AFGWC/TN - 79/002

TRAINING GUIDE
FOR
SEVERE WEATHER FORECASTERS

BY

MSgt Charlie A. Crisp

November 1979

UNITED STATES AIR FORCE
AIR WEATHER SERVICE (MAC)
AIR FORCE GLOBAL WEATHER CENTRAL
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Presented here is a formal and detailed training guide designed for a forecaster's initial exposure to the Air Force Global Weather Central's (AFGWC) severe weather function. This TN details the analysis procedures for all charts and prognostic tools available to the severe weather function. Significant severe weather parameters are analyzed at the surface, 850 mb, 700 mb, and 500 mb levels. Additionally, the 850/500 mb thickness and maximum wind charts are examined. Also discussed are the severe weather parameters chart and the 12-hour surface pressure change chart. A detailed, step-by-step evaluation of a synoptic (over)

20. (cont'd)
situation is presented along with appropriate forecasts and verification data. Finally, the automated prognoses available at AFGWC are discussed in relation to severe weather forecasting.

Prior to using this guide, forecasters should become familiar with AWSTR 200 (Rev), "Notes on Analysis and Severe Storm Forecasting of the Air Force Global Weather Central". AWSTR 200(Rev) is referred to briefly when relating analyzed parameters to those synoptic patterns producing severe thunderstorms and tornadoes. This TN will familiarize field users with the techniques used to produce the Military Weather Advisory (MWA).

PREFACE

This note is a formal, detailed, step-by-step guide to the practical aspects of severe weather forecasting. It is designed to supplement formal instruction and to summarize material presented. This note is not intended to serve as a self-instruction workbook. Rather, this work, AWSTR 200(Rev) and a competent forecaster should accompany the beginner through the wilderness of severe weather forecasting.

This note will consider required analysis and prognostic techniques, synoptic weather patterns, and numerical models required to produce high-quality forecasts of severe weather activity. Analyses are discussed parameter by parameter and level by level. Most of the figures are reproduced in multi-colored ink to facilitate parameter identification. An attempt has been made throughout this note to convey the philosophy and "flavor" as well as the mechanics of the art called severe weather forecasting.

Prior to launching into the details of this note, I feel obligated to express my deepfelt thanks to Mr Robert C. Miller, former Chief Scientist of the Air Force Global Weather Central's Environmental Applications Branch. His patience and training, plus the four and one half years of experience which I gained, helped build the reservoir of knowledge from which the techniques detailed in this guide were drawn.

I wish to extend thanks to Major William Irvine, and Captain James Hoke for their assistance in editing this paper. Captains Richard W. Anthony and John R. Bemis rendered invaluable encouragement, and assisted with technical matters. My appreciation is hereby tendered. The superb typing skills and infinite patience of Mrs Mary Zimmerman and SSgt Kathleen Tittle are greatly appreciated. Last, but by no means least, the author thanks his wife Margaret for her encouragement and patience throughout the development of this note.

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15 November 1979

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1 INTRODUCTION

The need for this technical memo became apparent when it was discovered that no publication exists outlining a detailed step-by-step description of analysis procedures for severe weather forecasting. As with any type of forecast, the severe weather forecast is only as good as the analyses used in making that forecast. If the parameters (to be discussed in detail later) are not accurately located through analysis, any prognosis of their location will also be in error. Because an accurate and detailed analysis is imperative, this guide is directed primarily toward analysis techniques used for finding the parameters of interest in severe weather forecasting. Significant severe weather parameters are analyzed at the surface, 850 mb, 700 mb, and 500 mb levels. Additionally, 850/500 mb thickness and maximum wind analyses provide insight into severe weather forecasting problems. Also discussed are the severe weather parameters and the 12-hour surface pressure change charts. Prior to using this guide, the forecaster should read AWSTR 200(Rev), Notes on Analysis and Severe Storm Forecasting Procedures of the Air Force Global Weather Central. The analysis techniques described in this technical report are, for the most part, the same techniques introduced by Col Robert C. Miller, USAF (Retired) and currently in use at the Air Force Global Weather Central (AFGWC).

Following the discussion of analysis techniques is an outline of the five severe weather synoptic patterns examined in AWSTR 200(Rev). This outline is included so the forecaster can compare the composite analysis with these synoptic patterns to determine where the greatest potential for severe weather, the threat area, is located. These same five synoptic patterns are used to determine the threat area on the composite prognosis. A description of the prognosis technique that worked very well for the example forecast is used to show the importance of parameter intensities and the actual thought processes that go into the severe weather forecast.

Finally, a description of techniques used to evaluate and adjust various AFGWC and National Weather Service (NWS) atmospheric prognostic models is included. Techniques to locate major severe weather parameters for use on a composite prognosis are examined in detail.

2 ANALYSIS TECHNIQUES

The approach used throughout this section will be to discuss individual parameters at a given level, to combine resulting analyses into a complete analysis at each level, and finally to transfer significant level features from the completed level analysis to an "overlay" upper-air composite analysis. The resulting composite analysis, which may appear confusing initially, allows an examination of the interaction of various parameters from several levels and an evaluation of their overall effect. Parameters are indicated by a consistent set of symbols and color coding on all charts, which have been reduced to 50 percent of their original size for convenience. An indication of key parameter intensity can be found at the end of Subsections 2.1 through 2.9 and can be used as a guide for evaluating severe activity potential.

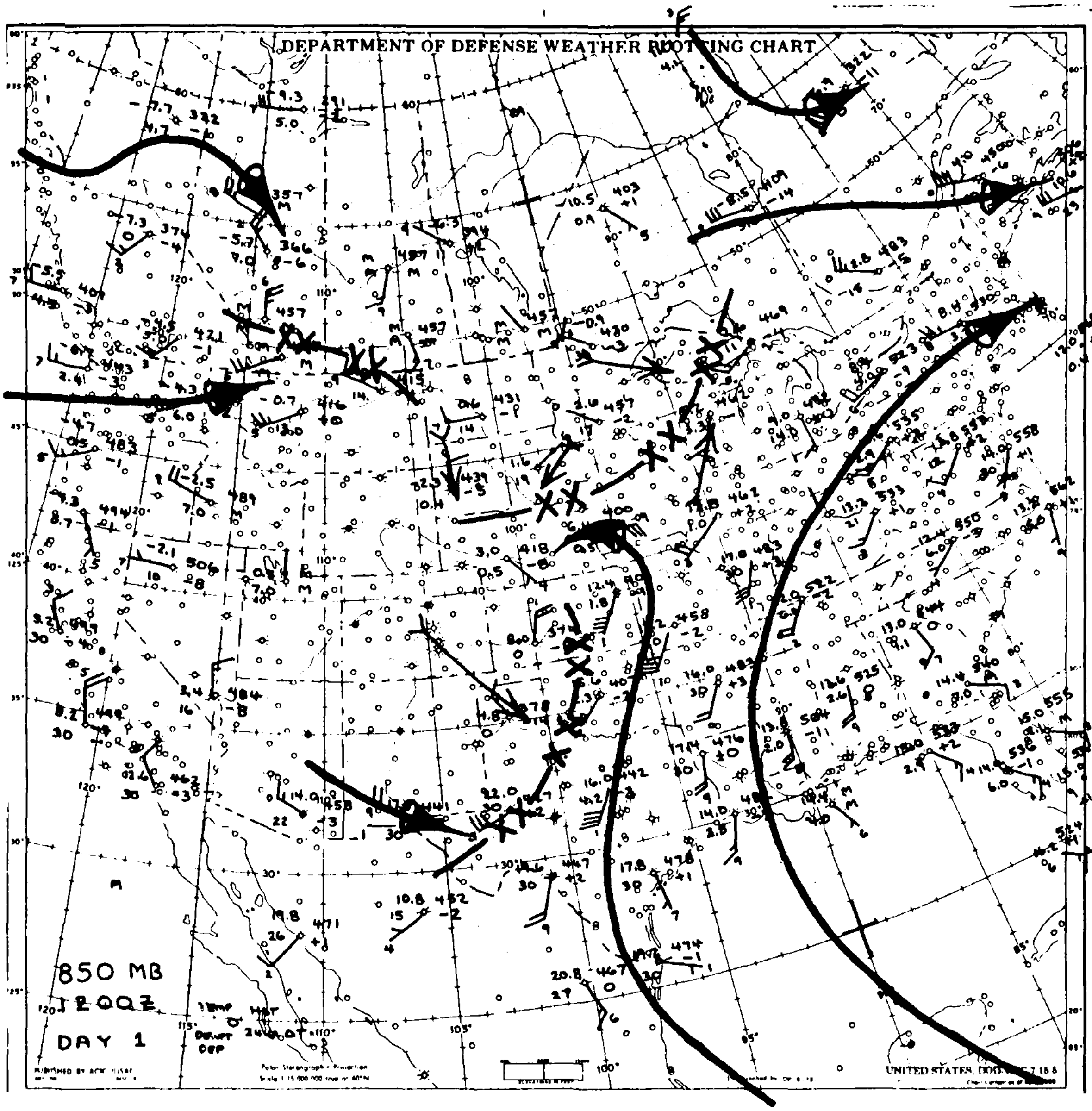
Before analyzing each chart, forecasters should be aware of certain appropriate and inappropriate analysis procedures for any chart used in this highly specialized type of forecasting. The severe weather forecaster is most concerned with unconventional map features. All values attached to the analyzed parameters must be considered relative to the immediate environment. Analysis of any particular level incorporates the use of all available information, such as the previous analysis, additional data from radar and satellite sources and from levels above and below the level of interest. A great deal of care must be taken not to ignore, change, or smooth data that may at first appear to be in error. Meticulous attention to minor changes and transitory features in the atmosphere is imperative. A highly systematic analysis routine is required to ensure the necessary attention to small details.

2.1 850 mb analysis. This very important chart enables the forecaster to estimate atmospheric stability and helps in forecasting changes in static stability. Each step in this analysis is essentially a separate analysis, but all analyses are done operationally on the same chart. These steps are shown here on separate illustrations to simplify the explanation of the complete level analysis. This entire process will be repeated for the 700 mb and 500 mb levels. Details in Figures 1 through 3 are combined into a completed analysis shown in Figure 4. The parameters listed at the bottom of Figure 4 have been transferred to the composite upper-air analysis shown in Figure 17.

2.1.1 Streamlines and convergence zones are the first parameters of interest (reference Figure 1).

2.1.1.1 Significant streamlines.

Maximum wind bands (jets) are important features since they may be associated with significant maximum moisture and thermal advection. Maximum wind band information is part of the vertical directional wind-shear term in the Severe Weather Threat (SWEAT) formula, which will be discussed later in its relationship to AF"WC's atmospheric prognostic models. This maximum wind band will be referred to as the low-level jet (LLJ). There is no minimum speed criterion for the LLJ.



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Convergence Zones (Red)

Maximum Wind Band (Jet) (Red)

Significant Streamlines (Red)

Figure 1. 850 mb Streamline Analysis.

Significant streamlines are also analyzed to assist in locating areas of moisture and thermal advection and especially in identifying convergence zones.

2.1.1.2 Convergence zones.

Convergence zones must be carefully analyzed to avoid always showing troughs in the streamline analysis. When a storm moves out of the Rocky Mountains the flow at 850 mb will come from the Gulf of Mexico, a primary moisture source. Strong westerly flow and southerly flow (from the Gulf of Mexico) converge. Weaker convergence zones are also important and, in some cases, are the only indication of a weak front.

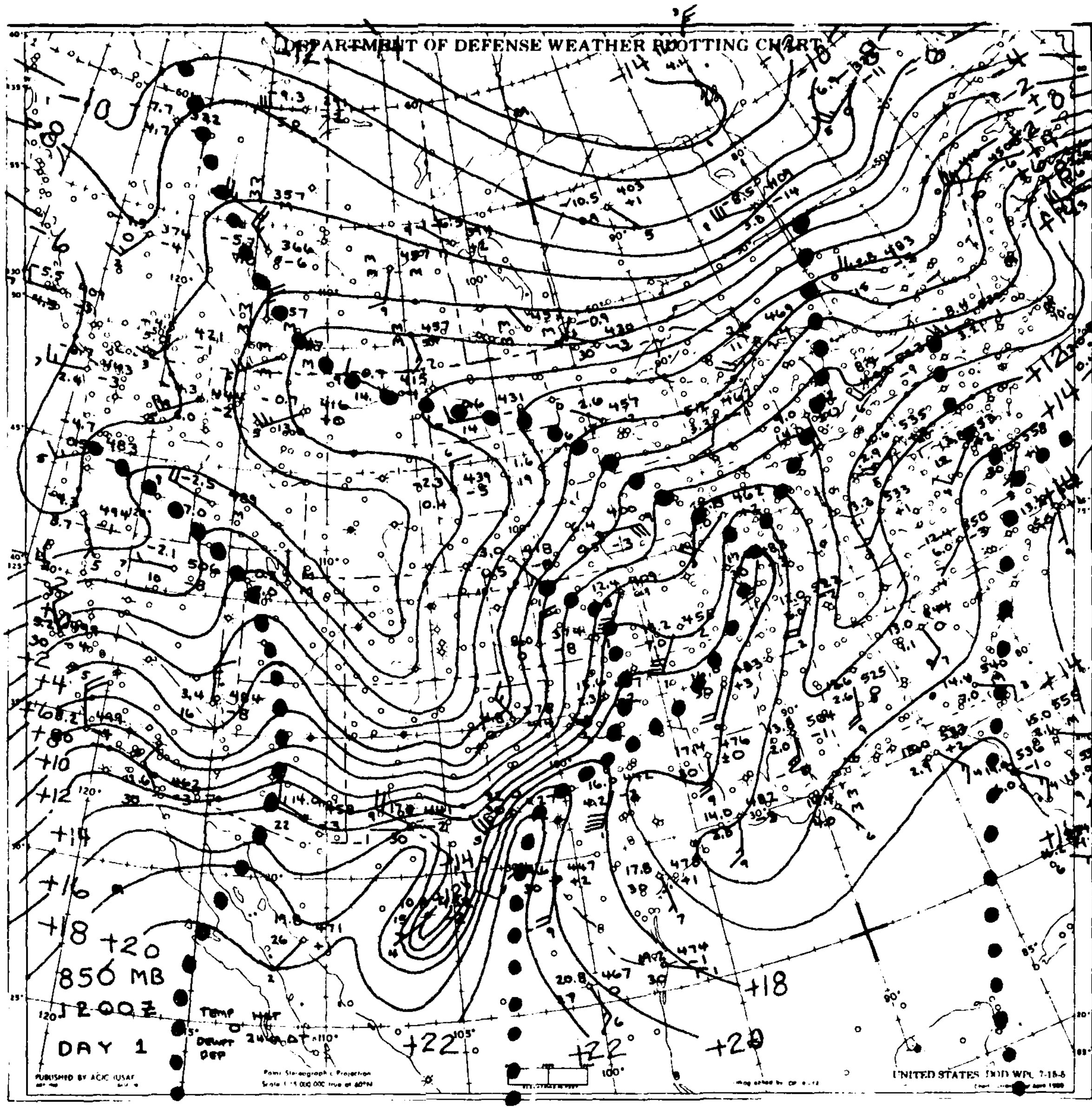
Accurate analysis of the convergence zones will assist in locating the most important thermal ridge and the main axis of maximum moisture advection near a potential severe weather threat area.

At this level in certain parts of the country, a minor trough or weak convergence zone is sometimes the first indication that moisture advection from a source region is occurring. If significant moisture is already present, the convergence zone may indicate a deepening of the moist layer.

2.1.2 A detailed analysis of the thermal field will correctly locate the thermal ridge (reference Figure 2). Analyze the isotherms every 2° C. Select an even numbered temperature that forms a continuous line across the entire chart as your first isotherm.

2.1.2.1 While analyzing the isotherms, remember to look for the thermal ridge and not just draw isotherms. To accentuate the thermal ridge, isotherms should parallel the streamlines wherever the data permit. Do not be reluctant to erase and adjust the pattern. A good analyst modifies his analysis continuously from start to finish.

2.1.2.2 The thermal ridge of prime interest will lie just ahead of the strongest convergence zone. A so note that in most cases, cold advection will be behind the convergence zone with warm advection ahead of it. An exception to this occurs in the southern plains when a strong southwesterly wind drives the dry line eastward ahead of the front and consequently ahead of the cold advection. Frequently a strong thermal ridge can be found on the lee side of the Rocky Mountains, as a result of katabatic (downslope) flow. At times, the same type of thermal ridge will occur on the lee side of the Appalachian Mountains.



Isotherms (Red)

Thermal Ridge (Red)

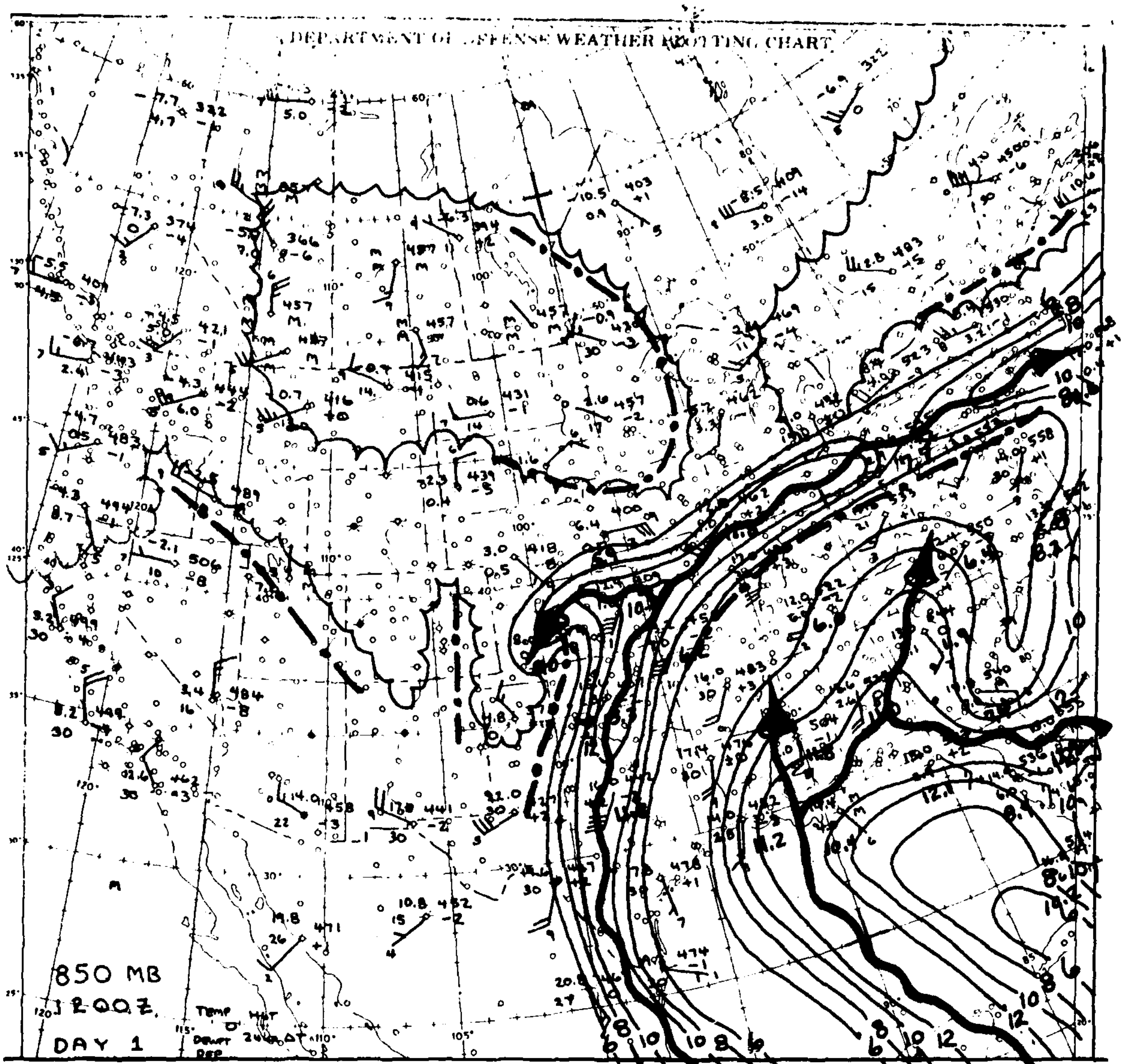
Figure 2. 850 mb Thermal Analysis.

2.1.3 A portion of the chart will require a detailed analysis of the significant moisture field. In preparation for this analysis, ensure that actual dewpoints are indicated in the area suspected of having the most moisture (reference Figure 3).

2.1.3.1 Isodrosotherms (isopleths of dewpoints) are analyzed starting with a dewpoint of 6^{o} C and in increasing values of 2^{o} C. When drawing these isodrosotherms, remember to analyze them for the axis of maximum moisture advection and areas of maximum moisture. The isodrosotherms should parallel the streamlines wherever the data permit. This accentuates the moisture axis. Do not just draw isolines, analyze them. Create the most representative field. There are times when subsidence will produce a moist, mixed layer lying just below the 850 mb level. As the day progresses, boundary layer turbulence caused by low-level winds will often result in a deeper mixed layer. Twelve hours later, on the next analysis, considerable moisture may now be available at the 850 mb level.

2.1.3.2 Additional regions of significant moisture are associated with areas having temperature-dewpoint spreads of 6^{o} C or less.

2.1.3.3 Dry lines are indicated where the streamline flow is from dry air into an area of significant moisture. The severe weather forecaster is primarily interested in determining regions where a maximum wind band is flowing across a dry line from dry to moist air.



Axis of Maximum Moisture Advection (Green)

Area of Significant Moisture (Green)

Axis of Maximum Moisture (Green)

Dry Line (Red)

Isodrosotherms (Green)

Figure 3. 850 mb Moisture Analysis.

2.1.4 This description of the 850 mb chart analysis has been partitioned into three distinct and separate analyses. All of these analyses are actually done operationally on the same chart as shown in Figure 4. All the parameters listed in Figures 1 to 3 are displayed in conspicuous symbols as shown in Figure 4.

2.1.5 Summarizing these key parameters at the 850 mb level in terms of intensity:

2.1.5.1 For the low-level jet,

Values of 20 knots or less indicates weak activity,

values 25 through 34 knots indicate moderate, and

35 knots or more indicate strong activity.

2.1.5.2 Low-level moisture (dewpoint depression values),

Values of 8° C or less indicate weak activity,

values of 9 through 12° C indicate moderate, and

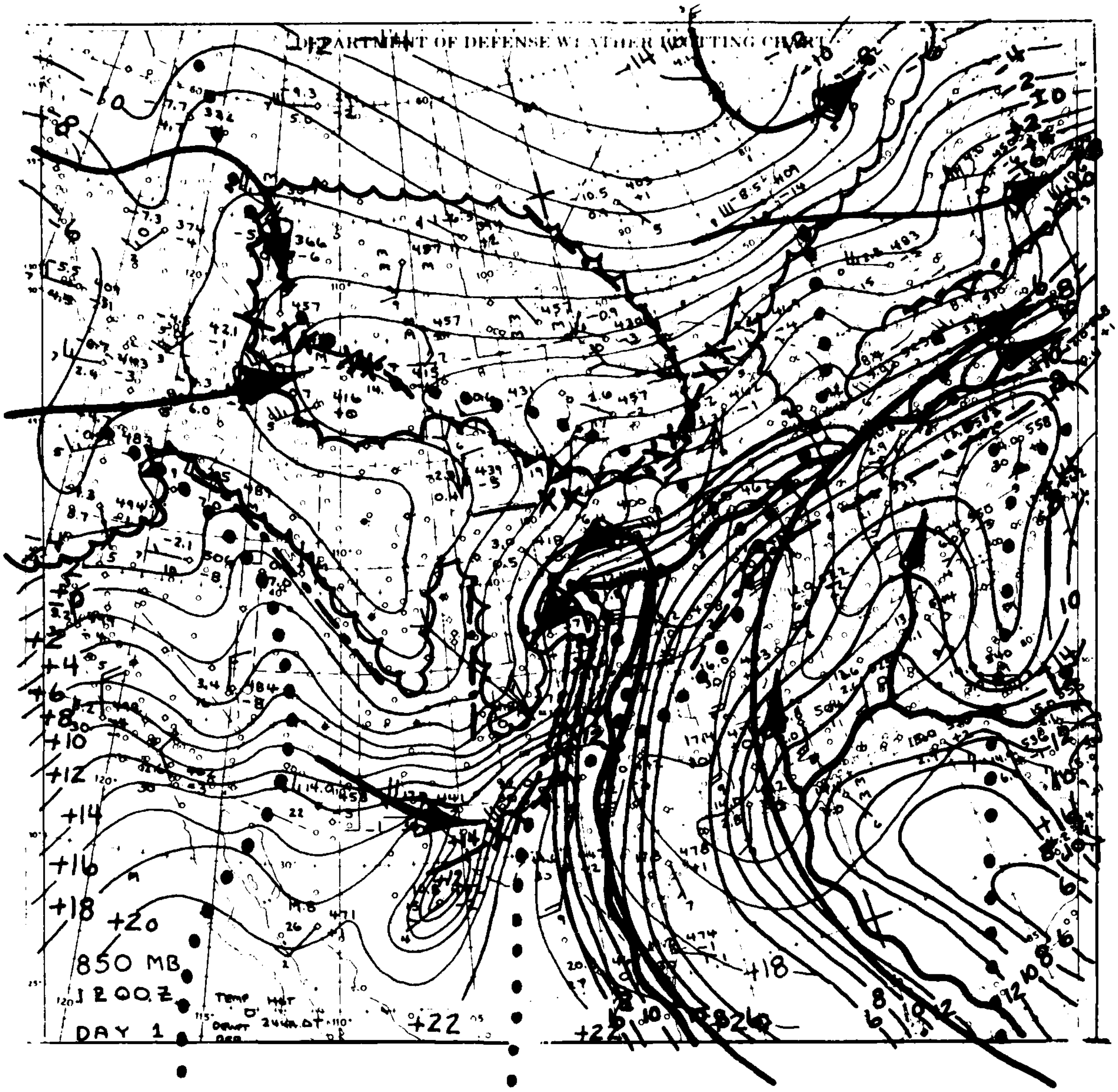
values greater than 12° C indicate strong activity.

2.1.5.3 Relationship of the thermal ridge (maximum temperature) to the axis of maximum moisture,

Ridge east of maximum moisture indicates weak activity,

ridge coincident with maximum moisture indicates moderate, and

ridge west of maximum moisture indicates strong activity.



Convergence Zone (Red)

Dry Line (Red)

Maximum Wind Band (Jet) (Red)

Axis of Maximum Moisture Advection (Green)

Identification Streamlines (Red)

Axis of Maximum Moisture (Green)

Thermal Ridge (Red)

Figure 4. Completed 850 mb Analysis.

2.2 700 mb analysis. Details in Figures 5 through 7 are combined into a completed analysis shown in Figure 8. Parameters listed at the bottom of Figure 8 have been transferred to the composite upper-air analysis, Figure 17.

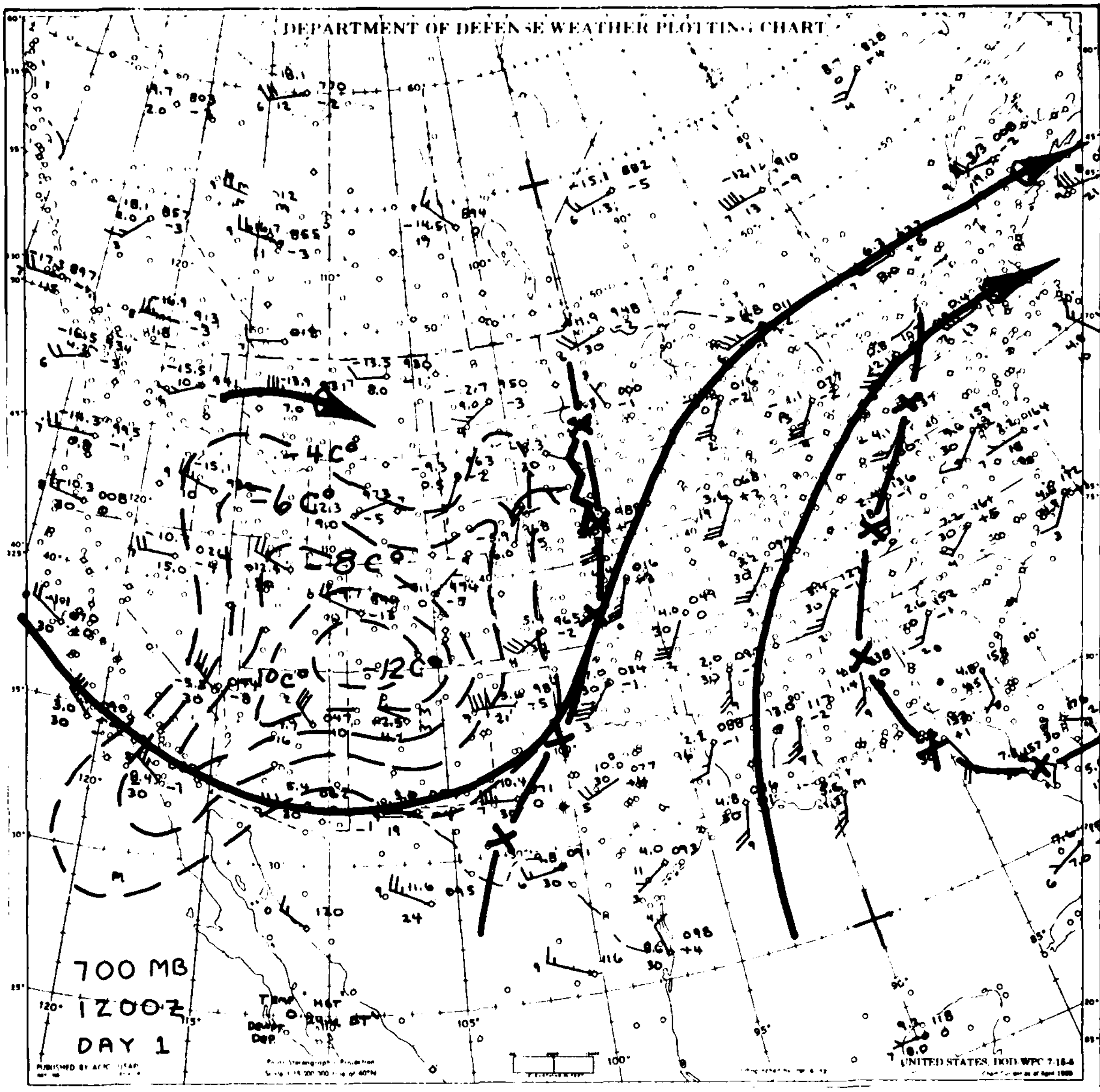
2.2.1 Streamlines and difluent zones are the primary parameters analyzed in this step. Secondary parameters include temperature falls (12 or 24 hour) and the temperature no-change line (12 or 24 hour). (Reference Figure 5.)

2.2.1.1 Maximum wind bands (jets) are important features because they produce dry intrusions. These wind bands are also useful in depicting areas of most rapid cold or warm-air advection.

2.2.1.2 Significant streamlines, which are not necessarily maximum wind bands, are drawn to help identify areas of difluence.

2.2.1.3 The significant temperature falls (over 12 hours from late fall through early spring and 24 hours from late spring through early fall) should be analyzed to indicate areas of cold advection.

2.2.1.4 The temperature no-change line (over 12 hours from late fall through early spring and 24 hours from late spring through early fall) will assist in forecasting the approximate position for squall-line development.



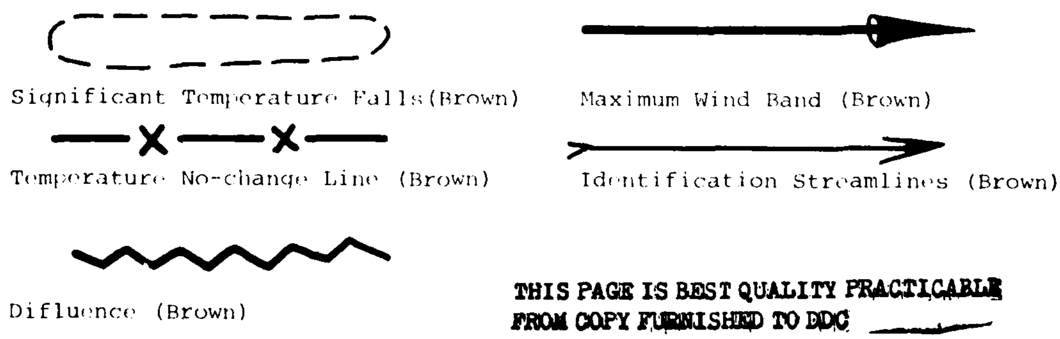
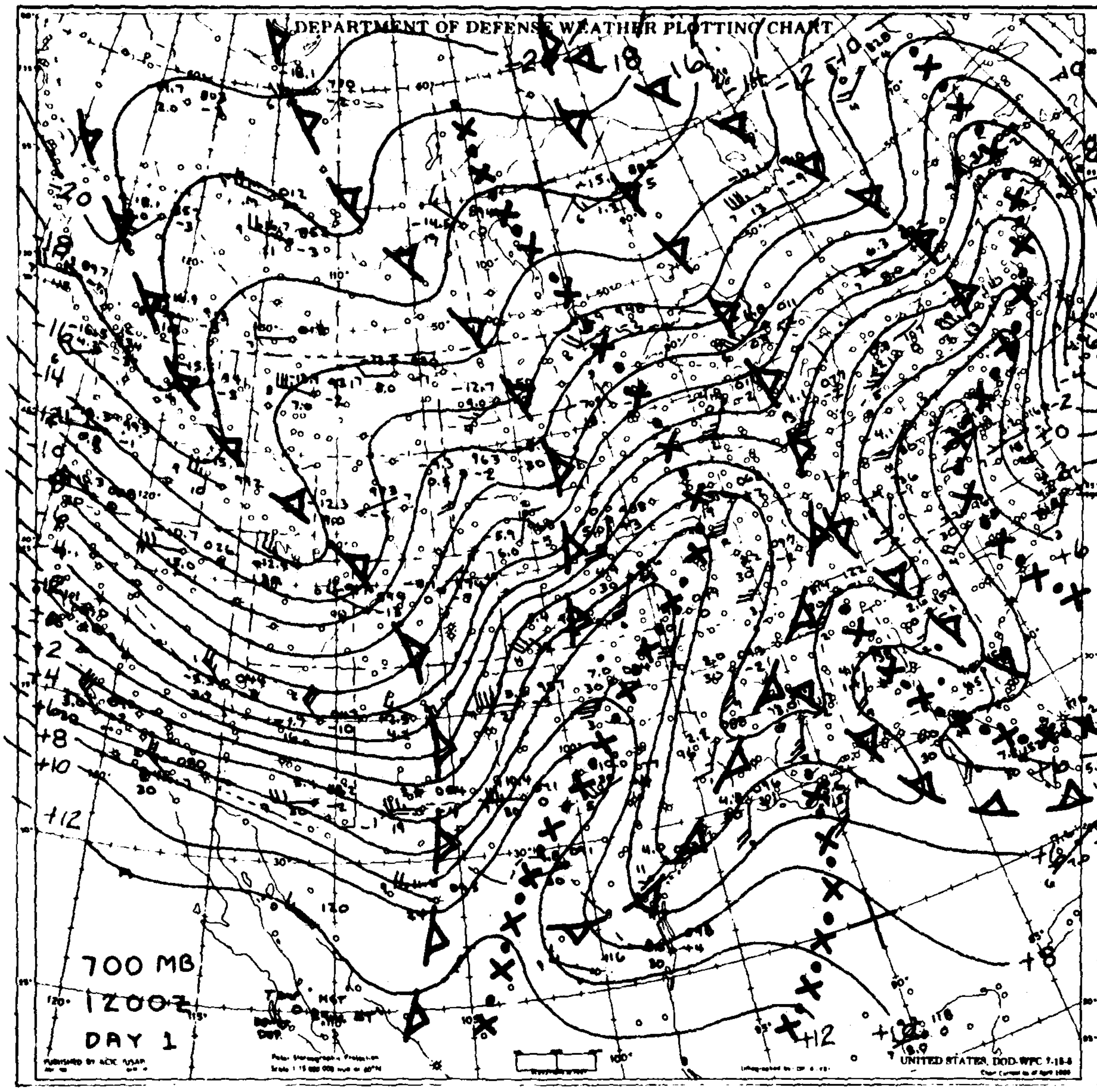


Figure 5. 700 mb Streamline and Temperature Fall Analyses.

2.2.2 Thermal troughs and ridges are located using the thermal analysis. Analyze isotherms every 2^{o} C. Select an even-numbered temperature that forms a continuous line across the whole chart for the first isotherm. (Reference Figure 6.)

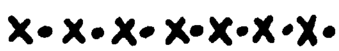
2.2.2.1 While analyzing the isotherms, remember to look for thermal troughs and ridges. Where possible, the isotherms should parallel the streamlines, so that the thermal troughs and ridges will be accentuated. The thermal ridge becomes important in late spring through early fall; at temperatures of 12^{o} C or greater (except in mountainous regions), convective activity is subdued or capped.

2.2.2.2 Use the current or previous 500 mb chart to assist in vertical stacking of the cold troughs. The previous 700 mb chart should be used to ensure temporal continuity. These troughs help to locate the most probable areas of vertical motion.



Isotherms (Red)

Thermal Troughs (Blue)



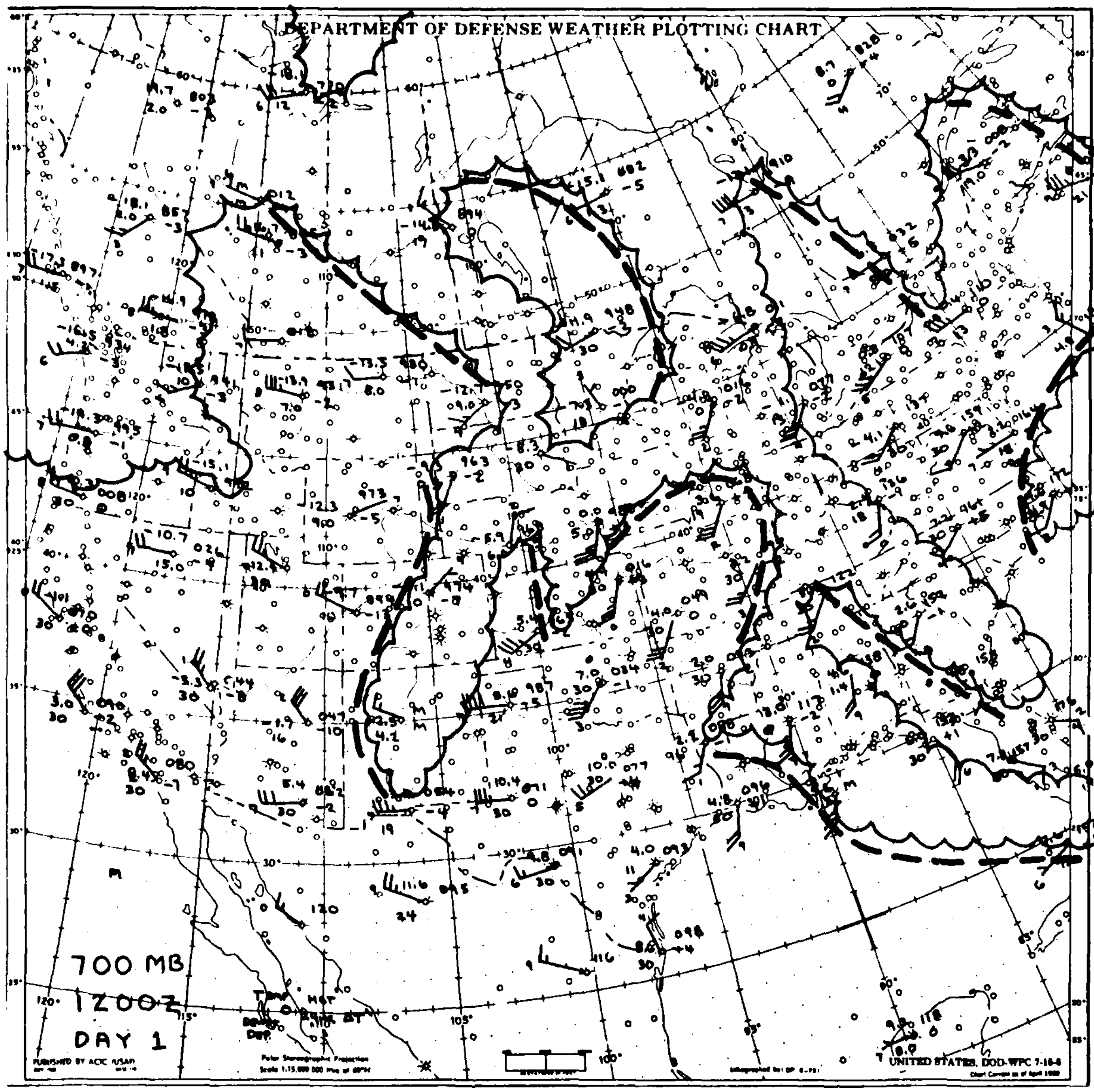
Thermal Ridge (Brown)

Figure 6. 700 mb Thermal Analysis.

2.2.3 The significant moisture field at 700 mb is defined by a temperature-dewpoint spread of 6^{o} C or less (reference Figure 7).

2.2.3.1 Areas of moisture detached from a primary moisture source and not solely explained by advection are most likely the result of upward motion associated with positive vorticity advection (PVA). These areas indicate that a minor short wave trough is a short distance upstream.

2.2.3.2 Dry lines are depicted when the streamline flow, especially a maximum wind band, crosses from dry to significantly moist air.



Significant Moisture (Green)

Dry Line (Brown)

Figure 7. 700 mb Moisture Analysis.

2.2.4 All three analyses discussed are completed on the same chart. All the parameters and symbols listed in Figures 5 through 7 are displayed in conspicuous symbols as shown in Figure 8.

2.2.5 Summarizing these key parameters at the 700 mb level in terms of intensity:

2.2.5.1 Intrusion of the dry line and:

Wind field weak or not available indicates weak activity,

wind from dry to moist at an acute angle of 10 to 40 degrees and speed 15 to 25 knots is moderate, and

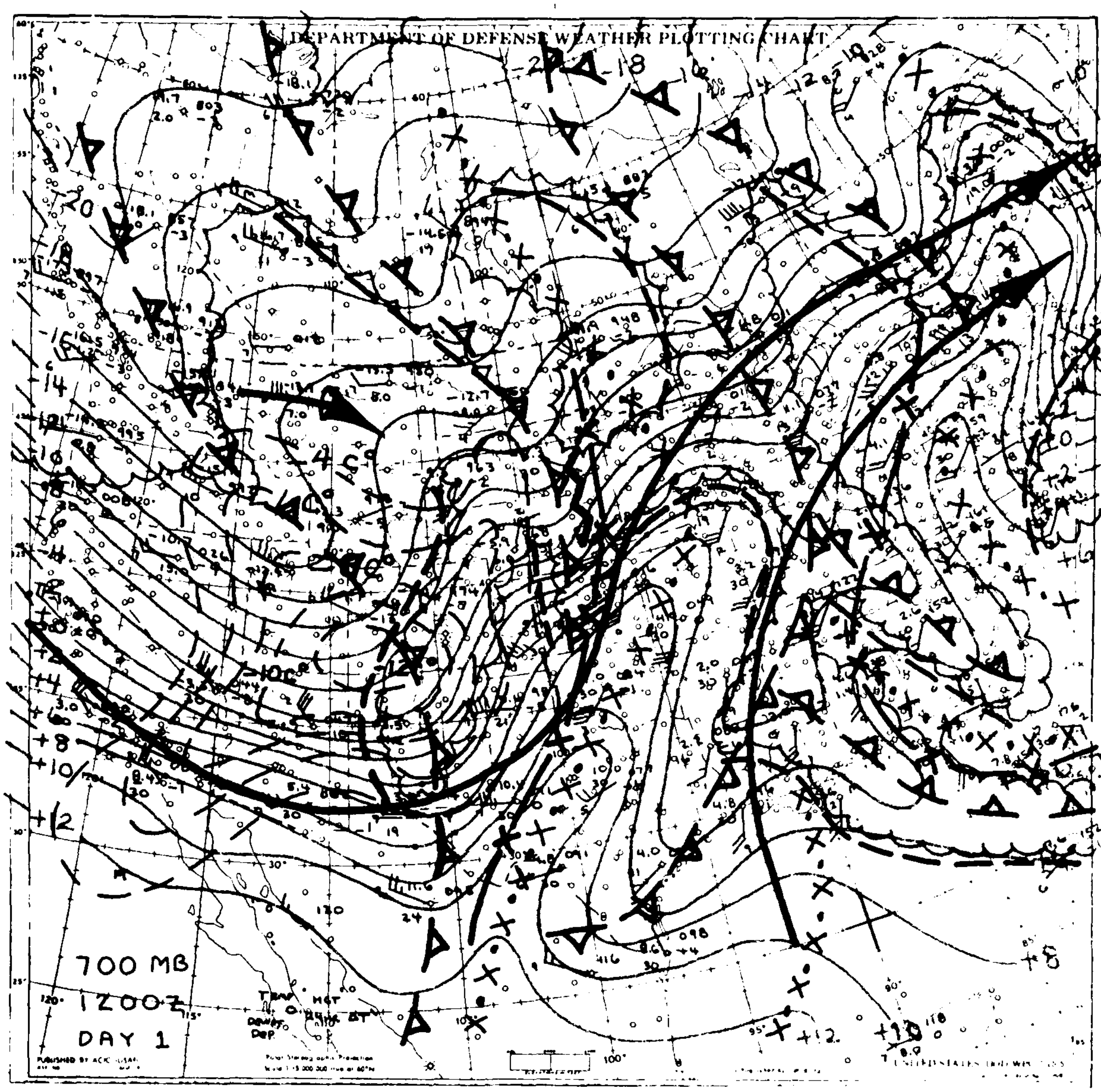
wind intruding at an angle of 40 to 90 degrees with wind speed of 25 knots or greater is strong.

2.2.5.2 Relationship of wind to temperature no-change line (or significant change line),

Wind crossing line at acute angle less than 20 degrees is weak,

wind crossing line at 20 through 39 degrees is moderate, and

wind crossing line at 40 through 90 degrees is strong.



Dry Line (Brown)

Maximum Wind Band (Jet) (Brown)

Temperature No-Change Line (Brown)

Identification Streamlines (Brown)

Difluence (Brown)

Thermal Ridge (Brown)

Figure 8. Completed 700 mb Analysis.

2.3 500 mb analysis. The details shown in Figures 9 through 11 are all included in the completed analysis shown in Figure 12. The parameters listed at the bottom of Figure 12 will be transferred to the composite upper-air analysis shown in Figure 17.

2.3.1 Streamlines, difluence, horizontal speed shear, and height falls are the first parameters analyzed (reference figure 9).

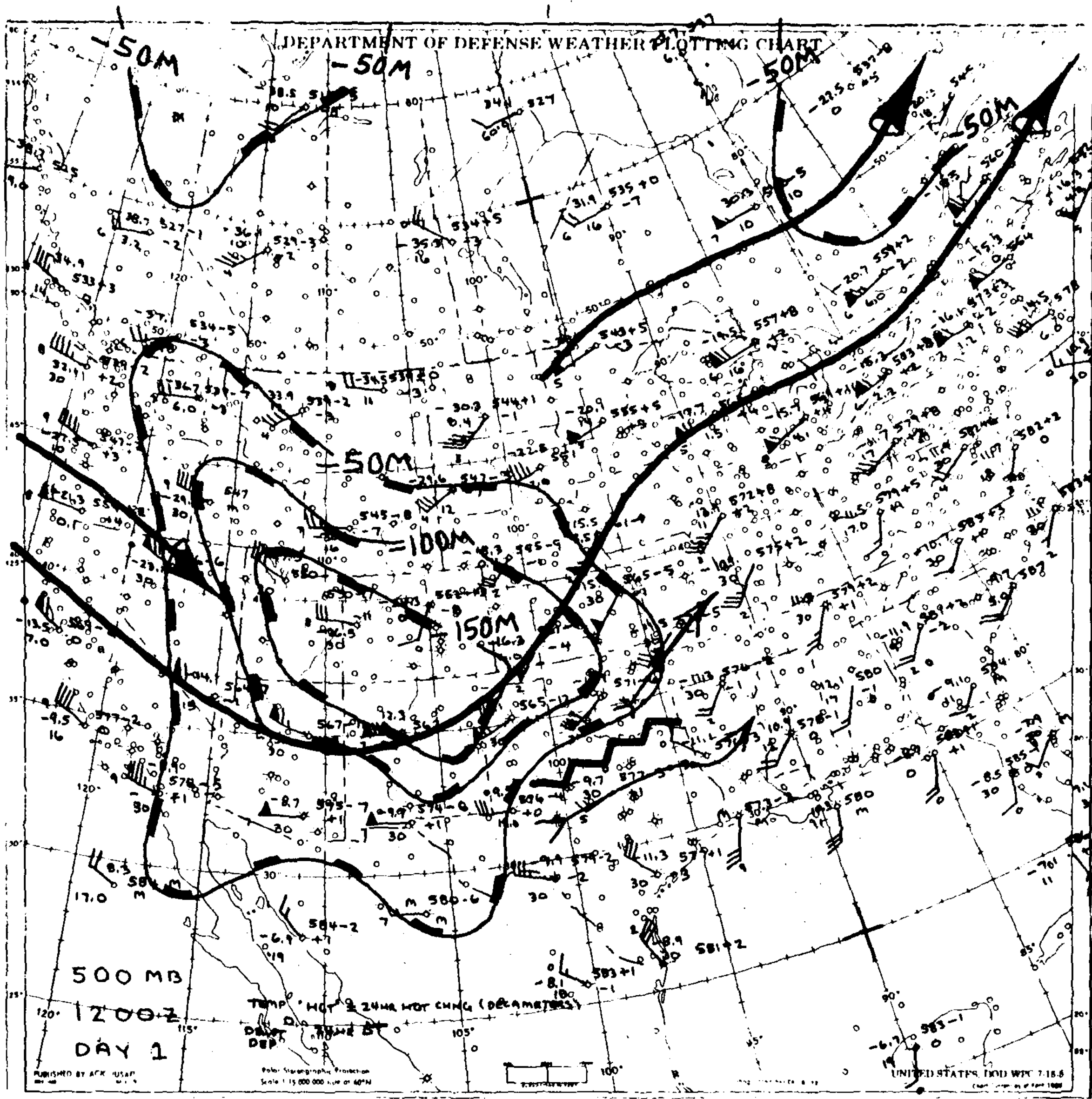
2.3.1.1 Significant streamlines.

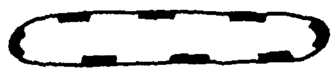
Maximum wind bands are the most significant streamlines. Their location and forecast position help to outline the severe weather areas (reference AWSTR 200(Rev), Chapter 3). The direction of flow is one factor considered in calculating the vertical (directional) wind-shear term in the SWEAT formula. Speed is also one of the terms in the SWEAT formula.

Any split in the flow has to be considered as possible branching of the maximum wind band (jet). Evaluate this carefully as the difluence parameter should lie between the two branches in the maximum wind band (jet). There are times when difluence is present and no branching is evident. In this case there may be a weaker flow pattern spreading away from the main jet.

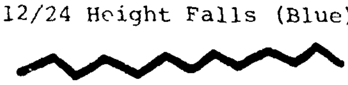
A rapid decrease in the speed of flow to the right of the jet, but moving in the same direction, will depict a horizontal speed shear zone. As in the previous paragraph, the weaker flow branching away from the jet may be considered a horizontal speed shear zone if the decrease in speed with distance is significant.

2.3.1.2 Height falls at this level furnish a clue to the location and movement of long and short wave troughs. Height fall areas also approximate the area of maximum positive vorticity. Because of the seasonal variation in the frequency of migratory waves, 12-hour height falls should be used from late Fall through early Spring (higher frequency) and 24-hour height falls should be used from late Spring through early Fall (lower frequency).

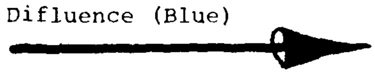




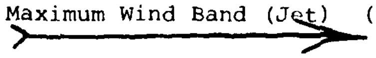
12/24 Height Falls (Blue)



Difluence (Blue)



Maximum Wind Band (Jet) (Blue)



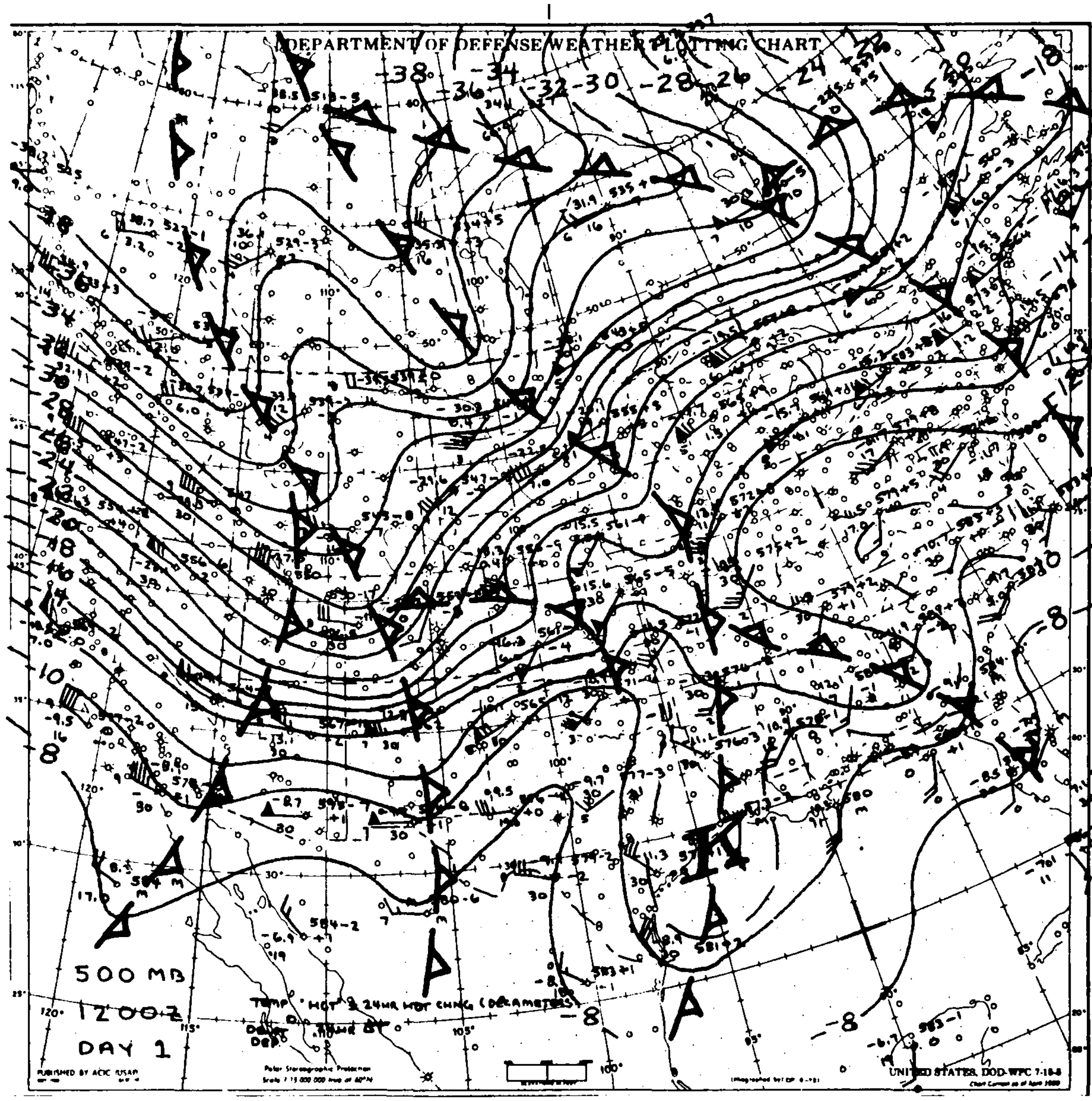
Identification Streamlines (Blue)

Figure 9. 500 mb Streamline and Height Fall Analyses.

2.3.2 A detailed analysis of the thermal field will accurately locate thermal troughs, an important parameter (reference Figure 10). Draw the isotherms every 2° C. Select as the first isotherm an even-numbered temperature that forms a continuous line across the whole chart. The height fall field can assist in the analysis of the thermal field. Note that the trough-like protrusions in the height fall field (Figure 9) appear as cold thermal troughs in Figure 10.

2.3.2.1 While analyzing the isotherms, remember to look for cold pools and thermal troughs and not just draw isotherms. The isotherms should parallel the streamlines wherever possible. Such analysis will enhance the short waves, but take care not to overdo it or the result will be thermal troughs that always coincide with streamline troughs. This tendency to draw thermal troughs coincident with streamline troughs should be avoided (unless observations indicate otherwise) for it will not depict warm or cold advection into or out of a streamline trough.

2.3.2.2 The thermal ridge is not used as a major parameter at this level. It must be considered, however, because most convective activity is subdued or capped near its axis and/or its eastern half, especially when the thermal ridge coincides with the streamline ridge.



Isotherms (Red)

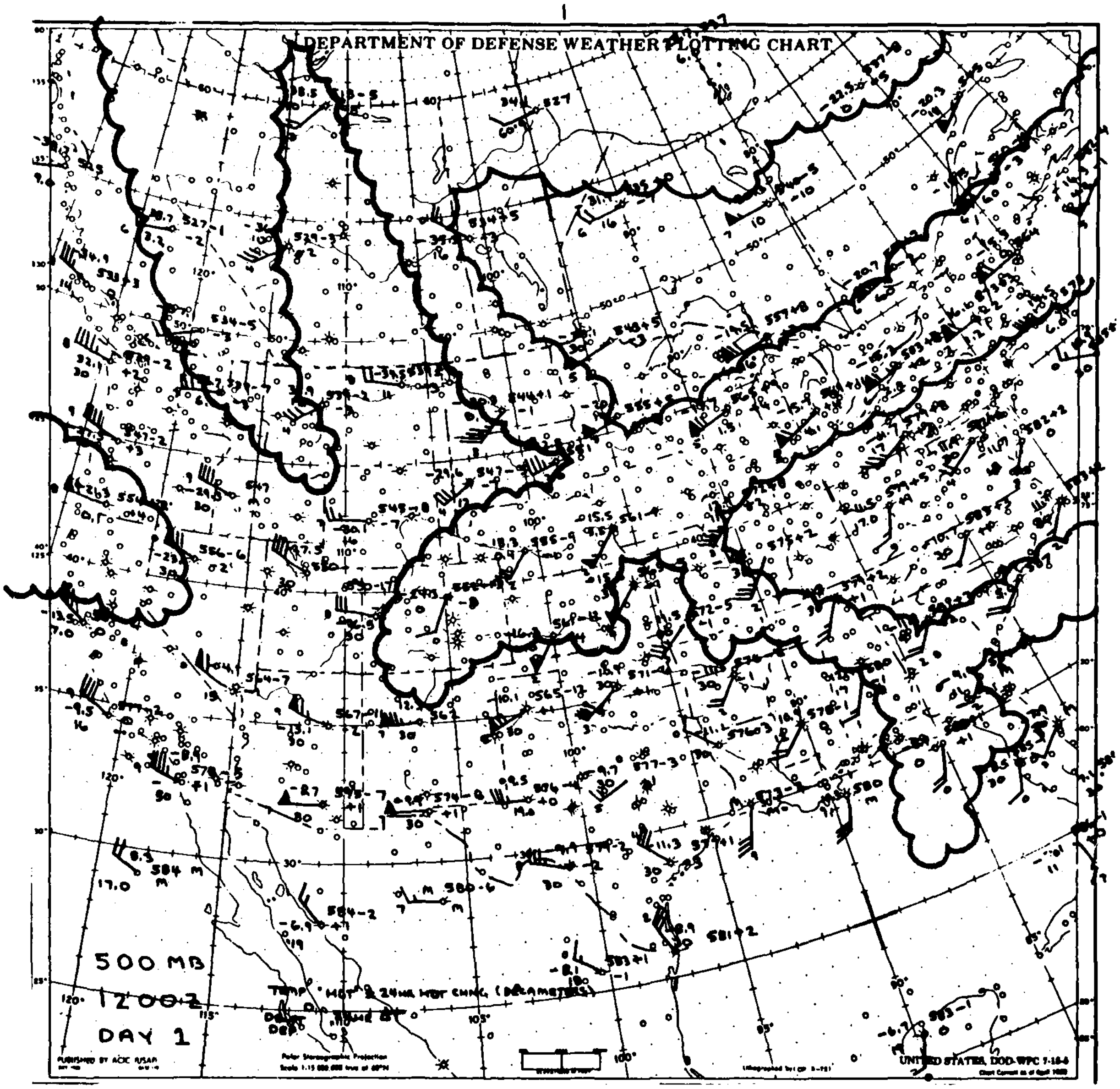
Thermal Troughs (Blue)

K

Cold Pools (Blue)

Figure 10. 500 mb Thermal Analysis.

2.3.3 The significant moisture field at 500 mb is defined by those areas where the temperature-dewpoint spread is 6° C or less and/or where the dewpoint is -17° C or greater (reference Figure 11). Detached areas of moisture, not solely explained by advection from a primary moisture source, most often result from vertical motion. These areas if associated with PVA will indicate that a minor short wave is a short distance upstream.



Significant Moisture (Green)

Figure 11. 500 mb Moisture Analysis.

2.3.4 All three analyses discussed are completed on the same chart. The parameters and symbols listed in Figures 9 through 11 are displayed in conspicuous symbols in Figure 12.

2.3.5 Summarizing the key parameters at the 500 mb level in terms of intensity:

2.3.5.1 Vorticity advection,

Neutral or negative vorticity advection is weak,

positive vorticity advection with the wind crossing vorticity isopleths at angles less than 30 degrees is moderate, and

positive vorticity advection with the wind flow crossing vorticity isopleths at angles greater than 29 degrees is strong.

2.3.5.2 Mid-level jet strength,

Less than 35 knots is weak,

35 through 49 knots is moderate, and

jets that are 50 knots or greater are strong.

2.3.5.3 Mid-level shear zone (over 90 nm),

Less than 15 knots is weak,

15 through 29 knots is moderate, and

30 knots or greater is strong.

2.3.5.4 Height falls during the previous 12 or 24 hour period (use 12 hour falls from late Fall through early Spring and 24 hour falls from late Spring through early Fall),

Less than 30 meters is weak,

30 through 60 meters is moderate, and

greater than 60 meters is strong.

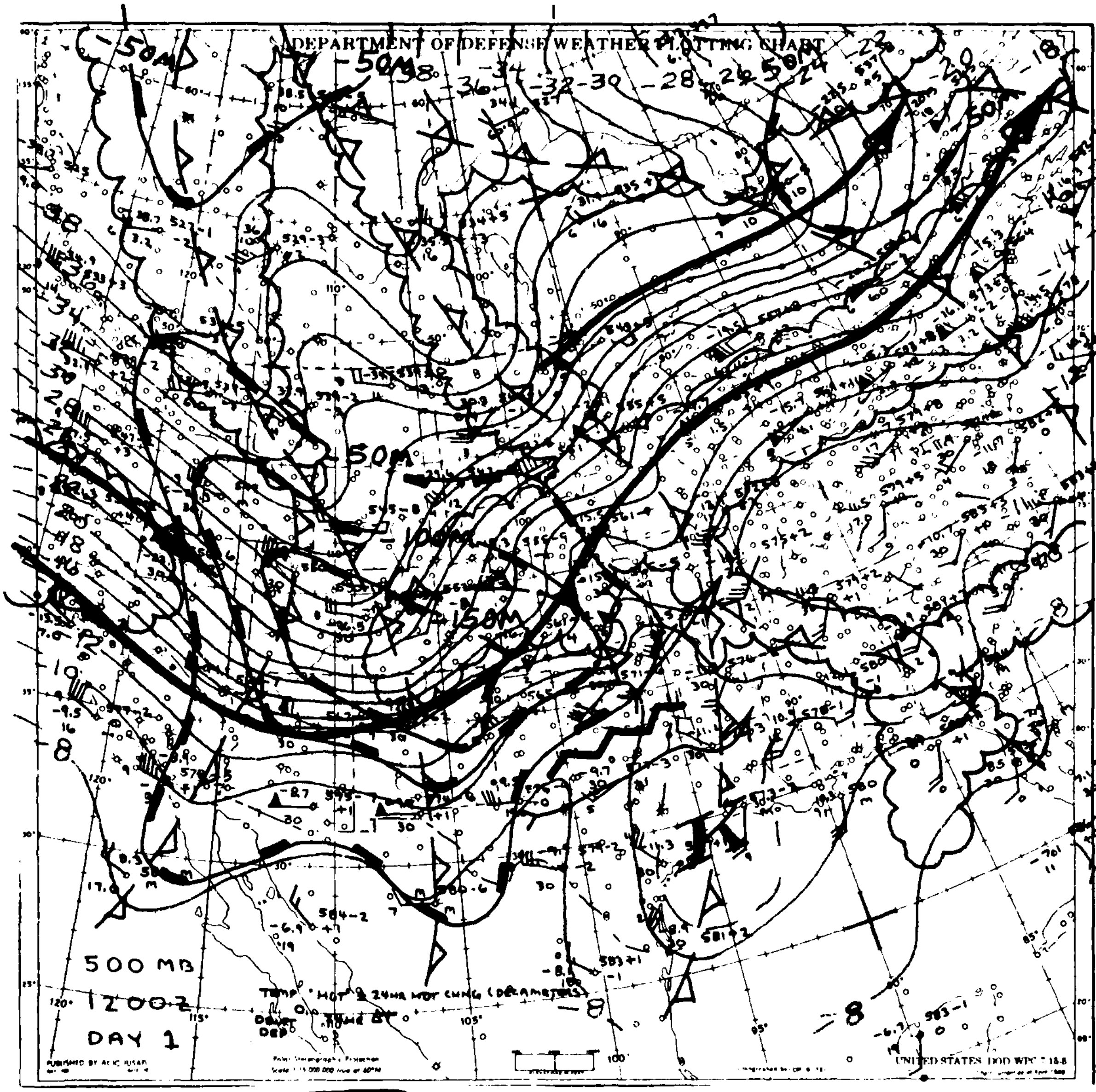
2.3.5.5 The important isotherm value for severe weather by month are:

December, January, and February...-16^{o} C,

March, April, October, and November...-14^{o} C,

May and June...-12^{o} C, and

July, August, and September...-10^{o} C.



12/24-hour Height Falls (Blue)

Thermal Troughs (Blue)

Difluence (Blue)

Cold Pools (Blue)

Maximum Wind Band (Jet) (Blue)

Identification Streamlines (Blue)

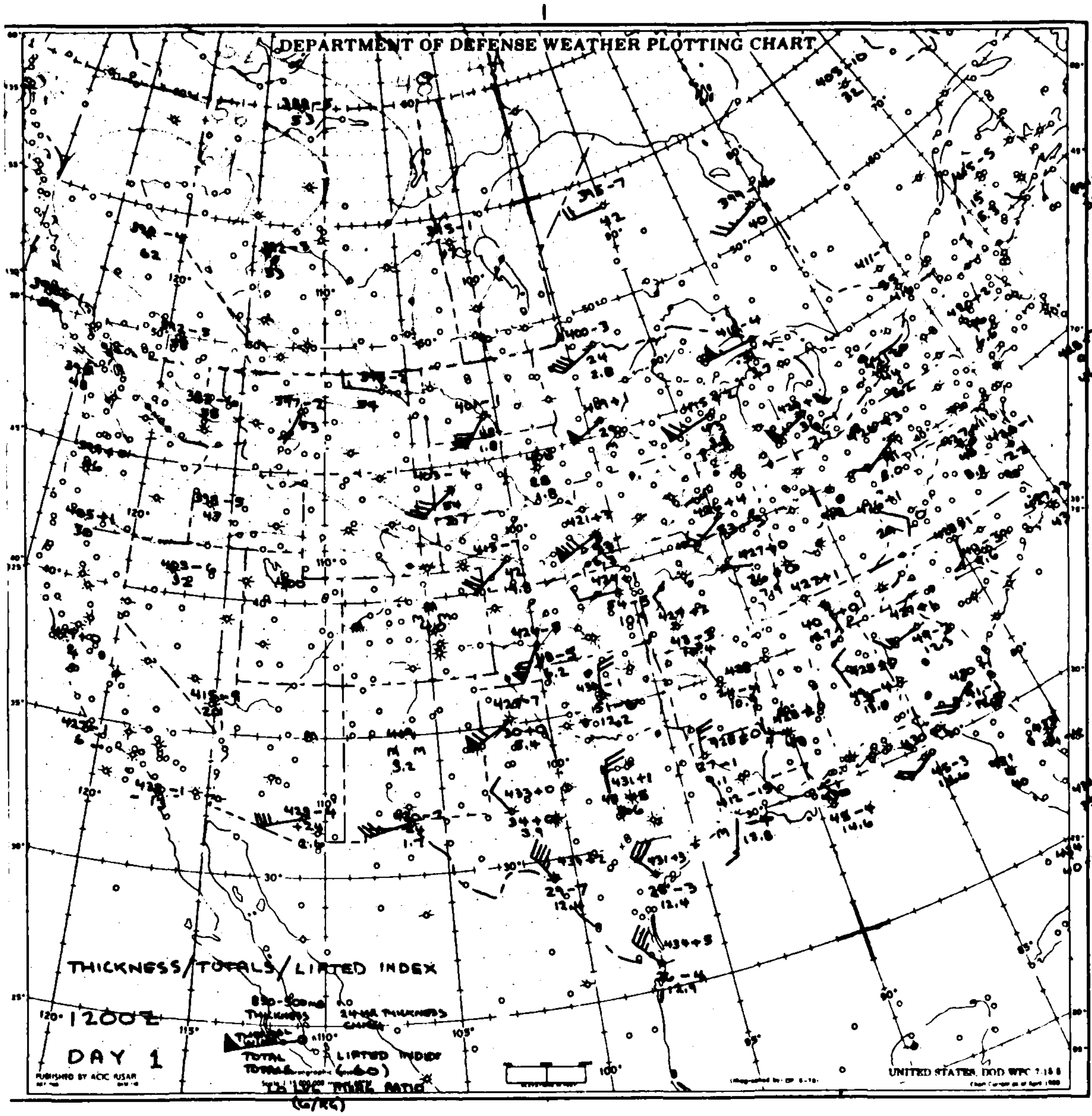
Figure 12. Completed 500 mb Analysis.

2.4 850/500 mb thickness analysis. The thickness chart can be used by the severe weather forecaster to delineate the approximate area of potentially severe activity by locating the most probable area for squall-line development (reference Chapter 4 of AWSTR 200(Rev)). Details shown in Figures 13 and 14 are all included in the completed analysis, as shown in Figure 15. The parameters listed at the bottom of Figure 15 will be transferred to the composite upper-air analysis (Figure 17).

2.4.1 Vertical totals, cross totals, and a combination of the two (total totals) can be used to provide an approximate delineation of the most unstable areas. Reference Chapter 8 of AWSTR 200(Rev) for the definition of vertical totals, cross totals, and total totals. Figure 13 indicates only total totals.

2.4.1.1 Total totals are routinely analyzed on this chart. Areas with total totals equal to or greater than 44 are analyzed at intervals of 2 or 4.

2.4.1.2 At certain times of the year, vertical totals or cross totals are more important than total totals in some parts of the country.



Total Totals (Orange)

Figure 13. 850/500 mb Total Totals Analysis.

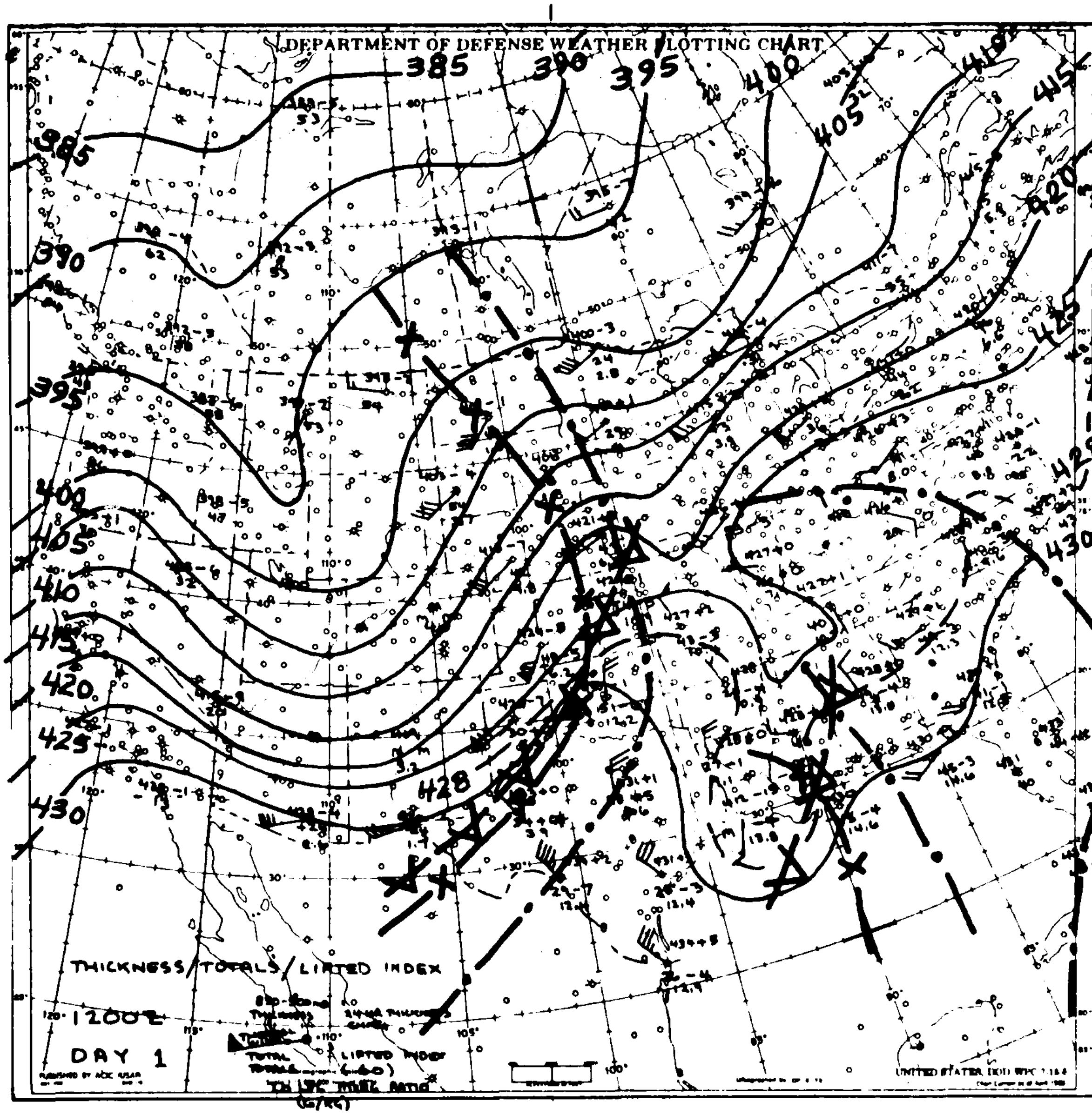
2.4.2 Isopleths of 850/1000 mb thickness are drawn at 20 - 50 meter intervals starting with an even value. Twenty meter intervals are used from late spring through early fall and 50 meter intervals from late fall through early spring. Variations of these values may be used to provide a finer analysis. The thickness ridges, no-change lines, and areas of maximum anticyclonic wind are the parameters that will be analyzed (reference Figure 14).

2.4.2.1 When analyzing the isolines of thickness, remember to look for the thickness ridge and not just draw isolines. Note that squall lines tend to develop 100 nm upstream from the thickness ridge.

2.4.2.2 The thickness no-change line is found using 12-hour changes from late fall through early spring and 24-hour changes from late spring through early fall.

The no-change line should reflect the location where significant thickness falls begin. If there is a broad band of 10 to 20 meter falls with an area of 40 to 60 meter falls behind it, then the no-change line should be at the leading edge of the larger falls. The no-change line delineates the leading edge of the significant cold-air advection.

2.4.2.3 The wind field used on this chart is the 850/500 mb thermal wind. The parameter of interest here is the axis of maximum anticyclonic curvature in the thermal wind streamlines or, as stated in AWSTR 200(Rev), the area of maximum anticyclonic wind shear.



Thickness Ridge (Black)

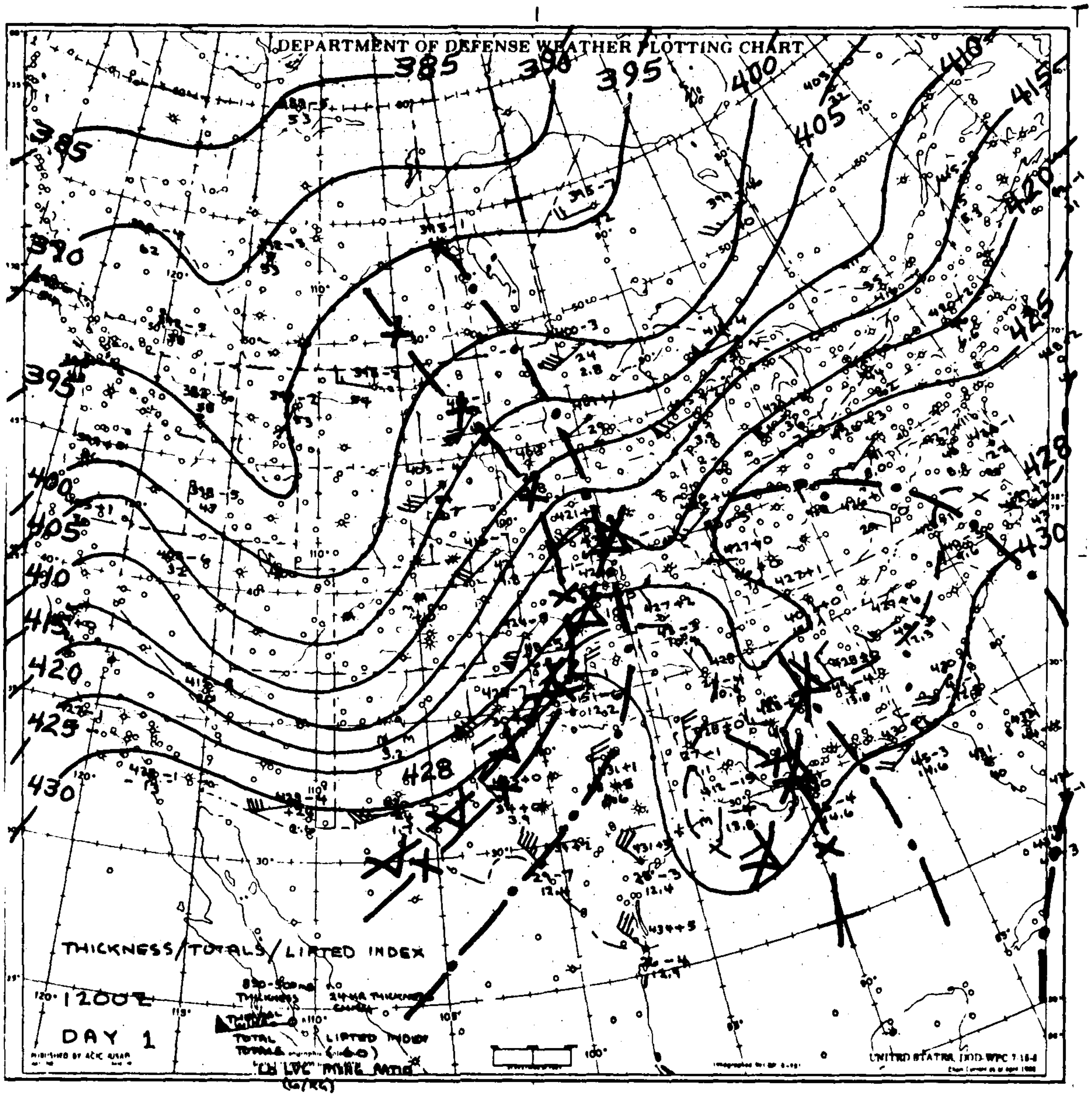
Thickness No-Change Line (Black)

Zone of Maximum Anticyclonic Wind (Thermal Wind) Shear (Black)

Isolines of Thickness (Black)

Figure 14. 850/500 mb Height Analysis.

2.4.3 All the analyses discussed are accomplished on the same chart. The parameters and symbols listed in Figures 13 and 14 are displayed in Figure 15.



Total Totals (Orange)

Thickness Ridge (Black)

Thickness No-Change Line (Black)

Zone of Maximum Anticyclonic Wind (Thermal Wind) Shear (Black)

Figure 15. Completed 850/500 mb Thickness Analysis.

2.5 Severe Weather Parameter Work Chart. This chart is designed for quick reference to parameters that can be derived from a skew-T analysis. Below is a list of some of these key parameters and, where applicable, reference material describing derivation and use. Some of these parameters may be considered when developing a severe weather parameter worksheet. Figure 26 shows one possible combination of parameters.

2.5.1 The 12-hour temperature change values at 850 mb assist in locating areas of low-level warm advection.

2.5.2 The 12-hour temperature change values at 700 mb assist in locating areas of cold advection.

2.5.3 The 12-hour temperature change values at 500 mb assist in locating areas of cold advection.

2.5.4 The 12-hour height change values at 500 mb assist in determining the trough movement as well as delineating areas of strong cold advection.

2.5.5 Hail size...AWSTR 200(Rev), Chapter 9. Thunderstorms which produce hail .75 inches in diameter or larger are classified as severe.

2.5.6 Maximum surface gust...AWSTR 200(Rev), chapter 10. Thunderstorms which produce gusts of 50 knots or greater are classified as severe.

2.5.7 Average mixing ratio (g/kg) in the lower 100 mb above ground level...AWSM 105-124, Chapter 4. When using this mean mixing ratio as a forecast parameter, the following intensity guidance applies:

8 g/Kg or less is weak,

9 through 12 g/Kg is moderate, and

13 g/Kg or greater is strong.

2.5.8 Height of the wet bulb zero...AWSTR 200(Rev), Chapter 7. Wet-bulb zero height (above ground level) as a severe weather parameter will indicate the following intensities:

Below 5,000 feet and above 11,000 feet is weak,

5,000 to 7,000 feet and 9,000 to 11,000 feet is moderate, and

7,000 to 9,000 feet is strong.

2.5.9 Critical (convective) temperature...AWSM 105-124, Chapter 4. This is the temperature necessary to generate thermals that reach the convective condensation level (CCL). Clouds will begin to form at this level. When the critical temperature is less than the expected maximum surface temperature, convective cloudiness can be expected. The larger the diference between the expected maximum temperature and the critical temperature the more likely that severe thunderstorms will occur.

2.5.10 Cumulonimbus tops...AWSM 105-124, Chapter 4, Para 4.23; positive and negative areas (cumulonimbus top is the top of the positive area plus 1/3 of the thickness of the positive area).

2.5.11 Tropopause height...AWSM 105-124, Chapter 6. Compare radar reported tops to these heights. Thunderstorm tops which come within 5,000 feet of (or penetrate) the tropopause are considered potential severe weather producers.

2.5.12 Lifted index...AWSM 105-124, Chapter 5. When used as a severe weather forecast parameter, consider the following intensity indicators:

Minus 3 or greater is weak,

Minus 3 through minus 5 is moderate, and

Minus 6 or less is strong.

2.5.13 Vertical totals...AWSTR 200(Rev), Chapter 8.

2.5.14 Cross totals...AWSTR 200(Rev), Chapter 8.

2.5.15 Total totals...AWSTR 200(Rev), Chapter 8. When used as a severe weather forecast parameter, the following intensity indicators apply:

Values less than 50 are weak,

Values of 50 through 55 indicate moderate, and

Values greater than 55 are strong.

2.5.16 K Index...NWS Forecasters' Handbook No. 1, July 1976, pages 5-12.

2.6 Maximum Wind Analysis. This automated chart, (see Figure 16) produced by the AFGWC computer system, has plotted maximum winds from individual RAOBs with the height of the wind indicated. When the AFGWC product is not available, the NWS tropopause wind chart, 300 mb chart, or 200 mb chart may be used instead. The maximum wind chart is substituted whenever the 500 mb wind field is too weak to identify properly the maximum wind band (primarily in summer). When substituting a higher wind field for the one at 500 mb, remember that the 500 mb maximum wind band is a reflection of the true jet stream at higher levels. Mental adjustments must be made for vertical stacking. Significant features will be transferred to the composite chart as shown in Figure 17 when the 500 mb wind field is too weak to show a pronounced maximum wind band.

2.6.1 Isotachs (isolines of wind speed) are drawn at an appropriate interval considering the overall wind field. Isotachs are drawn to locate the axis of maximum wind and to isolate the maximum wind cores.

2.6.2 Significant streamlines, other than the maximum wind axis, are drawn to assist in identifying difluent zones.

2.6.3 Difluent zones are indicated where the flow of the axis of maximum wind branches significantly.

2.6.4 Horizontal speed shear zones are indicated when there is a significant decrease in speed per distance from the axis, or from the edge of the maximum wind band. The symbol is like the one used on the 500 mb chart but the color code is purple.

2.6.5 Maximum wind analysis key parameters and their intensities:

2.6.5.1 Upper-level jet,

Wind speeds less than 55 knots indicate weak activity,

values 55 through 85 knots indicate moderate, and

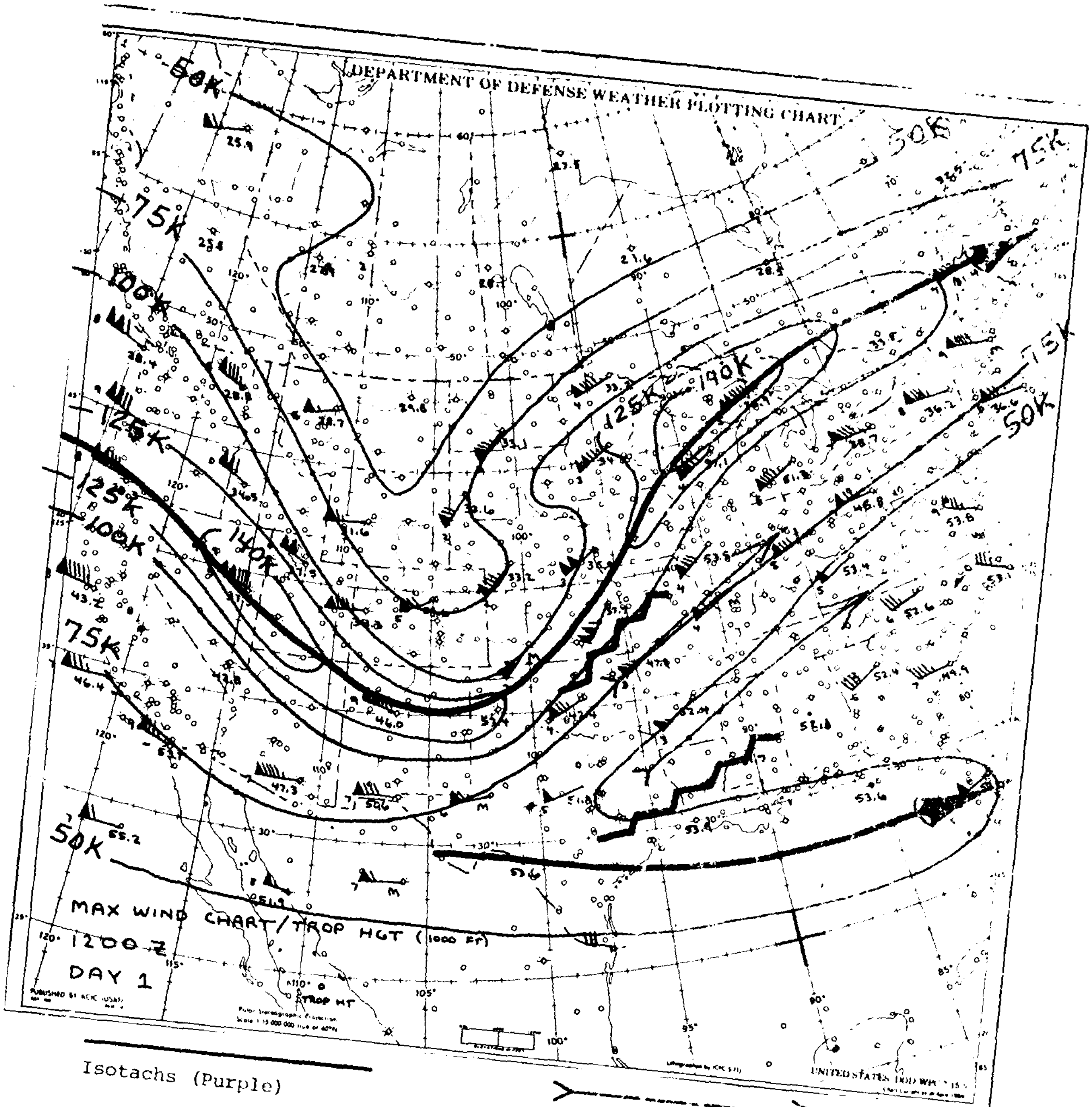
values greater than 85 knots indicate strong activity.

2.6.5.2 Upper-level shear (over a 90 nm horizontal distance)

Values less than 15 knots are weak,

values between 15 and 29 knots are moderate, and

sear values greater than 30 knots are strong.



Isotachs (Purple)

Streamlines (Purple)

Identification (On Composite)

Difluence (Purple) (On Composite)

Maximum Wind Core (Purple) (On Composite)

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Maximum Wind Band (Jet) (Purple) (On Composite)

Figure 16. Maximum Wind Analysis.

2.7 Upper-air composite. All the significant parameters discussed and indicated in Figures 4, 8, 12 and 15 are placed on the same chart (reference Figure 17). The primary purpose of this composite chart is for comparison of the predominant patterns with known severe weather patterns. Surface fronts, squall lines, and lows from the continuity chart for the upper-air data-base time (00/12Z ± 3 hours) should also be indicated on this composite chart for use in short-range forecasting by extrapolation.

2.8 12-hour pressure change analysis (surface). On the surface 12-hour pressure change chart, pressure falls are used more extensively than the pressure rises.

2.8.1 Both pressure rises and falls should be analyzed. The axis connecting the maximum rise center to the maximum fall center will assist in making a short-range extrapolation prognosis of the movement of a significant low pressure center.

2.8.2 In most productive severe weather situations, a concentrated area of pressure falls appears to be more significant than a widespread area. A pressure fall area indicates many changes in the parameters discussed, especially those at lower levels (850 mb).

2.8.2.1 Movement and shape of an area of falls provide clues to probable areas of maximum low-level convergence and changes in the low-level wind field. If the pressure falls extend, in an elongated shape, south of the warm front and east of the cold front a low-level jet is most likely transfering warm, moist air northward in this region.

2.8.2.2 Location of falls will indicate the direction a surface low is moving.

2.8.2.3 Used in conjunction with other clues, the falls also may indicate temperature and moisture advection.

2.8.3 Use the following values of 12-hour surface pressure falls as intensity indicators:

Less than 1 mb is weak,

values from 1 to 5 mb indicate moderate activity, and

values greater than 5 mb indicate strong activity.

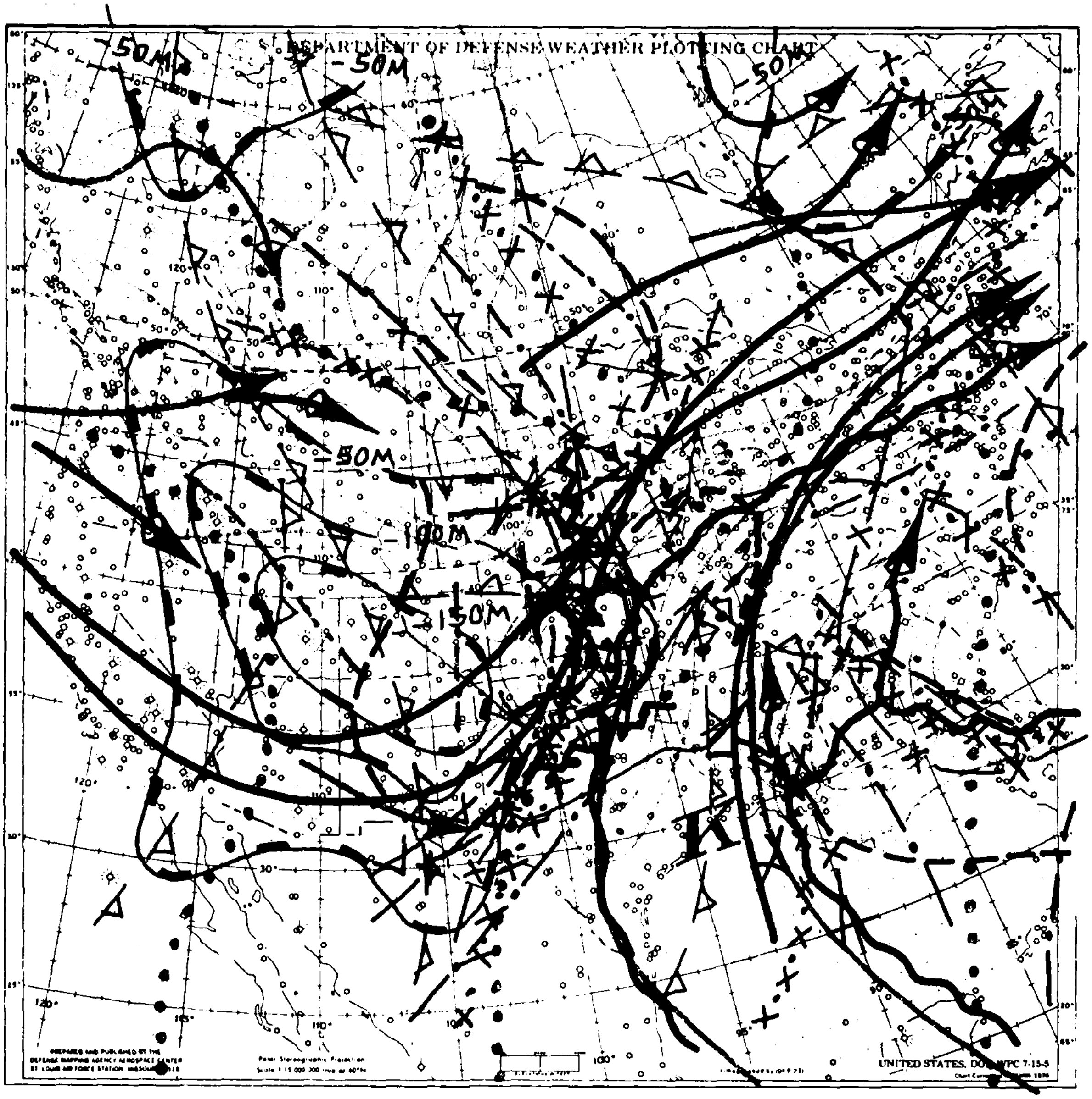


Figure 17. Upper-air Composite Analysis.

2.9 Surface Analysis. This chart, probably the most significant tool routinely available, is received more frequently and has the densest reporting station network of any available. The color-coded symbols shown in Figures 18 through 21 are used in the completed analysis shown in Figure 22. (Optional symbols and their color codes may be transferred to the composite analysis).

In this memo, fronts will not be defined rigidly. Emphasis instead will be on discontinuity lines. The following is a list of discontinuities of interest to the severe weather forecaster·

Temperature	Surge lines
Dry lines	Convergence zones
Dewpoint	Squall lines
Pressure change	Fronts
Pressure troughs	

The analysis techniques outlined in the following subsections will assist in locating these discontinuities.

2.9.1 Step one (reference Figure 18). Analyze the surface pressure field. Isobars are drawn every 2 millibars, starting with an even value. When analyzing pressure, do not just draw isolines, but look for pressure troughs, highs, and lows. The fronts and some other discontinuity lines should be drawn coincident with the pressure troughs. The pressure trough is a discontinuity and is the first indicator that some other discontinuity may be near. There are many types of discontinuities that are of interest to the severe weather forecaster. The strength of a discontinuity depends on the isopleth gradient ahead of or behind the line of most evident change. Some discontinuity lines can not be found on the surface chart displayed in Figure 18; on any particular day some are present and some are not.

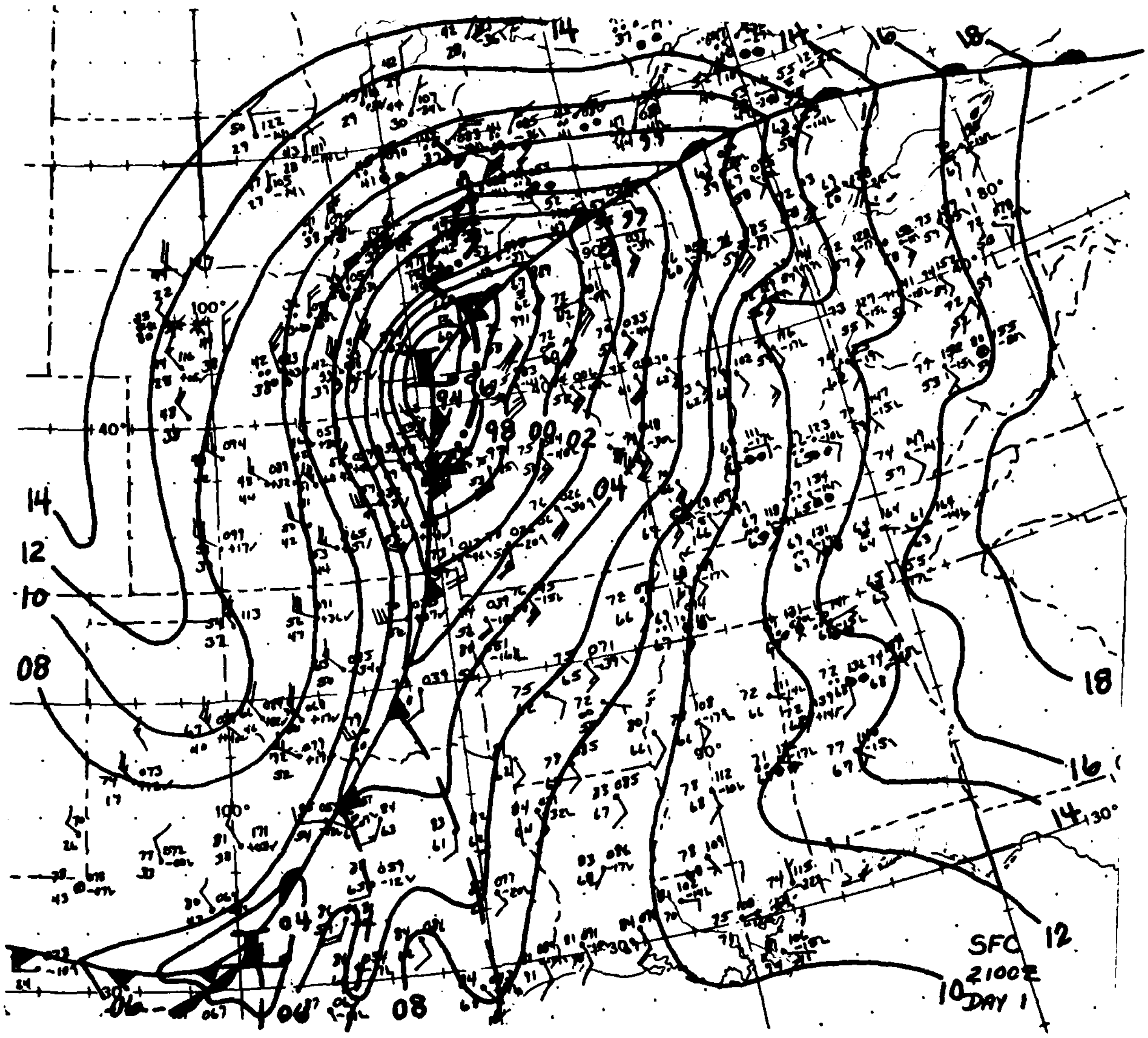
2.9.1.1 Temperature - A rapid change from cold to warm or warm to cold.

2.9.1.2 Dry line - A rapid change from moist to dry air or dry to moist air.

2.9.1.3 Dewpoint - Significant change from moist (dewpoint of 55° F or greater) to more moist or the reverse.

2.9.1.4 Three-hour pressure rises and falls - The pressure no-change line defines this discontinuity.

2.9.1.5 Pressure trough - Evaluate the pressure values along a line drawn normal to the axis of the pressure trough. The pressure decreases upon approaching the axis and then increases upon leaving it. The pressure trough axis defines the discontinuity.



Isobars (Black)

Dry Line (Brown)

Cold Front (Black)

Squall Line (Black)

Warm Front (Black)

L *H*

Low and High Pressure Centers (Black)

Pressure Trough (Black)

Figure 18. Isobaric Surface Analysis.

2.9.1.6 Surge line (wind) - The surge line indicates wind speed convergence, that is, an area of strong winds moving into an area of weaker winds. The leading edge of the stronger wind area is considered the discontinuity line. Such a discontinuity is commonly found along the lee slopes of mountain ranges and often accompanies an upper-air trough and cold advection aloft.

2.9.1.7 Convergence zone (vectorial) - The merging of winds with different directions is a convergence zone. An example is wind flow from the WSW-WNW merging with winds from the SSE-SSW. The angle at which they meet and the speed determines the strength of the convergence.

2.9.1.8 Squall line - A squall line is a first-order pressure discontinuity with thunderstorms along it. The squall line is a combination of two or more of the discontinuity lines already discussed. Strength of the squall line is determined by the number of coincident discontinuity lines. For a detailed description of squall line development, see Chapter 4 of AWSTR 200(Rev).

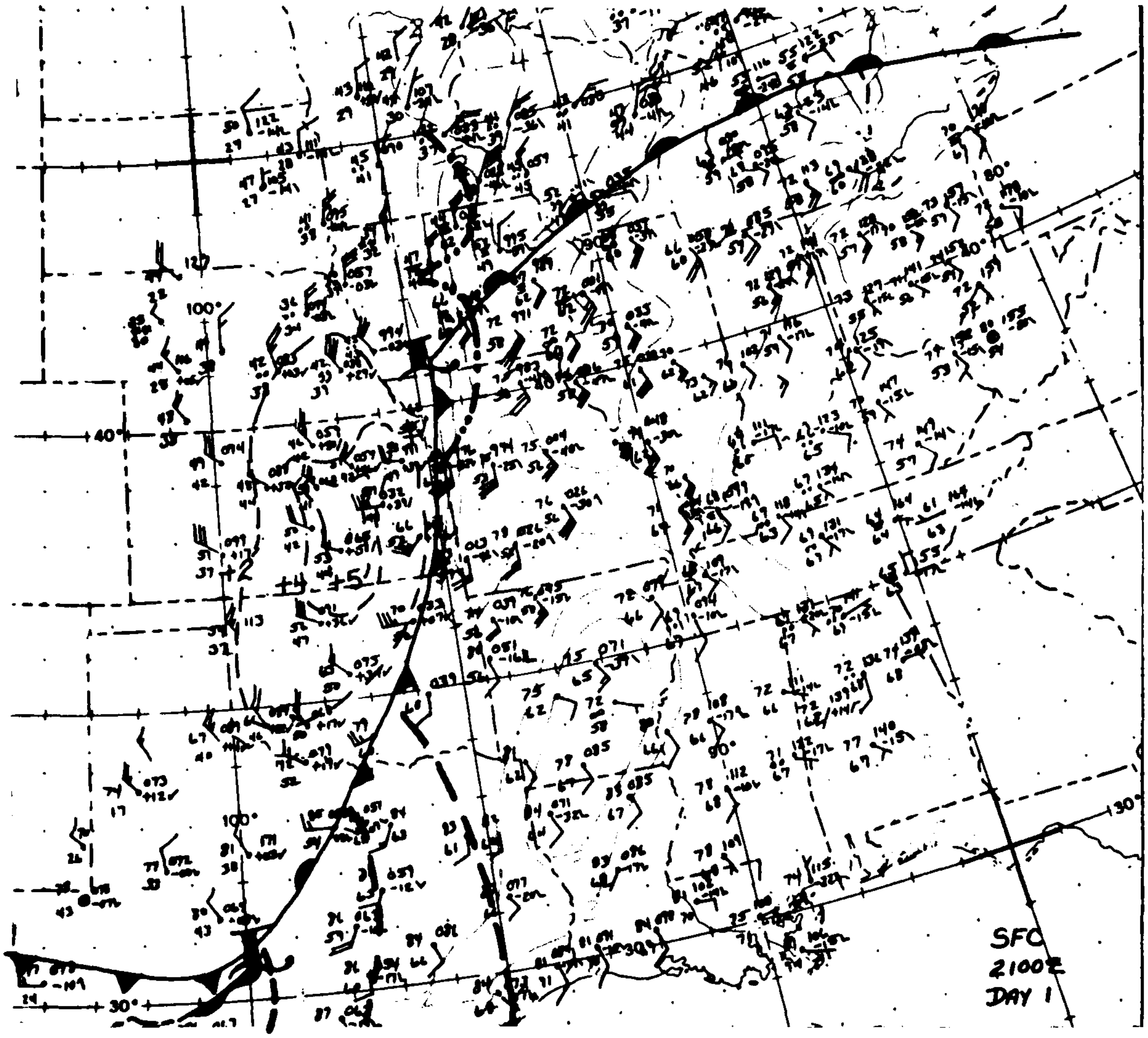
2.9.1.9 Front - This is also a special case of a discontinuity line. A front is a combination of two or more discontinuities (in order of importance): temperature, dewpoint, pressure trough, convergence zone, dry line, surge line, pressure change, squall line. An old squall line (that is, one in which the thunderstorms have dissipated) is often confused with a front.

2.9.2 Step 2. The standard weather symbols (in their designated colors) should be plotted where the weather is occurring. The weather will assist in properly locating some of the discontinuity lines.

2.9.3 Step 3 (reference Figure 19). The 3-hour rises and falls should be analyzed for significant values. The symbols and color codes are shown in Figure 19.

2.9.2.1 A combination of falls and rises will assist in determining the direction of movement of lows, highs, and discontinuity lines.

2.9.2.2 Falls will assist in locating areas of moist and/or warm advection.

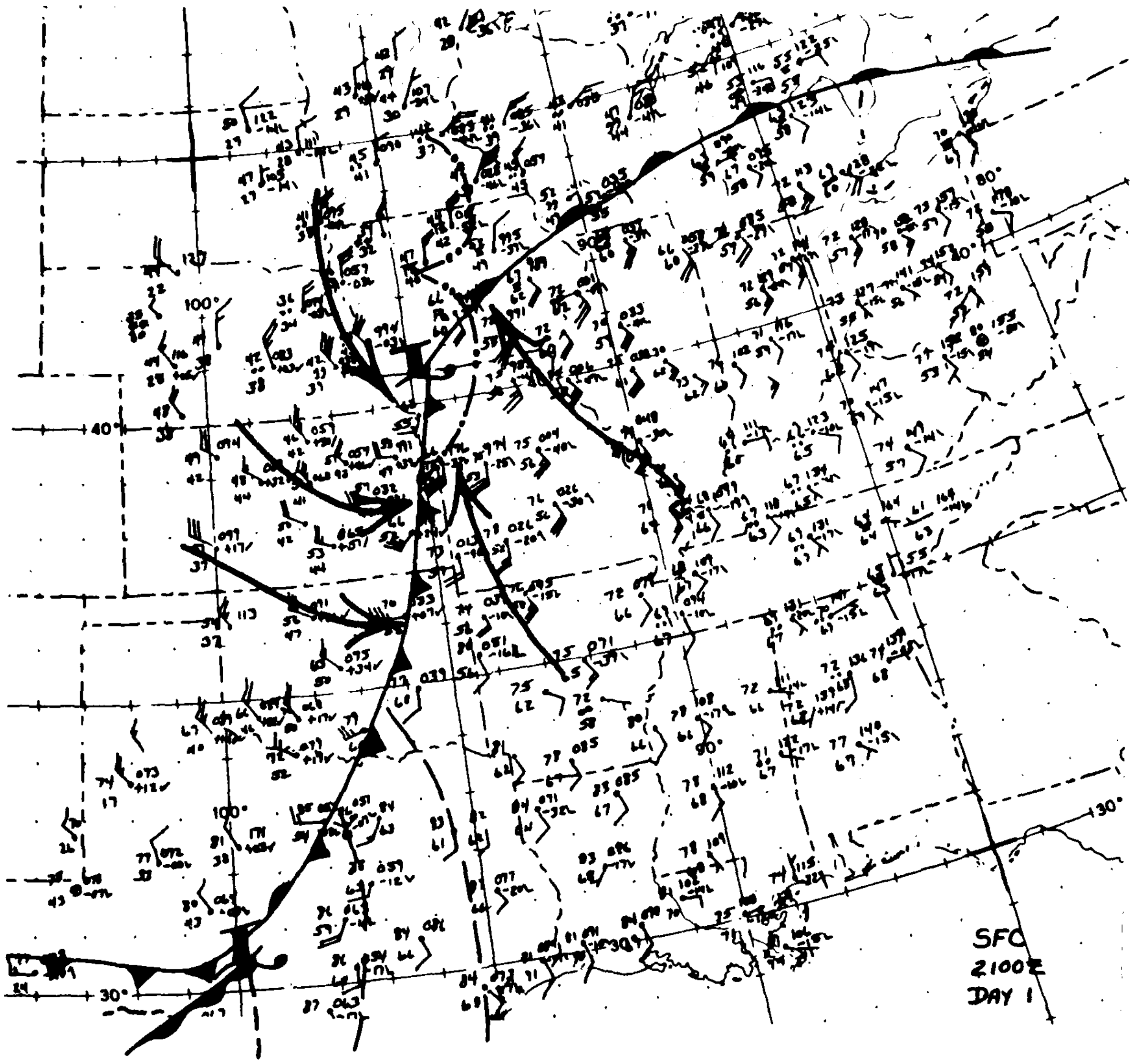


Significant 3-hour Pressure Falls (Orange)

Significant 3-hour Pressure Rises (Blue)

Figure 19. Isallobaric Surface Analysis.

2.9.4 Step 4 (reference Figure 20). Significant streamlines should be drawn to highlight the maximum convergence area and, in many cases, assist in locating the maximum wind band at lower levels. The symbols and color code are indicated in Figure 20.



Significant Streamlines (Red)

Figure 20. Surface Streamline Analysis.

2.9.5 Step 5 (reference Figure 21). The thermal and moisture analyses will help track the low-level thermal ridge, the axis of maximum moisture advection, and the axis of maximum moisture. Symbols and their color codes are shown in Figure 21.

2.9.4.1 Locating the thermal ridge is accomplished by picking an isotherm that will accurately depict the warmest air. When drawing these isotherms, remember to analyze for the thermal ridge.

2.9.4.1 In locating the axis of maximum moisture advection, start with the 55° F isodrosotherm (isopleth of dewpoint) and draw isodrosotherms at an interval that will adequately define the moist air. When analyzing the isodrosotherms, remember to look for the axis of maximum moisture advection.

2.9.6 All the different analyses accomplished in Figures 18 through 21 are done on the same chart. Figure 22 shows what the complete surface should look like.

2.9.7 Summarizing key parameter values and their intensities:

2.9.7.1 Dewpoint,

Values of 55° F or less indicate weak activity,

values between 56 and 64° F indicate moderate, and

values greater than 64° F indicate strong activity.

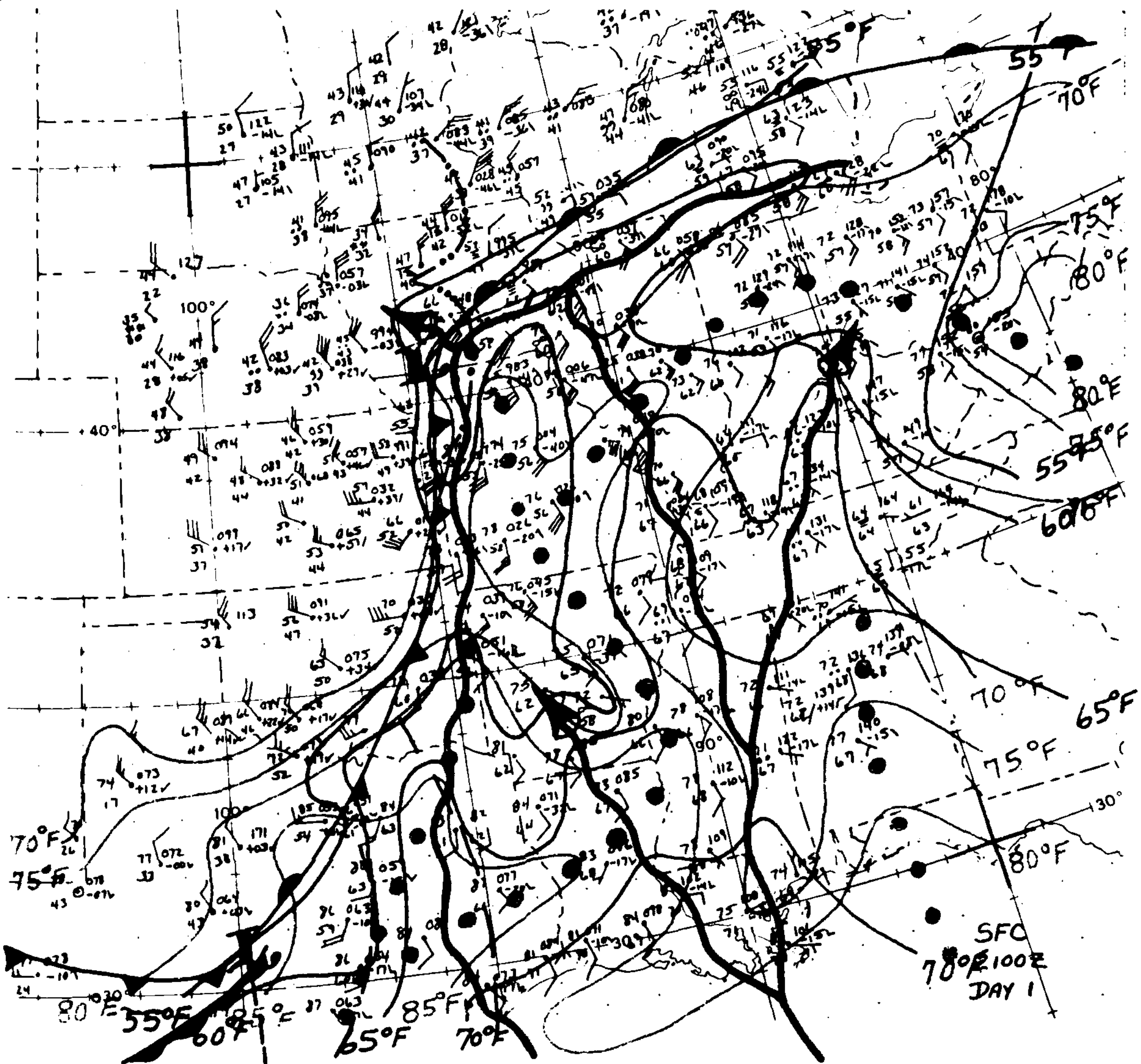
2.9.7.2 Lowest pressure in potential threat area,

Greater than 1010 mb indicates weak activity,

pressure between 1010 and 1005 mb indicates moderate, and

pressure less than 1005 mb indicates strong activity.

2.10 Summary. There are other charts which can assist in severe weather forecasting, but the ones described in this section will give a good foundation from which to work. The upper-air charts are available every 12 hours and should be analyzed as soon as possible. The surface chart, available every hour, should be analyzed at least once every three hours. When severe weather is occurring or expected to occur in the near future, surface charts should be analyzed every hour. When analysis proficiency is attained, interactions of primary parameters can be associated with the severe weather synoptic patterns.



Isodrosotherms (Green)

Axis of Maximum Moisture Advection (Green)

Axis of Maximum Moisture (Green)

Isotherms (Red)

Thermal Ridge (Red)

Figure 21. Surface Thermal and Moisture Analyses.

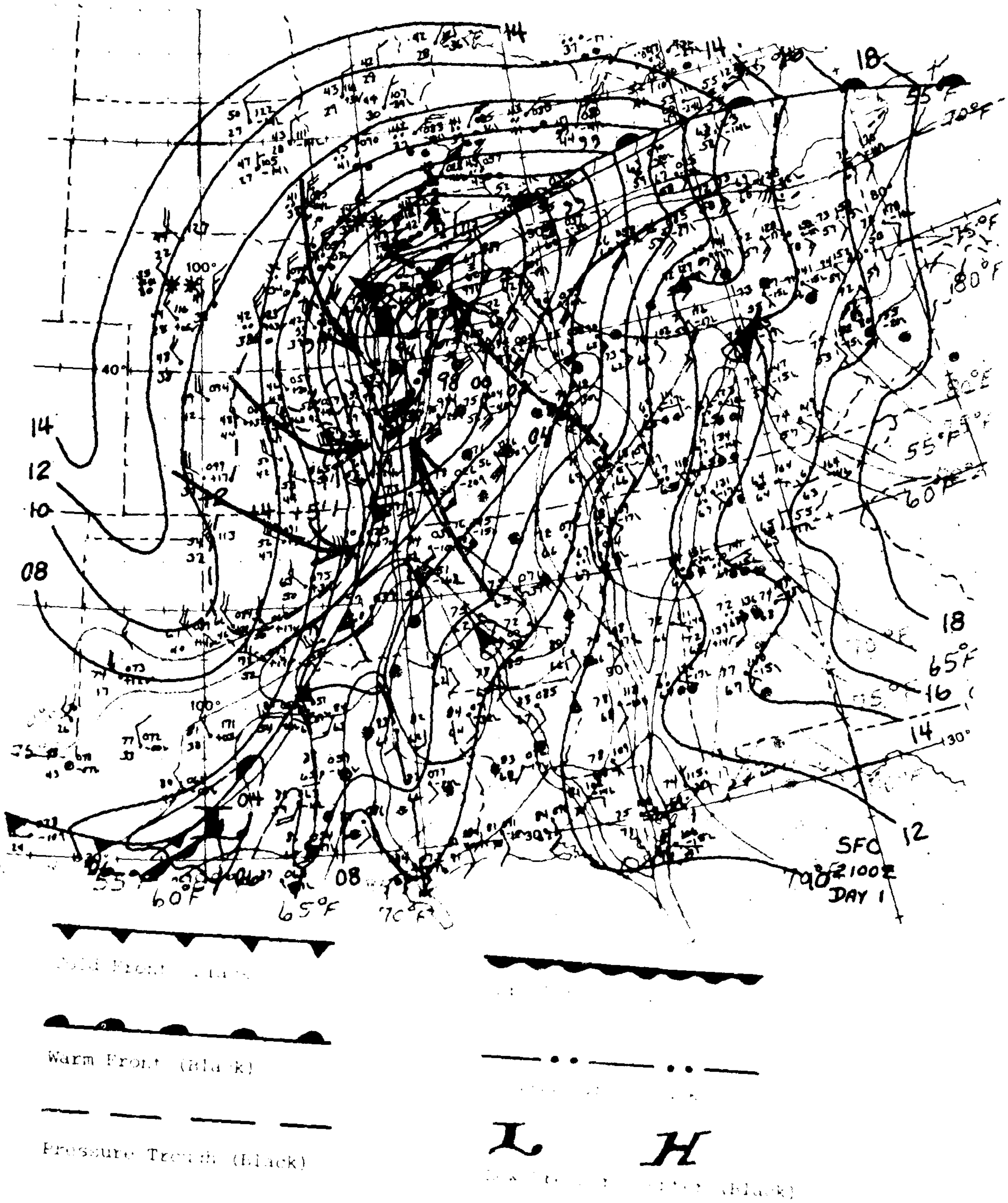


Figure 22. Completed Surface Analysis

3 SYNOPTIC PATTERNS

An outline of the synoptic patterns, as consolidated from the details presented in Chapter 3 of AWSTR 200(Rev), is included to highlight major characteristics of severe weather. This outline includes the distinguishing characteristics, initial outbreak location, severe weather area placement, secondary zone, triggering mechanism, convective development pattern, and duration of activity. Caution: Do not expect to see these classical patterns in all cases. Most of the severe weather occurrences are associated with combinations of two or more patterns or modifications of the classical pattern.

3.1 Pattern A: Dry-line Thunderstorms (Type 1 airmass).

3.1.1 Distinguishing characteristics:

3.1.1.1 A well-defined SW jet at 500 mb.

3.1.1.2 A warm, dry intrusion from the SW (surface to 700 mb).

3.1.1.3 An area of significant maximum moisture advection from the south (surface to 850 mb).

3.1.1.4 Considerable streamline convergence along the dry line (850 mb and 700 mb).

3.1.1.5 Very large hail, damaging winds, and tornadoes (most often in groups or families).

3.1.2 Initial outbreak location:

3.1.2.1 In the area of maximum moisture gradient between the dry air and the maximum moisture axis.

3.1.2.2 Usually confined to the edges of the dry air at 850 mb and 700 mb.

3.1.3 The severe weather area should extend along and 200 miles to the right of the 500 mb jet (in the area of difluence) and from the maximum low-level convergence downstream to the place where the low-level moisture decreases to a value insufficient to support severe weather.

3.1.4 The secondary severe weather area will be located along and 150 miles to the right of the 500 mb horizontal speed shear zone and from the low-level convergence downstream to the place where the low-level moisture decreases to a value insufficient to support severe weather.

3.1.5 The triggering mechanisms are maximum diurnal heating, low-level intrusion of warm, moist air, and/or upper-level jet maximum passage.

3.1.6 Convective development is characterized by unusually rapid growth (15 to 30 minutes) from inception to maturity with almost immediate production of large hail, damaging winds, and/or tornadoes.

3.1.7 The severe weather activity will normally last from 6 to 8 hours or until the mixing of moist and dry air masses is complete and the low-level winds diminish. Though rare, an exception to this guidance occurs when there is an unusually well-defined dry intrusion driven by strong winds (usually greater than or equal to 30 knots from the surface to 700 mb) which causes the severe activity to continue for a much longer time.

3.2 Pattern B: Frontal thunderstorms (Type 1 air mass).

3.2.1 Distinguishing characteristics:

3.2.1.1 A well-defined SW jet at 500 mb.

3.2.1.2 A dry intrusion from the SW (surface to 700 mb).

3.2.1.3 A low-level jet transporting significant moisture from the south (surface to 850 mb).

3.2.1.4 A major low pressure center with a cold and warm front.

3.2.1.5 Strong cold advection from the W-NW (surface to 500 mb).

3.2.1.6 Cool, moist air at the 700 mb and 500 mb cold trough axes. These troughs will lie immediately west of the threat area.

3.2.1.7 The tornado families are usually associated with mesoscale lows.

3.2.2 Initial outbreak location:

3.2.2.1 Look for initial activity along or just ahead of the surface cold front in the region of strong upper-air cold advection, strong low-level warm moist advection, and SW dry instrusion.

3.2.2.2 Location depends on the speed of the cold front and the dry surge into the moist air.

3.2.3 The severe weather area should extend along and 200 miles to the right of the 500 mb jet (in the zone of difluence) and from the dry intrusion to the place where the low-level moisture decreases to a value insufficient to support severe weather activity.

3.2.4 A secondary area may be located along and 150 miles to the right of the horizontal speed shear zone and from the dry intrusion to the place where the low-level moisture decreases to a value insufficient to support severe weather activity.

3.2.5 The triggering mechanisms are:

3.2.5.1 Intersection of the low-level jet (850 mb) with the warm front.

3.2.5.2 Intersection of the low-level jet (850 mb) with the 500 mb jet.

3.2.5.3 Movement of the dry-line (dry intrusion).

3.2.5.4 Intersection of discontinuity lines, particularly the special case of intersecting squall lines.

3.2.6 The convective development pattern is characterized by pre-frontal squall lines with one or more mesoscale lows (25 to 100 miles in diameter) that form at the intersection of the low-level jet (850 mb) and the 500 mb jet. Mesoscale lows will also form at the intersection of the low-level jet (850 mb and the warm front and in the area where two discontinuity lines intersect.

3.2.7 The severe activity can occur during all hours of the day or night, since it does not depend on diurnal heating to act as a trigger. This activity will continue as long as the air mass ahead of the squall line remains critically unstable. The Type B pattern is usually the last of a series of Type A severe weather producing systems.

3.3 <u>Pattern C: Frontal overrunning</u>.

3.3.1 Distinguishing characteristics:

3.3.1.1 A WSW-WNW 500 mb jet or a strong 500 mb westerly horizontal wind speed shear zone is present.

3.3.1.2 A dry intrusion from the SW is present at 700 mb.

3.3.1.3 An east-west stationary frontal zone is present with warm, moist tropical air overrunning it.

3.3.1.4 Isolated tornadoes may occur with surface temperatures of 50° F or higher. Widespread large hail and damaging winds may also be present.

3.3.2 Initial outbreak location:

3.3.2.1 Scattered thunderstorms develop on and north of the front as a result of overrunning.

3.3.2.2 Thunderstorm activity reaches severe limits as the squall line forms along the leading edge of the dry intrusion.

3.3.3 The severe weather (threat) area is delineated on the north side by the 500 mb jet and on the south side by the stationary front. The western boundary will be 50 miles west of the axis of maximum overrunning of moisture. The eastern boundary will probably depend on a decrease in the temperature lapse rate, a decrease in overrunning, or a combination of both.

3.3.4 There is no known secondary area of activity.

3.3.5 The triggering mechanism is the dry intrusion into the active thunderstorms produced by overrunning. If this dry intrusion is lost, the activity will decrease to an intensity less than severe.

3.3.6 Convective development patterns.

3.3.6.1 Overrunning thunderstorms are intensified by the dry intrusion.

3.3.6.2 Threat areas are favorable for the development of mesoscale lows and mesoscale highs. These mesoscale features move in a direction 30 degrees to the right of the 500 mb flow toward higher temperatures and lower pressures.

3.3.6.3 Intense pressure gradients are present around the mesoscale features.

3.3.6.4 Tornadoes occur either singly or by two's and three's separated by 25 to 50 miles.

3.3.6.5 This Type C pattern changes to Type E pattern if a well defined cold front accompanied by strong cold-air advection overtakes the active thunderstorm area.

3.3.7 Maximum activity occurs for 6 hours, starting at the time of maximum heating or when the dry intrusion enters the active area. Life of the dry intrusion and the mesoscale system also determine the life of the severe activity.

3.4 Pattern D: Cold-core Tornadoes.

3.4.1 Distinguishing characteristics:

3.4.1.1 The 500 mb jet is more southerly than in the other patterns.

3.4.1.2 The surface low will be deepening with cool, dry air advection at all levels around the bottom of it.

3.4.1.3 The low-level jet transports warm, moist air from the SSE toward the north and under the cold air aloft.

3.4.1.4 There is a 500 mb cold-core low present.

3.4.2 The initial outbreak location is found in the warm, moist underrunning air between the 500 mb jet and the cold closed isotherm center at 500 mb.

3.4.3 The severe weather area extends from approximately 150 miles to the right of the 500 mb jet to the cold core low center and from the intense low-level convergence ahead of the dry intrusion (SW boundary) to the east or northeast limit of the underrunning unstable warm, moist air.

3.4.4 There is no known secondary zone.

3.4.5 Triggering mechanisms are the intense low-level convergence and increasing instability caused by the 500 mb cold-air advection over the low-level warm moist advection.

3.4.6 Convective development characteristics:

3.4.6.1 Widespread storms produce hail of increasing amount and size westward from the jet to the 500 mb cold-core low.

3.4.6.2 Numerous funnel clouds occur, but tornadoes seldom occur. When they do, they occur singly and not in families.

3.4.7 The most violent storms occur between noon and sunset when warm, moist air is most unstable by virtue of maximum low-level heating. Weaker storms may occur at any hour, however, the intensity of the storms decreases rapidly after sunset.

3.5 Pattern E - Squall line.

3.5.1 Distinguishing characteristics.

3.5.1.1 A well defined westerly jet is present at 500 mb.

3.5.1.2 A dry source is well defined by the 700 mb warm sector.

3.5.1.3 A south to southwest low-level flow pattern carries warm moist air into the area.

3.5.1.4 The warm, moist air overruns cooler air (usually a warm front).

3.5.1.5 There is considerable low-level convergence and a squall line forms in all cases.

3.5.2 The initial outbreak location is where the 700 mb dry air intrusion meets the frontal lifting of warm, moist low-level air and the strong 500 mb cold advection.

3.5.3 The severe weather area extends along and south of the 500 mb jet but north of the 850 mb warm front and from the 700 mb cold front to the place where instability decreases to a value below the minimum required to support severe activity.

3.5.4 If the 700 mb dry intrusion is strong enough to extend well to the south of the 850 mb warm front, the secondary zones may occur along the 500 mb horizontal speed shear zone and along transitory, but active, squall lines.

3.5.5 The triggering mechanisms are frontal lifting, cold advection at 500 mb, diurnal heating, and the 700 mb dry intrusion.

3.5.6 Convective development pattern.

3.5.6.1 The frontal or pre-frontal squall line is almost always well defined.

3.5.6.2 The timing of the 500 mb cold advection and its intensity are difficult to forecast.

3.5.6.3 Many severe thunderstorms continue until midnight, or until the air mass becomes too stable to produce severe activity.

3.5.7 The maximum severe activity (both quantity and intensity) occurs from the time of maximum heating until a few hours after sunset.

3.6 Conclusion. It is imperative that the forecaster know how the various severe weather parameters, outlined in Section 2, interact to produce severe weather. The first step toward the accomplishment of this is the understanding of the idealized severe weather synoptic patterns outlined in this section. After this understanding has been achieved and experience gained, the forecaster will begin to see how the day-to-day synoptic patterns deviate from the idealizations and at times combine to produce somewhat more complex severe weather patterns.

4 SHORT-RANGE PARAMETER FORECASTING

4.1 The short-range parameter forecasting method to be described here is only one of many methods of prognostication. The description of any step-by-step method is demonstrated well by example. The analyses shown in Figures 1 through 22, the surface continuity chart (Figure 23), and the 0000Z upper-air composite prognosis (Figure 24) will be used to help describe the method. For severe weather to occur many parameters of moderate to strong intensity must occur, in the same place at the same time. A description of what constitutes a weak, moderate, or strong parameter can be found in Chapter 5 of AWSTR 200(Rev). These descriptions will be used to evaluate the analyses and prognoses of the following example. In order to summarize the shortrange forecast method and to show the importance of the parameter intensities, the thought processes which should be followed when producing a severe weather area forecast are described. The forecast area is shown in Figure 24, and the actual reports of severe weather (from STORM DATA, see reference 2) are shown in Figure 25. The forecast area superimposed on the severe weather reports and the reports themselves are for the period 2100Z on 9 Nov 75 to 0300Z 10 Nov 75.

4.2 The short-range parameter forecast, in most cases, is directly related to the movement of surface lows and discontinuity lines, especially fronts and squall lines. The surface system is used because it is available each hour. Positions of the various upper-air parameters must be inferred by vertical consistency.

4.2.1 Various methods are used to forecast the movement of surface systems. The example described here uses a combination of continuity and an empirical movement rule. In the latter the 500 mb wind direction and 40 to 50% of the 500 mb wind speeds are used.

4.2.1.1 Movement of the surface system may be determined by continuity. This essentially means that the system will continue to move as it has in the past (reference Figure 23). Care should be taken in using this method. If the surface system is not well developed, continuity may be unreliable and some other method should be employed. Continuity should never be used alone. Consideration must always be given to possible changes that may affect the surface system's movement and intensity.

4.2.1.2 The empirical rule using the 500 mb flow as the steering and driving mechanism for surface-based systems works well for an organized dynamic system. However, consideration must be given to changes in the vertical stacking of the system (especially with developing systems). Thought must also be given to changes that may occur in the 500 mb flow pattern. These changes will affect the development and steering of the surface system.

4.2.2 One method of upper-air parameter forecasting is the use of vertical consistency (stacking) of upper-air parameters relative to the

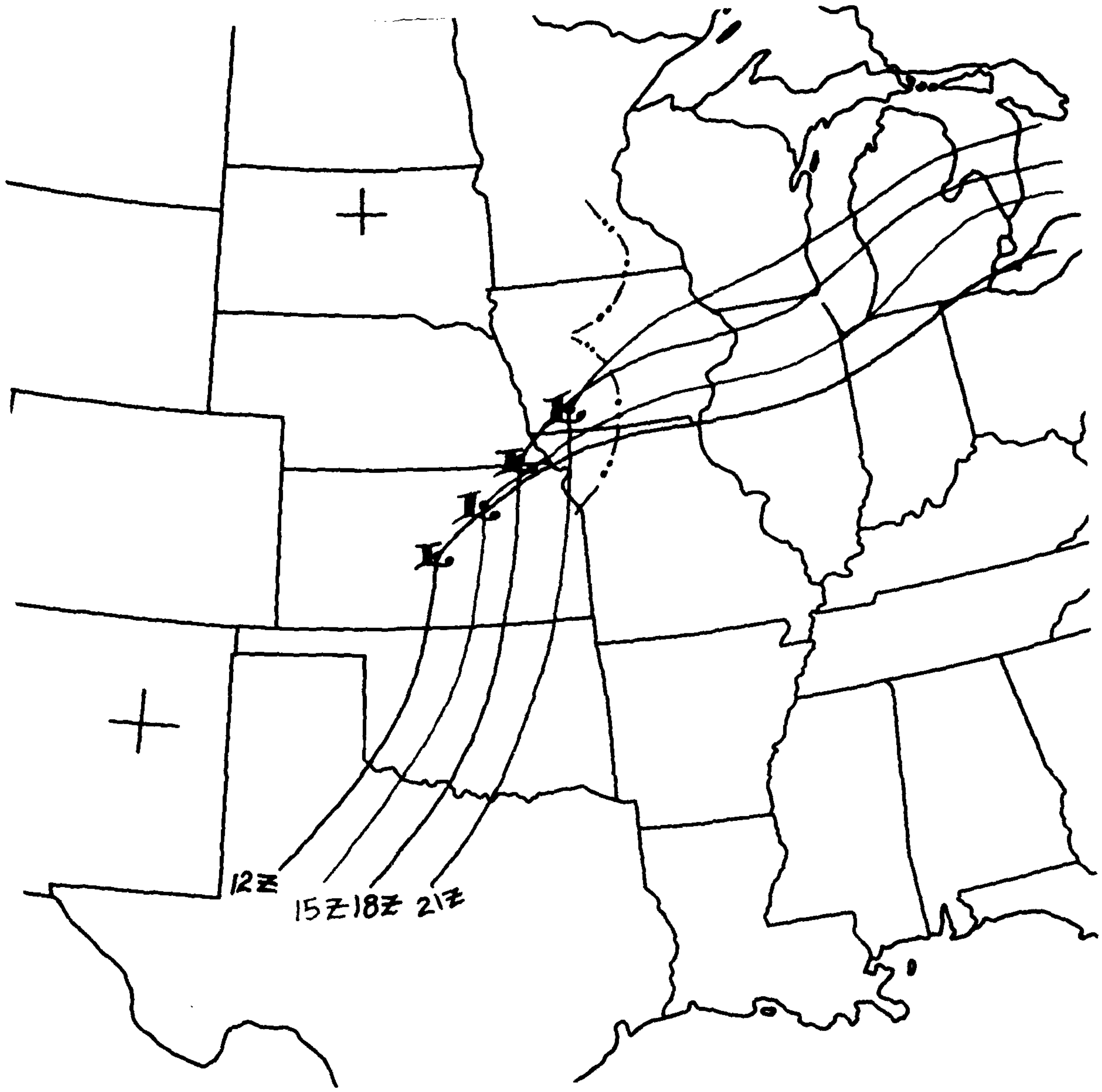
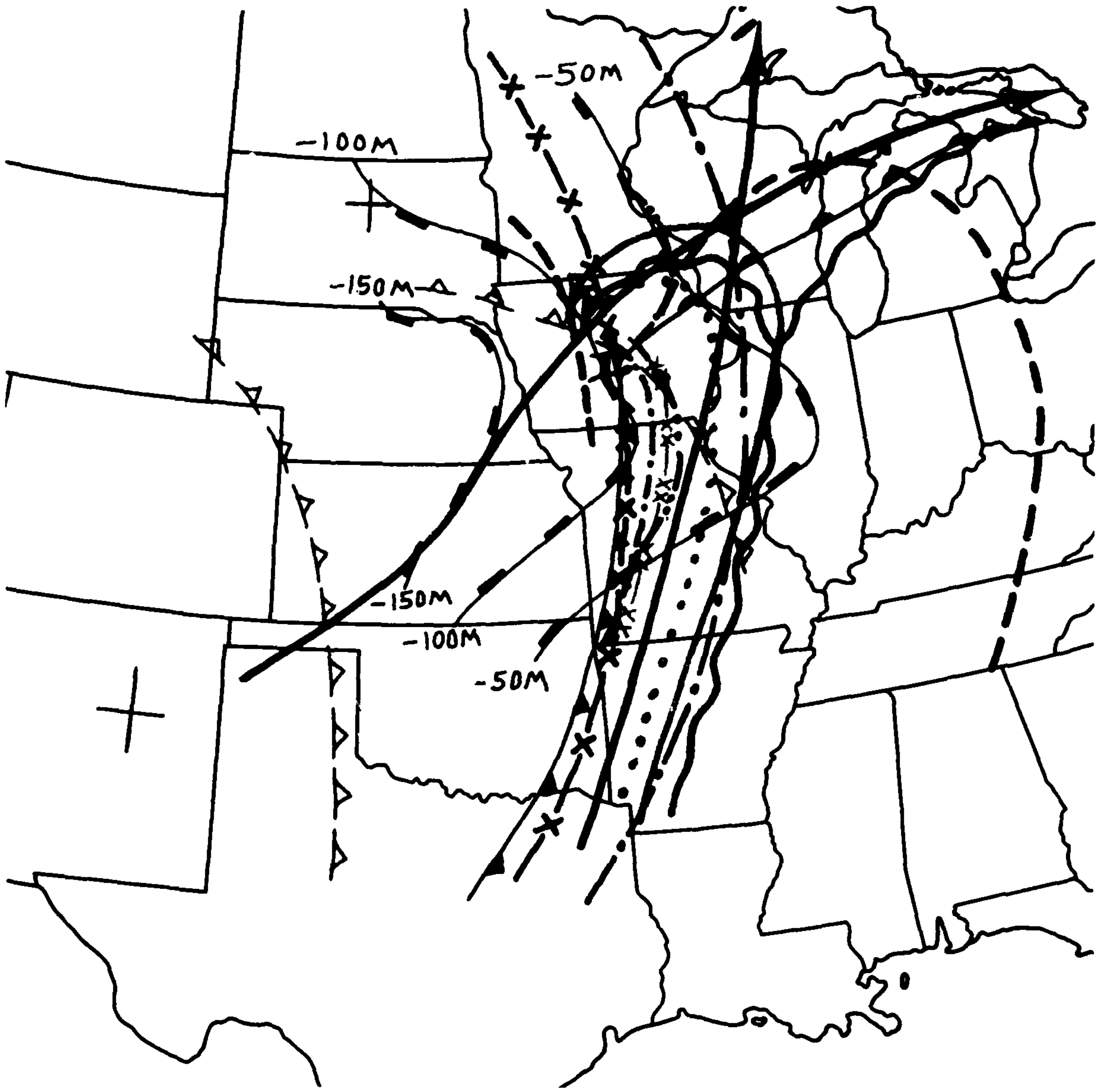
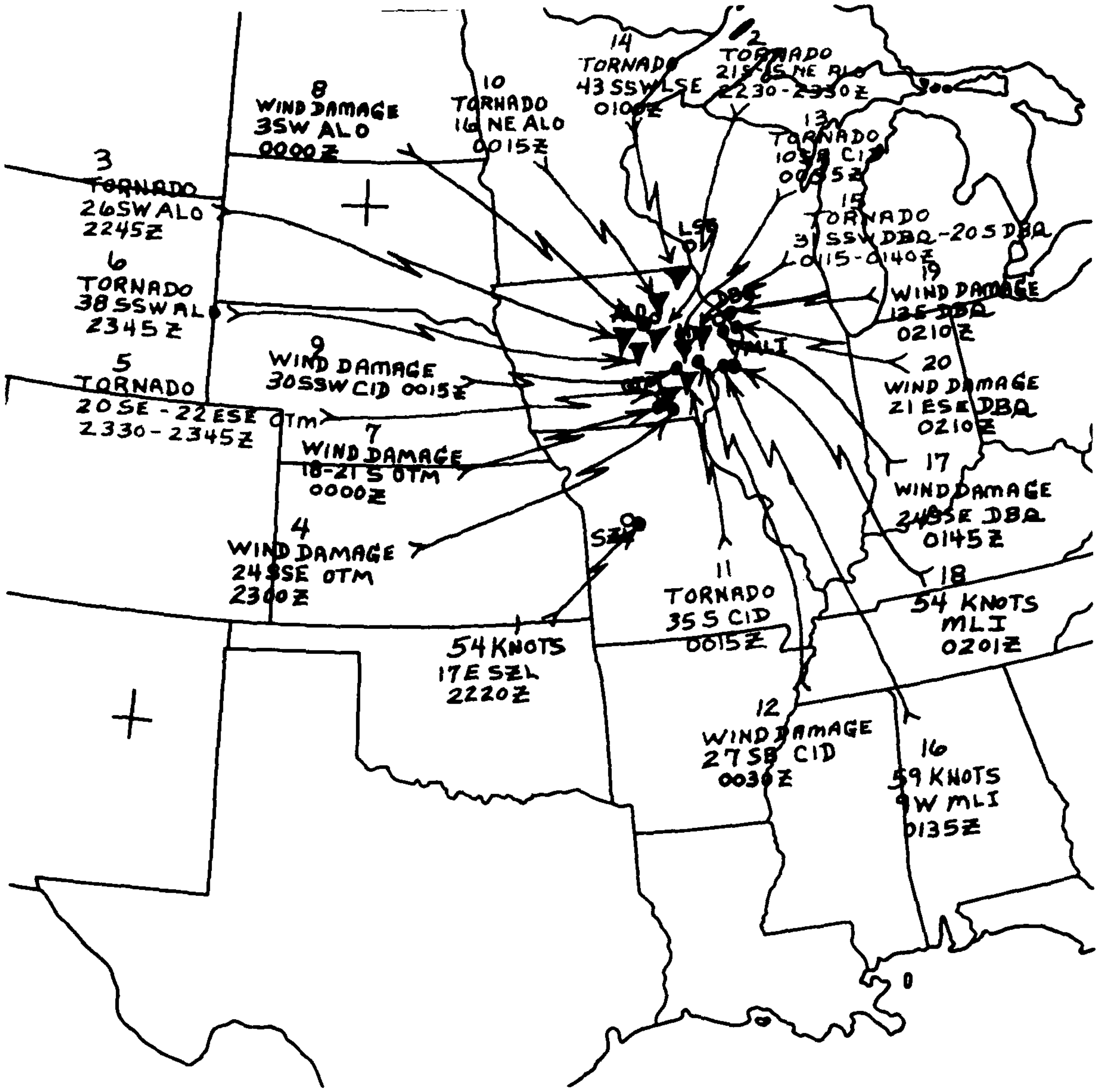


Figure 23. Surface Continuity Chart.



Threat Area

Figure 24. 12-hr Composite Prognostic Chart (Valid 0000Z 10 Nov 75).



Threat Area (Yellow)

Figure 25. Severe Weather Reports 2100Z 09 Nov 75 to 0300Z 10 Nov 75 (From Storm Data).

surface system.

4.2.2.1 The first step in this procedure is to locate accurately the surface system (low and any discontinuity lines, especially the fronts and squall lines). This location is done by completing an accurate surface analysis with consideration given to the vertical stacking of the system (850 mb isotherm packing, stacking of the upper-air height contour troughs, and relationship to the jet stream).

4.2.2.2 The second step is to analyze the upper-air charts (850 mb, 700 mb, 500 mb, 850/500 mb thickness, and the maximum wind) for the desired parameters outlined in Section 2. The positions of the upper-air parameters should then be related to the position of the surface low and any discontinuity lines, especially fronts and squall lines. This can be done for the example here by using the 1200Z surface position from the continuity chart (Figure 23) and relating the positions of the parameters from the upper air composite analysis (Figure 17) to that of the surface system.

4.2.2.3 The third step is to forecast the position of the surface system for the midpoint (0000Z) of the forecast period and then position the upper-air parameters relative to the surface system (as was also done in the composite analysis - step 2). Changes expected in the vertical stacking of the parameters should be considered. The combination of the forecast surface system position and the vertical stacking of the upper-air parameters relative to the surface system produces a severe weather composite prognosis.

4.3 Having completed surface and upper-air composite prognoses, the forecaster is ready to determine the severe weather threat area. This is accomplished by comparing the interaction of surface and upper-air parameters, shown on the composite upper-air and surface prognosis (Figure 24), with the five tornado-producing synoptic patterns (reference Setion 3 of this memo and Chapter 5 of AWSTR 200(Rev).

4.3.1 After comparing the interaction of parameters on the composite prognosis (Figure 24) to the synoptic patterns, the forecaster will see two synoptic patterns that this composite prognosis resembles. These two are the synoptic Type B and C patterns. The forecaster must now resolve the differences between the two threat areas (areas of potential severe weather or strong thunderstorms) and indicate one area for the final evaluation. The ideal combination of these two threat areas is shown in Figures 24 and 25. In this example the 500 mb jet was used for one side, the active squall line (at 2100Z) for the west side, and a line 200 nm to the right of the 500 mb jet for the third side. Finally, the eastern boundary was based upon the speed of movement of the system. Do not always expect to see the combination of synoptic patterns B and C to look just like this.

4.3.2 Once the threat area has been determined, the intensities of the interacting parameters are evaluated. This is done using the intensities described in Section 2 of this memo and Chapter 5 of AWSTR 200(Rev) and entering them on the Severe Thunderstorm and Tornado Parameter Worksheet (reference Figure 26 for the values determined for this example forecast). Once the values are assigned, an overall evaluation should be made to indicate the potential of the threat area. Because use of these intensities is subjective, the following is only a guide to determination of the potential of threat areas.

4.3.2.1 If a majority of the parameters on the worksheet are of strong or moderate intensity, then forecast severe thunderstorms or tornadoes.

Forecast RED (tornadoes accompanying severe thunderstorms) if most of the majority are strong.

Forecast BLUE (severe thunderstorms) if most of the majority are moderate.

4.3.2.2 If a majority of the parameters on the worksheet are of moderate or weak intensity then forecast moderate thunderstorms or general thunderstorms.

Forecast GREEN (moderate thunderstorms) if most of the majority are moderate.

Forecast ORANGE (general thunderstorm)activity if most of the majority are weak.

4.4 After all these evaluations have been completed, the final forecast can be prepared. In this example the majority of parameters considered were strong or moderate. Using this set of the majority, most were strong, consequently RED (tornadoes accompanying severe thunderstorms) is an appropriate forecast. It should be pointed out that an areal forecast such as this and any point warning issued by a centralized facility should be used as a guide to the local forecaster. The local forecaster, upon receiving a point warning, should neither ignore nor completely accept the warning but should immediately re-evaluate the potential for local severe weather using observations (such as radar) available to him locally. This additional information should be considered in light of the concepts presented here and in AWSTR 200(Rev).

SEVERE WEATHER AND TORNADO PARAMETER WORKSHEET						
Area: Eastern Iowa, NW Ill., Srn MN, and Nrn MO		Forecast valid time: 09/2100Z to 10/0300Z			Date: 09/10 Nov 75	
PARAMETER		1200Z Analysis		0000Z Prognosis.		Remarks/ Verification
		Value	Rating	Value	Rating	
500 mb Vorticity		Missing--	--------	--------	--------	
Stability	Lifted index	-6	S	-3	S-	
	Totals	56	S	52	M	
Middle Level	Jet	60-70 kt	S	60-70 kt	S	
	Shear	None----	--------	--------	--------	
Upper Level	Jet	100 kt	S	100 kt	S	
	Shear	None----	--------	--------	--------	
Low-level jet		55 kt	S	55 kt	S	
Low-level moisture		13.3	S	14	S	
850 mb maximum temperature field		West of moisture axis	S	West of moisture axis	S	
700 mb no-change line		Angle is 40-70 degrees	S	No change	S	
700 mb dry air intrusion		Angle is 60 deg 35 kt	S	No change	S	
12-hour surface pressure falls		Missing--	--------	5.9	S	
500 mb height change		Greater than 100 mb	S	Greater than 100 mb	S	
Height of the wet-bulb-zero above surface		Missing--	--------	--------	--------	
Surface pressure over threat area		999.9	S	994	S	
Surface dewpoint		63	M	63	M	

Figure 26. Severe Weather and Tornado Parameter Worksheet.

5 PARAMETER FORECASTING USING AUTOMATED MODEL OUTPUT

Section 2 discussed how the severe weather parameters were determined, Section 3 described how these parameters interacted to produce severe weather, and Section 4 developed a technique to forecast severe weather. Next, methods of using automated prognostic model output to forecast movements of these parameters will be examined. Any analysis of a chart is subjective since the forecaster must use imagination and skill in positioning the parameters. The forecast is also subjective because the forecaster depends on the subjective analysis and then must decide which prognostic model is handling the present synoptic pattern the best. The surface prognoses made by AFGWC and the NWS also provide guidance. The severe weather forecaster must constantly metwatch and update these prognoses during the day.

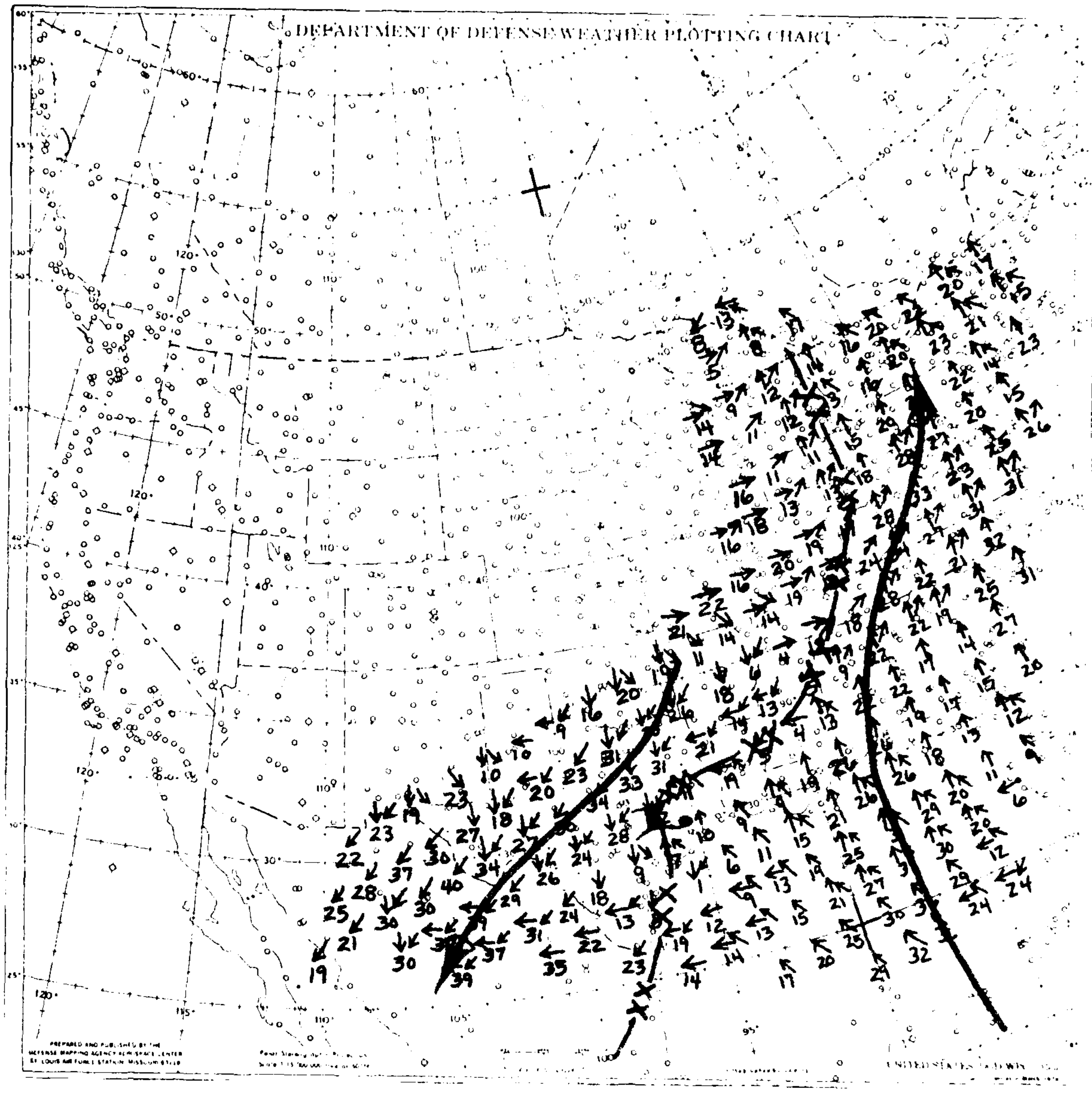
5.1 In making a composite prognosis, AFGWC's Boundary Layer Model (BLM) is used for the low-level wind, temperature, and moisture fields. The fine mesh model of AFGWC is used for the 500 mb thermal and wind fields. The automated SWEAT product, derived from output of these models, is used routinely by the advisory forecaster. By examining output from the same models as the automated program, the forecaster can see the weight placed on each parameter used to calculate the resulting SWEAT prognosis. For clarification of the parameters used to calculate SWEAT, see AWSTR 200(Rev), Appendix F. The example model output in this section <u>is not</u> for the same day as the analysis and prognosis discussed in Sections 2 and 4.

5.1.1 The BLM's 12-hour 600-meter (AGL) wind prognosis is used to locate the low-level convergence zones and the low-level jets (reference Figure 27).

5.1.2 The BLM's 12-hour 900-meter (AGL) temperature and dewpoint fields are used to locate the thermal ridge, low-level axes of maximum moisture and moisture advection (use the 600 meter fields to determine advection), and other significant moisture (reference Figure 28). This chart is analyzed much the same as the 850 mb analysis.

5.1.3 The AFGWC Fine-mesh 12-hour 500 mb prognosis isotherms must be analyzed to indicate cold pools and cold troughs. The wind field is examined to find the 500 mb jet, diffluence, and horizontal wind shear zone (reference Figure 29).

5.1.4 The BLM SWEAT prognosis (AFGWC) is an abbreviated composite prognosis presenting gridded SWEAT values larger than the threshold value of 250 (reference figure 30). Most of the parameters from the prognoses shown in Figures 27 through 29 are used to compute the significant values. Start with 300 (threshhold for severe thunderstorms) and draw for an interval of 100 (400 is the threshold for tornadoes). This prognosis should be used only for severe thunderstorm and tornado forecasting because it uses wind speed terms and a wind directional shear term. <u>Do not</u> use SWEAT for general thunderstorm forecasting.



L

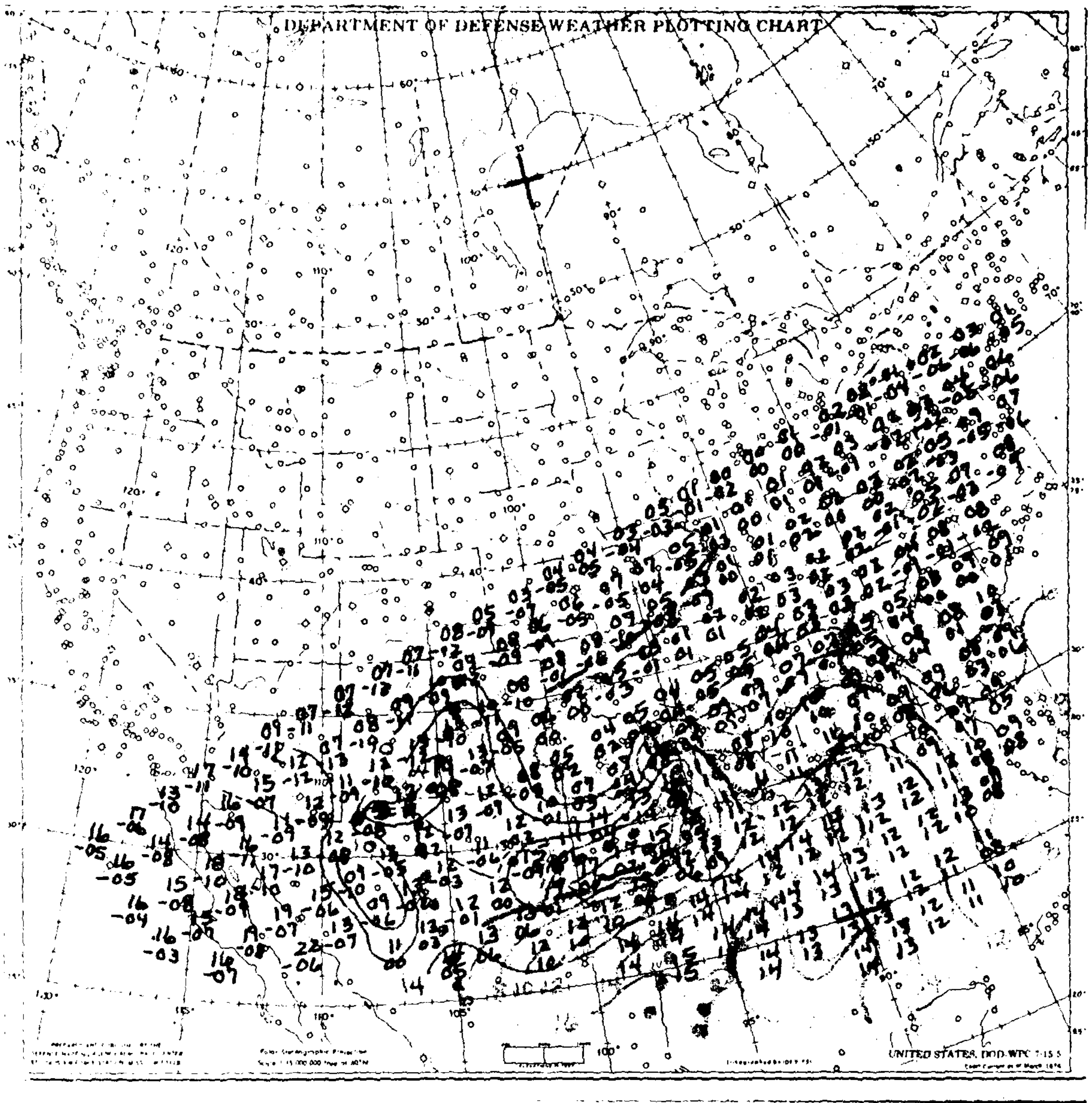
Cyclonic Circulation Center (Red)

——XX——XX——

Convergence Zones (Red)

Maximum Wind Band (Jet) (Red)

Figure 27. 600-m Wind Chart (12-hour Prognosis).

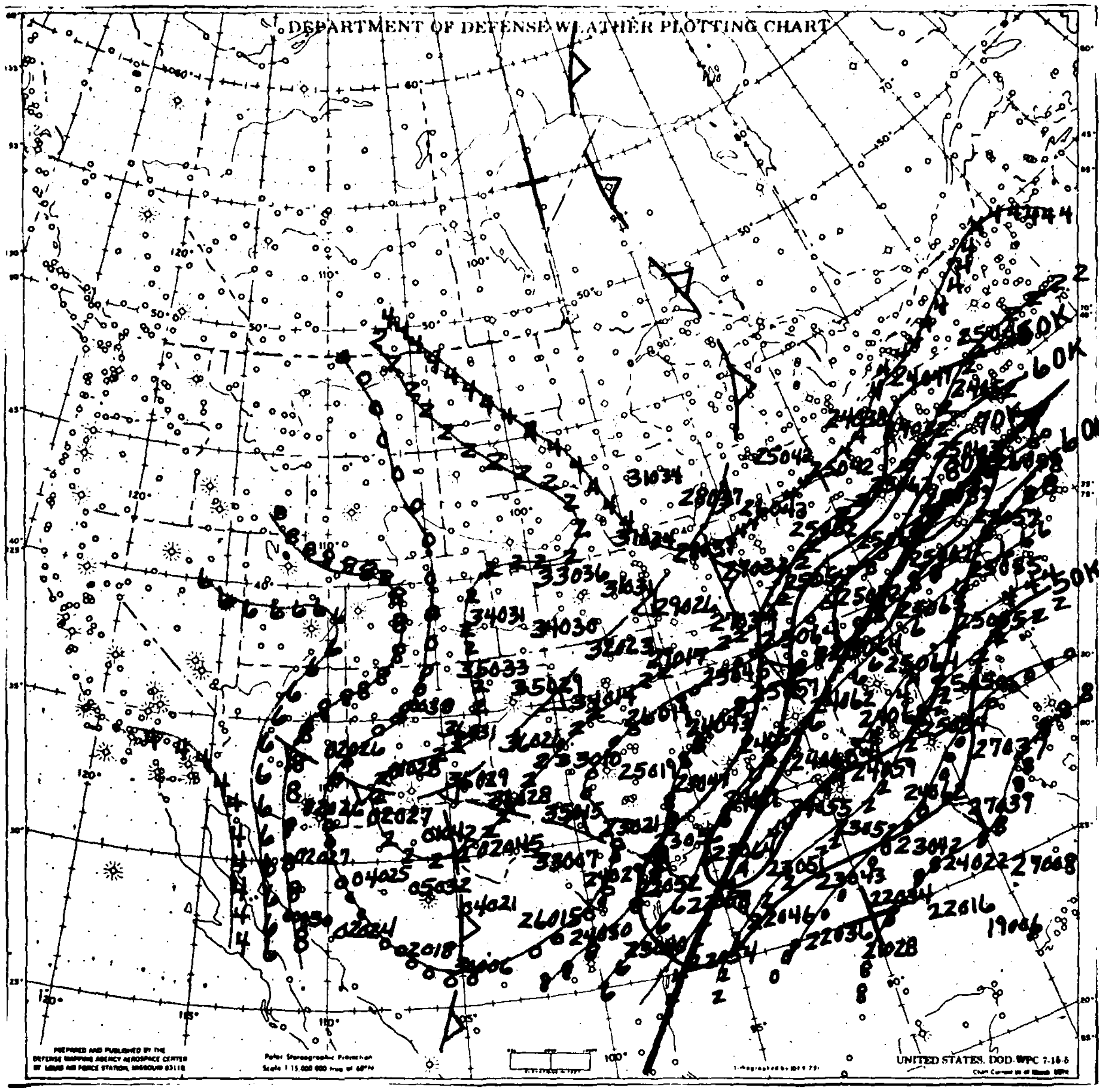


Thermal Ridge (Red)

Axis of Maximum Moisture Advection (Green)

Dry Line (Red)

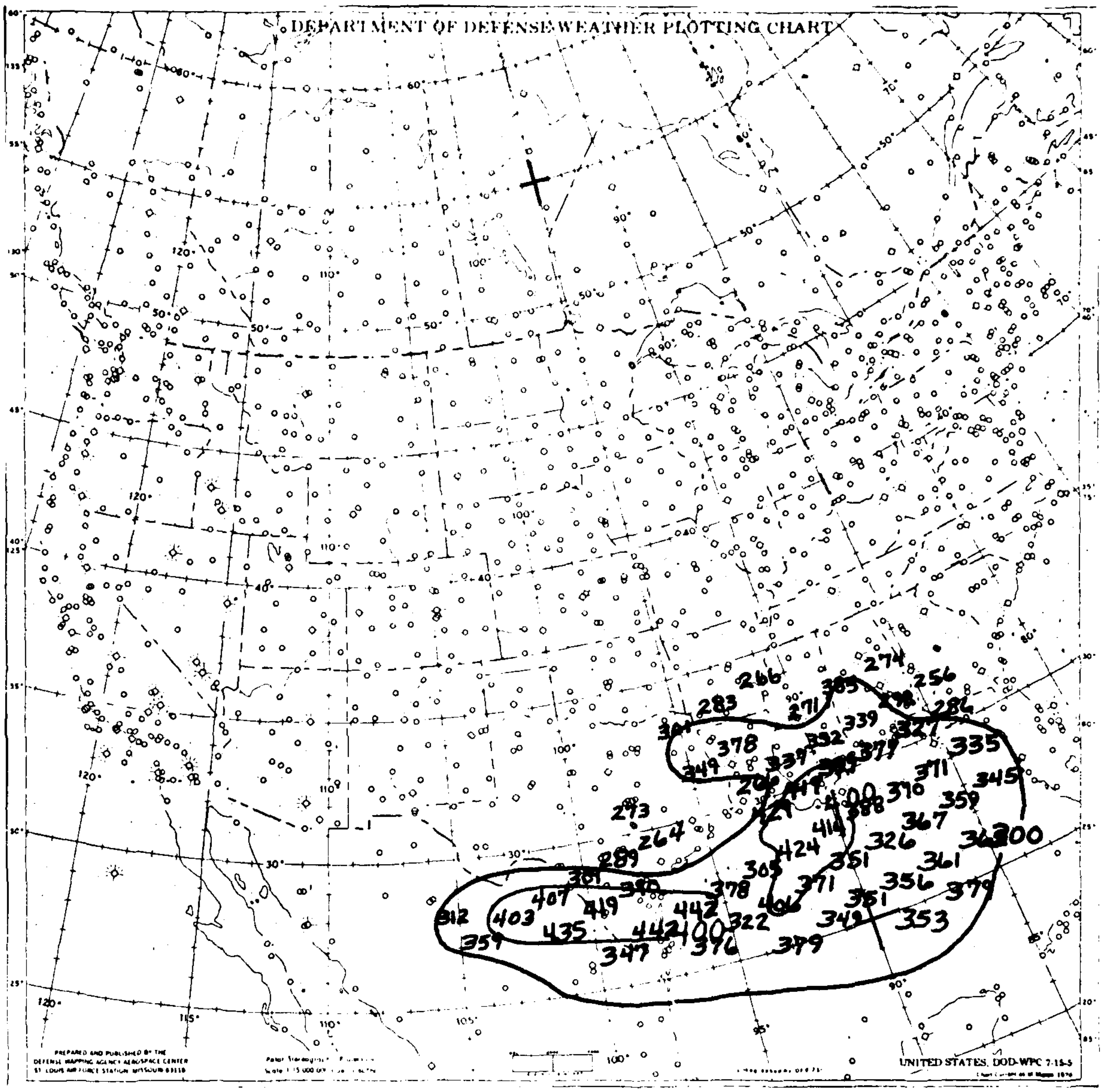
Figure 28. 900-m Temperature and Dewpoint Chart (12-hour Prognosis).



Thermal Troughs (Blue)

Maximum Wind Band (Jet) (Blue)

Figure 29. 500 mb Temperature and Wind Chart (1?-hour Prognosis).



300 SWEAT Values (Blue)

400 Plus Interval of 100 - SWEAT Values (Red)

These are both transferred to the composite prognosis in yellow.

Figure 30. BLM SWEAT Chart (12-hour Prognosis).

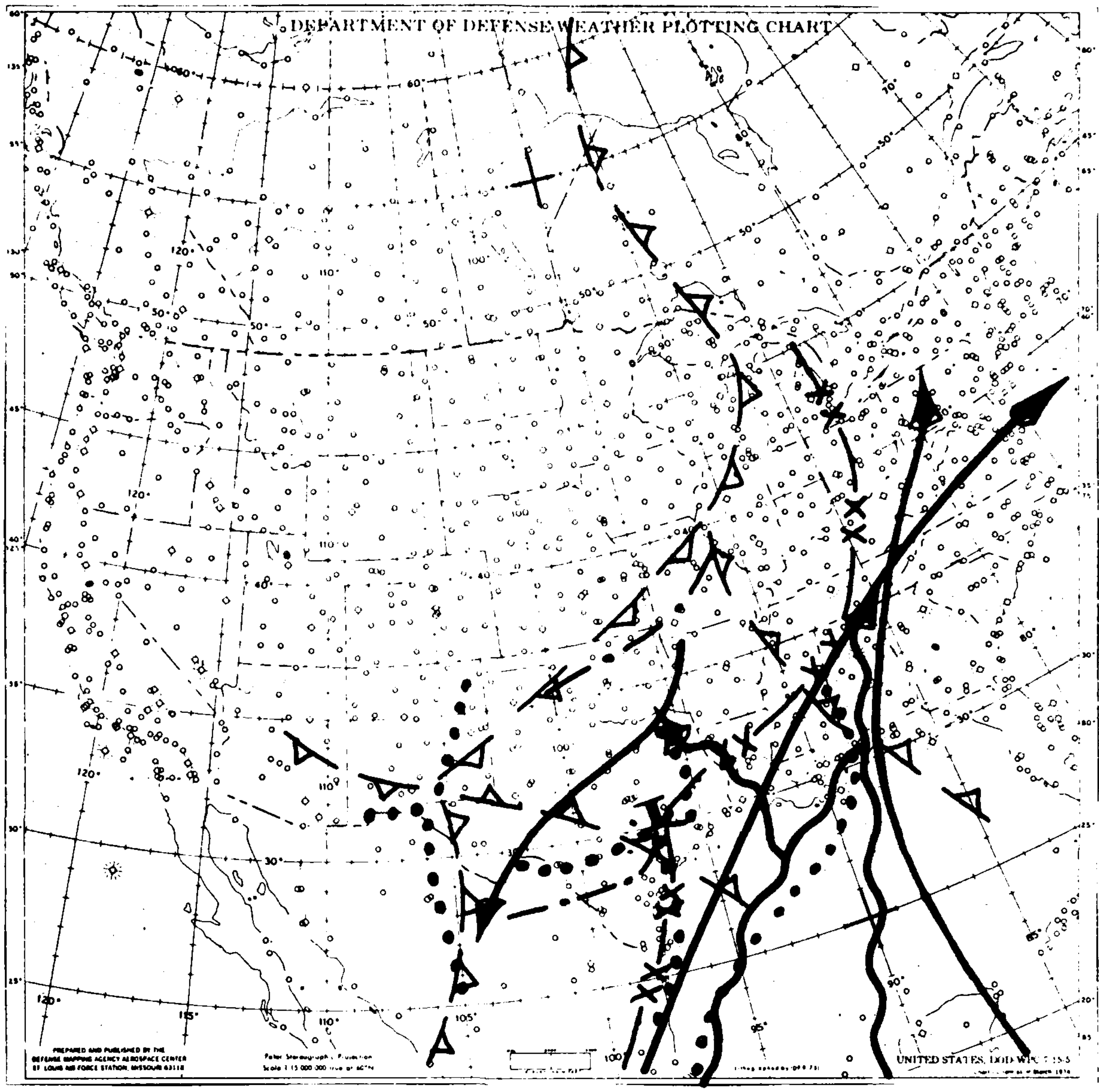


Figure 31. Composite Prognosis (12-hour Prognosis).

5.1.5 The 12-hour composite prognosis (Figure 31) should contain all of the parameters obtained from Figures 27 through 30 in the color codes indicated in each figure. The low-level dry lines may be obtained by relating Figure 27 to Figure 28.

5.2 The NWS 12-hour Limited-area Fine-mesh Model II (LFM II) forecast may be used to approximate the position of the major severe weather parameters for each level. A composite prognosis can be made from this product. The values for each parameter must be subjectively obtained by comparing the latest analysis with the prognosis.

5.2.1 The 500 mb height/vorticity panel (shown in Figure 32) is used to find the cold pools, cold troughs, jets, difluent zones, and PVA areas.

5.2.1.1 The cold pools are the vorticity centers and the cold troughs are the vorticity troughs. (Watch carefully for indications of minor short-wave troughs).

5.2.1.2 The jet should lie in the area of maximum packing of the height contours.

5.2.1.3 The difluent zones should be located where the contour gradient decreases rapidly.

5.2.2 The Mean Sea Level Pressure/1000-500 mb Thickness panel (MSL PRES/1000-500 THK) (shown in Figure 33) assists in locating fronts, convergence zones, low-level jets, the low-level thermal ridge, areas of maximum moisture advection, and the thickness ridge. The 500 mb panel and the thickness panel together aid in locating the area of maximum cold-air advection.

5.2.2.1 Generally, lows, fronts, and convergence zones lie in the 1000 mb pressure troughs. The fronts will also be indicated by thickness packing (behind a cold front and ahead of a warm front).

5.2.2.2 The low-level jets are located in the areas of strongest isobar packing. Consider the reduction of the effects of surface friction as you go aloft to assist with the direction of flow. Also consider vertical stacking when actually positioning the jet.

5.2.2.3 The low-level thermal ridge can be positioned by carefully considering its relationship to the position of lows, cold and warm fronts, convergence zones, low-level jets and the thickness ridge. Often the primary thermal ridge can be located just east of the low-level convergence zone.

5.2.2.4 Thickness contours will indicate the location of the thickness ridge axis.

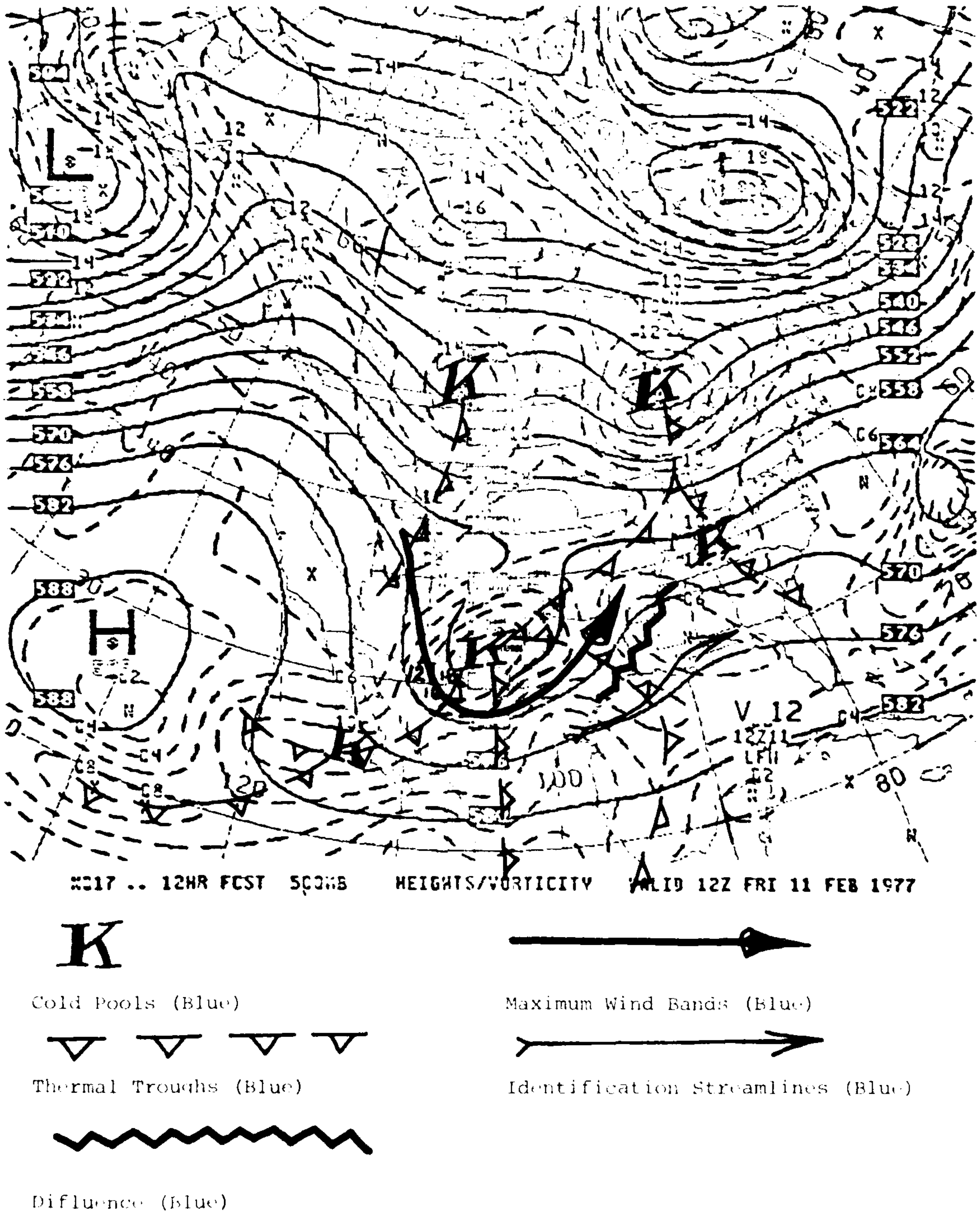
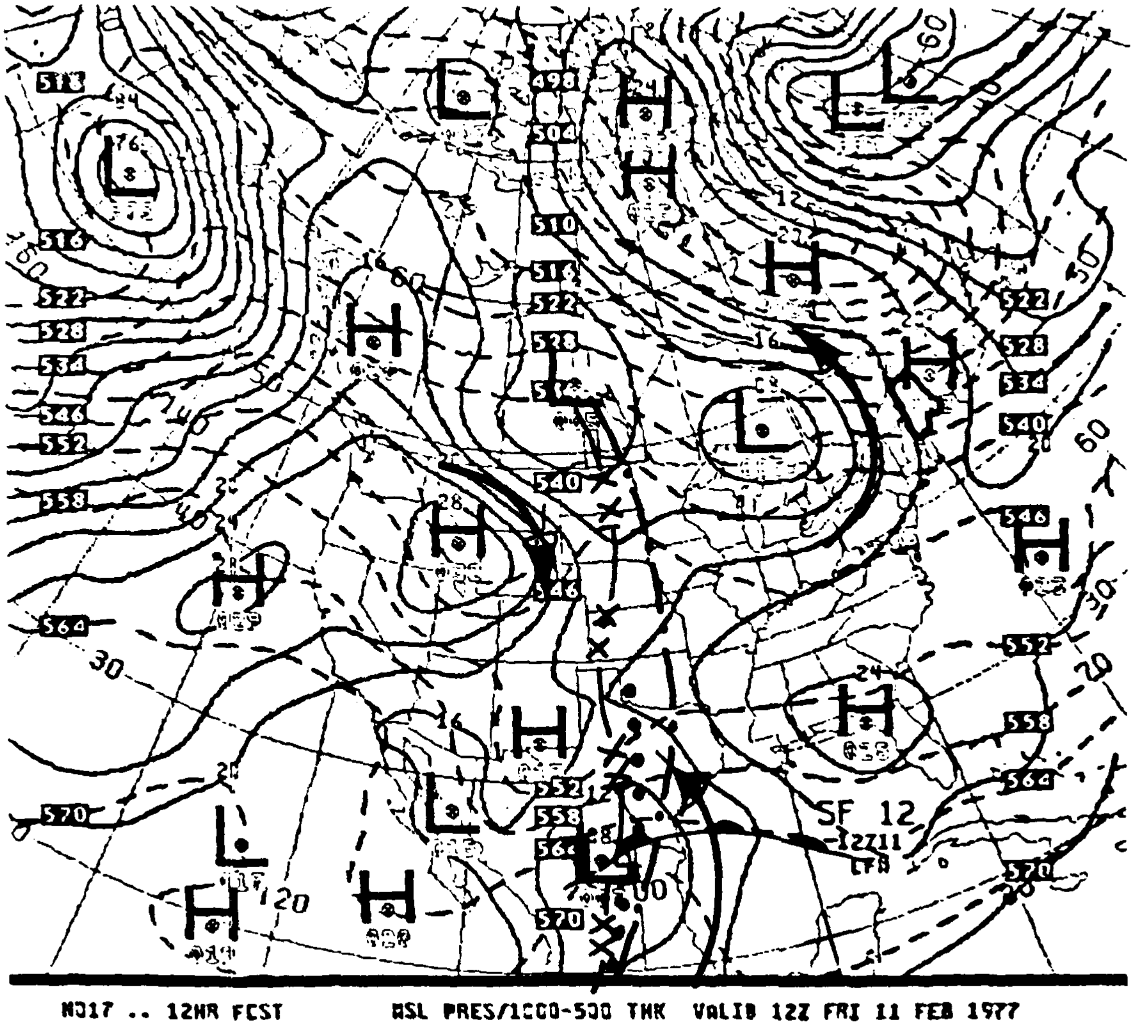


Figure 32. LFM 500 mb Vorticity Panel (12-hour Prognosis).



Low Pressure Center (Black)

Thermal Ridge (Red)

Warm Front (Black)

Convergence (Low Level) (Red)

Thickness Ridge (Black)

Maximum Wind Band (Jet) (Red)

Figure 33. LFM MSL Pressure/1000-500 mb Thickness Panel (12-hour Prognosis).

5.2.3 The low-level axis of moisture advection is the most difficult feature to find. The Precipitation and 700 mb vertical velocity panel (Precip /700 VERT VEL) (reference Figure 34) will, in strong situations, show precipitable moisture and assist in locating the area of maximum moisture. To find the axis of maximum moisture advection, check the latest 850 mb analysis and then relate this to the convergence zones and the low-level jet. This will allow close approximation of the location of the maximum moisture advection axis.

5.2.4 The 700 mb height/relative humidity panel (reference Figure 35) will show the 700 mb dry line.

5.2.4.1 The 700 mb jet will be located in the area of strongest contour gradient.

5.2.4.2 The dry line will form between the area with relative humidities greater than 70% and the area with relative humidities less than 50%. Of course, the dry intrusion will be that part of the dry line under the 700 mb jet.

5.2.5 First, assemble the LFM-II composite prognosis (reference Figure 36) by taking all the parameters (with proper color coding) and placing them on one chart. Then compare this with the severe weather synoptic patterns Determine which pattern, or which combination of two or more patterns exists and forecast the threat area.

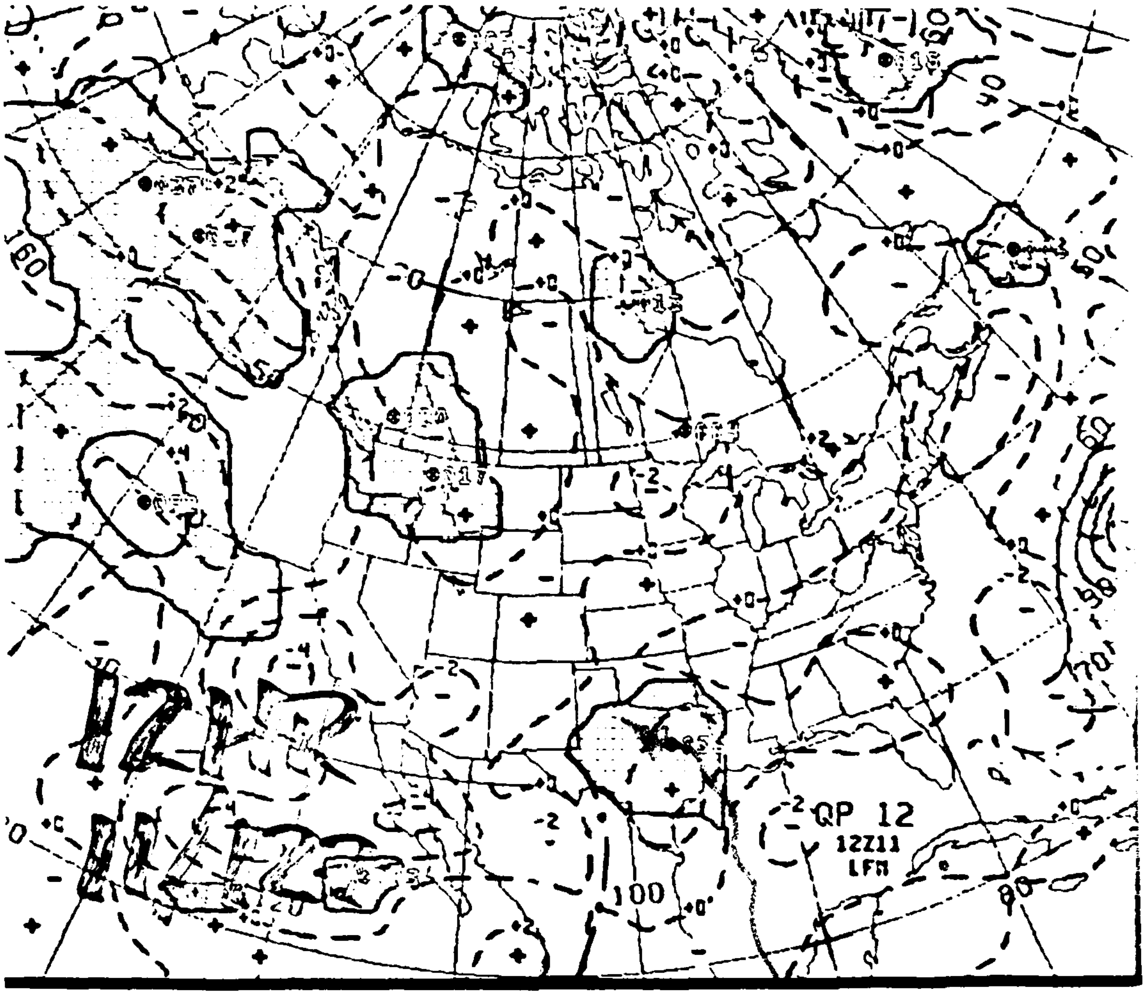
5.2.6 If the LFM-II is not handling the situation very well, then adjust each panel to fit the NWS model that is handling the situation best. There are certain situations in which one of the three NWS models w ll work better than the others.

5.2.6.1 The seven-layer hemispheric, primitive equation model (7LPE) best handles the situation in which a short wave is progressing down the back side of the long-wave trough until it reaches the axis of the longwave trough (digging trough).

5.2.6.2 The barotropic model best handles the situation in which the short-wave moves from the axis of the long-wave trough up the front side.

5.2.6 3 The LFM-II appears to split the difference between the barotropic and the 7LPE models.

5.2.7 The barotropic and 7LPE prognoses only provide the forecasts of the 500 mb height field and the vorticity field, so it would be a major project to construct the panels shown on the LFM-II. If the barotropic or 7LPE prognosis is handling the situation best, then use an adjustment procedure for finding the major parameters needed for a complete composite prognosis. Adjust the LFM-II 500 mb height/vorticity panel to coincide with the barotropic or 7LPE and then relocate all the other panels accordingly.



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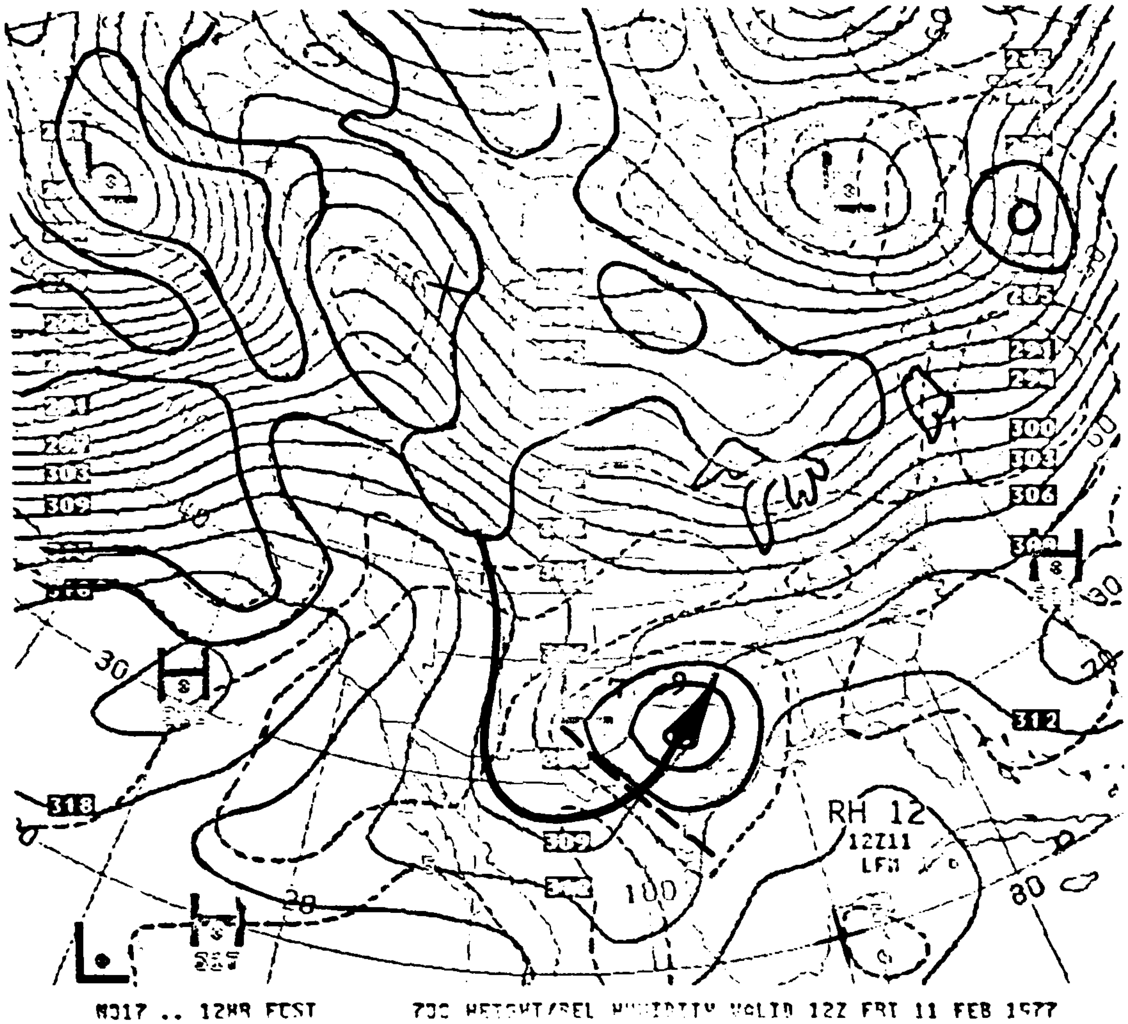
Axis of Maximum Moisture Advection (Green)

Dry Line (Red)

Figure 34. LFM Precipitation/700 mb Vertical Velocity Panel (12-hour Prognosis).



Maximum Wind Band (Jet) (Brown)

Dry Line (Brown)

Figure 35. LFM 700 mb Height and Relative Humidity Panel (12-hour Prognosis).

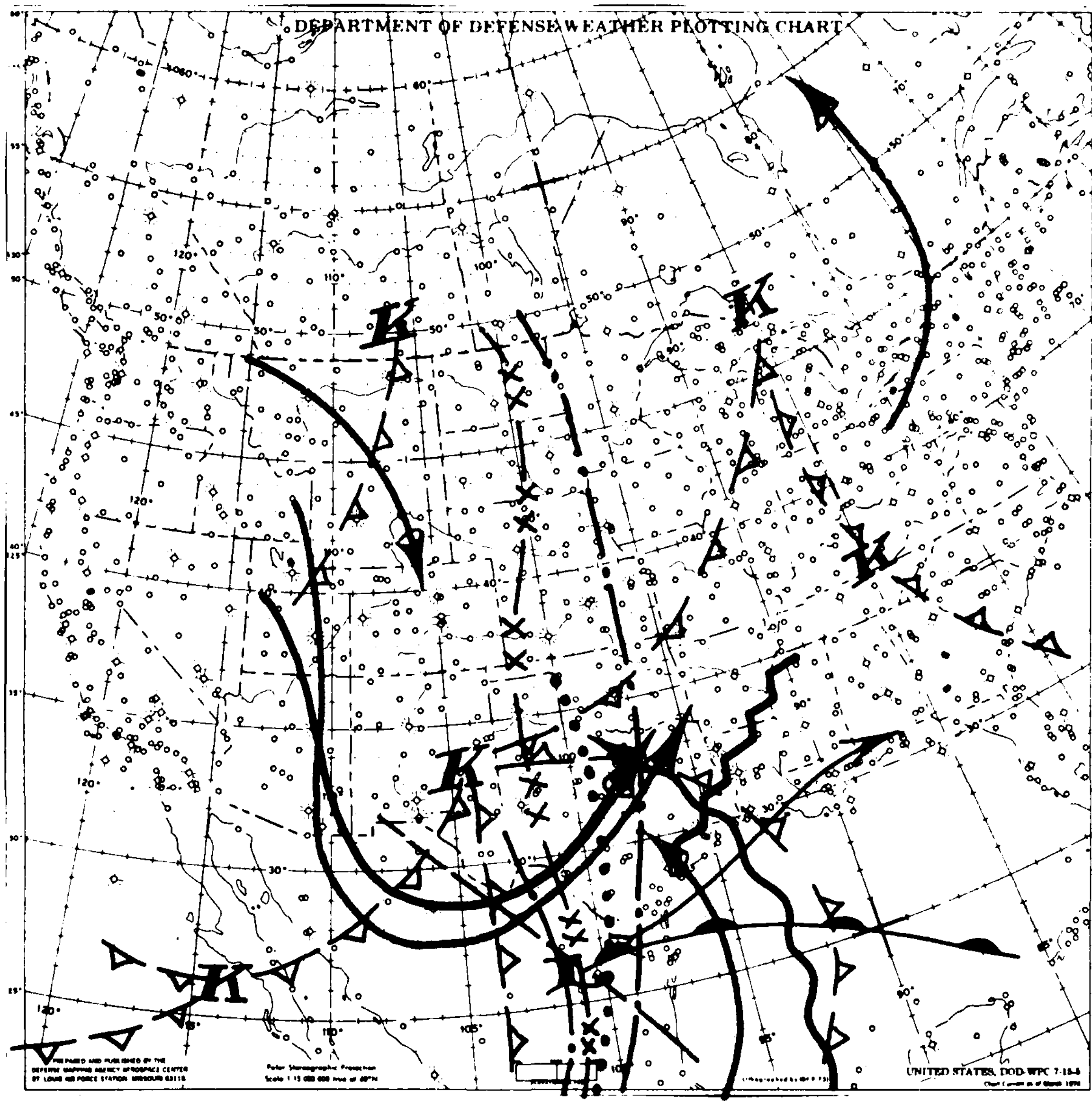


Figure 36. LFM 12-hour Composite Prognosis.

6 CONCLUSIONS AND COMMENTS

The emphasis on analysis cannot be overstressed. At almost any step in making a severe weather forecast, reference is made to the analysis package. The analysis package and the composite analysis are used for comparison with the ideal severe weather synoptic patterns. The knowledge of severe weather parameter interactions at various levels in the atmosphere (the five synoptic patterns) is absolutely essential in making a severe weather forecast. The accuracy of the example prognosis and severe weather forecast shown in Section 4 depended heavily on the accurate analyses of all charts involved. To evaluate properly any of the AFGWC or NWS atmospheric prognostic models, the analysis package must be used to evaluate the intensities of the severe weather parameters. At its best, the composite prognosis and consequently the forecast of severe weather is only as good as the prognostic tools and the original analysis.

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(1) Miller, Robert C. 1974: Notes on analysis and severe storm forecasting procedures of the Air Force Global Weather Central, AWSTR 200(Rev), HQ Air Weather Service, Scott AFB, IL, 91 pp.

(2) ____________ Nov 1976: STORM DATA, Volume 18, Number 11, NOAA/EDI, National Climatic Center.