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EASTERN PACIFIC CUT-OFF LOW OF APRIL 21 - 28, 1974

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ABSTRACT

A low aloft developed along the Oregon-northern California coast in April 1974. This cold low and associated upper level trough continued inland producing a variety of abnormal weather over the Region. Tropical moisture became involved with this system producing areas of locally heavy precipitation. This paper summarizes events preceding, during, and as the low was weakening and moving northeast.

I. INTRODUCTION

During the period April 21 - 28, 1974, the Western Region of the National Weather Service experienced a variety of anomalous weather that included strong, warm south-to-southwesterly winds over Arizona and Utah, heavy snow in the Sierra Nevada and eastern Oregon, moderate-to-heavy rain over portions of eastern Washington and northern Idaho and near-blizzard conditions along the Montana-Canadian border northwest of Cut Bank. This contrasting weather was associated with a cold low that moved south along the coast, then curved north-northeastward and finally northeastward across the Region. We recognize that a strong springtime cut-off low regime over the Region is usually associated with anomalous weather. Our main purpose is to summarize such an event and try to show the merits of taking satellite pictures and the large-scale flow pattern into account when using National Meteorological Center (NMC) numerical model guidance.

II. ANTECEDENT CONDITIONS

In the middle of April 1974, a "high-index" pattern persisted over much of the Northern Hemisphere. Strong westerlies left the Asiatic coast in the vicinity of China, progressed eastward across the Pacific, over North America and into the Atlantic where they became "split" in the vicinity of 30W. This "split" in the flow was quasistationary most of the winter and into spring. The mean ridge position affecting the western United States was in the vicinity of 110 to 120W.

Prior to the storm under discussion, a closed low had briefly affected the western United States during the period April 18 - 20th. Figure 1 shows the Northern Hemisphere pattern for 0000Z, Thursday, April 18, 1974. Note particularly the strong westerlies across the Pacific. A trough at 130W had been moving east in this westerly current and was now showing signs of "splitting" in accord with the "hydraulic jump" [1] analogy. The flow did "split" but the associated closed low continued eastward along 40N.

By 0000 GMT, April 21 (Figure 22) the main low had moved into Nebraska leaving a portion over northwest Arizona. The strong belt of westerlies over the Pacific was developing into a series of intense full-latitude troughs and ridges (i.e., the "high-index" pattern was deteriorating). One such trough along 150W was being followed by strong, warm-air advection near the dateline. At this time it did not appear strongly developmental.

III. DEVELOPMENT OF CUT-OFF LOW

By 0000Z, Tuesday, April 23 (Figure 3), the trough along 150W had moved eastward and intensified considerably along the West Coast. According to AIREPS, strong north-northwest winds of 110 knots were present at 250 mb along 140W. The ridge following in the Gulf of Alaska was also gaining strength and amplitude. In contrast the pattern upstream from the dateline to the Asiatic coast appeared to be returning to "high index" again. Westerly winds on the order of 130 knots in the vicinity of the tropopause were present between 45N and 50N from the Asiatic coast eastward to the dateline by 0000Z April 24th. Another jet maximum of 110 to 130 knots was present between 150W and 160W into southern Alaska. Figure 4 shows these jet areas at 300 mb. This latter jet bridged across the top of the West Coast low, completely cutting it off from the westerlies in 24 hours (Figure 5). This "cut-off" low was the upper-air feature associated with a week of anomalous weather over the Western Region. The low center reached its lowest latitude on Wednesday the 24th before moving slowly north-northeastward, taking four days to move out of the Region.

NMC analyzed positions of the 500 mb and associated surface low centers from April 21 - 25 are plotted in Figure 6. Positions of the low center as determined by VHRR IR satellite imagery are also plotted in Figure 6. Surface low centers agree much more closely to satellite imagery positions than the analyzed upper-air positions.

Analyses at 12-hour intervals showing the progress of the system across the Western Region are shown in Figures 7 - 12 for the period 00 GMT/26 - 1200 GMT/28. Note particularly that there were two centers indicated on most of these charts.

Surface fronts were very difficult to analyze once the low had cut-off and probably did not exist from the classic model viewpoint. For example, the analysis from NMC for 12Z/23 carried a front from northeast California southward along the Sierra Nevada but at 700 mb (Figure 13) the usual increase in thermal gradient to the west of the surface frontal position is not evident. However, the satellite pass at 1700Z on the 23rd (Figure 14) does show a solid cloud band along 120 - 123W. This cloud band appeared to move eastward (Figure 15) but the surface pattern became complex with low centers over southeast Montana, eastern Washington, central Idaho and east-central Nevada by 12Z/24. The overall effect of surface fronts was thought to be minimal with this storm, however. The main effect of the strong temperature gradient was probably keeping surface pressure gradient strong east of the general low-pressure area. This resulted in gusty south-to-southwesterly winds which were strongest when the low was offshore but decreased as the low moved northeast. Although somewhat fractured, the cloudiness depicted in Figure 14 suggests a continuous band of tropical moisture streaming northeastward across Baja California.

A number of significant weather events occurred from 06Z/24 to 12Z/25. Snow fall at Blue Canyon, California, totaled 14 inches. Four to six inches of snow was recorded in the Cascades of Oregon, and two to five inches fell over much of eastern Oregon, particularly the south portion.

Precipitation amounts of around one inch were recorded over and east of the Cascade Mountains in Washington, with Yakima, Washington, receiving 1.24 inches. Over one foot of new snow was recorded at Paradise Ranger Station in Mt. Rainier National Park.

To understand these precipitation areas, one must study the VHRR IR picture for 0600Z/April 24 (Figure 15). This picture continues to show intrusion of tropical moisture across Baja into southwest United States. An area of cumulonimbus between 120W and 125W, north of 35N is apparent as is a triangle-shaped cloud area bounded by 40/118, 46/115, and 47/121. When the VHRR photo for 1800Z, Wednesday, April 24, is examined (Figure 16), the movement of the above cloud areas can be traced. The enhancement of clouds along the Sierra Nevada Range and northward into southern Oregon corresponds to an area of PVA at 500 mb. An even more solid area of clouds can be found north of 45N from 120W to off the coast. This area was considered to be the cloudiness which was located near 45N/120W in Figure 15 and also associated with PVA in the northwest quadrant of the cutting-off low. Precipitation along the eastern slopes of the Washington Cascades was no doubt enhanced by upslope conditions.

Further evidence of the existence of tropical moisture being drawn into the low system is shown in the VHRR IR image for Thursday morning, April 25 (Figure 17). At this time the complex low center was moving onshore around 42N. The source of this moisture (extensive cloudiness) across central Baja into New Mexico and southeast Arizona is south of 25N.

A period of heavy rain occurred over the northern Idaho mountains during the 24-hour period starting at 12Z on the 25th. Referring again to Figure 17, there is an enhanced area along 118W between 38 and 43N. It appears from the VHRR IR for 0400Z on the 26th (Figure 18) that this cloudiness and a portion of the Baja cloudiness which had expanded and moved due north, combined over eastern Washington and Idaho. This merger then accounted for the heavy rains that totaled up to one inch in the Idaho mountains.

One other significant weather event occurred before the low exited the region on Sunday, the 28th. This was over the northwest portion of Montana east of the Continental Divide. Heavy precipitation in the form of rain and snow, with near-blizzard conditions caused six-to eight-foot drifts and closed some main roads. A number of newborn calves did not survive. See Figure 19. Upslope precipitation contributed to the intensity of the precipitation. Examination of the 500-mb charts for Saturday the 27th, Figures 10 and 11, suggests that the upper low may have "looped" ala Jacobson [2] during its migration across Montana.

IV. PROGNOSTIC GUIDANCE

Computer guidance during the life cycle of this cut-off low was generally good except for the crucial period during which the low recurved as it reached the West Coast. The guidance errors followed a characteristic pattern: baroclinic progs superior to the barotropic in showing the trough deepening and eventually cutting-off, but when the low recurved and started moving northeastward the barotropic handled the situation better. The baroclinic erred at recurvature time by moving the low and associated trough eastward and then southeastward into the Plateau. The forecaster's dilemma is when to switch his allegiance from one model to the other.

The 72-hour 500-mb prog valid 0000Z, Tuesday, April 23 (Figure 20), was excellent. It indicated a deepening trough along 130W with the possibility of a closed low off the Oregon coast. To appreciate fully the excellence of this prognosis, one needs to compare it with Figure 21, the initial 500-mb analysis from which the prognosis was made. The strong belt of westerlies across the Pacific began to show signs of buckling along the West Coast on the 20th and the 72-hour prognosis showed how this would develop over the subsequent 3-day period.

On the shorter range progs the initial indication that a cut-off low would develop was in the baroclinic series that began with the 1200Z, Monday, April 22, data (Figure 22). The computer series advertised the beginning of the cut-off low development off the northern California coast to take place in 36 hours (0000Z, Wednesday, April 24). The barotropic prog valid for the same time period was not available due to computer problems.

Both the barotropic and PE computer runs 12- and 24-hours later, based on initial data for 0000Z, Tuesday, April 23, and 1200Z, Tuesday, April 23 (Figures 23 - 26), handled the associated trough and low off southwest Oregon and northwest California well. The similarity of the output from the two models suggests the main development had ceased, with the low continuing to move southward until 00Z/24th. The PE did indicate too much southward movement.

The prog series, both barotropic and PE, initialized from 0000Z, Wednesday, April 24, data (Figures 27 and 28) developed a premature trend of moving the low inland. The PE was more in error, moving the low to northeast California. This had serious consequences on forecasts issued for most of the Region for Friday. Initial analysis over the eastern Pacific on both of these runs is considered poor and the probable reason for the misleading prognoses. Satellite imagery suggests the low center was apparently two degrees farther south than analyzed, and thus the strongest wind belt was also farther south.

The ejection of a cut-off low northeastward is usually forecast better by the barotropic model than the PE. This was the case on the 24th. The 1200Z, Wednesday, April 24, barotropic guidance (Figure 29) verified well on the low moving slowly northeastward into extreme southwest Oregon in 36 hours. The PE series based on the same initial data (Figure 30) erred in moving the low eastward into northern California.

From the PE prog series based on 0000Z, Thursday, April 25, initial data (Figure 31), the previous PE trend of moving the low eastward into north-central Nevada by 1200Z, Friday, April 26, was continued*.

*As mentioned earlier, once the low began moving inland two and sometimes three centers could be drawn.

Of the two prog series based on 1200Z, Thursday, April 25, data (Figures 32 and 33), the barotropic position and height field verified better than the PE as the low moved into central Oregon. The PE prog series appears to have kept a strong area of vorticity rotating around the southern portion of the low that resulted in the low being forecast inland and southeastward toward the Plateau. This vorticity did appear to exist according to our interpretation of the satellite imagery* but it actually rotated around the "parent" low and moved northeast rather than east as forecast by the PE.

By Sunday, April 28, the low had become an open short wave and was absorbed into the westerlies as it continued through Montana into the Dakotas.

The height change pattern is often useful in determining motion of lows and troughs. The centers of 24-hour height change at 500 mb are plotted in Figure 34. There was a sharp south-southeastward movement to the center of greatest 24-hour height fall from 0000Z/22 to 0000Z/24. The height rises following this center moved eastward into the Gulf of Alaska. The movement of both these areas was superbly shown by the 72-hour prog discussed earlier and only seemed to advertise the ensuing development.

Cut-off lows will usually be displaced northeastward by the approach of a strong short wave from the west or northwest. The movement of the low northeastward on the 24th seems related to a short wave along 160W that was moving east-northeastward. This short wave did not "open up" the West Coast low, however, but moved rapidly "over the top" into western Canada, much as indicated by NWP guidance. It was followed by another short wave on the 25th that also moved northeast "over the top"**.

Cut-off low development in April is not uncommon, but there were some characteristics of this storm that resulted in stronger weather departures than normal. The insertion of tropical moisture into the low was vividly displayed by satellite imagery. Northward surges of tropical moisture into the southwest portion of the United States are uncommon at this time of year. It is believed that this addition of moisture had a pronounced effect on the weather over the northeast portion of the Region, more specifically the precipitation in northern Idaho and Montana***.

Were the "circulation centers" that appeared on the satellite imagery true low centers or vorticity centers? If they indicated upper low centers, then one wonders what effect the erroneous locations in some of the initial 500-mb analyses had on the progs. The PE, which is normally superior in handling "digging" lows, did admirably, except for 1200Z/24 and 0000Z/25 when it overforecast the digging†.

*This would be the bright enhanced area along 40N just on and off the West Coast in Figures 17 and 18.

**See Figures 27 - 33 for initial positions.

***The great Montana snowstorm of April 6 - 8, 1975, was associated with a similar entrainment of tropical moisture.

† ⊙ on prog charts denotes actual observed center.

Throughout the early stages of this cut-off low, a long-wave trough was present in the vicinity of 175W. Minor short waves moving around this feature and then east-northeastward were enough to initiate a slow northeastward motion of the cut-off as they approached, but, as mentioned, were not strong enough to eject it northeastward. While moving "over the top", they apparently induced a slight eastward motion to the low. The more rapid northeastward motion of the cut-off beginning of the 26th seems to be more related to the building of a ridge between 125 - 135W (see Figure 34), rather than the approach of a strong short wave. The mean ridge returned to the vicinity of 120W by the first part of May.

The thermal structure of the low as it moved inland was anomalous by Jacobson's definition [2], i.e., the cold air is concentrated south of the center. Consequently, it is not surprising if the low actually "looped" as it moved over Montana.

The closed low preceding the low under discussion that moved inland on the 18th and continued east may well have had some influence on the intensity of the second cut-off low by weakening the long-wave ridge along the coast. The cutting-off seems related to the well-defined south-southwest jet along 160W that eventually bridged across at northern latitudes. Also to be considered would be the dispersion of energy downstream related to the intensification off Asia.

V. CONCLUSIONS

With similar situations in the future, Western Region forecasters should be alert to:

1. The insertion of tropical moisture into southwest United States. This can be determined by GOES satellite imagery.

2. A "high-index" pattern upstream with possible "bridging" at northern latitudes. GOES and NOAA can also be used to verify these developments.

3. Vorticity or low centers depicted by satellite imagery differing from analyzed positions and subsequent effects on prognosis.

4. Moving cut-off lows out to the northeast or east too rapidly as a short wave approaches from the west.

5. The cold air to the south of the low as it moves inland may behave as an anomalous low.

VI. REFERENCES

[1] REX, D. F. *Tellus*, Volume 2, No. 3, 1950.

[2] JACOBSON, A. L. *Upper-Air Lows Over Northwestern United States.* ESSA TM, WBTM 39, 1969.

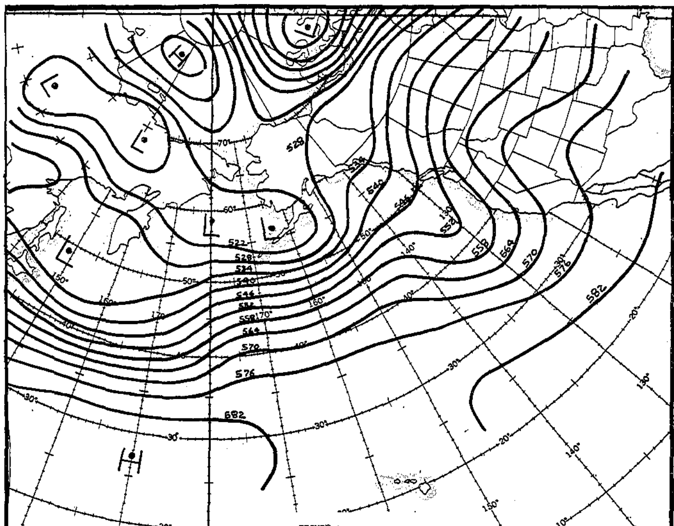

FIGURE 1.
500mb Analysis 0000Z, Thu. April 18, 1974

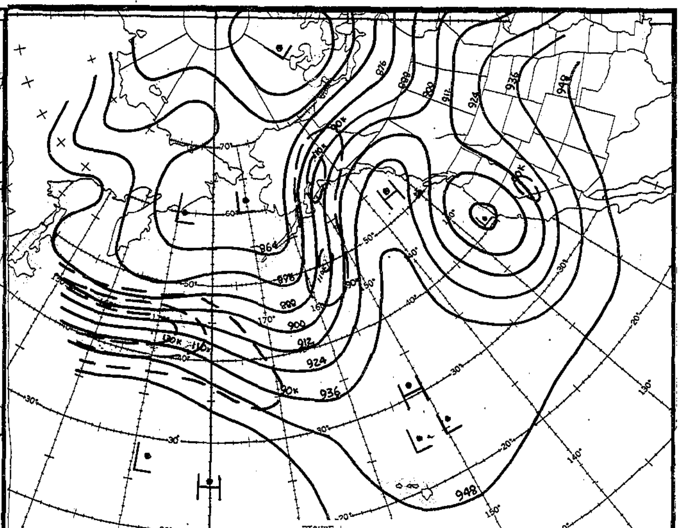

FIGURE 4.
300mb Analysis 0000Z, Wed. April 24, 1974

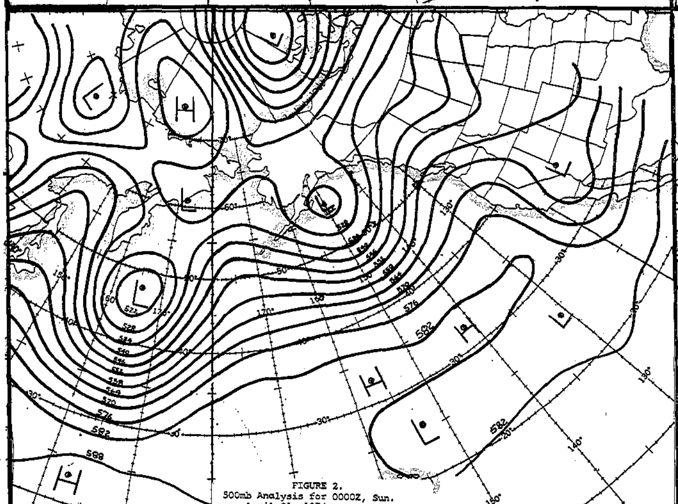

FIGURE 2.
500mb Analysis for 0000Z, Sun. April 21, 1974

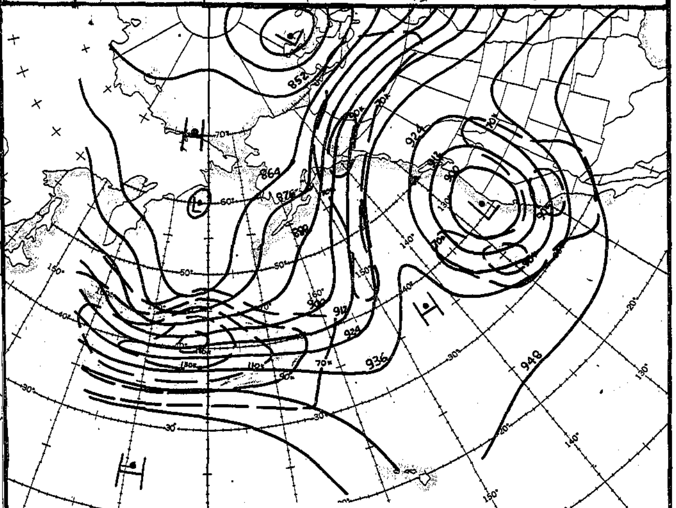

FIGURE 5.
300mb Analysis 0000Z, Thu. April 25, 1974

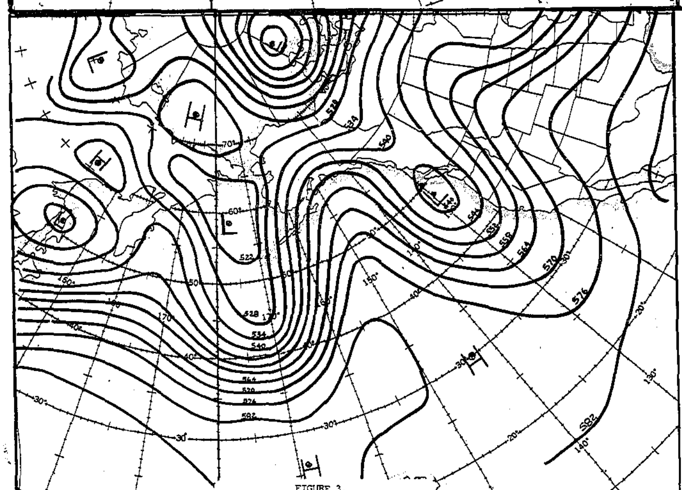

FIGURE 3.
500mb Analysis for 0000Z, Tu. April 23, 1974

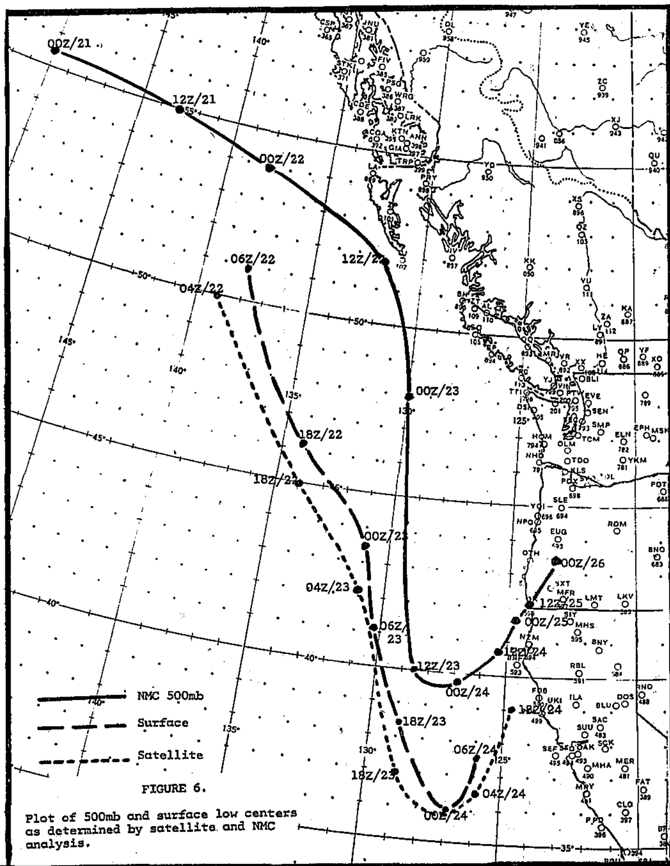

FIGURE 6.

Plot of 500mb and surface low centers as determined by satellite and NMC analysis.

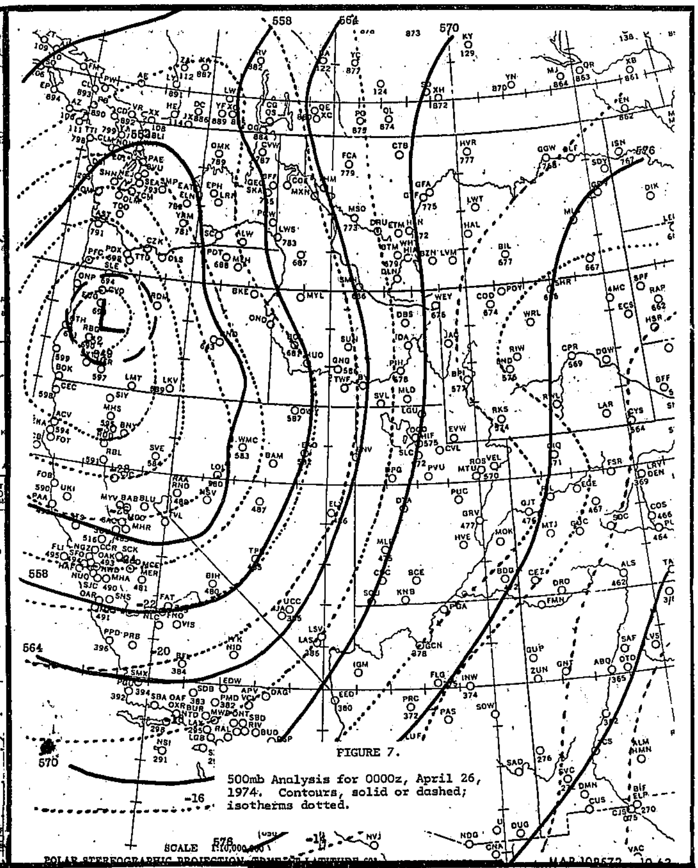

FIGURE 7.

500mb Analysis for 0000z, April 26, 1974. Contours, solid or dashed; isotherms dotted.

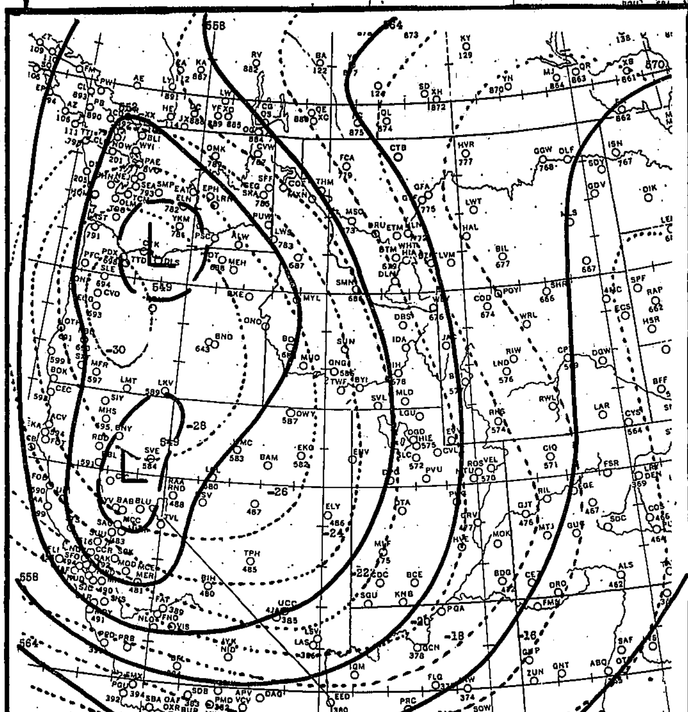

FIGURE 8.

500mb Analysis for 1200Z, April 26, 1974. Contours, solid or dashed; isotherms dotted.

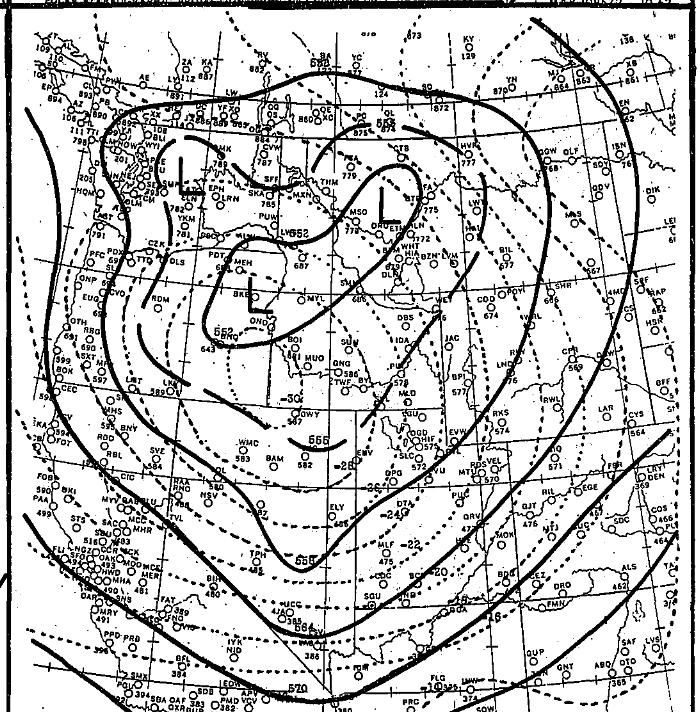

FIGURE 9.

500mb Analysis for 0000Z, April 27, 1974. Contours, solid or dashed; isotherms dotted.

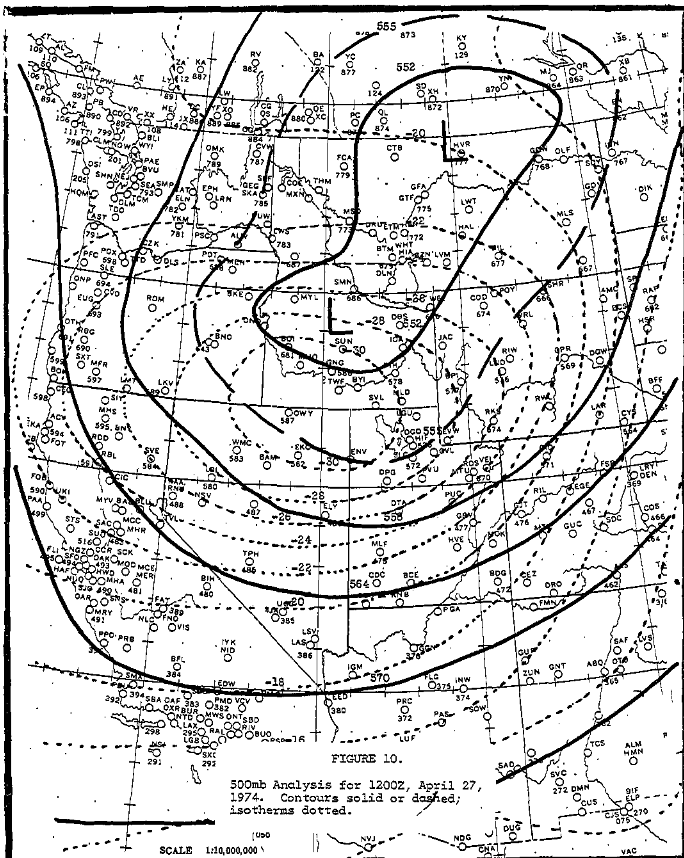

FIGURE 10.

500mb Analysis for 1200Z, April 27, 1974. Contours solid or dashed; isotherms dotted.

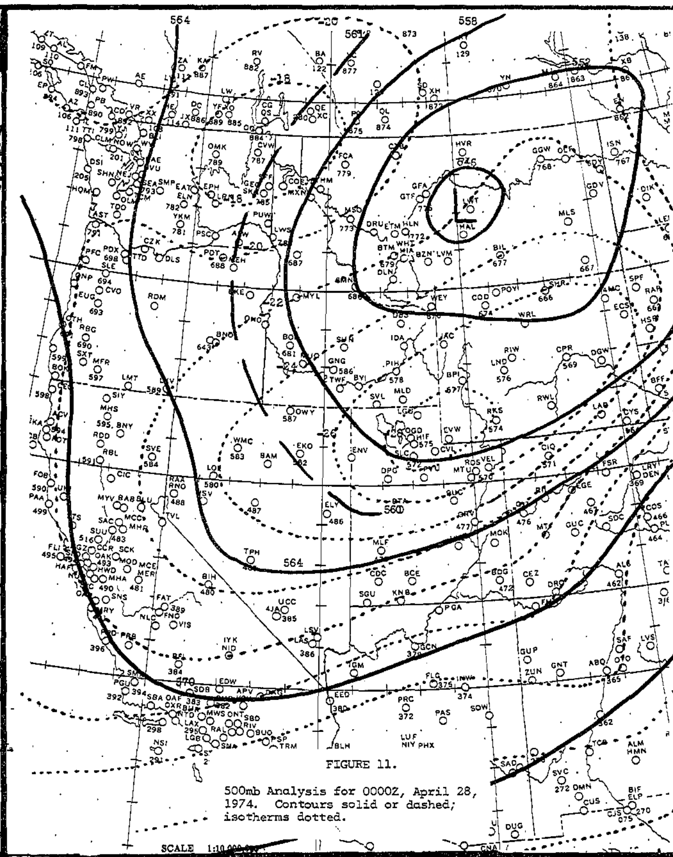

FIGURE 11.

500mb Analysis for 0000Z, April 28, 1974. Contours solid or dashed; isotherms dotted.

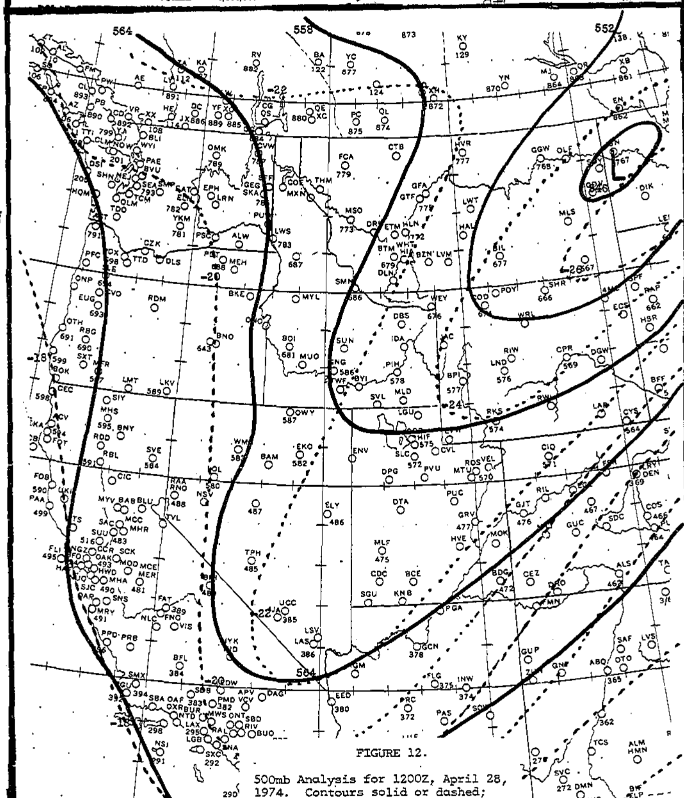

FIGURE 12.

500mb Analysis for 1200Z, April 28, 1974. Contours solid or dashed; isotherms dotted.

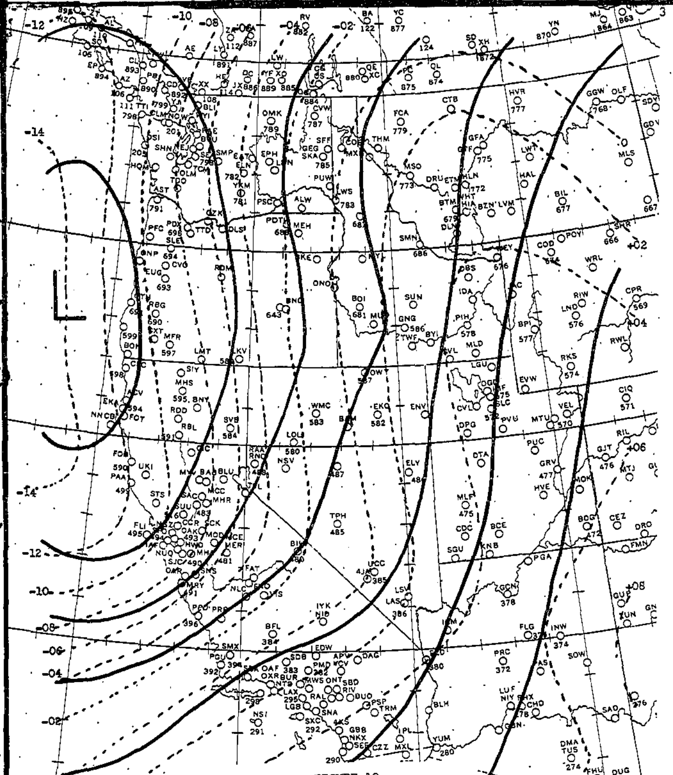

FIGURE 13.

700mb Analysis for 1200Z, April 23, 1974. Contours solid; isotherms dashed.

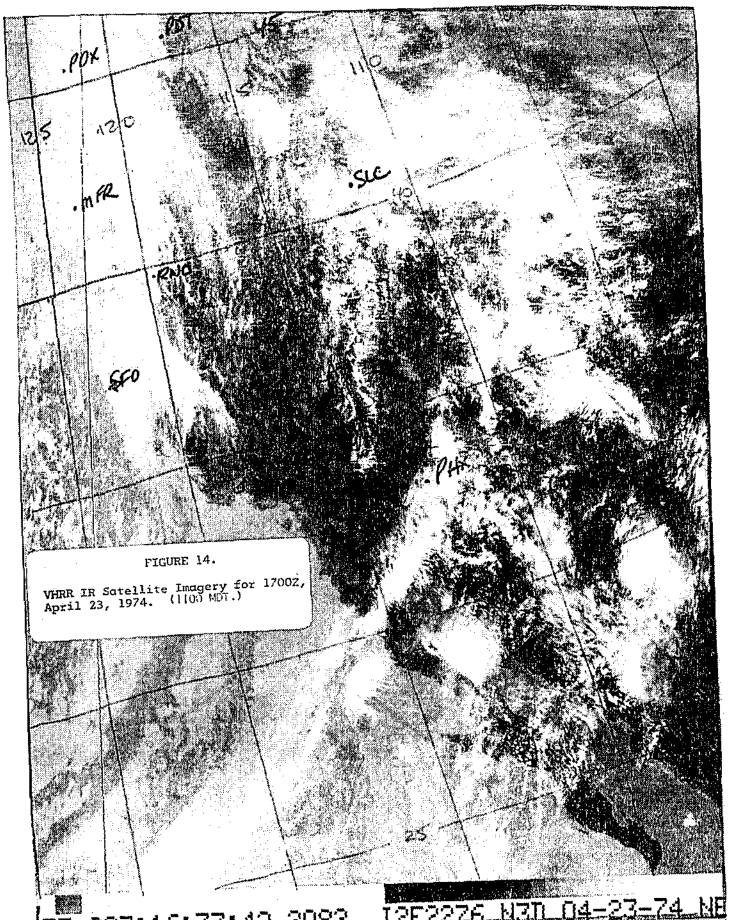

FIGURE 14.

VHRR IR Satellite Imagery for 1700Z, April 23, 1974. (1100 MDT.)

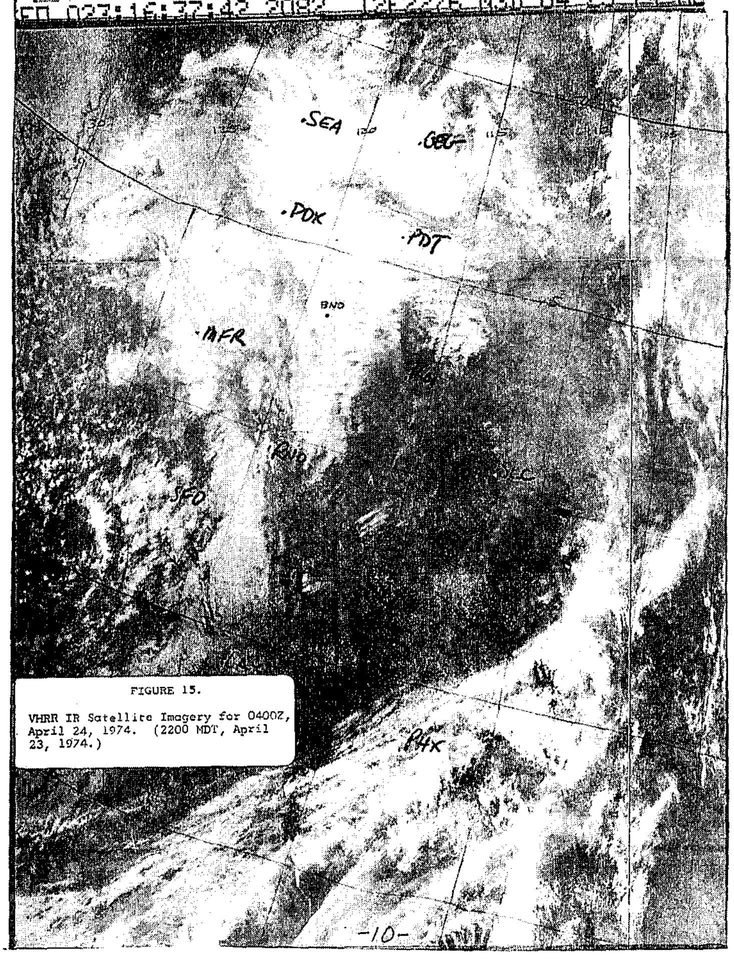

FIGURE 15.

VHRR IR Satellite Imagery for 0400Z, April 24, 1974. (2200 MDT, April 23, 1974.)

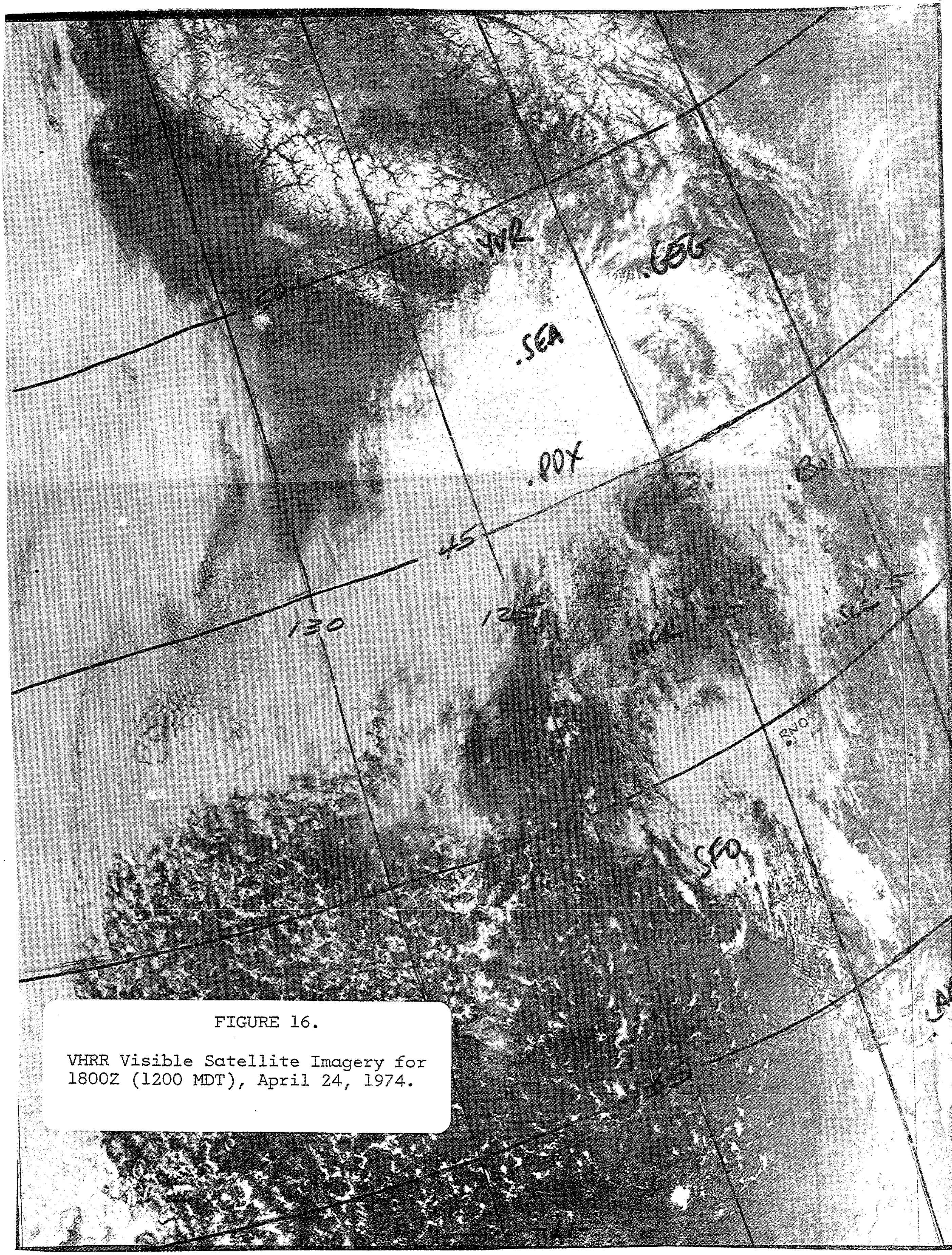

FIGURE 16.

VHRR Visible Satellite Imagery for 1800Z (1200 MDT), April 24, 1974.

FIGURE 17.

VHRR IR Satellite Imagery for 1700Z April 24, 1974 (1100 MDT).

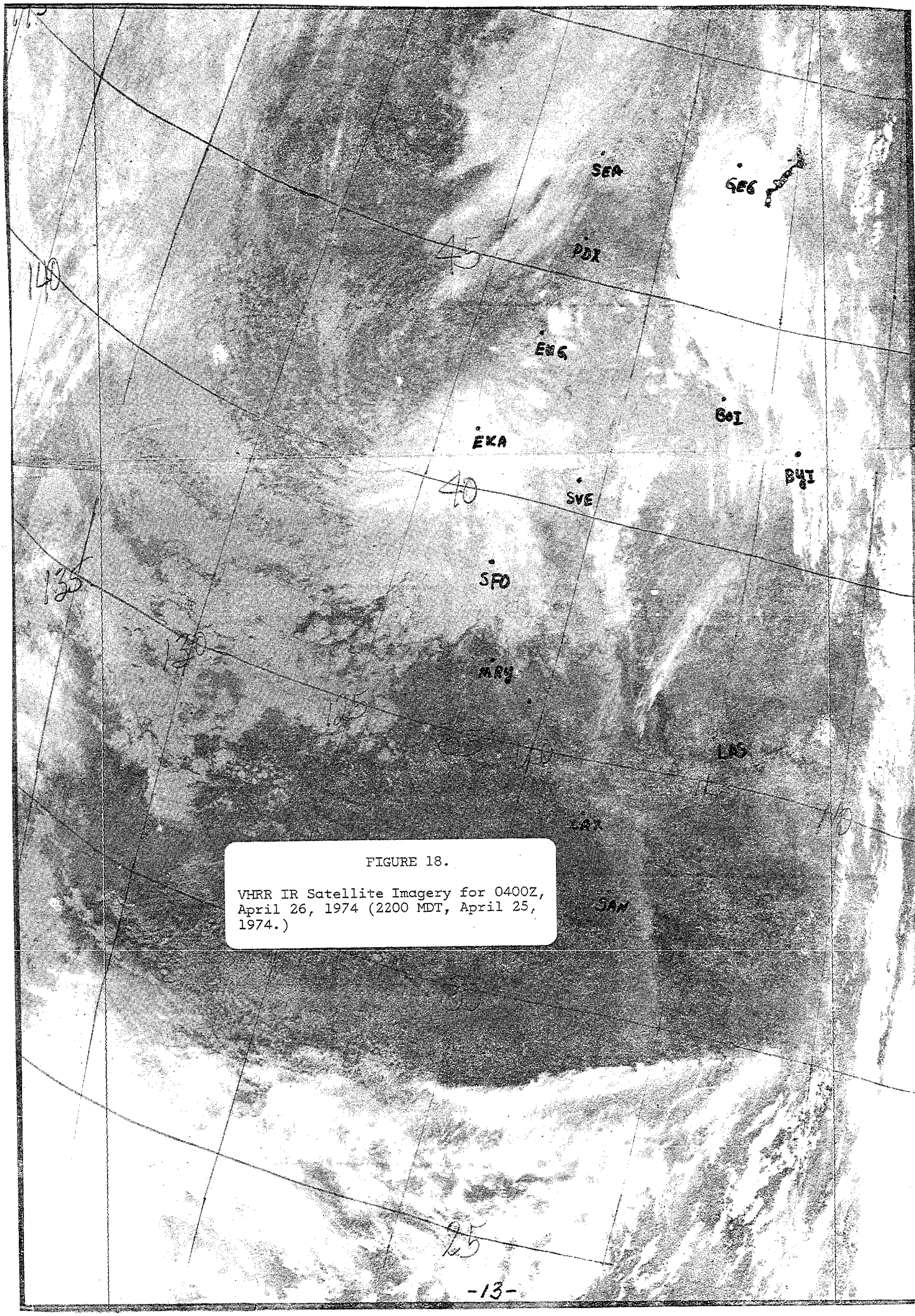

FIGURE 18.

VHRR IR Satellite Imagery for 0400Z, April 26, 1974 (2200 MDT, April 25, 1974.)

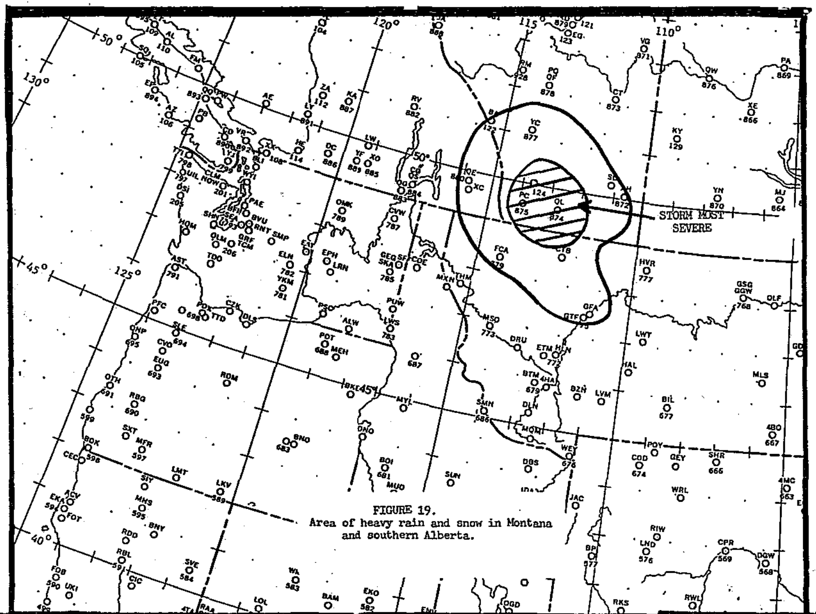

FIGURE 19.
Area of heavy rain and snow in Montana and southern Alberta.

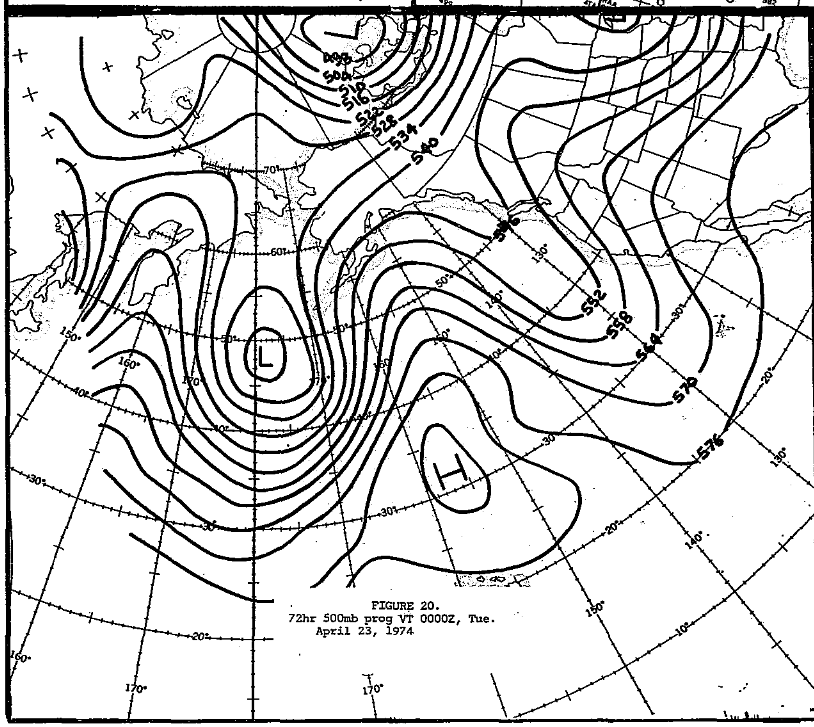

FIGURE 20.
72hr 500mb prog VT 0000Z, Tue. April 23, 1974

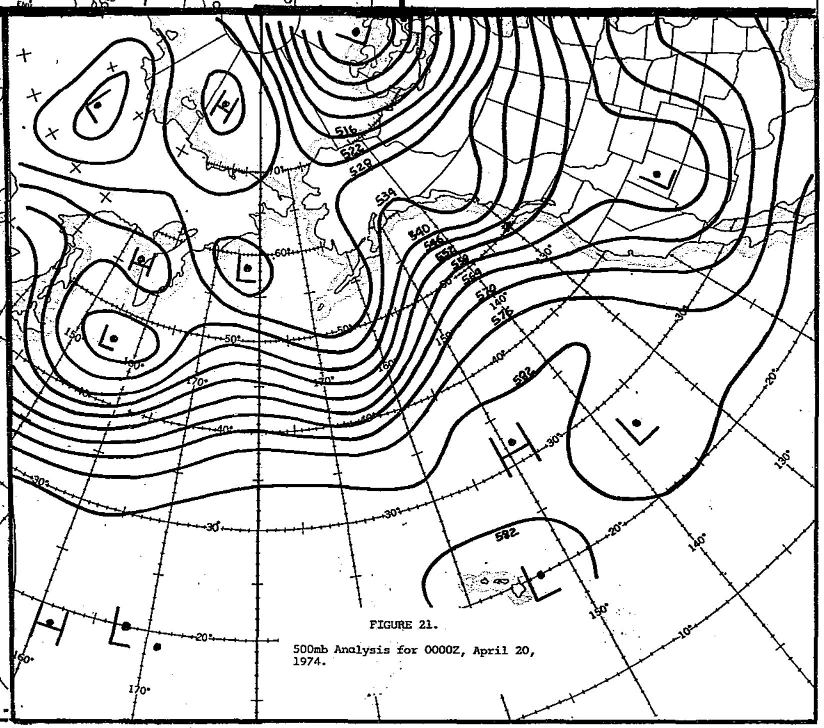

FIGURE 21.
500mb Analysis for 0000Z, April 20, 1974.

Figure 22a. Initial Analysis, 1200Z, Monday, April 22, 1974.

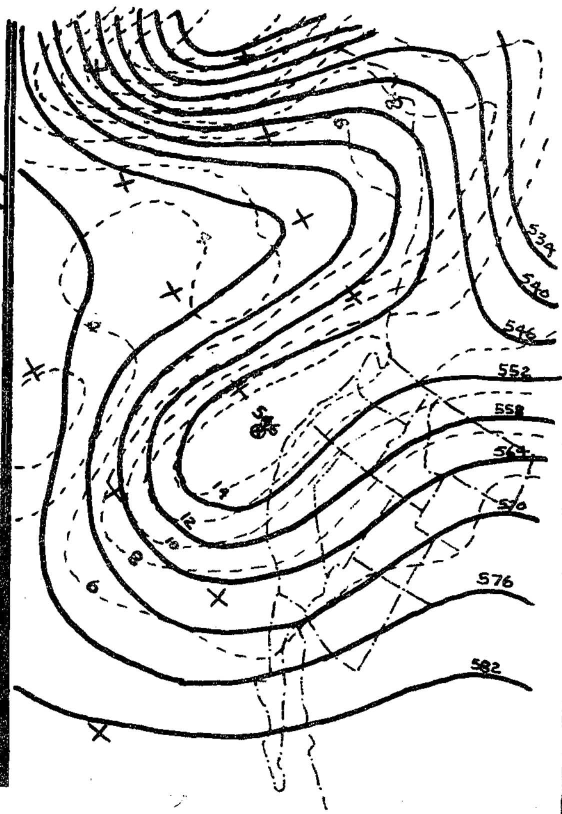

Figure 22b. 36-Hour PE Prog VT 0000Z, Wednesday, April 24, 1974.

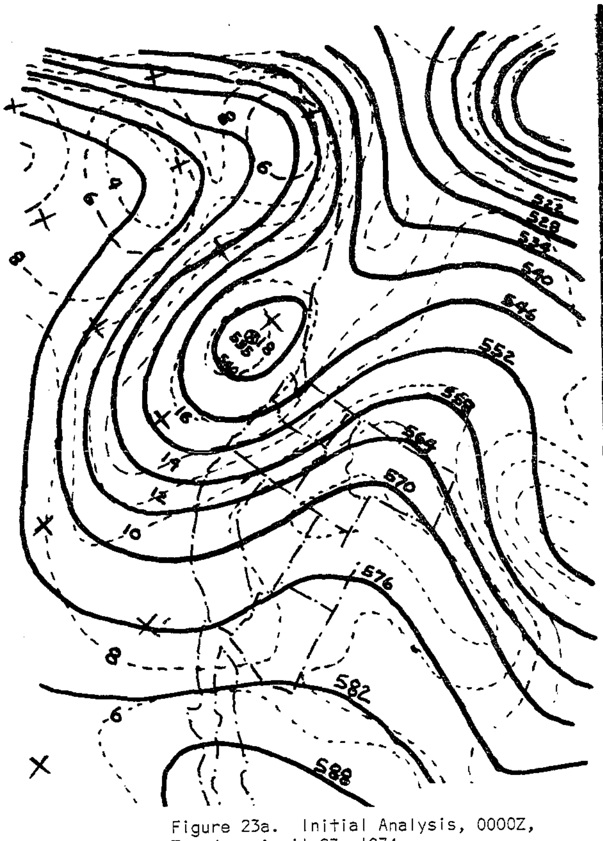

Figure 23a. Initial Analysis, 0000Z, Tuesday, April 23, 1974.

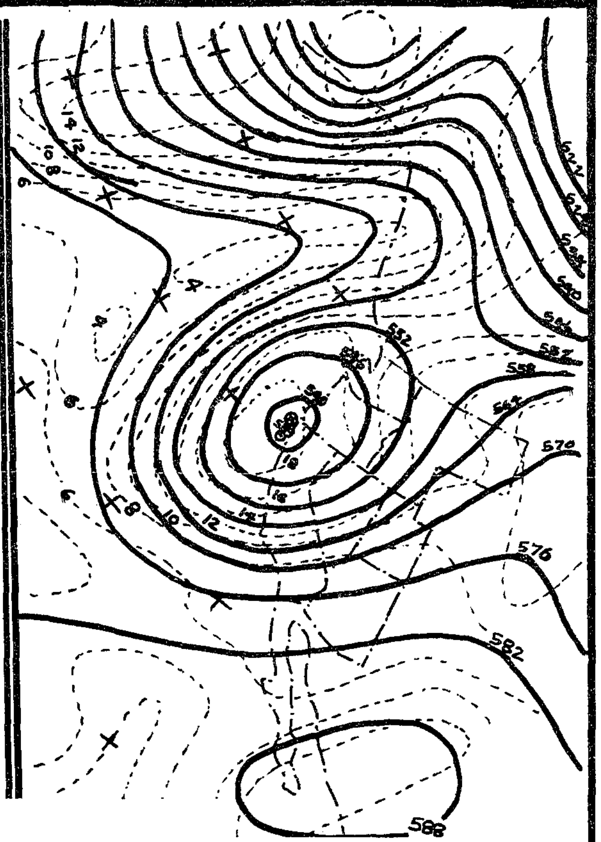

Figure 23b. 36-Hour Barotropic Prog VT 1200Z, Wednesday, April 24, 1974.

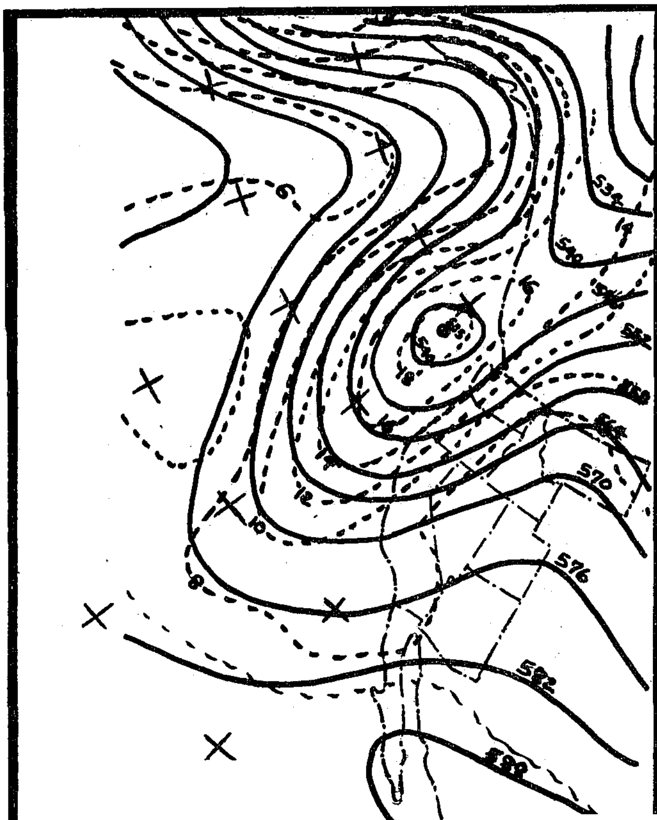

Figure 24a. Initial Analysis, 0000Z, Tuesday, April 23, 1974

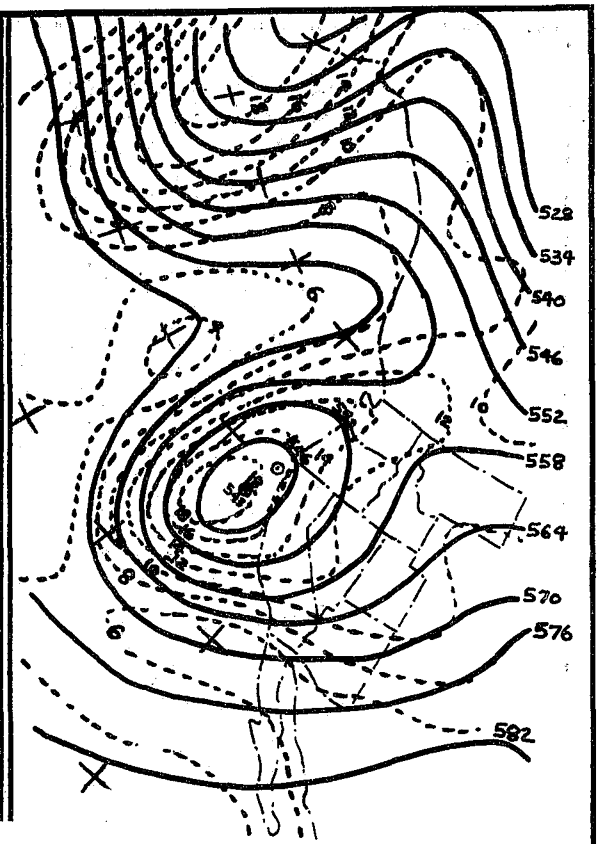

Figure 24b. 36-Hour PE Prog VT 1200Z, Wednesday, April 24, 1974.

Figure 25a. Initial Analysis, 1200Z, Tuesday, April 23, 1974.

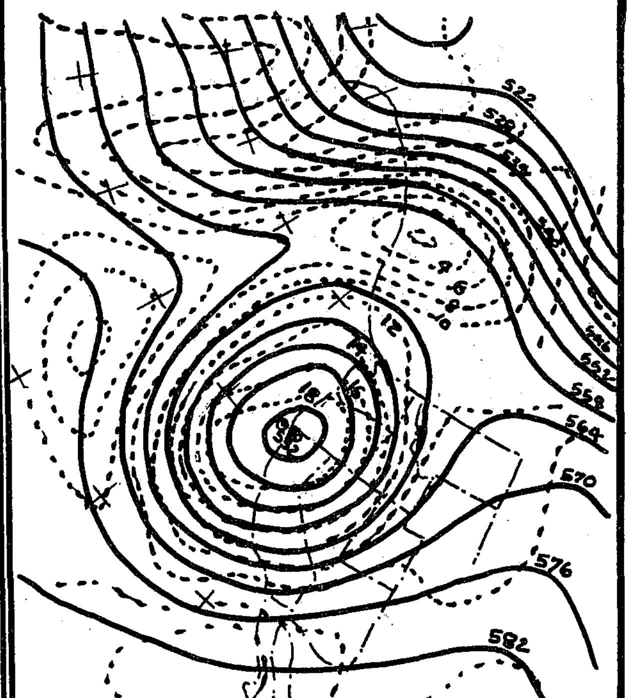

Figure 25b. 36-Hour Barotropic Prog VT 0000Z, Thursday, April 25, 1974.

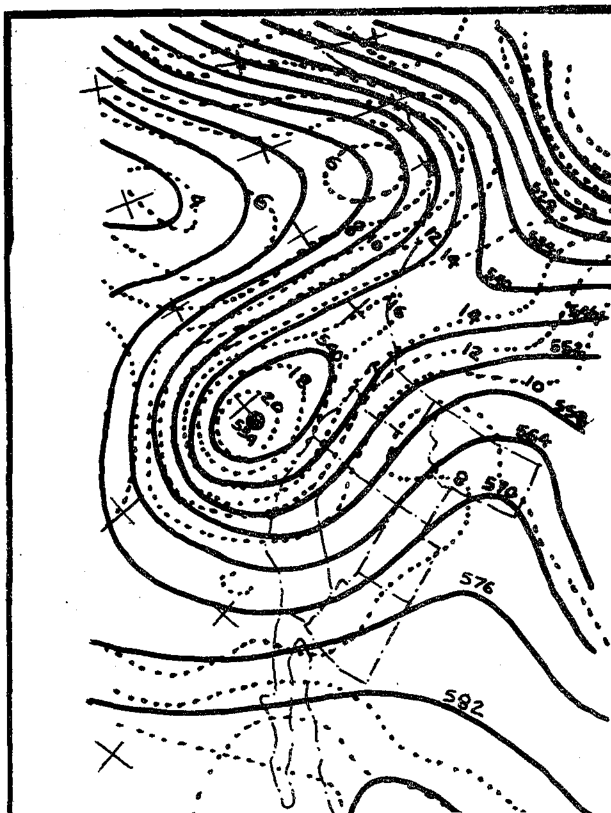

Figure 26a. Initial Analysis, 1200Z, Tuesday, April 23, 1974.

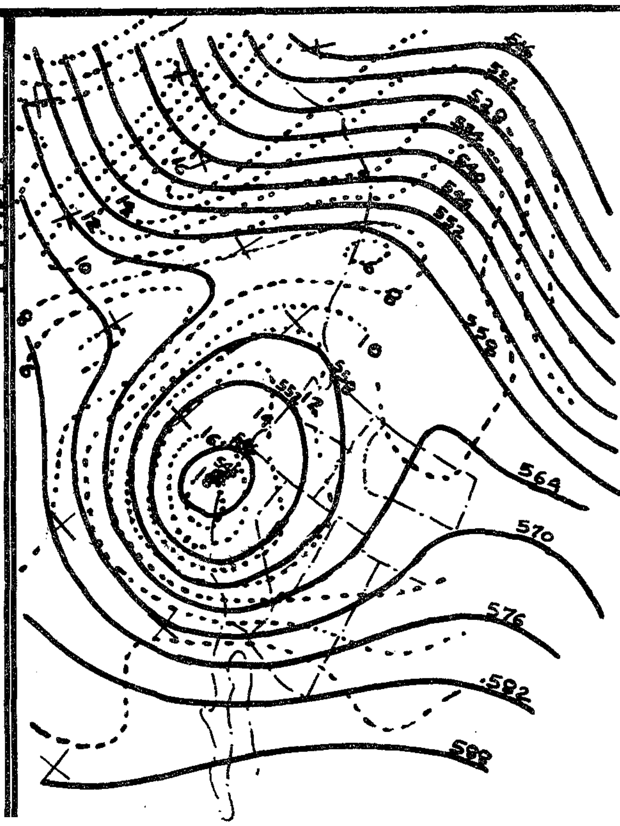

Figure 26b. 36-Hour PE Prog VT 0000Z, Thursday, April 25, 1974.

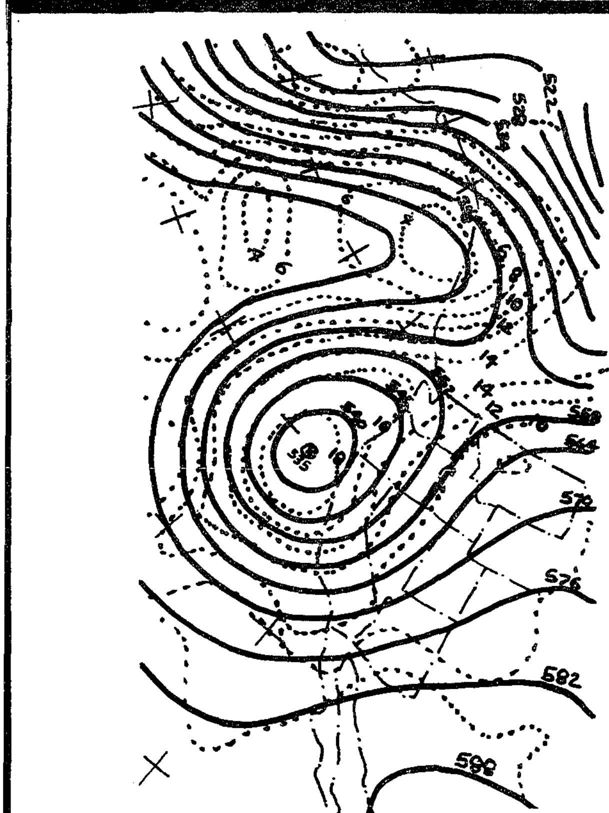

Figure 27a. Initial Analysis, 0000Z, Wednesday, April 24, 1974.

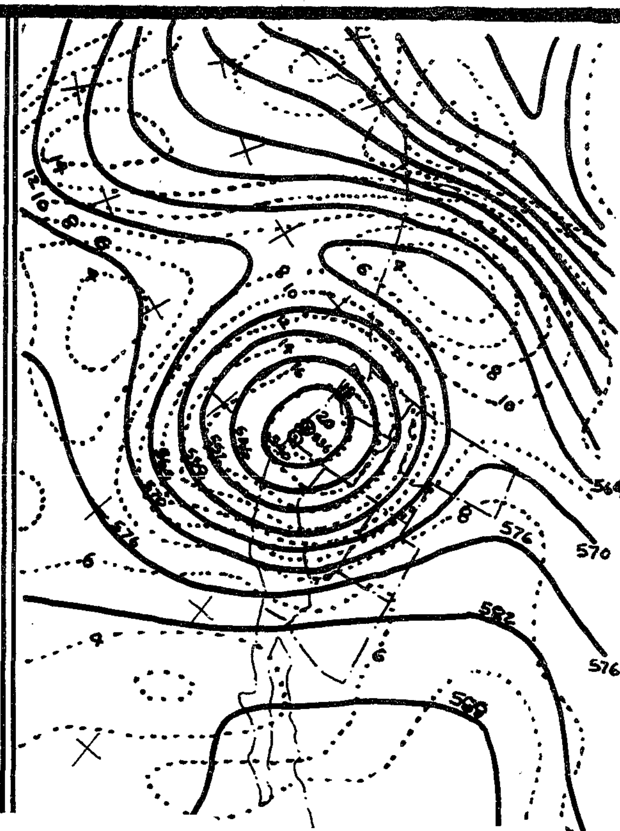

Figure 27b. 36-Hour Barotropic Prog VT 1200Z, Thursday, April 25, 1974.

Figure 28a. Initial Analysis, 0000Z, Wednesday, April 24, 1974.

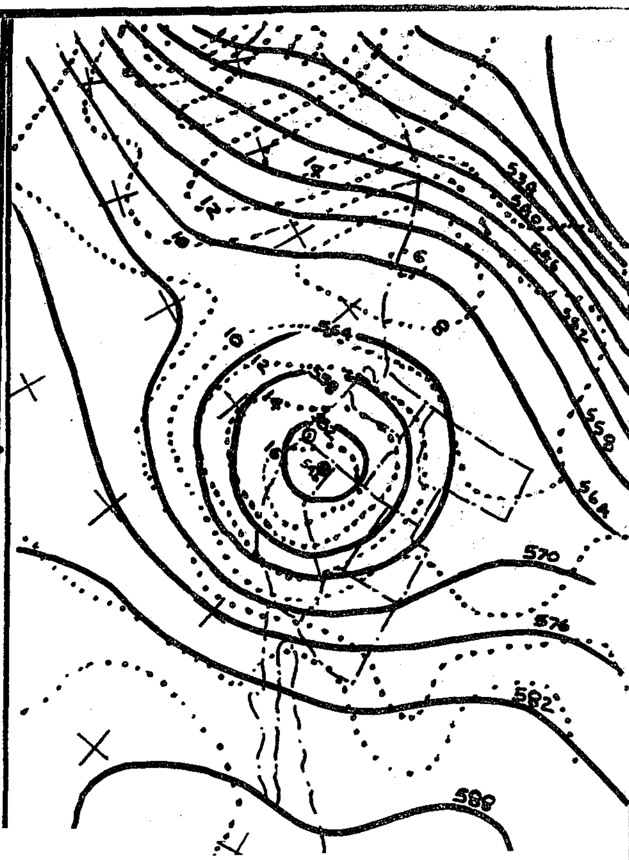

Figure 28b. 36-Hour PE Prog VT 1200Z, Thursday, April 25, 1974.

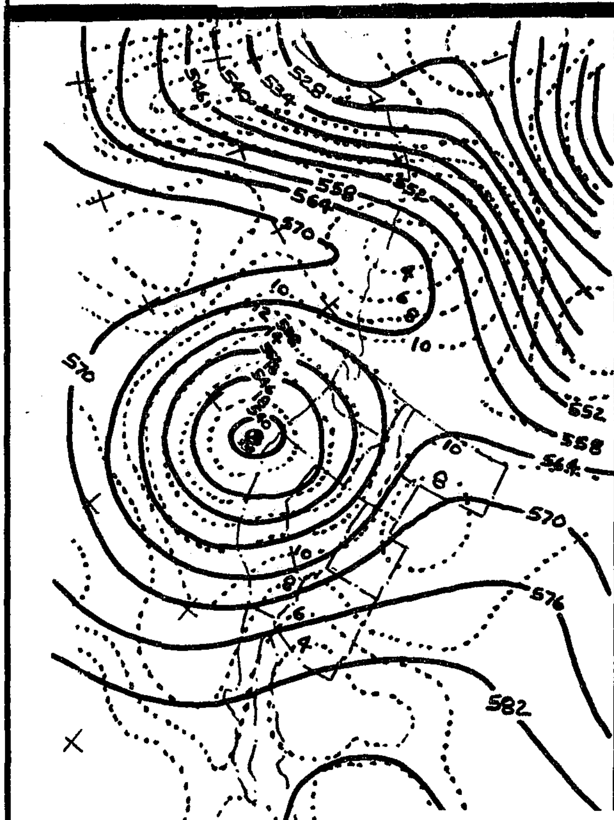

Figure 29a. Initial Analysis, 1200Z, Wednesday, April 24, 1974.

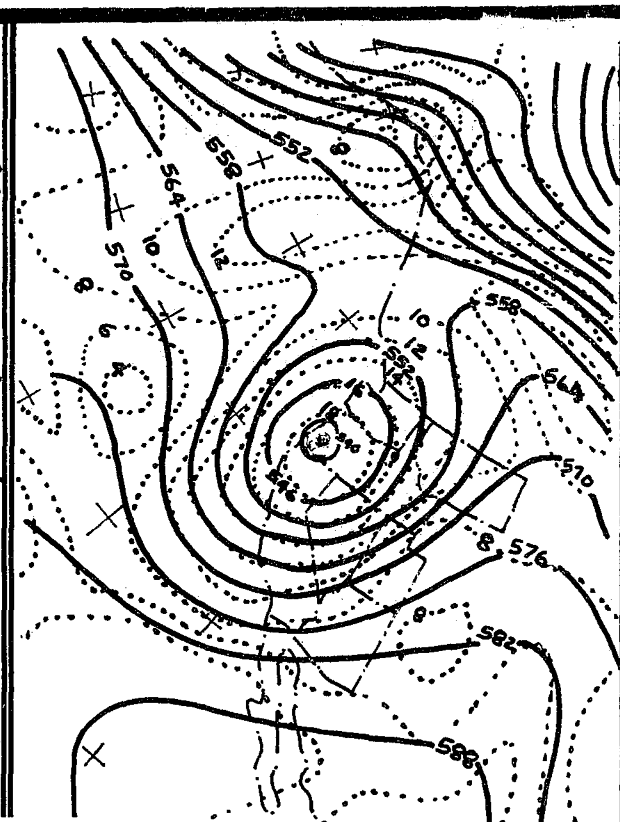

Figure 29b. 36-Hour Barotropic Prog VT 0000Z, Friday, April 26, 1974.

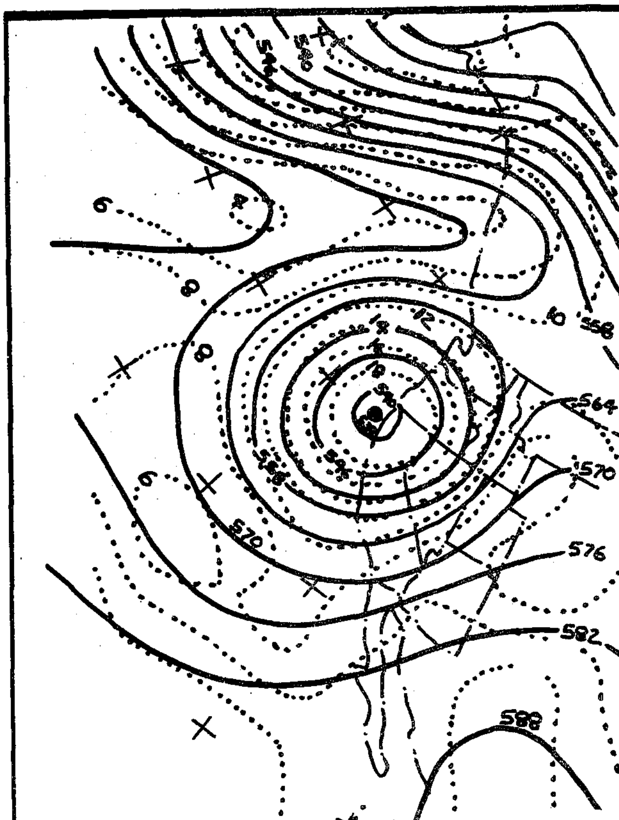

Figure 30a. Initial Analysis, 1200Z, Wednesday, April 24, 1974.

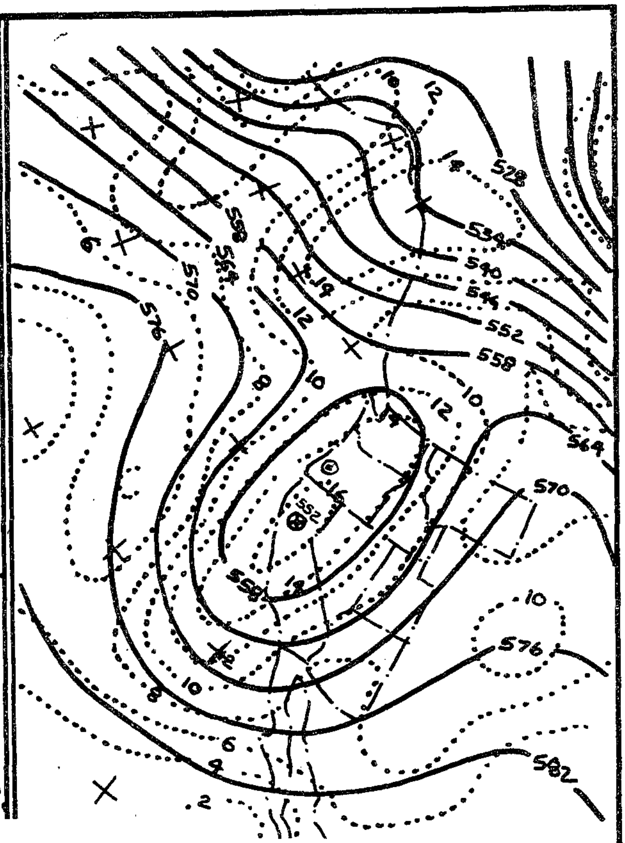

Figure 30b. 36-Hour PE Prog VT 0000Z, Friday, April 26, 1974.

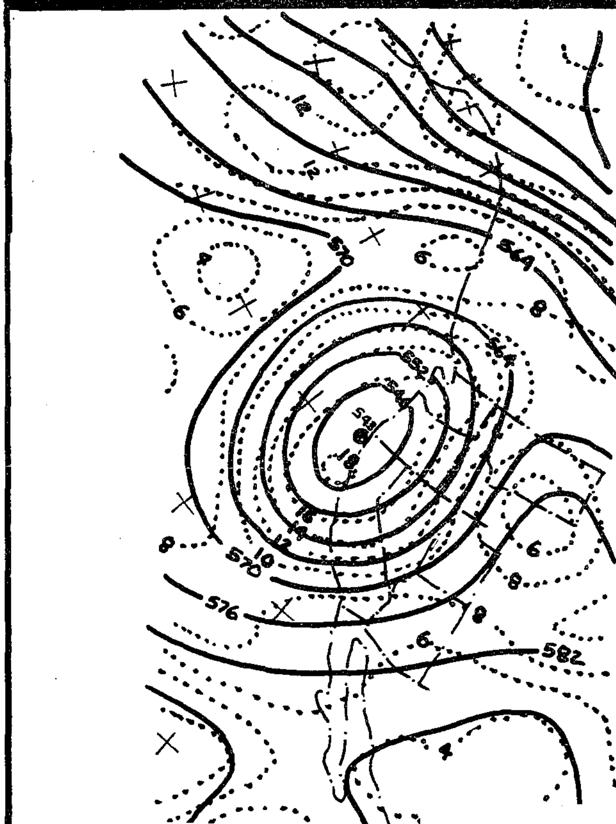

Figure 31a. Initial Analysis, 0000Z, Thursday, April 25, 1974.

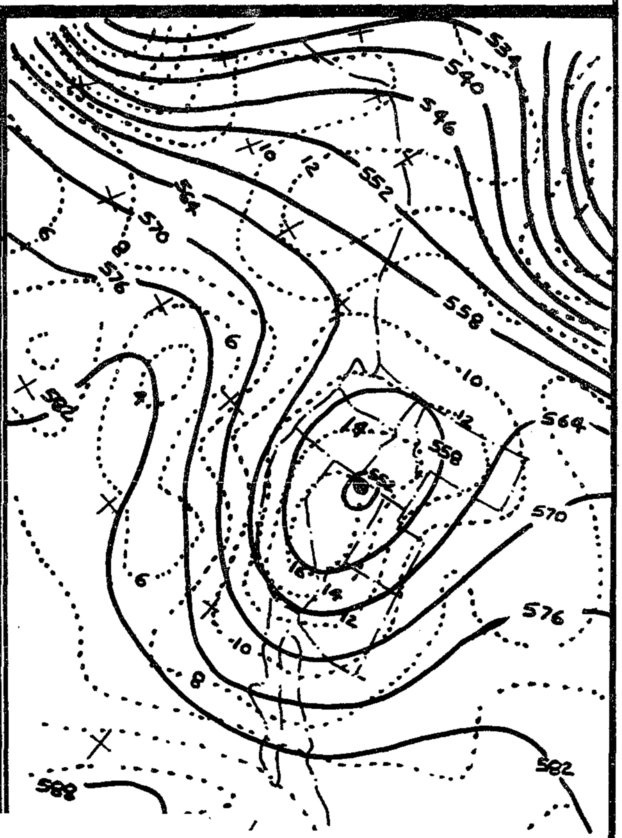

Figure 31b. 36-Hour PE Prog VT 1200Z, Friday, April 26, 1974.

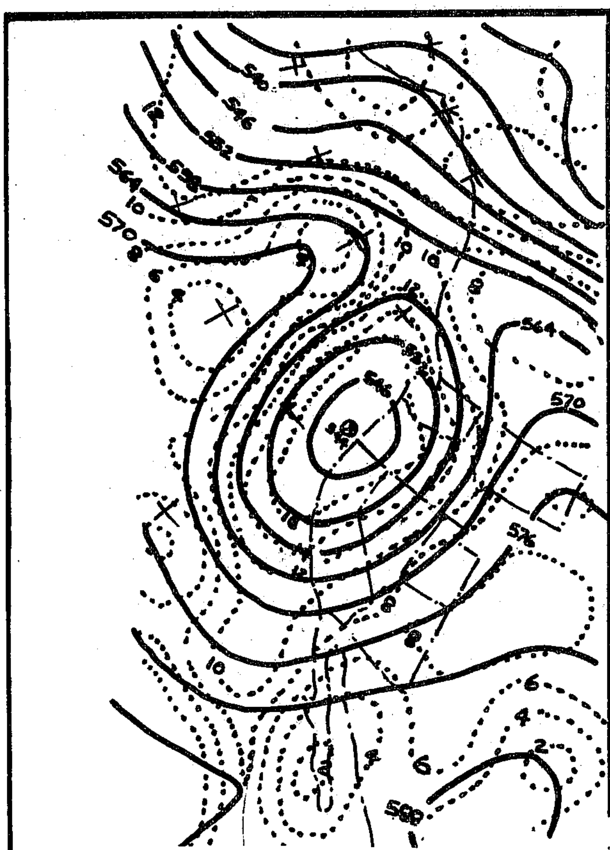

Figure 32a. Initial Analysis, 1200Z, Thursday, April 25, 1974.

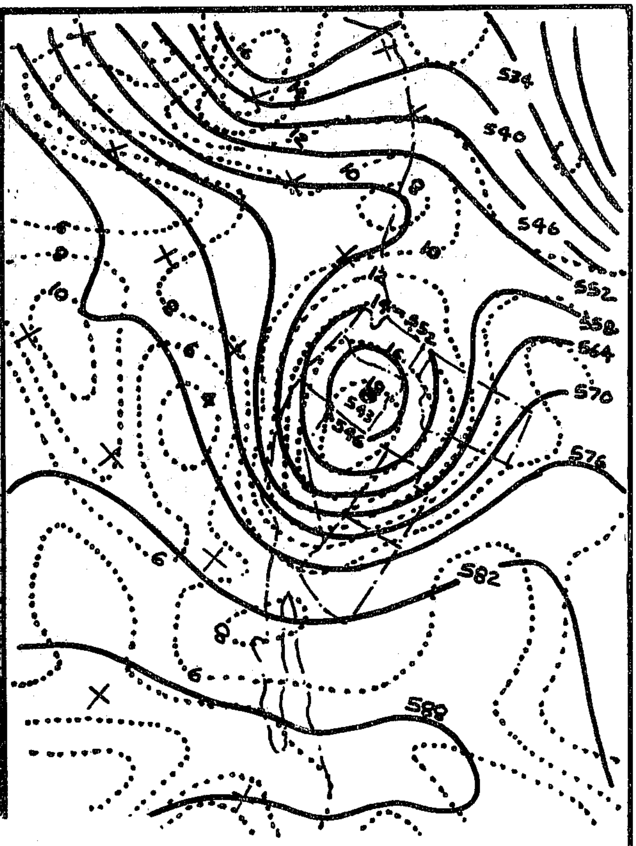

Figure 32b. 36-Hour Barotropic Prog VT 0000Z, Saturday, April 27, 1974.

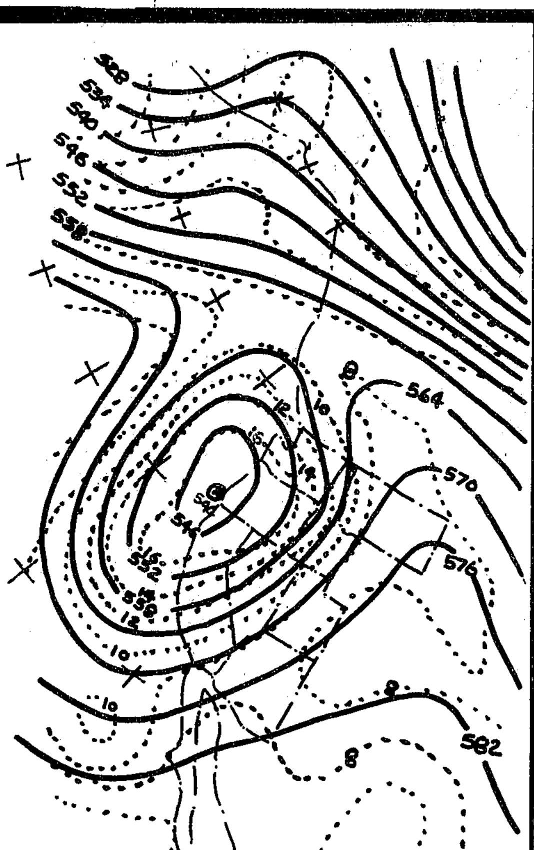

Figure 33a. Initial Analysis, 1200Z, Thursday, April 25, 1974.

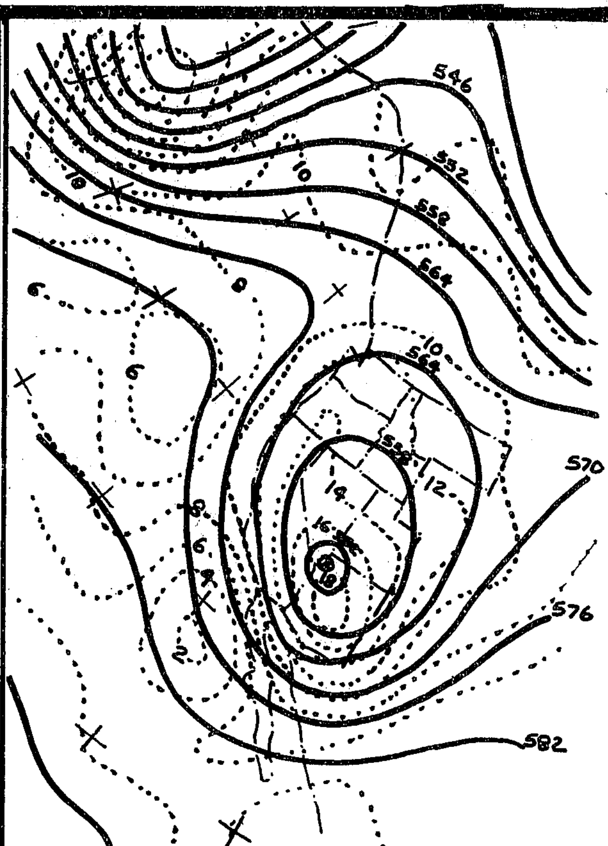

Figure 33b. 36-Hour PE Prog VT 0000Z, Saturday, April 27, 1974.

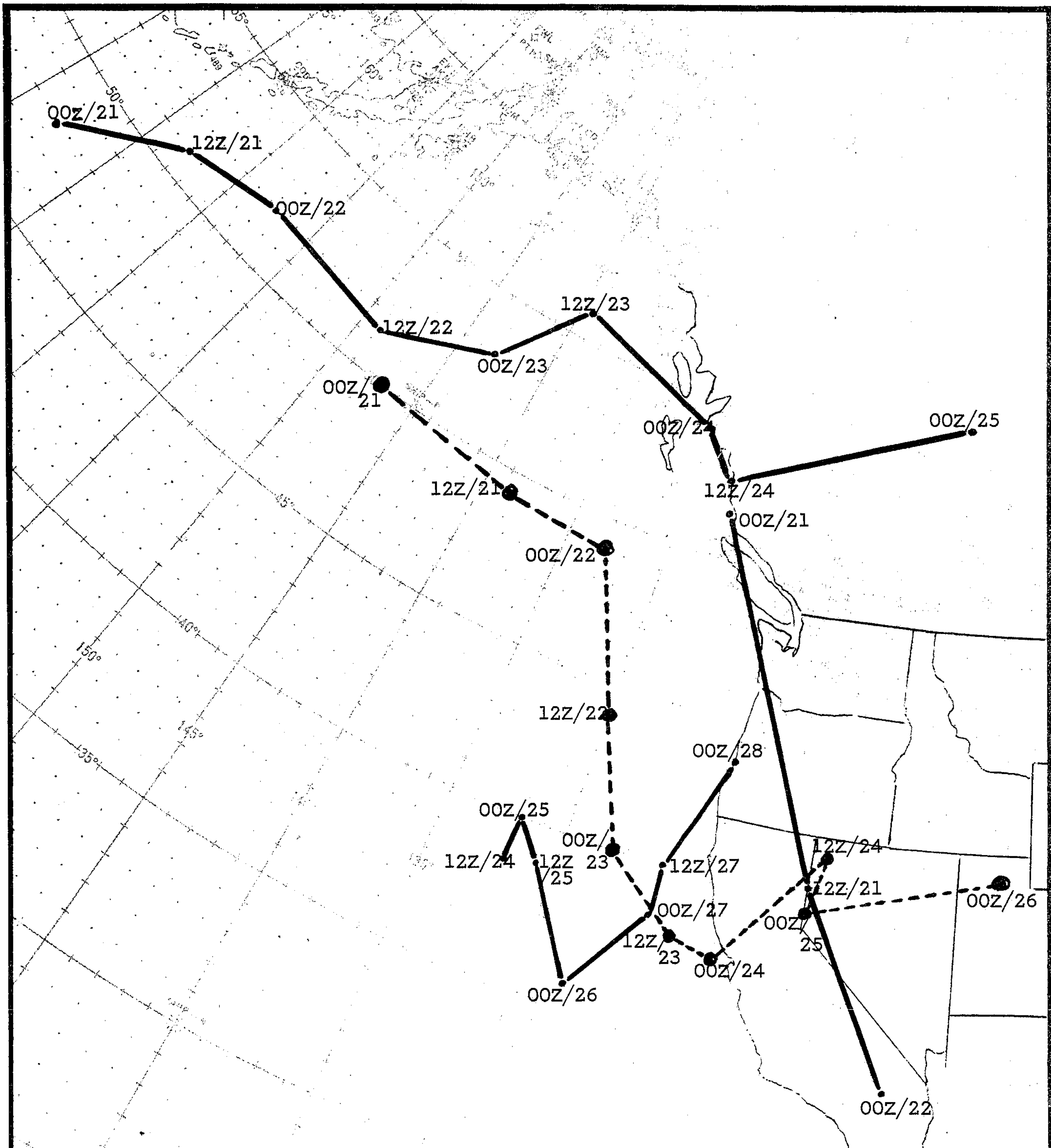

FIGURE 34. Centers of 24-Hour Height Changes at 500 mb.

RISES ——— FALLS - - - -

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