SQUALL LINE DEVELOPMENT

EDUCATIONAL MODULES

FOR THE

ATMOSPHERIC SCIENCES

Space Science and Engineering Center
University of Wisconsin-Madison
1225 West Dayton Street
Madison, Wisconsin 53706

Contributions by (alphabetical order)

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The development of this module for atmospheric science education through the use of video systems has been supported by the National Science Foundation under Grant SED79-19005.

September 1981

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I. Introduction

In this educational module for synoptic meteorology, entitled "Squall Line Development," the development and evolution of an intense squall line over the central United States on 12-13 May, 1978 is studied. The objectives of this educational module are to portray the atmospheric structure of a squall line environment and its evolution through 1) analyses of radiosonde and surface data, and 2) videocomputer displayed satellite imagery with superimposed atmospheric fields. This module assists students in the development of analysis skills and an understanding of atmospheric processes important to the development and maturation of severe weather-producing thunderstorms.

While the module is designed to be used over the course of a semester in an undergraduate synoptic laboratory course, some flexibility in length and academic level exists. Another educational module for synoptic meteorology entitled, "Cyclogenesis," provides a larger scale view of atmospheric conditions through study of the Midwest cyclone that accompanied this severe weather episode. Its use in conjunction with this module for severe weather study is complementary.

II. Description of the Module Contents

This module incorporates a variety of data sources and techniques to provide a comprehensive view of a developing squall line. Featured is a 40 minute videocassette showing geosynchronous satellite images and analyzed fields from the Man-computer Interactive Data Access System (McIDAS) videocomputer at the Space Science and Engineering Center (SSEC) of the University of Wisconsin-Madison. An Accompaniment Guide for use in conjunction with the videocassette outlines the sequence of images, technical information about the fields displayed (units, contour spacing, etc.) and features important to the formation of the squall line. This manual, the third component of the module, contains; 1) a description of the module contents and suggestions for its utilization, 2) a summary and discussion of important synoptic events concerning the 12-13 May, 1978 Midwest squall line, 3) a large selection of analyzed and unanalyzed maps of conventional and computer derived information for student analysis and study, and 4) a questionnaire in which students can evaluate the educational value of the module and offer suggestions for improvement.

III. Videocassette Discussion

The utilization of videocassettes in the atmospheric sciences to portray the evolution of the atmosphere brings an important visual dimension into the education process. The McIDAS videocomputer, used to construct the imagery for the videocassette contained in this module, has the capability of superimposing analyzed fields of meteorlogical data over satellite imagery and forming a time sequence to enhance a student's ability to relate theory to actual weather situations.

The videocassette displays sequences of visible and infrared geosynchronous satellite imagery from 12-13 May, 1978 along with a series of surface and upper air fields to depict atmospheric structure and evolution during the morning and late afternoon of May 12. The sequences in the videocassette were constructed from surface observations at 3 hour intervals from 1300 GMT May 12 to 0400 GMT May 13 and from radiosonde observations taken at 1200 GMT May 12 and 0000 GMT May 13. These sequences provide students with a temporal and spatial perspective of the synoptic scale surface and upper air features in the vicinity of the squall line. The following is a list of the videocassette contents.

Satellite imagery

Infrared
Enhanced infrared
Visible
High resolution visible

Miscellaneous analyses superimposed over satellite images

Reported severe weather locations
Manually digitized radar

Surface analyses superimposed over satellite images

Mean sea level pressure
Divergence
Temperature
Dewpoint
Mixing ratio advection
Equivalent potential temperature
Equivalent potential temperature divergence

(The contents of the remainder of the list are shown first for 1200 GMT May 12 and then for 0000 GMT May 13.)

Upper air analyses superimposed over satellite images

850 mb height and temperature
850 mb temperature advection
850 mb streamline, isotach and dewpoint
850 mb dewpoint advection
700 mb height and temperature
700 mb temperature advection
700 mb streamline, isotach and dewpoint
700 mb dewpoint advection
500 mb height and temperature
500 mb temperature advection
500 mb height and isotach
500 mb streamline and absolute vorticity
300 mb height and temperature
300 mb height and isotach
300 mb isotach and divergence
850 mb and 500 mb streamline
Total totals index

Soundings (4)

Cross Section

Isentropic analyses superimposed over satellite images

300 or 305 K with pressure, streamline and mixing ratio
320 K with pressure, streamline and isotach

IV. Academic Considerations

The academic level of this severe weather study assumes that introductory courses in atmospheric dynamics and thermodynamics have been completed. Some of the topics that may be investigated in conjunction with the module are:

1) the use of the conventional map package to focus on basic criteria for severe weather analysis and forecasting used today that were originally pioneered by Fawbush, Miller and Starret, (1951);

2) the use of videocomputer-derived fields to portray kinematic and dynamic relations, such as the link between divergence and vertical motion through the principle of mass continuity, or the physical processes of advection of temperature, moisture or vorticity;

3) The use of radiosonde data to plot soundings and calculate static stability parameters. The study of stability theory may be conducted at a variety of academic levels (Hess, 1957; Wallace and Hobbs, 1977; Haltiner and Martin, 1957; Petterssen, Vol. I, 1956; and Palmen and Newton, 1969);

4) The use of selected maps and McIDAS fields to examine models of thunderstorm and squall line development from investigations by Ludlam (1963) Newton (1959, 1963), Browning (1964), Lemon and Doswell (1980) and others. Although the thunderstorm is a mesoscale phenomena, these authors mention the influence of specific synoptic scale conditions which create an atmosphere favorable for development of severe weather producing storms;

5) The use of upper air maps to investigate the influence of propagating upper tropospheric jet streaks in relation to severe weather occurrances. Analysis and study of the isentropic charts and cross sections will familiarize students with interactions between various levels of the atmosphere and

provide insight into the structure of jet streaks in relation to severe weather occurrences (Reiter, 1963; Cahir, 1971; Newton, 1959, 1963; Uccellini and Johnson, 1979).

These suggestions illustrate the flexibility of the subject matter and academic level which is available during the utilization of this module.

A number of classroom approaches using the module contents are possible. The map package should be used to develop analysis skills, although all unanalyzed maps need not be assigned. To realize the full benefit of the module, some surface, upper air (both isobaric and isentropic) and derived fields should be analyzed at different time periods to study the spatial and temporal evolution of the atmosphere surrounding the squall line. During the development of the module at the University of Wisconsin-Madison, students analyzed approximately 35 maps. Additional analyzed maps from the contents of the module were distributed to provide a comprehensive view of atmospheric structure within the limited time available for classroom work during the semester.

Student access to the videocassette and classroom discussion of the features evident in the images will provide a more complete understanding of the physical and dynamical processes and geometric structure of the squall line. At the University of Wisconsin-Madison the videocassette was shown in the classroom early in the semester to introduce students to the case. Frequent references were made to the imagery throughout the semester. By appointment, a videotape player and monitor were made available to students for viewing the videocassette outside of the classroom (this was encouraged). Finally, the videocassette was again shown to the entire class during group discussion of the case study near the end of the semester.

V. Synoptic Discussion

A) Background

In the central United States, the months of April through June are the period which contains the climatological maximum of severe weather occurrences. In late April and early May of 1978 a series of upper tropospheric short wave troughs amplified and developed closed circulations over the inner mountain region of the western United States. These troughs subsequently propagated east-northeastward, resulting in widespread precipitation to the east of the Rocky Mountains. In conjunction with one of these troughs, major outbreaks of severe weather occurred in Texas on the evening of May 2nd and in Florida on May 3rd. By May 6th another 500 mb closed low had entered the western United States and during the period May 6 through 9 this system spawned severe weather in the Gulf Coast states and New York. During these same four days a series of two short wave troughs approached the West Coast. Although the first of these waves weakened as it crossed the nation, it helped initiate an extensive squall line on May 11 which buffeted Texas and Oklahoma with tornadoes, high winds and large hail. The following day the second of the short waves amplified rapidly over the north central United States and instigated strong cyclogenesis and intense squall line development over the mid-Mississippi Valley.

These two short wave troughs, which crossed the central United States from May 11 through 13, are summarized in the satellite images shown in Figure 1. The first cyclone, located over the Great Lakes states, failed to intensify during its northeastward movement between 1300 GMT and 1900 GMT. The second system, which is the focal point of this educational module, was initially a disorganized region of cloudiness over the Northern Plains. However, over the next 15 hours the system propagated to the east and evolved into a remarkably well organized extratropical cyclone and squall line complex, producing one of the major severe weather outbreaks of 1978. The squall line stretched from Illinois to Texas and contained thunderstorms which reached heights of over 60,000 feet. The spectacular development and maturation of the entire squall line and individual cumulonimbus clusters ahead of the advancing cold front is traced within the last three images of the time sequence in Figure 1. Use of the satellite imagery in conjunction with the synoptic overview will help create a more unified picture of the systematic structure of the cyclone/squall line complex of May 12-13. A more complete discussion of the storm's satellite imagery is provided after the following synoptic discussion.

On the morning of May 12th, three low pressure centers were evident at the surface in the central United States. Cyclones in southeast Wisconsin, northern Oklahoma and southeastern South Dakota were connected by a complex array of fronts (Figure 2a). While cyclogenesis continued in South Dakota, the Oklahoma cyclone slowly dissipated and the Wisconsin cyclone moved northeastward. At 850 mb, circulation centers were associated with each of the three surface systems and an extensive area of moist southwesterly flow extended from Texas to the Ohio River Valley. In the upper troposphere a shallow, broad trough covered the western two-thirds of the United States with its axis extending southward through the Great Plains (Figure 3a). Vorticity maxima were located over the surface cyclone in Wisconsin and upwind of a region of rainshowers in Tennessee and Mississippi. Between the mornings of May 12th and 13th the cyclone in southeastern South Dakota intensified rapidly while it moved to northeastern Illinois (Figure 4) and triggered a squall line

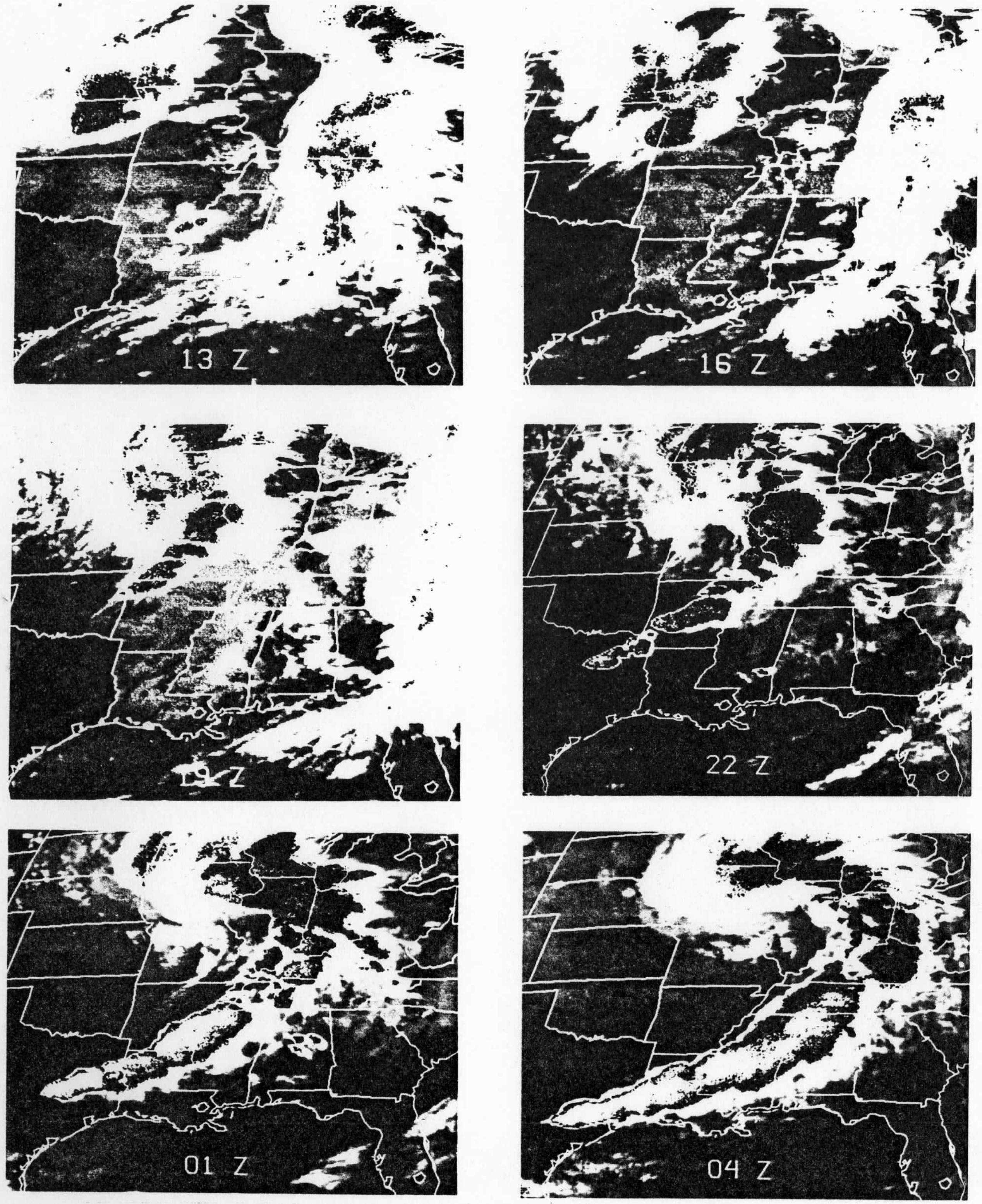

Fig 1. GOES-East Enhanced Infrared Imagery 1300 GMT May 12 to 0400 GMT May 13, 1978.

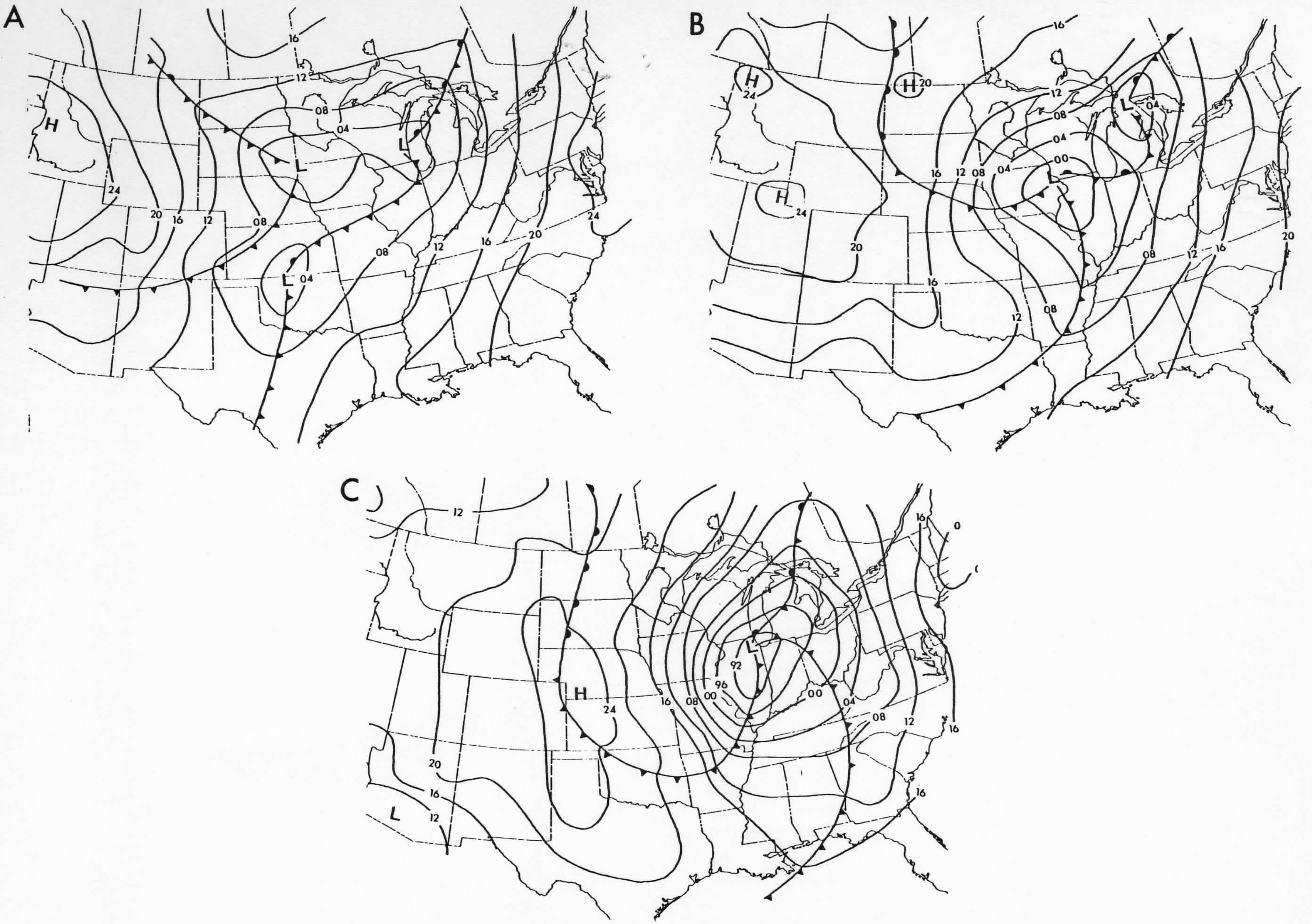

Fig. 2: Surface pressure (solid; interval 4 mb) and frontal analyses for 1200 GMT 12 May, 1978 (A), 0000 GMT 13 May, 1978 (B), 1200 GMT 13 May, 1978 (C).

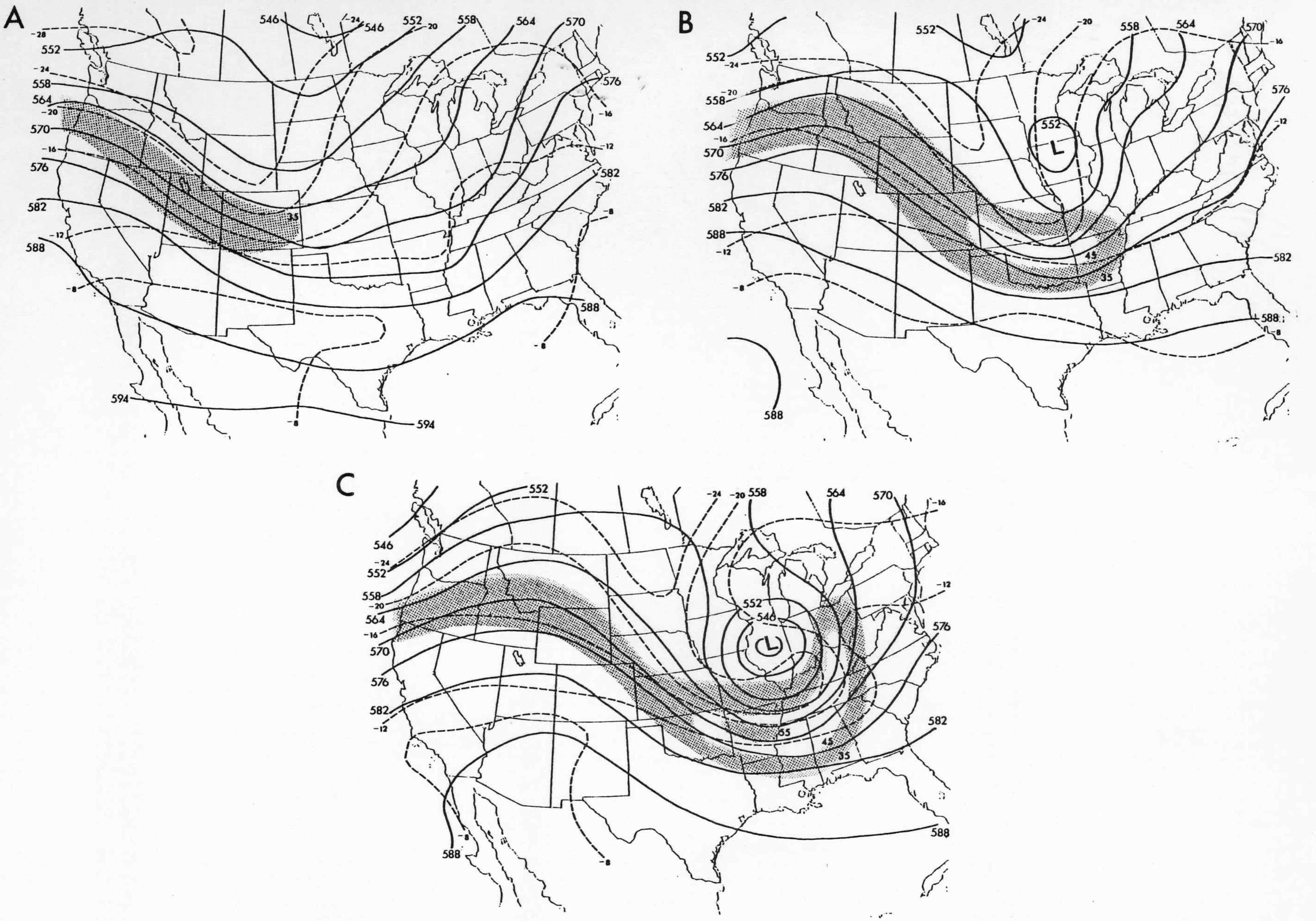

Fig. 3: 500 mb height (solid; interval 6 gpdm), temperature (dashed; interval 4°C) and wind speed (above 35 m/s with 10 m/sec interval) analyses for 1200 GMT 12 May, 1978 (A), 0000 GMT 13 May, 1978 (B) and 1200 GMT 13 May, 1978 (C).

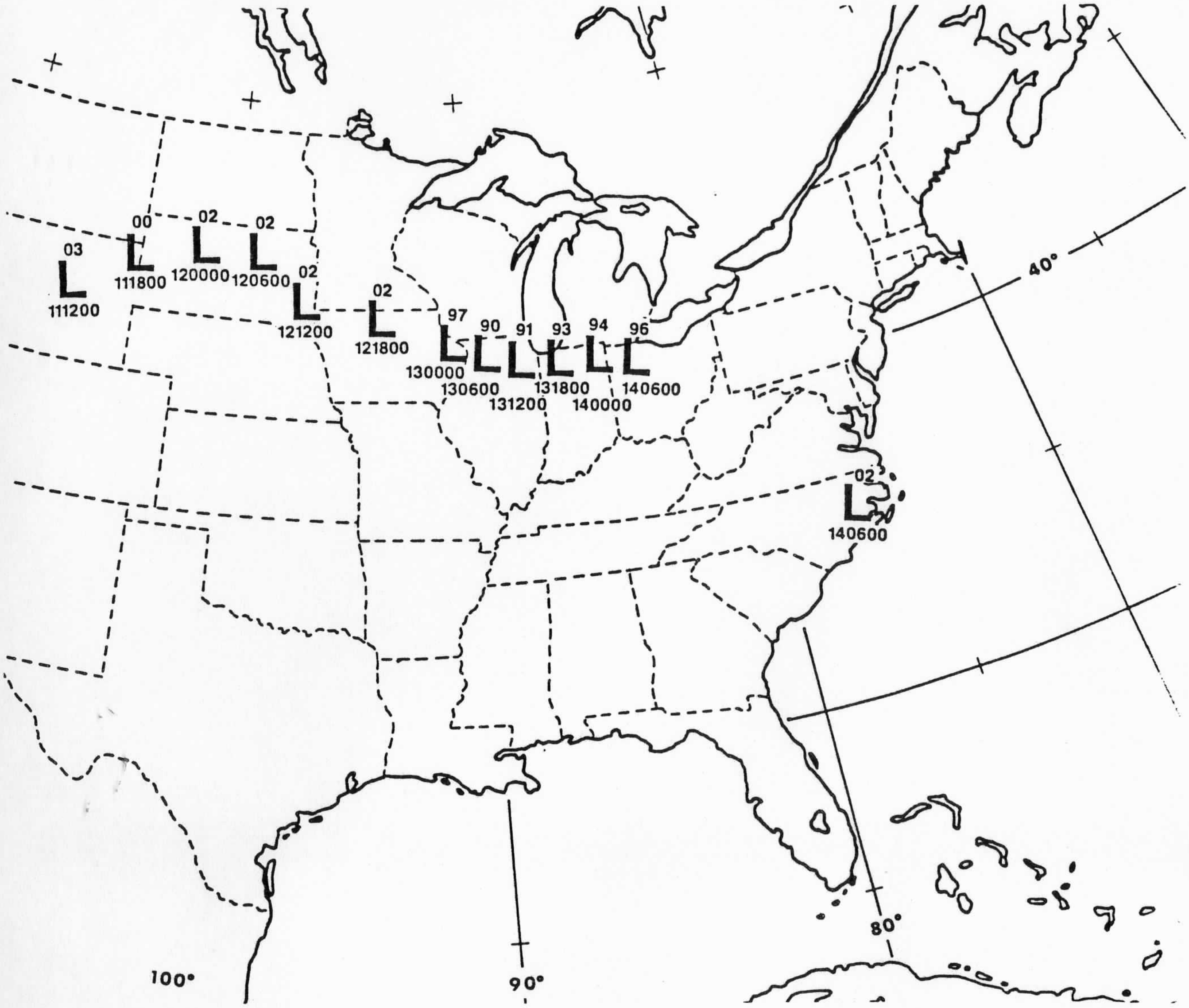

Fig. 4: Cyclone position and intensity from 1200 GMT 12 May to 0600 GMT 14 May, 1978. The day of the month followed by the Greenwich mean time is plotted below the cyclone (L). The central pressure of the cyclone ([mb] leading digit(s) omitted) is plotted above.

ahead of its advancing cold front. At 1200 GMT on May 12 the main vorticity maximum which instigated cyclogenesis was located in southwestern Wyoming. An intense 300 mb jet streak was entering southwestern Kansas with a region of strong divergence just north of the jet's leading edge. At sunrise an area of thunderstorms reaching 46,000 feet had formed within this upper level divergent region (Figure 5a). These thunderstorms continued to develop through the morning hours and by noon the northern part of the nascent squall line was established from western Missouri through eastern Kansas and Oklahoma (Figure 5b). This development occurred within a region of strong convergence ahead of the surface pressure trough which extended southward from the intensifying cyclone in north central Iowa. (See Videocassette: SFC divergence; 1200 GMT: 850 mb heights and temperatures; 850 mb streamlines, windspeeds and dewpoints; 500 mb heights and temperatures; 500 mb streamlines and absolute vorticity; 300 mb windspeeds and divergence.)

As the cyclone deepened, strong southerly winds ahead of the advancing surface pressure trough continued to transport moisture into Arkansas, Illinois and other mid-Mississippi Valley states. Around 1900 GMT the first reports of tornadoes were received in Missouri and Arkansas, where cumulonimbus towers reached 52,000 feet (Figure 5c). A second, less intense squall line formed behind the first and later in the afternoon spawned a tornado in Missouri. This second line formed in Kansas within a region destabilized by strong mid-tropospheric cold air advection and where strong 850 mb convergence and upper level divergence were occurring. (See videocassette: SFC streamlines and pressure; 0000 GMT: 850 mb temperature advection; 700 mb temperature advection; 300 mb wind speeds and divergence.)

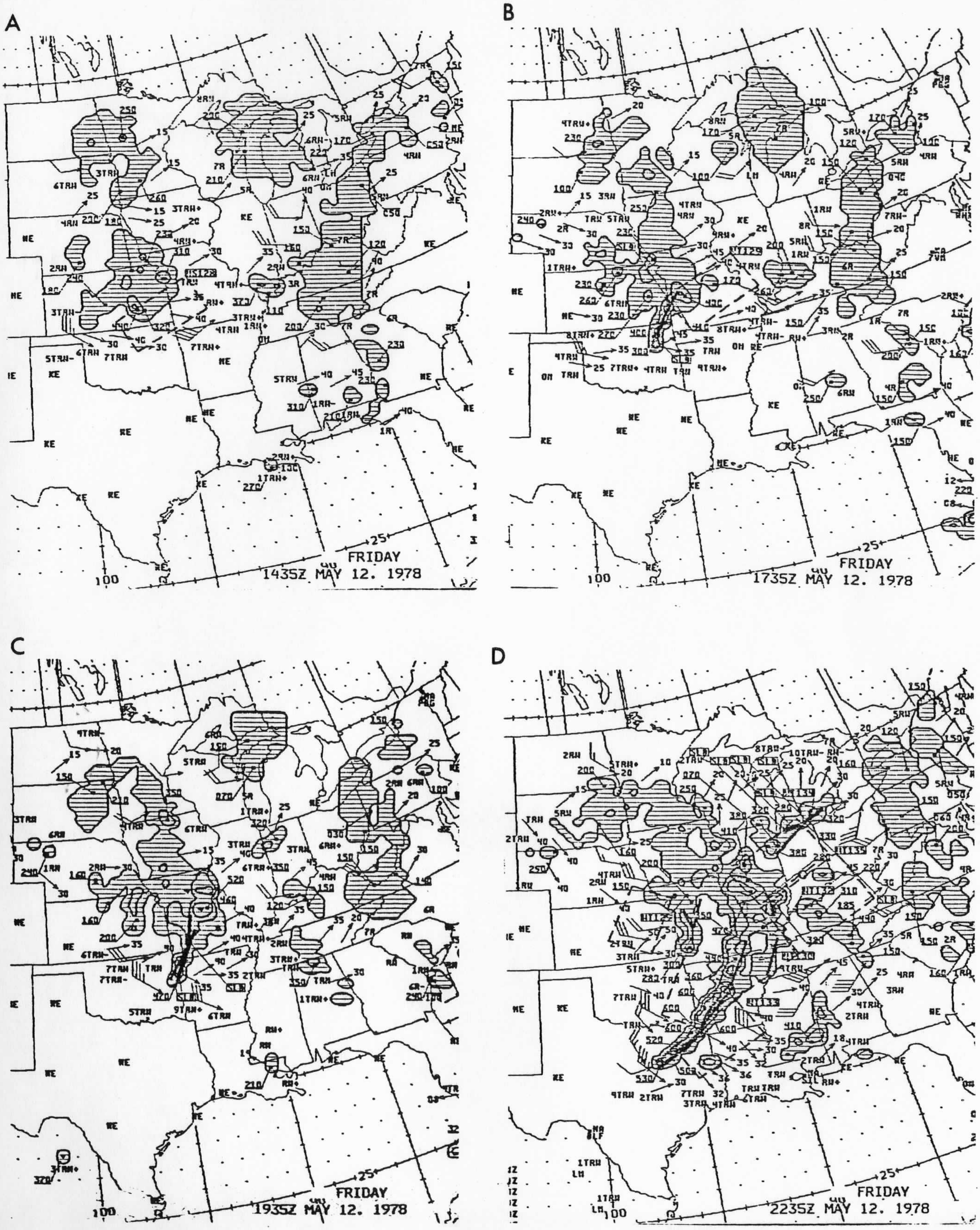

Fig. 5: NMC radar summary for 1435 GMT (A), 1735 GMT (B), 1935 GMT (C) and 2235 GMT (D) 12 May 1978 (more detailed description on following page).

E F

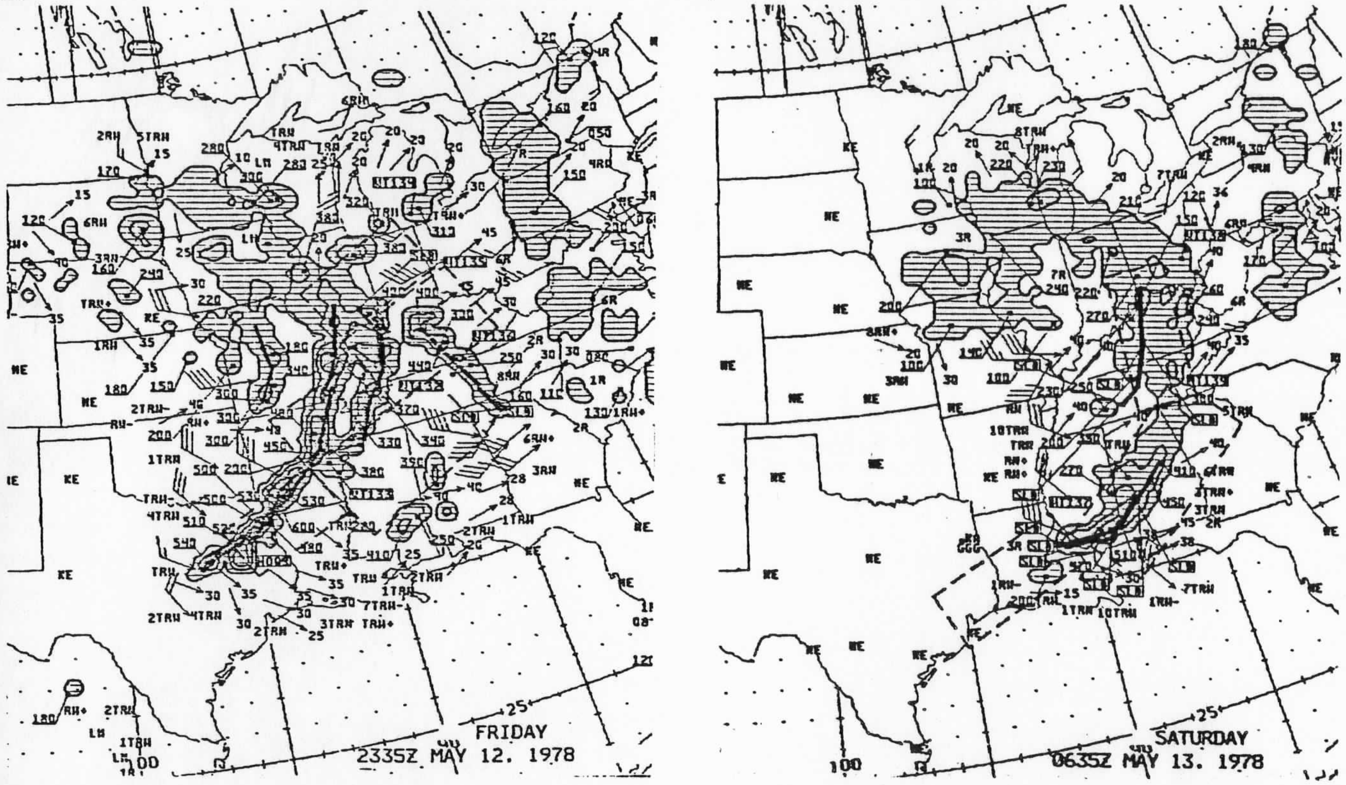

Fig. 5: (cont) NMC radar summary for 2335 GMT 12 May 1978 (E) and 0635 GMT 13 May 1978 (F). Three different echo intensities are indicated by the contours within the hatched area. Severe weather watch areas valid at the time of the summary are outlined by dashed lines. Area movement is indicated by wind barbs [kts], and cell movement and speed [kts] is given by arrows with the speed printed near the arrow head. Precipitation type, change in intensity, and percent coverage is also indicated (ie. 7TRW+ means 70% of the hatched area is covered by thunderstorm echoes which are increasing in intensity). A solid black line indicates the location of a continuous band of radar echoes.

By late afternoon the main squall line extended from central Illinois south-southwestward through Missouri and Arkansas into extreme northeast Texas. Radar reports indicated numerous cloud tops reaching 60,000 feet (Figure 5d). Additional development, probably associated with convergence along the main line's outflow boundary, was initiated ahead of the squall line in Illinois and Tennessee. Moderate thunderstorms also formed along a surface convergence line in northern Indiana and southern Michigan, however no severe reports were received due to these storms. (See videocassette: SFC divergence; manually digitized radar.)

At 0000 GMT May 13 the surface cyclone was located in eastern Iowa. Severe weather was reported at numerous locations within the main squall line, which stretched southward from the circulation center (Figures 2b and 5e). On the 305 K isentropic surface a tongue of mixing ratios greater than 8 g/kg reached northward from the Gulf Coast states into southern Illinois. Strong cold air advection was occurring in the lower and middle troposphere behind the main squall line where the secondary line was dissipating. Positive vorticity advection in association with upper level divergence was occurring at 500 mb over much of the squall line. (See videocassette: 0000 GMT: 305 K pressure, streamlines and mixing ratios; 850 mb temperature advection; 700 mb temperature advection; 500 mb streamlines and absolute vorticity; 300 mb wind speeds and divergence.)

Over the next six hours, the surface cyclone moved into northern Illinois and intensified rapidly (Figure 4). The northern half of the squall line weakened by midnight into a broad area of thundershowers (Figure 5f). In the Gulf Coast states, the squall line also decreased in intensity, but at a much slower rate. All along the surface trough, values of convergence decreased as the winds behind the trough became increasingly parallel to the winds ahead of it. The frequency of severe weather occurrances had decreased markedly by midnight and the major portion of the severe weather outbreak was over. (See videocassette: SFC PRE and STR; SFC DIV.)

The severe weather associated with these thunderstorms injured nearly 70 people and accounted for over twenty tornadoes as well as numerous reports of large hail and damaging winds by 0900 GMT May 13. (Figure 6). Most of the severe weather occurred in Illinois, Missouri, Arkansas and Texas, although the most devastating storm occurred in Tupelo, Mississippi, where a tornado injured 18 people while carving a 15 mile long path through the city. The next afternoon a squall line developed over the Eastern Seaboard ahead of the surface frontal zone spawning 6 more tornadoes and leading to 10 reports of large hail. No injuries were reported in conjunction with these storms. (See videocassette: Severe weather locations).

B) Satellite Imagery

Major cloud features evident in the geosynchronous satellite imagery in the videocassette are present in the sequence of six images provided in Figure 1. The sequence vividly portrays the organized structure that develops from an amorphous distribution of clouds at 1300 GMT and shows the evolution of synoptic, subsynoptic and mesoscale atmospheric phenomena over the central United States on May 12-13, 1978. At 1300 GMT May 12 the synoptic scale characteristics of the cloud shapes and orientations of the two extratropical cyclones are chaotic compared with 0400 GMT, May 13. Several interesting features are evident in the satellite image from 1300 GMT. The region of high cloudiness in Nebraska and Kansas is associated with upward vertical motion and an upper tropospheric divergence maximum. A small comma-shaped cloud

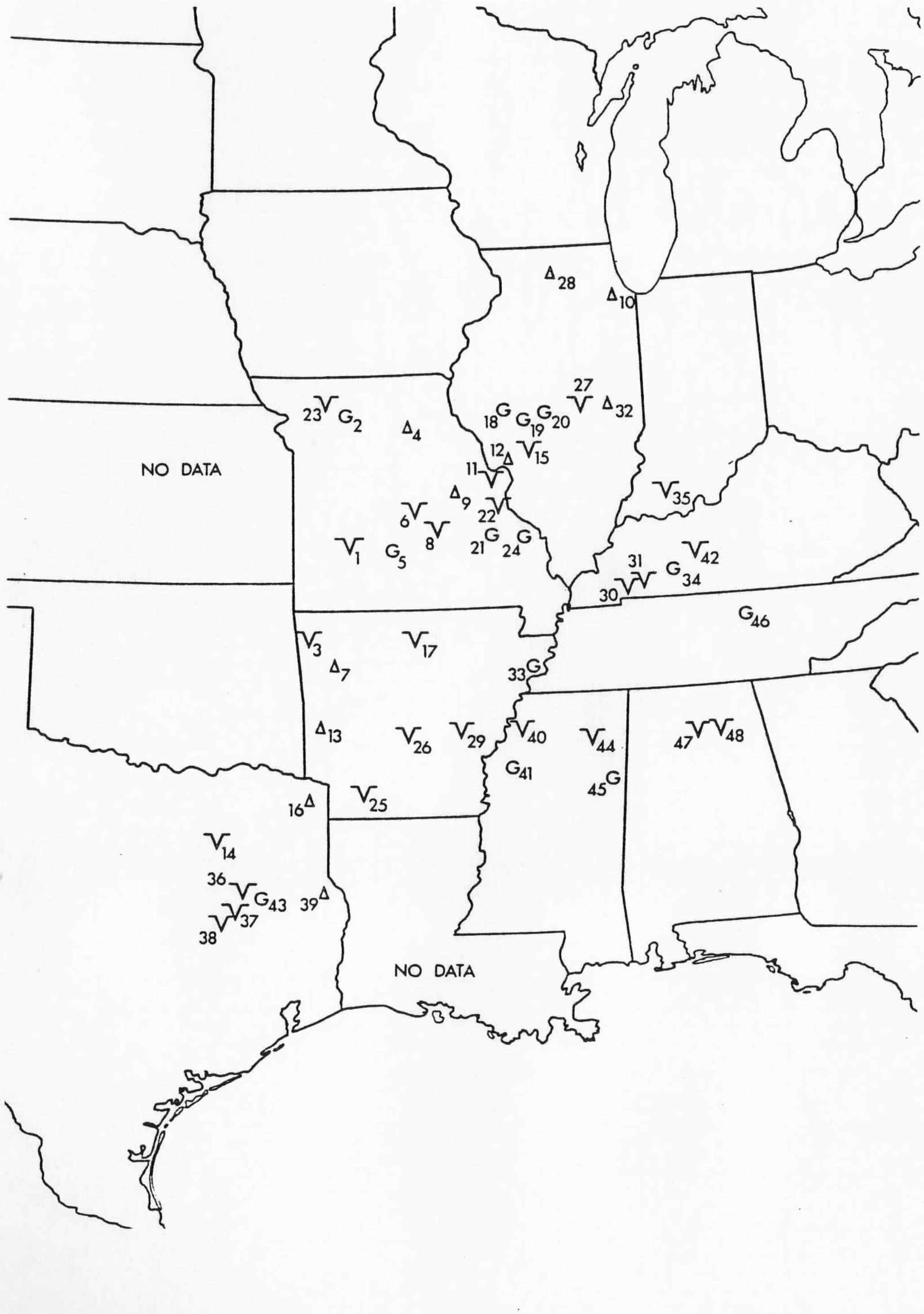

Fig. 6: Severe weather events occuring between 1200 GMT 12 May and 0900 GMT 13 May, 1978. The events are numbered in approximate chronological order. The numbers also correspond to the more detailed description of individual events located on the following page.

#	Event	Time (GMT)	State	Comments
1	Tornado	1900	MO	Destroyed numerous farm buildings
2	Wind	NA	MO	Wind damage
3	Tornado	1914	AR	Little damage
4	Hail	NA	MO	1" diameter; broke windows
5	Wind	NA	MO	Tractor trailer & mobile homes blown over
6	Tornado	2015-2100	MO	Reaching a width of 400 yd. it injures 3 during its 22 mi. path
7	Hail	2045	AR	1" in diameter
8	Tornado	2100	MO	Touched down briefly damaging a farm house
9	Hail	NA	MO	1 3/4" diameter; damaged autos and houses
10	Hail	NA	IL	3/4" diameter
11	Tornado	2105	MO	Short, narrow treetop path, some damage
12	Hail	est. 2100	IL	1 3/4" diameter
13	Hail	2110	AR	1 3/4" diameter
14	Tornado	2130	TX	Small and ropelike it formed in a developing thunderstorm
15	Tornado	2150-2230	IL	Swept thru 2 counties damaging 35 farms, $245,000 damage
16	Hail	2200	TX	1 3/4" diameter
17	Tornado	2210-2230	AR	Moved E touching down several times, $200,000 in damage
18	Wind	2210	IL	56 Knots
19	Wind	2210	IL	Over 50 Knots
20	Wind	2210	IL	Over 50 Knots
21	Wind	NA	MO	Mobile home blown down a hill injuring 3
22	Tornado	2300	MO	Four Mile long damage path
23	Tornado	2320	MO	1 mile long damage path -100 yds. wide
24	Wind	NA	MO	Demolished 3 acres of timber

#	Event	Time (GMT)	State	Comments
25	Tornado	2345	AR	Moved E; destroyed barn, car & mobile home
26	Tornado	0000	AR	Trees downed along short, narrow path
27	Tornado	0000	IL	Cut 8 mi. path-43 homes damaged and 3 people hurt
28	Hail	0040	IL	1 3/4" diameter
29	Tornado	0100	AR	Moved SE; damaged 2 farm buidlings
30	Tornado	0100	KY	Moved ENE; damaged/destroyed 105 farm houses and buildings
31	Tornado	0125	KY	Moved ENE; damaged/destroyed 110 farm houses & barns
32	Hail	NA	IL	1 3/4" diameter
33	Wind	0140	AR	5 people injured, mobile home blew over
34	Wind	0145	KY	Blew down 2 barns & a tool shed
35	Tornado	0220	IN	Moved E; $60,000 damage to 6 buildings
36	Tornado	0220	TX	These three storms had short narrow
37	Tornado	0220	TX	tracks reported by sherrifs.
38	Tornado	0220	TX	May be the same storm.
39	Hail	0230	TX	1 3/4" diameter
40	Tornado	0235-0400	MS	Frequent reports of damage, 35 mi. path
41	Wind	NA	MS	50 Kt. winds caused widespread minor dmg.
42	Tornado	0245	KY	Moved ENE; damaged 3 houses and 15 barns
43	Wind	0300	TX	54 Knot gust
44	Tornado	0425-0500	MS	Hits Tupelo, 18 injured, $5 million dmg.
45	Wind	NA	MS	100 Kt. wind, extensive dmg., 4 injured
46	Wind	0600	TN	Tore off roofs and blew down trees
47	Tornado	0615	AL	3 houses, 15 mobile homes hit, 11 hurt
48	Tornado	0635	AL	Possible multiple vortex tornado caused house and tree damage

Fig. 6: (cont) Listing of severe weather events from 1200 GMT 12 May to 0900 GMT 13 May, 1978. To ascertain the location of the event, utilize the event number in conjunction with the map on the preceding page

pattern, associated with upper tropospheric vorticity advection, is evident in western Nebraska and Kansas and is a signature of the potential for the strong cyclogenesis that ensues during the next 15 hours. Another feature of interest in the sequence of images is the dry tongue, due to subsidense in the vicinity of the upper tropospheric wind maximum, which is entering Illinois at 0000 GMT. This tongue of dryer air combined with the high level clouds in the vicinity of the cyclone center creates the classic comma-shaped cloud field associated with mid-latitude cyclones. The vorticity maximum evident in the first three images near the Great Lakes, moves northeastward during the sequence while rain showers spread into northern Michigan and drier air is drawn into the system's circulation from the southwest. The third vorticity maximum, indicated by a comma-shaped cloud pattern in northeastern Mississippi at 1300 GMT, progresses eastward across the southeastern United States between 1300 and 1900 GMT. The positions of all three maxima evident in the imagery can be verified through inspection of the vorticity distribution computed from radiosonde information. (See videocassette: weather symbols; 1200 GMT and 0000 GMT: 500 mb streamlines and absolute vorticity.)

The diurnal temperature cycle at the earth's surface is evident in the satellite sequence from 1300 GMT to 0400 GMT. In the absense of clouds, the progressive darkening of the satellite images corresponds to the heating of the ground by absorption of incoming solar radiation, while brightening corresponds to radiational cooling. Warming is particularly evident in Illinois during the early morning and until 1900 GMT in Texas and Oklahoma. A low stratocumulus cloud layer in the mid Mississippi Valley obscures any surface heating in that region. In stark contrast to the magnitude of temperature oscillations over the land is the steady, relatively cool temperature of Lake Michigan in the 1600 and 1900 GMT images. In subsequent images the land-sea contrast is shrouded by gradual cloud contamination of the infrared data.

In addition to the investigation of larger scale processes like cyclogenesis and the diurnal temperature cycle, the satellite images provide an excellent opportunity to observe squall line formation and evolution. An early signature of squall line development is evident in southeastern Kansas and Oklahoma in the 1600 GMT image. Note the region of deep convection near the Kansas-Missouri border that becomes a dominant feature of the satellite imagery. The main squall line develops rapidly southward from this feature which is located near the center of the surface cyclone. This development occurs along the surface convergence zone associated with the cold front and by 0400 GMT extends from the Great Lakes to the Gulf of Mexico. The thunderstorms with the highest vertical development usually possess the coldest cloud top temperatures determined from the infrared brightness data. In the imagery the middle portion of the brightness scale has been colored black by the computer. Therefore, the highest cloud tops represented by the coldest infrared temperatures are depicted in the images as regions of white surrounded by black. In a comparison of the cloud top temperature along the squall line, the coldest cloud tops are found in conjunction with the southern portion of the squall line. Thus, the convection with the greatest vertical development is in the southern portion of the squall line. This assertion is supported by radar derived cloud top height measurements. At times, the estimation of cloud top heights from satellite infrared brightness information is complicated by the variable emissivity of cirrus. With the development of the main squall line southward, a large cirrus shield created from cumulonimbus outflow advances rapidly eastward until by 0400 GMT the width of the squall line and also the tops of the various clouds is difficult to discern. A second line of thunderstorms can be seen developing south of Lake Michigan between 1900 and 2200 GMT.

Through closer examination of the imagery, the non-uniformity of the convection within the squall line becomes increasingly apparent. In certain images and sequences of images, individual thunderstorms and thunderstorm cluster life cycles can be distinguished. At 1900 GMT an intense individual thunderstorm cell surrounded by weaker convection is visible in south-central Missouri. Between 1900 and 0100 GMT some of the older thunderstorms in the northern portion of the squall line dissipate as they enter Illinois, Kentucky and Tennessee,while strong redevelopment occurs east of the dissipated cells. A thin line of convective clouds, probably composed of towering cumulus, is visible in the imagery prior to further southward development of the main squall line. Examples of these thin lines of convection, which may not be detected by radar, are found at the southern tip of the squall line in the 1900, 0100 and 0400 GMT manual images. Scattered thunderstorms ahead of the main squall line can be detected in the 1300, 2200 and 0100 GMT images in Arkansas, Mississippi and Alabama respectively.

Further examination of small scale phenomena and cloud motions in the videocassette satellite imagery reveals many other features of interest. Two of these features illuminated in the videocassette are overshooting cumulonimbus turrets within the squall line through the utilization of half mile resolution imagery and relative cloud motion derived from the time sequenced imagery. When the satellite imagery provided in this module is used in conjunction with surface, upper air and radar data, a comprehensive description of the atmospheric conditions and processes which led to the severe weather outbreak on May 12 and 13, 1978 can be attained.

C) Discussion

Fifty years ago, many meteorologists stated that convection was random and its prediction would never be possible. Today, the National Severe Storms Forecast Center (SELS) routinely issues severe weather forecasts. The pioneering work in the development of methods to forecast severe storms was accomplished by Fawbush and Miller in the early 1950's. Although empirical forecast methods have been refined in recent years, the primary guidelines set forth by Fawbush and Miller are still utilized today. Miller (1972) listed five atmospheric conditions which are highly correlated with severe weather events:

1) Large quantities of moisture must be available in the lower layers of the atmosphere, and drier air aloft and/or upwind of the threat area.

2) A conditionally unstable thermal structure of the atmosphere and a subsidence inversion located in the lower troposphere.

3) Strong middle level winds with strong wind shear over the threat area.

4) A lifting mechanism to help initiate the severe convection.

5) A favorable freezing level within the thunderstorms, typically between 6 and 12 thousand feet.

With all of these conditions occurring in the atmosphere, as on May 12-13, the probability of severe thunderstorm development is high.

1) Moisture

The development of the moisture supply for the thunderstorms on May 12th originated about two days earlier with an intense southwesterly low level jet that formed from Texas northeastward into Illinois between an anticyclone located along the Gulf Coast and an Alberta low which was traversing southern Canada. This pattern of strong northward moisture transport from the Gulf of Mexico persisted through 1200 GMT on May 12 with south southwesterly winds at 850 mb up to 30 m/s and mixing ratios near 12 g/kg over most of the central United States. (See videocassette: 1200 GMT: 850 mb streamlines, wind speed and dewpoints; 300 K pressure, streamlines and mixing ratio.)

Miller found that dry air in the middle troposphere was nearly as important as abundant moisture at low levels. Dry air, which enhances the degree of convective instability, was present at 700 mb throughout the south central United States on the morning of the 12th. The vertical temperature and moisture structure of a typical severe weather sounding is illustrated by the early morning sounding for May 12th from Monette, MO (Figure 7). This rapid decrease of the mixing ratio in the vertical was prevalent throughout the south central United States (see Videocassette: 1200 GMT: 700 mb streamlines, wind speed and dewpoints; soundings).

2) Thermal structure

On the morning of May 12, the low level inversion and instability which Miller emphasized were either forming or already present over the south central United States in conjunction with strong vertical directional wind shear in the lower troposphere. Warm moist Gulf of Mexico air was being transported from the south-southeast below 850 mb. With the wind veering rapidly with height, hot arid air from the west-southwest was moving near the 850 mb level into the same geographical region. Through this combination of temperature and moisture advection, convectively unstable conditions developed in the region of the low level inversion which possessed a strong vertical moisture

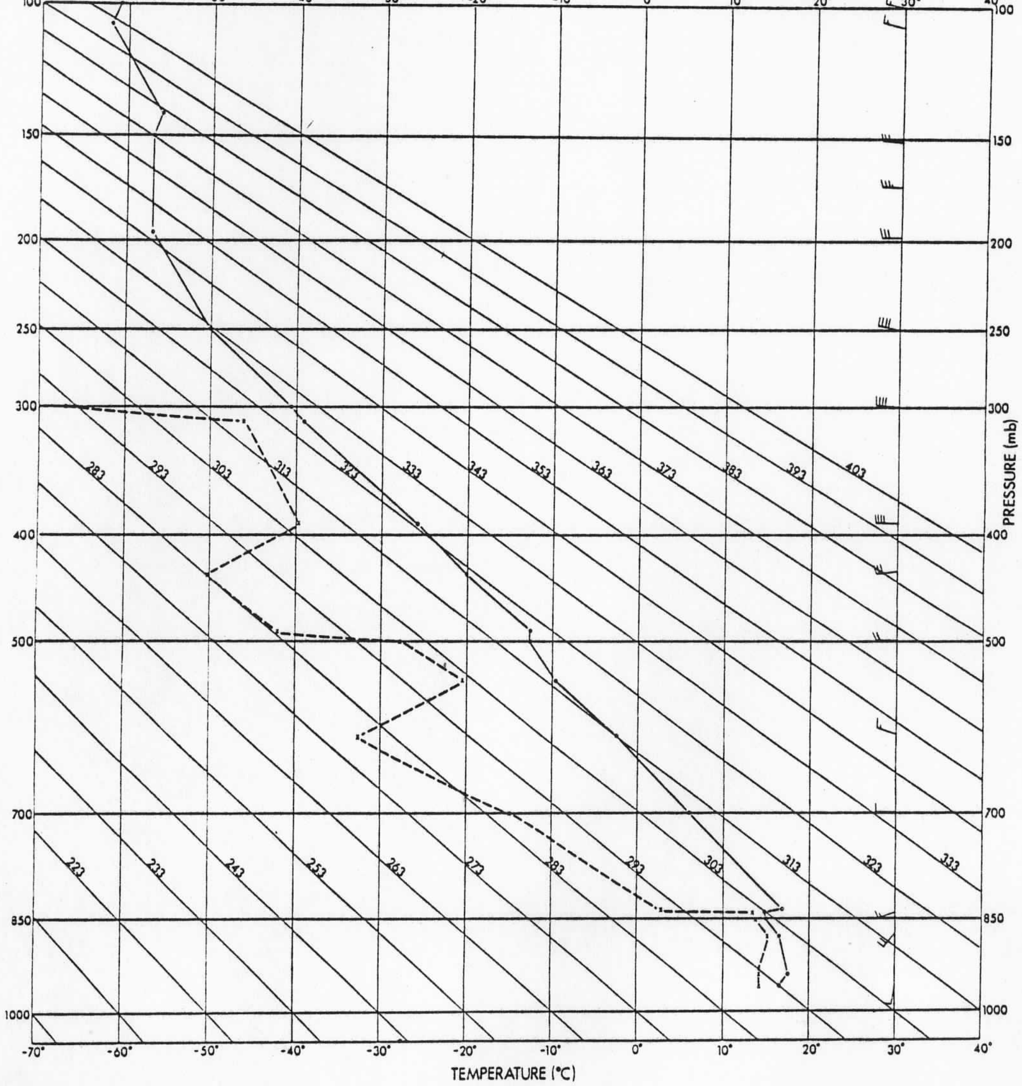

Fig. 7: Vertical atmospheric sounding plotted on a Stüve diagram and derived from radiosonde data over Monette, Mo. at 1200 GMT 12 May, 1978. Temperature (solid), dewpoint (dashed) and wind barbs ([m/s] along 30°C isotherm) are included.

gradient. Veering of the wind in the vertical preceded the strengthening of the low level inversion in Arkansas and southern Illinois (Figure 8). In addition to forming an inversion which suppressed weak convection in the low troposphere, large scale differential advection of temperature acted to destabilize the entire troposphere. For a number of hours surrounding 1200 GMT on May 12, strong lower tropospheric warm temperature advection occurred throughout the Mississippi Valley. Over the same region weak 700 mb cold temperature advection was prevalent, while much colder air was moving into Illinois and Missouri at 500 mb. As the atmosphere in the mid Mississippi Valley was being destabilized, a broad region of near dry adiabatic lapse rates in the mid troposphere was already present in the southern Great Plains. The results of the destabilization process are illustrated in Monette's sounding (Figure 7). (See videocassette: 1200 GMT: 850 mb streamlines and 500 mb streamlines; 850 mb temperature advection; 700 mb temperature advection; 500 mb temperature advection; soundings.)

One final factor which is frequently significant in the generation of instability is sensible heating of the boundary layer by solar radiation. Large scale subsidence associated with negative vorticity advection upstream of the two vorticity maxima in southeast Wisconsin and western Tennessee produced clear skies during the early morning hours through Illinois, Missouri and Arkansas. Consequently, a narrow tongue of maximum temperatures in the upper 70's developed from the combination of warming due to subsidence and sensible heating. (See videocassette: 1200 GMT: 500 mb streamlines and absolute vorticity; visible satellite images.)

3) Wind field

Miller also emphasized that strong lower tropospheric winds and veering of the wind in the vertical were closely associated with severe thunderstorm formation. Strong mid-level wind speeds and shears were present during the May 12th severe weather case. On the 700 mb surface at 1200 GMT May 12 wind speeds near 25 m/s were located over Colorado. During the next 12 hours the wind maximum intensified to 30 m/s while propagating into the mid-Mississippi Valley. At the same time a 65 m/s jet streak at the 300 mb level was entering Missouri.

At 1200 GMT May 12 the axis of the low level jet on the 305 K isentropic surface extended from Texas northeastward through western Tennessee into Ohio. Twelve hours later a wind maximum of 25 m/s had been established over Arkansas and southern Illinois. Veering of the wind in the vertical was evident in the precedent soundings on the morning of May 12 throughout the mid-Mississippi Valley (Figure 8). This directional wind shear has been linked to tornadic storm development and its effect on the stability of the troposphere has already been discussed. (See Videocassette: 1200 GMT and 0000 GMT: 700 mb streamlines, wind speed and temperature advection; 300 mb heights and wind speed; 300 K or 305 K pressure, streamlines and mixing ratios; 850 mb streamlines and 500 mb streamlines; 850 mb streamlines, wind speed and temperature advection; soundings; 850 mb temperature advection; 850 mb dewpoint advection; 700 mb temperature advection; 700 mb dewpoint advection.)

4) Lifting Mechanism

Fawbush and Miller concluded that a triggering or lifting mechanism was important for the release of convective instability in the development of thunderstorms. On May 12th, upward vertical motion was provided by a combination of strong surface convergence and upper tropospheric divergence associated with the advancing short wave trough (Figures 3a,b,c). During the squall line's formation, this 500 mb short wave trough amplified rapidly over the

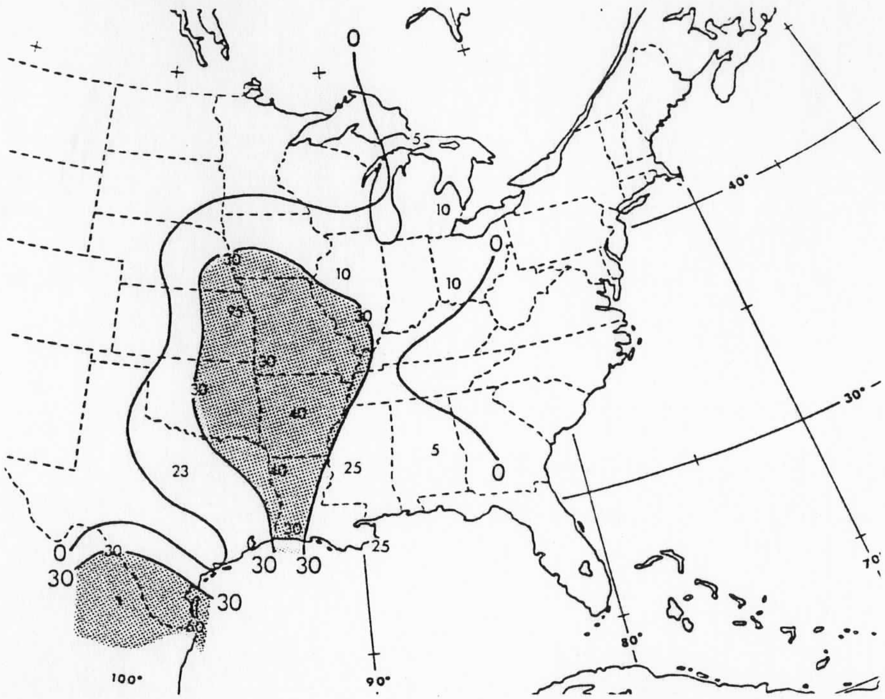

Fig. 8: Vertical directional wind shear between 850 mb and 500 mb (500 mb direction minus 850 mb direction) over the central United States at 1200 GMT on 12 May, 1978. The numbers plotted and analyzed are derived utilizing the rules governing the SWEAT index. The result is set to zero if 1) the 850 mb wind is between 260° and 120° (through north), or 2) the 500 mb wind is between 320° and 200° (through east), or 3) the difference between 500 mb direction and 850 mb direction is negative. The region where the wind veers greater than 30° within the layer is shaded.

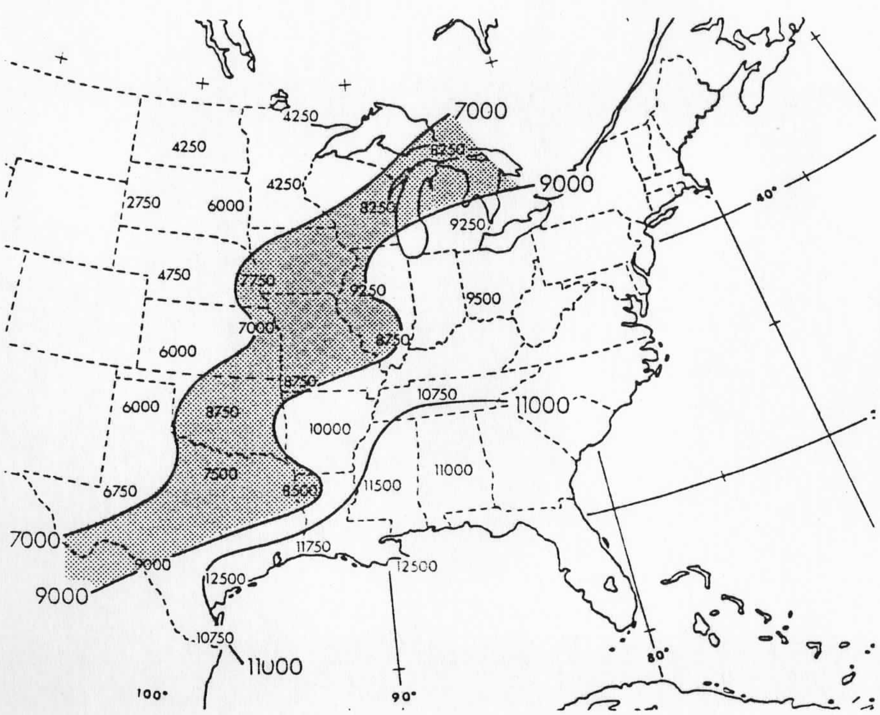

Fig. 9: Height [ft] where the wet bulb temperature equals 0°C over the central United States at 1200 GMT on 12 May, 1978.

Great Plains leading to strong positive vorticity advection, a condition which implies upper tropospheric divergence over the incipient squall line. This superposition of vorticity advection with the squall line is indicated by the computer derived vorticity advection calculations from 0000 GMT May 13 and the 2335 GMT NMC radar summary. Computer calculations for 300 mb also show divergence over the same region, while strong convergence was indicated at the surface in the vicinity of the cold front. Low level convergence maxima were frequently located south of the squall line prior to its continued southward extension. Convergence ahead of the main squall line's low level surge of cooler air possibly contributed to continued development throughout the afternoon as the squall line moved out ahead of the surface front. (See videocassette: SFC divergence; SFC θ_E divergence; manually digitized radar; 1200 GMT and 0000 GMT: 300 mb wind speed and divergence; 500 mb streamlines and absolute vorticity.)

5) Freezing level

Once thunderstorms form, the height of the freezing level within the clouds is highly correlated to severe weather potential (Miller, 1972). The freezing level for the convection is forecasted by finding the height where the wet-bulb temperature of the atmosphere is zero degrees Celsius in the precedent soundings. Heights ranging from 7,000 to 9,000 feet were shown to be favorable for tornadoes while large hail development frequently occurred with heights between 7,000 and 12,000 feet. Wet bulb zero heights between 8,000 and 10,000 feet were present in the threat region prior to the May 12th outbreak (Figure 9).

The severe weather outbreak of May 12th was well forecasted through the use of basic criteria set forth by Fawbush and Miller (1951). Numerous favorable precedent conditions were found prior to the squall line development and strong dynamical forcing of the outbreak was provided by an intense upper tropospheric disturbance. This combination of conditions and processes created a classic severe weather case.

VI. Map Package Contents

An extensive series of maps and radiosonde data prepared from conventional data are supplied with the module (see Appendix A). This series includes surface, isobaric, isentropic and radar charts. Additionally, gridded fields of McIDAS derived quantities and a set of hand analyzed charts for the period 12 May 1200 GMT to 13 May 1200 GMT are provided. The following is a list of the maps provided with the module.

Maps provided with Squall Line Module

1. Analyzed Charts (those noted below)

2. Surface Charts

   a. 12 May 1200 GMT*
   b. 12 May 1800 GMT*
   c. 13 May 0000 GMT*
   d. 13 May 0600 GMT*
   e. 13 May 1200 GMT*

3. Isobaric Charts
   300 mb, 500 mb, 700 mb, 850 mb

   a. 11 May 1200 GMT
   b. 12 May 0000 GMT
   c. 12 May 1200 GMT*
   d. 13 May 0000 GMT*
   e. 13 May 1200 GMT*
   f. 14 May 0000 GMT
   g. 14 May 1200 GMT

4. Isentropic Charts
   5°K interval

a.	11 May 0000 GMT	300 - 305 K	
b.	11 May 1200 GMT	300 - 305 K	
c.	12 May 0000 GMT	300 - 305 K	
d.	12 May 1200 GMT	290 - 325 K	305 K analyzed
e.	13 May 0000 GMT	290 - 325 K	305 K analyzed
f.	13 May 1200 GMT	290 - 320 K	305 K analyzed

5. Radar Charts/NMC Facsimile Product

   a. 12 May 1035 GMT
   b. 12 May 1435 GMT
   c. 12 May 1735 GMT
   d. 12 May 1935 GMT
   e. 12 May 2035 GMT
   f. 12 May 2135 GMT
   g. 12 May 2235 GMT
   h. 12 May 2335 GMT
   i. 13 May 0135 GMT
   j. 13 May 0235 GMT
   k. 13 May 0435 GMT
   l. 13 May 0535 GMT
   m. 13 May 0635 GMT
   n. 13 May 1435 GMT

6. Isentropic Cross Sections
HON -OMA -UMN -LIT -JAN -BVE

a. 12 May 1200 GMT*
b. 13 May 0000 GMT*
c. 13 May 1200 GMT*

*hand analyzed copy included

7. McIDAS Derived Fields

a.	Surface fields	12 May 1300 GMT divergence
		12 May 1500 GMT divergence
		12 May 1800 GMT divergence
		12 May 2100 GMT divergence
		13 May 0000 GMT divergence
		13 May 0300 GMT divergence
		13 May 0600 GMT divergence
b.	12 May 1200 GMT	850 mb temperature advection
		850 mb dewpoint advection
		850 mb divergence
		700 mb temperature advection
		700 mb dewpoint advection
		700 mb divergence
		500 mb temperature advection
		500 mb divergence
		500 mb vorticity advection
		300 mb temperature advection
		300 mb divergence
c.	13 May 0000 GMT	850 mb temperature advection
		850 mb dewpoint advection
		850 mb divergence
		700 mb temperature advection
		700 mb dewpoint advection
		700 mb divergence
		500 mb temperature advection
		500 mb divergence
		500 mb vorticity advection
		300 mb temperature advection
		300 mb divergence

8. Radiosonde data

VII. MODULE EVALUATION

This module, developed over the past 18 months, is an experiment in the development of new educational resources in atmospheric science. The new resources expand upon the traditional case study by incorporating videocomputer technology to display the evolution of atmospheric structure through use of satellite imagery and meteorological fields. An important need in development is feedback from instructors and students to evaluate the utility of new educational resources and to facilitate improvements in content and quality. A questionnaire is included in this manual for distribution to participating students.

MODULE EVALUATION: SQUALL LINE DEVELOPMENT

This questionnaire is provided to allow you to express your opinion on the effectiveness of this module as a teaching device in the atmospheric sciences. Your answers to the following questions, and any additional comments you may have, will help to determine if the videotape meets this goal or if changes are necessary. When answering the following questions, please write legibly and express your opinion fully. Thank you.

1) Do you feel the videotape presents the material in a logical manner?

YES ____

NO ____

COMMENT:

2) Did the pace of the videotape segments listed below allow you to distinguish important features of the satellite imagery and derived fields? Please comment on specific fields that you would change.

	FAST	ALL RIGHT	SLOW
SURFACE FIELDS	____	____	____
UPPER AIR FIELDS	____	____	____
COMBINED FIELDS	____	____	____

COMMENT:

MODULE EVALUATION: SQUALL LINE DEVELOPMENT

3) The overall pace of the videotape was:

MUCH TOO FAST ____

SOMEWHAT TOO FAST ____

JUST RIGHT ____

SOMEWHAT TOO SLOW ____

MUCH TOO SLOW ____

COMMENT:

4) The visual quality of the videotape was:

VERY GOOD ____

ACCEPTABLE ____

NEEDS IMPROVEMENT ____

WHAT IMPROVEMENTS ARE NEEDED?

MODULE EVALUATION: SQUALL LINE DEVELOPMENT

5) Did the accompaniment guide aid in your understanding of the videotape contents?

YES ____

SOMEWHAT ____

NO ____

COMMENT:

6) Would a voice narration help in your understanding of the videotape contents?

YES ____

NO ____

DON'T KNOW ____

COMMENT:

MODULE EVALUATION: SQUALL LINE DEVELOPMENT

7) In helping you to visualize the processes that occur in the atmosphere, the videotape was:

VERY BENEFICIAL ____

HELPED SOMEWHAT ____

DID NOT HELP ____

COMMENT:

8) As an aid to understanding material presented in this course the videotape was:

VERY HELPFUL ____

HELPED SOMEWHAT ____

DID NOT HELP ____

COMMENT:

MODULE EVALUATION: SQUALL LINE DEVELOPMENT

9) If you were teaching this course would you use this videotape in your class?

DEFINITELY ____

YES, WITH EXCEPTIONS ____

NO ____

COMMENT:

10) Is there some way you would change the sequences of images or the looping structure to improve the videotape?

YES ____

NO ____

COMMENT:

MODULE EVALUATION: SQUALL LINE DEVELOPMENT

11) Are there any synoptic fields or other features that you feel should be added or deleted on the videotape? Why?.

ADDED:

DELETED:

12) Are there any other suggestions to improve this module (videotape, accompaniment guide, synoptic discussion, map package)?

COMMENT:

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APPENDIX A

CASE STUDY MAP PACKAGE

1. Analyzed Charts

Surface Charts
a. 12 May 1200 GMT
b. 12 May 1800 GMT
c. 12 May 0000 GMT
d. 13 May 0600 GMT
e. 13 May 1200 GMT

Isobaric Charts
300 mb, 500 mb, 700 mb, 850 mb
a. 12 May 1200 GMT
b. 13 May 0000 GMT
c. 13 May 1200 GMT

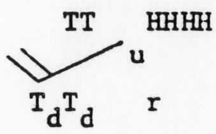
Isentropic Charts
305 K Surface
a. 12 May 1200 GMT
b. 13 May 0000 GMT
c. 13 May 1200 GMT

Isentropic Cross Sections
HON -OMA -UMN -LIT -JAN -BVE
a. 12 May 1200 GMT
b. 13 May 0000 GMT
c. 13 May 1200 GMT

Squall line Development and Cyclogenesis Plotting Models

Surface Maps: Standard WMO United States station model

Pressure Surfaces:



TT : Temperature [°C]

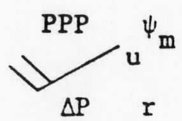
T_dT_d: Dew Point [°C]

HHHH : Geopotential height [m]

r : Mixing ratio [g/kg]

u : Units digit of wind speed [m/s]

Isentropic Surfaces:



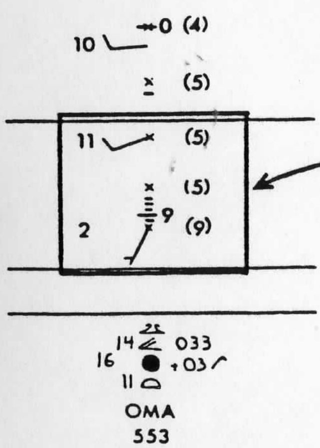
PPP : Pressure [mb]

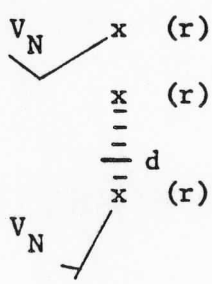
ΔP : Pressure change between Θ and Θ + 5K surfaces [mb]

ψ_m : Montgomery stream function (leading 2 or 3 missing) [m^2/s^2]

r,u : (same as above)

Isentropic Cross Section:



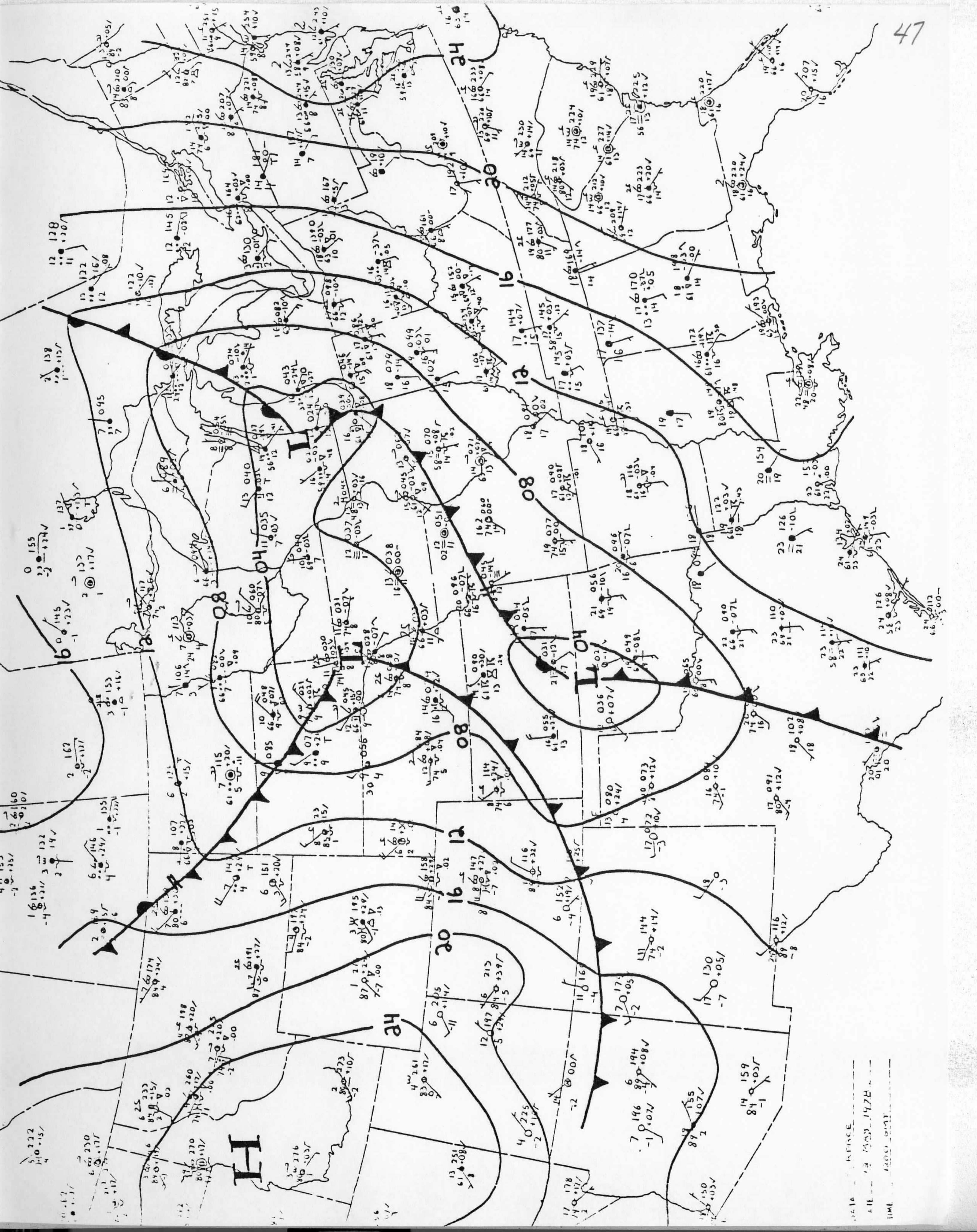


(r) : Mixing ratio [g/kg] at point x

— d : $\left.\begin{matrix}3\\2\end{matrix}\right\}$d3 Θ value [°K] (with 2 or 3 missing)(ie. — 9 = 293K or 393K)

V_N : Wind speed normal to the cross section [m/s]

- : Isentropic value every 2K


H
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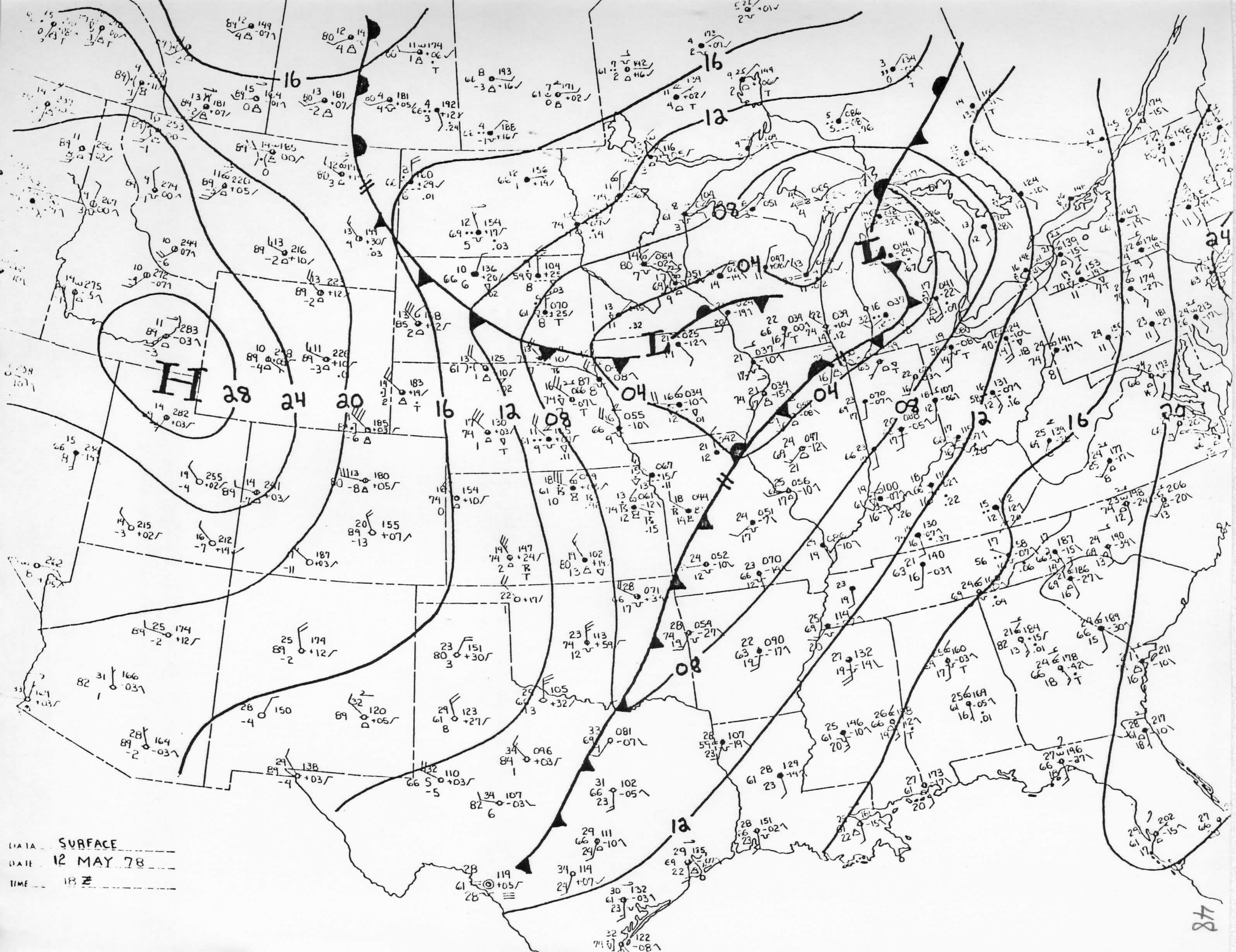
MAY 1978



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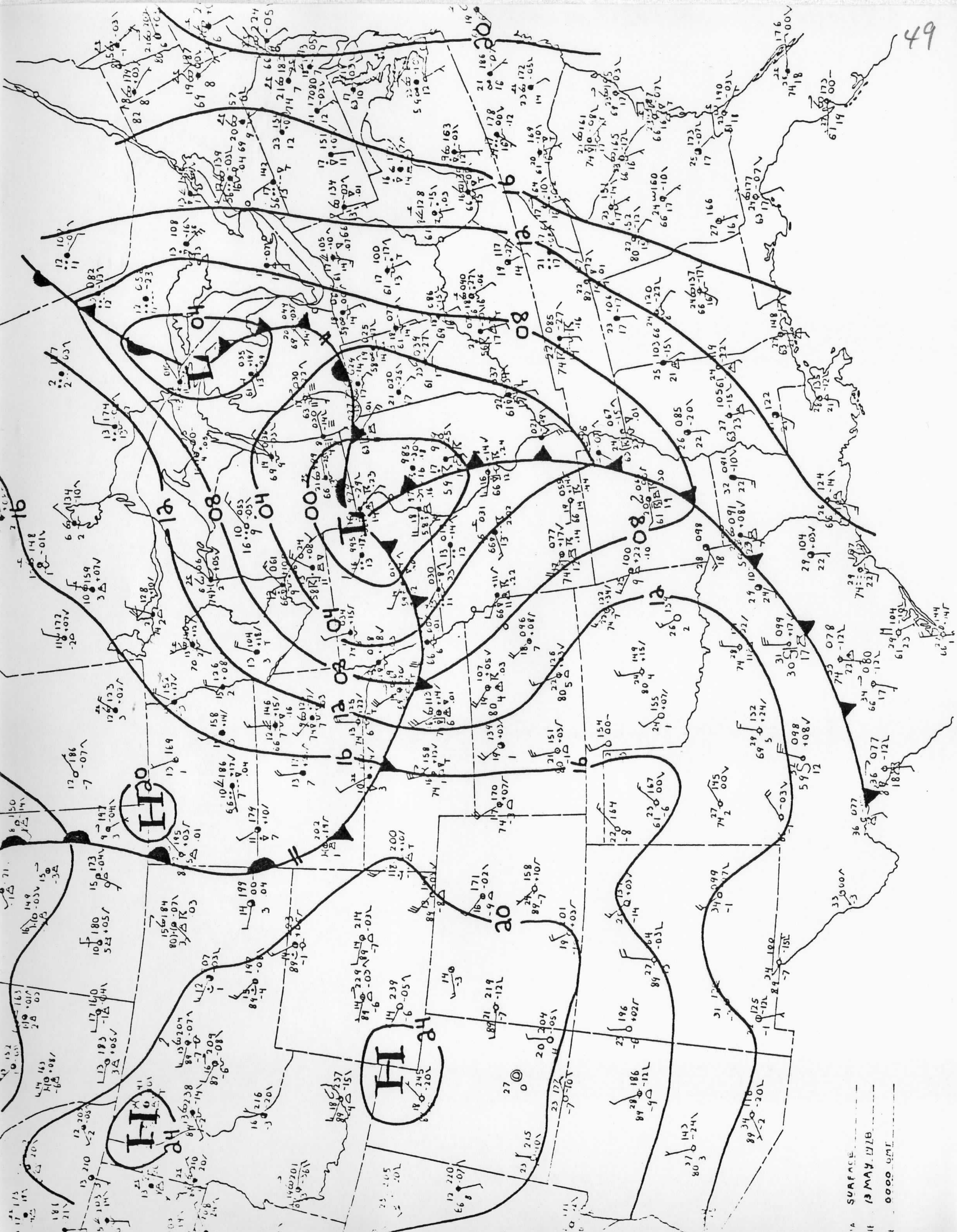
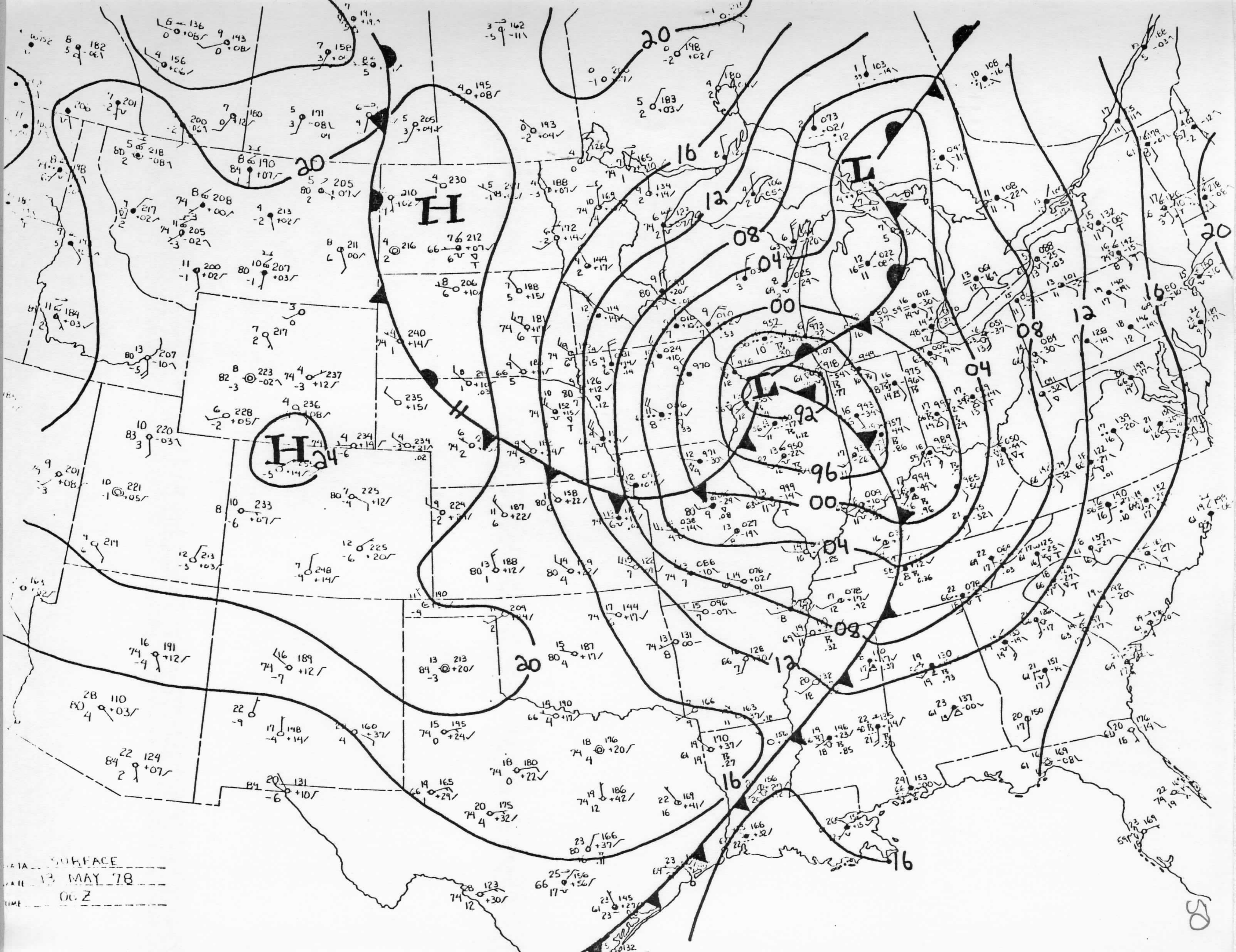
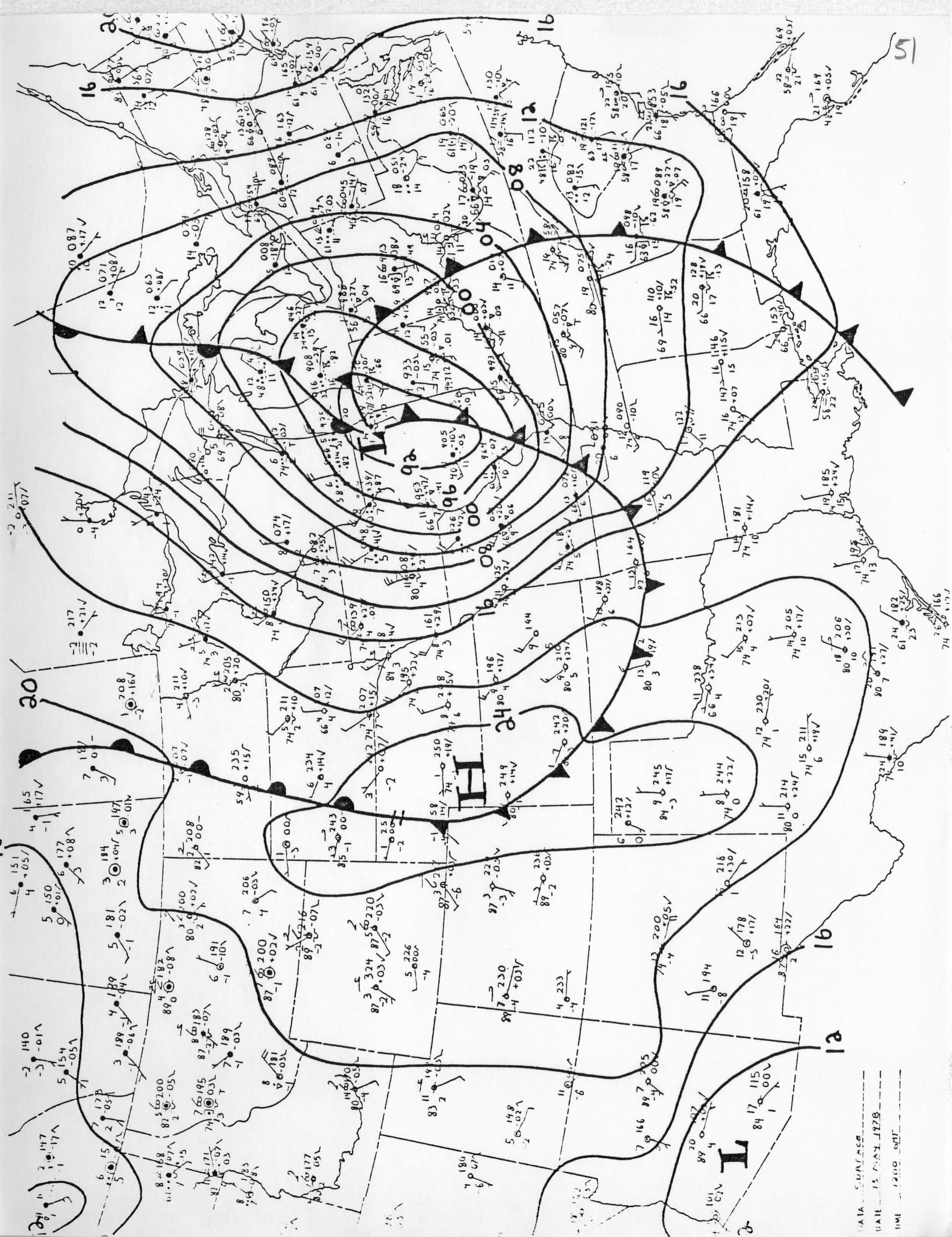
24
20
16
12
08
04
DATA SURFACE
DATE 12 MAY 78
TIME 18 Z


SURFACE
13 MAY 1978
0000 GMT



50



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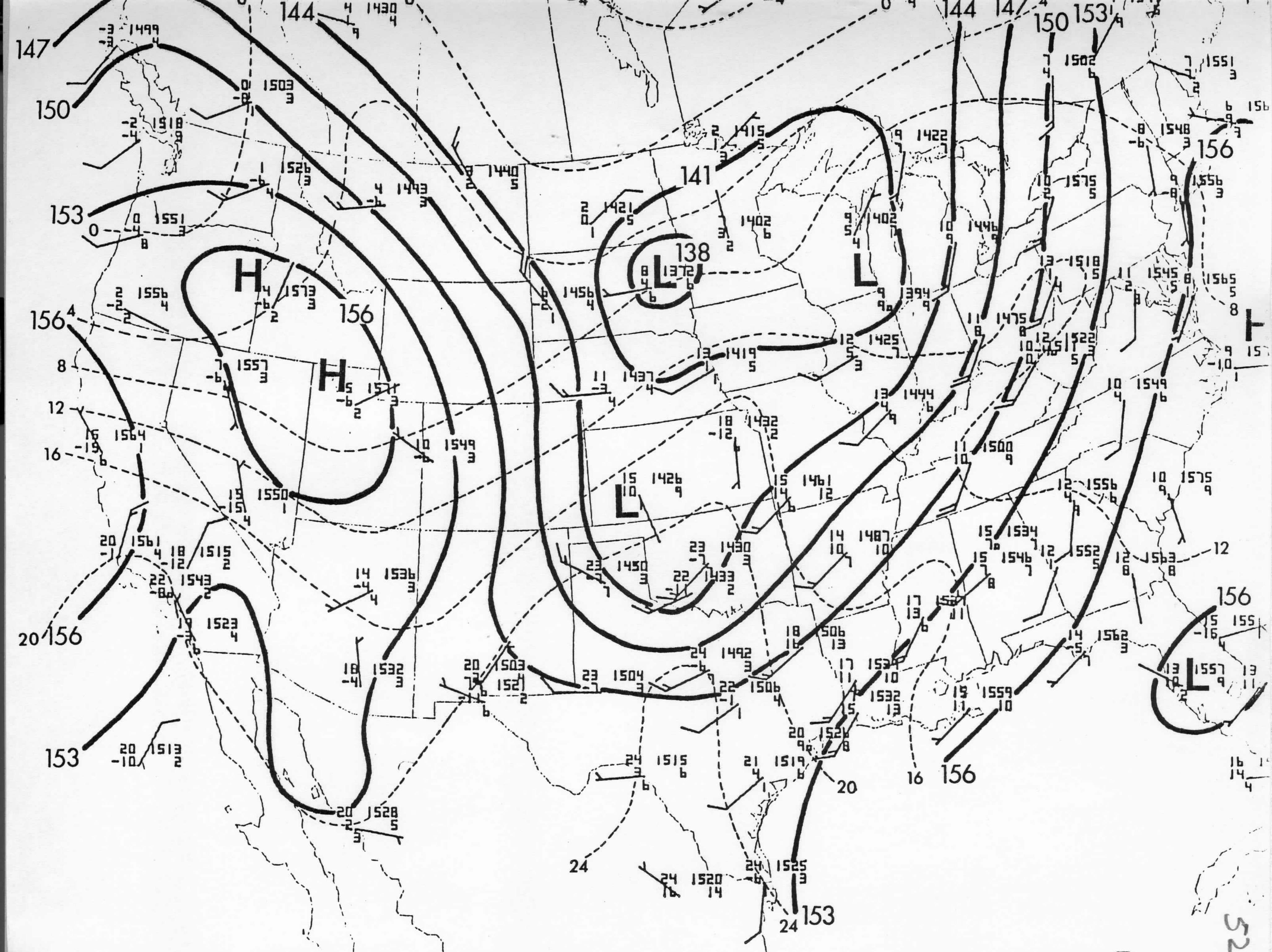
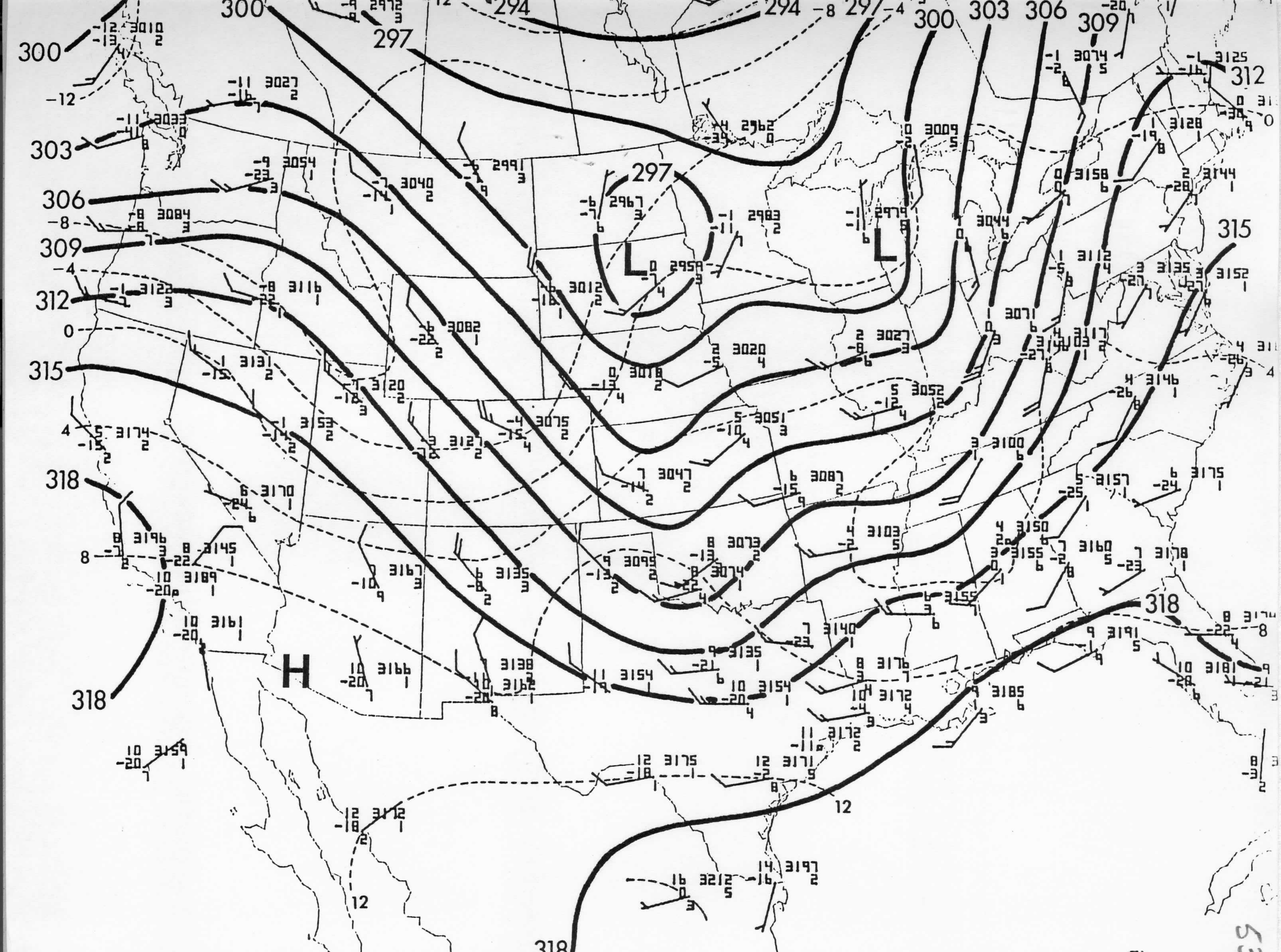
TIME 1200 GMT



PRESSURE 850MB 12UT 12 MAY 1978



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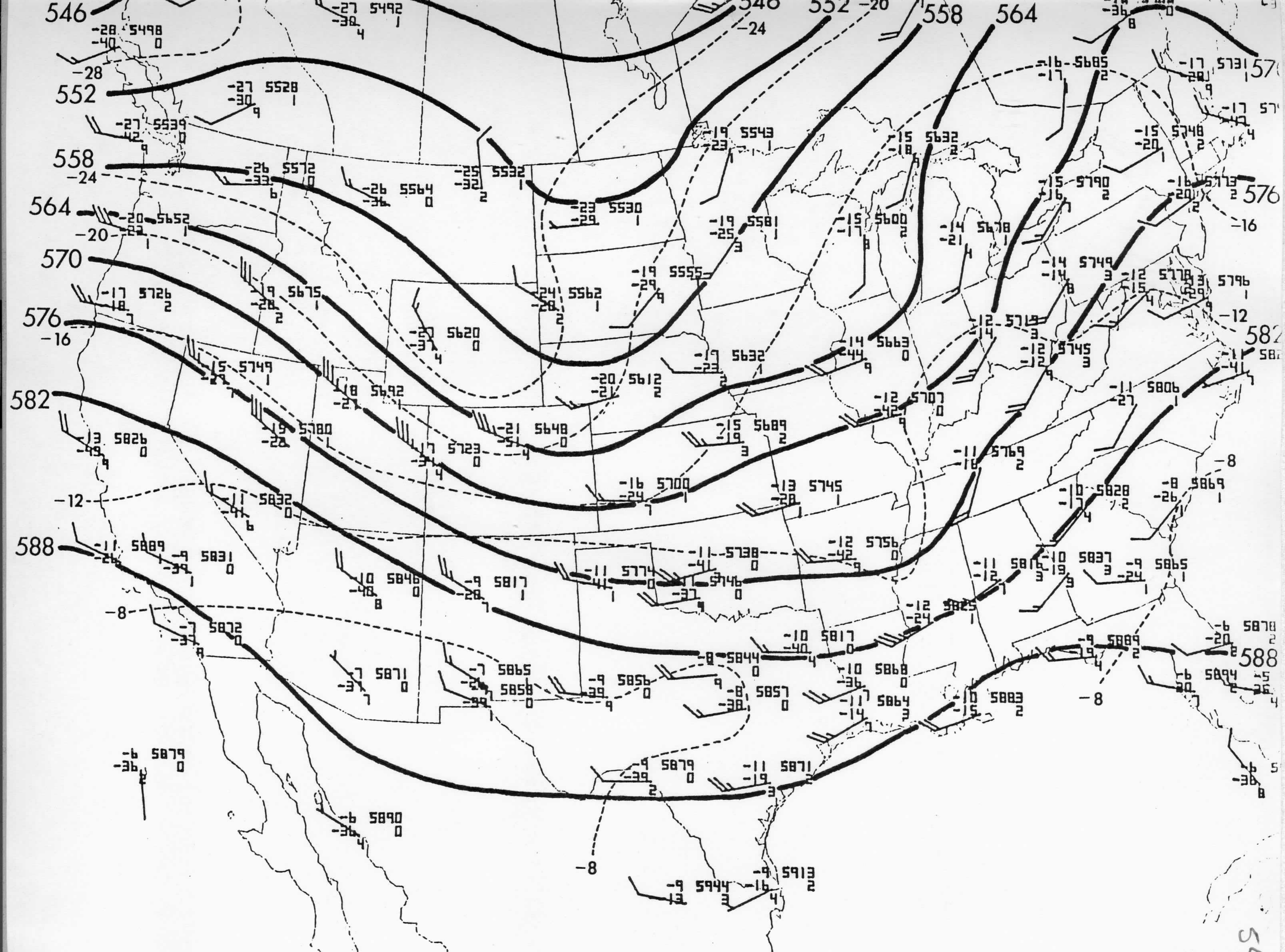

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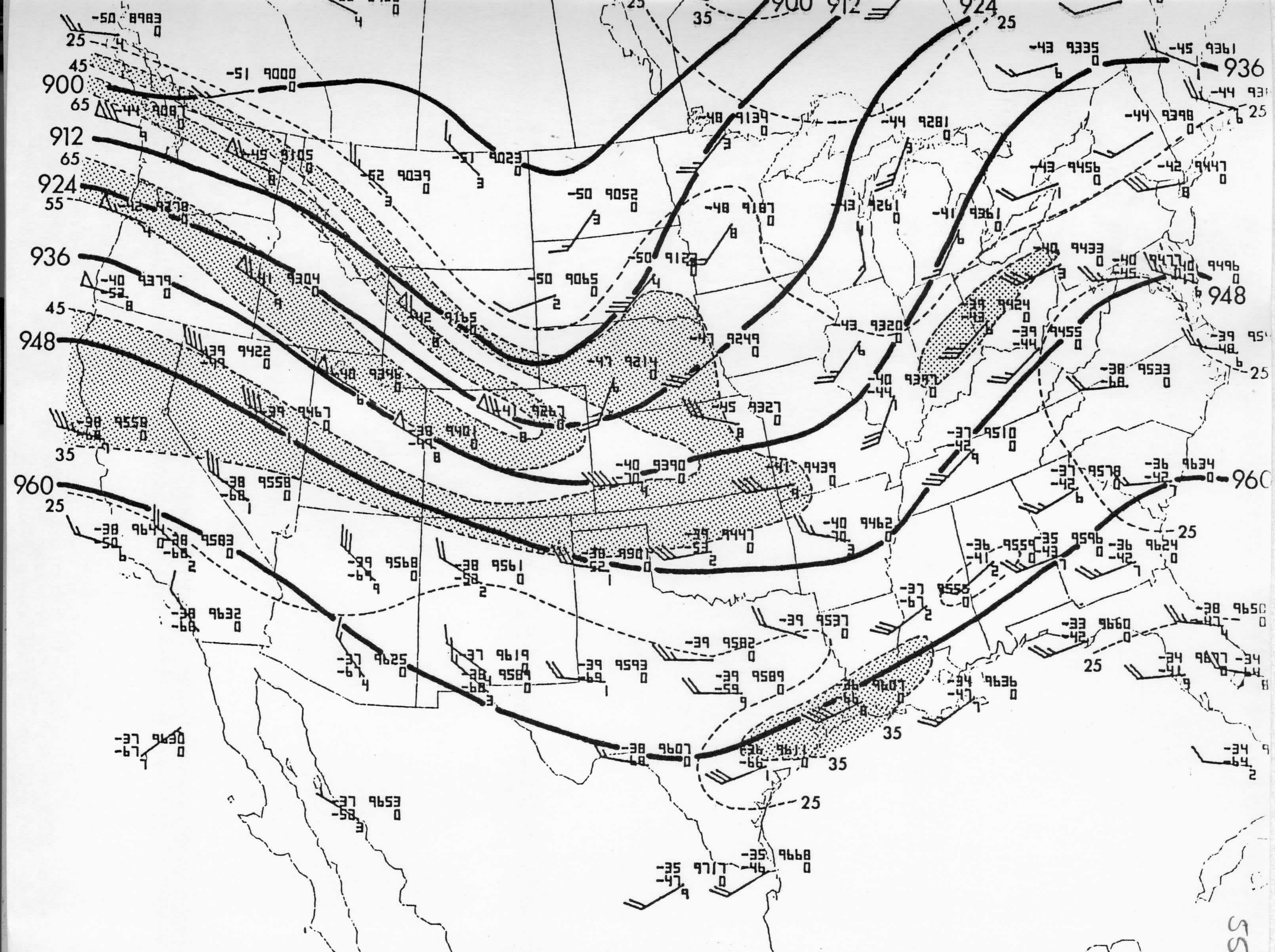

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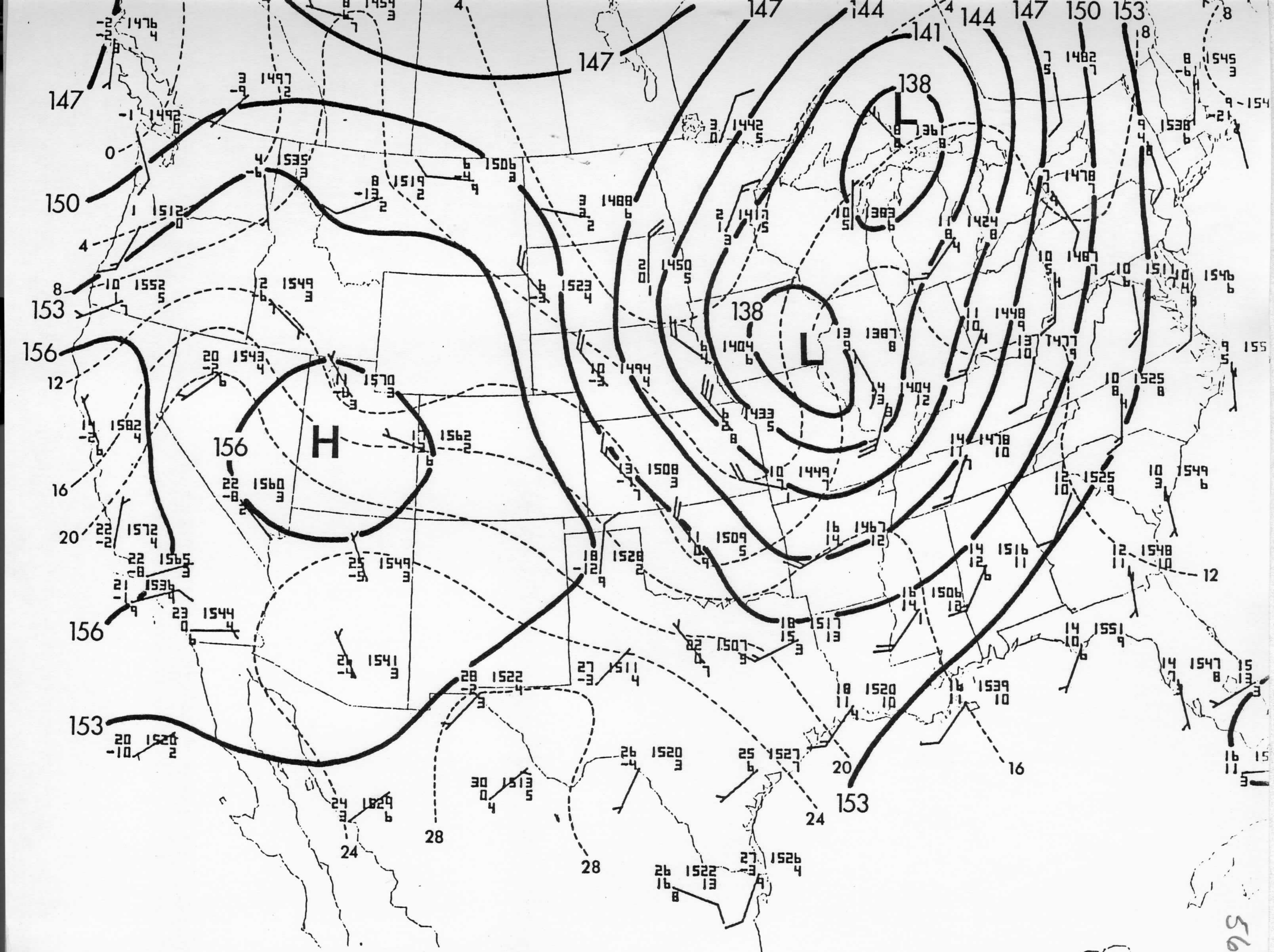
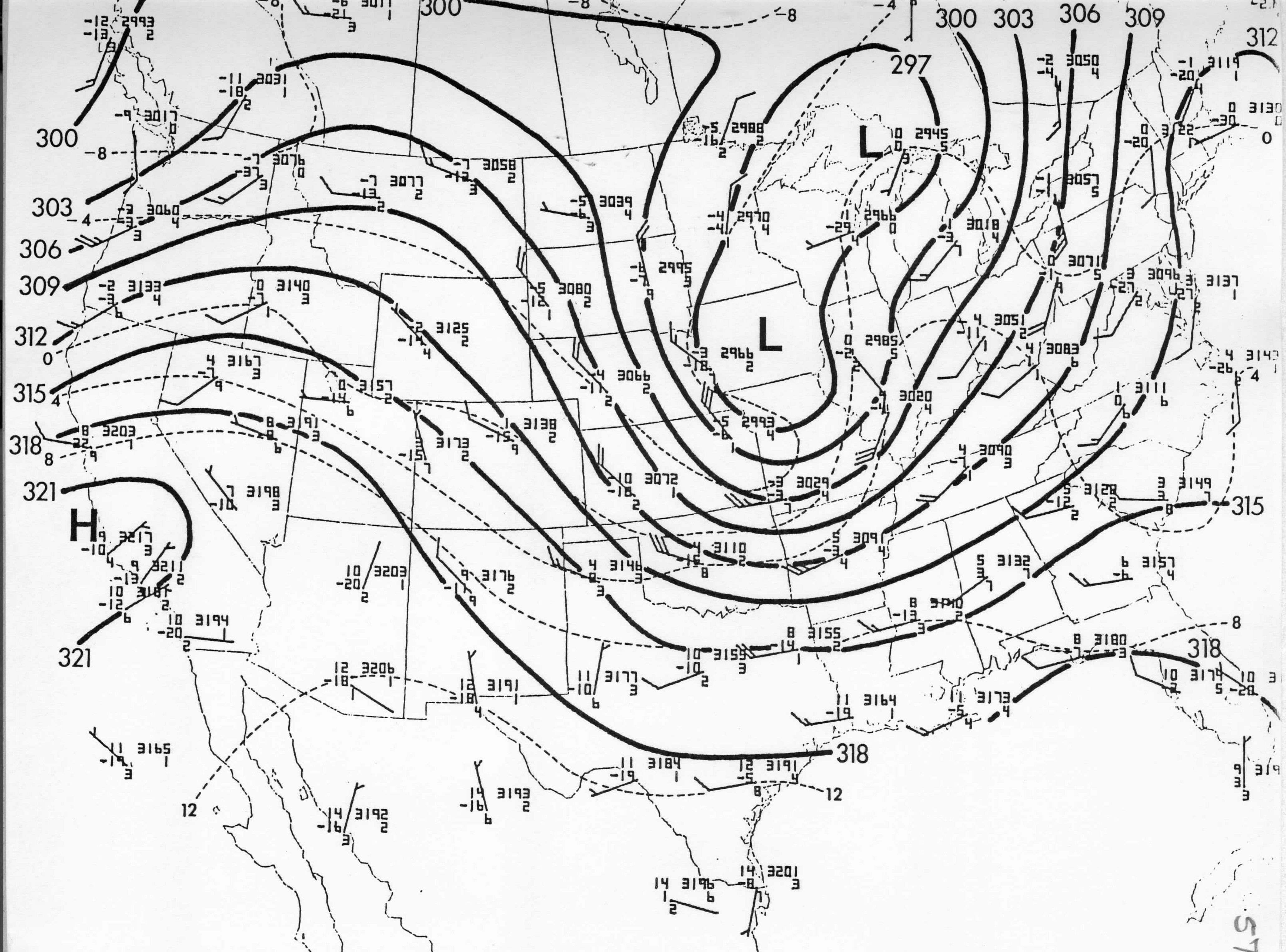


PRESSURE 850MB 00UT 13 MAY 1978

56



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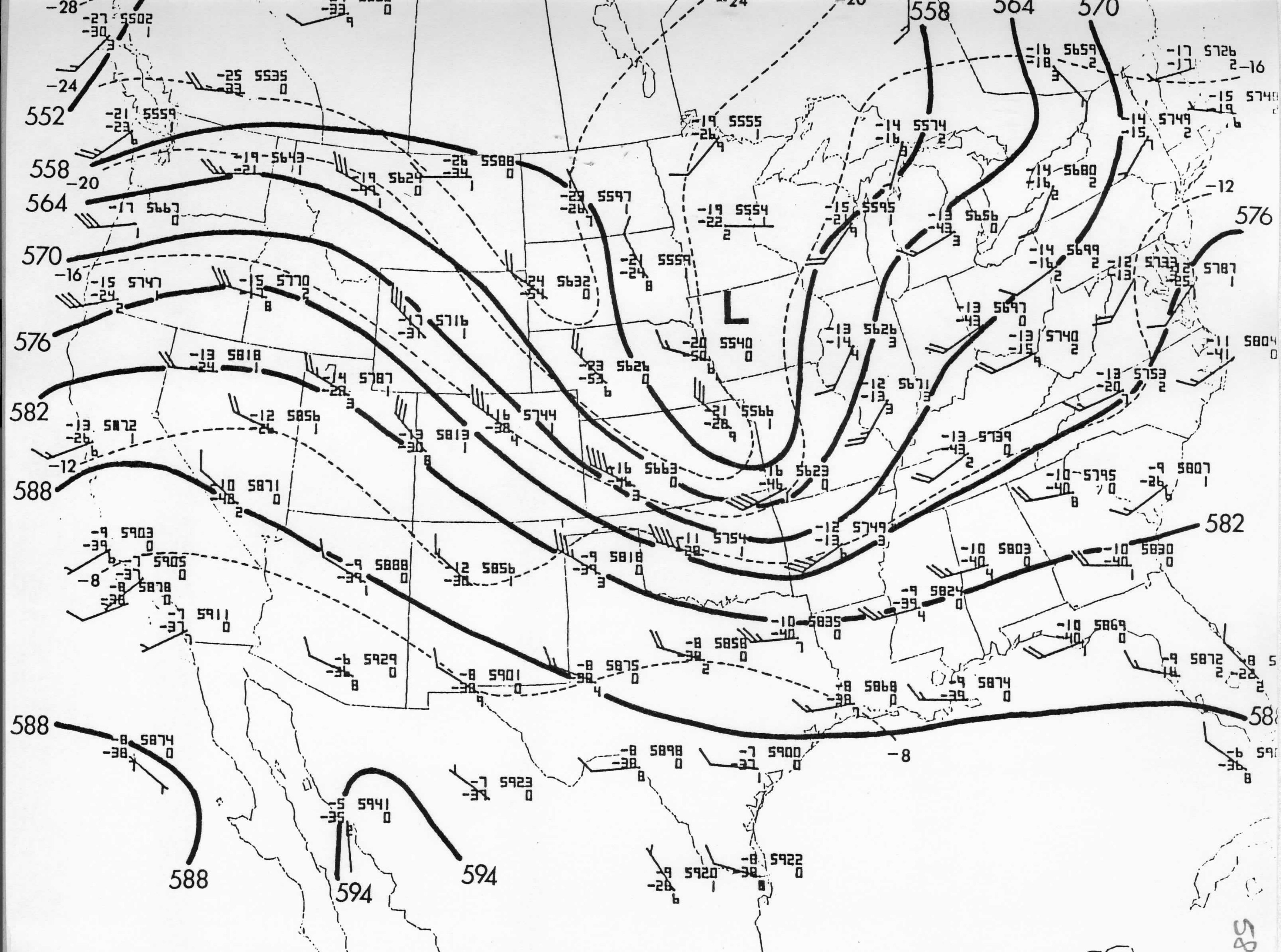

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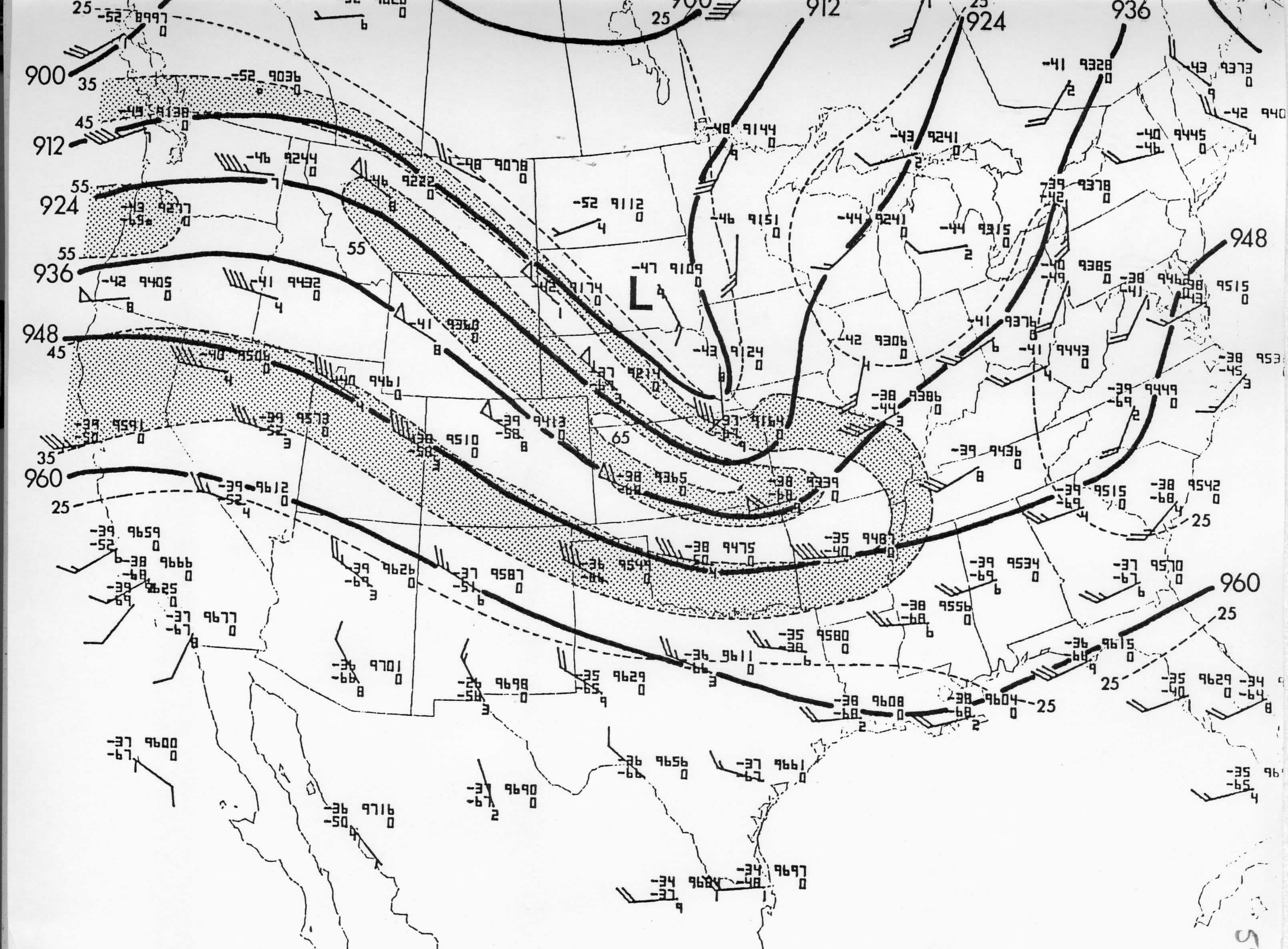

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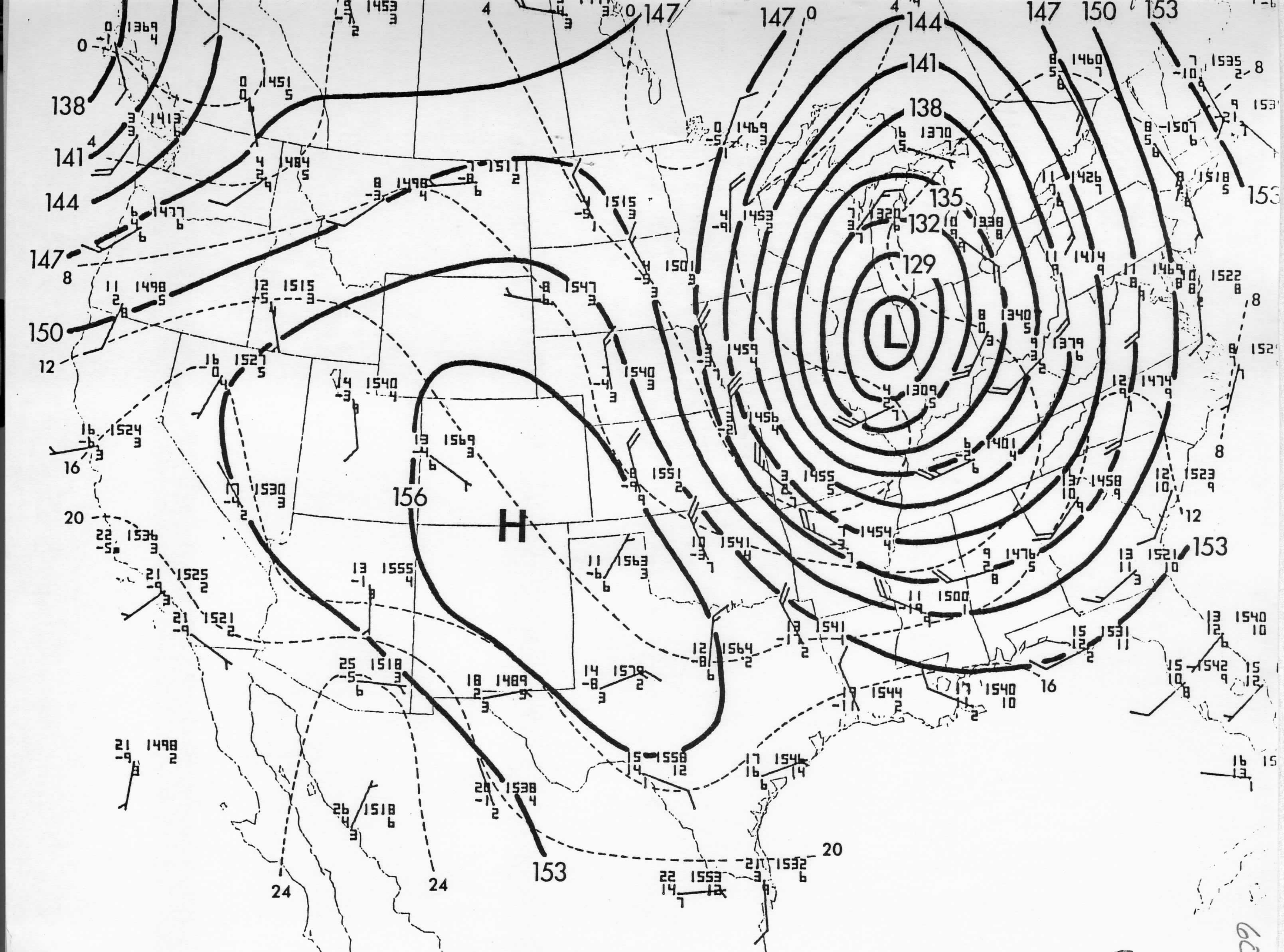

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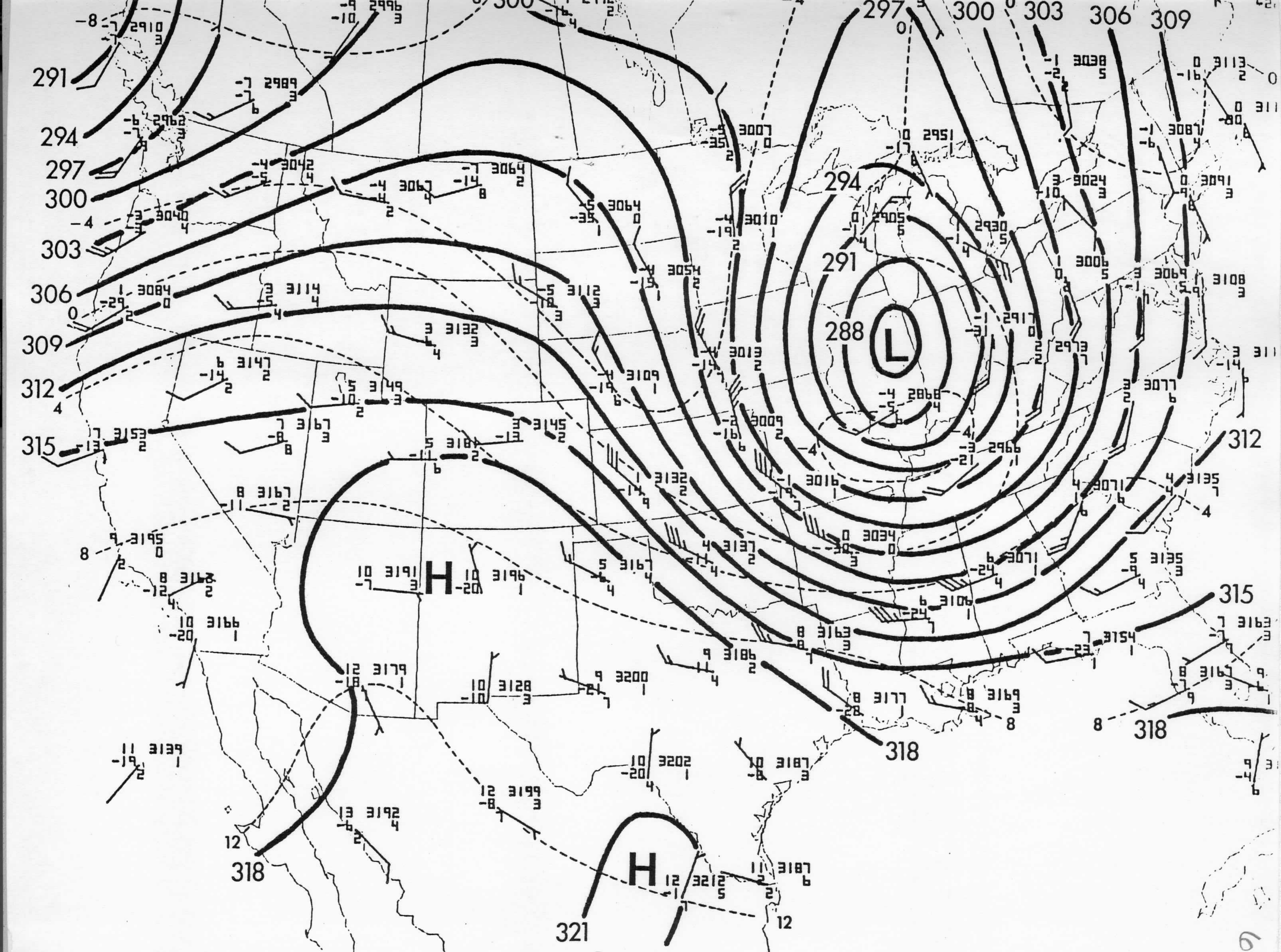

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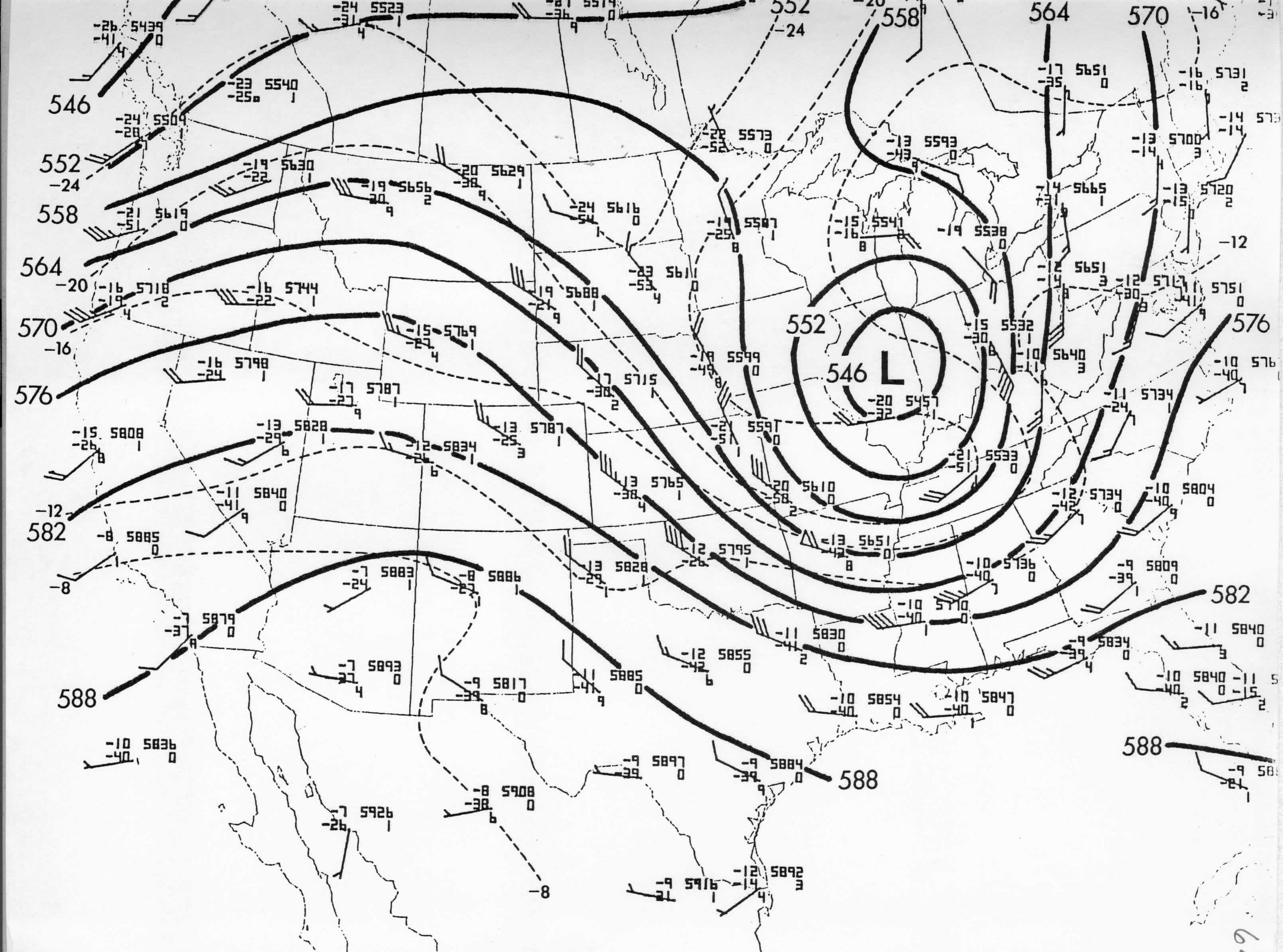

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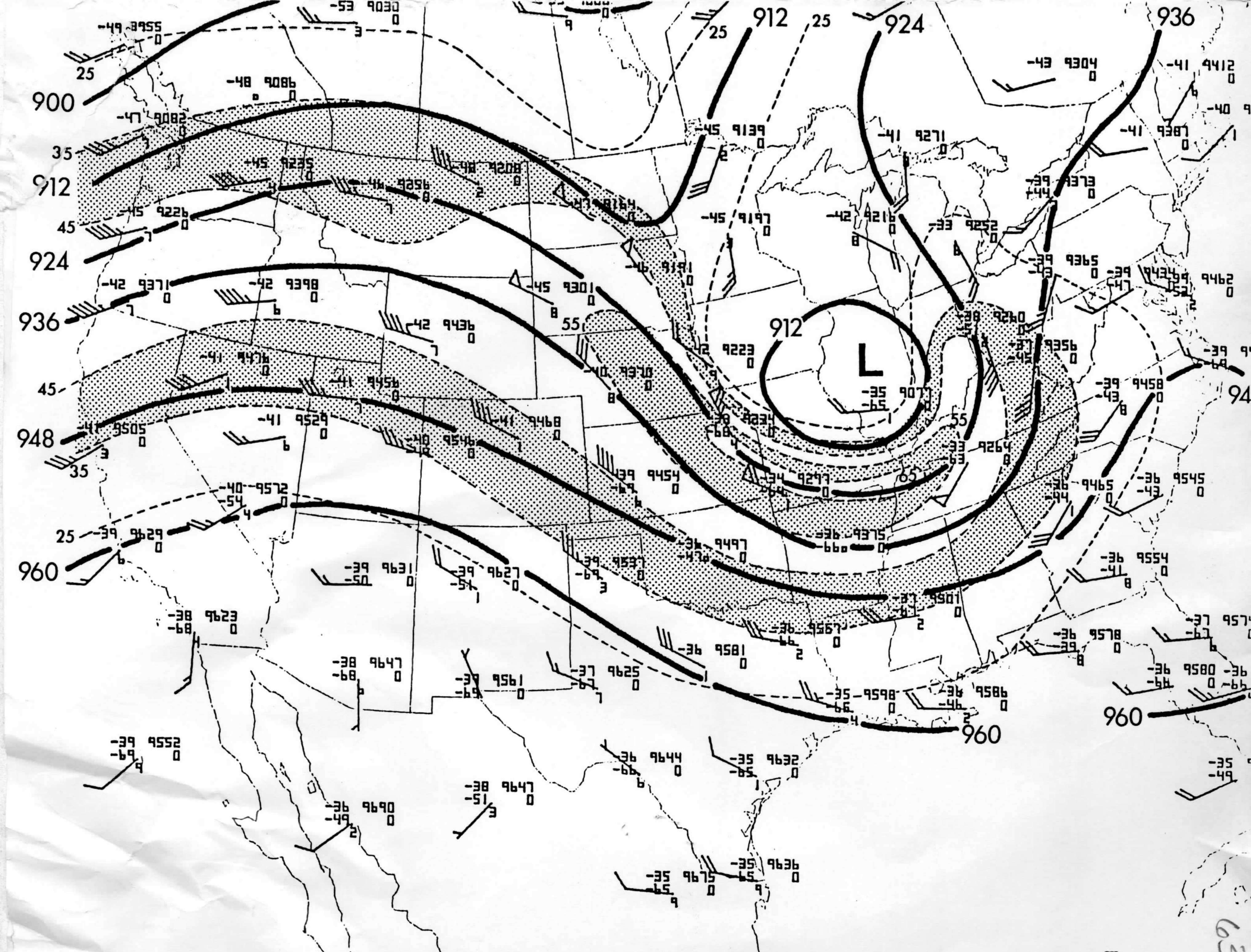

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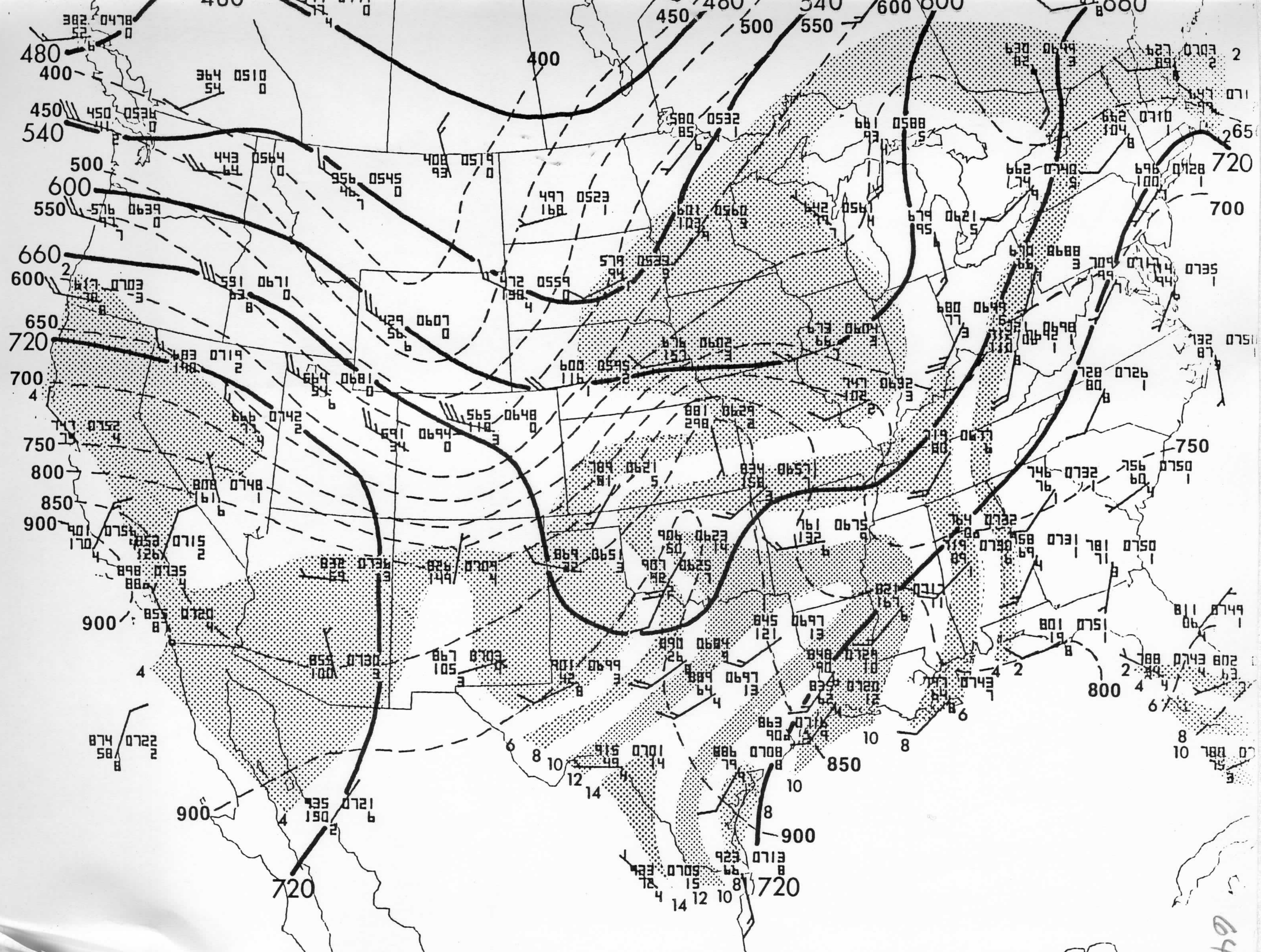
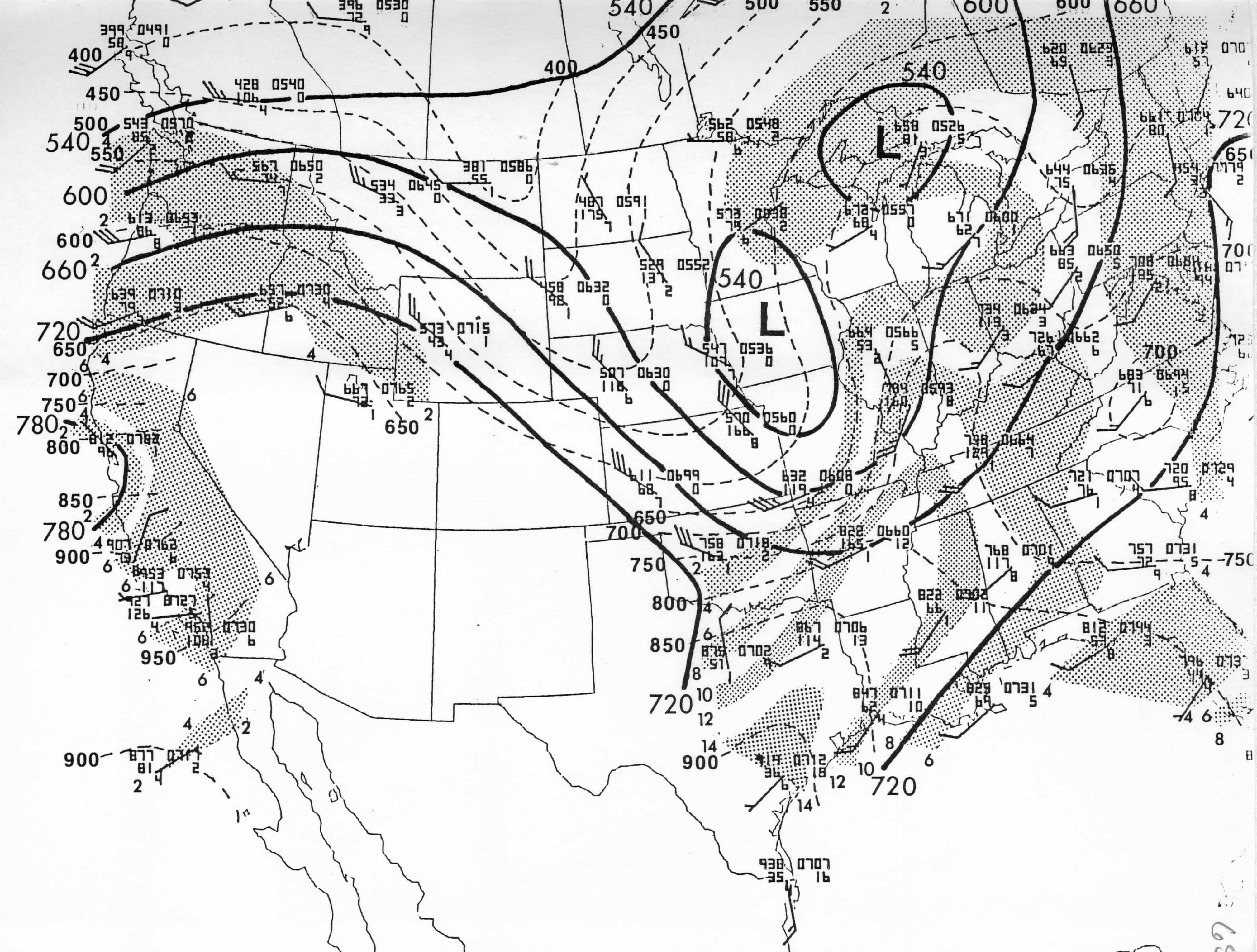


ISENTROPIC 305K 12UT 12 MAY 1978



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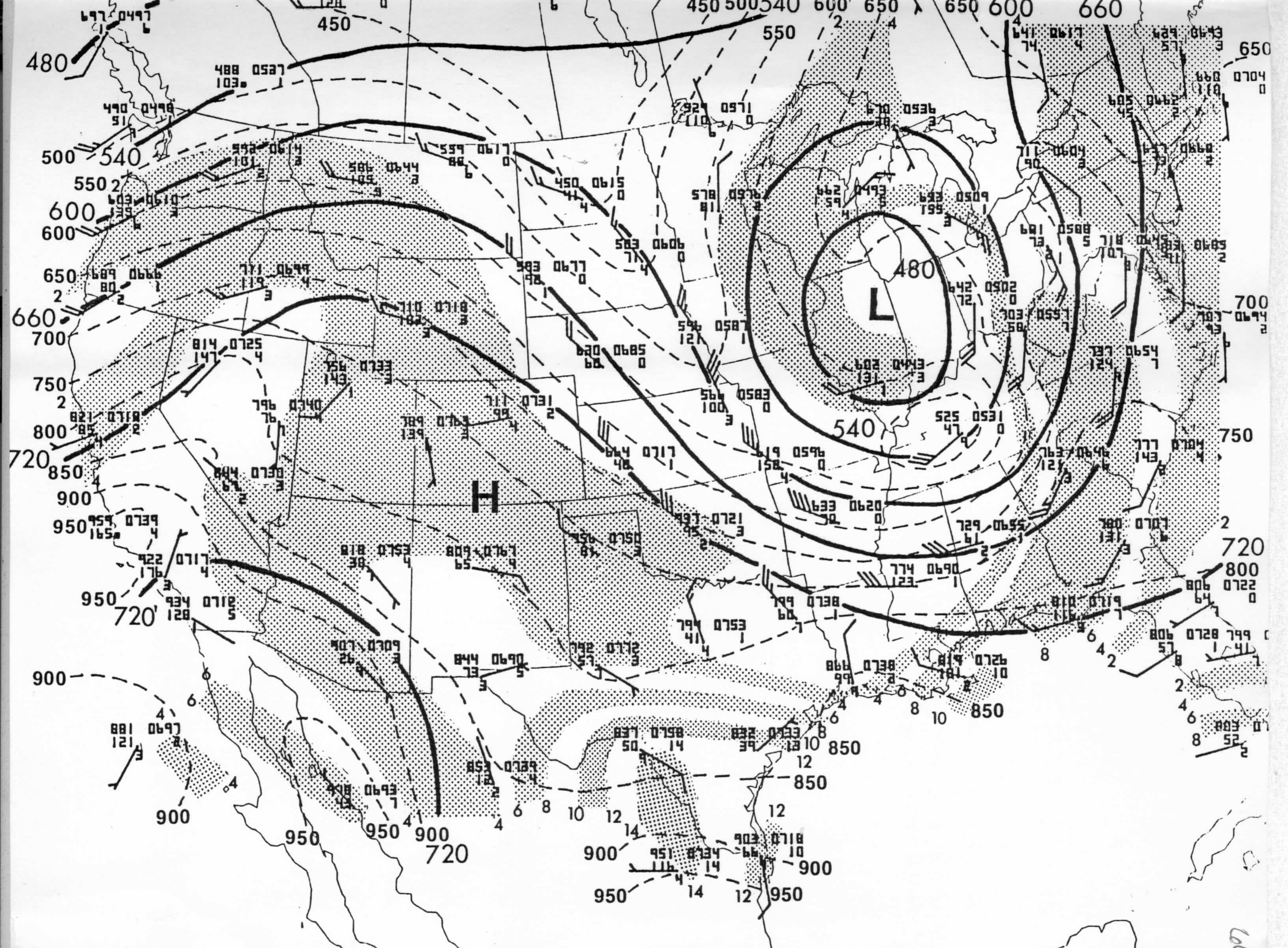

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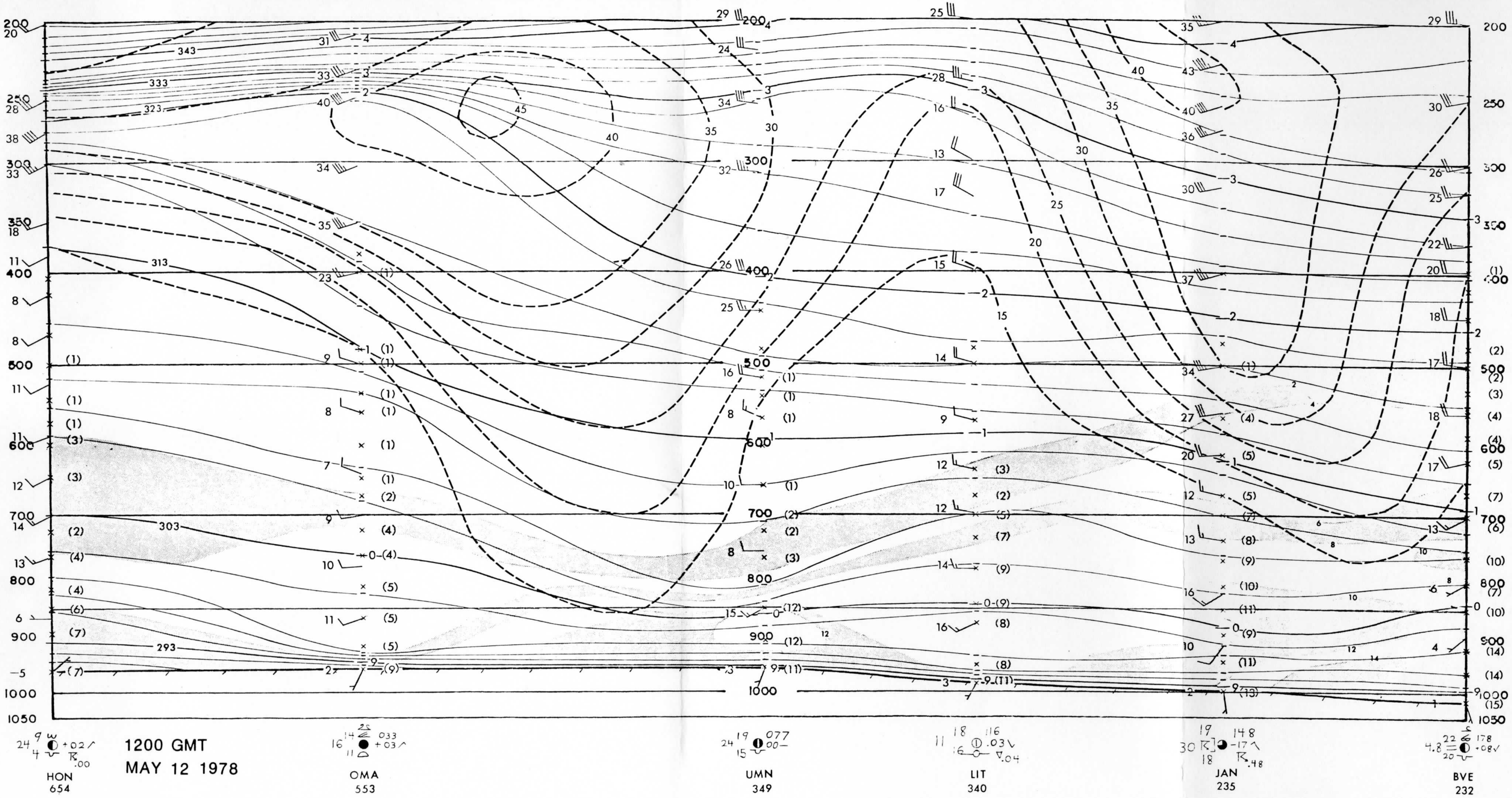
1200 GMT
MAY 12 1978
HON
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OMA
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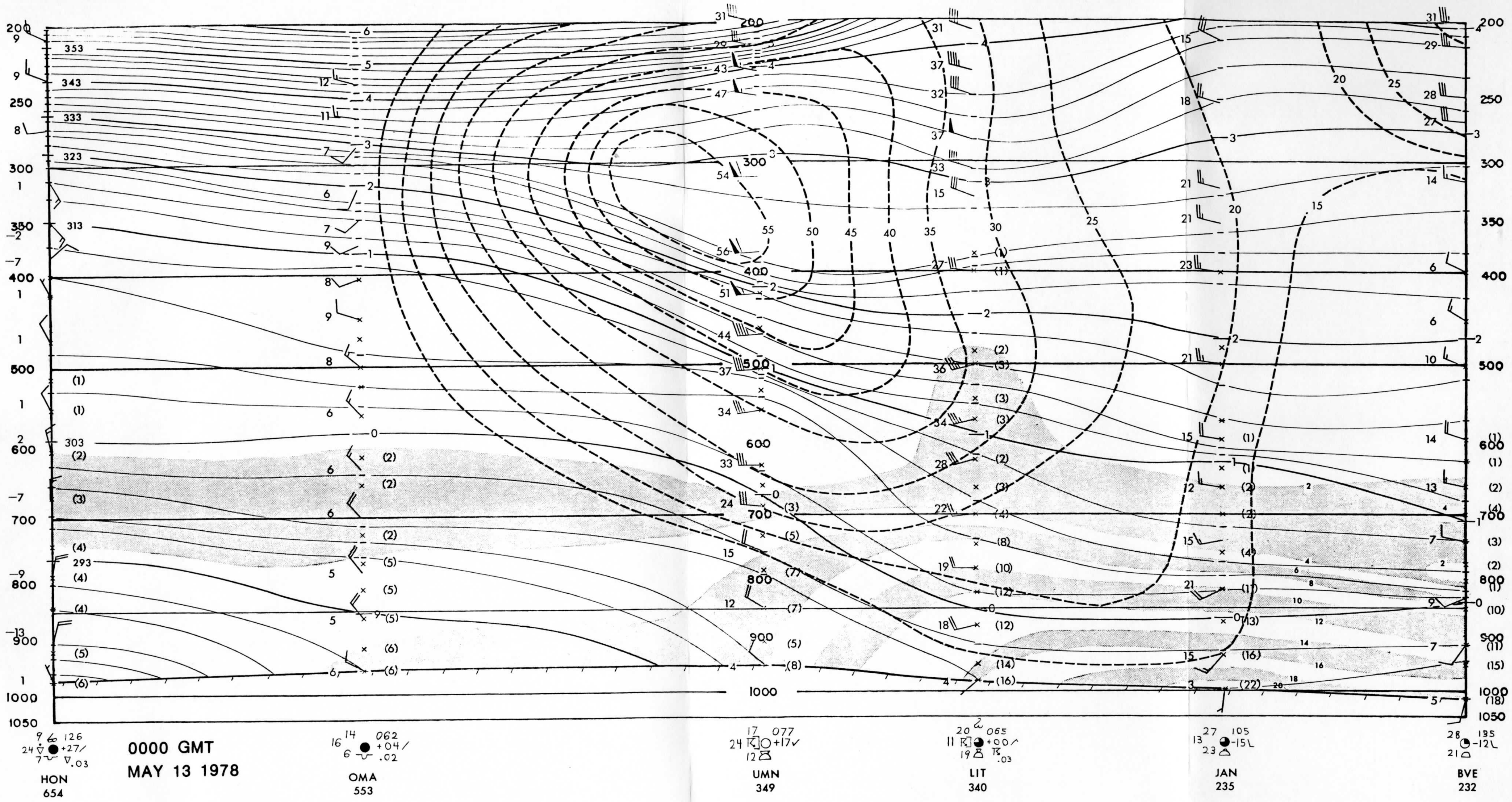
UMN
349
LIT
340
JAN
235
BVE
232


0000 GMT
MAY 13 1978
HON
654
OMA
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340
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235
BVE
232
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250
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700
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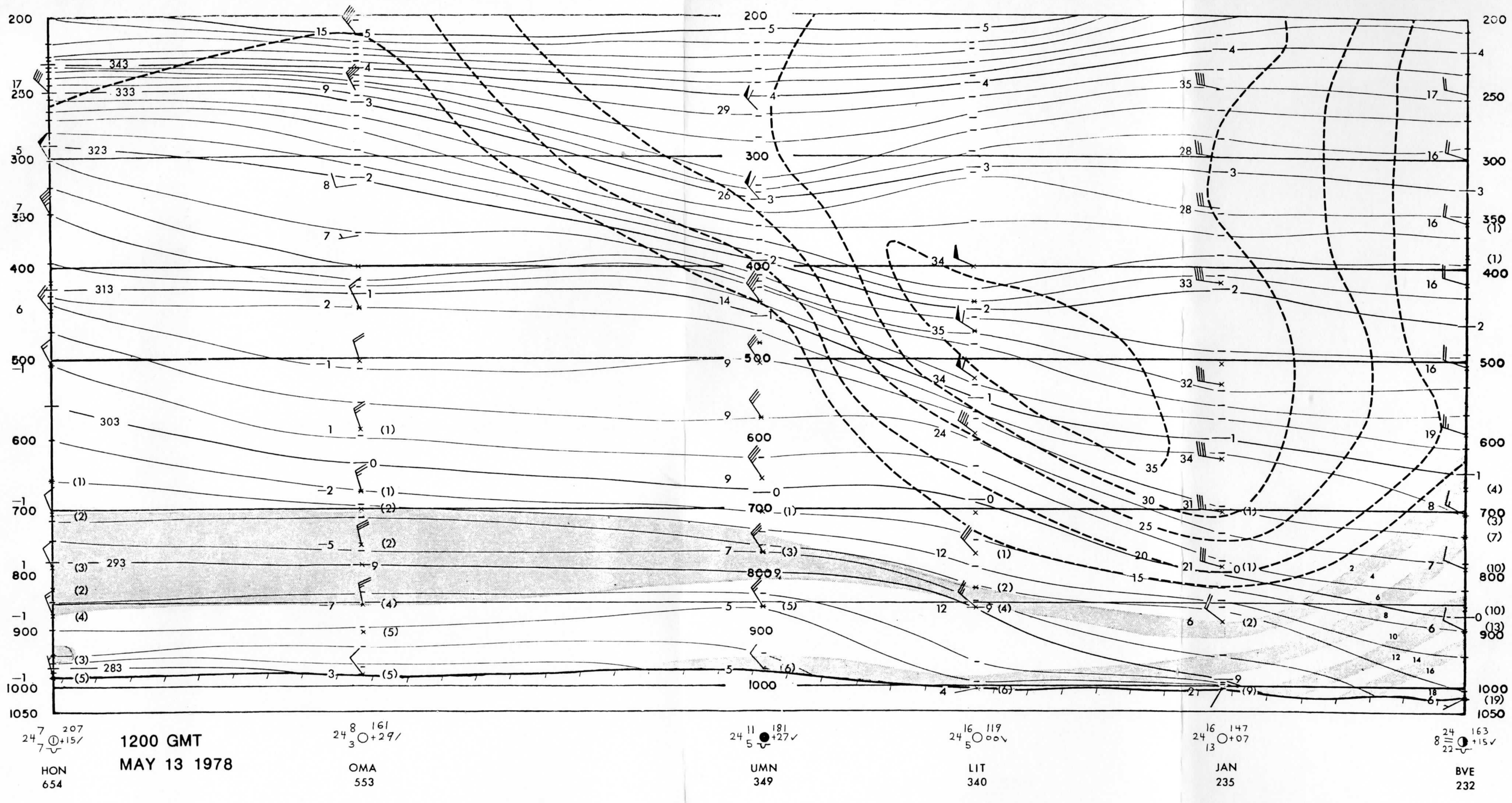
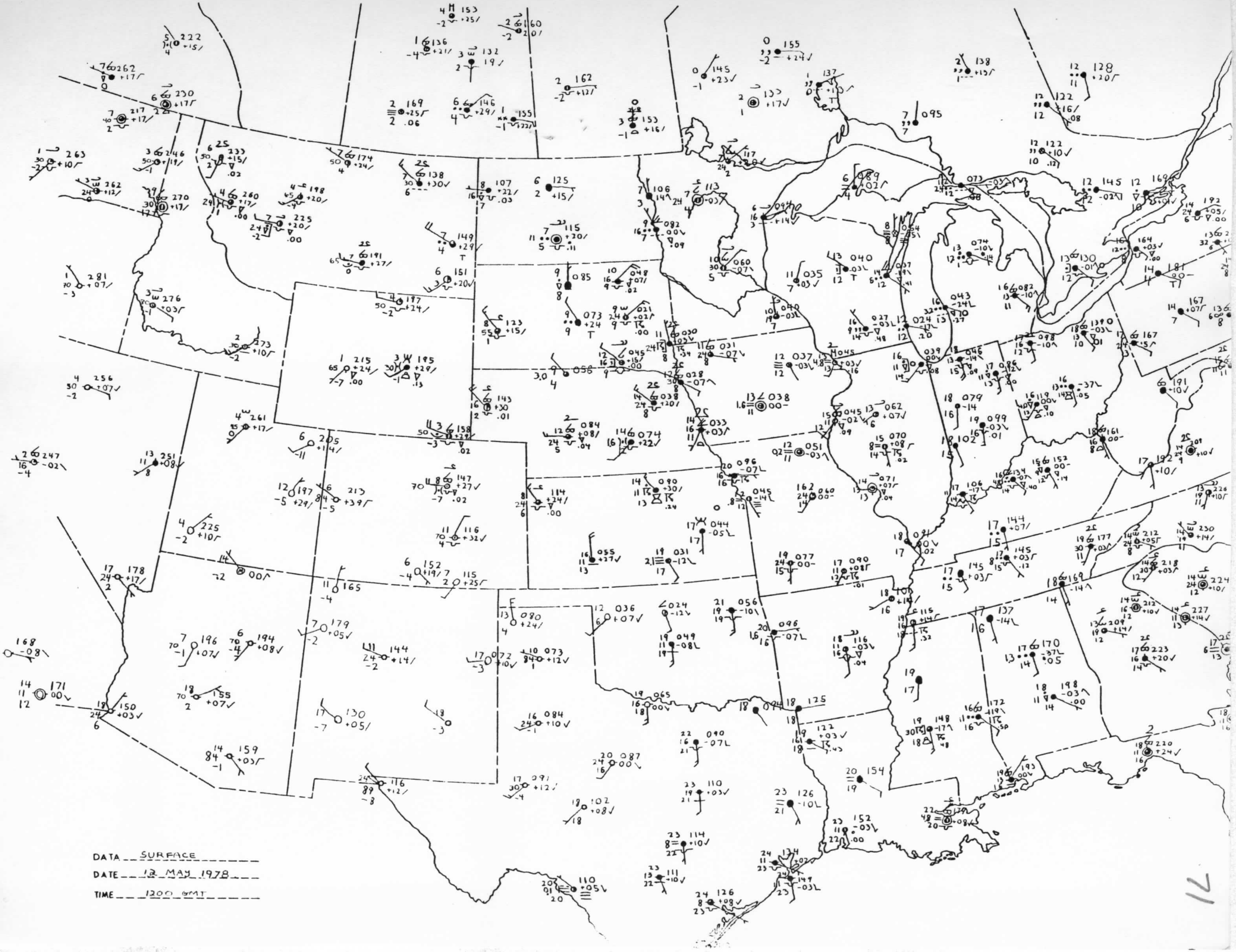
900
1000
1050


1200 GMT
MAY 13 1978
HON
654
OMA
553
UMN
349
LIT
340
JAN
235
BVE
232

2. Surface Charts

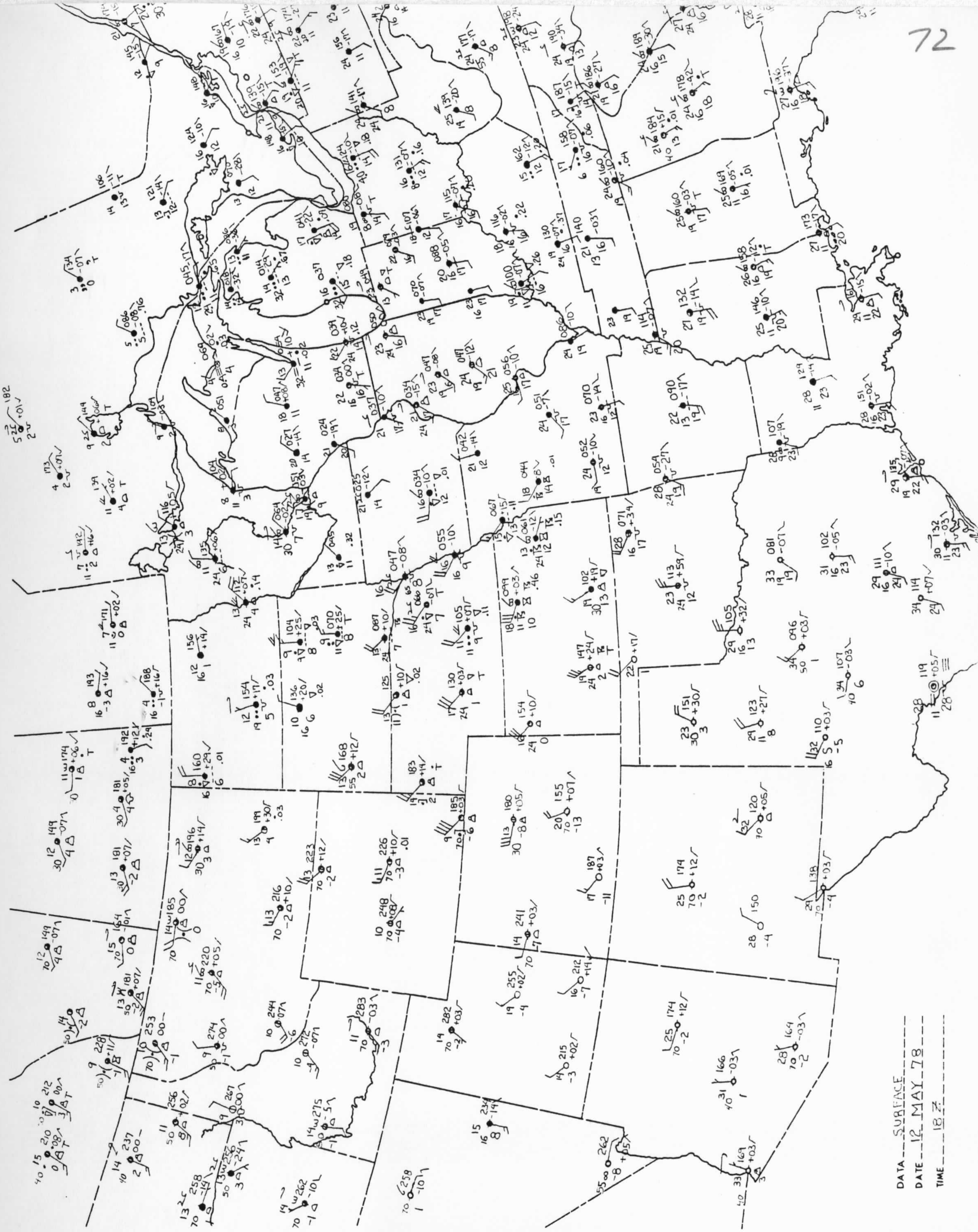
a. 12 May 1200 GMT
b. 12 May 1800 GMT
c. 13 May 0000 GMT
d. 13 May 0600 GMT
e. 13 May 1200 GMT



DATA SURFACE

DATE 12 MAY 1978

TIME 1200 GMT



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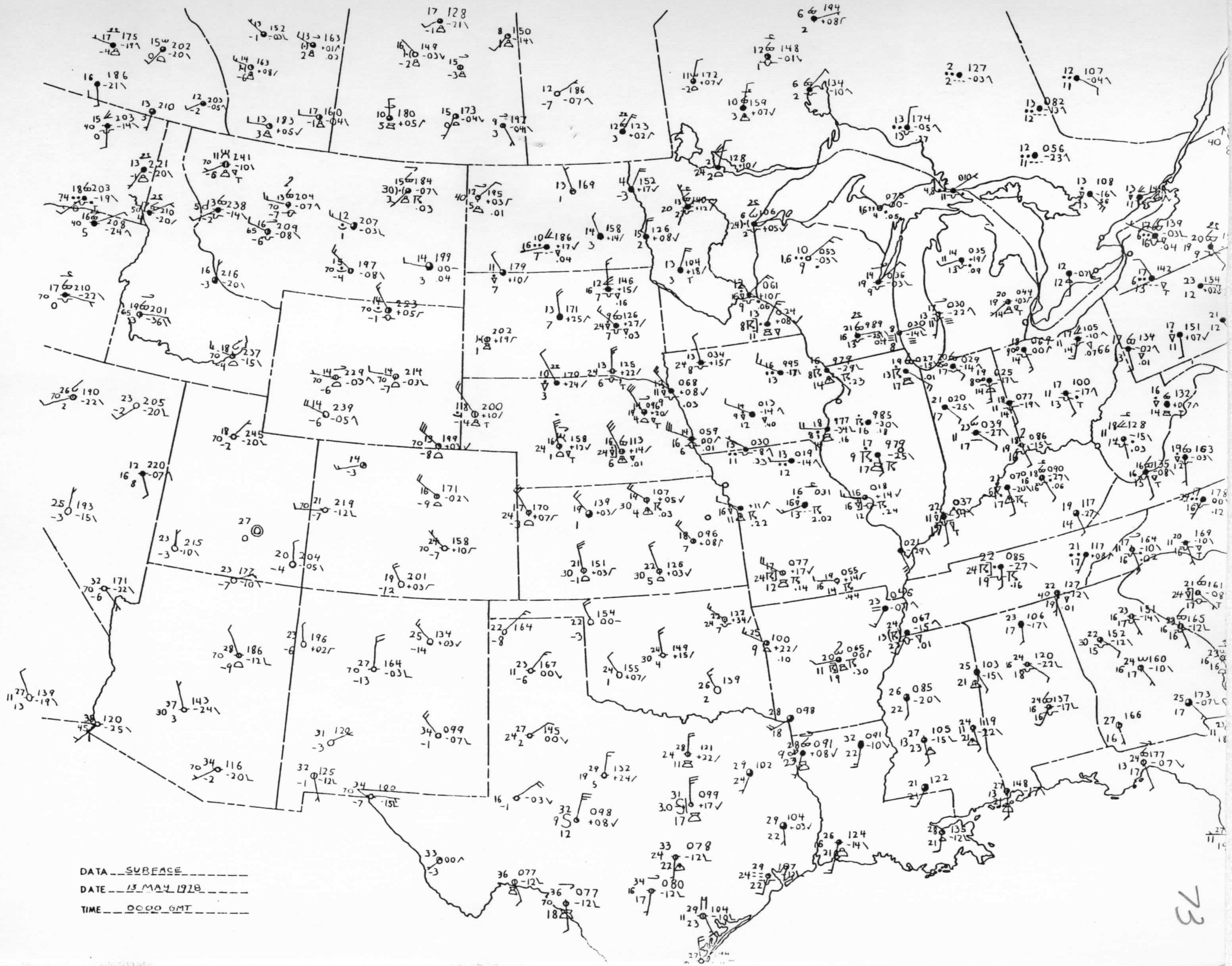
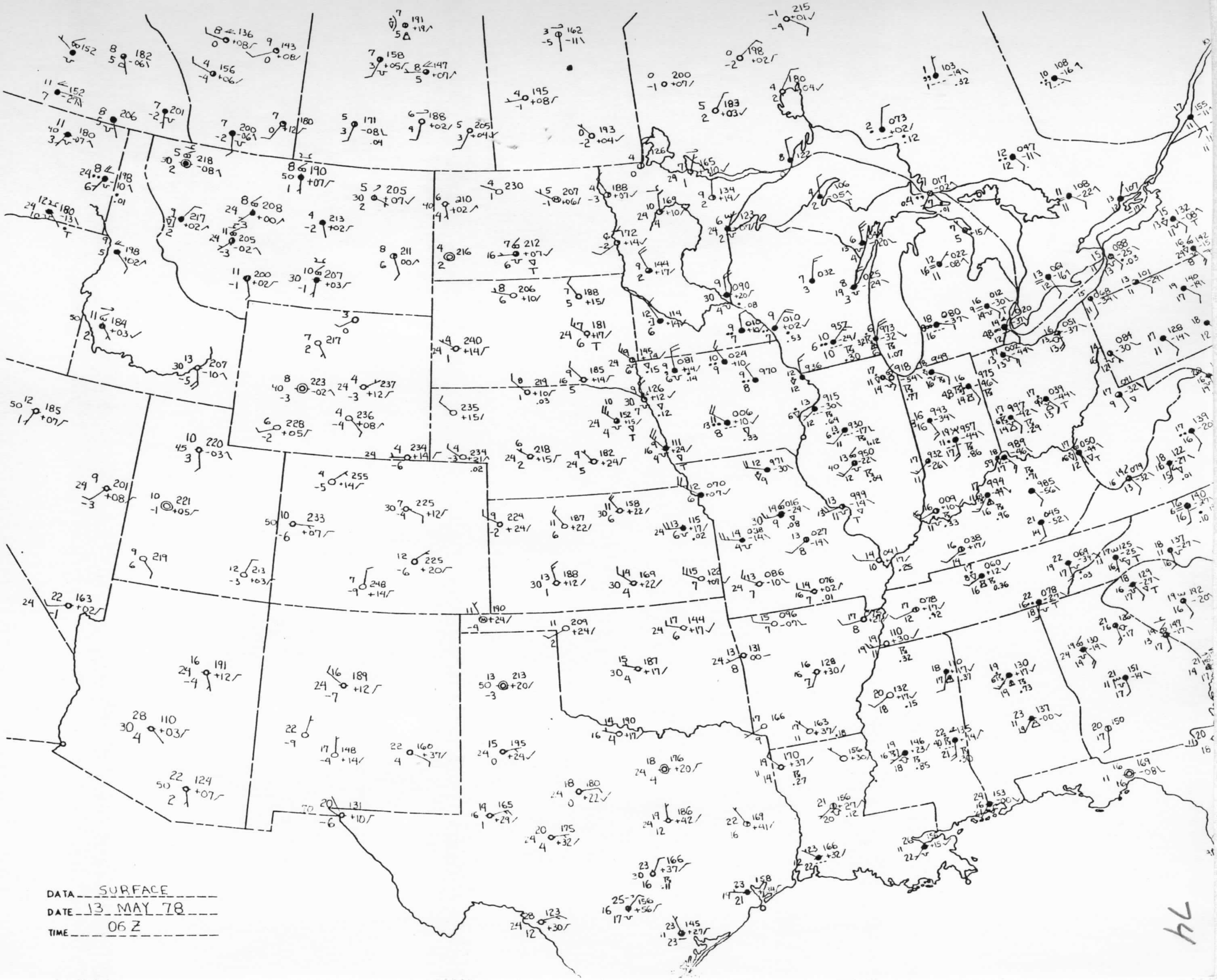
DATE 12 MAY 78
TIME 18Z



DATA SURFACE

DATE 13 MAY 1928

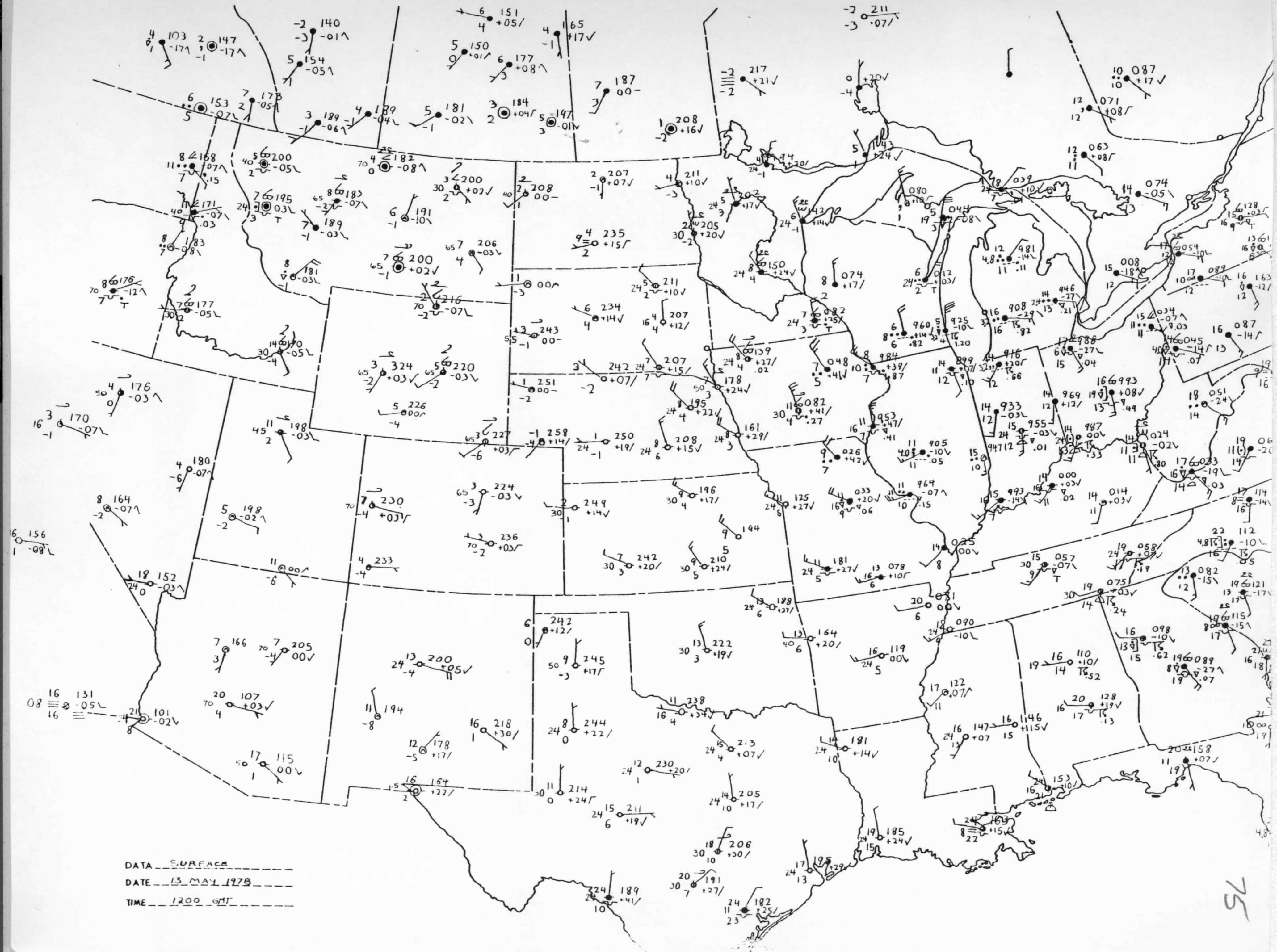
TIME 0000 GMT



DATA SURFACE

DATE 13 MAY 78

TIME 06Z



DATA SURFACE
DATE 13 MAY 1978
TIME 1200 GMT

3. Isobaric Charts
   300 mb, 500 mb, 700 mb, 850 mb

a. 11 May 1200 GMT
b. 12 May 0000 GMT
c. 12 May 1200 GMT
d. 13 May 0000 GMT
e. 13 May 1200 GMT
f. 14 May 0000 GMT
g. 14 May 1200 GMT

PRESSURE 850MB 12UT 11 MAY 1978

PRESSURE 700MB 12UT 11 MAY 1978

PRESSURE 500MB 12UT 11 MAY 1978

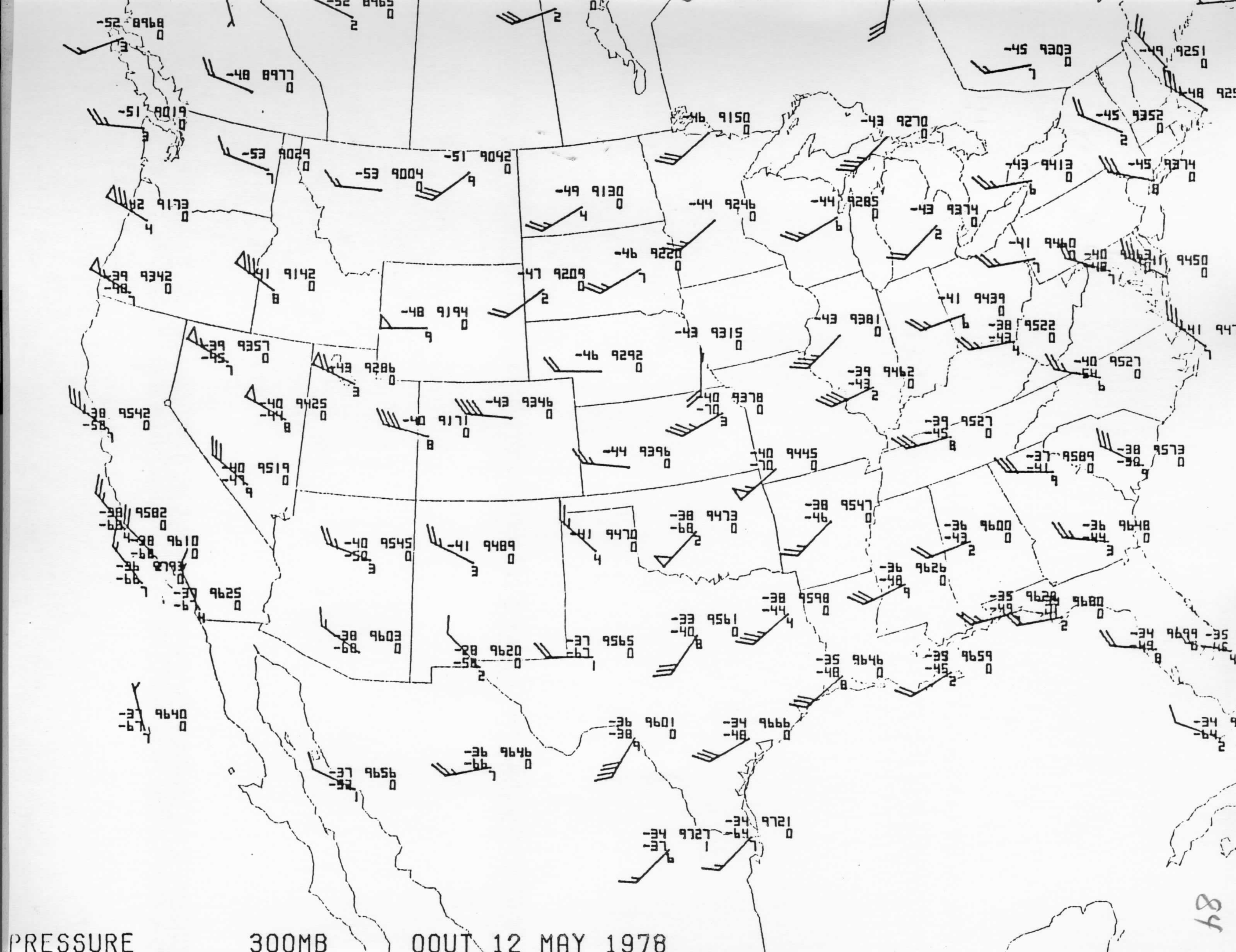
PRESSURE 300MB 12UT 11 MAY 1978

80

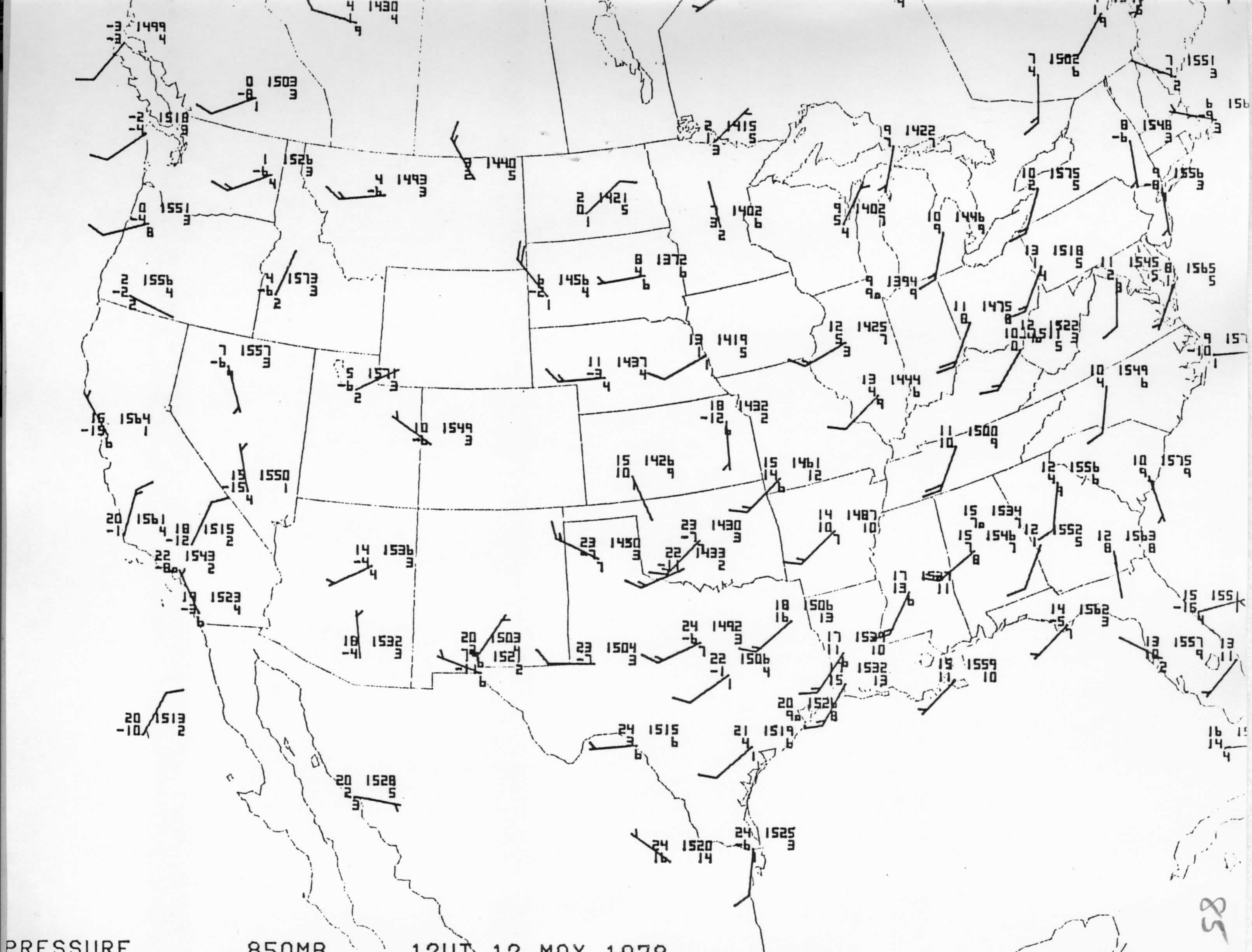
PRESSURE 850MB 00UT 12 MAY 1978

PRESSURE 700MB 00UT 12 MAY 1978

PRESSURE 500MB 00UT 12 MAY 1978

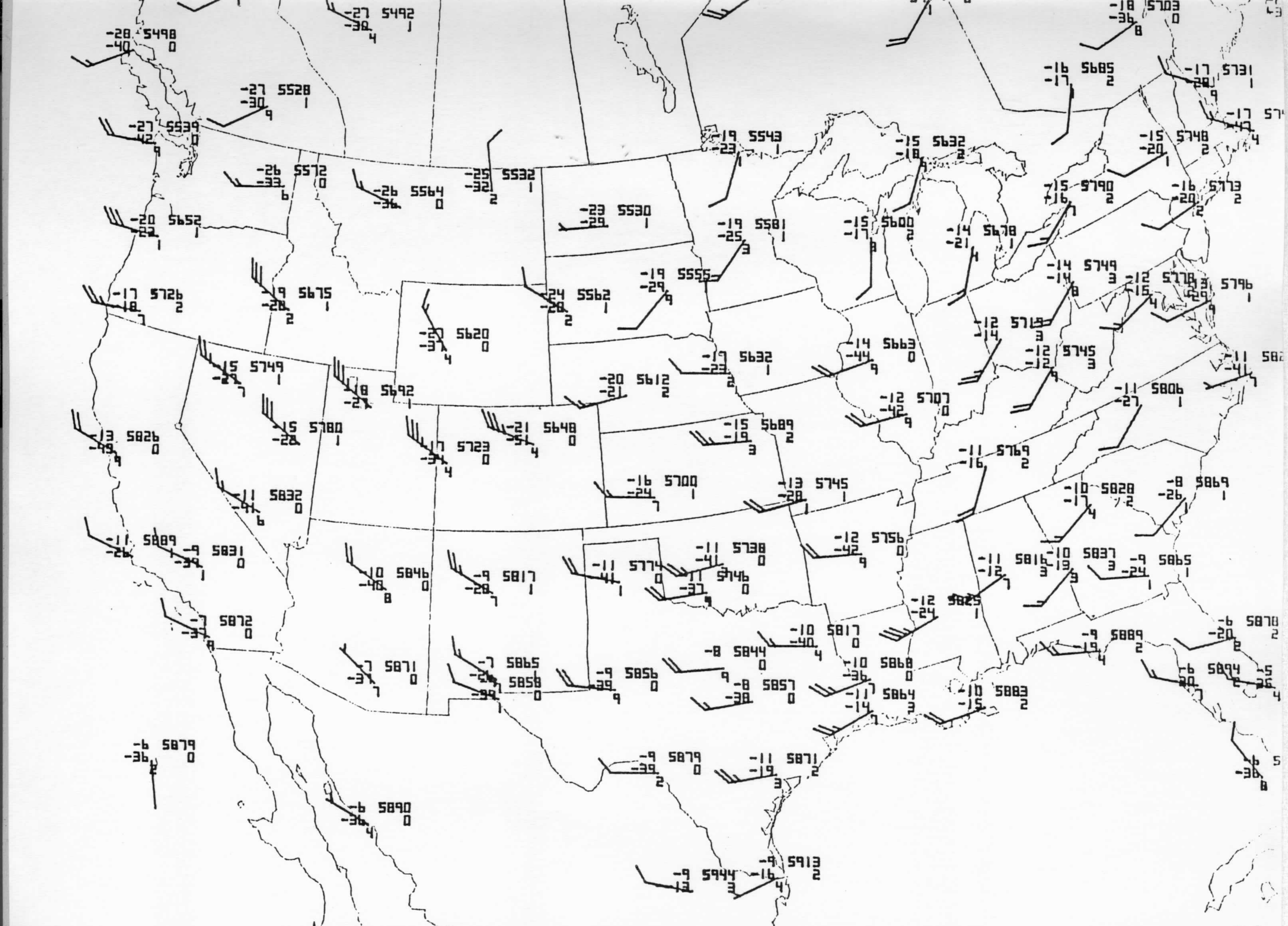


PRESSURE 300MB OOUT 12 MAY 1978



PRESSURE 850MB 12UT 12 MAY 1978

PRESSURE 700MB 12UT 12 MAY 1978



PRESSURE 500MB 12UT 12 MAY 1978

PRESSURE 300MB 12UT 12 MAY 1978

PRESSURE 850MB 00UT 13 MAY 1978

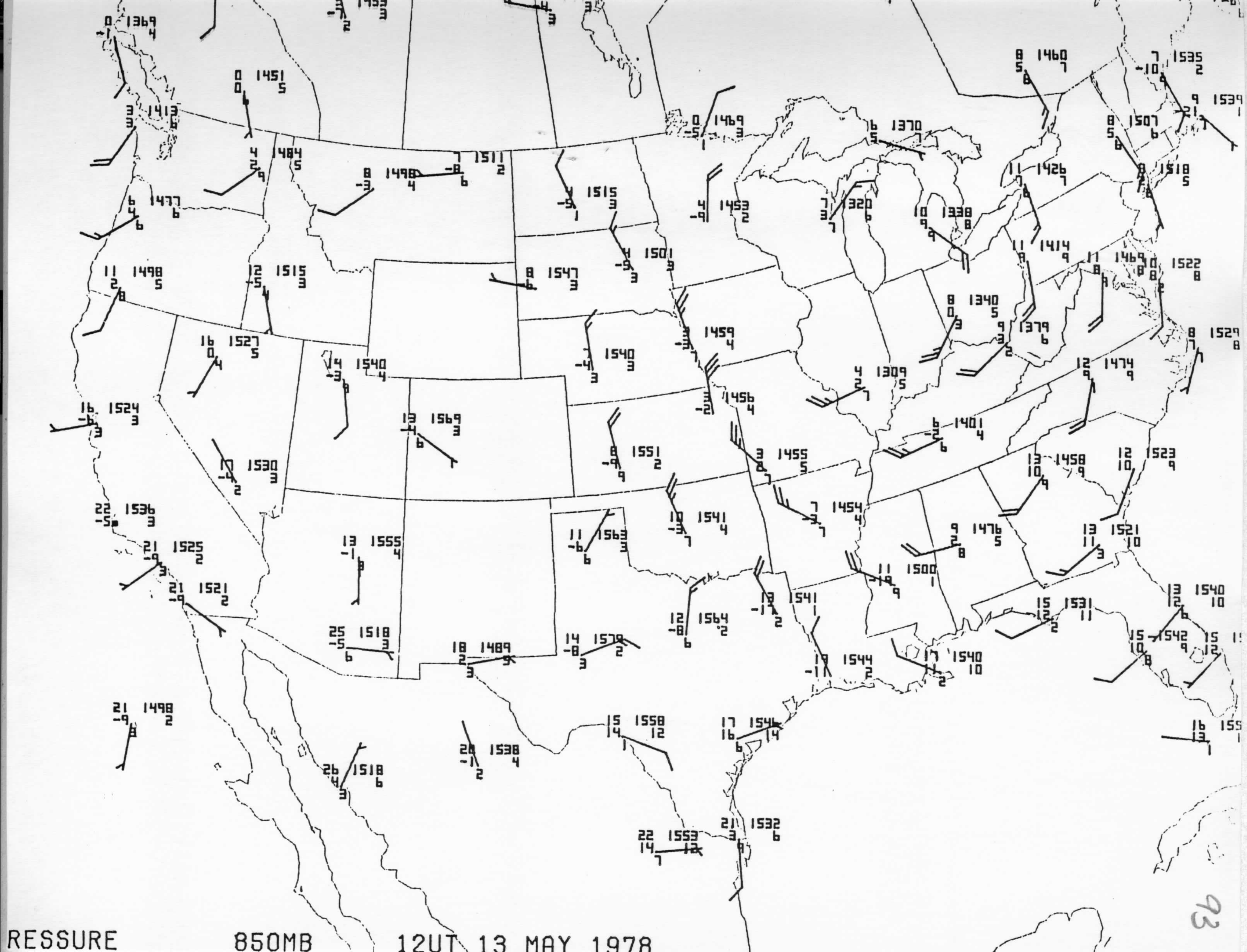
RESSURE 700MB 00UT 13 MAY 1978

PRESSURE 500MB 00UT 13 MAY 1978

91

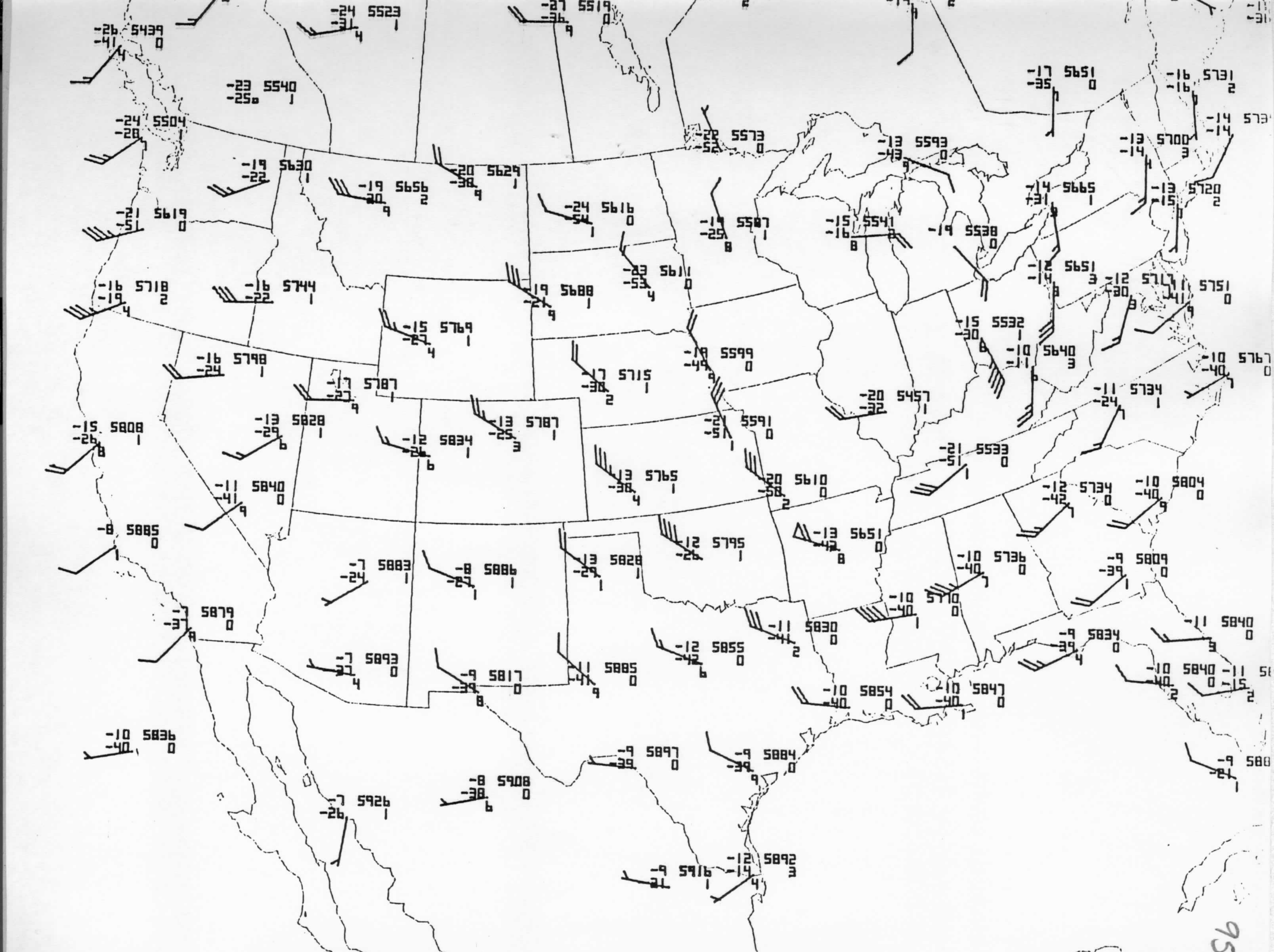
RESSURE 300MB 00UT 13 MAY 19

92



RESSURE 850MB 12UT 13 MAY 1978

PRESSURE 700MB 12UT 13 MAY 1978



RESSURE 500MB 12UT 13 MAY 1978

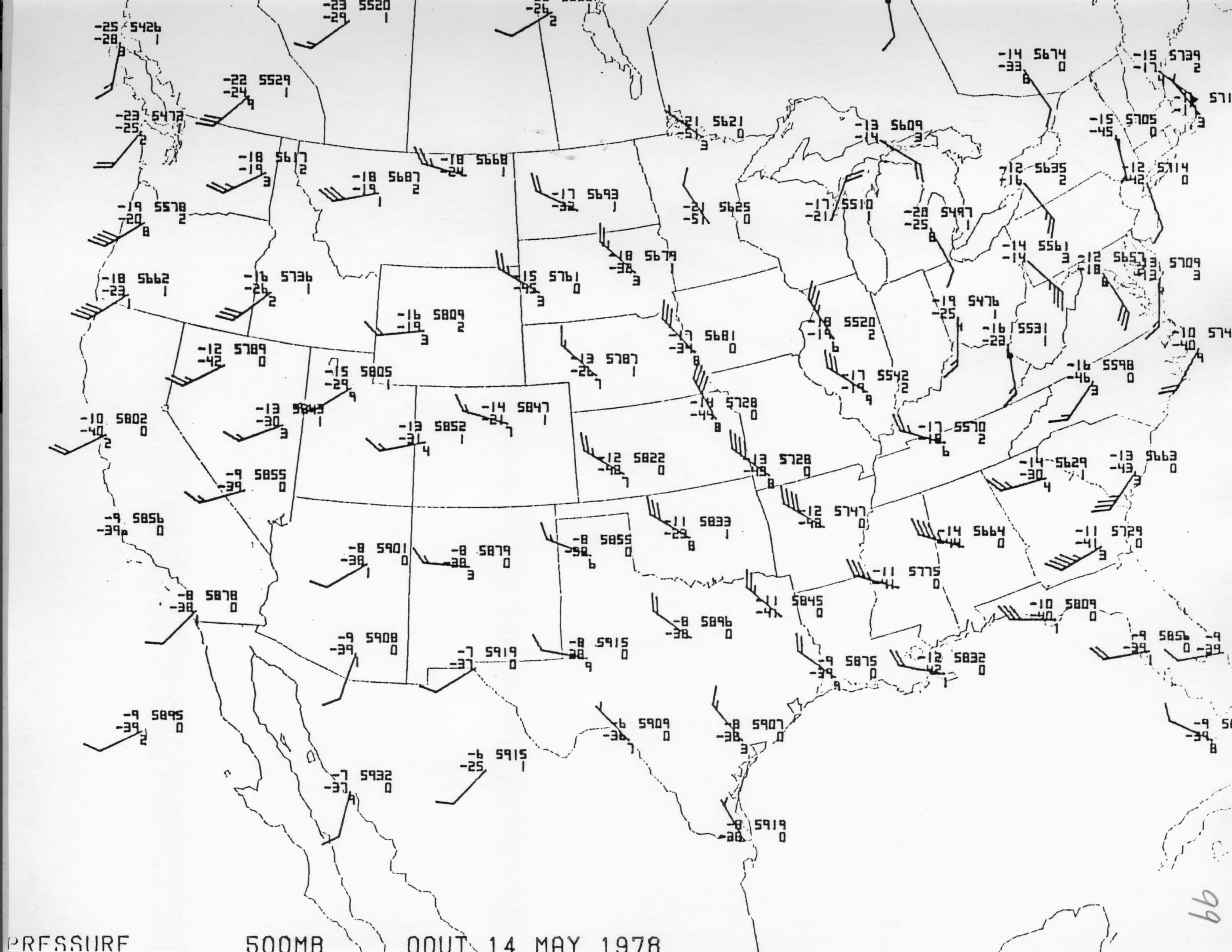
95

PRESSURE 300MB 12UT 13 MAY 1978

96

PRESSURE 850MB 00UT 14 MAY 1978

PRESSURE 700MB 00UT 14 MAY 1978



PRESSURE 500MB OOUT 14 MAY 1978

PRESSURE 300MB 00UT 14 MAY 1978

100

PRESSURE 850MB 12UT 14 MAY 1978

101

PRESSURE. 700MB 12UT 14 MAY 1978

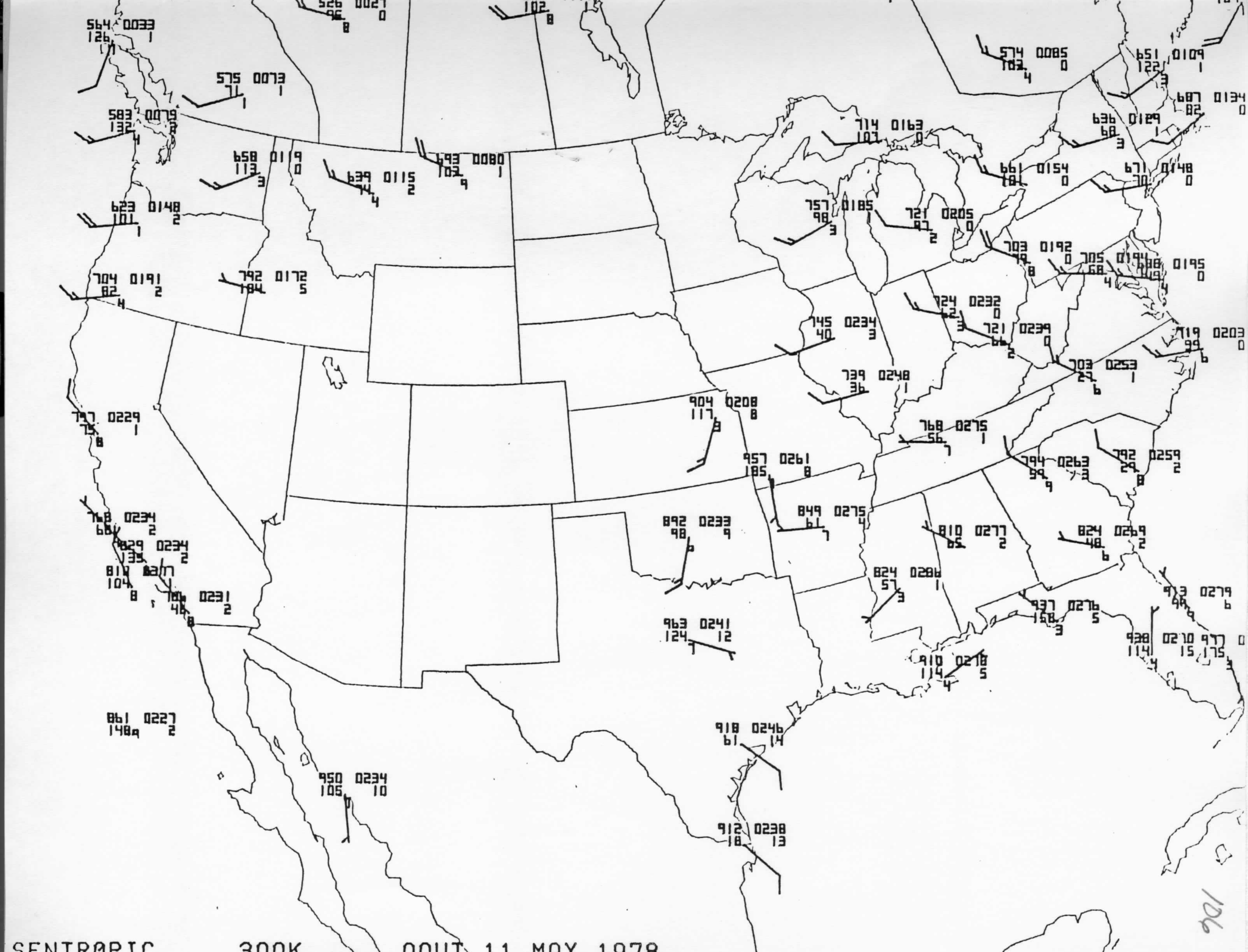
103

PRESSURE 500MB 12UT 14 MAY 1978

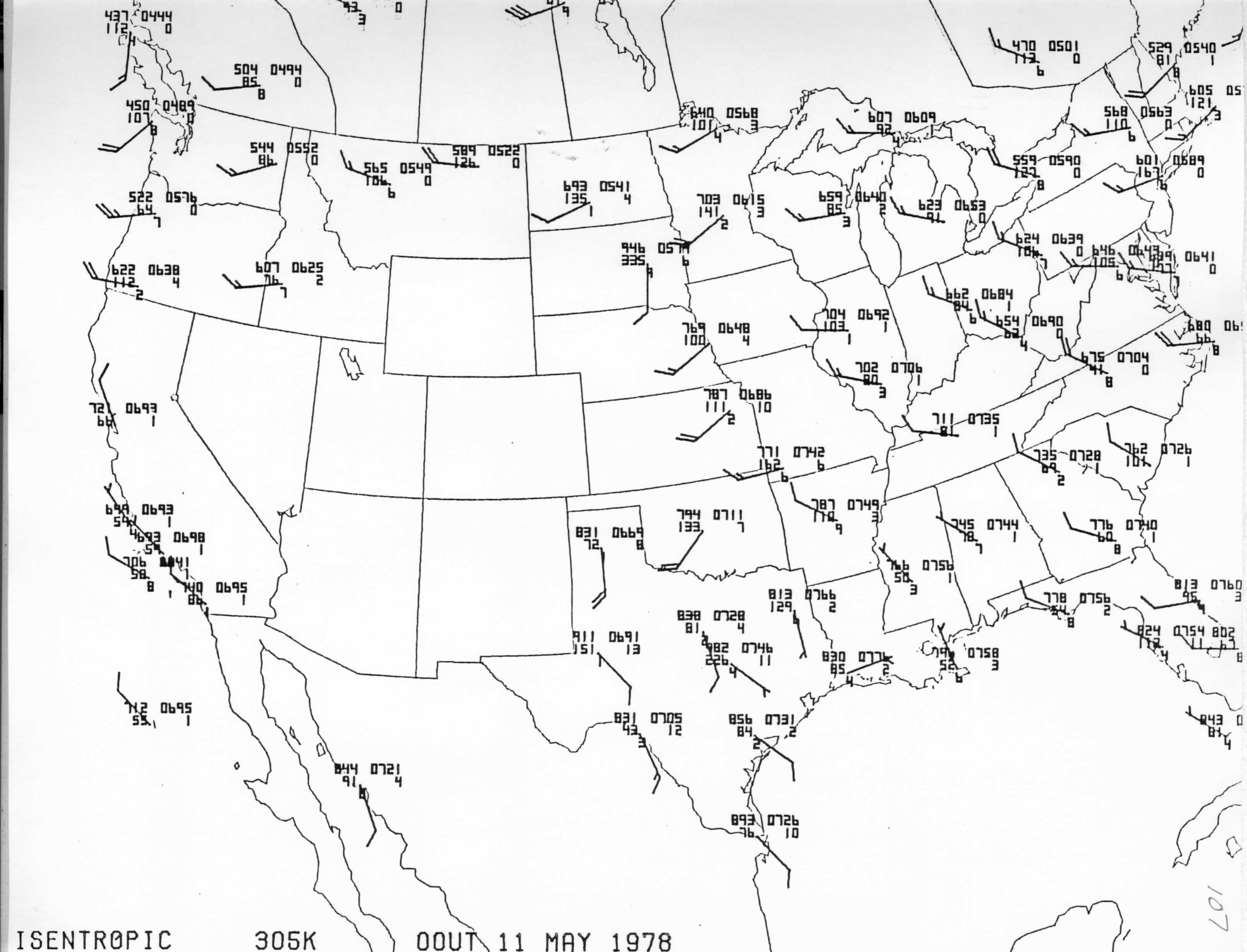
PRESSURE 300MB 12UT 14 MAY 1978

4. Isentropic Charts
5 K interval

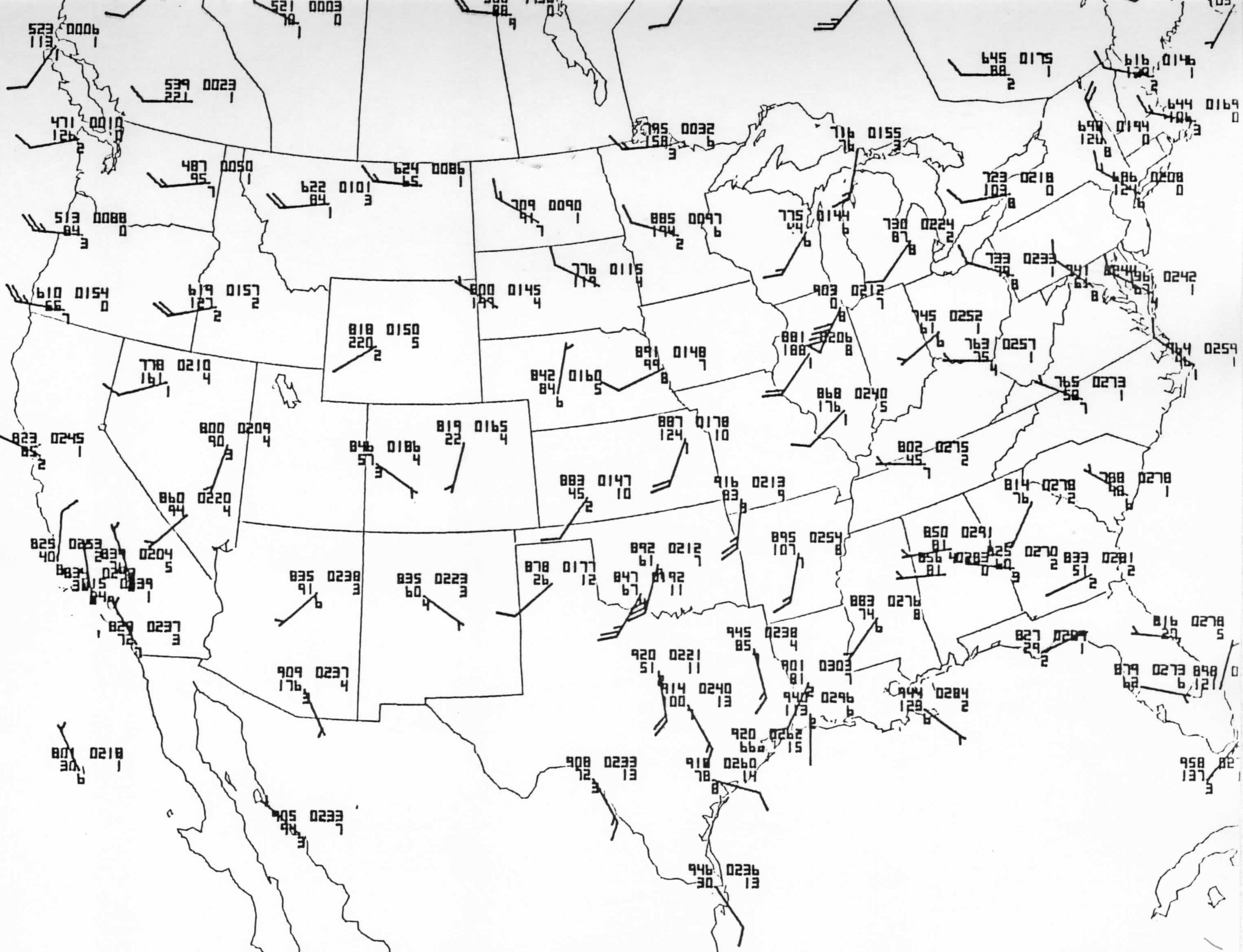
a.	11 May 0000 GMT	300 - 305 K
b.	11 May 1200 GMT	300 - 305 K
c.	12 May 0000 GMT	300 - 305 K
d.	12 May 1200 GMT	290 - 325 K
e.	13 May 0000 GMT	290 - 325 K
f.	13 May 1200 GMT	290 - 320 K



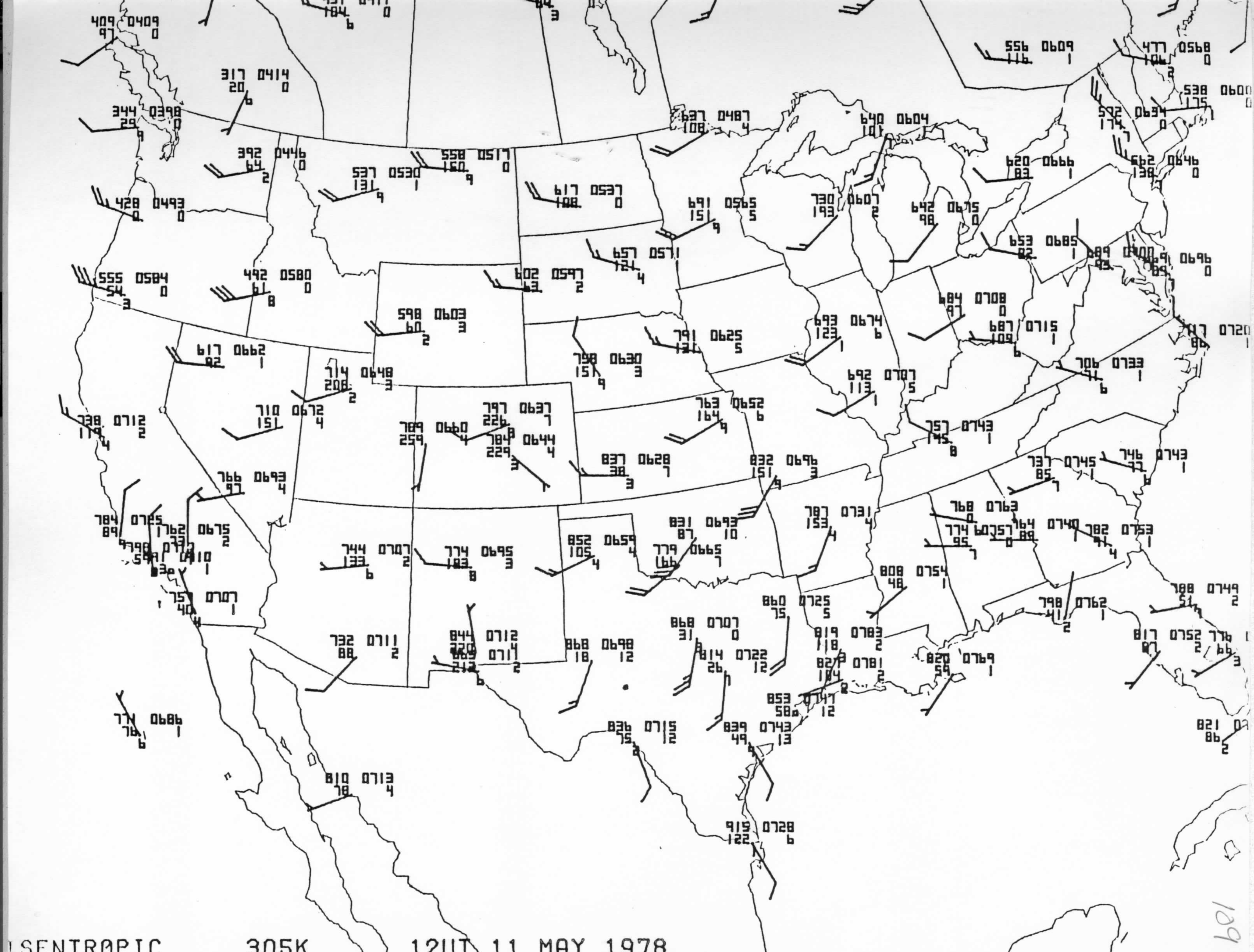
SENTRØPIC 300K 00UT 11 MAY 1978



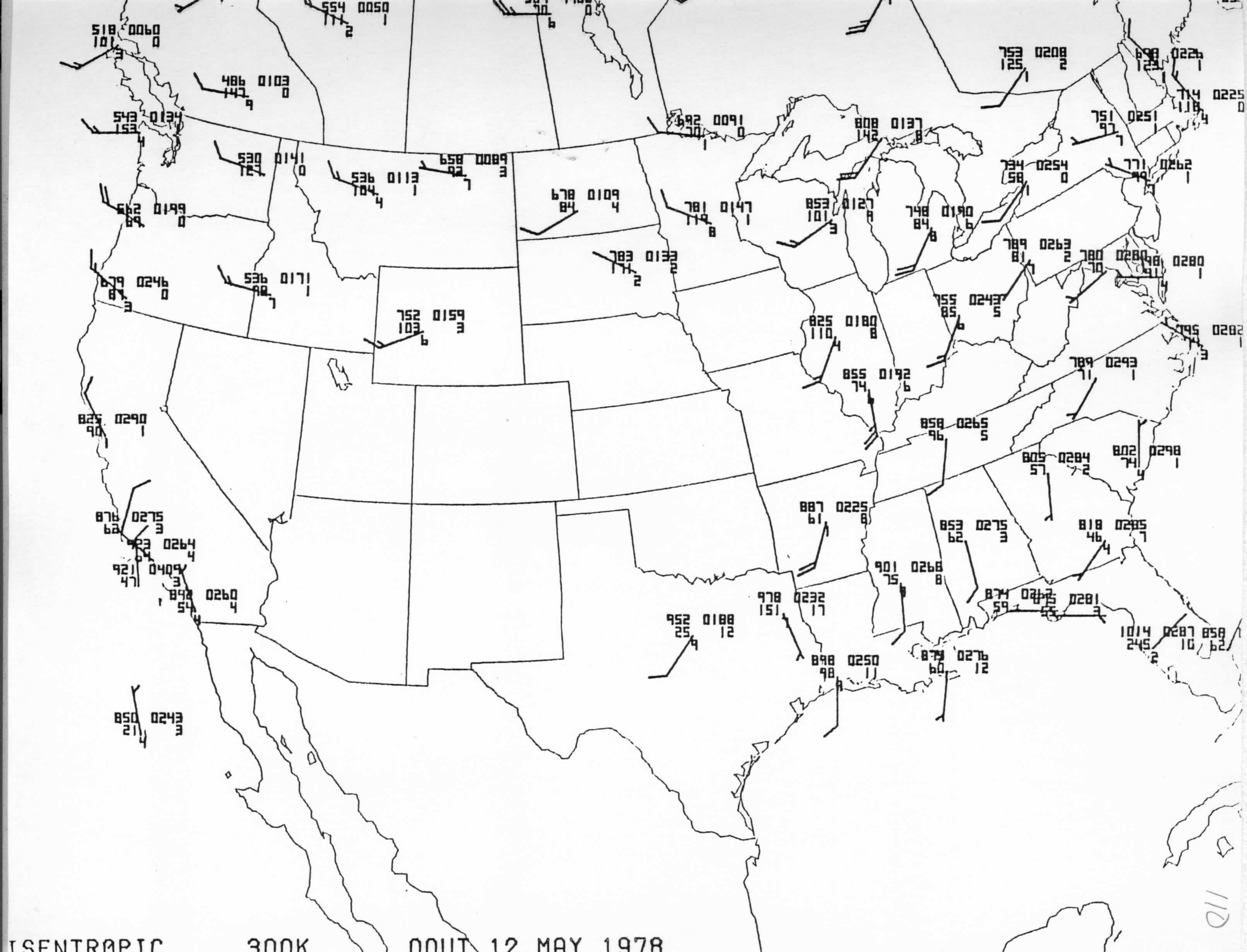
ISENTROPIC 305K 00UT 11 MAY 1978



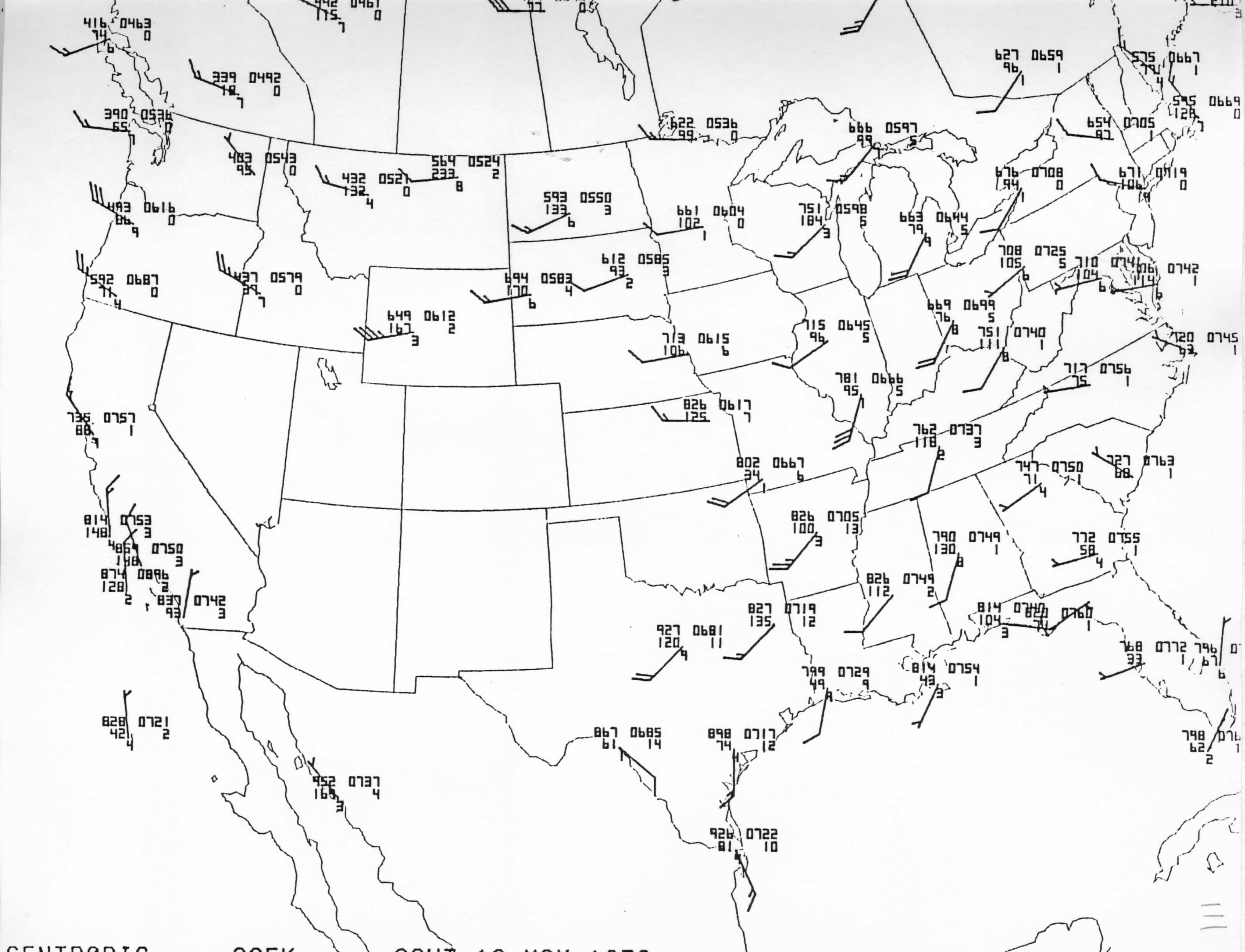
ISENTROPIC 300K 12UT 11 MAY 1978



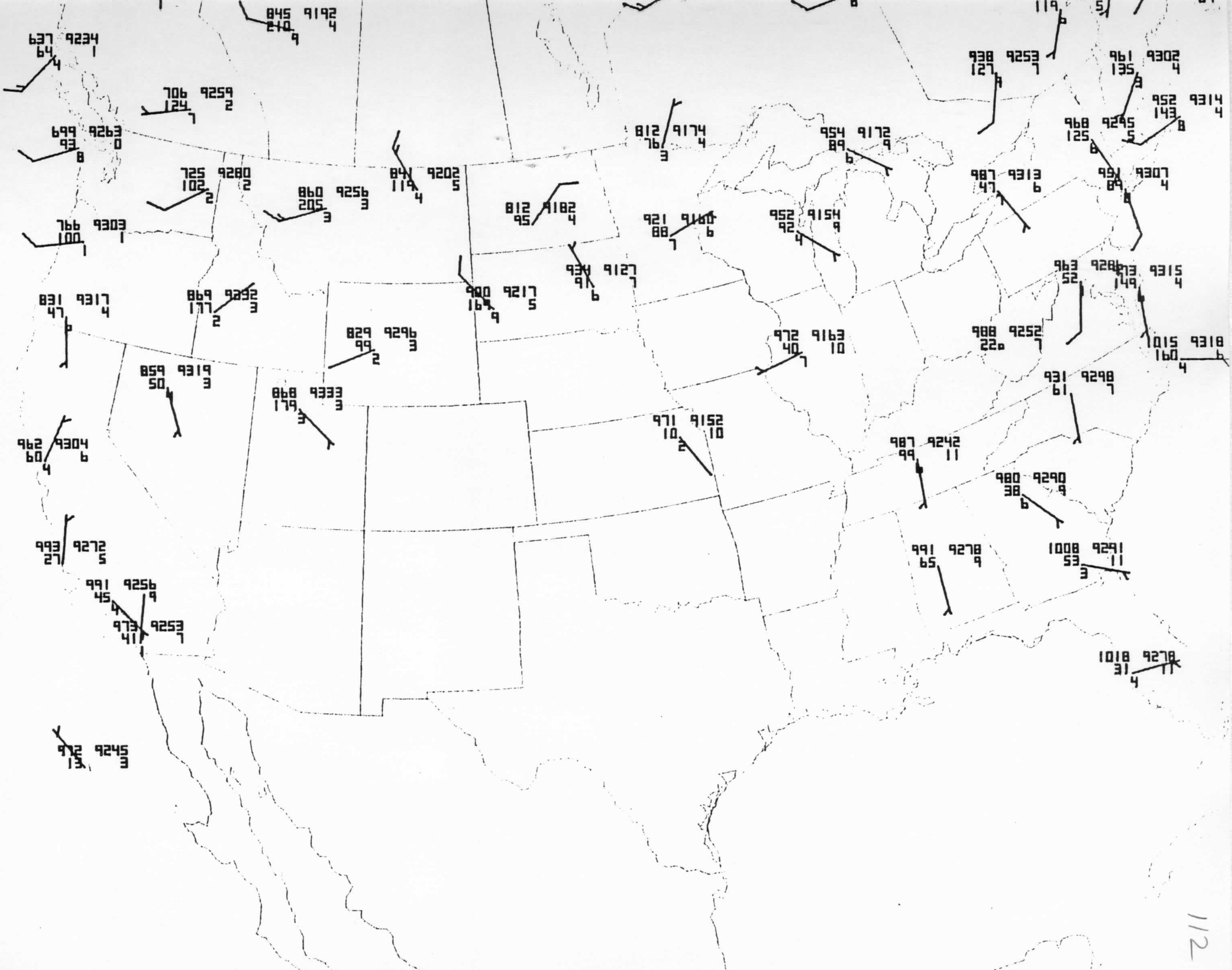
ISENTROPIC 305K 12UT 11 MAY 1978



ISENTROPIC 300K 00UT 12 MAY 1978



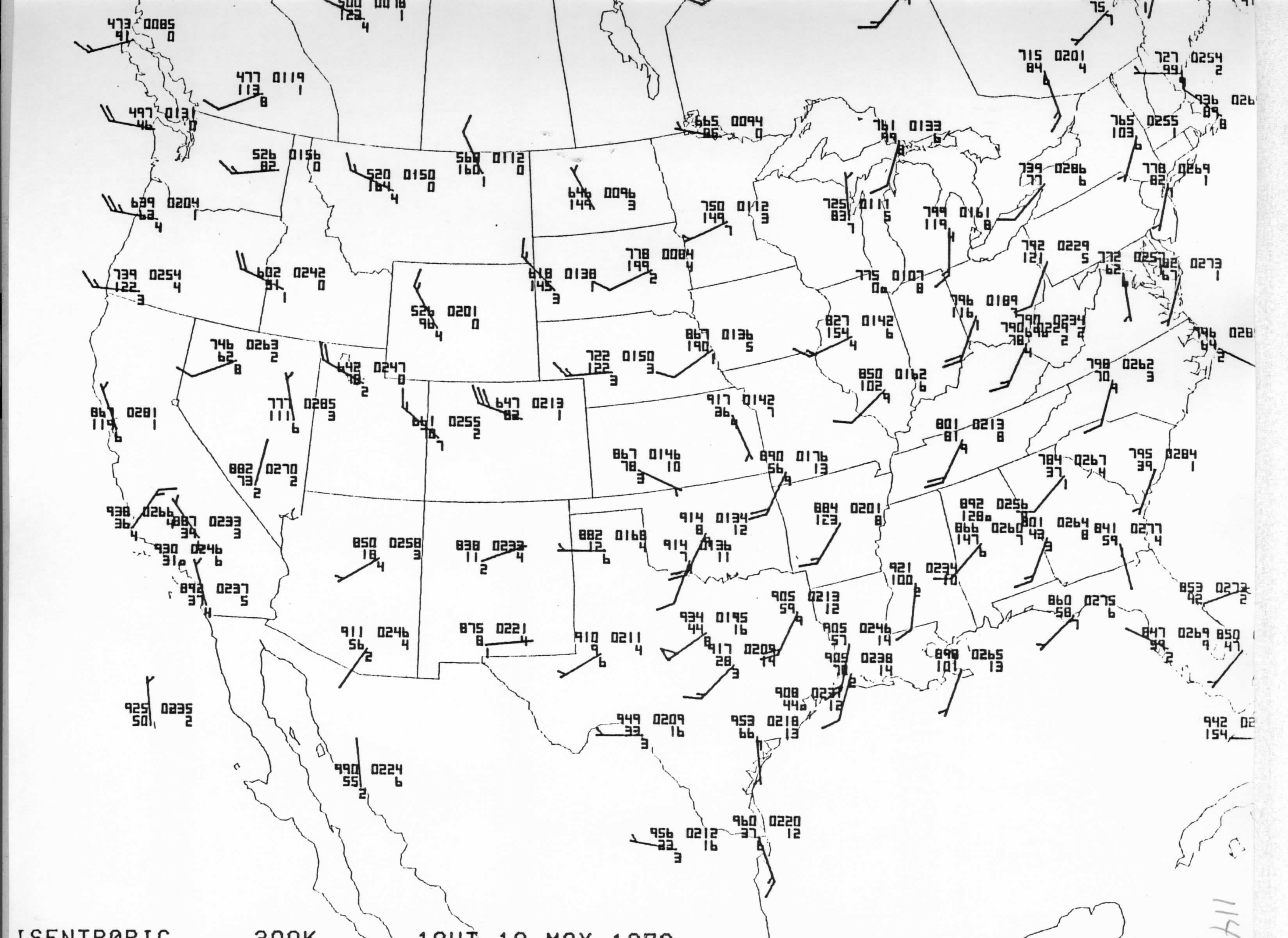
SENTROPIC 305K 00UT 12 MAY 1978



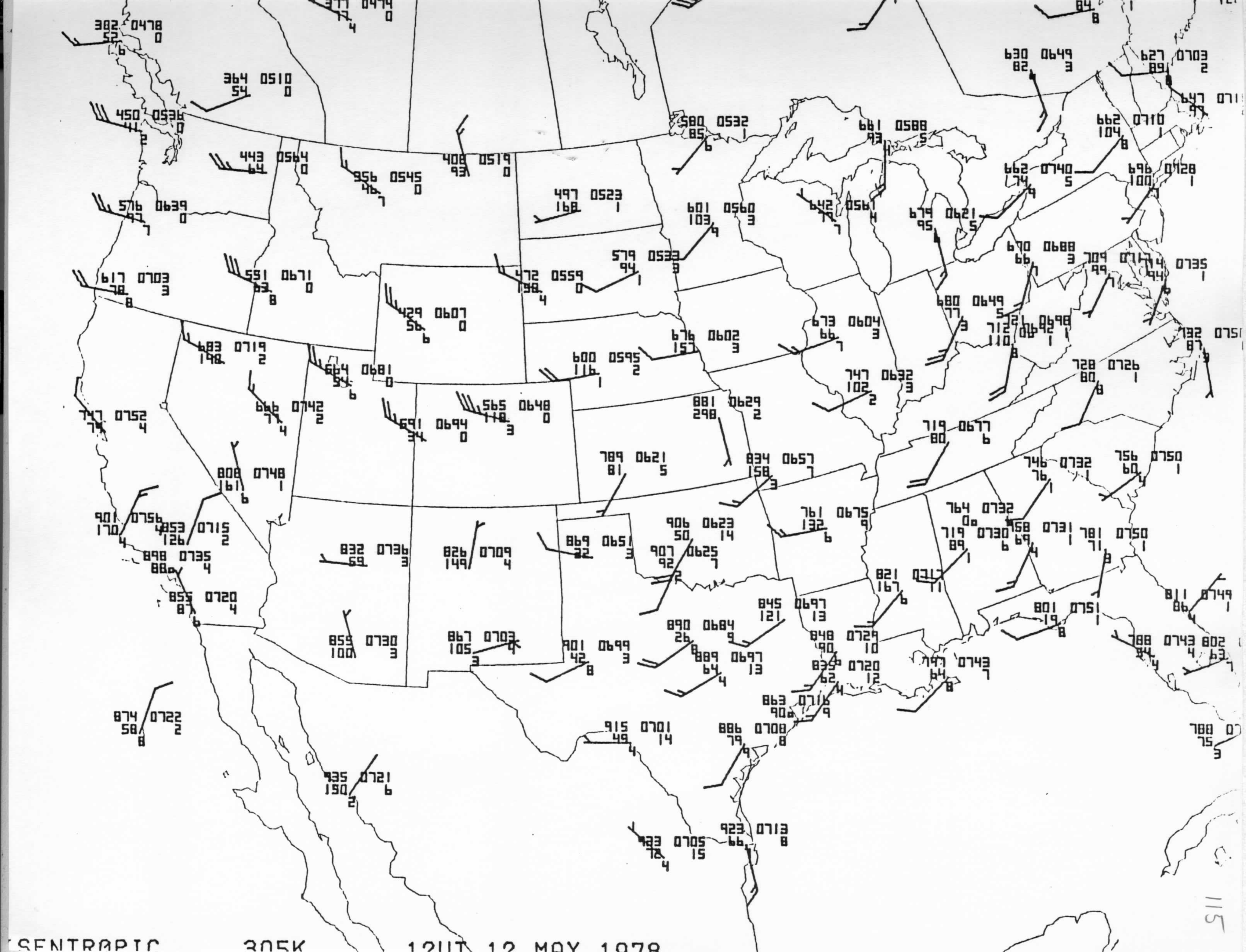
ISENTROPIC 290K 12UT 12 MAY 1978

112

ISENTROPIC 295K 12UT 12 MAY 1978



ISENTROPIC 300K 12UT 12 MAY 1978



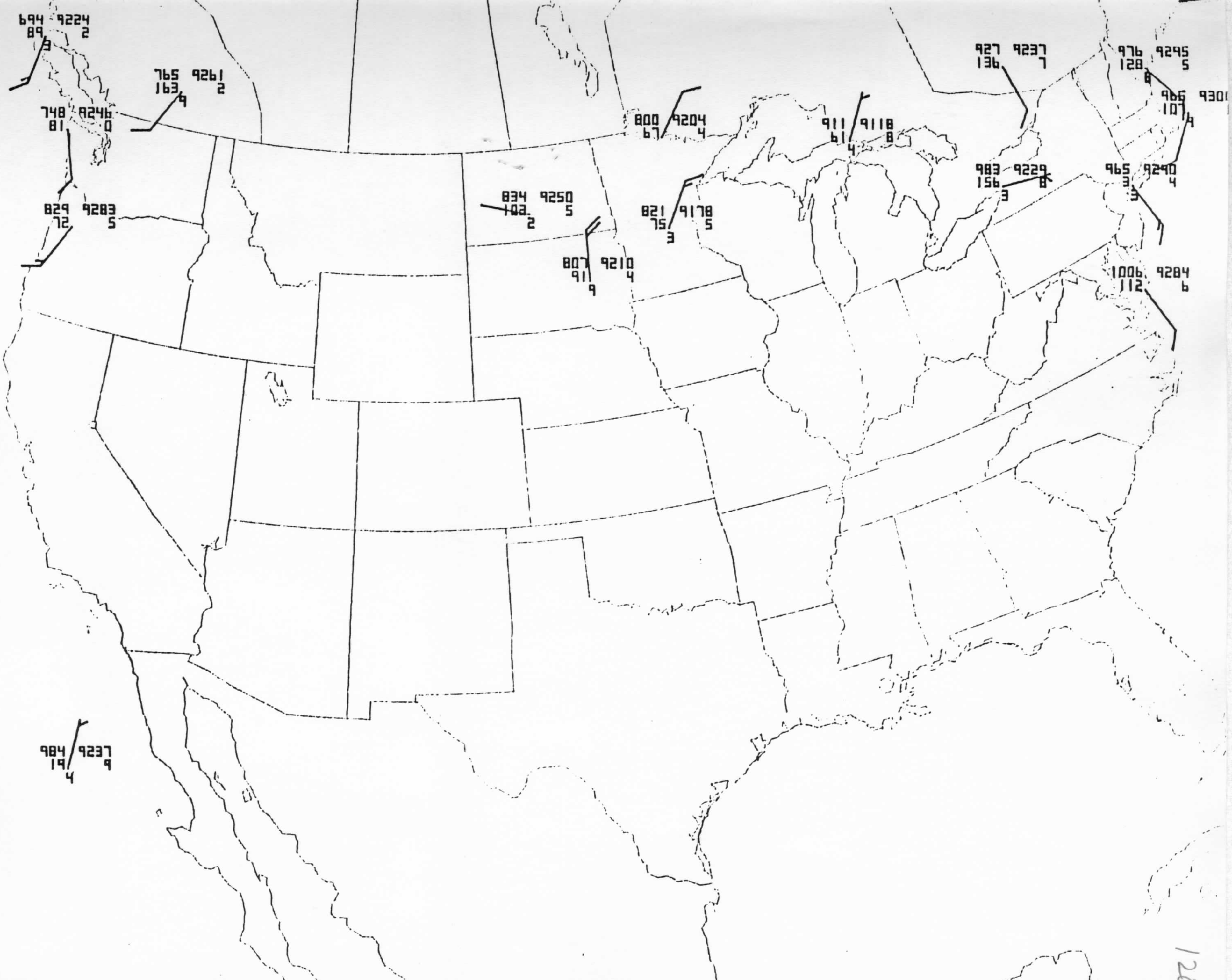
ISENTROPIC 305K 12UT 12 MAY 1978

ISENTROPIC 310K 12UT 12 MAY 1978

ISENTROPIC 315K 12UT 12 MAY 1978

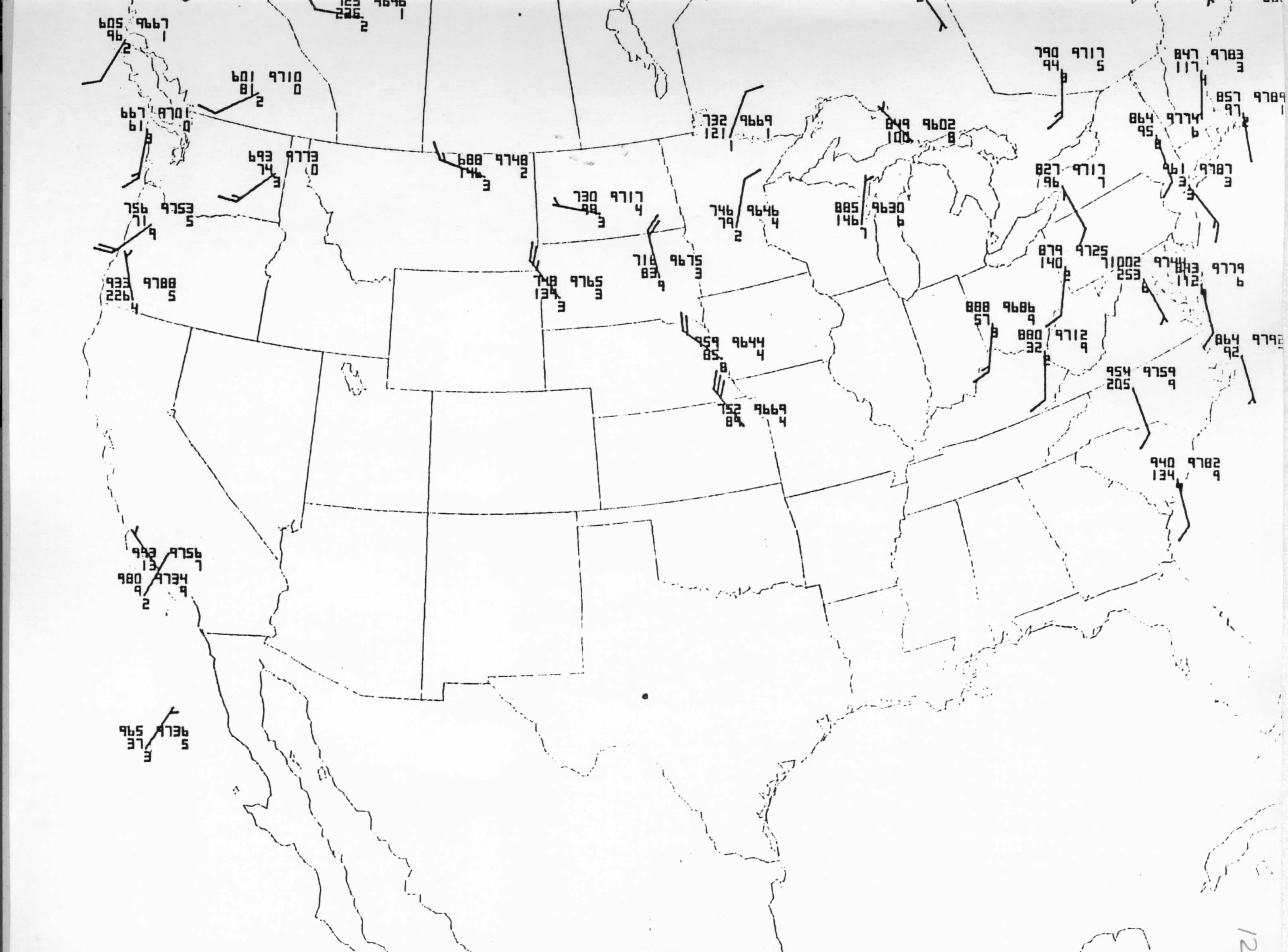
ISENTR0PIC 320K 12UT 12 MAY 1978

SENTROPIC 325K 12UT 12 MAY 1978

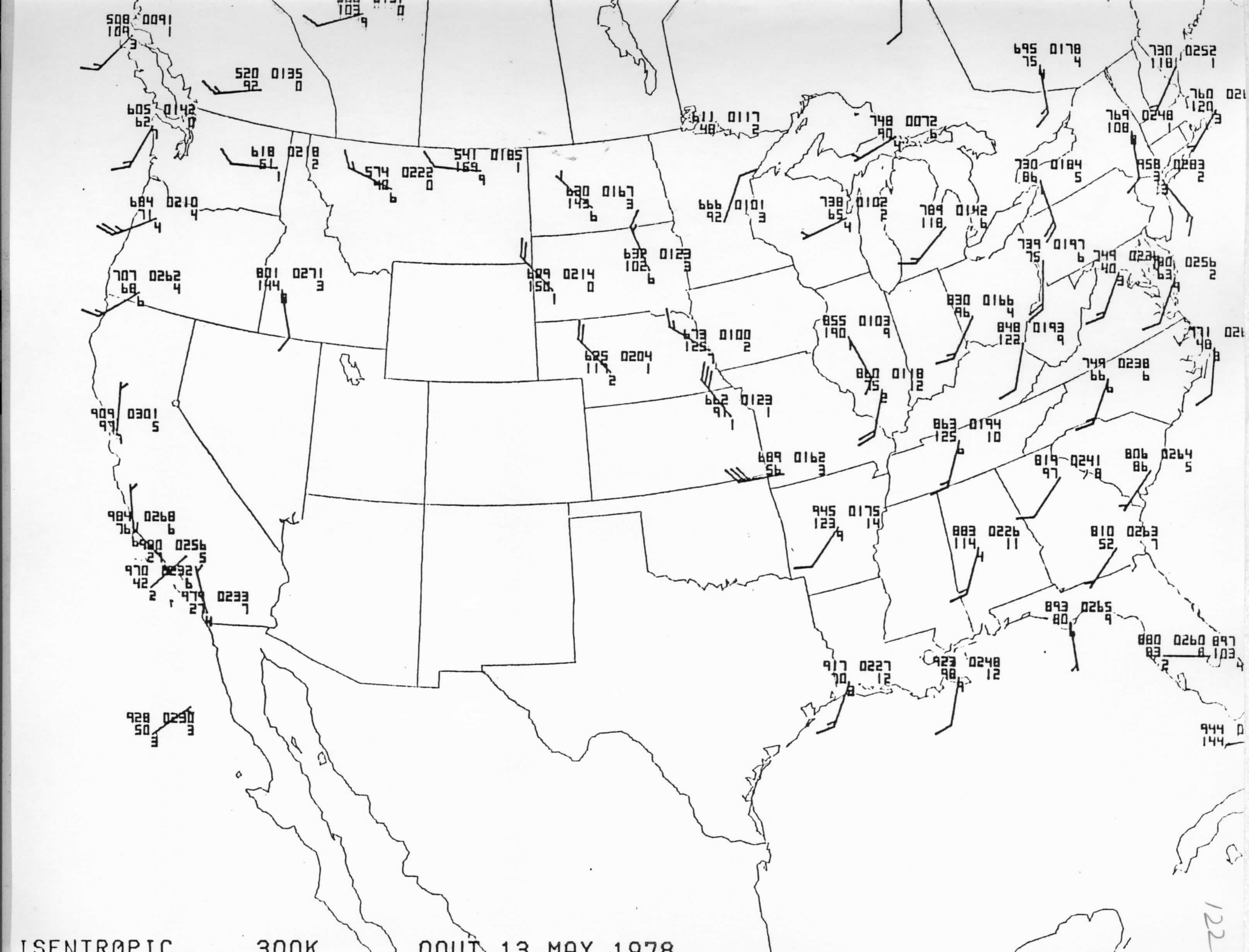


ISENTROPIC 290K OOUT 13 MAY 1978

120



ISENTRØPIC 295K 00UT 13 MAY 1978



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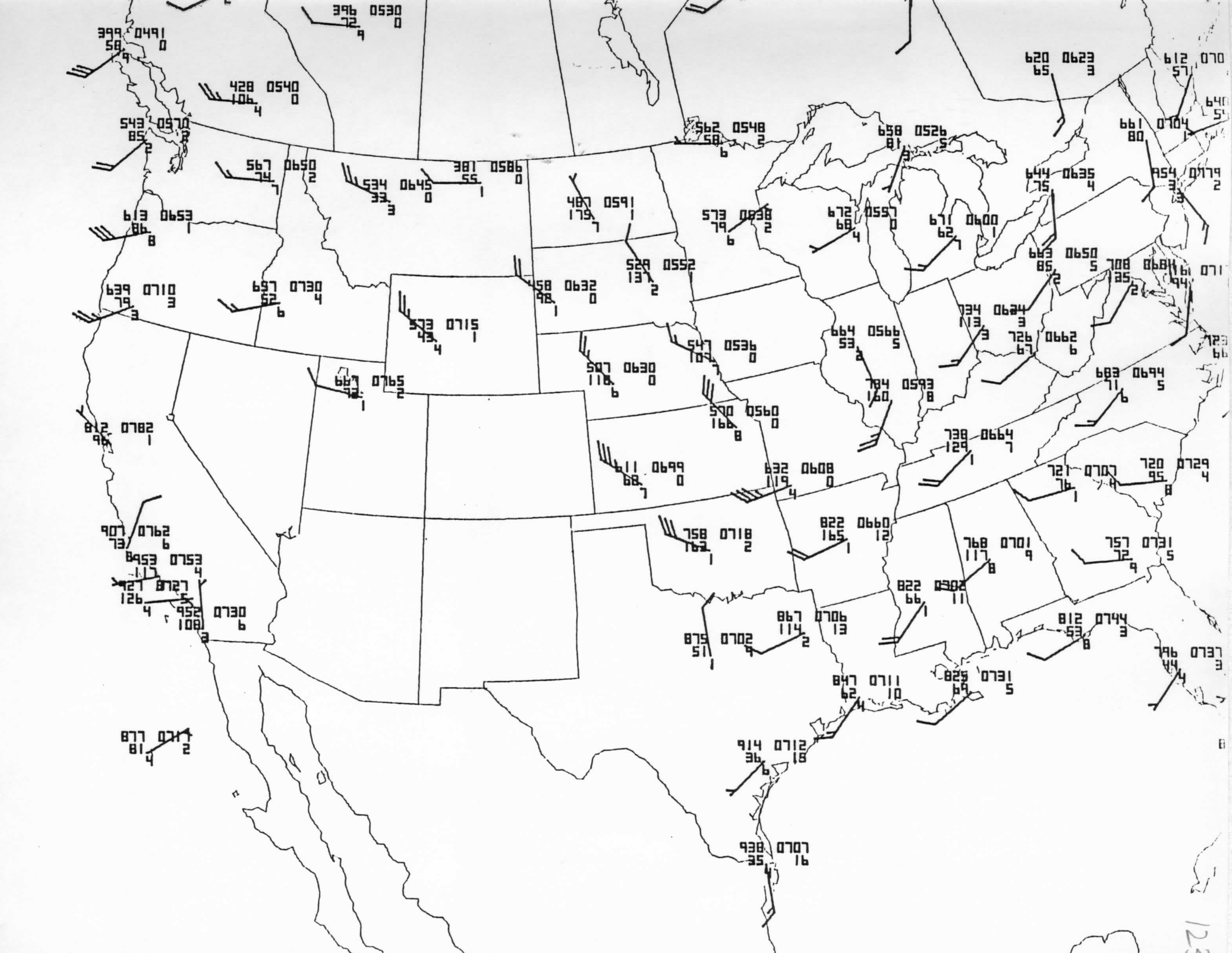
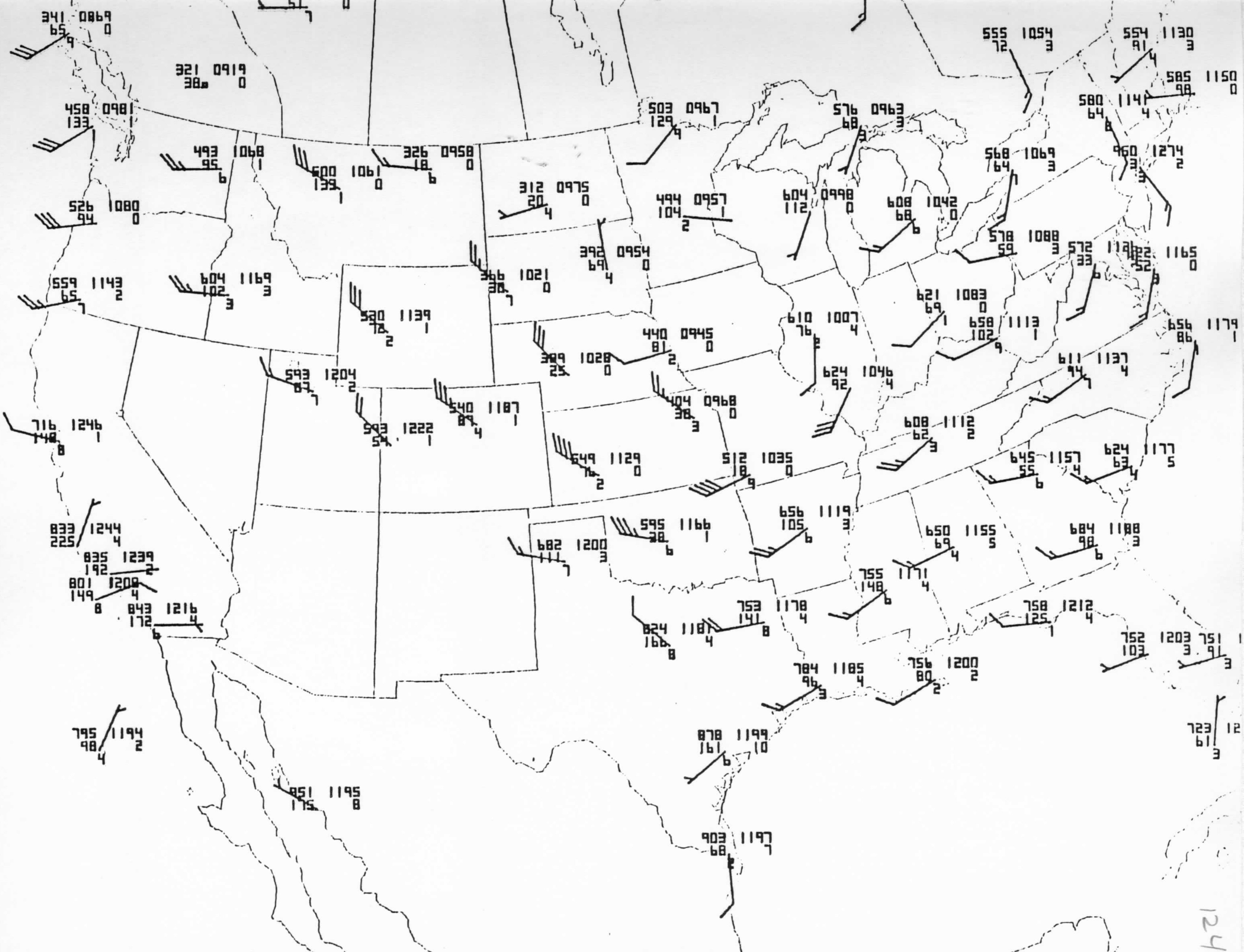
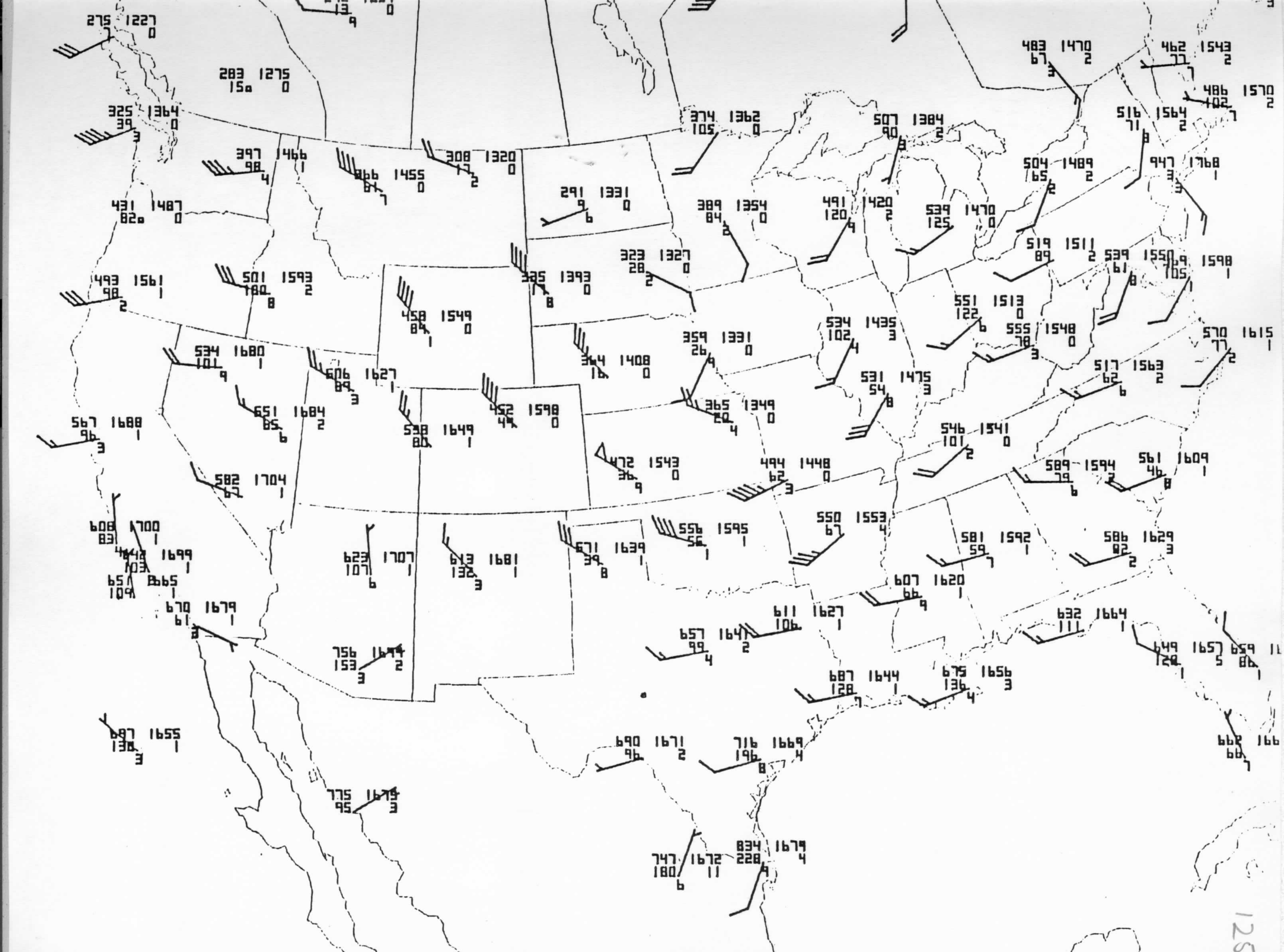


ISENTROPIC 305K 00UT 13 MAY 1978

123



ISENTRØPIC 310K 00UT 13 MAY 1978

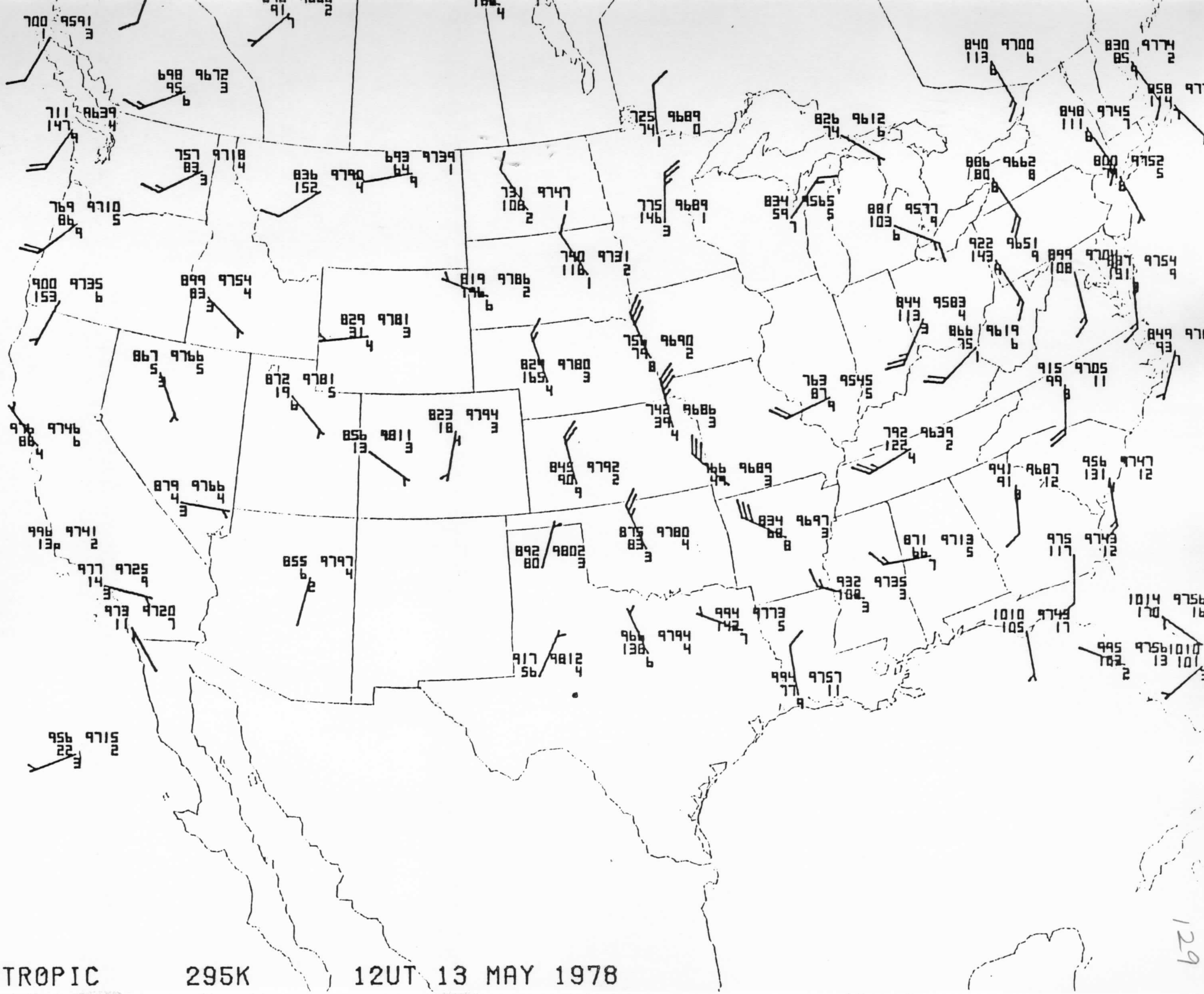


SENTROPIC 315K 00UT 13 MAY 1978

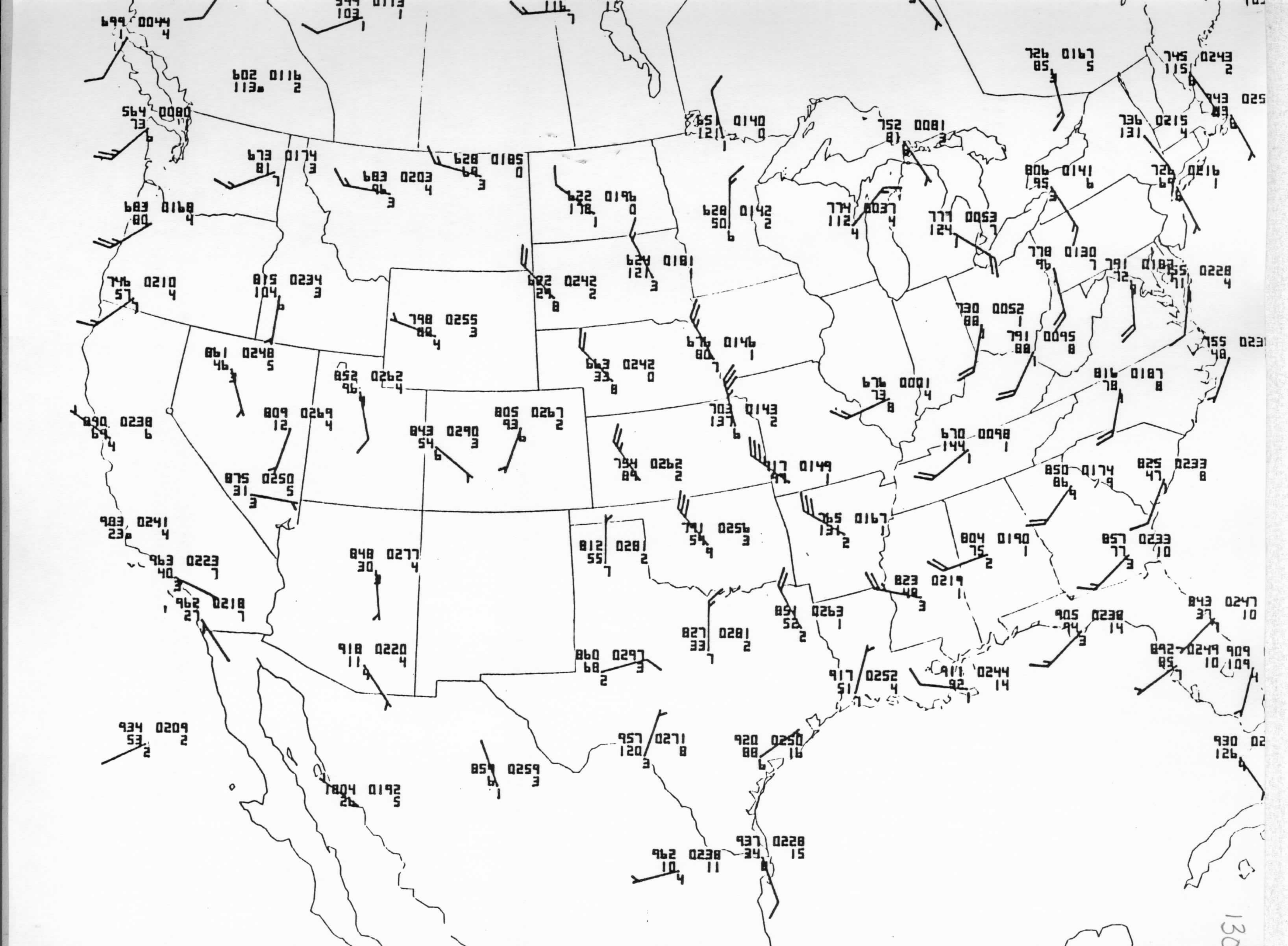
ISENTROPIC 320K 00UT 13 MAY 1978

ISENTRØPIC 325K 00UT 13 MAY 1978

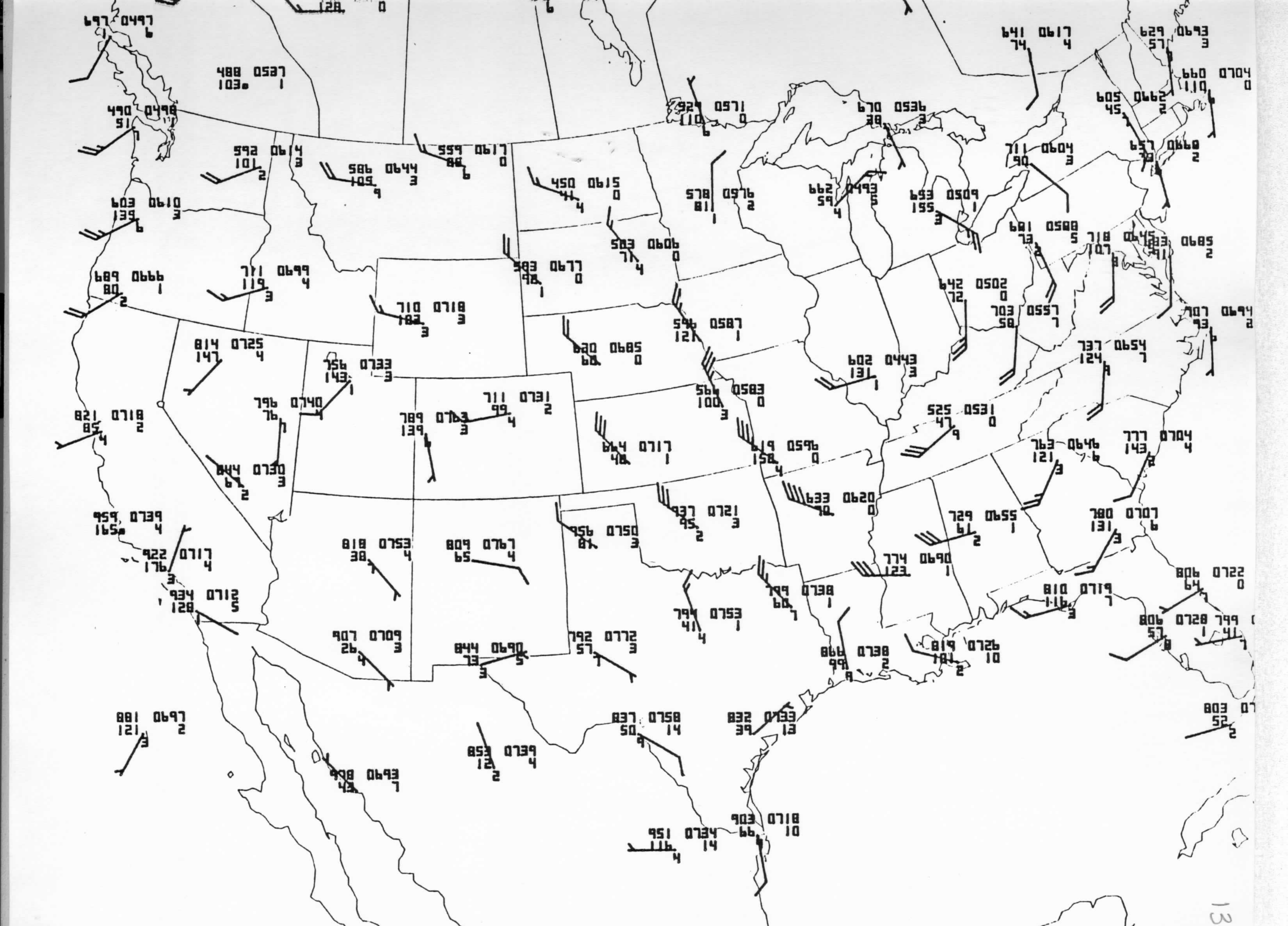
ISENTROPIC 290K 12UT 13 MAY 1978



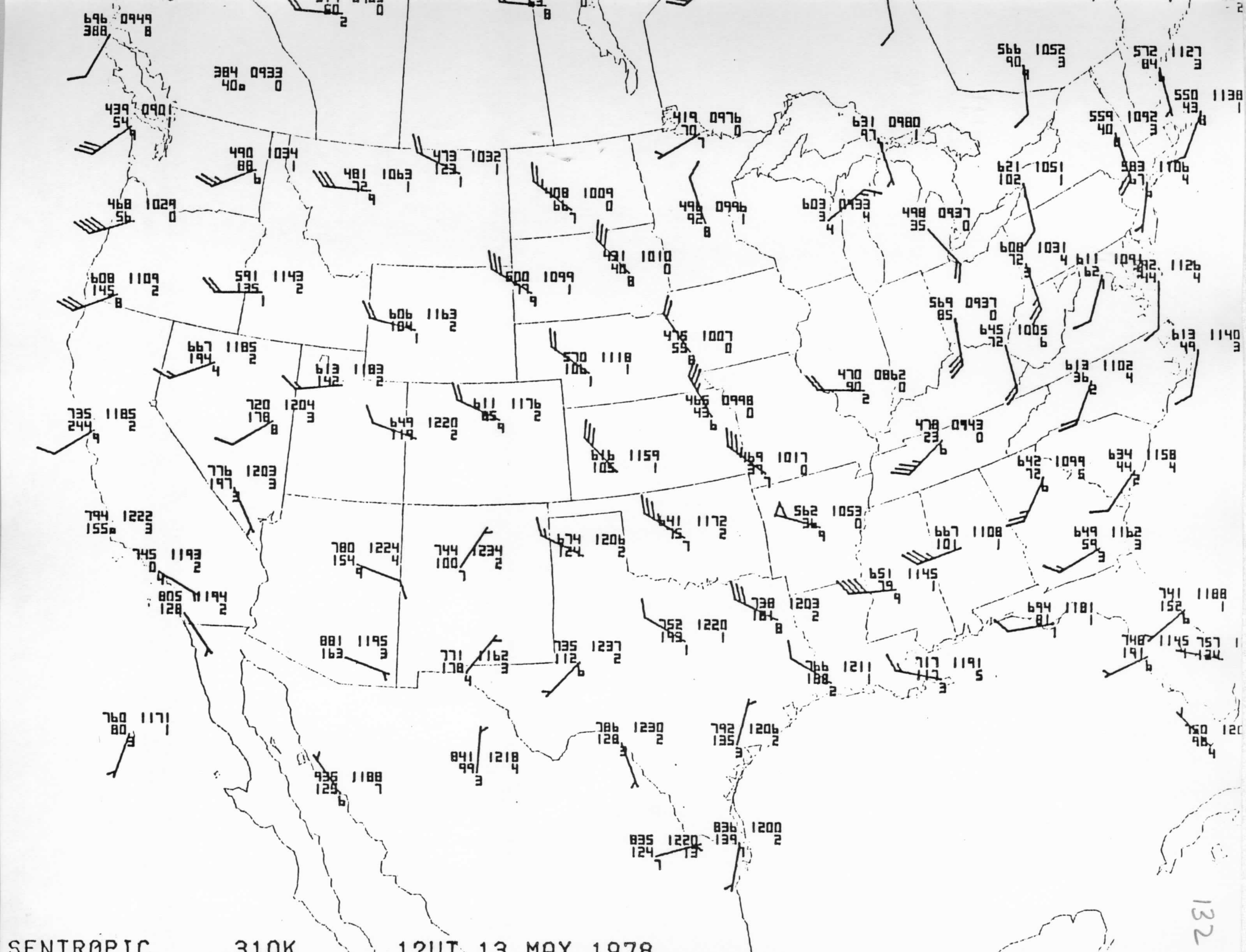
ISENTROPIC 295K 12UT 13 MAY 1978



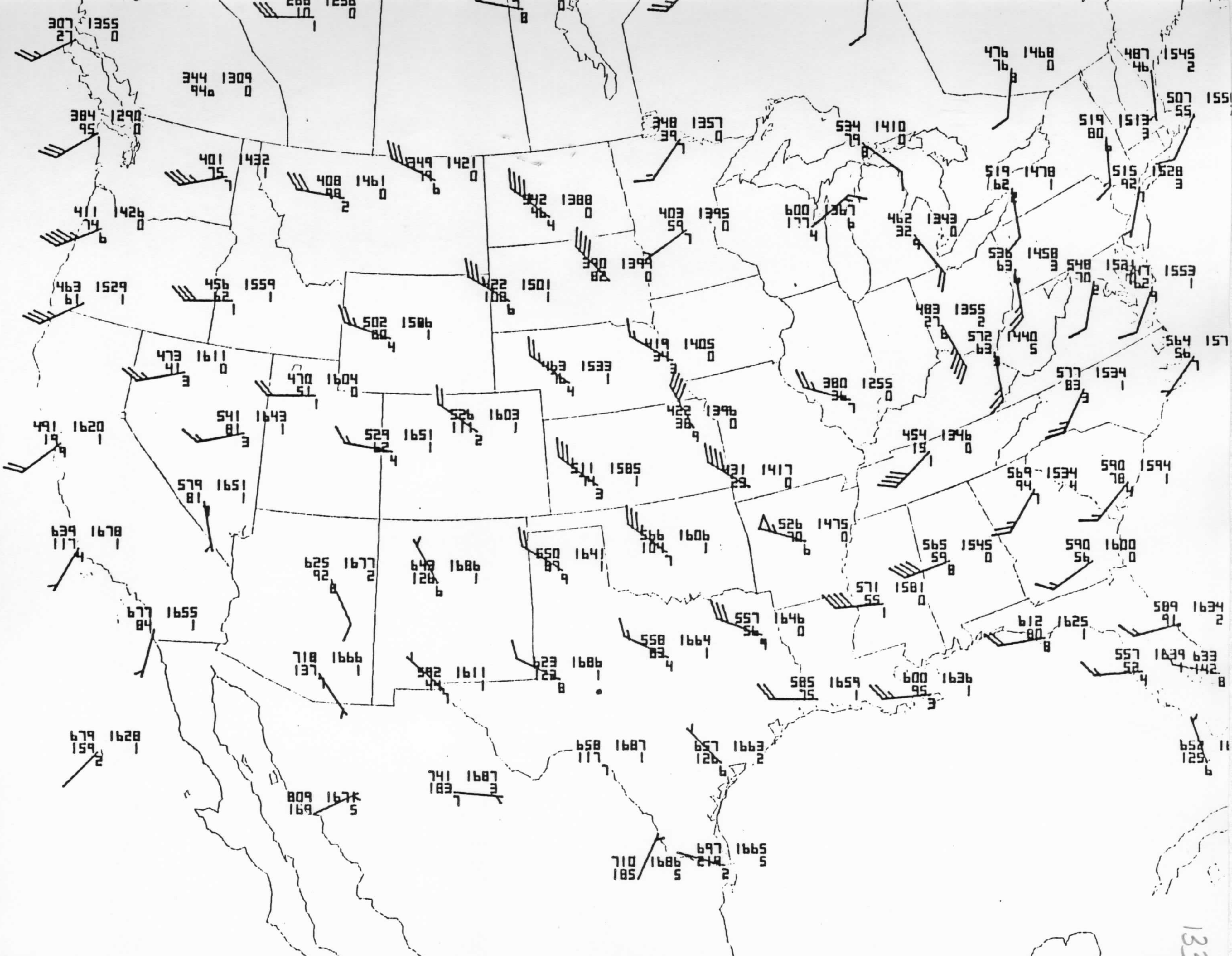
ISENTROPIC 300K 12UT 13 MAY 1978



ISENTROPIC 305K 12UT 13 MAY 1978



SENTROPIC 310K 12UT 13 MAY 1978

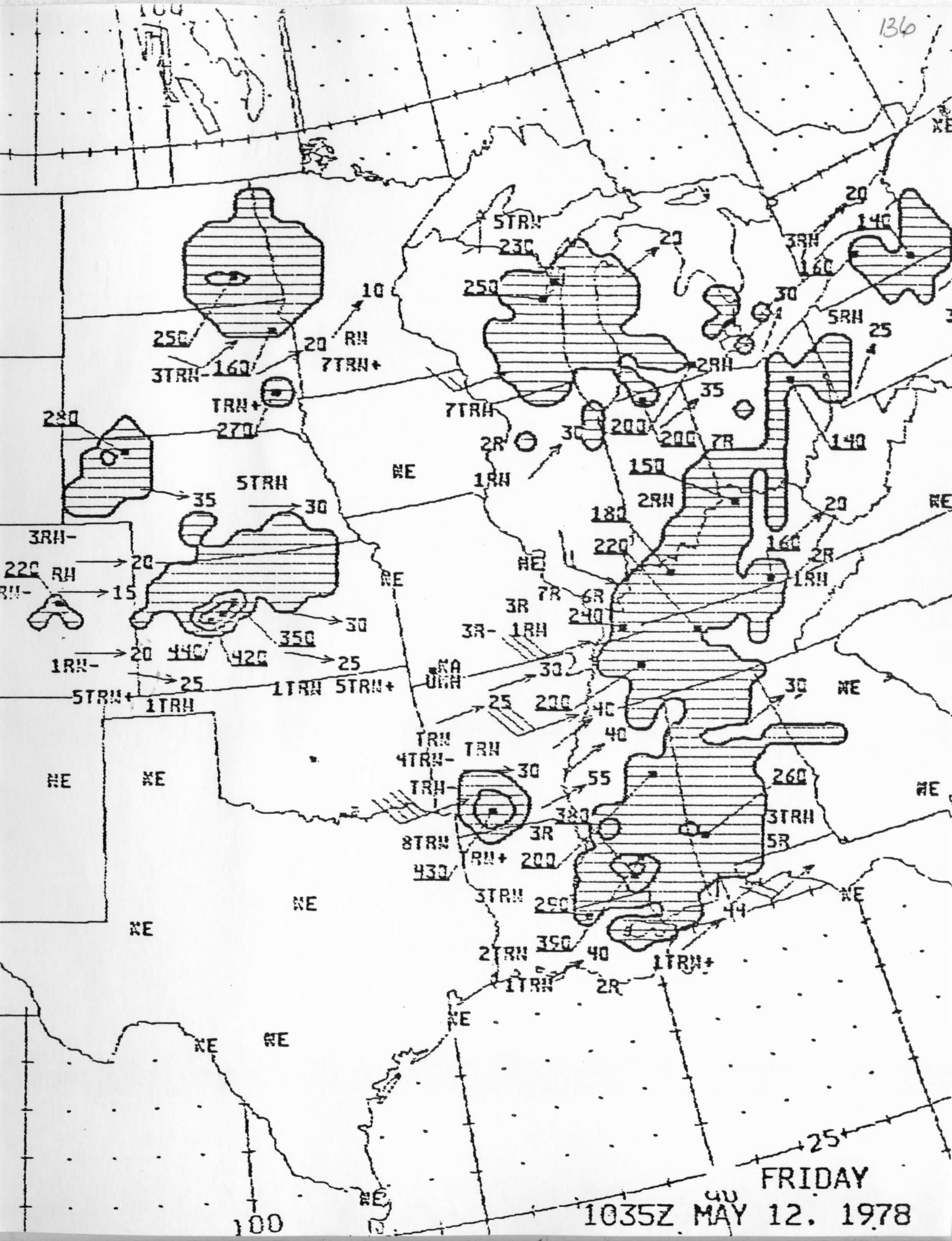


ISENTROPIC 315K 12UT 13 MAY 1978

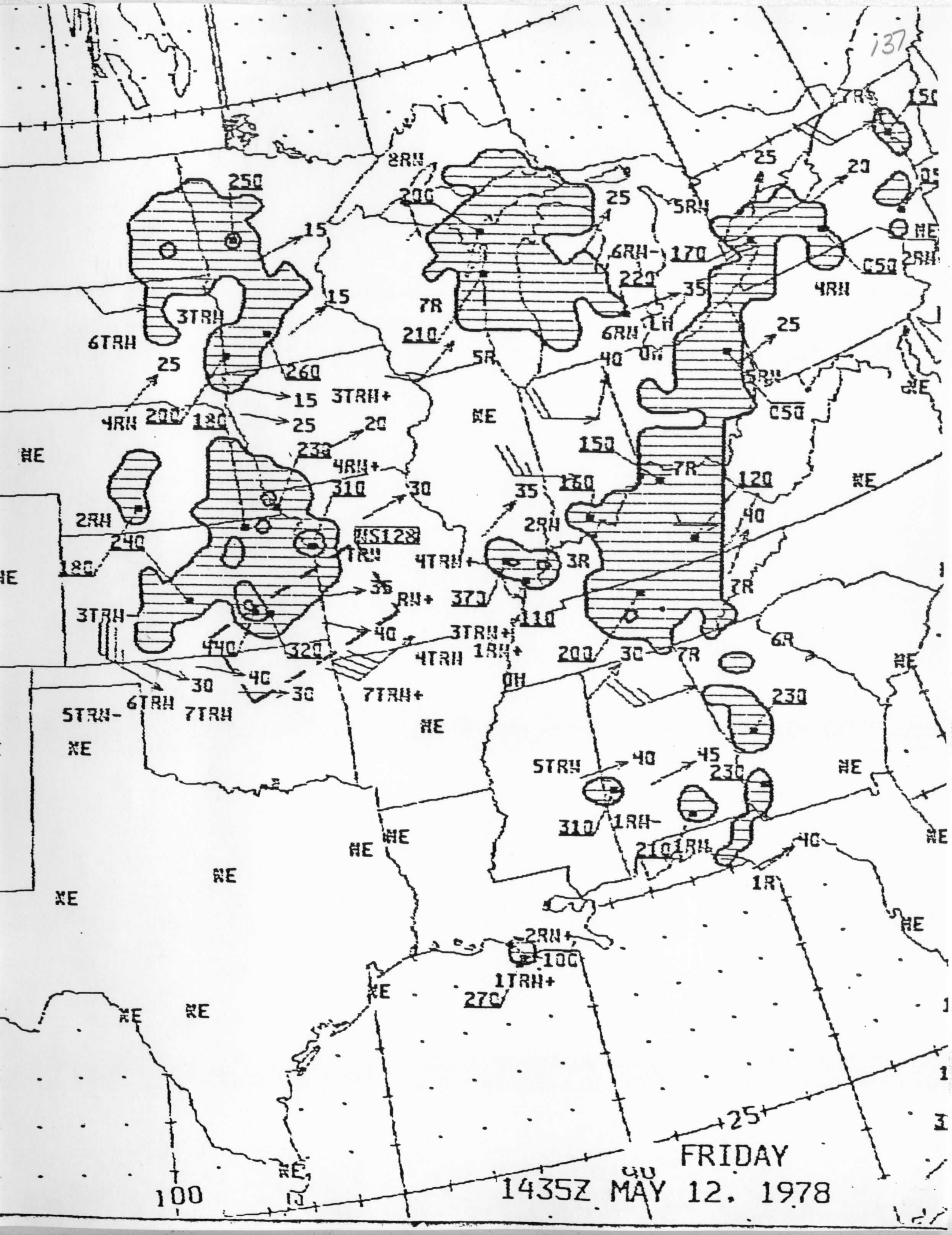
ISENTROPIC 320K 12UT 13 MAY 1978

5. Radar Charts/NMC Facsimile Product

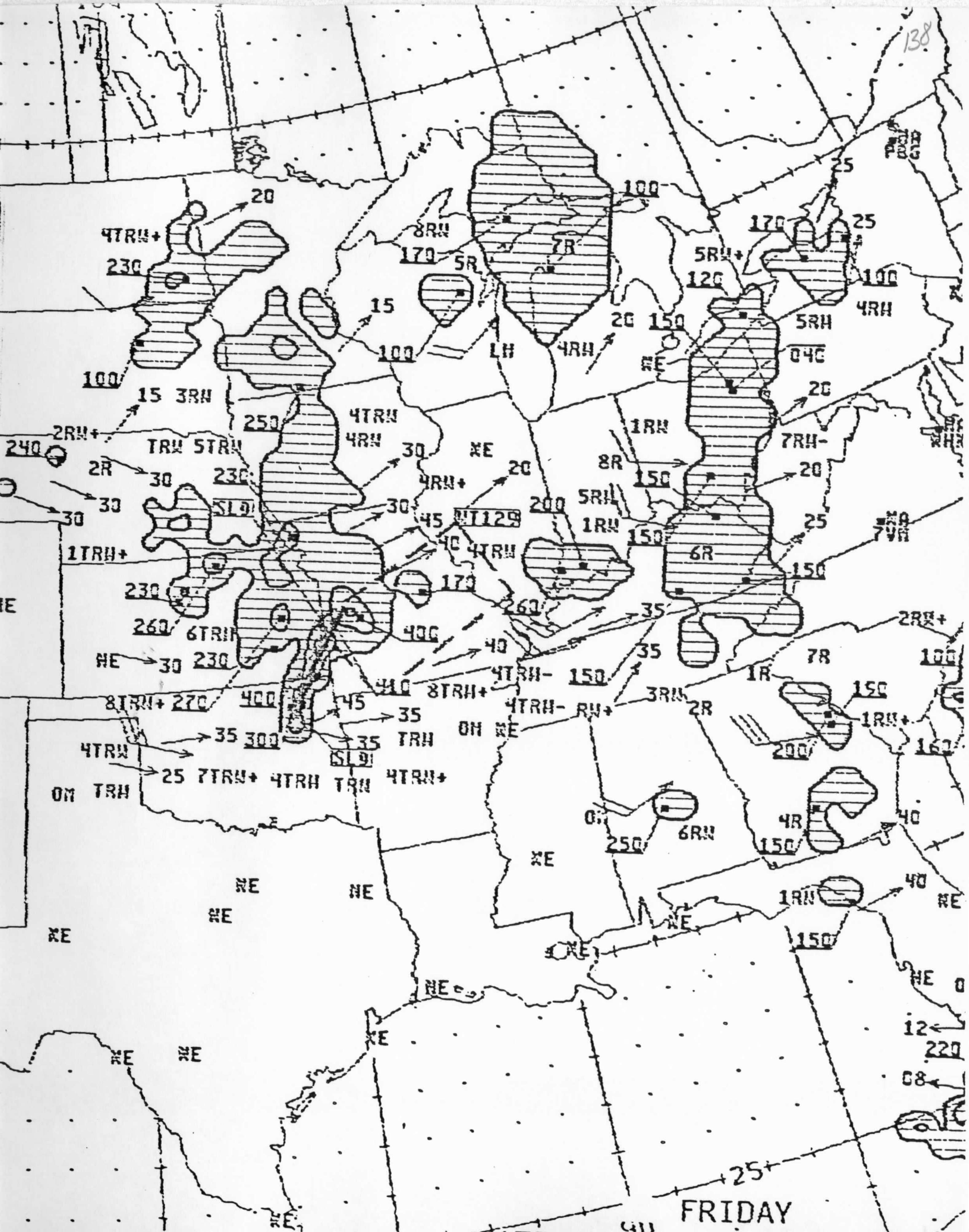
a. 12 May 1035 GMT
b. 12 May 1435 GMT
c. 12 May 1735 GMT
d. 12 May 1935 GMT
e. 12 May 2035 GMT
f. 12 May 2135 GMT
g. 12 May 2235 GMT
h. 12 May 2335 GMT
i. 13 May 0135 GMT
j. 13 May 0235 GMT
k. 13 May 0435 GMT
l. 13 May 0535 GMT
m. 13 May 0635 GMT
n. 13 May 1435 GMT



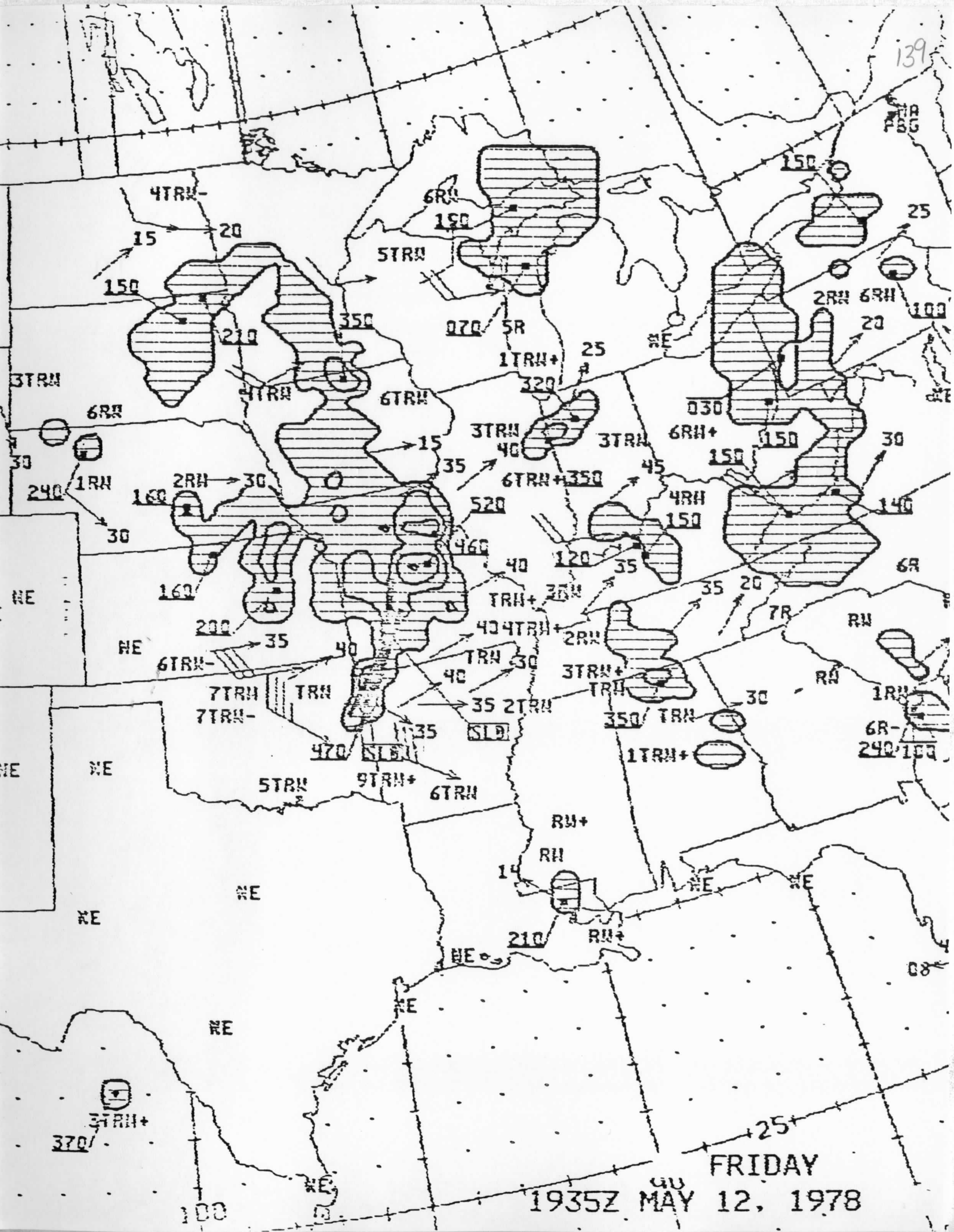
FRIDAY
1035Z MAY 12. 1978



FRIDAY
1435Z MAY 12, 1978

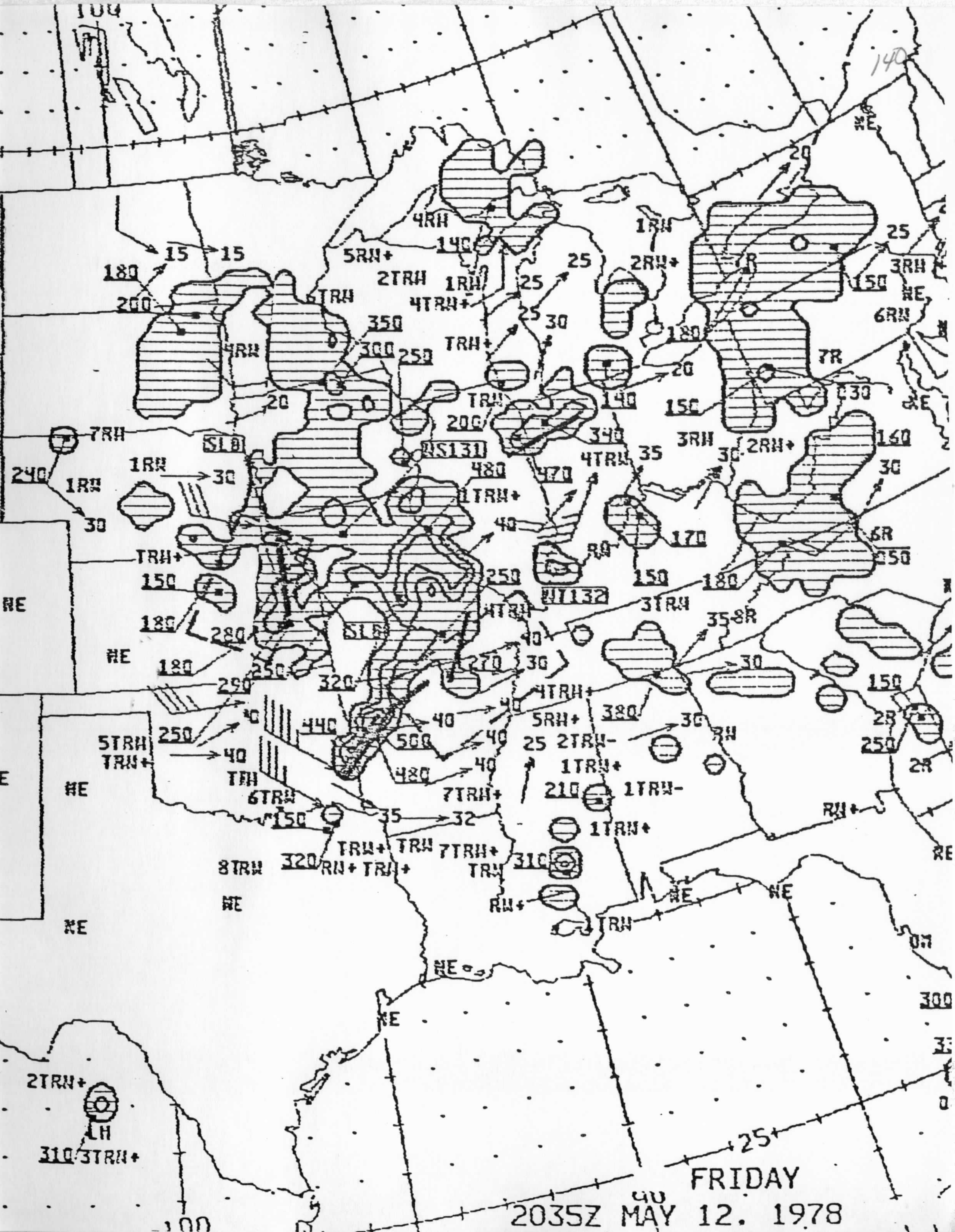


FRIDAY
1735Z MAY 12, 1978



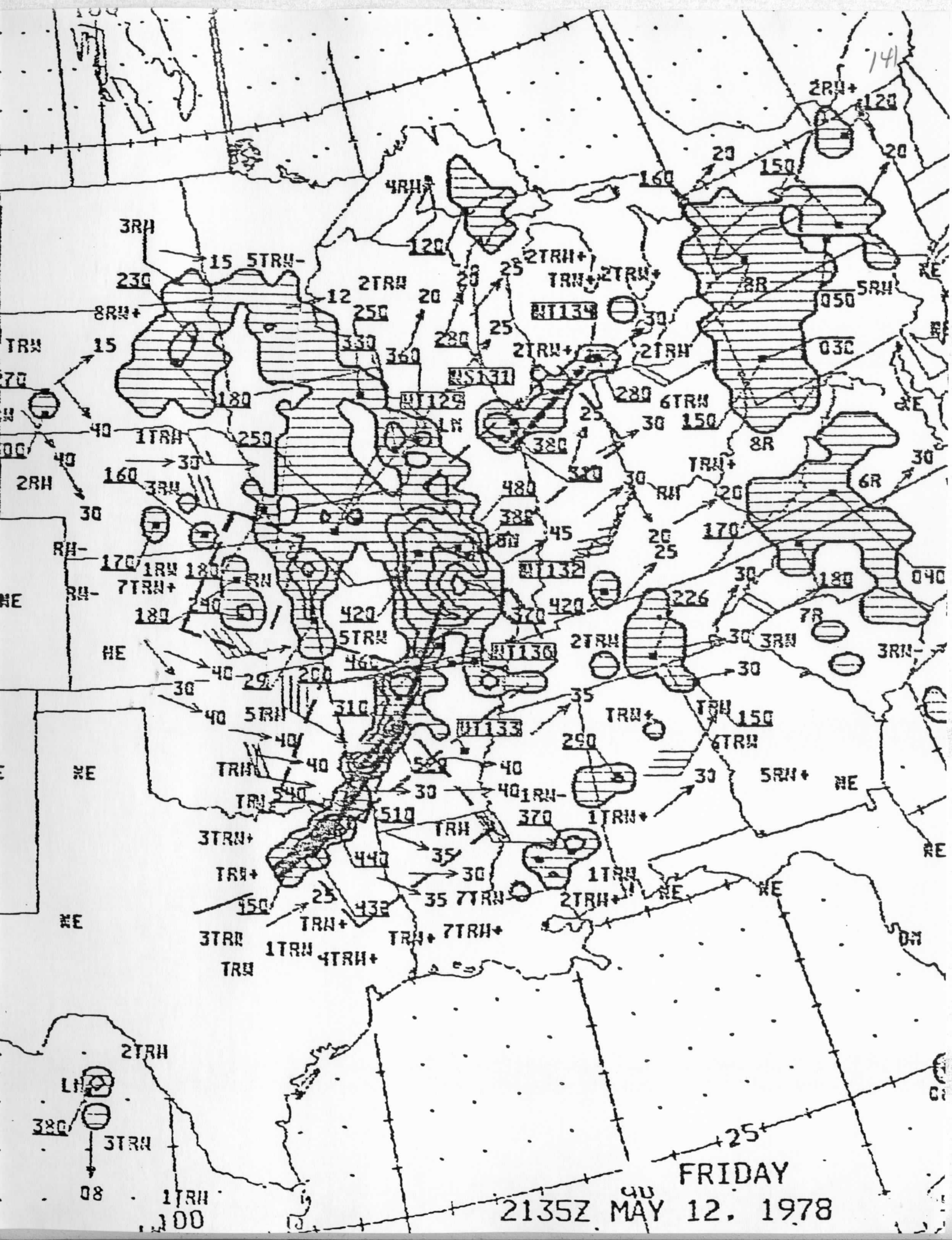
FRIDAY
1935Z MAY 12, 1978

140



FRIDAY

2035Z MAY 12. 1978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120
20
150
160
4RW
3RW
120
15 5TRW-
2TRW+
TRW+ 2TRW+
230
12 2TRW
25
8RW+
250
20
WT134
8R
050 5RW
TRW
15
330
360
280
25
30
2TRW+
2TRW
030
270
WS131
180
WT129
280 6TRW
LN
150
40 1TRW
250
25
30
40
380
8R
2RW
160
3RW
30
320
TRW+
30
RW
20
6R
30
480
380
45
20
170
RW-
170 1RW
180
25
WT132
7TRW+
040
RW-
420
370
420
226
30
180
NE
7R
180
420
5TRW
2TRW
30 3RW
3RW-
NE
40
29
200
460
WT130
30
30
40 5TRW
310
35
TRW+
TRW 150
40
WT133
6TRW
NE
TRW
40
40
290
5RW+
NE
TRW
540
30
40 1RW-
30
1TRW+
510
370
3TRW+
TRW
35
440
30
TRW+
1TRW
NE
NE
25
35 7TRW
2TRW+
450
432
NE
TRW+
3TRW
TRW+ 7TRW+
1TRW
4TRW+
TRW
OM
2TRW
LN
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3TRW
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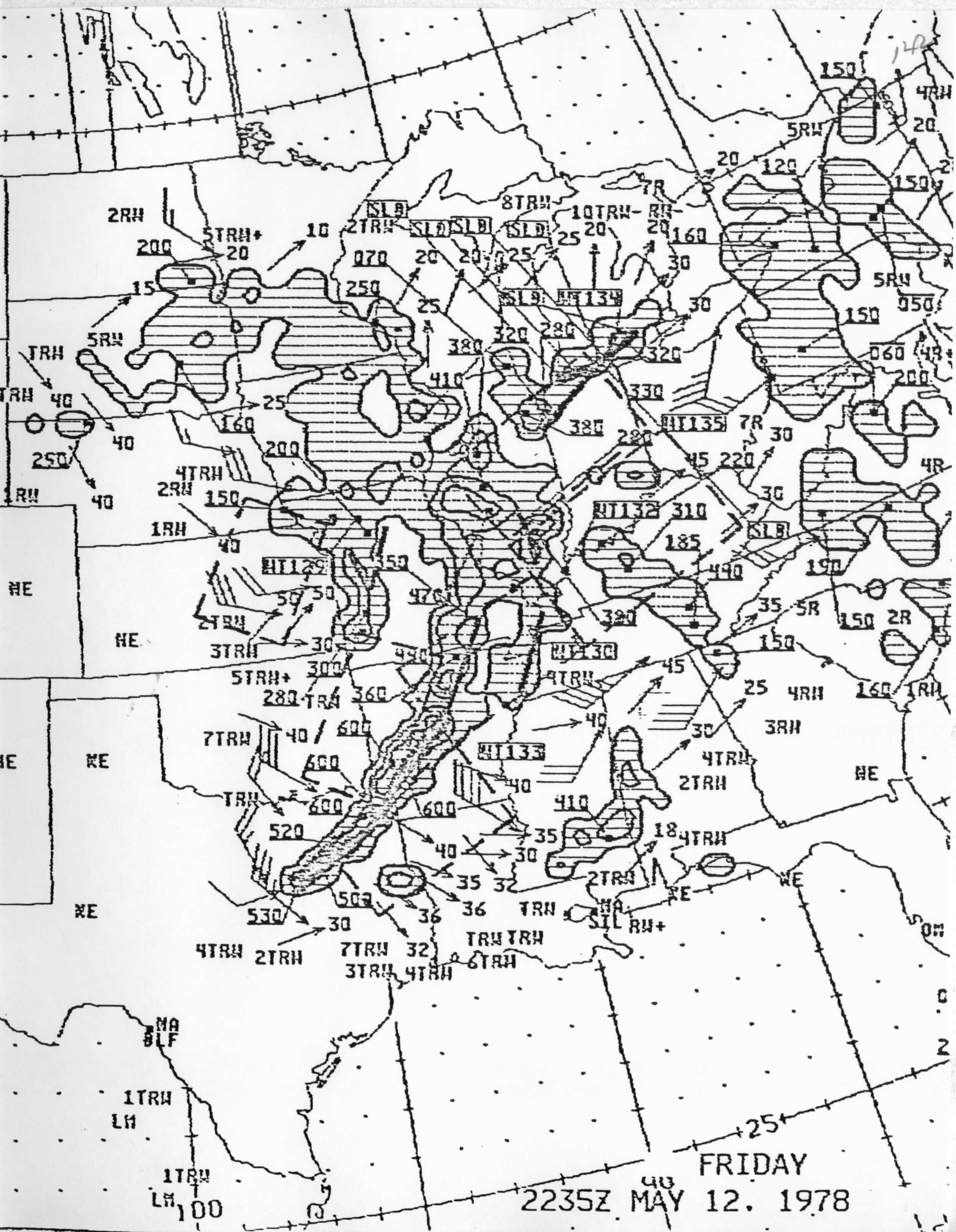
08
1TRW
100
FRIDAY
2135Z MAY 12, 1978


2RW
5TRW+
20
200
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15
5RW
TRW
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250
40
4TRW
2RW
150
1RW
40
NE
NE
2TRW
3TRW
5TRW+
300
280
TRW
7TRW
600
520
530
30
4TRW
2TRW
7TRW
32
3TRW
4TRW
6TRW
TRW TRW
SLB
070
250
20
25
380
410
160
200
8TRW
10TRW-RW-
20
160
30
MT134
320
330
380
MT135
7R
30
220
45
MT132
310
185
490
390
MT130
4TRW
45
40
MT133
410
35
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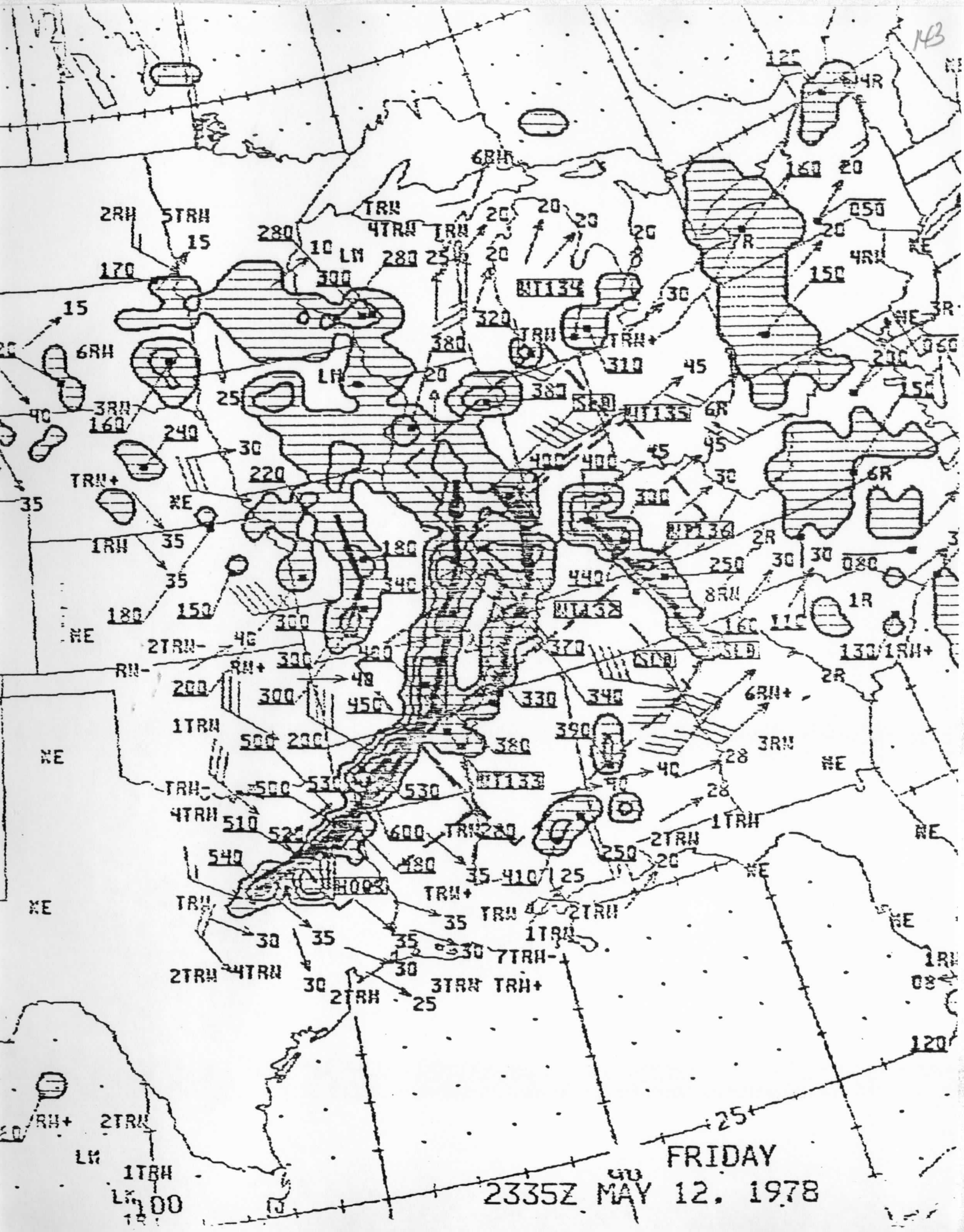
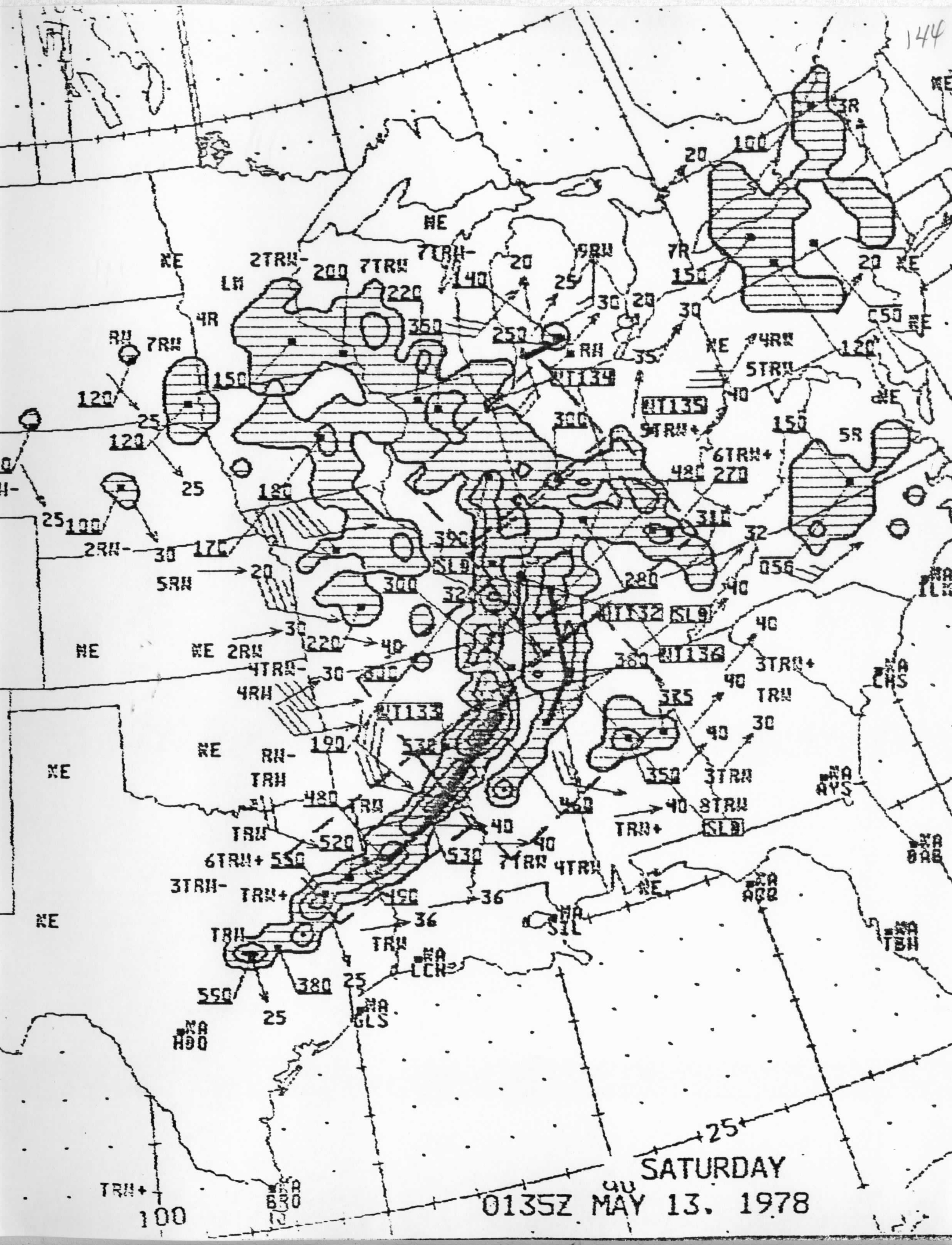
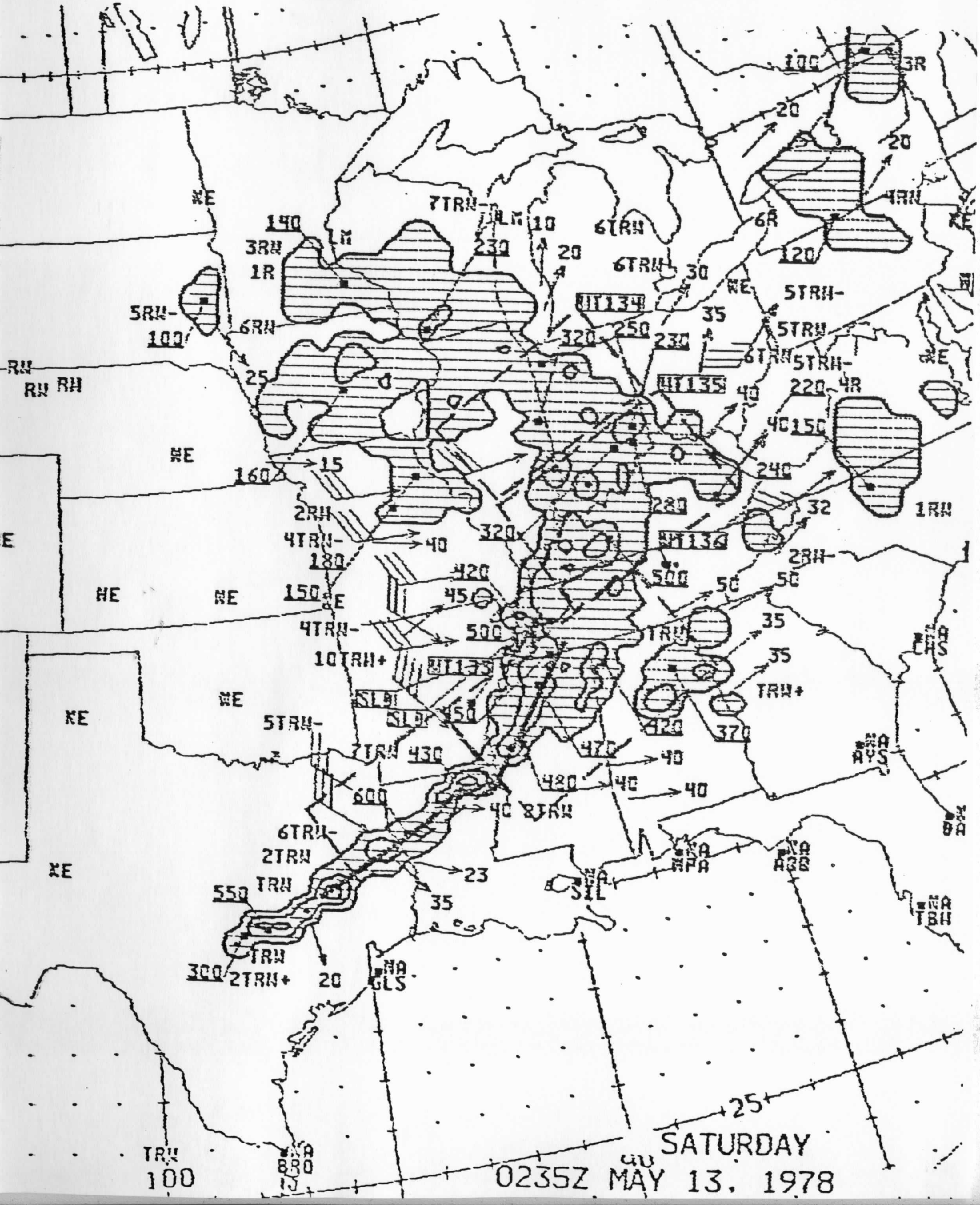
4TRW
2TRW
MA
SIL
RW+
NE
150
5RW
20
120
150W
5RW
050
060
200
4R
190
150
2R
150
160
1RW
4RW
3RW
NE
25
30
4TRW
2TRW
MA
BLF
1TRW
LM
1TRW
LM
100
25
OM
FRIDAY
2235Z MAY 12. 1978



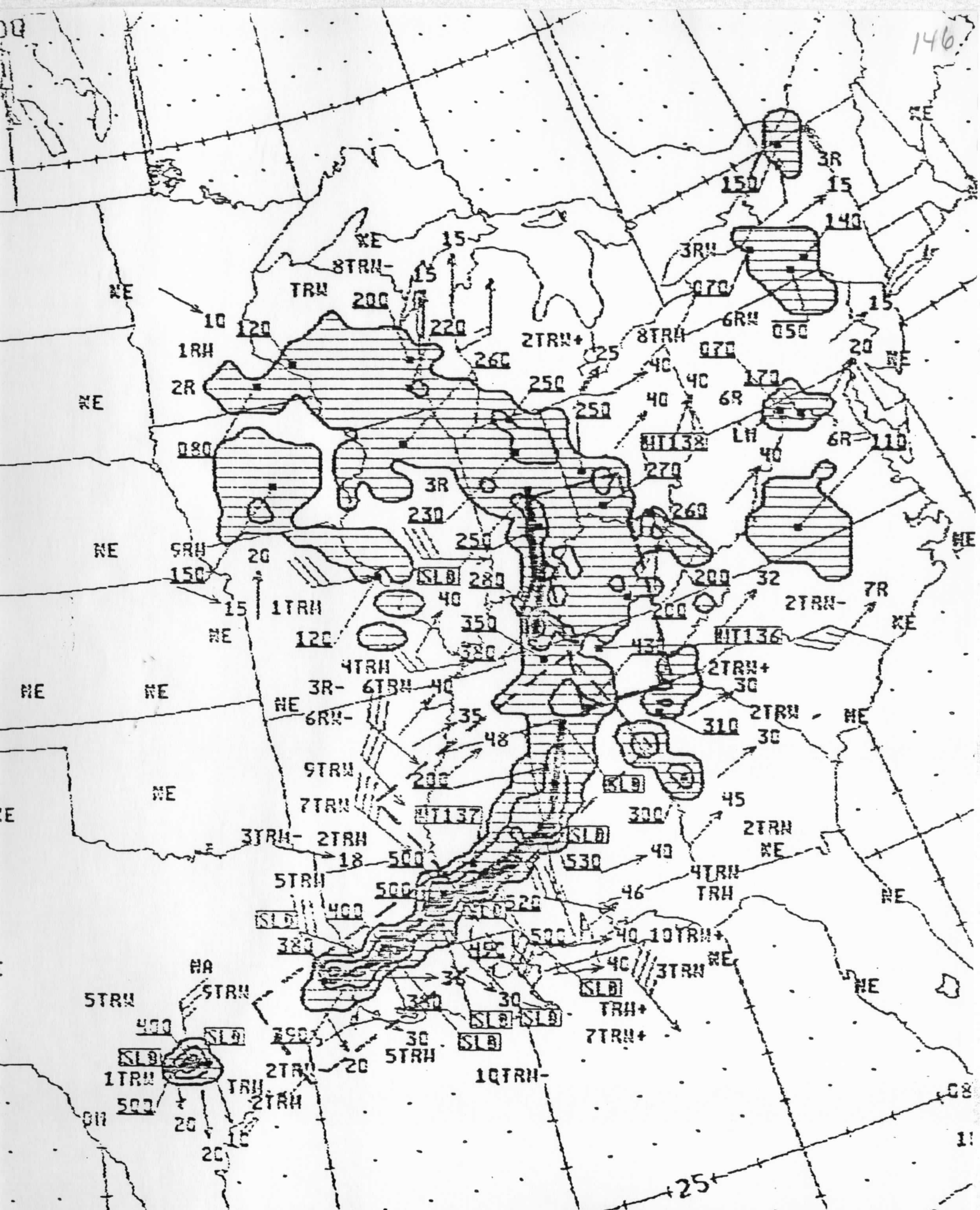
FRIDAY
2335Z MAY 12. 1978



SATURDAY
0135Z MAY 13. 1978

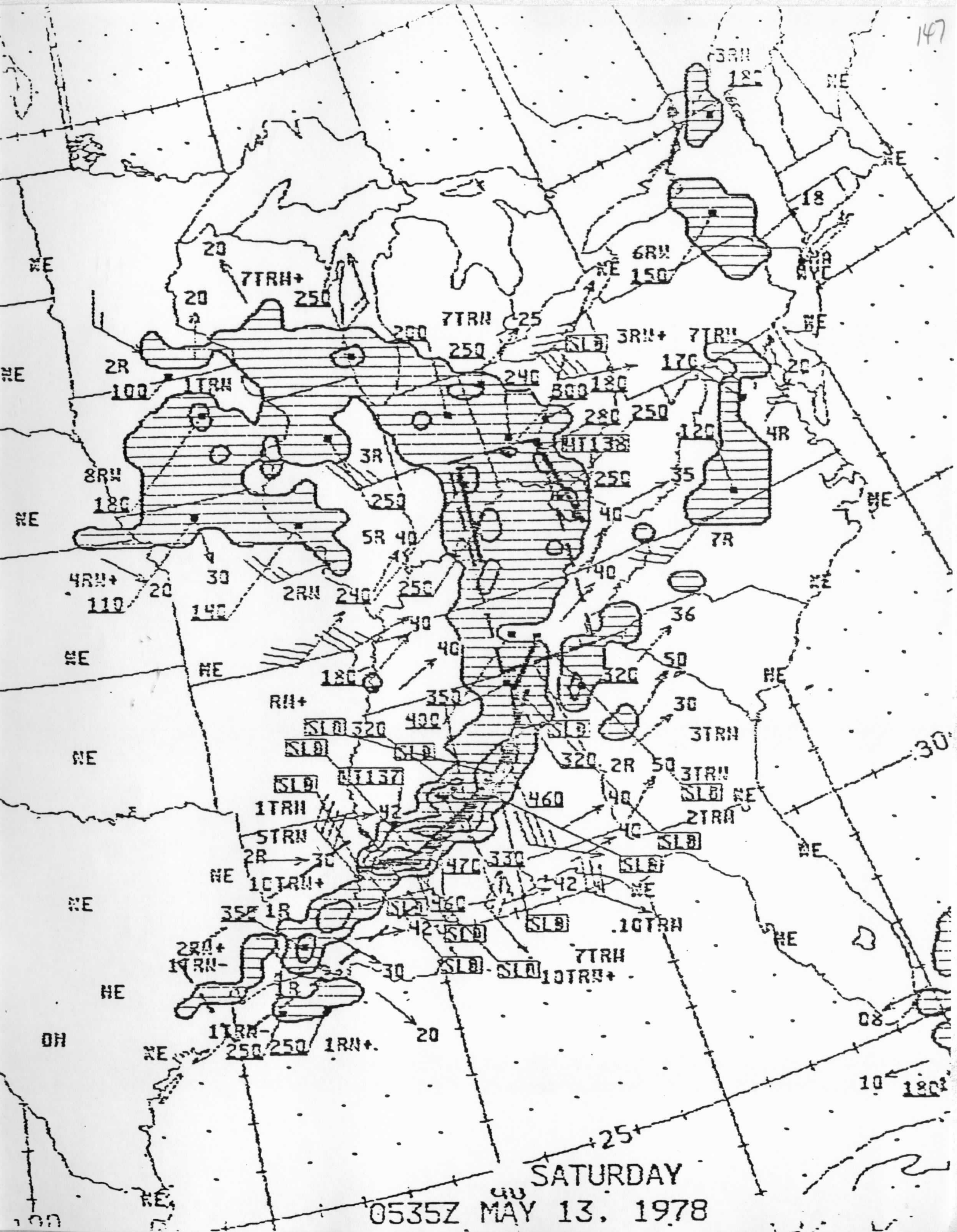


SATURDAY
0235Z MAY 13, 1978



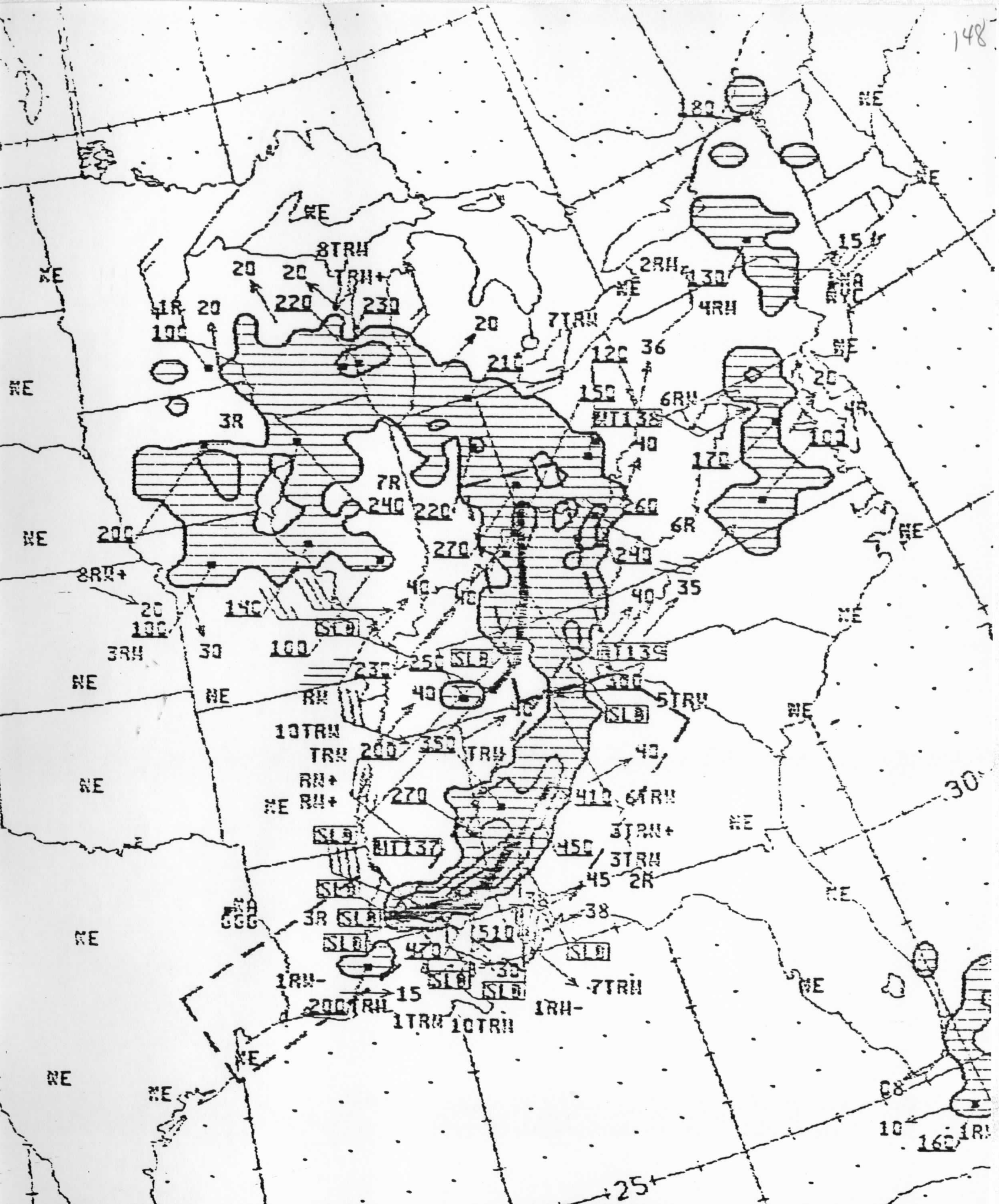
SATURDAY

0435Z MAY 13, 1978

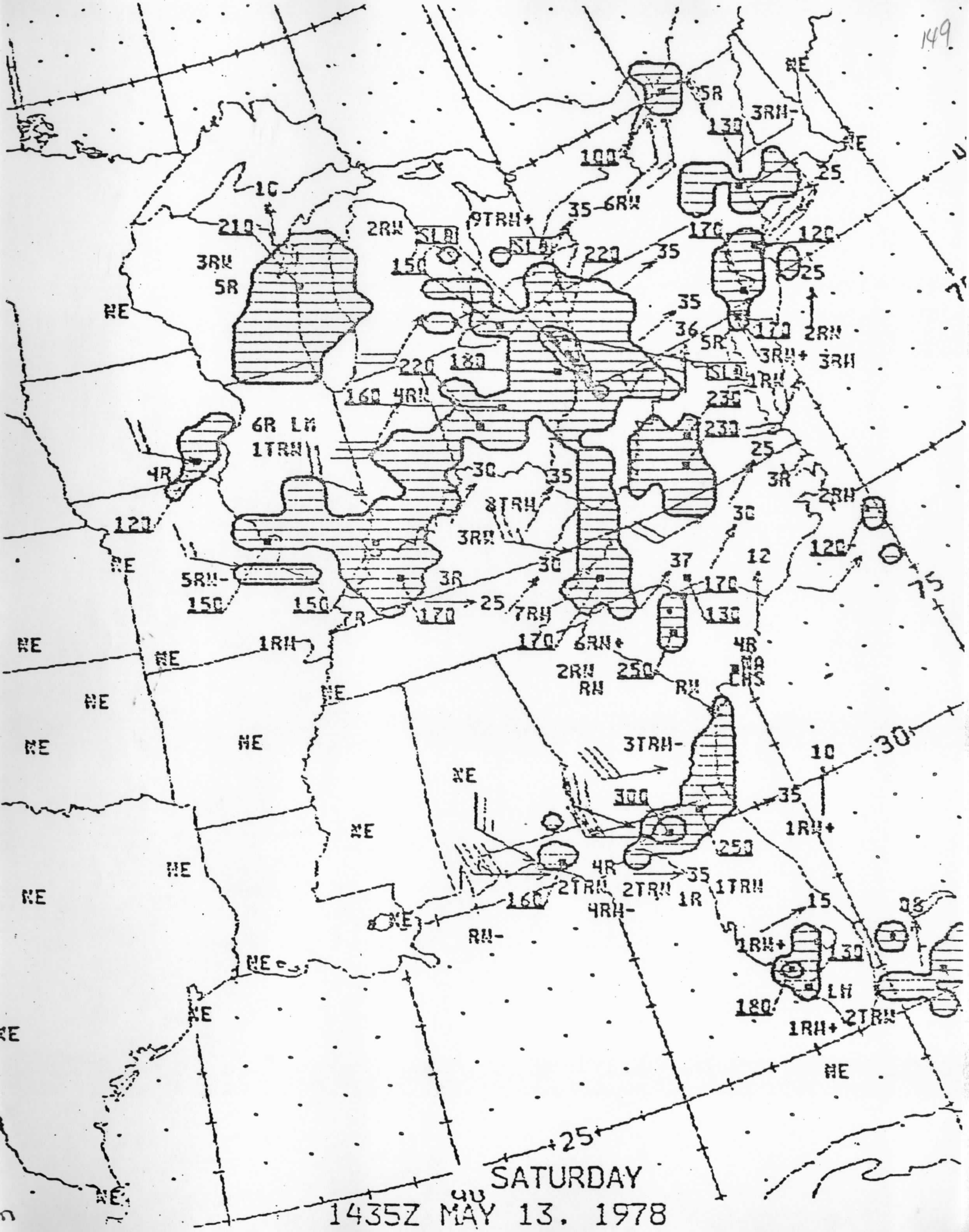


SATURDAY

0535Z MAY 13, 1978



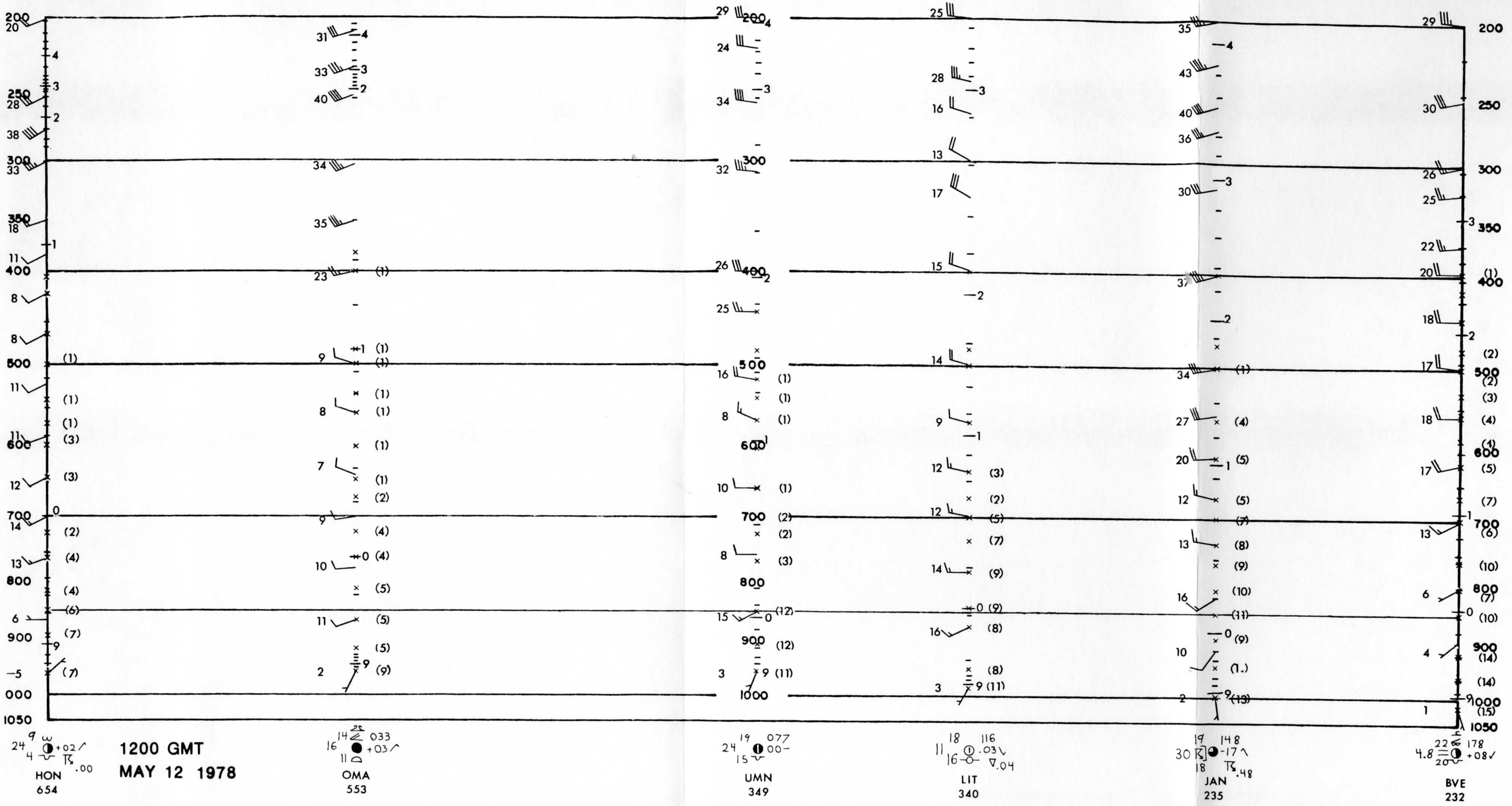
SATURDAY
0635Z MAY 13, 1978

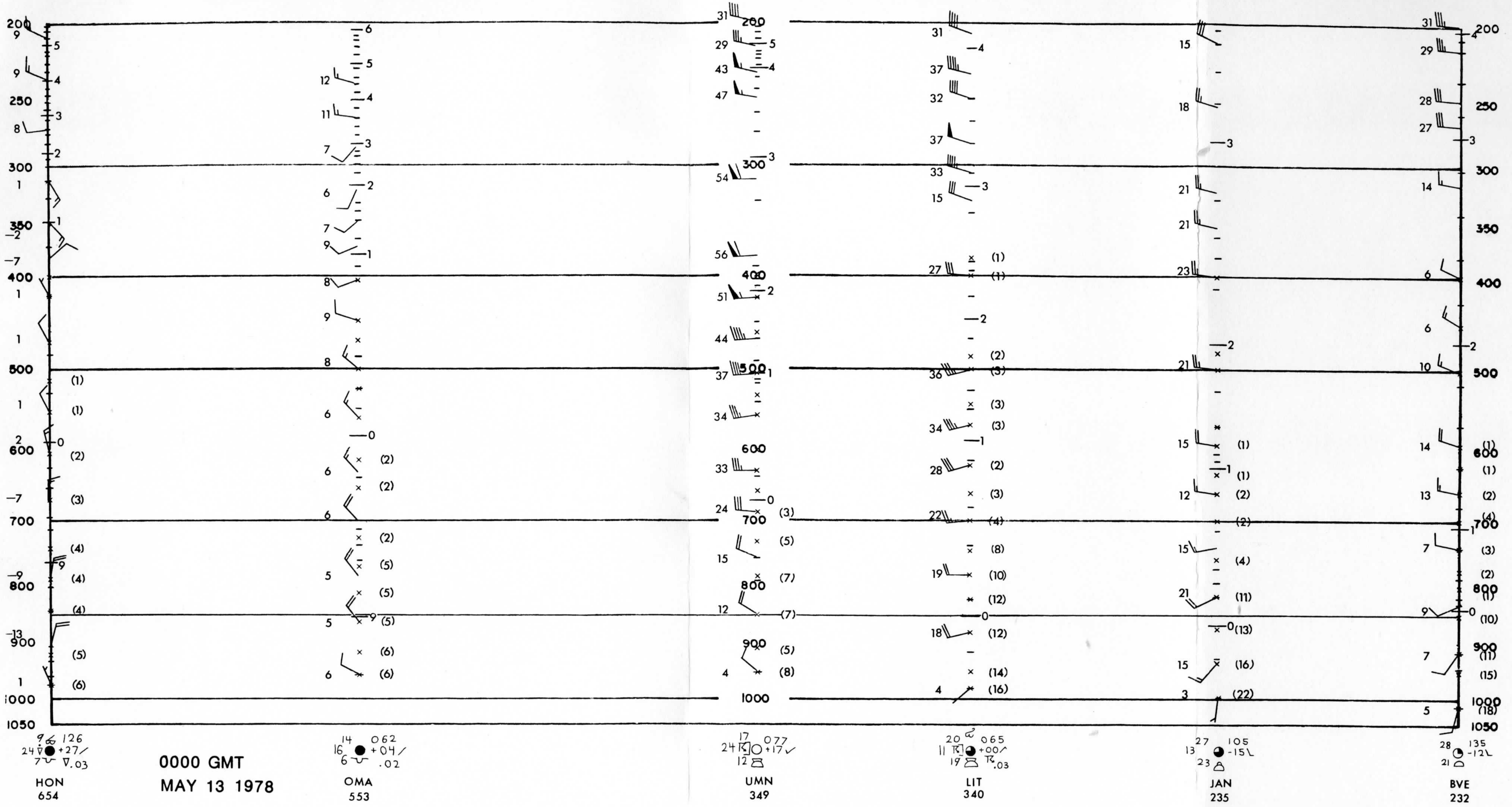


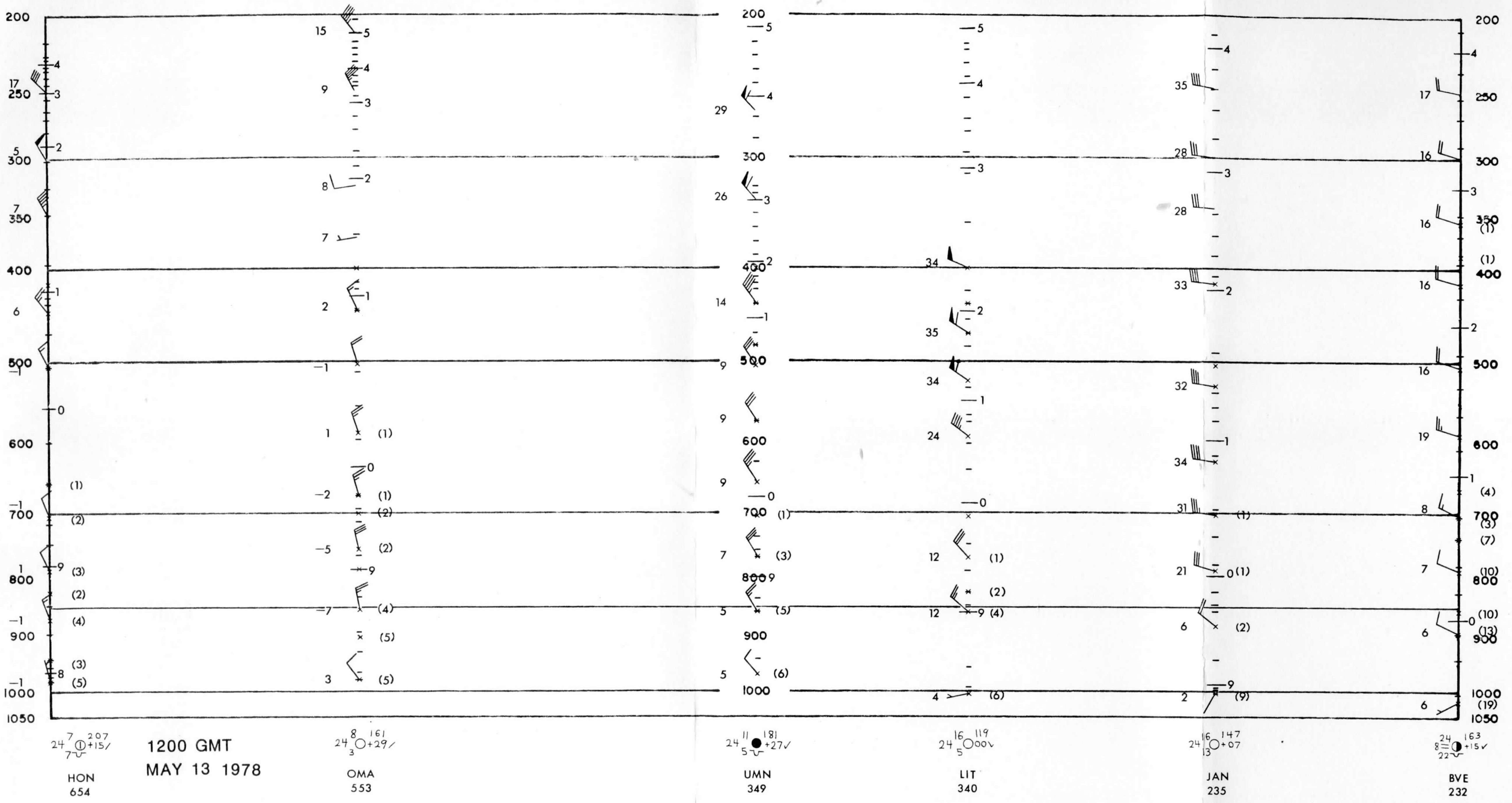
SATURDAY
1435Z MAY 13. 1978

6. Isentropic Cross Sections
HON -OMA -UMN -LIT -JAN -BVE

a. 12 May 1200 GMT
b. 13 May 0000 GMT
c. 13 May 1200 GMT


1200 GMT
MAY 12 1978
HON
654
OMA
553
UMN
349
LIT
340
JAN
235
BVE
232


200
250
300
350
400
500
600
700
800
900
1000
1050
HON
654
0000 GMT
MAY 13 1978
OMA
553
UMN
349
LIT
340
JAN
235
BVE
232


1200 GMT
MAY 13 1978
HON
654
OMA
553
UMN
349
LIT
340
JAN
235
BVE
232
200
250
300
350
400
500
600
700
800
900
1000
1050

7. McIDAS Derived Fields

a. Surface fields	12 May 1300 GMT divergence 12 May 1500 GMT divergence 12 May 1800 GMT divergence 12 May 2100 GMT divergence 13 May 0000 GMT divergence 13 May 0300 GMT divergence 13 May 0600 GMt divergence
b. 12 May 1200 GMT	850 mb temperature advection 850 mb dewpoint advection 850 mb divergence 700 mb temperature advection 700 mb dewpoint advection 700 mb divergence 500 mb temperature advection 500 mb divergence 500 mb vorticity advection 300 mb temperature advection 300 mb divergence
c. 13 May 0000 GMT	850 mb temperature advection 850 mb dewpoint advection 850 mb divergence 700 mb temperature advection 700 mb dewpoint advection 700 mb divergence 500 mb temperature advection 500 mb divergence 500 mb vorticity advection 300 mb temperature advection 300 mb divergence

-2	-4	-3	0	3	3	2	0	-2	-3	-0	4	5	3	-1	-6	-8	-6	-4
-3	-3	0	5	6	2	-1	-6	-9	-8	-3	2	3	0	-5	-10	-11	-9	-7
-2	0	4	6	3	-2	-7	-11	-13	-12	-7	-2	-0	-3	-8	-14	-15	-13	-10
0	1	3	1	-3	-6	-8	-10	-11	-12	-9	-5	-3	-5	-10	-15	-17	-14	-10
4	4	2	-0	-3	-5	-6	-5	-4	-6	-7	-5	-4	-5	-9	-12	-13	-10	-5
5	5	4	2	0	-1	-2	-0	0	-2	-5	-5	-5	-5	-5	-4	-3	-1	-0
3	4	2	0	-0	-2	-5	-6	-6	-8	-8	-6	-5	-4	-1	2	5	5	5
1	2	0	-3	-6	-10	-15	-17	-16	-13	-7	-3	-2	-2	-0	3	7	7	6
0	1	0	-2	-7	-14	-19	-18	-14	-9	-2	1	2	0	0	2	4	4	4
2	1	0	-0	-4	-11	-15	-13	-9	-5	-0	3	5	5	4	3	2	2	2
3	2	1	2	0	-4	-8	-7	-4	-3	-2	0	5	8	8	6	1	2	1
4	3	4	5	4	1	-1	-2	-1	-2	-4	-2	3	7	8	6	4	2	0

SFC
DIV 121300 FOR 0 HOURS CONTOUR INT= 5
NORTHWEST 49.0 111.0 SOUTHEAST 29.5 81.0

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-2	-3	-3	-1	2	2	-2	-9	-12	-10	-7
-5	-5	-5	-3	0	1	0	-2	-5	-8	-6	-2	0	-1	-6	-12	-15	-13	-10
-8	-6	-5	-3	-1	-3	-6	-7	-9	-11	-10	-6	-4	-6	-10	-16	-19	-16	-12
-4	0	2	1	-1	-5	-7	-8	-9	-11	-10	-8	-6	-7	-11	-15	-18	-15	-10
3	11	14	10	3	-1	-4	-5	-4	-5	-6	-6	-6	-8	-9	-11	-10	-7	-2
6	13	15	11	5	0	-3	-3	-1	-1	-3	-5	-6	-7	-7	-4	-2	1	4
5	7	6	3	0	-2	-5	-7	-7	-8	-9	-8	-8	-7	-4	-0	3	5	8
2	1	-1	-3	-4	-4	-8	-14	-17	-17	-13	-9	-7	-5	-2	0	3	4	5
0	-0	-0	-1	-4	-7	-12	-17	-20	-17	-10	-4	-2	-1	0	0	0	1	0
-0	-0	2	2	-4	-12	-17	-18	-17	-13	-6	-0	2	3	3	1	-0	0	0
-0	-0	4	5	-2	-11	-16	-15	-12	-9	-6	-1	3	6	5	3	2	2	2
0	1	5	7	0	-6	-9	-8	-6	-7	-7	-4	0	3	4	4	4	1	3

SFC DIV 121500 FOR 0 HOURS CONTOUR INT= 5
NORTHWEST 49.0 111.0 SOUTHEAST 29.5 81.0

-8	-8	-4	-0	2	3	3	2	1	1	1	-0	-0	0	-2	-9	-15	-15	-13
-9	-7	-3	1	3	2	1	-0	-3	-2	-2	-4	-4	-5	-8	-14	-19	-18	-14
-5	-3	-0	1	0	-0	-1	-3	-7	-7	-7	-8	-9	-9	-11	-15	-20	-19	-14
1	3	3	0	-3	-4	-2	-3	-7	-9	-9	-8	-8	-8	-9	-12	-15	-14	-10
6	9	7	1	-4	-5	-4	-5	-8	-9	-8	-5	-4	-5	-7	-8	-8	-6	-2
10	13	10	4	-1	-3	-4	-6	-8	-10	-9	-6	-4	-5	-5	-2	-0	1	4
11	14	12	6	1	0	0	-0	-3	-6	-10	-11	-9	-7	-4	-0	2	4	7
6	11	10	3	0	2	4	3	0	-4	-10	-14	-12	-8	-4	-0	1	1	2
-3	2	3	-1	-1	1	0	-4	-8	-9	-10	-11	-8	-5	-2	-1	-1	-2	-3
-10	-6	-2	-2	-2	-4	-11	-18	-20	-17	-11	-7	-4	-1	-0	-1	-2	-2	-1
-9	-5	-1	0	-2	-10	-19	-25	-23	-17	-11	-6	-2	-0	0	-0	-1	-0	1
-5	-3	0	1	-3	-11	-19	-22	-16	-11	-9	-7	-4	-1	-0	-0	-0	0	3

SFC
DIV 121800 FOR 0 HOURS CONTOUR INT= 5
NORTHWEST 49.0 111.0 SOUTHEAST 29.5 81.0

-6	-4	1	6	5	0	-3	-6	-7	-5	-2	-1	-3	-5	-6	-9	-14	-15	-11
-4	-2	3	7	3	-4	-8	-8	-8	-6	-5	-6	-10	-11	-9	-9	-11	-14	-11
2	1	5	6	2	-3	-6	-7	-9	-10	-9	-10	-12	-12	-9	-7	-7	-9	-7
9	7	6	5	3	0	-3	-6	-8	-10	-9	-8	-10	-11	-9	-6	-4	-3	-0
10	8	5	2	2	2	-0	-1	-2	-3	-2	-3	-9	-12	-9	-4	-0	2	5
10	6	0	-5	-3	1	5	6	7	5	2	-4	-13	-14	-8	-1	2	6	9
4	1	-6	-11	-8	-0	6	8	8	5	-2	-12	-18	-14	-6	-0	3	5	7
-4	-6	-9	-11	-7	-0	4	5	2	-3	-12	-19	-18	-10	-3	-0	0	1	1
-9	-10	-10	-8	-5	-2	-2	-4	-7	-13	-18	-19	-13	-4	-0	-0	-1	-1	-1
-8	-9	-8	-6	-6	-9	-14	-18	-19	-18	-17	-13	-8	-2	0	0	-1	-2	-2
-5	-5	-5	-6	-9	-15	-23	-26	-22	-17	-13	-9	-6	-3	-0	0	-0	-2	-3

SFC
DIV 122100 FOR 0 HOURS CONTOUR INT= 5
NORTHWEST 49.0 111.0 SOUTHEAST 29.5 81.0

-3	-2	2	8	10	5	-1	-5	-6	-4	-1	-0	0	1	1	0	-3	-8	-7
-5	-2	4	11	12	8	3	-0	-3	-3	-2	-3	-5	-6	-5	-4	-6	-9	-7
-6	-3	2	7	7	5	5	3	-0	-3	-5	-8	-13	-16	-13	-8	-6	-7	-5
-0	0	1	1	-0	-0	2	2	-1	-6	-8	-11	-18	-22	-18	-10	-5	-4	-2
6	6	3	-0	-3	-3	-3	-3	-5	-9	-9	-11	-17	-22	-17	-8	-1	0	1
10	10	5	1	-2	-4	-5	-5	-6	-6	-6	-8	-14	-18	-14	-4	2	4	5
14	12	6	-1	-5	-3	-0	0	0	0	-1	-7	-13	-16	-13	-4	2	5	6
12	9	0	-7	-10	-3	4	6	7	6	-0	-10	-14	-14	-9	-3	2	5	5
0	-2	-8	-14	-13	-3	6	8	8	5	-3	-12	-14	-9	-3	0	2	3	2
-11	-13	-15	-15	-11	-1	6	5	2	-0	-7	-13	-13	-6	-0	1	2	1	0
-11	-13	-13	-12	-9	-4	-0	-4	-9	-10	-11	-12	-11	-5	-1	0	0	-0	-0
-7	-10	-11	-11	-11	-11	-10	-14	-18	-17	-13	-10	-8	-5	-2	-0	-0	-1	-1

SFC DIV 130000 FOR 0 HOURS CONTOUR INT= 5
NORTHWEST 49.0 111.0 SOUTHEAST 29.5 81.0

-0	-1	-0	3	7	7	4	4	4	2	0	-0	0	1	2	1	-2	-8	-15
-3	-3	-0	4	7	7	5	5	4	3	1	-0	-2	-3	-2	-1	-2	-5	-8
-4	-3	-0	1	3	4	6	7	6	2	-1	-6	-11	-12	-9	-5	-3	-4	-5
-0	-1	-1	-1	0	5	8	8	3	-2	-9	-15	-20	-21	-17	-10	-5	-4	-4
3	0	-1	-2	-0	4	6	2	-3	-10	-16	-19	-22	-25	-22	-13	-5	-1	0
3	2	1	0	0	2	2	-1	-6	-11	-13	-12	-14	-18	-19	-14	-5	1	4
4	4	2	1	2	4	4	1	-2	-5	-4	-2	-3	-8	-12	-11	-4	2	6
3	1	-0	-2	0	4	6	5	3	3	4	4	1	-4	-9	-9	-4	1	5
-0	-2	-6	-7	-4	3	8	9	9	9	8	4	-2	-8	-12	-9	-4	-0	0
-2	-5	-9	-11	-6	3	11	12	11	9	5	-1	-8	-12	-11	-5	-1	-0	-1
-3	-6	-10	-13	-8	1	9	9	6	3	-0	-6	-10	-11	-8	-2	0	1	0
-2	-6	-11	-14	-10	-1	3	1	-0	-2	-4	-7	-10	-9	-6	-2	0	1	0

SFC DIV 130300 FOR 0 HOURS CONTOUR INT= 5
NORTHWEST 49.0 111.0 SOUTHEAST 29.5 81.0

0	0	1	4	6	5	5	5	6	6	6	6	5	5	5	4	-0	-7	-12
3	2	3	5	6	6	6	6	7	6	6	4	2	0	-0	-1	-3	-6	-8
4	3	3	4	4	4	5	6	5	3	0	-3	-9	-11	-11	-10	-8	-7	-5
2	1	1	2	3	4	5	6	3	-1	-7	-15	-22	-24	-20	-16	-12	-8	-5
1	0	2	3	5	6	7	6	1	-5	-12	-20	-26	-27	-23	-18	-12	-6	-2
1	2	4	6	7	8	7	5	1	-3	-9	-14	-18	-18	-17	-15	-12	-5	-0
-1	1	3	4	5	5	3	1	-0	-3	-5	-6	-7	-7	-9	-10	-10	-5	-0
-3	-1	-0	-0	1	1	-0	-3	-4	-5	-4	-3	-1	-1	-3	-7	-8	-6	-2
-3	-2	-2	-1	0	3	2	-0	-3	-2	-1	0	2	0	-3	-7	-7	-5	-3
1	0	-1	-2	1	6	8	5	3	3	5	5	3	-0	-4	-6	-5	-1	-0
5	3	-0	-2	0	7	11	10	9	8	7	5	3	-0	-3	-4	-1	1	3
6	4	1	-1	1	8	11	12	11	9	6	3	2	1	-1	-3	-1	2	3

SFC
DIV 130600 FOR 0 HOURS CONTOUR INT= 5
NORTHWEST 49.0 111.0 SOUTHEAST 29.5 81.0

-Ø	-6	-7	-7	-5	-1	-Ø	-1	-1	-Ø	Ø	Ø	1	2
-5	-14	-14	-14	-11	-4	Ø	Ø	-Ø	-Ø	-Ø	Ø	1	2
-5	-12	-14	-15	-13	-5	1	3	2	Ø	Ø	1	2	2
-2	-6	-6	-8	-7	-3	Ø	3	5	4	3	3	2	-Ø
-2	-3	-11	-5	-2	-Ø	2	4	4	5	4	3	2	-1
-1	-13	-26	-15	-6	Ø	6	11	8	6	7	6	3	1
-1	-10	-23	-13	-6	Ø	10	20	15	10	12	13	8	4
-2	-4	-10	-6	-3	Ø	5	13	10	7	11	13	8	4
-1	-2	-5	-6	-Ø	1	2	5	4	2	4	8	5	1

TAD 850 FROM 1212ØØ CONTOUR INT 2

-17	-1	9	4	Ø	-Ø	-Ø	-Ø	-Ø	Ø	Ø	Ø	1	5
-1Ø	2	8	2	-5	-5	-1	-Ø	-Ø	-Ø	Ø	Ø	1	6
-1	2	2	-4	-1Ø	-12	-8	-3	-2	-2	-1	-3	Ø	8
Ø	-Ø	-6	-8	-7	-1Ø	-12	-8	-1Ø	-9	-7	-8	-3	4
Ø	-3	-12	-15	-5	-7	-6	-7	-4	-2	-1	-1	5	8
1	-Ø	-8	-7	5	Ø	-6	-9	1	12	11	9	14	14
2	5	4	8	15	-6	-18	-3Ø	-5	9	1Ø	8	7	8
3	4	Ø	-1	5	-1	-14	-19	Ø	14	17	14	Ø	1
-Ø	1	-5	-11	-8	-3	-6	-13	Ø	9	2Ø	2Ø	-2	-1

AD 85Ø FROM 1212ØØ CONTOUR INT 2

-25	-16	-23	-25	-10	0	-0	-3	-2	2	11	15	1	-10
5	7	-8	-22	-21	-15	-17	-19	-12	-6	1	8	1	-5
32	15	-9	-31	-30	-19	-17	-18	-14	-14	-13	-6	-6	-7
17	5	-8	-17	-16	-5	-1	-4	-7	-11	-15	-11	-7	-6
4	4	6	-4	-2	10	14	4	-9	-17	-14	-6	-0	-0
1	14	15	-1	-7	3	11	3	-10	-16	-11	-2	-3	-12
13	19	12	-7	-14	-3	4	2	-4	-8	1	3	-5	-14
19	17	4	-8	-9	-0	7	1	-6	0	14	9	-7	-9
12	12	8	0	-6	0	5	-2	-7	8	22	6	-13	-8

IV 850 FROM 121200 CONTOUR INT 5

-2	-0	-0	-1	-3	-3	0	1	0	-1	-0	0	0	1
-2	-1	-2	-8	-12	-7	2	4	1	-0	-0	0	1	2
-3	-3	-9	-17	-19	-11	-0	2	2	0	-0	1	1	2
-10	-10	-14	-23	-17	-8	-0	1	2	0	1	4	4	2
-15	-18	-28	-35	-24	-8	2	4	3	1	3	7	7	4
-19	-26	-33	-29	-14	-2	4	4	4	2	3	4	4	1
-14	-20	-22	-14	-3	1	5	6	5	2	3	1	-0	-0
-6	-7	-9	-4	-0	2	3	2	2	3	6	4	-0	-0
-1	-1	-2	-2	-1	0	1	0	1	5	8	4	-1	0

TAD 790 121290 CONTOUR INT= 2

3	11	16	10	1	0	14	11	1	-9	-7	1	9	19
11	15	13	1	-11	-9	11	15	5	-4	-3	0	5	8
-0	-6	-11	-19	-27	-27	-6	4	3	-1	-4	-7	2	1
-8	-13	-15	-16	-18	-21	-13	-2	3	-0	-15	-31	-20	-31
-8	-10	-9	-9	-8	-9	-8	-3	-2	-3	-15	-17	-16	-27
-6	-5	-0	1	4	1	-3	-6	-14	-15	-7	5	21	16
10	14	21	19	14	-1	-14	-28	-42	-24	9	47	40	44
11	15	18	15	9	-3	-10	-30	-55	-35	11	42	39	24
1	3	4	2	-0	-5	-7	-24	-44	-28	2	36	38	30

D 700 FROM 121200 CONTOUR INT 2

-6	2	10	4	-0	-12	-24	-24	-17	-8	5	18	6	-4
6	19	20	3	-4	-12	-26	-28	-15	-8	-1	7	1	-0
8	22	11	-13	-11	-4	-13	-12	-2	-7	-16	-14	-11	-4
15	26	8	-18	-10	3	-2	-0	10	3	-12	-17	-16	-14
19	33	13	-8	-1	3	-0	3	11	5	-8	-13	-11	-11
22	22	0	-11	-3	-2	-2	7	13	8	-4	-11	-7	-5
14	1	-20	-19	-3	2	8	16	17	11	4	-2	-3	-3
3	-9	-21	-14	-0	8	13	15	15	11	10	4	-3	-3
-0	-4	-7	-4	-2	3	5	6	3	-3	-0	0	-2	1

V 700 FROM 121200 CONTOUR INT 5

-1	-0	-1	-1	-2	-2	-3	-2	-1	-0	0	1	1	1
-2	-3	-5	-5	-6	-3	-0	-0	-2	-2	0	1	2	2
-10	-13	-12	-10	-9	-6	-2	-2	-6	-5	-1	0	2	4
-19	-18	-13	-13	-7	-7	-6	-6	-10	-8	-3	-1	2	5
-19	-13	-11	-14	-11	-11	-11	-9	-10	-8	-3	0	3	4
-17	-13	-10	-9	-5	-8	-8	-4	-4	-4	-3	1	4	3
-10	-8	-6	-2	0	-0	-0	0	-0	-1	-4	-2	0	0
-1	-0	-0	0	2	3	0	0	4	1	-4	-5	-3	-2
1	1	-0	-0	2	5	2	1	4	1	-5	-6	-4	-3

TAD 500 121200 CONTOUR INT= 2

-26	-15	-2	1	-0	0	7	5	-3	-6	-0	5	4	6
-7	5	10	-0	-6	-1	10	14	6	-3	-1	3	1	7
-1	19	12	-9	-11	0	12	23	21	9	0	-2	-5	3
-0	15	0	-25	-16	6	10	13	17	11	1	-7	-12	-7
-1	7	-11	-30	-12	11	9	-1	-3	-8	-19	-20	-9	-5
0	-1	-15	-24	-10	4	2	-3	-5	-18	-34	-25	-2	2
-0	-6	-13	-10	-3	-1	-2	-1	0	-12	-26	-12	6	3
4	0	-0	1	-2	-3	-3	1	12	7	-9	-8	2	7
11	10	9	3	-5	1	2	1	14	20	2	-8	-0	13

IV 500 FROM 121200 CONTOUR INT 5

-9	-6	-2	0	1	1	0	1	2	3	3	2	2	2
-11	-10	-5	-0	3	3	1	0	0	1	3	5	5	4
-7	-7	-1	5	7	5	1	-1	-2	-3	-1	3	6	4
8	5	8	12	9	3	-0	-0	-1	-6	-7	-0	3	1
15	10	6	7	4	2	3	3	-0	-6	-4	1	2	-0
4	-0	-3	-3	-0	5	9	1	-11	-13	-1	7	8	5
-4	-8	-11	-7	0	8	8	-6	-20	-17	-1	9	10	9
-3	-6	-7	-4	-0	1	-2	-9	-9	-2	1	1	2	2
-1	-2	-2	-1	-2	-7	-11	-4	13	21	8	-5	-7	-5

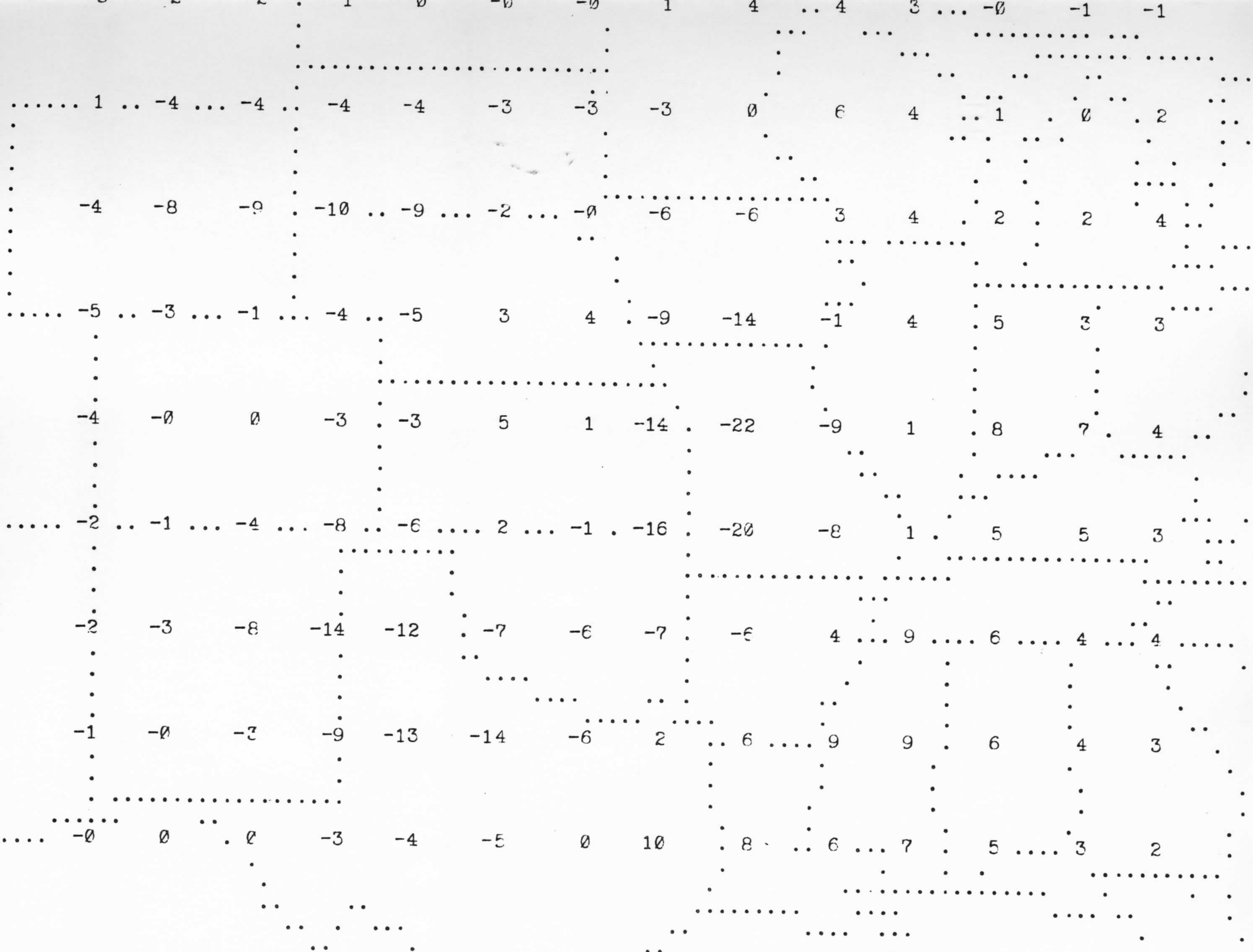
VAD 500 FROM 121230 CONTOUR INT 2

-25	-9	-0	Ø	Ø	-4	-10	-4	-1	-0	2	2	5	9
-42	-10	6	6	4	-0	-9	-9	-5	-1	2	3	5	8
-22	3	17	15	14	12	-0	-8	-11	-4	Ø	Ø	3	7
-12	4	19	23	27	24	8	-8	-14	-4	1	1	2	6
-5	5	11	11	17	21	6	-12	-19	-8	5	8	9	7
-5	Ø	1	Ø	8	14	6	-5	-14	-12	-4	5	1Ø	6
-4	-1	-Ø	Ø	2	5	3	-1	-8	-12	-7	Ø	7	2
Ø	2	3	2	-1	-2	-3	-6	-9	-7	-1	3	5	1
1	3	2	Ø	-5	-7	-6	-8	-8	-2	2	2	4	6

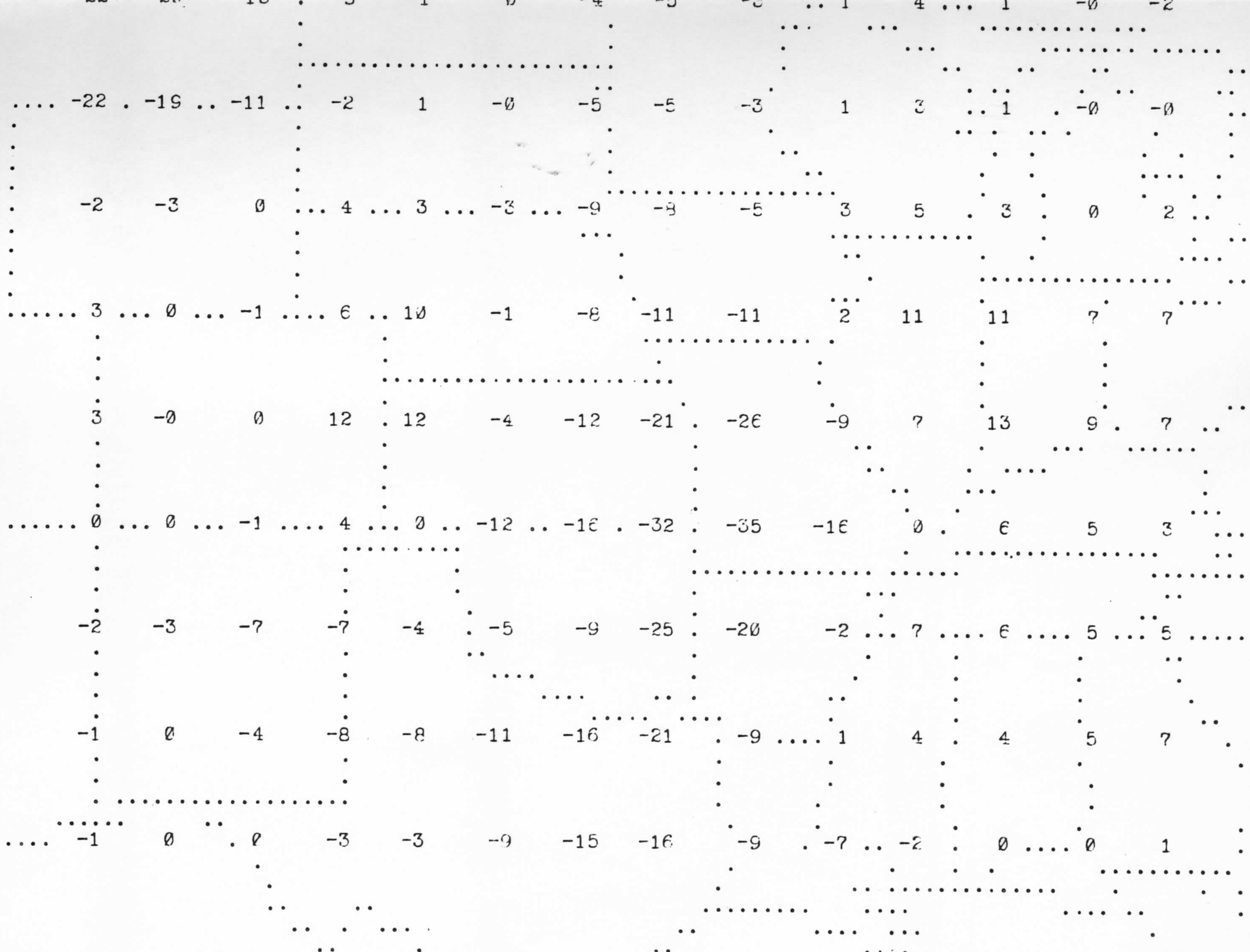
TAD 3ØØ FROM 1212ØØ CONTOUR INT 2

17	-0	-17	-8	2	-2	-15	-9	-2	-13	-1	21	20	14
21	-6	-19	-6	13	5	-29	-46	-36	-27	-5	21	27	28
-14	-18	-23	-22	9	43	20	-21	-38	-40	-18	4	16	26
-22	-6	-18	-42	1	66	76	43	0	-21	-13	7	11	15
-15	-1	-10	-26	-2	24	29	28	9	-5	6	23	17	6
-20	-12	-8	-0	3	-12	-13	-3	-5	1	20	28	11	-8
-24	-19	-0	18	19	-1	-11	-7	-10	-0	11	20	10	-12
-10	-0	11	20	13	-2	-12	-9	-9	-15	-15	2	15	0
-3	9	20	14	4	1	-9	-9	-12	-19	-20	-0	19	12

IV 300 FROM 121200 CONTOUR INT 5



TAD 850 FROM 130000 CONTOUR INT 2



DAD 850 FROM 130000 CONTOUR INT 2

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-5	-2	1	-1	-8
17	26	23	15	8	-2	-14	-13	-14	-15	-4	4	-3	-23
3Ø	19	7	5	9	1Ø	1	-17	-36	-36	-9	6	-1	-28
17	3	-3	-1	2	12	16	-1	-3Ø	-36	-18	-Ø	-2	-15
11	1	Ø	1	-Ø	1	5	-4	-19	-17	-11	-9	-12	-11
5	-6	-7	1	4	3	-5	-24	-29	-16	-5	-6	-11	-11
-4	-16	-2Ø	-9	5	14	8	-9	-22	-17	-11	-5	-6	-8
-5	-12	-21	-15	-Ø	11	13	7	-1	-5	-9	-6	-3	-4
Ø	-Ø	-11	-16	-8	-4	1	6	6	7	1	-4	-3	-1

DIV 85Ø FROM 13ØØØØ CONTOUR INT 5

175

-1	-3	-5	-3	-0	-2	-3	-2	-1	-1	-1	-0	0	2
-2	-4	-6	-4	-3	-6	-7	-3	-1	0	1	0	1	6
-5	-4	-2	0	-0	-6	-4	-0	-4	1	8	5	3	8
-6	-4	-0	2	-3	-8	-4	-5	-19	-11	6	9	4	5
-5	-3	-0	1	-1	-3	2	-3	-24	-21	-3	3	2	5
-2	-1	0	-0	-4	-4	-1	-3	-9	-5	4	5	3	6
-1	-1	-2	-3	-3	-0	3	2	1	5	8	7	3	4
-0	-1	-2	-2	-1	1	3	2	2	4	8	7	2	3

TAD 700 FROM 130000 CONTOUR INT 2

-8	-8	-7	-4	-1	-2	-16	-31	-35	-15	-4	-12	-11	-3
-2	0	3	-0	-0	5	3	-8	-17	-9	-0	-19	-33	-20
0	4	3	-5	-3	9	11	3	-5	7	11	-12	-38	-37
2	2	-0	-7	5	13	0	-17	-10	7	21	16	-11	-21
1	-0	-4	-3	5	2	-24	-37	-21	-1	8	11	-6	-17
-2	-6	-7	-7	-1	-10	-40	-48	-19	2	8	8	-11	-26
-3	-4	-5	-1	7	2	-26	-44	-26	-6	1	20	13	-17
-0	0	0	1	5	9	1	-7	-11	-18	-22	5	18	-13
-0	0	1	3	2	5	16	18	-0	-20	-33	-10	8	-13

DAD 700 FROM 130000 CONTOUR INT 2

4	12	16	11	16	18	1	-8	-0	2	0	-1	-2	-5
10	29	30	13	7	6	-4	-10	-8	-2	1	4	0	-15
9	24	15	-5	-11	-8	-5	-12	-25	-25	-2	14	12	-10
6	15	5	-6	-3	5	14	2	-31	-42	-23	-0	13	13
5	15	10	0	-0	9	10	-6	-25	-23	-13	-10	-5	8
5	12	11	0	-2	0	-9	-27	-26	0	18	5	-6	0
6	8	7	7	5	-1	-15	-21	-15	9	23	10	-4	-0
4	3	0	5	10	5	0	-0	-5	1	13	7	-0	-2
8	4	-1	-2	7	16	19	10	-4	-5	6	10	8	8

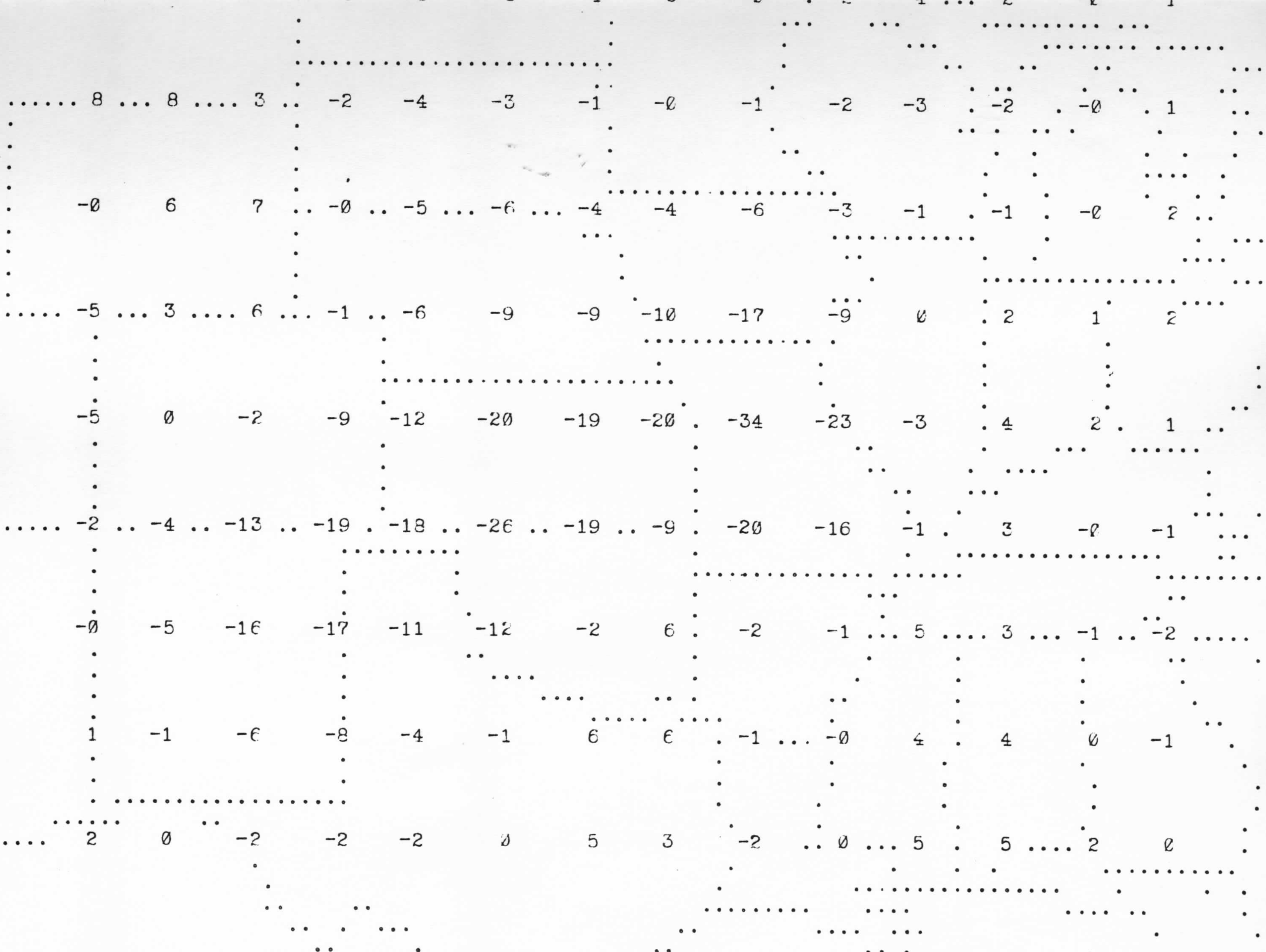
DIV 700 FROM 130000 CONTOUR INT 5

-7	5	15	9	-0	-0	8	13	20	16	-9	-30	-14	5
12	14	11	-2	-12	-8	2	12	24	25	4	-19	-16	-5
5	3	-3	-12	-11	-0	11	16	17	15	11	-0	-7	-12
5	3	-3	-7	0	11	23	21	3	-6	1	5	0	-5
-3	2	6	7	4	-1	-3	-6	-20	-23	-6	4	4	3
-17	-5	10	17	13	-2	-18	-32	-43	-32	-8	5	7	2
-14	-5	9	15	6	-3	-14	-19	-19	-7	3	5	0	-2
-6	-1	6	-0	-14	-13	-2	5	8	13	13	4	-5	-4
-3	-0	4	-6	-20	-9	8	10	8	13	16	8	-6	-5

DIV 500 FROM 130000 CONTOUR INT 5

12	7	4	-0	-2	-1	-0	1	1	1	2	0	-0	-0
8	2	2	-0	-3	-3	-1	-0	2	6	6	-0	-4	-4
1	-2	-1	-1	-5	-4	-3	-3	3	13	12	1	-7	-9
-11	-12	-7	-5	-5	-5	-9	-12	1	18	19	7	-3	-6
-12	-9	-4	-3	-7	-16	-24	-17	7	26	27	15	0	-4
-5	-1	2	-0	-10	-27	-29	-4	21	24	16	7	-0	-3
-0	1	3	3	-3	-18	-19	1	15	6	-2	-3	-2	-2
0	0	2	3	2	-4	-7	2	6	-4	-11	-7	-2	-1
-0	0	1	2	1	-0	-0	3	1	-7	-11	-3	3	5

VAL 500 FROM 130000 CONTOUR INT 2



TAD 500 FROM 130000 CONTOUR INT 2

-48	-12	23	12	-15	-20	23	50	36	16	3	-6	3	17
-12	21	31	-9	-56	-59	-6	46	54	25	-3	-12	-6	-4
-4	8	-4	-40	-62	-58	-15	44	62	29	-1	-9	-13	-22
-4	-3	-17	-25	-31	-35	4	61	70	43	27	15	-7	-25
-5	1	2	7	-6	-32	-1	40	31	20	19	10	-8	-19
-11	-2	7	6	-18	-44	-9	16	-5	-23	-21	-14	-11	-16
-17	-1	8	-1	-31	-39	-3	19	-3	-25	-22	-7	-3	-15
-0	7	14	2	-21	-23	-1	10	-4	-17	-7	6	0	-10
-0	0	3	0	-12	-5	4	7	-3	-8	6	12	0	-8

[illegible]IV 320 FROM 130000 CONTOUR INT 5

8. Radiosonde data

Pressure	Temperature	Dewpoint	Wind	GPM
[mb]	[°C]	[°C]	dddfff [°][m/s]	[gpm]

12 Z 12 MAY 1978

PRESS	TEMP	DEW PT	WIND	GPM	PRESS	TEMP	DEW PT	WIND	GPM
72220	121200								
1019	21.8	17.5	160005	11	389	-21.7	-24.7	271018	7788
863	14.2	6.2	245006	1437	350	-25.7	-55.7	276022	8560
850	14.0	-5.0	250007	1565	322	-29.8	-48.7	280026	9146
808	11.8	-18.2	267008	1990	300	-33.5	-42.5	275025	9659
785	16.0	-14.0	276007	2233	271	-40.1	-47.1	275027	10362
700	9.0	-1.0	270008	3193	250	-44.5		280030	10907
648	6.0	-4.0	298007	3828	215	-52.7		285031	11890
600	.2	-3.4	316008	4452	150	-69.9		270033	14125
535	-6.1	-9.7	305013	5362	137	-70.4		275036	14634
520	-6.5	-21.5	302014	5585	103	-72.5		272021	16347
500	-8.9	-18.9	290014	5890	100	-71.3		275020	16521
434	-15.7	-33.7	266013	6972					
72229	121200								
1003	16.4	15.6	180003	141	279	-40.8	-56.2	245026	10060
1000	16.2	13.1	180004	167	250	-47.1		250022	10800
972	17.8	9.8	215012	410	200	-59.1		260040	12236
949	17.4	14.6	221012	615	166	-67.9		259035	13379
928	18.2	10.2	226013	807	156	-65.6		265038	13719
850	14.6	6.6	250018	1555	150	-63.7		270013	13994
700	2.8	.5	245021	3162	126	-69.7		266013	15048
555	-4.9	-6.9	260022	5015	122	-69.5		265013	15240
500	-10.7	-12.3	255027	5827	115	-62.3		270013	15599
393	-21.9	-23.8	250028	7621	100	-65.7		285014	16455
289	-38.9	-43.5	248023	9823					
72232	121200								
1018	20.6	19.9	130002	6	400	-21.1	-27.1	265022	7566
1000	22.4	20.8	160004	161	367	-24.7	-54.7	264023	8197
850	15.0	11.5	245005	1562	300	-34.3	-47.3	255027	9634
760	10.2	9.3	235008	2504	280	-38.5	-51.5	255028	10112
743	10.8	-19.2	235008	2692	257	-43.4	-82.6	255031	10670
700	9.2	1.2	240013	3187	250	-45.3		255030	10879
500	-10.1	-14.6	270019	5883	167	-65.5		270038	13414
464	-14.1	-19.1	265020	6455	132	-71.9		260030	14851
449	-15.3	-45.3	265020	6704	100	-70.9		290016	16491
72235	121200								
1003	19.0	17.5	170005	101	276	-39.7	-69.7	253042	10120
897	20.2	11.2	212013	1065	250	-45.1		250040	10788
850	17.2	12.7	220016	1528	221	-51.0		250044	11585
700	5.8	3.2	285015	3155	174	-61.1		260033	13109
649	1.0	-.3	277015	3769	135	-64.7		268025	14677
558	-5.5	-7.6	255028	4972	128	-61.3		274024	15005
500	-11.7	-23.7	255035	5823	114	-66.7		285020	15714
494	-12.1	-42.1	256035	5915	100	-66.7		290014	16506
400	-22.1	-52.1	250037	7496					
72240	121200								
1014	23.8	22.1	170004	4	453	-17.9	-19.0	253027	6613
867	16.4	15.1	225012	1361	435	-17.3	-47.3	255027	6917
850	17.2	14.6	225014	1530	395	-21.8	-51.8	255031	7621
820	16.2	9.4	225013	1829	280	-39.3	-69.3	258039	10074
808	16.4	3.4	231013	1962	250	-46.1		250042	10839
752	13.8	-16.2	254016	2569	212	-53.7		260044	11890
700	10.0	-4.0	275012	3168	200	-56.7		260041	12287
612	2.5	-3.4	255020	4268	100	-71.5		295015	16511
500	-11.1	-14.1	255026	5864					

PRESS	TEMP	DEW PT	WIND	GPM	PRESS	TEMP	DEW PT	WIND	GPM
72247	121200								
998	19.4	18.6	160004	122	334	-32.9	-62.9	301020	8780
918	17.4	15.6	210018	841	316	-35.7	-75.0	305022	9146
885	19.8	13.8	226018	1156	300	-38.7		300019	9526
850	17.8	15.7	245015	1504	230	-50.7		265028	11280
812	15.4	11.0	264013	1895	200	-57.5		265036	12197
794	15.8	-1.2	276011	2085	170	-60.3		284033	13216
700	7.2	-22.8	290009	3136	166	-58.1		287033	13365
579	-3.7	-33.7	281014	4663	143	-58.3		305026	14304
558	-3.7	-33.7	285015	4954	109	-69.5		287016	15966
500	-9.7	-39.7	285013	5810	100	-67.9		285014	16482
72250	121200								
1011	25.6	23.5	160006	7	500	-8.9	-15.9	255004	5910
968	22.0	20.6	167014	388	315	-32.9	-38.9	250020	9321
945	26.0	8.0	175017	599	295	-36.2	-51.1	250019	9756
869	22.2	4.2	188013	1332	250	-44.9		260026	10905
850	24.2	-5.8	195010	1524	186	-59.0		270030	12804
827	24.8	-5.2	202010	1763	119	-74.1		271021	15513
700	13.6	-16.4	205004	3195	100	-75.3		280018	16524
552	-3.1	-11.1	254005	5133					
72255	121200								
1008	23.4	22.9	160003	35	612	3.7	-10.8	275015	4268
1000	23.6	22.3	165005	105	514	-10.1	-12.9	272021	5659
938	19.8	18.4	197012	663	500	-11.5	-19.5	270022	5871
931	22.4	10.4	200012	728	485	-13.3	-16.3	269022	6104
916	25.0	12.0	207013	870	478	-13.7	-43.7	269022	6215
850	20.8	3.8	240010	1521	440	-16.1	-46.1	265022	6841
812	16.6	13.7	255008	1914	300	-35.9	-65.9	260031	9606
792	17.6	5.6	295006	2127	250	-45.7		260038	10846
762	17.0	-13.0	290006	2456	205	-55.9		264041	12137
700	12.0	-2.0	270007	3172	193	-56.6		270043	12500
683	10.4	-10.6	266008	3377	100	-72.7		280010	16531
672	9.4	-2.6	264008	3512					
72260	121200								
964	19.4	19.4	190003	402	223	-54.7		280022	11517
943	21.2	20.2	210010	593	200	-57.7		275027	12208
905	20.6	17.9	236018	950	195	-53.9		277030	12369
857	24.8	-5.2	252018	1424	191	-54.1		280034	12500
674	6.2	-23.8	275016	3454	157	-57.4		280033	13719
565	-1.3	-31.3	275011	4878	139	-63.9		295032	14508
500	-7.7	-37.7	275018	5839	118	-64.1		310011	15511
378	-25.1	-55.1	270020	7926	108	-67.7		290015	16048
300	-39.1	-69.1	280024	9555	100	-66.7			16512
72261	121200								
975	20.6	19.9	280002	313	293	-39.4	-71.9	285016	9756
923	24.2	19.3	277003	792	250	-46.9		260022	10824
850	24.4	3.4	273006	1514	223	-52.1		267027	11572
700	11.8	-18.2	263013	3172	212	-53.0		270030	11890
525	-7.0	-18.8	260021	5487	100	-71.9		295009	16504
500	-8.7	-38.7	275011	5873					
72265	121200								
914	15.6	-3.4	240006	874	400	-21.1	-51.1	270021	7541
906	22.4	-1.6	247006	949	319	-35.5	-65.5	280022	9146
887	24.2	-5.8	262008	1133	255	-48.2		285025	10670
850	23.4	-6.6	275010	1504	230	-52.5		288022	11346
700	10.8	-19.2	310009	3152	200	-52.7		315027	12249
659	8.2	-21.8	280007	3652	182	-53.3		305026	12857
567	-2.5	-32.5	290017	4867	136	-67.1		305014	14673
500	-8.7	-38.7	280018	5852	121	-66.3		292015	15380
478	-10.5	-40.5	280017	6199	100	-71.5		270017	16520

PRESS	TEMP	DEW PT	WIND	GPM	PRESS	TEMP	DEW PT	WIND	GPM
72270	121200								
883	22.0	-10.0	290001	1206	300	-38.5	-68.5	310012	9588
850	19.4	-10.6	290006	1534	250	-48.9		315012	10812
821	17.0	-13.0	290012	1829	224	-53.9		322017	11525
764	15.5	-14.5	305012	2439	157	-63.2		280028	13719
700	10.2	-19.8	310008	3174	140	-66.3		290022	14455
636	3.2	-26.8	309010	3960	133	-63.1		290019	14768
545	-3.7	-33.7	290010	5182	100	-71.7		275014	16484
500	-8.9	-38.9	290010	5868					
72327	121200								
994	16.0	16.0	195008	188	250	-47.9		240035	10741
850	10.6	9.7	220020	1507	241	-49.9		240042	10975
700	3.4	.8	230020	3106	189	-61.6		240049	12500
640	-.5	-2.1	224019	3829	166	-66.5		275033	13318
616	.2	-.4	222019	4136	155	-59.7		298022	13740
500	-10.9	-15.9	215019	5774	135	-63.1		259015	14597
424	-18.3	-23.3	215024	7012	111	-60.9		261012	15807
285	-39.9	-44.5	245031	9862	100	-64.1		240010	16451
264	-44.4	-74.4	245037	10365					
72340	121200								
991	17.2	15.5	200004	172	468	-14.3	-44.3	285019	6255
969	20.2	11.2	199012	365	327	-35.0	-65.0	295029	8841
850	13.8	10.5	240017	1486	300	-39.9	-69.9	295022	9451
831	14.2	10.1	245016	1677	250	-50.1		280029	10668
700	4.0	-2.0	275015	3101	238	-51.5		275034	10975
663	1.6	-11.4	275015	3540	188	-59.7		270029	12491
654	.0	-4.7	275016	3650	169	-56.7		271028	13162
626	-1.9	-8.9	277015	3999	108	-65.3		285018	15935
617	-2.5	-20.5	278015	4114	100	-64.1		285015	16405
500	-11.7	-41.7	280018	5751					
72349	121200								
958	16.6	14.2	190004	438	435	-20.1	-50.1	265027	6789
939	17.4	14.3	200011	609	388	-25.7	-39.7	270037	7621
874	16.5	15.2	225022	1219	311	-39.1	-46.1	274038	9185
850	15.0	13.6	240015	1461	300	-40.7		275039	9431
841	14.8	13.3	243014	1551	250	-49.9		280042	10646
832	16.8	2.8	246013	1642	195	-57.1		265032	12243
700	6.0	-15.0	270009	3085	170	-57.1		265036	13109
603	-2.5	-32.5	290013	4286	150	-57.1		270029	13903
541	-9.3	-20.3	287016	5135	139	-55.7		271026	14386
500	-12.7	-27.7	270020	5740	106	-62.1		285013	16085
490	-12.7	-42.7	268021	5894	100	-61.1		280013	16446
72353	121200								
958	18.8	18.3	180005	397	388	-25.0	-40.7	270034	7621
927	17.6	16.8	206015	680	300	-39.5	-53.5	270032	9440
912	19.6	15.2	218018	820	250	-50.3		275039	10658
904	24.6	17.6	225020	897	228	-55.1		275041	11253
892	25.2	-4.8	226020	1014	216	-55.8		275043	11585
850	23.0	-7.0	235017	1434	196	-56.9		285037	12195
700	7.6	-13.4	245013	3075	161	-56.1		281028	13462
632	-.3	-15.3	258015	3904	119	-65.3		287021	15343
500	-11.5	-41.5	265022	5737	100	-64.9		280015	16403

PRESS	TEMP	DEW PT	WIND	GPM	PRESS	TEMP	DEW PT	WIND	GPM
72363	121200								
886	10.0	.0	270003	1099	250	-48.7			10719
881	18.2	-.8	276005	1147	207	-56.9			11936
850	22.6	-7.4	300017	1455	200	-55.3			12155
700	8.6	-13.4	320011	3097	180	-55.1			12827
500	-10.9	-40.9	285020	5774	150	-59.7			13978
400	-21.9	-38.9		7450	114	-68.1			15658
300	-38.3	-52.3		9494	100	-68.9			16443
72365	121200								
839	11.0	-4.0	080002	1619	437	-15.5	-45.5	298027	6841
833	15.4	-1.6	274003	1679	338	-30.7	-60.7	298023	8722
813	16.2	-1.8	310006	1885	300	-37.9	-51.9	300022	9556
700	6.4	-7.6	320022	3134	250	-47.9		305025	10785
636	1.0	-13.0	316019	3912	200	-57.1		305029	12226
610	1.2	-18.8	310021	4247	165	-60.8		305032	13414
500	-9.5	-28.5	300026	5813	100	-70.5		280022	16470
72425	121200								
987	17.8	6.8	190002	255	300	-39.3	-44.2	250024	9454
947	17.6	4.7	205011	609	250	-49.5		270028	10675
850	10.2	.2	235015	1520	200	-61.7		270043	12095
700	3.0	-27.0	215018	3111	186	-60.3		273042	12546
633	-4.7	-9.6	205019	3914	156	-66.5		283027	13626
630	-3.3	-3.3	205019	3952	150	-66.5		285022	13863
500	-12.1	-12.1	235019	5751	133	-59.9		271015	14603
389	-25.0	-27.7	245019	7621	100	-62.1		255013	16374
72433	121200								
987	17.6	14.3	180005	171	383	-27.5	-30.6	245022	7673
916	16.2	12.5	221013	809	300	-39.7	-44.0	220030	9385
901	16.4	8.4	226012	950	250	-48.5		230038	10607
850	13.2	4.2	245009	1443	225	-52.8		230051	11280
782	9.3	2.7	275011	2134	188	-59.9		230043	12432
726	5.5	-.7	275014	2743	155	-57.3		265023	13645
700	4.6	-12.4	275013	3049	138	-60.3		265021	14374
500	-12.5	-42.5	275018	5698	100	-59.3		260007	16386
449	-18.3	-48.3	267020	6510					
72451	121200								
916	15.0	13.9	360006	790	400	-23.7	-53.7	270040	7355
893	15.4	14.1	008006	1006	300	-40.1	-70.1	275044	9384
871	13.8	12.5	015006	1218	284	-42.9	-78.7	280047	9756
850	14.8	9.8	165000	1425	250	-49.3		285043	10603
807	15.2	-6.8	244003	1865	210	-56.7		285043	11726
726	10.2	-17.8	300009	2743	150	-55.9		295040	13863
700	7.2	-13.8	300012	3053	112	-57.9		285026	15712
500	-15.7	-23.7	280017	5704	100	-62.9		290013	16418
72456	121200								
973	13.8	13.2	150001	269	270	-51.1		287032	10016
956	20.6	17.4	154001	420	250	-51.7		280041	10516
945	21.2	16.2	157001	520	238	-50.9		288046	10836
920	19.0	12.0	164002	752	232	-51.5		295048	10975
908	21.4	-8.6	167002	865	210	-54.7		298044	11643
881	21.0	-9.0	175003	1125	200	-52.1		300042	11957
850	17.6	-12.4	185004	1432	193	-48.3		298035	12190
700	4.8	-10.2	240013	3049	161	-54.1		275024	13368
500	-15.5	-19.5	270023	5685	150	-52.5		285032	13824
442	-22.1	-23.8	270023	6605	145	-52.7		285034	14024
328	-39.7	-51.7	284026	8719	120	-55.1		295018	15243
308	-43.3	-81.5	290028	9146	100	-60.1		305009	16409
300	-44.9		290027	9322					

PRESS	TEMP	DEW PT	WIND	GPM	PRESS	TEMP	DEW PT	WIND	GPM
72520	121200								
974	16.2	4.2	180007	365	313	-38.7	-43.7	270029	9139
937	19.2	3.2	212014	696	300	-40.5		270033	9429
850	12.8	.8	225013	1523	285	-42.9		270038	9756
760	5.1	-2.2	225008	2439	186	-63.5		285055	12500
700	1.2	-4.8	215012	3116	162	-67.9		301036	13353
638	-4.5	-6.9	225020	3855	150	-62.5		315019	13822
626	-3.1	-3.1	225020	4005	133	-62.3		304010	14564
500	-13.7	-14.5	235018	5750	125	-57.9		285007	14951
400	-25.1	-27.4	255021	7408	100	-59.5		250007	16352
72528	121200								
998	15.4	7.4	160004	224	367	-30.5	-40.5	269020	8057
925	16.6	1.6	207014	870	327	-37.3	-44.3	277020	8865
889	13.8	.8	220014	1206	300	-42.7		280021	9453
863	9.8	.8	223014	1454	200	-59.1		285050	12090
850	9.8	1.8	225014	1580	162	-66.9		288037	13386
700	.2	.2	260007	3161	150	-61.1		285027	13857
541	-10.1	-10.3	233014	5188	100	-60.5		290005	16379
500	-15.1	-16.5	240017	5790					
72532	121200								
982	13.2	11.1	240003	201	452	-18.7	-48.7	270021	6402
959	17.2	11.2	278010	402	328	-39.7	-69.7	245022	8706
850	12.0	5.0	260012	1423	300	-42.7		235026	9312
752	6.8	.1	270017	2439	200	-56.5		235039	11958
706	2.2	-1.1	270016	2956	191	-58.5		238035	12249
700	1.8	-8.2	270015	3025	170	-53.9		248025	12989
656	-2.5	-12.5	265017	3544	150	-54.9		260020	13791
646	-2.5	-20.5	265017	3666	128	-59.1		263020	14795
553	-8.4	-29.2	265020	4878	123	-56.3		264020	15046
500	-13.9	-43.9	270019	5659	100	-56.7		255012	16359
72553	121200								
958	13.8	11.0	200003	405	250	-57.1		240040	10425
942	19.0	4.0	221008	548	247	-57.7		241038	10501
920	19.2	3.2	234011	751	231	-53.1		255025	10928
850	13.4	1.4	250010	1424	206	-54.7		255028	11663
700	1.6	-5.4	255009	3022	200	-52.3		255030	11853
500	-17.5	-23.5	280011	5632	164	-50.2		270031	13109
334	-39.7	-42.8	247035	8522	150	-49.1		280018	13728
300	-46.7		240035	9245	100	-58.3		285015	16330
72562	121200								
912	12.2	7.2	270005	849	378	-33.3	-35.4	220021	7621
909	13.0	5.0	270005	877	335	-39.9	-42.3	205021	8470
850	11.2	-2.8	270013	1439	300	-46.9		205025	9212
743	.8	-4.2	274013	2541	287	-49.5		213024	9504
700	-.5	-13.5	275014	3019	250	-46.3		260020	10414
625	-7.1	-21.1	271019	3915	150	-49.9		275025	13777
529	-16.5	-17.4	260022	5182	120	-52.1		280021	15228
500	-19.7	-20.6	260014	5613	100	-56.5		285017	16396
72576	121200								
833	1.2	-4.8	240002	1700	300	-42.1		310057	9163
823	2.8	-8.2	266002	1797	287	-43.5		310058	9451
700	-5.7	-21.7	320011	3085	217	-50.9		295038	11307
626	-11.5	-41.5	327016	3951	180	-51.7		295047	12500
500	-26.9	-36.9	330014	5620	135	-51.1		292028	14386
376	-39.3	-52.3	302034	7622	100	-61.1		275023	16291
326	-39.9	-69.9	306045	8598					

72637 121200

981	15.6	11.8	170005	233	382	-28.5	-32.5	218014	7661
850	10.4	9.4	215014	1442	362	-30.5	-60.5	216014	8045
726	4.0	1.9	190014	2743	356	-30.5	-60.5	217014	8164
700	1.4	.2	190015	3039	312	-38.7	-48.7	225015	9085
582	-7.5	-8.3	193014	4502	300	-41.1		230016	9353
570	-9.7	-10.8	196014	4664	184	-63.2		255046	12500
556	-9.1	-14.1	200012	4856	176	-65.1		256040	12779
500	-13.7	-20.7	215013	5671	150	-59.3		260016	13767
453	-18.5	-30.5	228016	6415	131	-57.1		255015	14620
414	-23.9	-53.9	223015	7079	100	-57.7		245010	16326
400	-25.7	-30.5	220014	7329					

72645 121200

980	13.8	12.7	160004	213	300	-43.5		190014	9252
850	9.0	5.1	045004	1404	241	-54.9		190023	10670
777	2.9	.7	010010	2134	228	-58.7		202023	11039
700	-.7	-1.3	010005	2980	207	-59.9		222023	11644
500	-14.9	-17.0	200007	5596	189	-58.1		245024	12195
379	-29.5	-32.8	195011	7621	150	-52.5		245014	13690
316	-39.9	-44.2	191011	8900	100	-57.5		245013	16278

72654 121200

956	9.4	8.3	040005	392	387	-35.1	-37.6	232011	7395
950	11.2	9.0	229005	444	367	-38.1	-40.9	237014	7763
896	11.2	7.4	262006	933	300	-50.3		230034	9113
850	7.8	4.3	270005	1371	271	-52.2		225039	9756
718	2.2	-10.1	245014	2743	250	-53.9		235026	10293
700	.4	-6.6	240014	2956	234	-49.3		237025	10722
579	-12.3	-12.3	256011	4442	140	-52.5		268025	14062
546	-14.7	-25.7	258009	4889	134	-51.0		270027	14329
500	-19.3	-29.3	230009	5550	123	-47.7		276023	14908
428	-28.5	-58.5	230008	6684	100	-51.1		280017	16264

72655 121200

969	8.4	5.3	050002	317	447	-23.2	-34.3	225016	6402
912	10.4	3.4	078008	820	400	-29.9	-41.9	230020	7208
850	7.0	3.0	360001	1403	373	-34.1	-37.4	236021	7701
834	6.6	3.7	322002	1559	342	-39.7	-53.7	238021	8301
824	7.4	-13.6	298003	1658	300	-47.7		230018	9181
777	5.6	-11.4	265007	2134	250	-57.5		225021	10358
755	3.4	-3.6	262007	2373	240	-58.3		225025	10615
731	2.2	-27.8	248007	2634	226	-56.3		230026	10975
713	.8	-29.2	233006	2835	190	-51.1		230021	12114
700	-.7	-10.7	220006	2982	181	-53.3		237021	12428
533	-14.9	-14.9	237009	5098	150	-50.7		250018	13645
500	-19.1	-25.1	230012	5578	100	-53.5		260013	16268

72662 121200

902	8.2	2.2	320008	965	436	-32.1	-36.4	295015	6540
888	8.8	1.8	320013	1094	372	-41.7	-55.8	280011	7621
850	6.0	-2.0	325020	1454	319	-51.3		282011	8657
752	-1.5	-10.8	325022	2439	250	-45.5		275020	10261
700	-6.1	-16.1	325015	3008	200	-46.7		280023	11744
642	-11.1	-14.1	318014	3679	150	-50.5		280022	13635
514	-22.1	-33.1	302010	5354	127	-50.1		277024	14721
500	-23.7	-27.9	305011	5556	100	-54.9		280028	16265
464	-28.1	-39.1	298015	6097					

72734 121200

981	11.6	11.6	090003	220	323	-39.7	-44.7	220019	8775
949	13.2	12.1	146005	499	300	-43.9		225022	9275
850	9.2	6.9	215004	1421	206	-62.7		246039	11686
700	-.5	-1.7	195010	3008	200	-57.9		250041	11870
500	-15.5	-18.2	220009	5630	150	-53.5		250019	13703
365	-32.6	-37.0	210015	7926	100	-54.9		240009	16302

PRESS	TEMP	DEW PT	WIND	GPM
72747	121200			
967	6.0	2.1	070002	360
913	7.2	2.8	081004	832
850	2.4	.9	025003	1415
700	-4.5	-34.5	340004	2962
500	-19.1	-22.8	210010	5542
442	-25.3	-41.3	211011	6448
370	-35.3	-41.3	226019	7711
346	-39.9	-47.9	235019	8174
300	-48.3		235022	9130
250	-58.9		215026	10301
235	-60.7		220026	10688
189	-52.1		241026	12074
150	-49.3		245020	13580
146	-49.4		255022	13719
100	-52.1		250015	16220
72764	121200			
951	7.2	5.0	080003	505
850	2.0	.5	050010	1423
700	-5.9	-6.8	015005	2968
640	-8.8	-10.7	320004	3658
500	-23.1	-29.1	270004	5529
386	-38.5	-42.0	267003	7366
332	-47.3		230007	8382
278	-54.1		200014	9541
200	-48.7		255015	11680
100	-51.9		280021	16198
72768	121200			
931	6.0	4.8	320006	700
922	7.0	4.8	323008	780
850	3.2	1.7	330015	1444
700	-6.1	-7.5	330008	2995
617	-13.1	-13.9	333012	3970
577	-17.1	-47.1	335011	4476
500	-24.7	-31.7	355011	5534
400	-38.3	-45.3	345014	7111
354	-46.3		343015	7937
322	-50.1		330015	8561
268	-53.3		302012	9752
233	-47.5		290013	10664
150	-49.5		290021	13556
100	-52.1		275021	16195

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PRESS	TEMP	DEW PT	WIND	GPM
72220	130000			
1017	24.0	19.2	170003	11
972	21.0	10.0	164005	405
961	21.4	12.4	169005	504
922	18.0	16.1	179006	862
908	18.4	9.4	180005	993
850	14.0	10.0	225005	1555
835	13.4	8.4	245005	1705
824	14.4	-7.6	260006	1817
755	13.2	-1.8	286010	2553
725	10.2	2.2	288011	2893
715	9.4	-6.6	285011	3008
700	8.0	-7.0	280010	3183
617	2.0	-28.0	279016	4212
608	1.4	-7.6	280017	4330
500	-9.7	-39.7	275021	5869
276	-39.5	-69.5	268033	10184
250	-45.5		265038	10852
200	-56.9		255039	12298
158	-63.7		275034	13766
108	-69.9		310020	16067
100	-69.1		310019	16526
72229	130000			
997	23.2	18.6	180003	141
979	23.4	17.4	185008	300
850	13.8	12.2	225015	1515
700	4.8	3.1	255017	3130
633	.2	-3.2	270014	3943
537	-5.7	-35.7	279020	5244
500	-10.1	-40.1	275023	5798
400	-21.9	-51.9	275026	7477
368	-25.7	-55.7	272024	8086
303	-38.2	-68.2	265026	9451
250	-49.3		280024	10747
222	-55.7		285022	11514
185	-60.7		286026	12663
156	-59.1		290029	13719
150	-58.7		290027	13974
138	-59.7		294025	14496
104	-70.1		300019	16219
100	-63.9		300018	16456
72232	130000			
1015	26.8	22.9	180007	6
1000	24.2	21.2	185008	137
950	20.8	18.9	205008	585
850	15.8	10.8	235010	1542
835	14.4	11.1	243010	1693
803	16.0	-14.0	256010	2024
710	10.4	-5.6	260013	3048
700	10.6	-5.4	265013	3175
500	-9.3	-39.3	290015	5870
380	-25.0	-55.0	300011	7926
300	-38.5	-68.5	275022	9593
250	-47.5		270032	10821
214	-55.1		270034	11831
200	-56.3		270035	12262
150	-61.7		295024	14065
100	-71.9		335012	16511

PRESS	TEMP	DEW PT	WIND	GPM	PRESS	TEMP	DEW PT	WIND	GPM
72235	130000								
999	28.2	25.8	180006	101	343	-29.9	-59.9	275026	8613
850	16.4	13.8	230021	1507	300	-38.1	-68.1	280026	9551
734	11.5	-8.7	260014	2743	242	-49.2		290023	10975
700	7.6	-13.4	270013	3140	210	-56.5		301029	11907
625	-.1	-19.1	278017	4059	165	-59.2		295038	13414
586	-.4	-30.4	280021	4573	132	-61.9		280029	14816
500	-8.9	-38.9	270024	5822	100	-71.3		310016	16493
72240	130000								
1012	27.2	22.2	200006	4	601	1.0	-29.0	277024	4410
967	22.0	19.0	206010	404	500	-8.1	-38.1	275017	5864
920	19.2	16.1	213012	836	300	-38.1	-68.1	280022	9597
901	21.2	13.2	216013	1016	250	-46.5		300021	10829
850	17.8	10.8	230014	1519	184	-56.7		305022	12804
798	15.6	5.6	247014	2057	150	-63.7		295023	14089
769	16.6	-13.4	257013	2371	139	-67.5		289023	14552
700	10.6	-19.4	275014	3161	128	-66.3		283022	15050
635	5.3	-24.7	275025	3963	100	-73.3		310018	16519
72247	130000								
996	30.0	24.0	240004	122	300	-35.8	-38.2	284025	9572
850	18.8	14.9	261011	1516	250	-45.1	-65.4	305023	10813
700	8.5	-13.5	270019	3153	192	-56.0		310031	12500
613	-.3	-30.3	274019	4231	165	-59.5		299026	13482
611	.6	-29.4	275020	4257	142	-66.9		290030	14405
500	-10.4	-40.4	279029	5831	129	-63.1		287030	14990
394	-22.1	-35.6	280019	7621	100	-71.3			16524
345	-28.3	-30.1	278022	8585					
72250	130000								
1009	32.2	22.2	170010	7	443	-14.9	-44.9	274011	6845
1000	28.8	18.8	175011	87	419	-17.5	-22.3	265014	7264
949	25.0	18.0	187013	551	400	-19.1	-49.1	270016	7610
924	28.2	21.2	177013	788	367	-22.7	-49.9	275022	8231
922	28.2	9.2	176013	807	300	-34.5	-48.5	275020	9688
850	27.2	-2.8	210008	1526	287	-38.9	-51.9	280021	9995
700	14.4	-7.6	200007	3199	250	-44.9		270026	10929
664	11.0	-19.0	240002	3641	200	-54.5		270034	12388
615	4.8	-7.9	295003	4268	169	-62.7		272020	13446
531	-5.7	-14.7	325007	5448	105	-73.9		320011	16294
518	-5.9	-35.9	313007	5642	100	-72.7		325011	16580
500	-7.9	-37.9	295008	5918					
72255	130000								
1007	30.2	23.2	180005	35	514	-7.7	-37.7	285013	5683
1000	28.0	23.2	180006	97	500	-7.3	-37.3	285010	5898
945	23.2	21.0	205006	597	445	-13.1	-43.1	299009	6795
924	22.8	20.2	229006	794	300	-37.1	-67.1	295015	9653
903	25.8	15.8	243005	996	235	-47.4		280019	11280
850	25.2	6.2	240004	1528	184	-53.7		299016	12890
700	11.6	-5.4	270008	3189	144	-65.5		290016	14421
530	-6.9	-7.7	285014	5444	102	-74.5		308013	16470
518	-7.9	-14.9	285013	5623	100	-73.3		310012	16586
72260	130000								
965	28.2	13.2	360009	402	395	-20.9	-50.9	295023	7621
866	19.6	9.6	359011	1348	213	-49.8	-87.1	295028	11890
850	22.1	.3	356010	1509	137	-66.1		274020	14684
700	9.6	-10.4	260010	3154	121	-65.9		290018	15437
500	-7.8	-37.8	291020	5851	100	-71.9			16577

PRESS	TEMP	DEW PT	WIND	GPM	PRESS	TEMP	DEW PT	WIND	GPM
72261	130000								
973	36.0	15.0	180004	313	613	4.8	-25.2	275005	4268
962	33.6	14.6	182004	416	500	-7.1	-37.1	269007	5895
850	25.6	.4	211004	1518	400	-19.7	-49.7	278009	7591
771	19.2	-10.8	234004	2364	200	-52.8		280012	12365
700	11.5	-11.9	257004	3181	100	-74.5			16587
676	8.6	-12.4	265004	3471					
72265	130000								
913	34.4	.4	050007	874	250	-43.5		315018	10867
850	27.0	-3.0	050005	1511	168	-59.7		270016	13414
700	11.4	-9.6	015005	3175	136	-68.5		280016	14735
567	-2.4	-22.0	275012	4878	126	-65.9		275017	15196
500	-7.9	-37.9	295014	5871	100	-73.7		290022	16571
277	-39.1	-69.1	310019	10171					
72270	130000								
882	33.6		220003	1206	400	-20.5	-50.5	305013	7595
870	30.0	.0	221003	1329	300	-26.3	-56.3	330012	9698
850	28.0	-2.0	225002	1535	283	-39.5	-69.5	326012	10108
700	11.6	-18.4	350004	3201	250	-45.3		315010	10946
500	-8.1	-38.1	300008	5905	100	-73.5		300014	16614
72327	130000								
989	21.8	18.6	160003	188	388	-25.5	-55.5	255028	7621
978	20.2	16.9	165008	285	326	-34.8	-64.8	260032	8841
850	13.8	11.5	220017	1485	309	-37.9	-67.9	264030	9233
732	6.0	3.5	245020	2731	300	-39.1		260027	9436
726	6.2	-.8	245020	2799	210	-59.9		288032	11768
700	4.0	-7.0	245021	3097	166	-60.9		276031	13233
610	-4.3	-13.3	249021	4198	157	-55.7		280029	13584
595	-3.5	-33.5	250022	4394	100	-62.5		305005	16407
500	-12.9	-42.9	255021	5743					
72340	130000								
987	24.6	20.8	220004	172	281	-40.1	-45.1	281048	9931
850	16.2	14.1	255019	1466	250	-45.1		280041	10720
806	14.6	13.0	265021	1918	229	-49.9		275045	11280
744	7.8	6.0	265021	2588	184	-61.5		282043	12688
700	4.6	-3.4	260023	3089	172	-56.1		285046	13109
644	.8	-10.2	245025	3764	168	-54.1		285040	13262
604	-3.8	-12.0	240029	4268	150	-56.3		275018	13985
537	-8.6	-10.1	250038	5182	128	-62.7		275018	14977
500	-11.7	-13.5	250036	5745	124	-60.5		275017	15174
383	-22.9	-26.1	272032	7740	107	-67.5		295014	16077
320	-33.9	-38.9	288035	9028	104	-65.5		295014	16249
302	-33.7	-38.4	280043	9434	100	-67.3		295014	16486
288	-38.1	-43.0	280050	9756					
72349	130000								
958	18.8	10.8	305010	438	514	-17.5	-47.5	260038	5413
953	18.6	1.6	304010	483	500	-15.7	-45.7	260041	5621
850	10.0	6.7	295020	1449	419	-22.1	-52.1	260054	6937
814	6.2	5.5	295021	1807	411	-19.9	-49.9	260055	7079
700	-2.9	-3.2	275027	3027	381	-23.2	-53.2	260059	7621
685	-3.5	-8.5	273028	3198	300	-37.9	-67.9	270059	9332
684	-3.9	-17.9	273028	3210	232	-48.3		280056	11061
659	-3.3	-33.3	268032	3504	204	-45.7		280038	11913
621	-6.5	-36.5	265036	3963	200	-46.1		280039	12045
545	-16.1	-46.1	256035	4973	100	-64.9		285020	16441

PRESS	TEMP	DEW PT	WIND	GPM	PRESS	TEMP	DEW PT	WIND	GPM
72353	130000								
969	25.0	2.0	350015	397	472	-12.3	-29.3	295043	6197
953	21.2	6.2	348015	542	389	-24.8	-39.1	285052	7621
850	11.0	.0	328018	1513	300	-37.7	-49.7	290055	9473
803	7.6	-5.4	319019	1984	250	-46.1		319076	10707
770	7.4	-9.6	306027	2329	200	-52.9		354101	12165
753	9.2	-10.8	299032	2513	169	-52.7		021121	13252
700	4.0	-15.0	295028	3112	150	-59.1	-63.1	040135	14010
607	-5.7	-20.7	290035	4249	126	-65.1		277026	15087
554	-6.9	-24.9	295040	4963	111	-66.3		285030	15853
512	-11.3	-28.3	291045	5573	100	-66.9		290017	16487
500	-10.7	-27.7	295045	5755					
72363	130000								
894	23.0	-4.0	020008	1099	300	-35.9	-65.9	300040	9546
850	17.6	-12.4	010008	1533	278	-39.7	-69.7	302039	10071
700	4.2	-7.8	285017	3149	250	-44.9		305037	10788
682	4.8	-8.2	287019	3361	232	-48.2		300045	11280
544	-6.5	-36.5	315028	5162	200	-54.1		305028	12246
525	-5.9	-35.9	311029	5440	174	-57.2		305035	13109
500	-8.7	-38.7	305032	5820	141	-61.3			14446
445	-16.0	-46.0	290033	6707	107	-70.1			16121
359	-29.3	-59.3	294035	8282	100	-67.7			16526
72365	130000								
841	25.6	-6.4	340010	1619	394	-22.0	-51.3	300022	7621
832	22.4	-7.6	340010	1713	288	-39.5	-53.5	306024	9857
700	8.6	-11.4	315008	3174	250	-46.7		300026	10810
661	3.8	-15.2	320012	3643	192	-57.0		300031	12500
566	-3.0	-22.7	315012	4878	112	-70.5		287020	15819
500	-11.9	-29.9	310014	5852	100	-68.3		290014	16495
72425	130000								
983	18.8	12.8	180004	255	507	-11.5	-14.4	271019	5639
881	11.2	10.5	204011	1184	500	-12.7	-15.2	270021	5745
850	12.8	10.0	215009	1485	476	-14.3	-44.3	269021	6119
841	13.8	4.8	217008	1575	388	-24.9	-54.9	270023	7621
757	6.2	4.0	253008	2451	307	-39.5	-69.5	267025	9285
700	4.2	1.2	255010	3091	300	-40.7		270024	9442
641	.4	-29.6	272008	3802	286	-43.2		265029	9756
632	-.9	-11.9	273008	3915	200	-60.5		235026	12076
626	-.9	-30.9	274008	3991	194	-60.3		238026	12266
614	-2.3	-32.3	277008	4145	189	-55.7		241026	12431
599	-3.9	-4.5	280009	4341	178	-55.2		250027	12804
588	-4.9	-8.5	279009	4487	161	-54.1		250024	13456
582	-4.9	-34.9	279009	4568	150	-57.1		250021	13907
523	-9.5	-39.5	272017	5400	100	-60.5		310007	16451
72433	130000								
981	20.6	20.6	170009	171	271	-43.7	-61.5	255040	10060
850	13.7	13.5	214022	1399	206	-58.1		264030	11844
778	11.0	5.9	220024	2134	185	-56.3		265026	12523
700	4.5	-4.2	219029	3014	181	-51.1		265026	12663
598	-4.2	-8.5	220031	4268	150	-54.9		268027	13874
540	-9.9	-11.3	227029	5071	139	-54.7		270028	14329
500	-11.7	-13.4	234025	5663	124	-54.3		285023	15092
384	-25.6	-29.6	265026	7621	100	-61.5			16447
300	-38.4	-44.4	264032	9370					

PRESS	TEMP	DEW PT	WIND	GPM	PRESS	TEMP	DEW PT	WIND	GPM
72451	130000								
925	21.0	.0	330011	790	469	-19.3	-49.3	311050	6135
918	18.4	-3.6	330012	855	400	-22.5	-52.5	305053	7310
850	12.6	-7.4	325017	1506	383	-24.8	-54.8	300054	7621
758	-.6	-13.5	330024	2439	309	-36.1	-66.1	300060	9146
700	-9.7	-17.7	320022	3067	246	-46.2		305052	10670
652	-7.5	-13.5	311024	3618	225	-47.2		305057	11280
633	-8.3	-23.3	310041	3848	200	-48.5		295043	12063
597	-8.1	-38.1	308044	4302	150	-57.7		275030	13915
554	-11.5	-41.5	305050	4878	133	-62.1		277026	14666
500	-16.3	-46.3	310050	5656	100	-65.1		260014	16415
72456	130000								
977	15.6	8.6	320009	269	423	-31.3	-40.3	315024	6773
965	15.8	6.8	321010	374	400	-34.5	-64.5	315022	7166
850	6.2	2.4	330027	1433	355	-37.7	-67.7	301023	7994
750	-1.3	-2.9	335031	2439	323	-35.7	-65.7	299030	8648
700	-5.5	-6.0	330030	2991	300	-36.9	-66.9	305038	9160
679	-6.9	-9.1	331030	3230	240	-40.1	-73.3	300035	10670
670	-5.9	-16.9	331030	3334	200	-44.3		295038	11926
614	-10.5	-20.5	335029	4012	150	-49.7		300033	13830
587	-12.1	-42.1	329027	4357	143	-51.9		303032	14141
544	-15.5	-45.5	320028	4935	130	-51.1		301027	14760
500	-21.5	-28.5	320028	5564	100	-63.7		285023	16415
72520	130000								
972	15.4	12.0	240004	365	482	-15.5	-18.5	265014	5979
850	9.8	5.1	205014	1492	474	-16.7	-33.7	265014	6105
759	3.2	2.3	200021	2422	355	-30.9	-60.9	255024	8213
700	-.5	-1.3	220018	3074	300	-39.9	-48.9	225020	9384
666	-2.5	-3.2	241014	3471	250	-49.3		210030	10603
661	-1.3	-2.1	247013	3531	214	-56.6		210032	11585
549	-11.3	-17.3	290010	4986	163	-60.5		236022	13311
540	-12.5	-28.5	290010	5113	150	-58.7		255025	13831
523	-11.7	-14.4	276009	5358	139	-55.3		265019	14313
500	-13.7	-16.0	260012	5701	100	-59.7		295008	16391
72528	130000								
988	15.6	12.9	100003	224	250	-50.3		210031	10592
850	7.4	6.9	175008	1484	205	-60.5		223028	11856
700	-.7	-1.3	195023	3061	157	-60.7		239023	13517
500	-14.5	-15.6	230011	5679	150	-59.1		250026	13802
369	-27.9	-30.4	214022	7921	133	-56.3		275009	14561
300	-39.1	-42.4	205025	9373	100	-59.5		235007	16358
72532	130000								
976	21.0	16.7	170003	201	381	-28.6	-55.5	230022	7621
956	21.2	17.4	176005	381	300	-41.7		210023	9291
850	13.3	8.9	170009	1385	221	-57.2		220036	11280
700	-.4	-2.1	165010	2982	207	-60.7		232032	11701
584	-5.1	-5.6	208010	4420	203	-52.7		235031	11825
550	-9.2	-9.5	220014	4878	191	-50.5		250023	12195
509	-10.9	-11.6	230012	5486	125	-53.1		270026	14939
500	-13.5	-14.2	228013	5623	100	-58.2			16394
72553	130000								
959	14.2	6.2	300012	405	400	-33.9	-63.9	244008	7151
936	12.7	5.5	310021	609	345	-39.7	-69.7	170010	8174
850	6.5	2.7	315020	1410	326	-39.7		170008	8561
767	-.3	-.7	315018	2243	312	-42.5		176008	8859
700	-2.8	-11.8	315018	2972	285	-41.1		219008	9472
603	-11.7	-15.7	310017	4134	144	-48.0		290027	14024
546	-16.4	-46.4	310017	4878	121	-50.1		270018	15184
500	-19.9	-49.9	301016	5544	100	-56.9			16409

PRESS	TEMP	DEW PT	WIND	GPM	PRESS	TEMP	DEW PT	WIND	GPM
72562	130000								
918	16.0	1.0	330013	849	400	-36.1	-66.1	323027	7221
850	10.4	-2.1	328020	1496	367	-37.3	-67.3	320034	7817
700	-4.0	-9.9	320020	3069	316	-35.3	-65.3	317048	8855
632	-10.9	-15.9	321021	3865	281	-39.5	-69.5	315053	9666
553	-16.3	-32.3	324022	4881	211	-48.1		308037	11590
500	-22.5	-42.9	322023	5629	156	-48.1		298032	13580
468	-26.4	-49.6	320025	6097	100	-59.9			16430
72576	130000								
834	12.6	-6.4	340003	1700	300	-41.2	-53.9	300050	9360
700	-2.0	-14.0	330003	3129	250	-49.2	-84.6	297062	10576
558	-13.9	-22.1	310027	4878	224	-54.1		295061	11288
540	-13.7	-26.7	306031	5137	182	-57.3		295058	12610
500	-17.1	-31.4	313036	5718	137	-55.7		298030	14411
457	-21.3	-37.3	318039	6387	100	-65.0			16370
360	-33.1	-44.1	305048	8101					
72637	130000								
977	21.6	14.6	240007	233	263	-50.5		278014	10176
850	11.4	8.3	238011	1420	250	-50.0		274016	10507
700	.9	-3.0	245018	3014	217	-56.1		246018	11419
645	-2.5	-32.5	250016	3658	200	-50.3		229016	11945
552	-7.8	-37.8	255015	4878	175	-54.1		229018	12809
500	-13.1	-43.1	263013	5651	150	-54.5		245023	13797
328	-38.9	-68.9	267011	8699	100	-55.9			16384
72645	130000								
978	15.6	9.6	060006	213	500	-14.9	-25.8	234018	5593
972	13.0	8.7	058006	265	488	-16.3	-20.5	231018	5776
935	10.4	8.1	040007	590	423	-24.1	-54.1	215018	6835
881	12.0	5.0	025007	1086	362	-33.5	-37.4	213015	7948
850	10.0	4.3	110005	1385	241	-53.3	-90.2	245033	10670
747	2.5	-2.8	260003	2439	212	-59.3		228022	11493
714	.4	-29.6	250003	2809	183	-52.1		228020	12429
700	-.2	-30.2	251003	2967	127	-50.9		246015	14800
593	-5.6	-35.6	215004	4268	100	-53.8			16345
537	-10.9	-40.9	224010	5049					
72654	130000								
967	9.4	5.0	330007	392	417	-32.3	-38.3	339006	6863
957	10.6	6.2	343010	478	400	-34.8	-49.8	007006	7155
905	5.4	3.6	007018	939	371	-39.3	-46.3	044002	7676
850	2.1	1.0	175020	1449	300	-47.5		154015	9102
700	-5.9	-7.1	355018	2993	213	-45.7		296016	11374
593	-12.6	-14.2	340014	4268	150	-48.7		285022	13694
500	-21.9	-25.2	345008	5555	100	-52.4			16336
72655	130000								
972	9.8	8.1	360004	317	344	-39.5	-44.2	183017	8217
960	10.2	7.0	007007	420	260	-54.3	-93.2	190030	10060
850	2.0	.7	035013	1418	239	-58.7		205025	10600
700	-3.7	-4.2	020011	2969	223	-52.1			11042
500	-19.1	-22.2	105001	5547					
72662	130000								
909	12.8	1.8	320015	965	319	-42.7		315048	8754
850	7.1	-.6	327018	1523	312	-41.3		315049	8904
762	-.7	-8.7	325023	2407	250	-45.5		315061	10394
700	-5.1	-12.1	325022	3079	200	-50.1		311043	11866
500	-23.9	-53.9	317020	5626	119	-52.8		275021	15243
373	-39.9	-53.9	315024	7695	100	-56.3			16356
345	-42.7		315027	8225					

PRESS	TEMP	DEW PT	WIND	GPM	PRESS	TEMP	DEW PT	WIND	GPM
72734	130000								
975	10.0	9.4	100003	220	319	-39.1	-43.4	285012	8808
850	8.4	8.1	341004	1359	234	-55.5		257012	10857
700	.2	-.6	226002	2942	181	-52.7		227018	12504
500	-14.2	-15.6	221003	5566	150	-55.1		230022	13710
378	-29.8	-33.0	260005	7621	100	-53.5			16309
72747	130000								
969	13.2	.2	360007	360	357	-37.9	-41.2	228022	7964
850	3.5	-1.1	030011	1442	260	-54.9		225038	10060
772	-2.9	-9.9	039009	2213	250	-57.1		225036	10317
756	-1.9	-31.9	037010	2379	230	-58.7		226032	10842
700	-5.8	-22.0	033012	2986	200	-50.9		233023	11736
584	-14.1	-15.2	196007	4381	100	-51.1			16246
500	-19.1	-24.9	235008	5551					
72764	130000								
958	11.0	3.0	260002	505	386	-38.3	-43.3	326005	7425
850	3.0	2.8	287002	1489	316	-50.5		267005	8764
700	-5.5	-5.9	287002	3038	298	-52.7		250003	9144
550	-18.1	-19.9	325007	4878	257	-46.9		290012	10112
500	-23.7	-26.3	336007	5591	100	-51.9			16299
72768	130000								
937	15.0	1.0	340003	700	400	-39.0	-46.0	271009	7164
933	13.4	-3.6	335003	736	337	-48.1		272011	8316
850	6.7	-5.1	278008	1510	214	-49.7		300038	11280
700	-7.0	-11.6	283012	3063	107	-52.9		280018	15799
500	-25.6	-35.0	267009	5592	100	-52.3			16236

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ACCOMPANIMENT GUIDE TO SQUALL LINE DEVELOPMENT VIDEOCASSETTE

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September 1981

VIDEOTAPE CONTENTS

A listing of the videocassette contents is provided on this page. The remainder of the guide details important features pertaining to the cyclone and squall line that are contained in the videocassette images. The time(s) of the satellite image(s) and analyses as well as the parameters depicted, contour intervals and units are given directly beneath the videocassette image(s).

Satellite imagery

Infrared
Enhanced infrared
Visible
High resolution visible

Miscellaneous analyses superimposed over satellite images

Reported severe weather location
Manually digitized radar

Surface analyses superimposed over satellite images

Mean sea level pressure
Divergence
Temperature
Dewpoint
Mixing ratio advection
Equivalent potential temperature
Equivalent potential temperature divergence

(The contents of the remainder of the list are shown first for 1200 GMT 12 May and then for 0000 GMT 13 May.)

Upper air analyses superimposed over satellite images

850 mb height and temperature
850 mb temperature advection
850 mb streamline, isotach and dewpoint
850 mb dewpoint advection
700 mb height and temperature
700 mb temperature advection
700 mb streamline, isotach and dewpoint
700 mb dewpoint advection
500 mb height and temperature
500 mb temperature advection

Upper air analyses superimposed over satellite images, cont.

500 mb height and isotach
500 mb streamline and absolute vorticity
300 mb height and temperature
300 mb height and isotach
300 mb isotach and divergence
850 mb and 500 mb streamline
Total totals index

Soundings (4)

Cross Section

Isentropic surfaces with satellite images

300 or 305 K pressure, streamline and mixing ratio
320 K pressure, streamline and isotach

Satellite Images

1) Central United States satellite images 12-13 May, 1978 . . . GOES-East (4 km resolution) . . . infrared and enhanced infrared sequences are for the period from 1300 GMT to 0400 GMT (interval: 1 hour). The visible sequence extends from 1300 GMT to 0000 GMT (interval: 1 hour).

a) The imagery for the morning of May 12 shows two distinct regions of cold infrared temperatures (bright areas). A broad area of light showers is located east of the Mississippi River Valley within a weak storm system. Further west, scattered rainshowers extend from the Dakotas to Kansas. A large thunderstorm over central Kansas is the first evident feature associated with the extensive line of convection that develops within this rapidly intensifying cyclone. The squall line develops rapidly southwestward during the afternoon as the cyclone cloud structure attains the classic comma shape. Behind the squall line, large scale clearing and the formation of a dry tongue to the southwest of the cyclone center are evident in the images. Cooling (brightening of the IR image) is also evident behind the front, especially in Oklahoma and Texas.

b) The enhanced infrared images allow for easier differentiation of subtle grey scale differences in infrared brightness. Progressively colder infrared temperatures are indicated by the color sequence black, blue, green, red and white. The cumulonimbus tops and cirrus clouds are the coldest regions of the imagery.

c) Afternoon shadows cast by cumulonimbus towers in the visible imagery help locate thunderstorms within the large area of cirrus blowoff. Lines of towering cumulus are also evident along the cold front prior to thunderstorm development. Low cloudiness to the east of the squall line, which was difficult to detect in the infrared imagery, is readily apparent in the visible imagery.

2) High Resolution satellite images . . . (1 km resolution) . . . Visible sequence is for the period from 1800 GMT to 0000 GMT (interval: 1 hour)

a) Parallel rows of cumulus clouds preceded the thunderstorms in Missouri and Arkansas. With sunset, numerous regions of intense convection can be discerned. During this sequence numerous severe weather events occurred throughout Missouri and southern Illinois. After 0000 GMT severe thunderstorms in Kentucky produced 3 tornadoes. Note the clearing associated with the dry tongue in the last images.

b) Note the protrusion of the the Ozark Mountains through the cloud deck in northern Arkansas. Gaps in the thunderstorm line are evident in the northern portion of the image. Numerous severe weather events were also associated with this portion of the squall line.

3) Severe weather report locations superimposed over satellite images sequence from 1300 GMT to 0400 GMT (interval: 1 hour)

The severe weather occurrances are scattered over a very large area of the central United States. Locations of severe weather reports indicate a long duration of severe storm intensity within the squall line. The majority of the tornadoes occurred in Missouri and Arkansas during the late afternoon of 12 May.

4) Manually digitized radar superimposed over satellite image sequence from 1335 GMT to 0435 GMT (interval: 1 hour)

The 0 isopleth indicates the limit of data availablility while other contours depict intensity of radar echoes. By late afternoon an extensive area of showers is located to the north and east of the low while an area of intense echoes stretches southward along the squall line. A weaker secondary thunderstorm line forms behind the main squall line in Nebraska and Kansas and subsequently spawns a tornado in Missouri. Scattered shower activity is present in the warm sector of the developing cyclone.

Surface fields

All fields are superimposed over satellite images (interval: 3 hours, 1300 GMT 12 May to 0400 GMT 13 May)

frame duration: 10s; 2s

5) Sea level pressure and surface streamline analyses

isobar interval = 4 mb

a) At 1300 GMT two cyclonic systems, one in southern Wisconsin and another in eastern South Dakota, dominate the circulation over the central United States. The streamlines in the analysis indicate convergence of mass into the cyclone centers. The circulation of the western cyclone becomes dominant by late afternoon. The squall line forms along the surface pressure trough in a region of streamline confluence as the cyclone center moves to central Illinois and deepens to 996 mb by 0400 GMT 13 May.

6) Surface divergence analyses

contour interval = $(5 \times 10^{-5}/s)/day$

a) In the analyses maximum values of convergence are located in the cyclone centers and along the surface pressure trough, within which the squall line develops. Convergence values along the trough decrease in the evening hours as winds behind the front become southwesterly, which is more parallel to the surface cold front. Divergent flow at the surface in Oklahoma and Texas is associated with clearing skies. By 0400 GMT a region of convergence extends southwestward from the cyclone center into the Great Plains.

7) Surface temperature analyses

isotherm interval = 5°C

a) The isotherm pattern in the vicinity of the developing cyclone resembles an 'S' shape, with warm air east of the low and cooler air moving into the Great Plains. However, diurnal heating/cooling and cloud cover alters the large scale lower tropospheric thermal pattern.

8) Surface dewpoint analyses

isodrosotherm interval = 5°C

a) A ridge of moisture extends from Texas to Michigan with the largest values being located in the Mississippi River Valley, as evidenced by the 15°C isodrosotherm. The combination of much drier air in the Great Plains and the moisture ridge creates a strong moisture gradient behind the cold front, along which the squall line becomes organized.

9) Surface mixing ratio advection analyses

contour interval = 2(g/kg)/day

Since large amounts of moisture are already present in the Mississippi River Valley, values of moist air advection (+) ahead of the squall line are smaller in magnitude than the values of dry air advection (-) to its rear. However, moisture is being transported northward within the region ahead of the developing thunderstorms. The advection of drier air decreases dramatically late in the day as the winds behind the squall line become more parallel to the front.

10) Equivalent potential temperature analyses

contour interval = 5 K (add 300 K to each label value)

With the combination of the large temperature and moisture gradients along the frontal boundary, the equivalent potential temperature gradient is even more pronounced along the frontal zone. The increase of equivalent potential temperature in clear regions within the warm sector of the cyclone during the day is due to sensible heating. A tongue of higher equivalent potential temperature is located to the east of the cold front.

11) Equivalent potential temperature divergence analyses

contour interval = 10°C/day

a) The divergence of the transport of equivalent potential temperature is expressed mathematically as $\vec{\nabla}\cdot(\theta_e\vec{V})$. Because this field combines the thermodynamic properties of temperature and moisture with the dynamic processes of transport and divergence, regions of convergence, (large negative values) are correlated with the location of thunderstorm development.

Upper Air Analyses

1200 GMT 12 May, 1978

Most fields are superimposed on satellite images

12) 850 mb geopotential height and temperature analysis

isohypse interval = 30 m; isotherm interval = 5°C

a) The broad area of lowest heights is associated with both surface lows. A thermal ridge extends through the Great Plains with warm air advection over the central United States. Strong cold air advection occurs to the west of the trough axis.

13) 850 mb temperature advection analysis

contour interval = 5°C/day

a) The line of zero temperature advection passes through the two circulation centers and along the trough axis. Warm air advection in the lower troposphere east of the trough aids in the destabilization of the mid-lower troposphere. At higher elevations west of the trough axis the discrepancy between the apparent values of cold air advection estimated from the height and thermal fields (#12) and calculated values of cold advection is due to the intersection of the 850 mb pressure surface with the earth. The calculated values are affected by the lack of wind data.

14) 850 mb streamline, isotach and dewpoint analysis

isotach interval = 5 m/s; isodrosotherm interval = 5 °C

a) This segment provides another opportunity to visually estimate the moisture advection utilizing the streamline, isotach and dewpoint analysis and gain greater insight into the composition of the computer derived field in #15. The low level wind maximum, which extends from

Arkansas to Ohio, is transporting abundant moisture northeastward from the Gulf of Mexico. The 10°C isodrosotherm extends from the Gulf of Mexico to southern Missouri. By contrast, much drier air is present in Oklahoma and Texas.

15) 850 mb dewpoint advection

contour interval = 5°C/day

a) The broad area of relatively uniform moisture in the mid-Mississippi River Valley results in small values of moisture advection in this region. The line of zero advection follows the 850 mb moisture ridge which stretches from Arkansas to Indiana.

16) 700 mb geopotential height and temperature analysis

isohypse interval = 60 m; isotherm interval = 5°C

a) The main trough at 700 mb extends from South Dakota to Texas. The geopotential height and thermal fields are nearly 90° out of phase.

17) 700 mb temperature advection analysis

contour interval = 5°C/day

a) Weak warm air advection is present over the central United States. Much stronger cold air advection is located in the plains with maximum values being co-incident with the 500 mb shortwave trough (#20).

18) 700 mb streamline, isotach and dewpoint analysis

isotach interval = 5 m/s; isodrosotherm interval = 5 °C.

a) Light west to southwesterly flow is present over the central United States. Wind maxima are located west of the Appalachians and over the High Plains. Dry air is already present over the region of future squall line development, contributing to the convective instability.

19) 700 mb dewpoint advection analysis

contour interval = 10°C/day

a) Greatest values of moisture advection (+) are located over Alabama. Smaller values of dry air advection (-) over Texas are primarily due to the relatively light winds at this level.

20) 500 mb geopotential height and temperature analysis

isohypse interval = 60 m; isotherm interval = 5°C

a) The geopotential height pattern indicates two short waves over the United States. The relatively strong winds and the large phase displacement of the thermal and height fields creates the strong temperature advection favorable for cyclone intensification. The coldest air is located over Montana.

21) 500 mb temperature advection analysis

contour interval = 5°C/day

a) Cold air advection is prevalent over much of the central United States, especially in the Central Plains. The 500 mb cold advection maximum is in the same location as the 700 mb maximum. Smaller advection values at 500 mb indicate that the cold air advection decreases with height, which leads to the amplification of the trough.

22) 500 mb geopotential height and isotach analysis

isohypse interval = 60 m; isotach interval = 5 m/s

a) A 30 m/s wind maximum that propagated into Colorado is located west of the trough axis. Locations of vorticity maxima can be inferred from contributions by the height contour curvature and the horizontal wind shear.

23) 500 mb streamlines and absolute vorticity analysis

vorticity contour interval = 2×10^{-5}/s

a) Three major vorticity maxima are present at 1200 GMT 12 May. The vorticity center over southern Lake Michigan is located directly above the surface low. The movement of the vorticity maxima in Wyoming is linked with positive vorticity advection (PVA) over the Northern Plains, and cyclogenesis. Negative vorticity advection (NVA) over Missouri and western Arkansas is likely associated with subsidence that dissipates clouds and made conditions favorable for a significant increase in temperature associated with sensible heating at the earth's surface.

24) 300 mb geopotential height and temperature analysis

isohypse interval = 120 m; isotherm interval = 5°C

a) At this level the thermal and geopotential height fields are more closely in phase than at lower levels, however, stronger winds in the upper troposphere still induce significant temperature advection.

25) 300 mb geopotential height and isotach analysis

isohypse interval = 120 m; isotach interval = 5 m/s

a) A strong upper tropospheric jet streak, in excess of 50 m/s, is propagating into the Kansas-Nebraska region in conjunction with the development of the surface low located beneath the front left quadrant of the jet.

26) 300 mb isotach and divergence analysis

isotach interval = 5 m/s; divergence contour interval = 1×10^{-4}/s

a) A 300 mb divergence maximum, located in the left front quadrant of the jet streak, suggests rising motion from southern South Dakota to

Kansas. Cold cloud tops are present in regions of 300 mb divergence while convergence at this level appears to be associated with clear skies or lower clouds.

27) 850 mb and 500 mb streamline analysis

a) The two streamline patterns indicate veering of the wind field in the vertical over the region in which the squall line develops. The temperature and moisture advections associated with this wind shear are a key to the formation of convective instability and subsequent severe thunderstorms.

28) Total totals index analysis

contour interval = 5 units

The large values of the index which coincide with abundant 850 mb moisture extend from Missouri southward to the Gulf of Mexico. The largest index value is associated with the single, unstable sounding at Dodge City, Kansas. High index values over Montana and South Dakota are due to the cool pool at 500 mb. Lack of moisture at 850 mb over TIK and SEP produces low index values.

Soundings

29) Little Rock, Arkansas (72340-LIT)

Totals index = 47; Lifted index = +1

An inversion exists at the surface with plentiful moisture in the low levels. Strong veering of the wind in the vertical and a large lapse rate in the upper troposphere are two severe weather ingredients present in this sounding.

30) Monett, Missouri (72349-UMN)

Totals index = 54; Lifted index = -5

The atmospheric structure for Monett, Missouri provides an excellent example of a severe weather precedent sounding. Moist air at low levels is capped by a temperature inversion with much drier air aloft. Veering of the wind with height, strong upper level winds and a large lapse rate complete the list of ingredients.

31) Tinker AFB, Oklahoma (72353-TIK)

Totals index = 35; Lifted index = -3

Very little low level moisture and a strong temperature inversion suggest that thunderstorm development will be difficult to initiate.

32) Stevenville, Texas (72260-SEP)

Totals index = 33; Lifted index = -4

Very dry conditions above 900 mb indicates that there is little moisture for thunderstorms. However, note that the upper tropospheric lapse rate is very steep.

<u>Cross Section</u> with isentropes, isotachs and isohumes

isentrope interval = 5°C; isotach interval = 10 m/s

isohume interval =2 g/kg

33) 1200 GMT 12 May from 72662 72562 72451 72353 72260 72255
(L-R RAP LBF DDC TIK SEP VCT)

a) The tight packing of isentropes at upper levels isolates the tropopause. At the surface a cold pool of air is located from RAP to DDC. The vertical structure of the southern portion of the cross section is characterized by a stable lower troposphere with weaker static stability aloft.

b) Use of the thermal wind concept places the upper tropospheric wind maximum north of DDC. The spreading of the isentropes to the right (south) of the jet indicates weaker stability in mid and upper levels. The tight packing and steep slope of the isentropes between LBF and TIK indicates a strong horizontal temperature gradient and suggests a frontal boundary.

c) A moist tongue of air is located at low levels from VCT to LBF, below a temperature inversion.

Isentropic analyses of pressure, streamlines and mixing ratio or wind speed
isobar interval = 50 mb; isohume interval = 2 g/kg;
isotach interval = 5 m/s

34) 300 K analysis

a) A large temperature gradient exists between the high pressure ridge in the central United States and the low pressure trough in the High Plains. The isobaric pattern in the vicinity of the Lake Michigan cyclone portrays a characteristic deformation of the thermal field.

b) Streamline flow across pressure contours on an isentropic surface are an indication of vertical motion. Thus, a broad region of rising motion is suggested east of the Mississippi River and into the Great Lakes region, while strong subsidence is suggested in the Central Plains.

c) A moisture tongue extends north and east from the Gulf Coast to the Ohio River Valley. Southwesterly winds over the mid-Mississippi Valley advect abundant moisture into Illinois. Drier air moves toward the surface (subsidence) in the Central Plains behind the developing cyclone and squall line.

35) 320 K analysis

a) This isentropic surface slopes from 300 mb in the Northern Plains to 550 mb in the Gulf of Mexico. A broad trough of colder air is located over the Great Plains while a warm thermal ridge is present in the eastern United States.

b) Streamlines on this isentropic surface have a smaller angle of intersection with the isobars, however, wind speeds are stronger. Subsidence to the west of the Great Plains trough and rising motion to the east of the trough correspond to the clear and cloudy areas in the satellite imagery.

c) An upper tropospheric jet streak with winds in excess of 40 m/s is located to the west of the Great Plains trough.

At this point in the videocassette it would be beneficial to review the important features from this time period before continuing with the next sequence of images and analyses.

Upper Air Analyses

0000 GMT 13 May, 1978

Most analyses are superimposed over satellite images

36) 850 mb geopotential height and temperature analysis

isohypse interval = 30 m; isotherm interval = 5°C

a) At this time, a deep, closed circulation is located over the Illinois-Wisconsin border with a trough extending southward through Arkansas. The tight packing of the geopotential height contours in the Central Plains indicates strong geostrophic winds. The geostrophic winds are oriented nearly orthogonal to the isotherm pattern.

37) 850 mb temperature advection analysis

contour interval = 5°C/day

a) Little warm air advection is indicated east of the 850 mb trough axis. Much stronger cold air advection has moved from the Central Plains to the mid-Mississippi Valley and is generally associated with clearing skies.

38) 850 mb streamline, isotach and dewpoint analysis

isotach interval = 5 m/s; isodrosotherm interval = 5°C

a) The circulation center of the cyclone is located in eastern Iowa. Strong northwesterly winds in excess of 20 m/s which are present along the Missouri-Kansas border bring dry air to the central United States behind the squall line. The 10°C isodrosotherm encloses an extensive region of warm, moist air east of the squall line.

39) 850 mb dewpoint advection analysis

contour interval = 5°C/day

a) The advection of drier air by strong northwesterly winds behind the squall line is indicated by the large negative values centered over the Missouri-Oklahoma border.

40) 700 mb geopotential height and temperature analysis

isohypse interval = 60 m; isotherm interval = 5°C

a) The amplitude of the trough at this level has increased significantly since 1200 GMT with the development of the circulation center now located in Iowa. The increased geopotential height gradient results in stronger winds across the central United States.

41) 700 mb temperature advection analysis

contour interval = 5°C/day

a) A cold air advection maximum is located over Missouri with smaller values elsewhere.

42) 700 mb streamline, isotach and dewpoint analysis

isotach interval = 5 m/s; isodrosotherm interval = 5°C

a) McIDAS generated streamlines indicate that the circulation is not closed at this level. Winds in excess of 25 m/s actually stretch in a narrow band from Kansas to southern Illinois (see map package). The thunderstorm activity creates a generally chaotic moisture field, however, dry air is notably present over the southern portion of the squall line.

43) 700 mb dewpoint advection analysis

contour interval = 10°C/day

a) Dry air advection is present behind the squall line. Other values of advection must be considered questionable due to the chaotic dewpoint field.

44) 500 mb geopotential height and temperature analysis

isohypse interval = 60 m; isotherm interval = 5°C

a) The amplitude of the trough has increased significantly over the past 12 hours with its axis now stretching from the circulation center in Iowa southward to Texas. The thermal and geopotential height fields remain out of phase suggesting that further cyclone development is possible.

45) 500 mb temperature advection analysis

contour interval = 5°C/day

a) A large region of cold air advection, coinciding with generally clear skies, extends from Missouri to the Oklahoma panhandle.

46) 500 mb geopotential height and isotach analysis

isohypse interval = 60 m; isotach interval = 5 m/s

a) A mid tropospheric wind maximum greater than 40 m/s is located near the bottom of the trough. Clear skies behind the squall line are located beneath this wind maximum.

47) 500 mb streamline and abolute vorticity analysis

vorticity contour interval = 2×10^{-5}/s

a) During the past 12 hours the vorticity maximum has intensified to 20 units and moved near the base of the trough in Missouri. An estimation of vorticity advection from this image indicates that the strongest PVA is over Illinois, while the strongest NVA is located over the Central Plains.

48) 300 mb geopotential height and temperature analysis

isohypse interval = 120 m; isotherm interval = 5°C

a) A region of temperatures colder than -50°C is located over North Dakota. A relatively zonal thermal field is present in the upper troposphere.

49) 300 mb geopotential height and isotach analysis

isohypse interval = 120 m; isotach interval = 5 m/s

a) The 50 m/s jet maximum is entering the bottom of the 300 mb trough as the surface cyclone intensifies. The inter-relationship between the location of the upper tropospheric jet streak, the surface low and the clear tongue is illustrated in this image.

50) 300 mb isotach and divergence analysis

isotach interval = 5 m/s; divergence contour interval = 1×10^{-4}/s

a) Strong divergence is still present in the front left quadrant of the jet streak. The superposition of the divergence maximum over the surface low suggests that further intensification of the cyclone is probable.

51) 850 mb and 500 mb streamline analysis

a) Veering of the wind with height is still present ahead of the squall line.

52) Total totals index analysis

contour interval = 5 units

Large values of the index are located along the squall line. Lower values in Oklahoma and Texas indicate a lack of severe thunderstorm potential. Very cold air at 500 mb is responsible for the large index values in the Dakotas and Nebraska.

Soundings

53) Jackson, Mississippi (72225-JAN)

Totals index = 46; Lifted index = -5

The atmospheric structure for Jackson, Mississippi provides a good example of an evening pre-squall line sounding. Warm moist air is present in the lower troposphere with strong vertical wind shear and a large lapse rate, all favorable conditions for severe thunderstorms.

54) Monett, Missouri (72349-UMN)

Totals index = 48; Lifted index = +5

This post squall line sounding shows relatively dry air in a shallow layer above the surface. Winds backing with height imply cold advection over the station, which was also indicated by previous calculations. A thunderstorm was reported within the hour prior to the sounding at Monett.

55) North Platte, Nebraska (72562-LBF)

Totals index = 53; Lifted index = +1

This station is located in the cool, dry air behind the cold front. A steep lapse rate from the surface to 600 mb helps produce a large totals index.

56) Green Bay, Wisconsin (72645-GRB)

Totals index = 44; Lifted intex = +7

This station is located north of the surface low where low clouds and more continuous precipitation are usually located. The lapse rate is not large and winds are light.

Cross Section with isentropes, isotachs and isohumes

57) 0000 GMT 13 May from 72662 72654 72553 72456 72349 72340 72235
(L-R RAP HUR OMA TOP UMN LIT JAN)

isentrope interval = 5°C; isotach interval = 10 m/s

isohume interval = 2 g/kg

a) Nearly vertical isentropes and little packing in the lower troposphere from TOP to LIT are an indication very unstable air. Near the surface the colder air to the north and warmer air to the south are evident. The steeply sloped and tightly packed isentropes depict the frontal location at upper levels. Note the difference in height between the polar and tropical tropopause.

b) The steep slope of the isentropes over UMN from 400-300 mb are directly beneath the location of the upper tropospheric jet streak. The southern edge of a strong moisture gradient and the surface cold front are both located near Little Rock, Arkansas.

Isentropic analyses of pressure, streamlines and mixing ratio or wind speed isobar interval = 50 mb; isohume interval = 2 g/kg; isotach interval = 5 m/s

58) 305 K analyses

a) At this time the ridge of warm air extends northeastward to the Ohio River Valley. A cold pool of air moves to the central United States. The warm air (low pressure) over the Rocky Mountains reflects the proximity of the earth's surface to the 305 K surface.

b) An area of upward vertical motion is implied to the east of the squall line with broad subsidence and clearing behind it.

c) A moisture ridge extends northeastward from Texas to Illinois along the squall line. Streamlines are oriented nearly perpendicular to the strong moisture gradient. The pattern indicates that drier air is moving into the lower troposphere behind the squall line.

59) 320 K analysis

a) A trough of cooler air lies to the west of the cloud mass.

b) Flow towards higher pressure indicates that subsidence is prevalent west of the trough axis.

c) A wind maximum in excess of 40 m/s is located over a region of subsidence and clear skies. The surface cyclone is located in the left front quadrant of this wind maximum.

SQUALL LINE DEVELOPMENT

Sequence	Time	Tape Counter
Title	0:15	006
Satellite Imagery	0:41	020
High Resolution Satellite Imagery	4:45	127
Severe Weather Reports	6:20	162
Manually Digitized Radar	7:30	184
Surface Analyses	9:31	225
Sea Level Pressure and Streamline	9:46	230
Divergence	11:09	256
Temperature	12:31	281
Dewpoint	13:52	306
Mixing Ratio Advection	15:14	329
Equivalent Potential Temperature	16:35	352
Equivalent Potential Temperature Divergence	17:56	374
Upper Air Analyses		
1200 GMT 12 May 1978		
850 mb Height and Temperature	19:39	401
850 mb Temperature Advection	20:01	407
850 mb Streamline, Isotach and Dewpoint	20:20	412
850 mb Dewpoint Advection	20:54	420
700 mb Height and Temperature	21:12	425
700 mb Temperature Advection	21:33	430
700 mb Streamline, Isotach and Dewpoint	21:54	435
700 mb Dewpoint Advection	22:27	444
500 mb Height and Temperature	22:44	448
500 mb Temperature Advection	23:07	453
500 mb Height and Isotach	23:23	457
500 mb Streamline and Absolute Vorticity	23:46	463
300 mb Height and Temperature	24:06	468
300 mb Height and Isotach	24:27	473
300 mb Isotach and Divergence	24:51	478
850 mb and 500 mb Streamline	25:13	484
Total Totals Index	25:35	489
Soundings	25:52	493
Little Rock, Arkansas	26:07	497
Monett, Missouri	26:18	499
Tinker AFB, Oklahoma	26:28	501
Stephenville, Texas	26:38	503
Isentropic Cross Section	26:47	506
Isentropic Analyses		
300 K	28:03	523
320 K	29:06	537
Upper Air Analyses		
0000 GMT 13 May 1978		
850 mb Height and Temperature	30:25	554
850 mb Temperature Advection	30:47	559
850 mb Streamline, Isotach and Dewpoint	31:04	563
850 mb Dewpoint Advection	31:40	571

Sequence	Time	Tape Counter
700 mb Height and Temperature	31:57	574
700 mb Temperature Advection	32:19	579
700 mb Streamline, Isotach and Dewpoint	32:36	583
700 mb Dewpoint Advection	33:12	590
500 mb Height and Temperature	33:29	594
500 mb Temperature Advection	33:52	599
500 mb Height and Isotach	34:00	602
500 mb Streamline and Absolute Vorticity	34:30	607
300 mb Height and Temperature	34:52	611
300 mb Height and Isotach	35:13	616
300 mb Isotach and Divergence	35:36	620
850 mb and 500 mb Streamline	35:57	625
Total Totals Index	36:20	630
Soundings	36:36	633
Jackson, Mississippi	36:53	636
Monett, Missouri	37:03	638
North Platte, Nebraska	37:13	640
Green Bay, Wisconsin	37:23	642
Isentropic Cross Section	37:33	644
Isentropic Analyses		
305 K	38:45	659
320 K	39:43	670
End		