (Fig. 11). At this time, shower activity was just beginning to move into the southeastern tip of Louisiana, while a solid line of thundersorms were moving through eastern Texas (Fig. 3b). The sounding shows a nearly saturated moist layer extended from the surface to approximately 975 mb. A moderately moist layer then continued upward to around 675 mb. Beyond this point, extreme drying occurred at mid-levels. The wind profile showed moderate veering with height, implying warm air advection in low layers. Wind speeds increased from 30 knots at 850 mb to 46

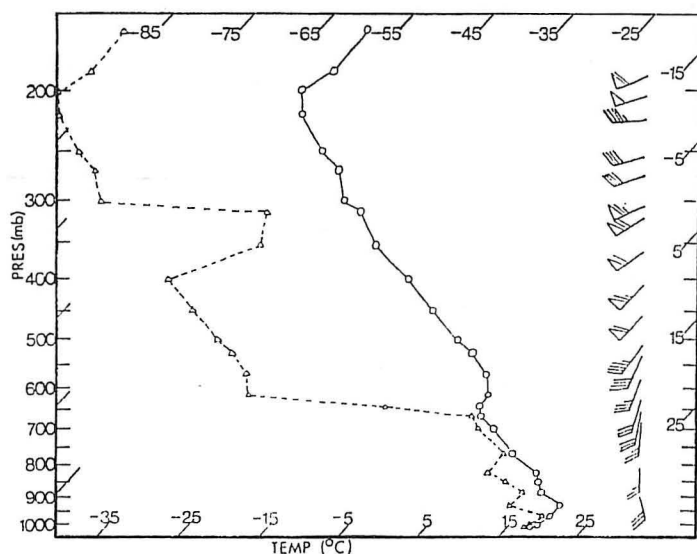


Fig. 11. Boothville rawinsonde sounding for 0000 GMT 1 February 1983.

knots at 500 mb with directions changing from 168 to 214 degrees, respectively. Thus, there was strong directional shear and weak to moderate speed shear. Vertical wind shear has been noted by Miller (8) to be an important factor in maintaining severe local storms. The southeasterly flow at the surface was transporting warm, moist air while the southwesterly flow aloft was advecting much drier air at mid and upper levels. The combination of dry air at mid-levels overriding moist air in lower levels plus veering winds enhanced the convectively unstable environment.

The authors chose the Lake Charles, Louisiana sounding (1200 GMT, 1 February) to contrast conditions after the passage of the squall line and cold front. Figure 12 shows an intrusion of dry air

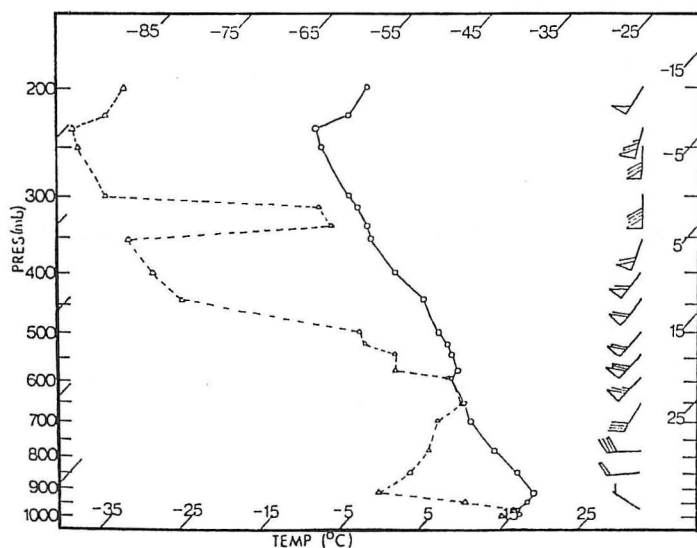


Fig. 12. Lake Charles rawinsonde sounding for 1200 GMT 1 February 1983.

at much lower levels. This dry air was associated with the dissipation of precipitation as evidenced by the radar report (Fig. 13). The sounding also shows winds backing with height in lower levels, which implies cold air advection. In the 950-900 mb layer there was a frontal inversion behind the cold front. The warm, moist air at the surface was being replaced by colder, drier air as the atmosphere returned to more stable conditions in the post-storm environment. The squall line, which remained active for up to 48 hours, moved southeastward into Florida on February 1-2 spawning widespread severe thunderstorms and tornadoes. This activity was documented to be one of the most devastating outbreaks of severe weather in recent Florida history (10).

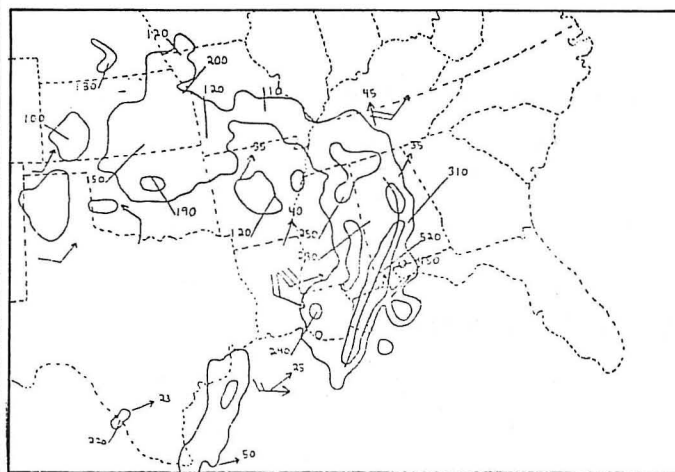


Fig. 13. National Meteorological Center radar summary for 1135 GMT 1 February 1983.

4. SUMMARY

A low pressure center in southeast Oklahoma sustained a northeastward movement on 1 February as a secondary wave developed on the warm front in southern Alabama. This wave sustained rain activity over the northern half of Alabama and Georgia. The squall line decreased in length and was confined to an area south of the warm front after 1200 GMT 1 February. Thunderstorm activity associated with this line continued over extreme southern Alabama and the western Florida panhandle into the evening hours of 1 February. By 2 February, the two low centers had merged into one occluded system, with a cold front trailing through South Carolina, Georgia, and into Florida.

Several factors contributed to the development of severe weather along the Gulf coast on the morning of 1 February. The significant features involved were:

1. A southerly flow from the Gulf provided an abundant moisture source.
2. Strong surface moisture convergence which aided the development of upward vertical motion.

3. Moderate to strong warm air advection at the surface and low levels was consistently located just ahead of the squall line as it moved eastward. Maddox and Doswell (11) have noted the importance of this parameter in locating severe weather.

4. Dry air at mid-tropospheric levels overriding moist air at lower levels strengthened the convectively unstable environment.

NMC products have significant problems in diagnosing mesoscale features which help one to forecast mesoscale weather systems. However, it is case studies similar to the one presented here, which provide information on where severe weather develops and where it will develop. A utilization of a combination of reanalyzed NMC products and selected objective analyses of various parameters as shown, can often provide the meteorologist with a better chance of accurately forecasting severe convection through an enhanced resolution of mesoscale features.

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NOTES AND REFERENCES

1. Mr. Joseph T. Rubino is a third year graduate student at Saint Louis University. He graduated with a B.S. degree from Saint Louis University in May, 1983. He is presently a research assistant working on a M.S. degree and enjoys applying isentropic techniques to predict the evolution and propagation of severe local storms and major winter snow storms.

2. Dr. James T. Moore is an associate professor of meteorology at Saint Louis University. He teaches dynamic meteorology, weather forecasting and analysis, severe storm prediction, isentropic meteorology, and air pollution meteorology. He is currently working on an NSF grant to investigate the use of isentropic meteorology in the short term forecasting of severe storms.

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