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A CASE STUDY OF THE SEVERE WEATHER THREAT TO THE MIDDLE ATLANTIC REGION ON JUNE 26TH, 1988.

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INTRODUCTION

During the morning of June 26th, 1988, the Severe Weather Checklist used at the WSFO at Philadelphia indicated the potential of severe weather over southern New Jersey during the afternoon hours. By late morning however, the Southern Region Mesoscale Program indicated that the severe weather threat was shifting south to Virginia, and that thunderstorm development in southern New Jersey would be suppressed. The purpose of this paper is to examine the meteorological parameters which helped to shift the severe weather threat area south of the Philadelphia forecast area.

SURFACE

A low pressure system was centered over northern Maine at 12Z on Sunday morning June 26th, 1988. A cold front extended south from the low pressure area, and was moving southeast through southern New York State, northern New Jersey, and southeastern Pennsylvania (Figure 1). Severe thunderstorms had developed along the cold front over upstate New York the preceding evening, but the thunderstorms had diminished to a weak line of showers with a few embedded thunderstorms by 12Z Sunday morning.

Dew points on Sunday morning were in the middle 50s behind the cold front, but were in the upper 60s to lower 70s south and east of the front. Afternoon temperatures to the east and south of the front were expected to rise into the low 90s, but would not exceed the convective temperature which was slightly above 100 degrees F.

The front was forecast to move through southern New Jersey during the afternoon hours where dew points were high, and where sunshine and surface heating was at a maximum. The convergence along the front was expected to increase during the late morning and early afternoon hours as the front moved southeast into a more unstable atmosphere caused by differential heating in clear air. These variables were the first indication that severe weather could form during the day in this area.

850 MB

A broad 850 millibar jet of near 30 knots was over southern

Pennsylvania and southern New Jersey at 12Z. An 850 millibar thermal ridge of 21 to 23 degrees C covered extreme southern New Jersey, and all of Delaware, Maryland and Virginia. Dew point temperatures in this area were between 12 and 15 degrees C., with the axis of the 850 millibar moisture ridge extending from ACY to IAD, and then continuing southwest along the maximum temperature ridge (Figure 2).

The prime threat area again appeared to be in southern New Jersey which was under an 850 millibar jet of greater than 20 knots, and where 850 millibar dew point temperatures were well above the 8 degrees C. threshold most often associated with severe weather.

One concern, however, was that the highest 850 millibar temperature and moisture remained just south of the forecast area in Maryland, Delaware, and Virginia. Another concern was that any cooling at 850 millibars could cause differential stabilization of the atmosphere which, in turn, would inhibit severe thunderstorm development. These concerns later proved to be significant factors in suppressing severe weather development in southern New Jersey.

700 MB

The atmosphere at 700 millibars was quite moist at 12Z over most of southern Pennsylvania and New Jersey, and this moisture extended south through much of the mid-atlantic states. Some mid-level drying was evidenced, however, on the morning satellite moisture channel and on the 12Z ACY sounding slightly below the 700 millibar moisture axis where dew point depressions were between 6 and 8 degrees C. (Figure 3). The presence of mid-level drying is a usually a positive indicator for severe weather formation provided that the drying is not extreme. Most severe weather in the Philadelphia forecast area occurs when the NGM R2 forecast is 45% or greater for this reason.

A 700 millibar no-change line extended from near ABE south to near MIV (Figure 3). This is a line of neutral temperature advection which occurs at the center of a temperature ridge or trough, or occurs when streamlines are parallel to temperature contours. The presence of a 700 millibar no-change line has been found to be a positive factor in severe thunderstorm formation when certain criteria are met. Miller (1) observed that the advancement of the leading edge of the no-change line into a position ahead of a pronounced middle-level trough is usually associated with deepening or intensification of surface low centers. Crisp (2) found that the relationship of wind to temperature no-change lines at 700 millibars was strong when the streamlines crossed it with an angle of greater than 40 degrees. The more rapidly this line is advected into an area, the greater the contribution of this factor is to severe weather formation. This line was forecast to move east and off the coast of southern New Jersey before noon, and well before the frontal passage. This would therefore diminish the chance of severe thunderstorm development over southern New Jersey, which otherwise, might have been enhanced by this variable.

Another 700 millibar no-change line extended from near PIT south through West Virginia, but this line was expected to remain south of the forecast area as the 700 millibar trof amplified and winds aloft slowly veered (Figure 3).

500 MB

Fairly strong positive vorticity advection was occurring over most of the forecast area. Winds at 500 millibars during the morning in the vicinity of ACY were near 25 knots - which is below the 35 knot threshold usually associated with severe weather; however, just north of the forecast area, a 70 knot jet extended from BUF northeast to PWM (Figure 4). The winds over southern New Jersey at this level increased to near 65 knots by 00Z as the 500 millibar jet moved south in response to the amplification of the 500 millibar trough.

The atmosphere over southern New Jersey was expected to become increasingly unstable during the day as cold air advection aloft began and surface temperatures remained steady or continued to slowly rise.

A 1000-500 millibar thickness ridge would pass through southern New Jersey during the day with 12Z thickness values between 576 and 578 decameters falling to near 570 decameters by 00Z. This is a favorable factor for the development of severe weather.

300 MB

All of southeastern Pennsylvania and southern New Jersey were in the right-rear quadrant of a 90-knot 300 millibar jetstream which was centered over New England (Figure 5). Although the position of the jet did not change appreciably during the day, the 300 millibar jet increased in speed to 110 knots by evening. Weak diffluence was indicated over the forecast area. These factors were again positive indicators for severe thunderstorm formation in or near the prime threat area of southern New Jersey.

SOUNDING, STABILITY AND DYNAMICS

The 12Z hodograph at ACY showed good directional and speed shear with height; however, strong veering was confined to the lowest 5 thousand feet, and mid-level winds were weaker than the low-level inflow (Figure 6). EI positive values during the morning at ACY and IAD were near 70 J/KG x 10 which is well above the 35 J/KG x 10 usually associated with severe weather (Figures 6 and 7). VS15 values at 12Z were near 14 (M/Sec) **2 which is slightly below the value of 18 (M/Sec) **2 generally associated with severe weather. EI (Energy Index) and VS15 (Vector Product Shear to 15thousand Ft.) are defined in Ref. 3.

Other thermodynamic indicators were not as supportive of a major severe weather outbreak, and probably one reason why severe weather did not develop over southern New Jersey. The most unstable lifted index values at 12Z ranged from minus 3 at IAD to plus 3 at ACY. The morning sounding at both ACY and IAD indicated equilibrium levels between 46 and 48 thousand feet with wet-bulb zero values ranging from 12 thousand ft at ACY to between 6 and 8 thousand feet further north and west (Figures 6 and 7).

SUMMARY OF MORNING DATA

Figure 8 shows the Severe Weather Checklist which is used by the WSFO in Philadelphia. After looking at the morning sounding and upper air data, the focus of concern for severe weather in the Philadelphia forecast area was in southern New Jersey where conditions appeared ripe for severe weather. The only factors which might have inhibited severe weather formation over this area were noted in Question 2 in Part A, and in Questions 7 and 9 in Part C. These inhibiting factors were mentioned earlier in this text.

A call was initiated to SELS at 14Z to request that the severe weather outlook area which covered the southern half of Delaware and Maryland, and all of Virginia, be extended north along the coast as far north as MIV and ACY. Both offices were in agreement, and this change was reflected in the 15Z update.

The Thunderstorm Potential Statement and the mid-morning Zone Forecasts issued by the WSFO at Philadelphia reflected the possibility of strong thunderstorms in southern New Jersey which might be accompanied by dangerous lightning, strong gusty winds, locally heavy rainfall and hail.

MESOANALYSIS

The Southern Region Mesoanalysis Program used at the forecast office at Philadelphia had many times in the past helped to delineate where severe weather was most likely to occur - and this day was no exception. At 15Z, the best Theta Advection field extended from central North Carolina northeast through eastern Virginia into southern Maryland and Delaware to extreme southern New Jersey (Figure 9). Surface Moisture Flux Convergence values were greatest in east central Virginia with weaker values over southern New Jersey and southern Maryland (Figure 10). The Shulhan Spot Index values (Ref. 4) were highest in the vicinity of DCA with the lowest recomputed LI values of near minus 8 over southeast Virginia and eastern North Carolina (Figures 11 and 12). Since most severe weather tends to form near the intersection of where the axis of theta advection and surface moisture flux convergence occurs, and where the spot index values are the greatest due to high dew points, the prime area of concern for severe weather already appeared to be south of the Philadelphia forecast area.

At 17Z, the cold front was approaching Philadelphia, but had not yet moved into southern New Jersey. Temperatures ahead of the front over southern New Jersey had climbed into the upper 80s and lower 90s, but only light rain showers were indicated by ACY radar along the front. A few isolated thunderstorms of DVIP 4 with tops to 25 thousand feet were evident over extreme southeastern Pennsylvania, but cloud bases in this area were near 6 thousand feet, and most of the precipitation remained aloft. Theta advection continued to decrease over southern New Jersey as cold advection increased (Figure 13). Most of the surface moisture flux convergence had ended over southern New Jersey as the atmosphere became increasingly more divergent - resulting in subsidence; however, moisture flux convergence values significantly increased over most of southern Virginia and northern North Carolina (Figure 14). The highest spot index values shifted south into central Virginia where recomputed lifted index values remained near minus 8. Further north in southern New Jersey, spot values were decreasing, and recomputed lifted index values began to increase (Figures 15 and 16). At this time it was evident that the severe weather threat to southern New Jersey had ended, with little or no significant convective development expected along the front in the Philadelphia forecast area. At 1748Z, a mesoscale update was issued by the forecast office at Philadelphia to inform the weather service office at Atlantic City of the changes in expected weather conditions (Figure 17).

By 19Z, the cold front had moved through Philadelphia, and was accompanied by only a few light rain showers. Activity along the front, which was now over southern New Jersey, had become spotty and light with no longer any indication of thunderstorm development. Theta advection and surface moisture flux convergence values continued to become increasingly negative over southern New Jersey as cold advection, surface divergence and subsidence increased. Spot values remained steady with lifted index values remaining steady or slowly rising over all of southeastern Pennsylvania and southern New Jersey (Figures 18-21). Further south over Virginia and northern North Carolina, theta advection, surface moisture flux convergence, and spot values continued to increase as the recomputed lifted index approached minus 10. A very good pressure rise/fall couplet had formed in response to the formation of a mesolow which was moving slowly east along the Virginia - North Carolina border (Figures 22 and 23). These dynamics continued for the next several hours as severe thunderstorms rapidly developed over the area. The NHK radar between 18 and 20Z observed and reported thunderstorms with tops to 60 thousand feet. Some of these thunderstorms contained large hail, hook echoes, wind gusts to 89 knots, and DVIP 5 rainfall intensities to 55 thousand feet. Figure 24 shows the frontal position at 00Z with the presence of a mesolow. A plot of the resulting severe weather is shown in Figure 25.

CONCLUSIONS

Although there have been numerous case studies on how the Southern

Region Mesoanalysis Program has helped to delineate where severe weather was most likely to occur, the purpose of this case study was to document a weather scenario at the WSFO-PHL where the mesoscale program was used to indicate when the severe weather threat to the Philadelphia forecast area had ended - even in areas where the front had not yet passed, and where surface temperatures and dew points were still very high. The atmospheric dynamics over southern New Jersey were not as strong as was first indicated by the morning severe weather checklist, and the atmosphere did not become as unstable as was originally anticipated. In fact, MESOS helped show that the dynamics and thermodynamics of the synoptic-scale features moved through southern New Jersey earlier than expected, and the atmosphere became more stable during the day. This was evidenced as strong cold advection at 850 millibars over southern New Jersey occurred for most of the afternoon hours while thermal advection remained neutral at 700 and 500 millibars. The atmosphere at 300 millibars actually warmed by 3 degrees C by the end of the day. EI positive values which were marginal for a severe weather outbreak during the morning over southern New Jersey fell sharply during the day as cold advection, subsidence and strong mid-level drying increased over the area. It became evident that the highest thickness values and the most unstable atmosphere shifted south of the forecast area well before the frontal passage.

The Severe Weather Checklist which was completed at 12Z was helpful in defining where the potential for severe weather would be the greatest over the forecast area, but the success of the checklist is dependent on the validity of the 12Z data which is used as well as how accurately the upper air systems follow what is forecast. The Southern Region Mesoscale Program, on the other hand, helps to later determine where the potential for severe weather will move with time, and measure the threat of its occurrence.

By using the Severe Weather Checklist which is used at the Weather Service Forecast Office in Philadelphia to determine the general areas of potential severe weather in a forecast area, and by using the Southern Region Mesoscale Program in determining a specific area of severe weather concern in a real-time setting, this office is able to better nowcast short-term weather occurrences, and to be more specific as to how a mesoscale weather pattern will affect a local area.

REFERENCES

(1) Miller, R.C., 1972: Notes on analysis and severe storms forecasting procedures of the Air Weather Service Global Weather Central. AWS Tech. Rep. No. 200 (rev)., 5-7.

(2) Crisp, C. A., 1979: Training Guide for severe weather forecasters. AWS AFGWC/TN - 79/002., 16.

(3) Stone, H. M., 1988: Convection Parameters and Hodograph Program - CONVECTA & CONVECTB, NOAA Eastern Region Computer Programs and Problems, NWS ERCP No. 37 Revised, National Weather Service, Garden City, NY.

(4) LaPenta, K., 1987: Severe Weather Potential (SPOT) Plotfile Generator, NOAA Eastern Region Computer Programs and Problems, NWS ERCP No. 41, National Weather Service, Garden City, NY.

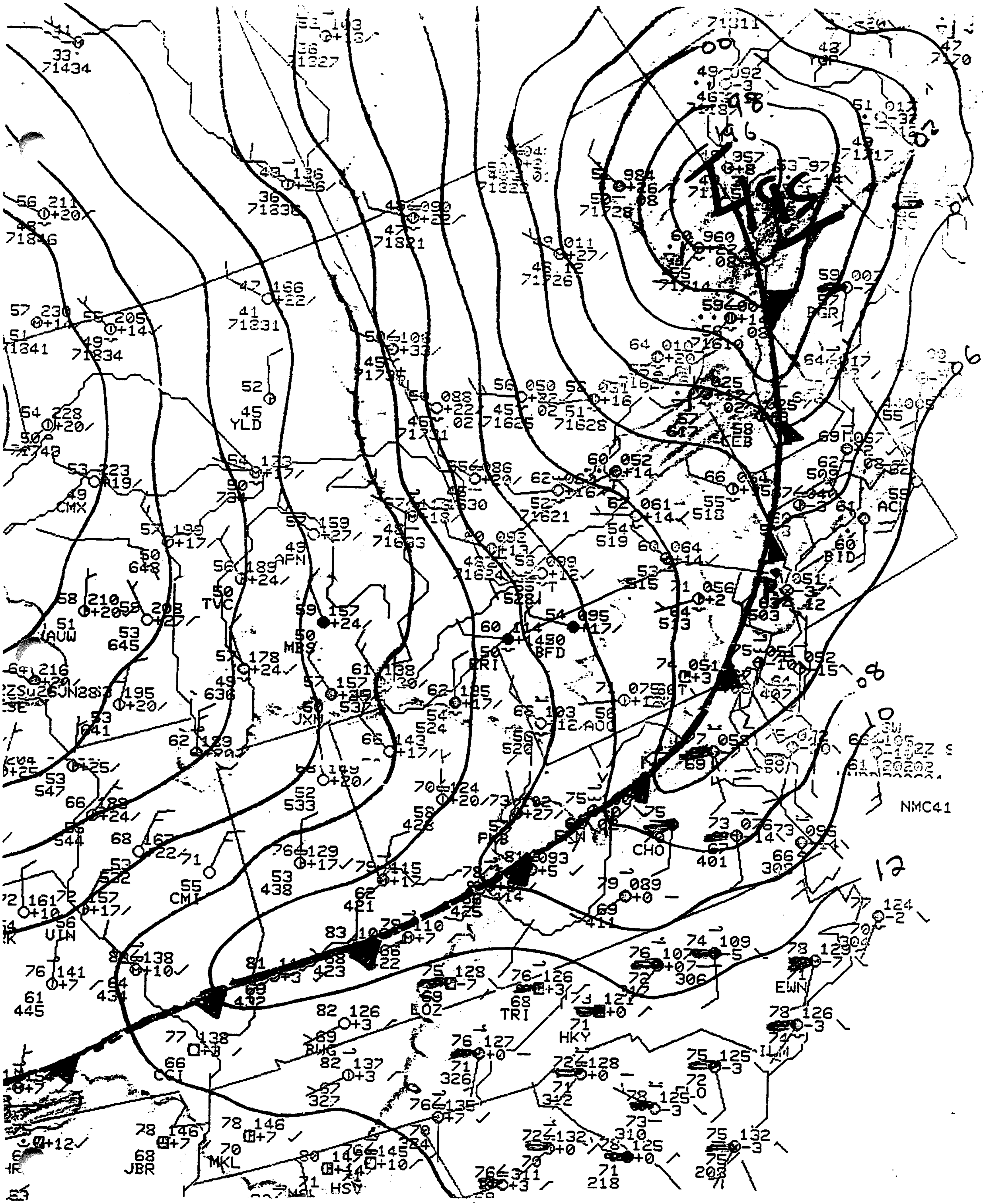


FIGURE 1. SURFACE CHART AT 12Z 6/26/88

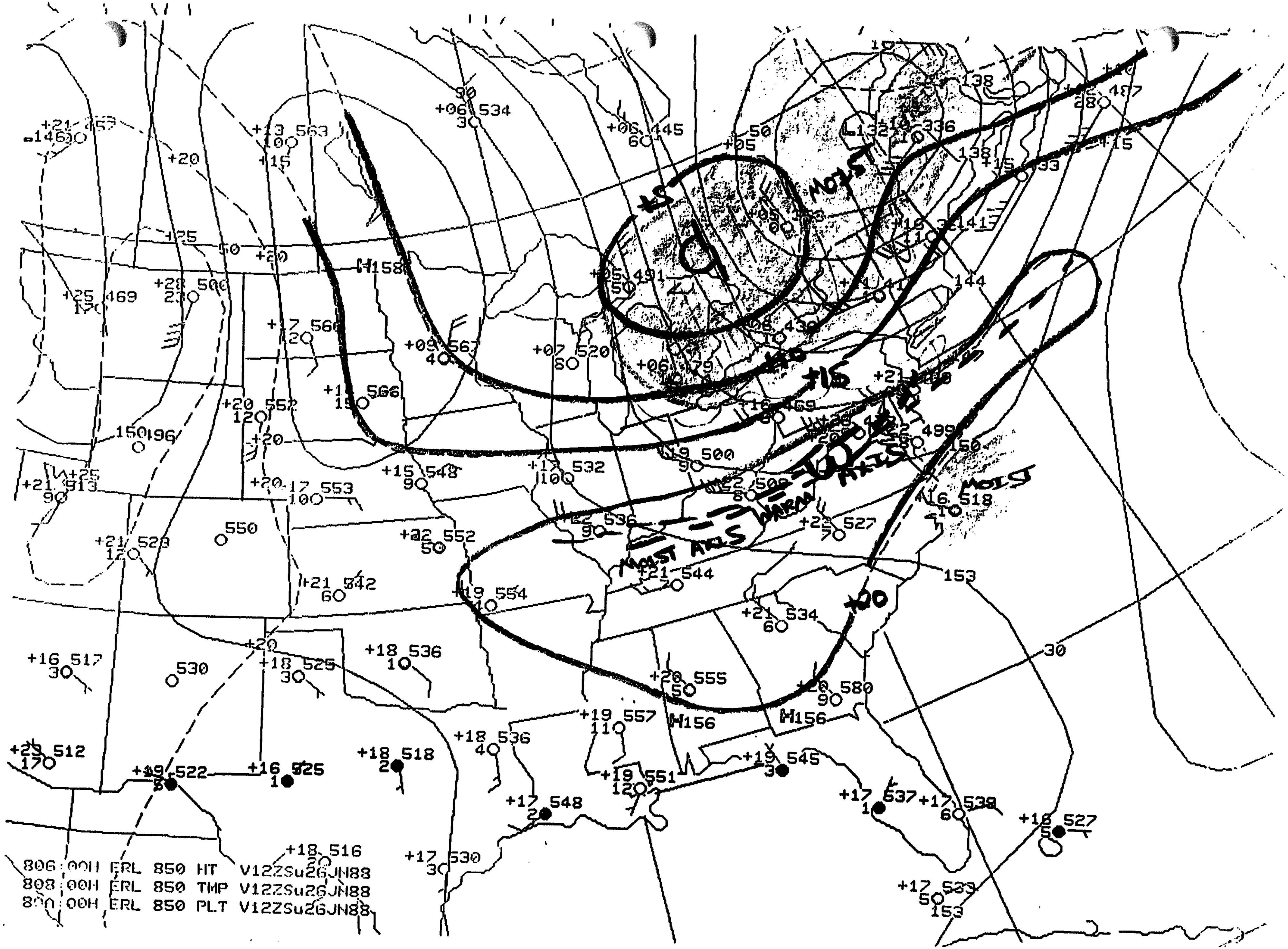


FIGURE 2. 850 MB HEIGHT/TEMPERATURE/WIND AT 12Z 6/26/88

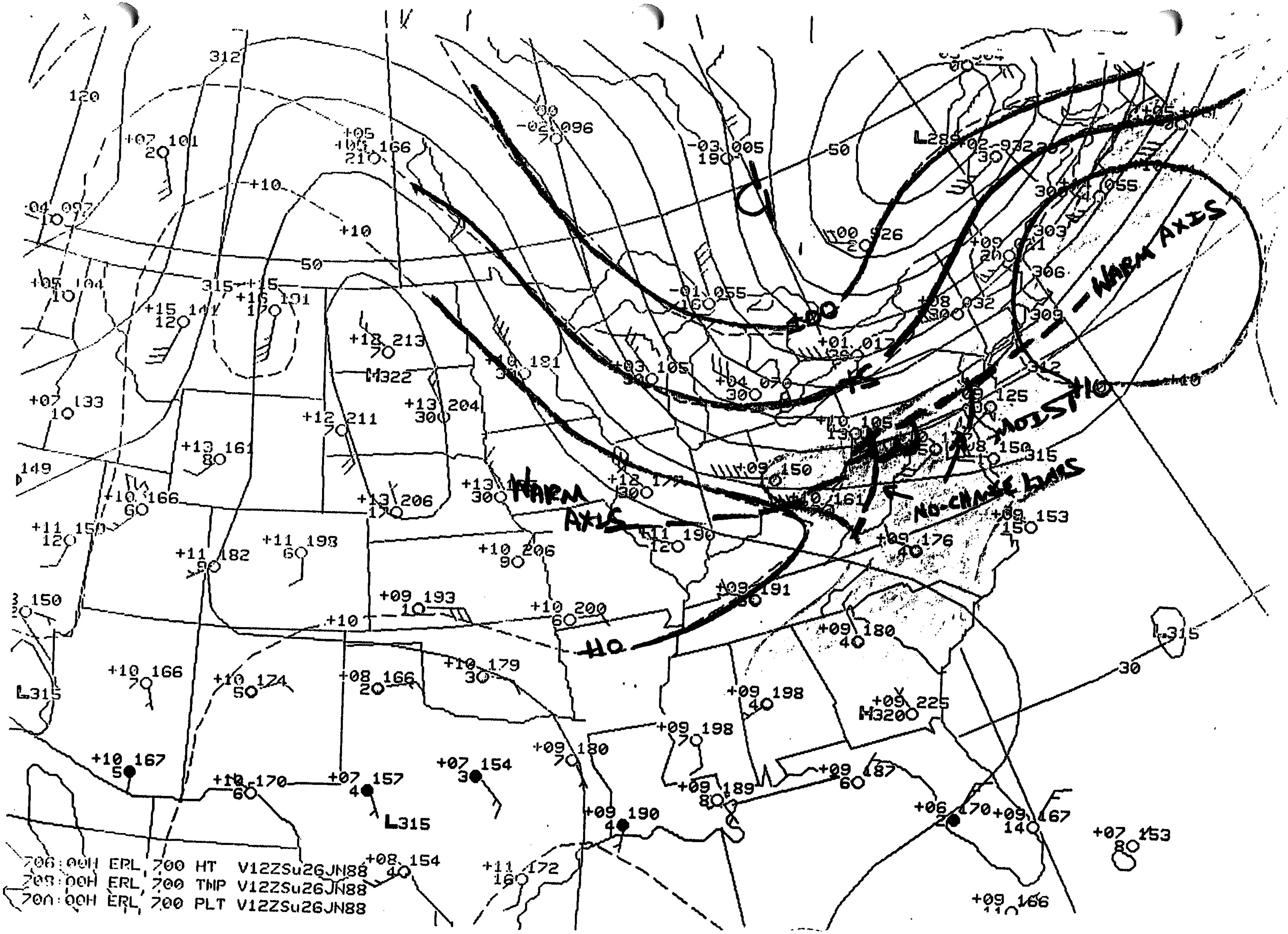


FIGURE 3. 700 MB HEIGHT/TEMPERATURE/WIND AT 12Z 6/26/88

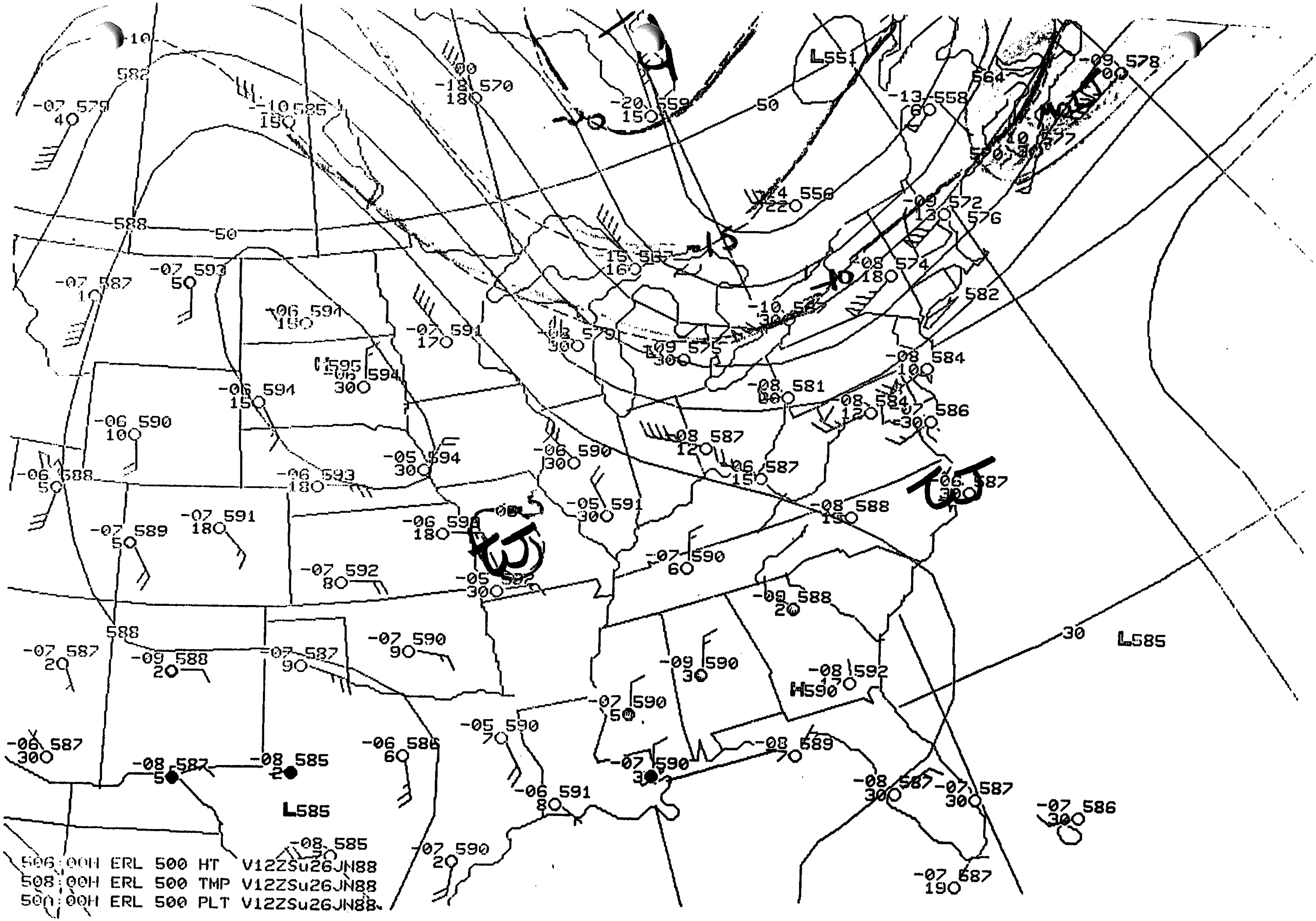


FIGURE 4. 500 MB HEIGHT/TEMPERATURE/WIND AT 12Z 6/26/88

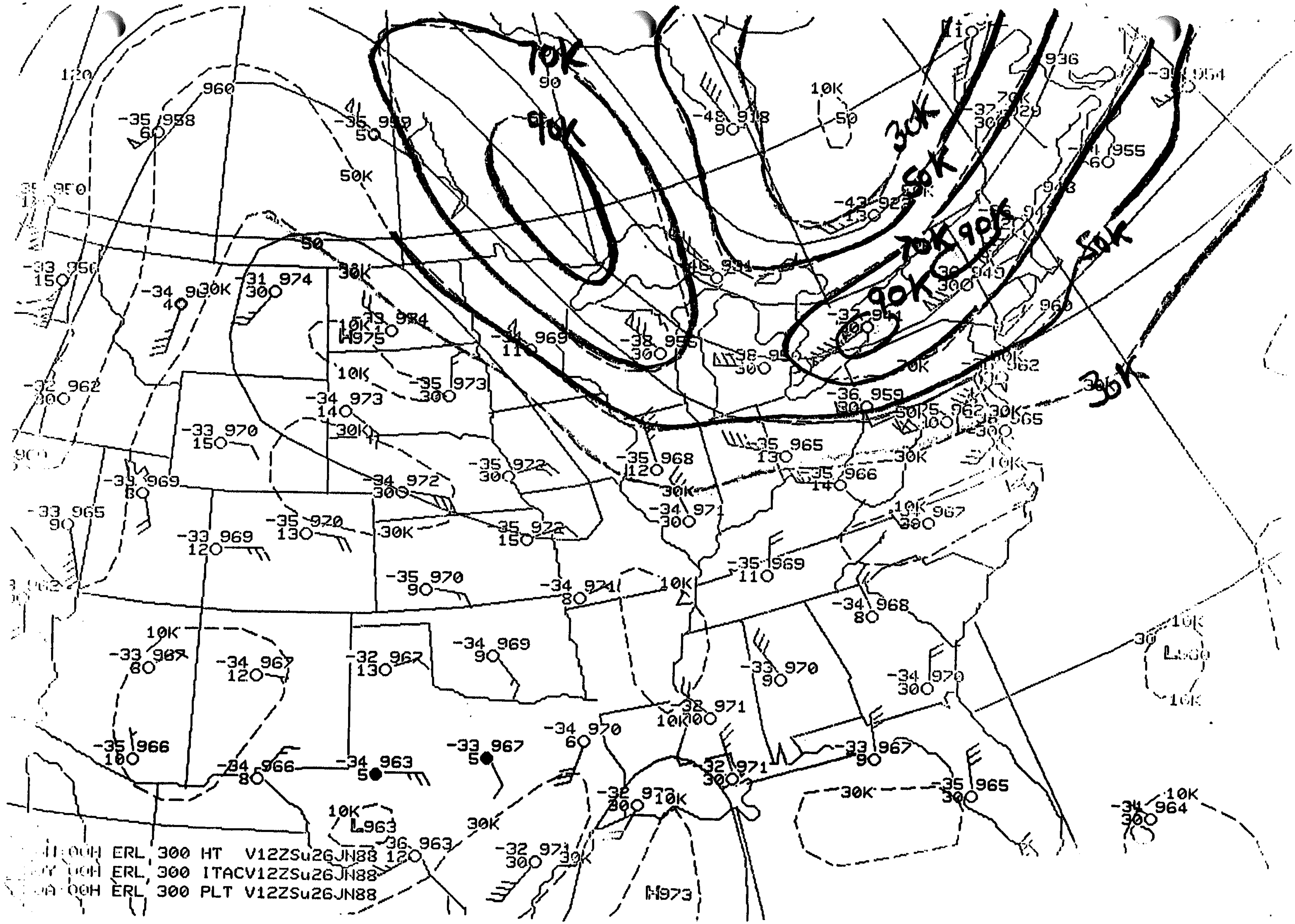


FIGURE 5. 300 MB HEIGHT/TEMPERATURE/ISOTACHS AT 12Z 6/26/88

B R N = 246
PI = 3536 (M/SEC)**2
B- = -139 (M/SEC)**2
SHP = 14 (M/SEC)**2
MMAX = 82 M/SEC
EL = 141 MB
EL = 475 HND FT
NPL = -888 HND FT

PARCEL FROM PMAX
ENTRAINMENT = 60 PERCENT
PO = 1003 MB
PMAX = 939 MB
LCL = 927 MB
LFC = 754 MB

EI = 53 J/KG X 10
EI+ = 69 (+ PART)
EI- = -15 (- PART)

ENERGY CHANGE IN LAYERS

P1	P2	
939	754	-15 J/KG X 10
754	186	153
186	100	-201

LI = 3
KI = 42
SWI = -5

CCL = 758 MB
C TMP = 39 C
C TMP = 102 F
WAVG = 1436 G/KG X 10-2

ACY 12Z 26 JUN 88

UNITS : KNOTS, LVLS : THSD FT (MSL)

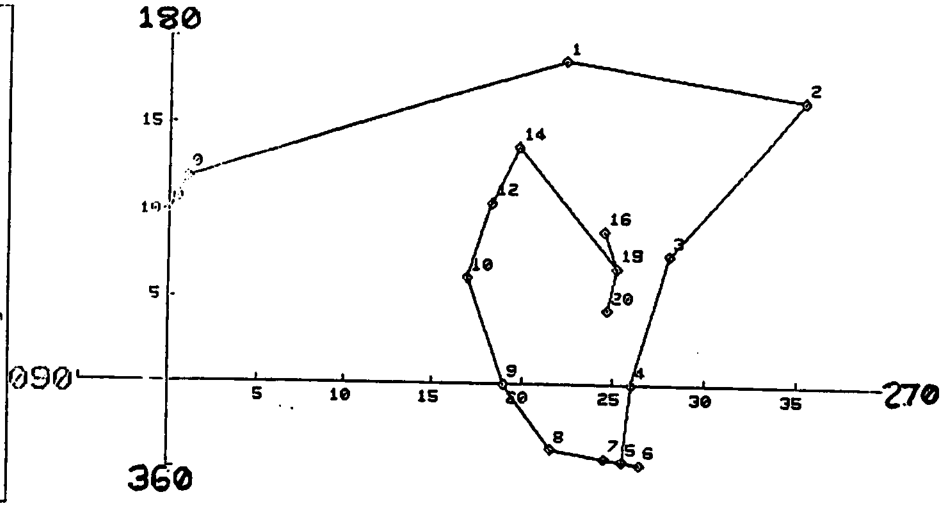


FIGURE 6. ATLANTIC CITY HODOGRAPH AT 12Z 6/26/88

B R N = 156
PI = 3273 (M/SEC)**2
B- = -114 (M/SEC)**2
SHP = 21 (M/SEC)**2
MMAX = 79 M/SEC
EL = 146 MB
EL = 467 HND FT
NPL = -888 HND FT

PARCEL FROM PMAX
ENTRAINMENT = 60 PERCENT
PO = 996 MB
PMAX = 934 MB
LCL = 822 MB
LFC = 732 MB

EI = 53 J/KG X 10
EI+ = 65 (+ PART)
EI- = -12 (- PART)

ENERGY CHANGE IN LAYERS

P1	P2	
934	732	-12 J/KG X 10
732	187	137
187	100	-205

LI = -3
KI = 40
SWI = -4

CCL = 769 MB
C TMP = 39 C
C TMP = 102 F
WAVG = 1563 G/KG X 10-2

IAD 12Z 26 JUN 88

UNITS : KNOTS, LVLS : THSD FT (MSL)

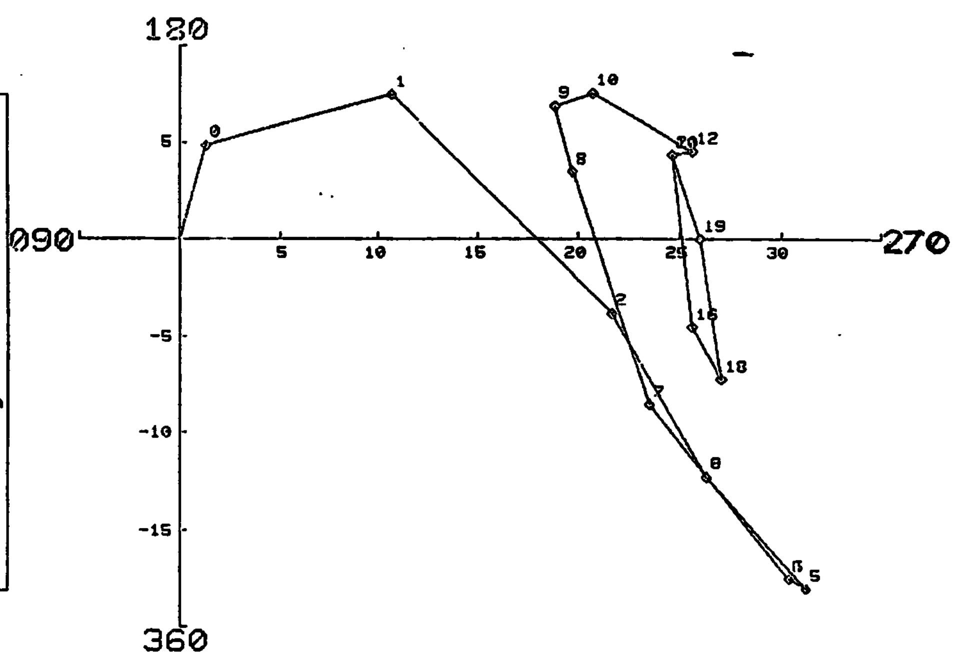


FIGURE 7. DULLES HODOGRAPH AT 12Z 6/26/88

DATE...6/26/88... SEVERE WEATHER CHECKLIST INITIALS. DAW

PRIMARY CONCERN FOR SVR WX IN SRN NJ AHEAD OF FROPA

PART A	YES	NO
*1. WILL A SYNOPTIC OR MESOSCALE CONVERGENCE ZONE (ie. FRONT, TROUGH, ETC.) AFFECT THE FORECAST AREA?	✓	
*2. WILL THE MINIMUM AMOUNT OF SOLAR HEATING OCCUR DURING THE DAY THAT IS NECESSARY TO INITIATE CONVECTION?		✓
*3. WILL THE 850MB DEWPOINT BE 8 DEG C OR GREATER?	✓	
*4. WILL THE SURFACE DEWPOINT BE 60 DEG F OR GREATER?	✓	
*5. WILL NEUTRAL OR POSITIVE VORTICITY ADVECTION OCCUR?	✓	

PART B	YES	NO
1. IS APPROACHING FRONT OR TROUGH ACTIVE DURING THE MORNING (MIDNIGHT TO NOON)?	✓	
2. ARE THERE CLEAR OR MOSTLY CLEAR SKIES OR LARGE CLEAR SLOTS DURING THE MORNING (IE. SOLAR HEATING WILL APPROACH MAXIMUM VALUES)?	✓	
*3. WILL LOW LEVEL WIND SPEED BE 20 KTS OR GREATER? (DEFINED AS ANY LEVEL BETWEEN THE BOUNDARY LEVEL AND 7,000 FT).	✓	
*4. WILL SURFACE DEWPOINT BE 65 DEG F OR GREATER?	✓	
*5. WILL WE BE UNDER OR TO THE LEFT OF THE 850MB JET? (SPEED AT OR GRTR THAN 20KTS) AND IN THE LEFT FRONT OR RIGHT REAR QUADRANT OF THE 300MB JET (SPEED AT OR GRTR THAN 70 KTS)?	✓	

PART C	YES	NO
1. ARE THERE LINES OF CUMULUS OR MIDDLE CLOUDS ON THE MORNING SATELLITE PICTURES?	✓	
2. ARE THERE NUMEROUS AND/OR ORGANIZED MORNING THUNDERSTORMS IN OUR AREA (MIDNIGHT TO NOON)?	✓	
*3. WILL A 1000-500MB THICKNESS RIDGE PASS THROUGH THE FORECAST AREA? → SRN NJ	✓	
*4. WILL THERE BE DIFFLUENCE AT 300MB?	✓	
*5. WILL THE ATMOSPHERE DESTABILIZE DUE TO TEMPERATURE ADVECTION AT VARIOUS LEVELS OF THE ATMOSPHERE?	✓	
*6. WILL THERE BE A 500MB WIND EQUAL TO OR GRTR THAN 35KTS, OR IS HORIZONTAL WIND SHEAR EQUAL TO OR GRTR THAN 30KTS/90NMI?	✓	
*7. IS THERE A 700MB NO CHANGE LINE TO THE WEST OF OUR AREA WITH WIND CROSSING IT AT GRTR THAN 40 DEGS?		✓
*8. WILL THERE BE DRY AIR IN THE MID TROPOSPHERE? (DETERMINED BY LOOKING FOR DEWPOINT DEPRESSIONS OF 5 DEG C OR GRTR NEAR THE 700MB LEVEL OR AT THE MOISTURE CHANNEL ON THE SATELLITE PICTURES) (note DO NOT ANSWER YES IF NGM R2 FORECAST < 45%)	✓	
*9. IS THE 850MB MAXIMUM TEMPERATURE RIDGE OVER OR TO THE WEST OF THE 850MB MOISTURE RIDGE?		✓
*10. IS EI+ ≥ 70 (OVER OR UPSTREAM FROM OUR FORECAST AREA) OR IN THE SPRING (APRIL JUNE), IS VS15 ≥ 18 (OVER OR UPSTREAM FROM OUR FORECAST AREA)?	✓ MARGINAL	

FIGURE 8. PHILADELPHIA SEVERE WEATHER CHECKLIST FOR 6/26/88

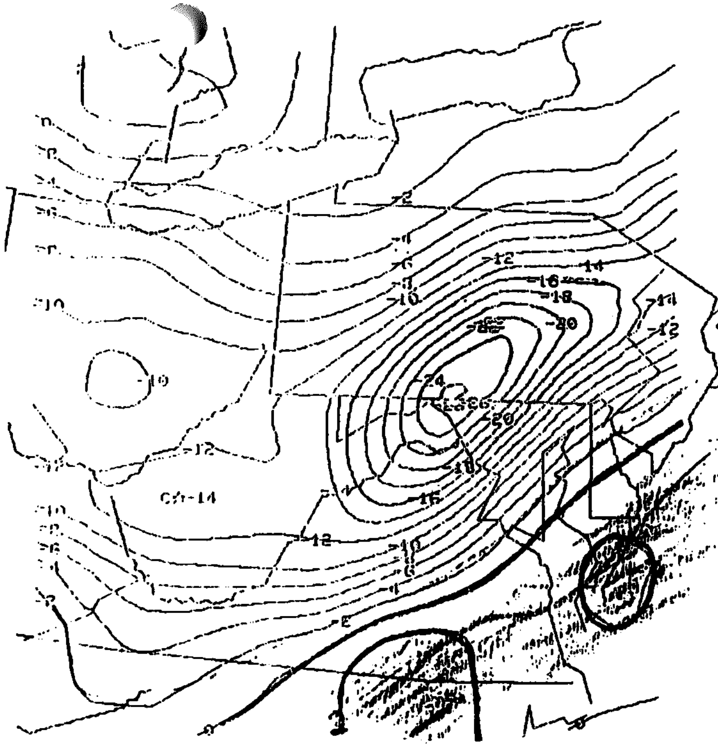


FIGURE 9. THETA ADVECTION (DEG F/HR *10) AT 15Z 6/26/88

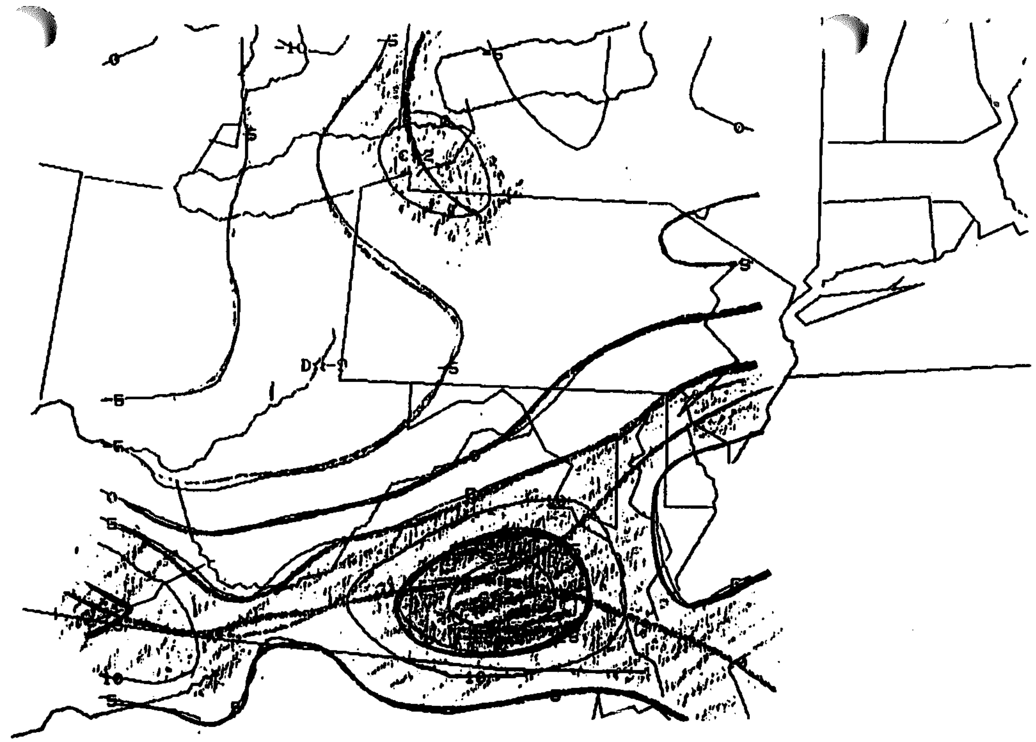
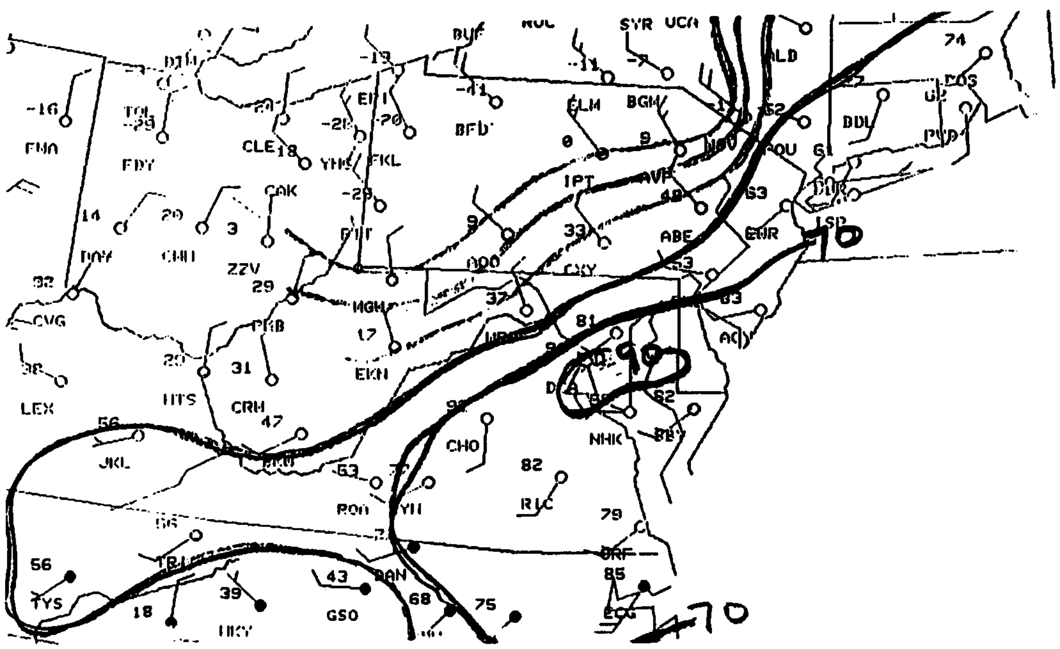


FIGURE 10. SFC MOIST FLUX CNVG (G/KG HR-1 *10) AT 15Z 6/26/88



... HEAT INDEX AT 15Z 6/26/88

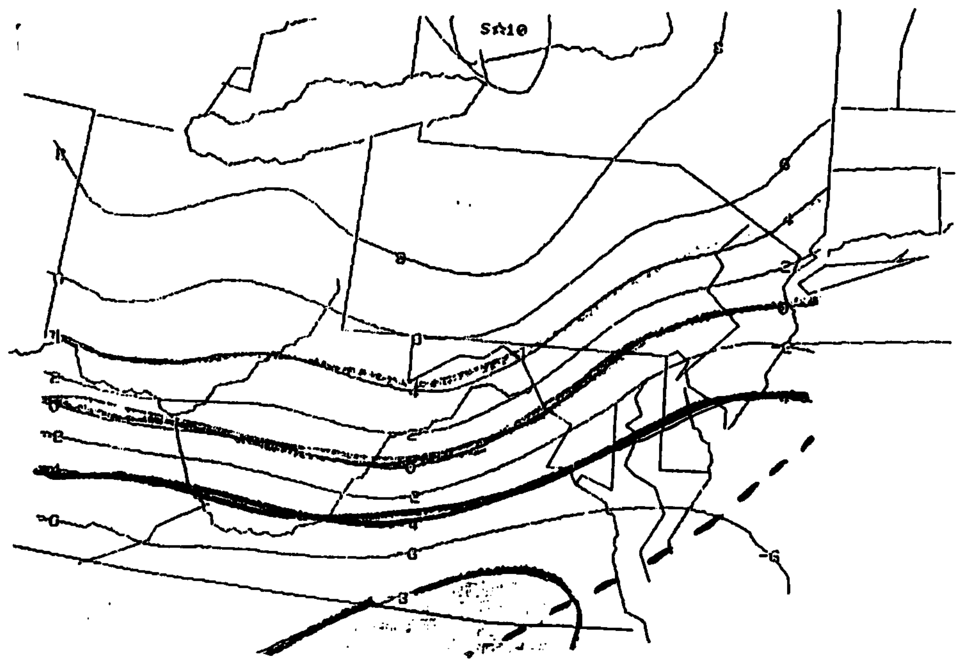


FIGURE 1_. SFC PARCEL LI (DEG C) AT 500 MB FOR 15Z 6/26/88

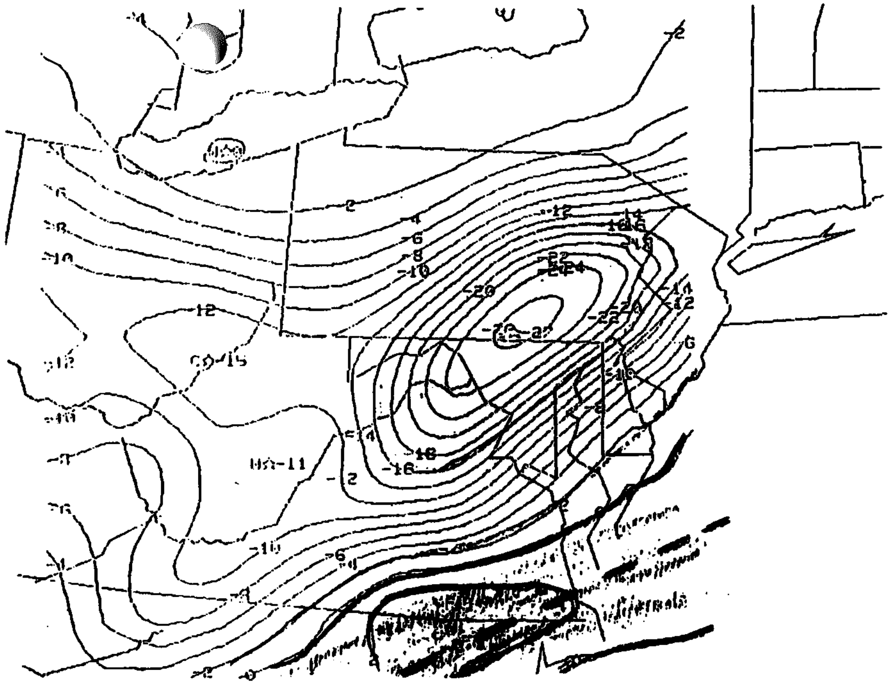


FIGURE 13. THETA ADVECTION (DEG F/HR *10) AT 17Z 6/26/88

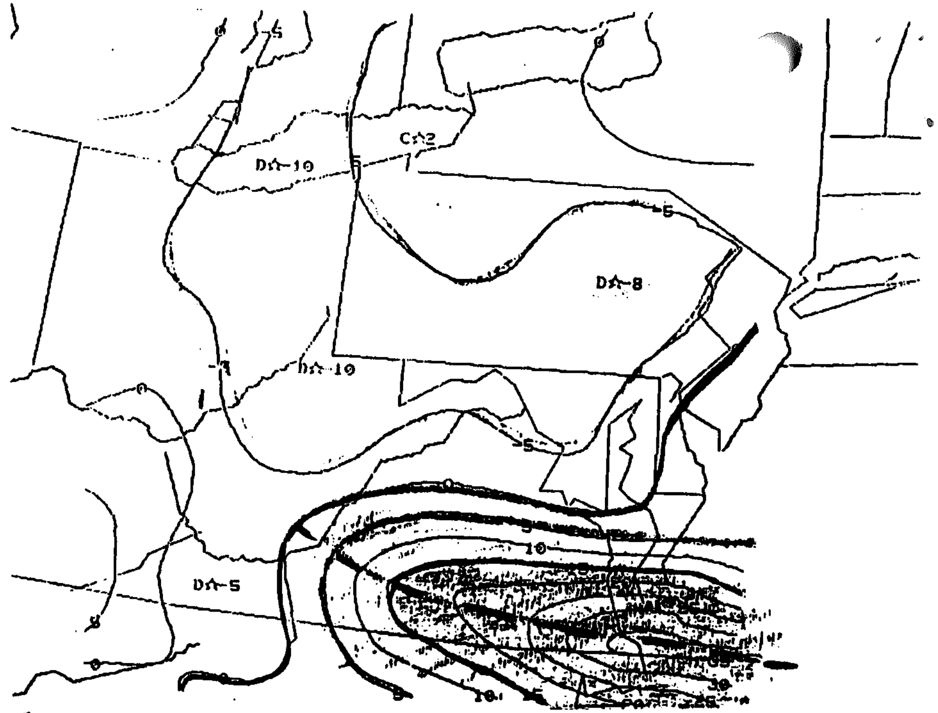


FIGURE 14. SFC MOIST FLUX CNVG (G/KG HR-1 *10) AT 17Z 6/26/88

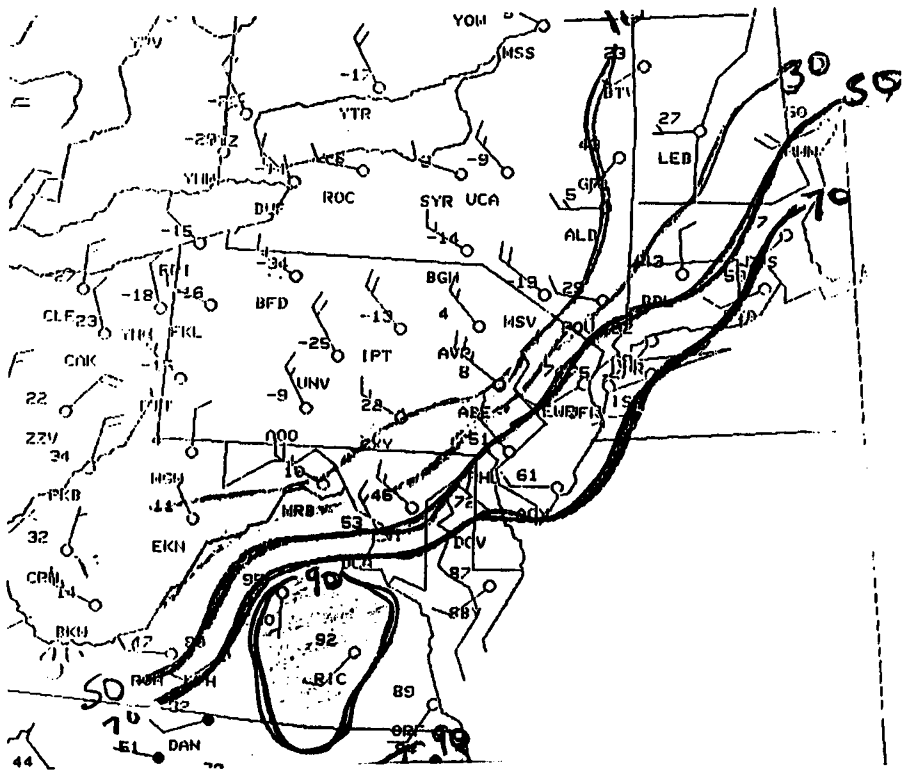


FIGURE 15. SHULHAN SPOT INDEX AT 17Z 6/26/88

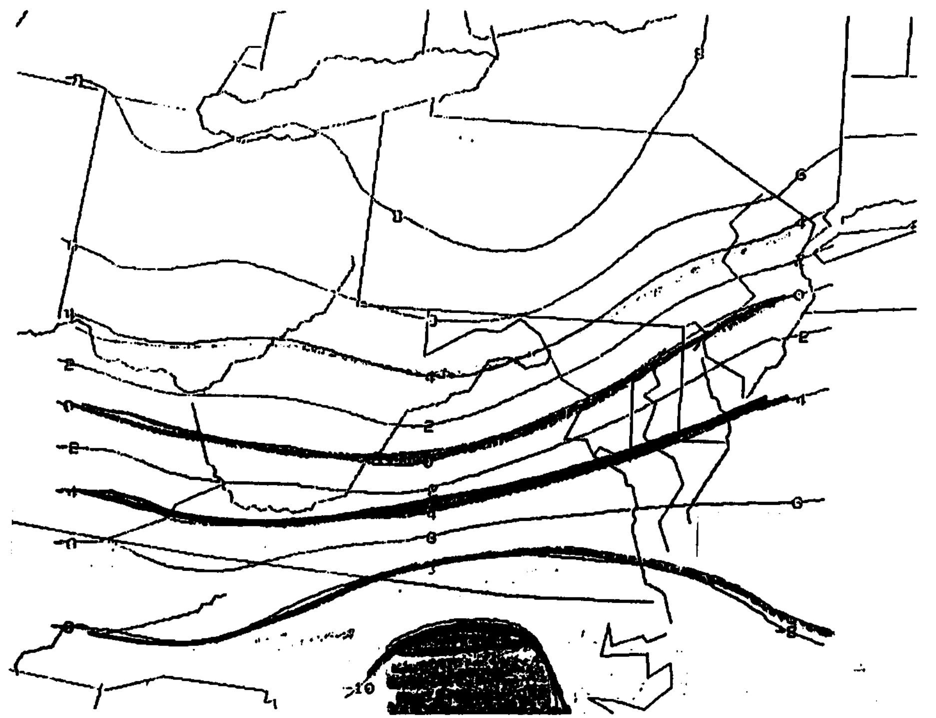


FIGURE 16. SFC PARCEL LIFTED INDEX AT 500 MB FOR 17Z 6/26/88

NNNN>HH<A<
<ZCZC PHLADMPHL
TTAA00 KPHL 261748
ALERT ADMINISTRATIVE MESSAGE
NATIONAL WEATHER SERVICE PHILADELPHIA, PA
145 PM EDT SUN JUN 26 1988

TO: WSO-ACY

FM: WSFO-PHL

RE: MESOSCALE UPDATE

JUST THOUGHT YOU WOULD LIKE TO KNOW CURR STATUS OF SHWR ACTIVITY MVG TWRDS YOUR ZONES. LATEST MESO-ANALYSIS INDICATES BEST DYNAMICS FOR SVR WX NOW RAPIDLY SHIFTING SOUTH TO SRN VA AND NRN NC WHERE THETA ADV AND SFC MOIST FLUX CNVG IS STRNGST. THE SHULHAN SPOT INDEX IS HIGHEST IN THIS AREA AS WELL WHERE SFC DEW PTS RMN HIGH AND WHERE PRESS FALLS ARE THE GREATEST.

FURTHER NORTH OVR SRN NJ AND NRN DE...THE ATMOS IS RPDLY BCMG MORE STBLE AND DRY...WITH ONLY SHWRS AND PSBLY AN ISOLATED TSTM NOW XPTD ALNG PCPN LN ASSOCIATED WITH FRNT. THIS SUPPORTED BY CURR SATL AND RADAR.

WERT

FIGURE 17. PHILADELPHIA MESOSCALE UPDATE

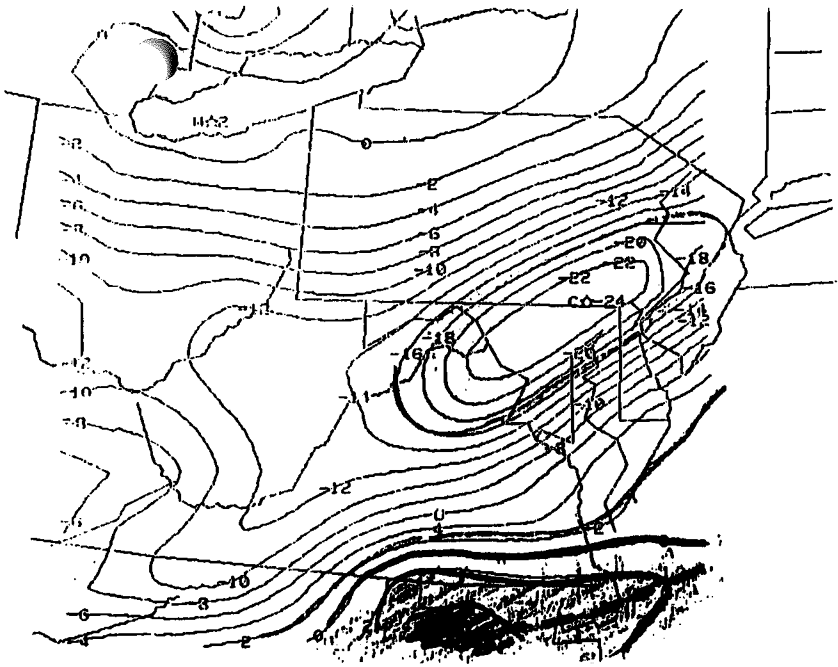


FIGURE 18. THETA ADVECTION (DEG F/HR *10) AT 19Z 6/26/88

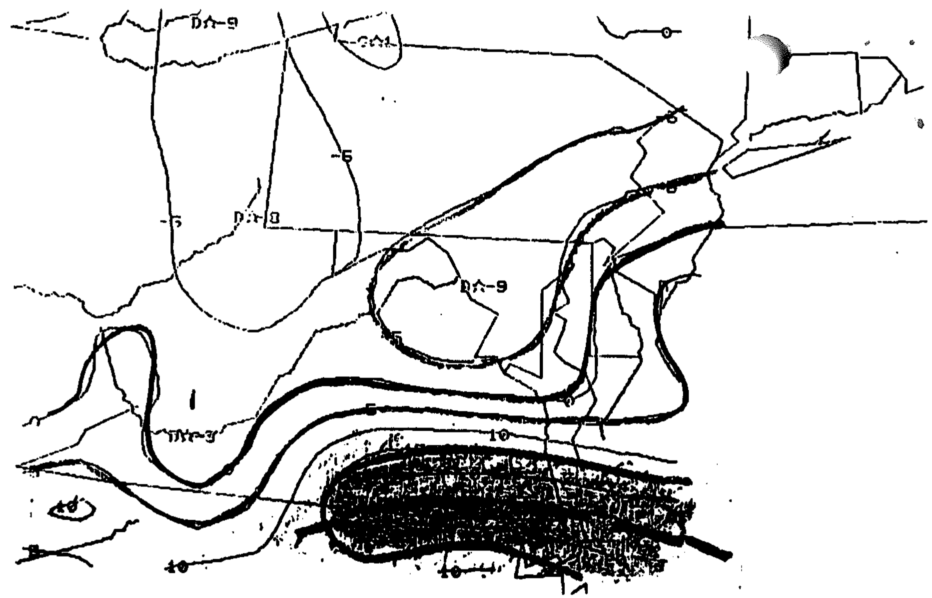


FIGURE 19. SFC MOIST FLUX CNVG (G/KG HR-1 *10) AT 19Z 6/26/88

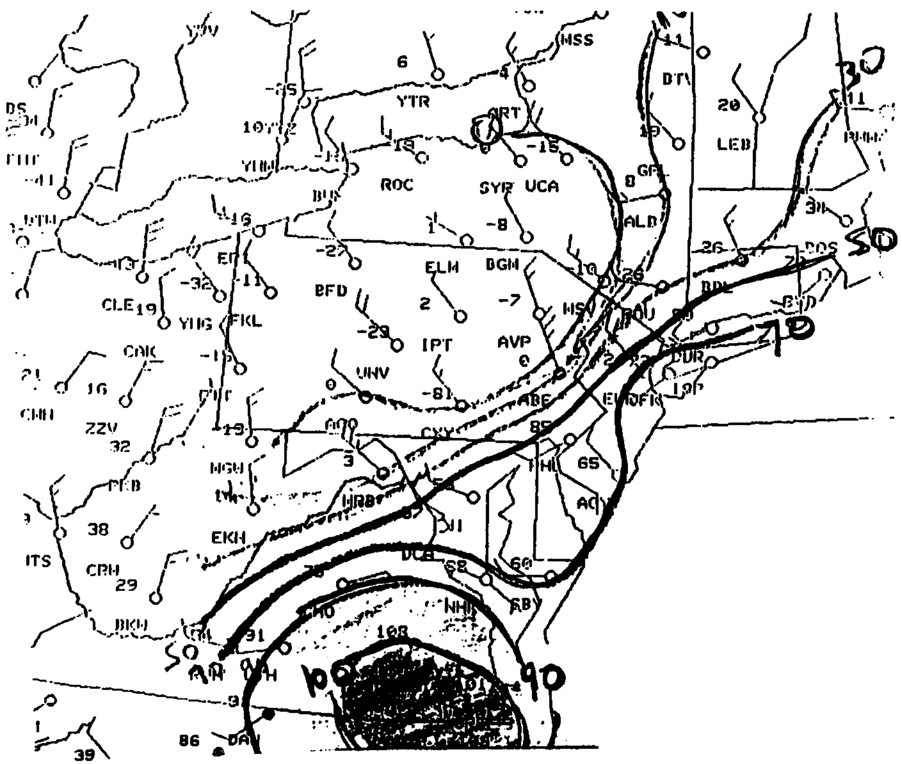


FIGURE 20. SHULHAN SPOT INDEX AT 19Z 6/26/88

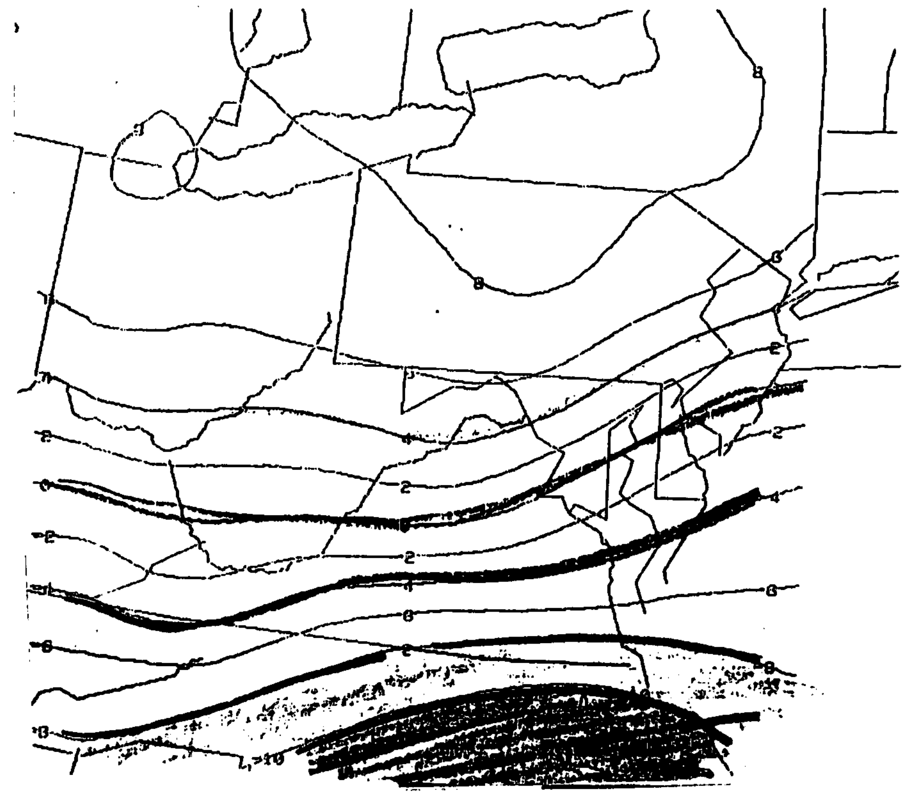


FIGURE 21. SFC PARCEL LI (DEG C) AT 500 MB FOR 19Z 6/26/88

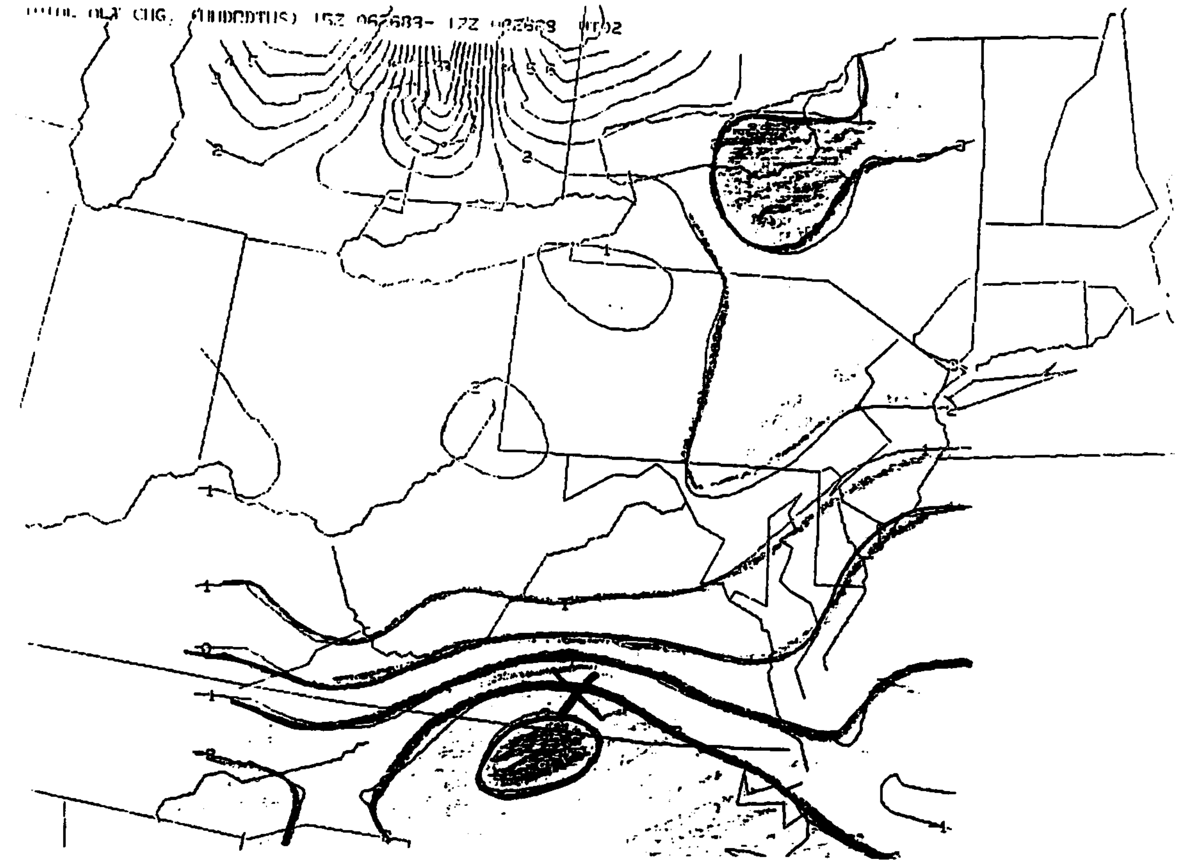


FIGURE 22. TOTAL ALT CHG (HNDRDTHS) FROM 15-17Z 6/26/88

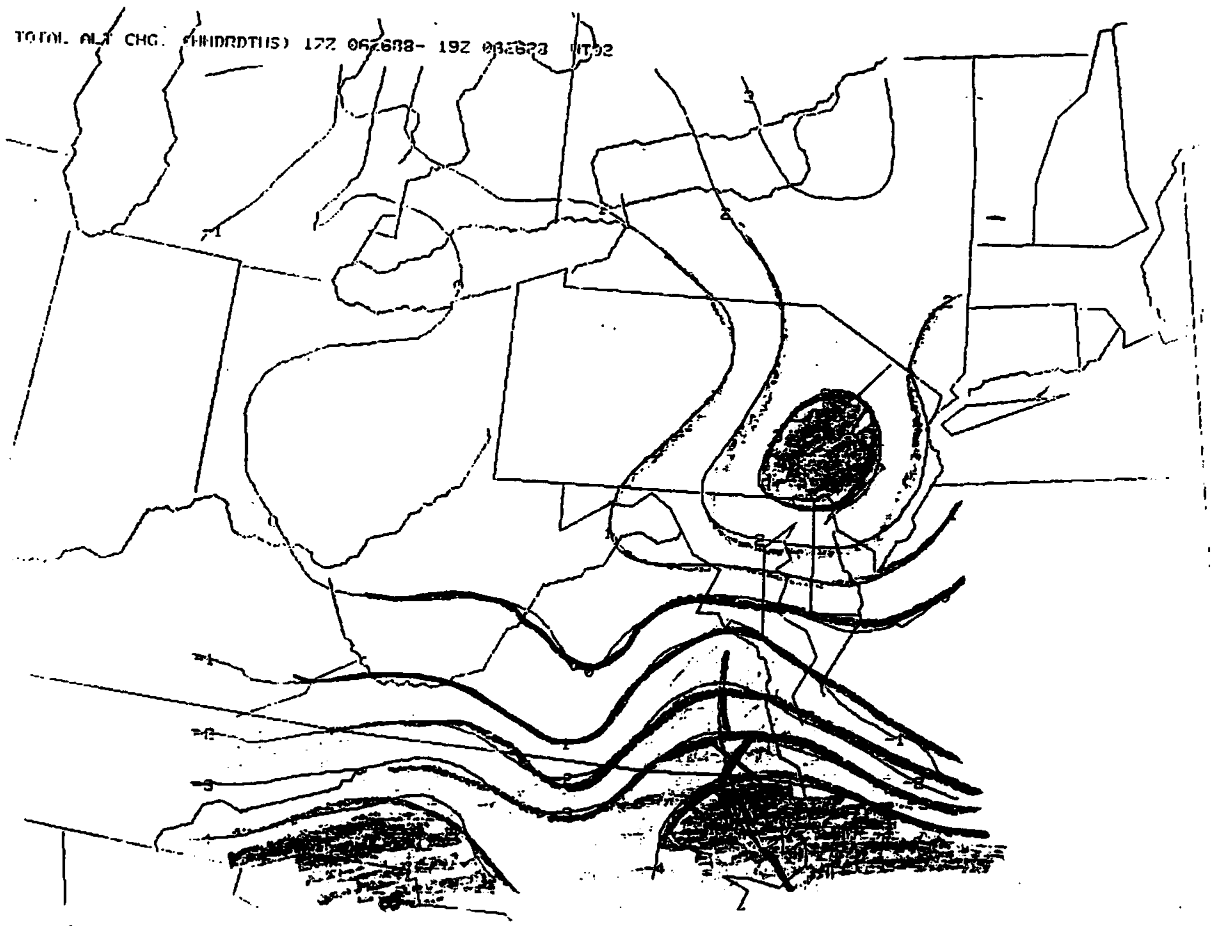


FIGURE 23. TOTAL ALT CHG (HNDRDTHS) FROM 17-19Z 6/26/88

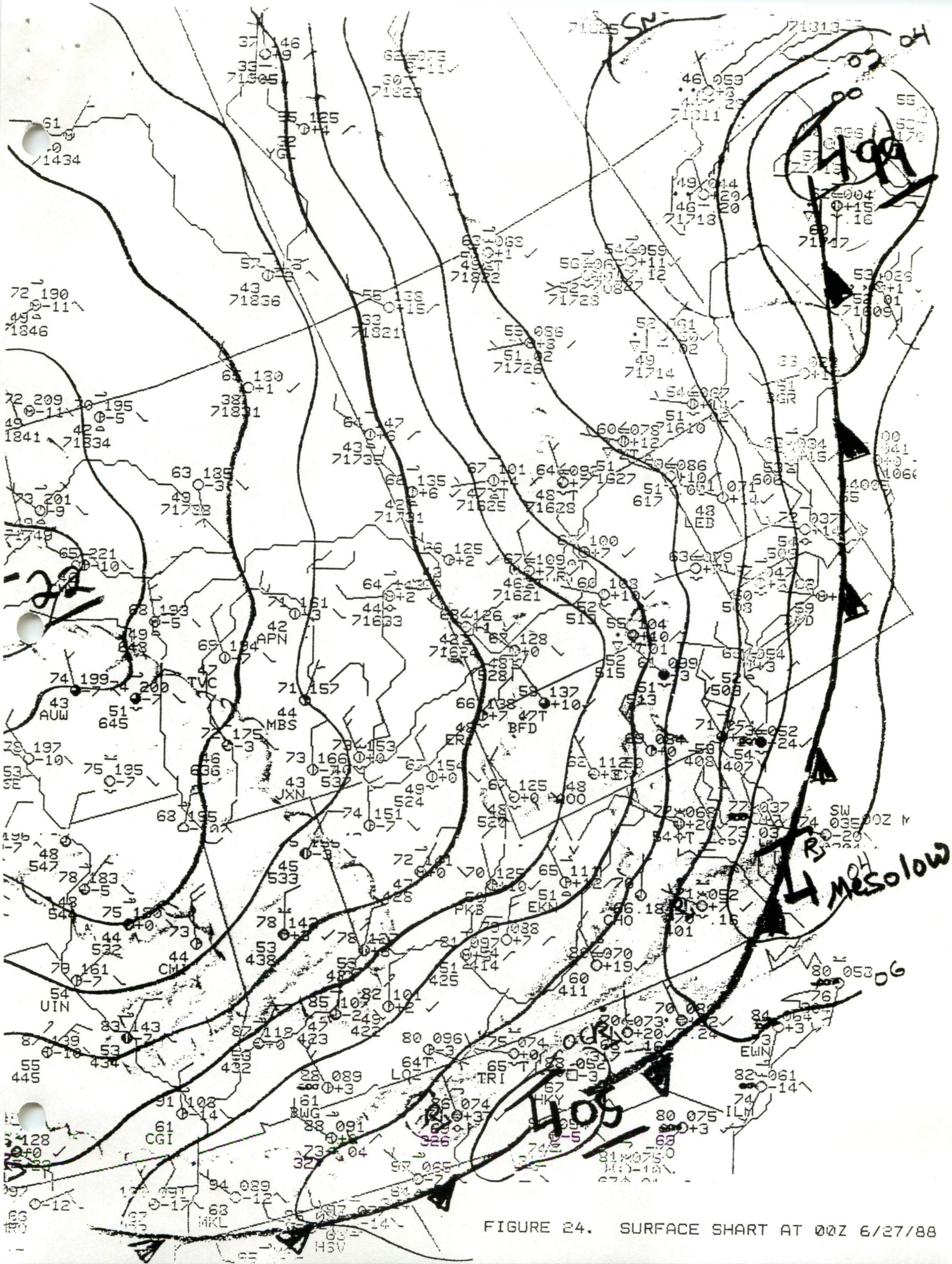


FIGURE 24. SURFACE SHART AT 00Z 6/27/88

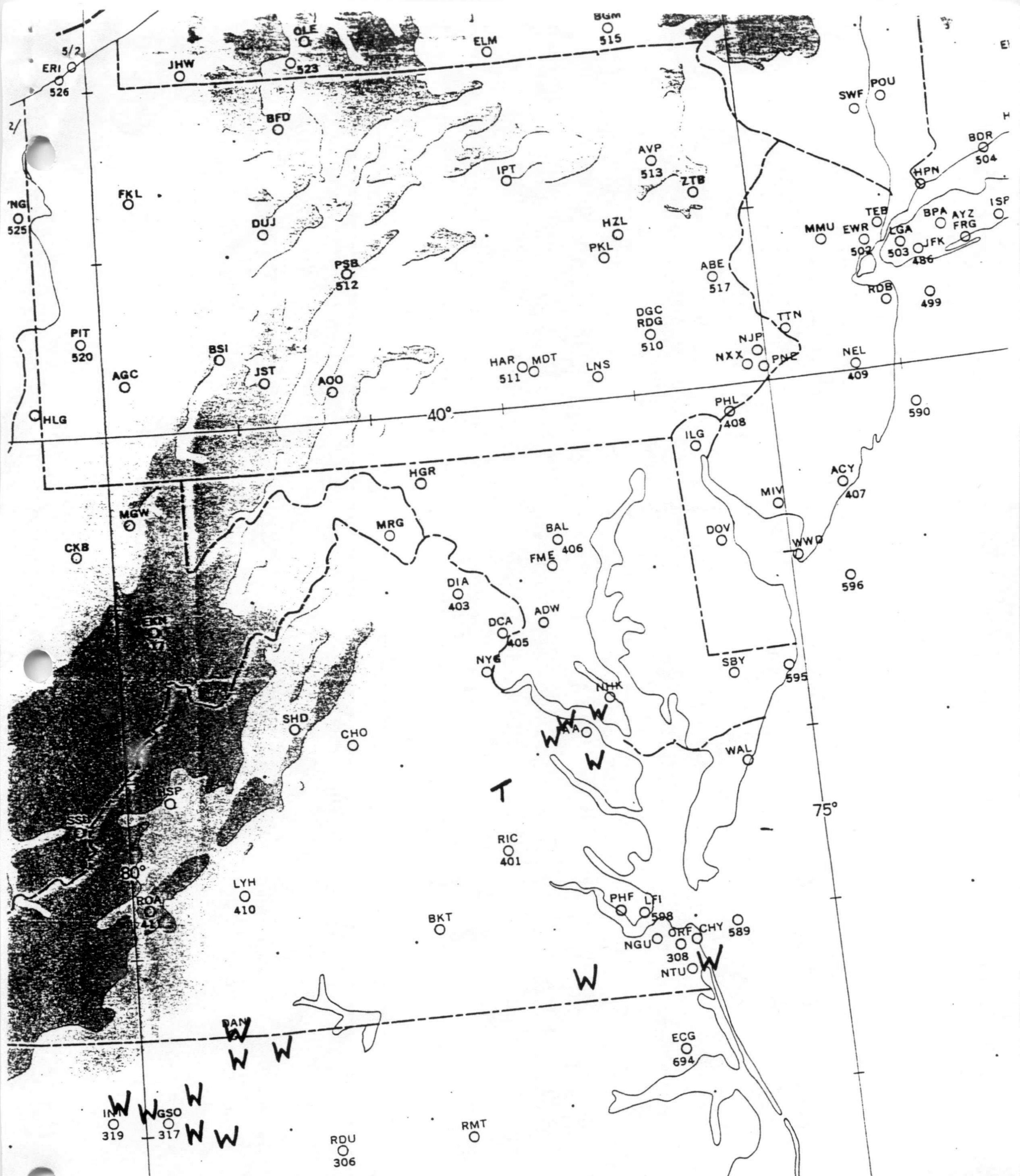


FIGURE 25. PLOT OF SEVERE WEATHER FOR THE AFTERNOON AND EVENING HOURS OF 6/26/88.

T = TORNADO
A = LARGE HAIL
W = WIND DAMAGE