EXAMPLES, APPLICATIONS, AND PROBLEMS
OF
THREE CASE STUDIES
OF
TIROS PICTURES

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PREFACE

This report was compiled by the Advanced Synoptic Laboratory of the Meteorology Department at the University of Wisconsin. The class members were for the most part experienced weather forecasters but had little or no experience in the interpretation of satellite photographs.

Using current TIROS 10 photographs furnished to us daily by ESSA, we have attempted to explain the pictures in terms of synoptic data and terrain features. The three case studies and the problems of interpretation are discussed.

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CASE STUDY I

November 5, 1965

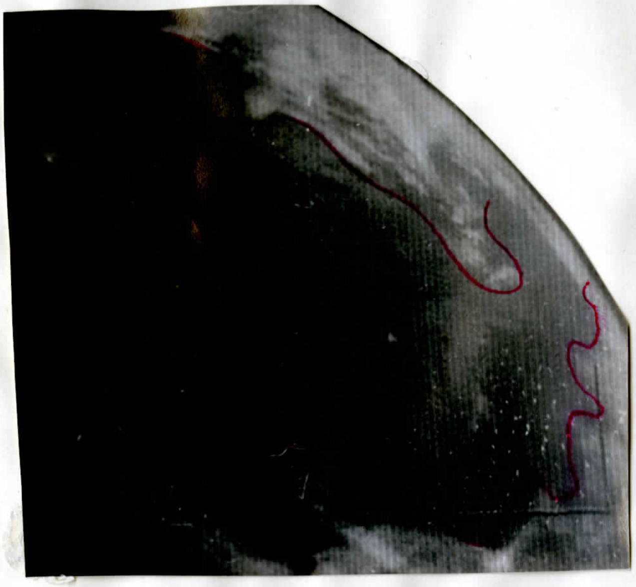


Figure 1

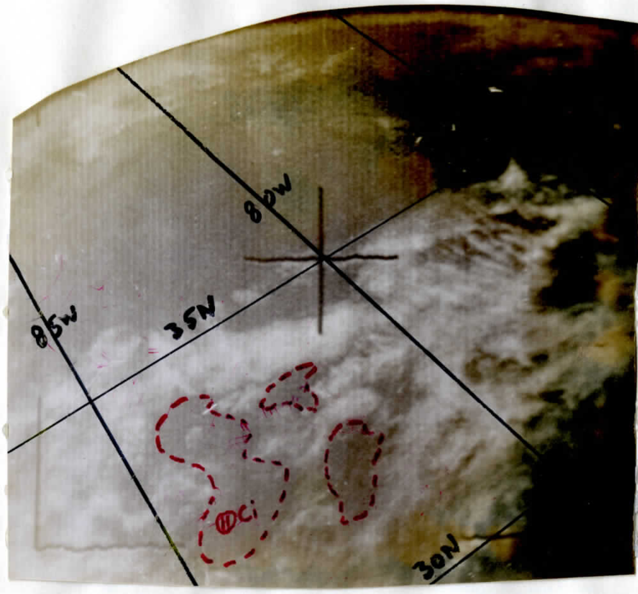


Figure 2

Figure 3

EXAMPLE A

Figures 1, 2, and 3 show the TIROS 10 pictures for the eastern coastline of the United States and were taken at about 1100 EST on November 5, 1965. Figures 4 and 5 are the 0600 EST 700 mb map and the horizontal weather depiction chart (HWD) for the same day.

Figure 3 clearly illustrates the boundary of the middle cloud layer and the clear area to the north of it. This can be correlated with the analysis on Figure 5. As a matter of fact, the picture gives a better idea of this boundary than the HWD analysis.

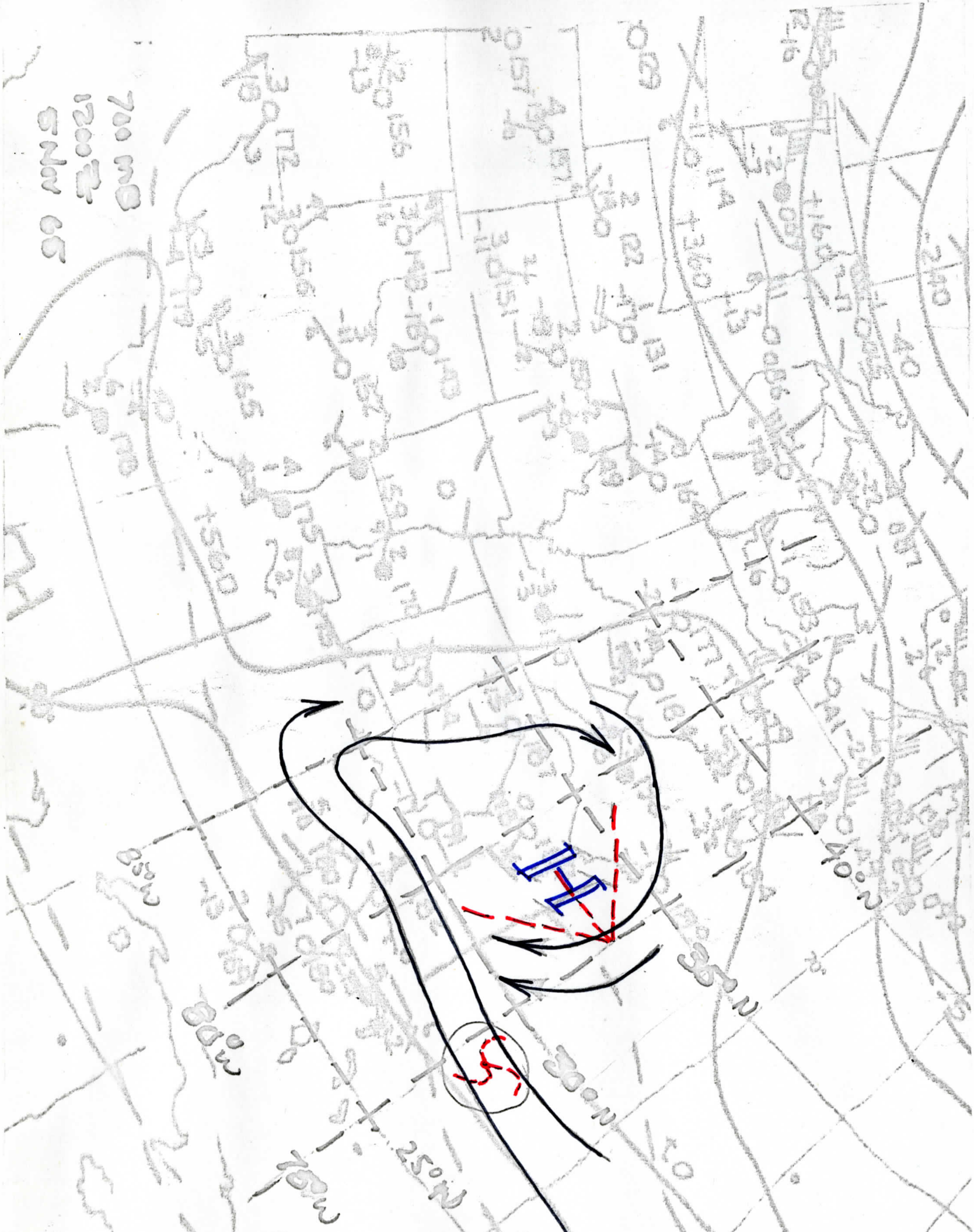


FIG. 4.

Fig. 4.

5 Nov 1965
1300 EST
HWD CHART

FIG 5.

A notable discrepancy between the pictures and the HWD is seen in Figure 2. In what appears to be a clear area in the picture, the HWD notes the presence of broken to overcast cirrus.

The cloud structure observed in Figures 2 and 3 is hard to correlate to the synoptic situation as best exemplified by the 700 mb map. A radial cloud pattern seen in the pictures is right in the area of a strong anticyclone. Also of interest is a vortex pattern off the Florida coast (circled in red). As no detailed data for this oceanic area is available, no explanation of this cloud pattern is attempted.

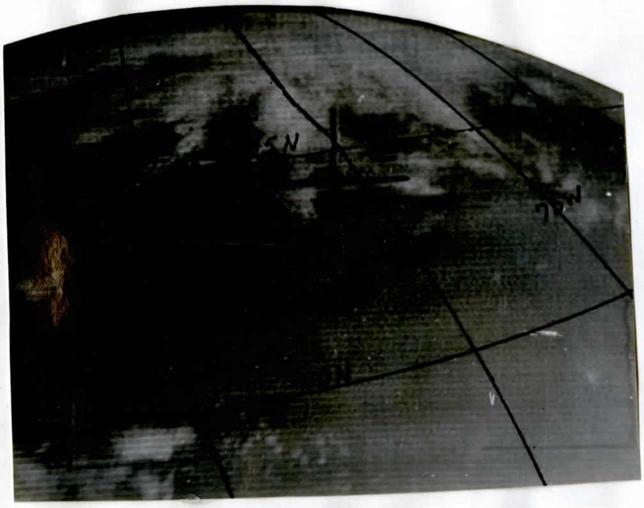


Figure 6
1100 CST, Nov. 5, 1965

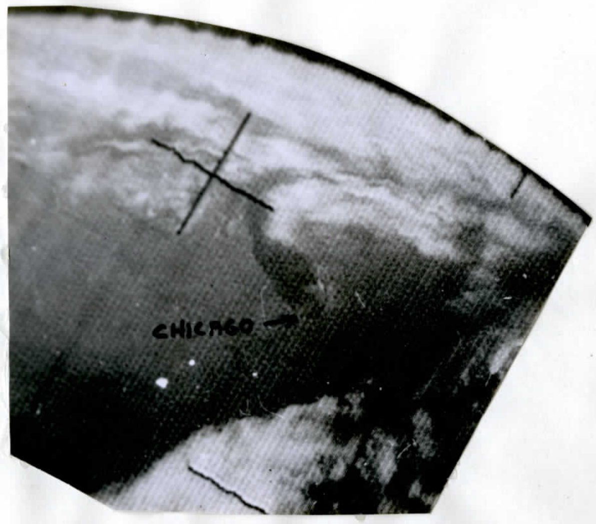


Figure 7
1100 CST, Nov. 14, 1965

EXAMPLE B

As can be seen from Figure 4, the Great Lakes area is under the influence of a strong anticyclone, with the resultant stratification and reduced visibilities due to pollution in the industrial areas. This reduction in visibilities is noted on the HWD chart, as well as in Figure 6 above. The contrast between Lake Michigan and the surrounding land is small, as both are covered by a partially reflecting haze and smoke layer.

In comparison, the contrast between land and water for the same area is much greater in Figure 7. Taken on November 14, when cyclonic northerly winds predominated in the area, pollution was at a minimum and visibilities were good.

The above example shows the necessity of obtaining a "contrast atlas" for various locations and for various seasons. In such a manner the increase in turbidity relative to a clear day (with good visibilities) could be obtained. It could also be used as an aid in detecting cirrus clouds.

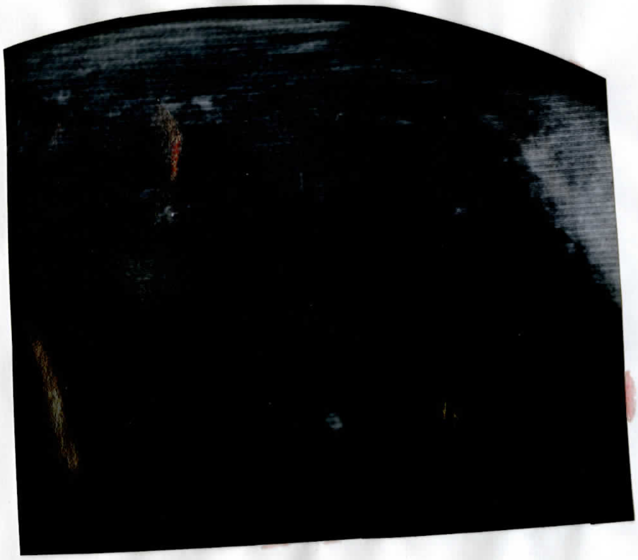


Figure 8

Figure 9

EXAMPLE C

The difficulty of detecting a uniform cirrus overcast is best illustrated by the two photographs above. The apparently cloudless sky allows us to detect various surface terrain features, such as the snow covered Mt. Elbart, the vegetation of the Rio Grande valley, and the forested highlands of the mountains.

By comparing the above pictures with Figure 10 (HWD for about the same time as the pictures), we detect the presence of widespread cirrus over most of the area. Using the HWD data, it is possible, with some imagination, to draw in the cirrus boundary as has been done for Figure 9. As pointed out previously, it would be possible to estimate the optical thickness of the cirrus

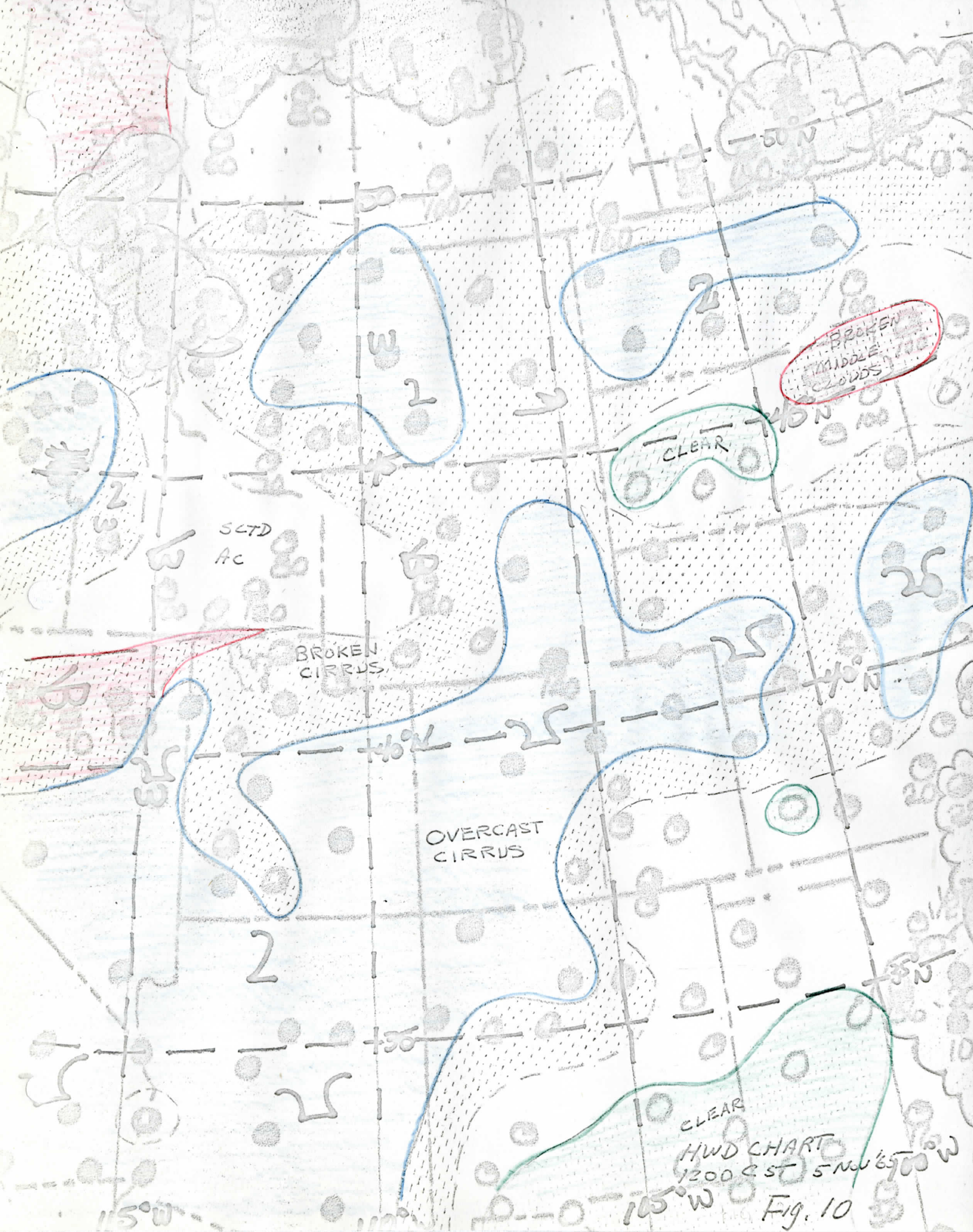

BROKEN
MIDDLE CLOUDS
CLEAR
SCTD
Ac
BROKEN
CIRRUS
OVERCAST
CIRRUS
CLEAR
HWD CHART
1200 CST 5 Nov '65

Fig. 10

if the contrast between the surface features for a clear day were available.

An interesting problem was presented by the bright spot at 33°N and 106°W seen in Figure 8. Initial attempts to explain this as a valley fog or thunderstorm were futile. After consulting a geological atlas, it was determined that this is the location of White Sands, New Mexico, an area of several hundred square miles of white gypsum sand with no vegetation cover.

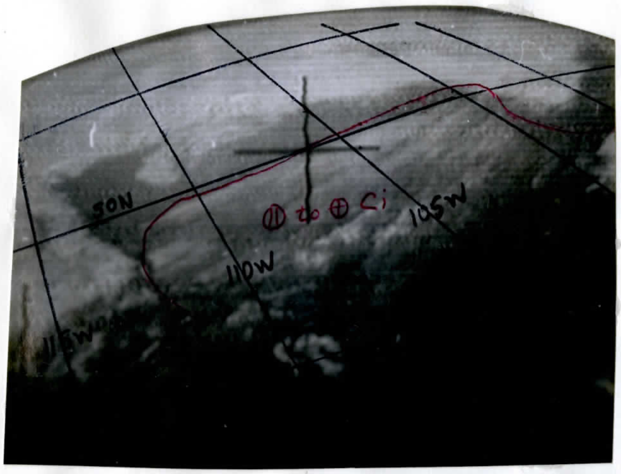


Figure 11

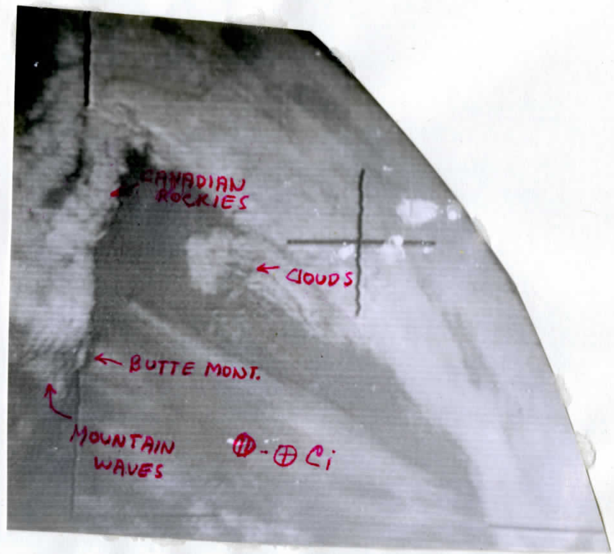


Figure 12

EXAMPLE D

A case where the cirrus is non-uniform is illustrated in Figure 11. The bands seen in this picture are not obvious from the HWD chart for this area, and in this case the satellite data gives much additional information. A glance at Figure 13 indicates that this is the approximate area of the jet stream, and it is possible to imply the northern boundary of the jet stream from Figure 12 where the cirrus bands are seen to disappear north of 50°N.

The presence of jet stream is also borne out by the presence of mountain waves in the region of Butte, Montana on the eastern slope of the Rocky Mountains. This is seen in Figure 12.

This picture also illustrates the difficulty in separating clouds from snow cover, such as that seen over the Canadian Rockies. This indicates the necessity of supplying the analyst with at least a weekly atlas of the snow cover over the region of interest.

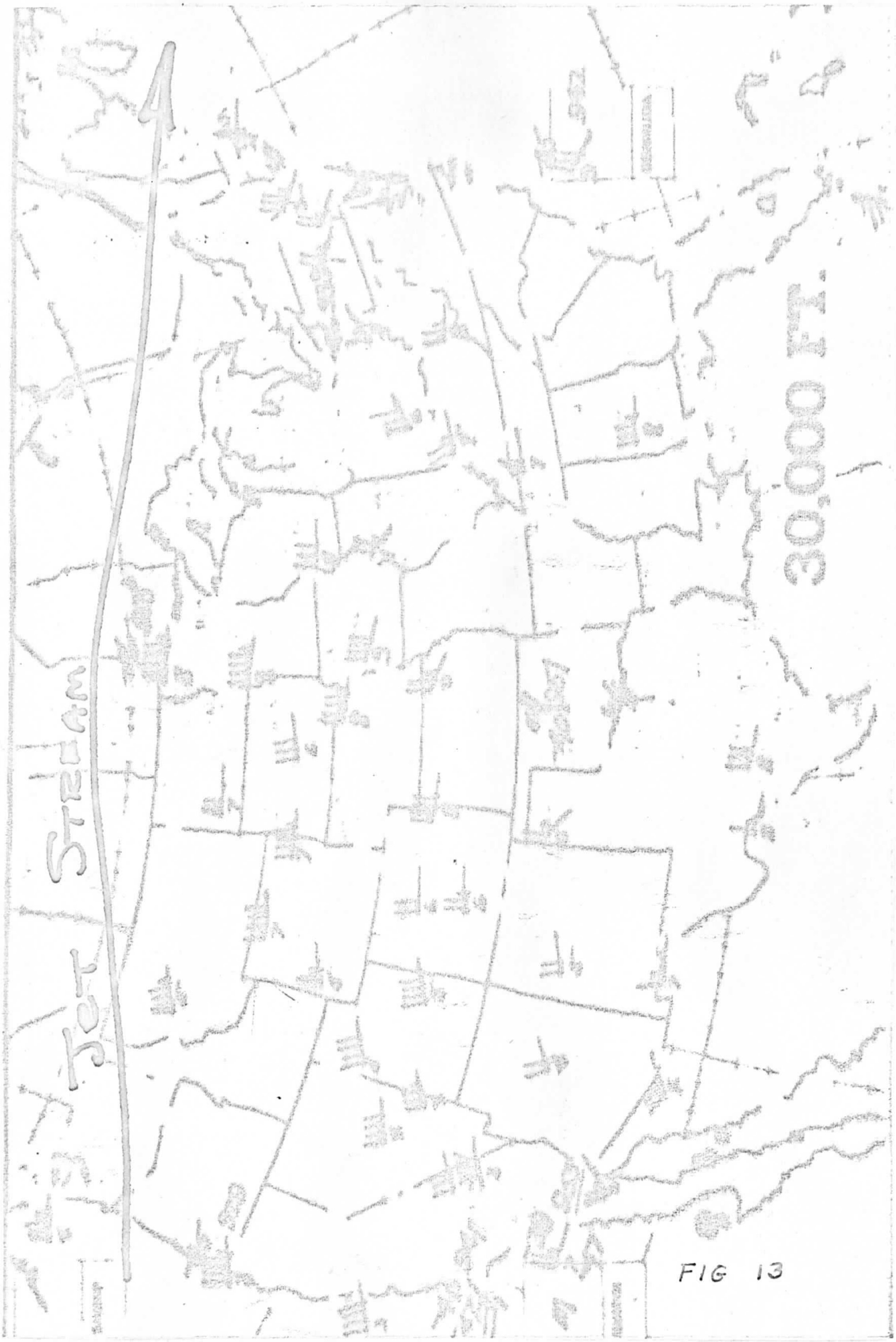


FIG 13

30,000 Ft. Winds at 0500 CST 4 Nov. 1965

SUMMARY AND CONCLUSIONS

The photographs studied in this paper were different from those previously discussed in class in that they did not deal with cyclonic storm systems, but rather with fair weather situations. From Example A, it appears that it is very difficult to correlate the observed cloud patterns with specific synoptic situations. The other examples illustrate the kind of information that can be obtained from satellites over fair weather areas.

The greatest difficulties encountered in the analysis were:

a. Detection of thin cirrus clouds.

b. Interpretation of cloud patterns previously unknown.

c. Distinguishing surface features and snow cover from actual clouds.

d. Separating low clouds from fog and from middle clouds. (Cirrus, when seen, presented no such problem.)

The greatest information obtained was:

a. Exact boundary of low and middle clouds (assuming the gridding is accurate).

b. Presence of cirrus bands over otherwise cloudless surface.

c. Location of jet stream and/or turbulence from the presence of the cirrus bands and mountain wave clouds.

The most useful tool to have when interpreting pictures associated with a fair weather pattern would be an atlas of reflectivity of the surface for a clear, cloudless day revised to indicate the presence of snow cover and the reflectivity changes due to seasonal changes in vegetation. An equally great aid would come from infrared data which would help in determining cloud heights and hence possibly the presence of thin cirrus clouds.

CASE STUDY II

November 6, 1965

The first part of this report refers to a series of eight pictures taken over the West Coast of North America. The first of the series, shown in Figure 1a, ranges from Alaska to southern British Colombia.

The most outstanding feature shown in Figure 1a is the long arc of clouds with a very sharp shadow cast by the northern edge. The band appears to be the most dense mass of clouds in the picture. To the far left of the picture is a less dense patch of clouds, probably stratus and fog. The clouds toward the south are well associated with the occlusion shown by the surface map (Figure 2). The TIROS cloud patterns were superimposed on this map and show a well-defined spiral of subsiding air behind the occlusion. The patches of clouds are probably bands of strato-cumulus. North of the arc, differentiation of clouds from snow is difficult. The sharp boundary extending north of the arc marks the mountain ranges from low coastal regions. Some river valleys can be seen cutting through the snow-covered mountains. Although some stations north of the arc are reporting snow falling, indicating cloudiness, this cloudiness cannot be distinguished from the snow cover.

Several analyses were attempted to help explain the arc around 57°N. This arc does not appear in the general cyclonic circulation of the surface low on the surface chart. However, several streamline analyses help explain the arc (Figure 3). The 700 and 500 mb streamline analyses correlated well with the arc, while the 200 mb did not. The convergence zone matched the sharp edge of the arc in the 700 and 500 mb charts.

A cross-section (Figure 4) and a complete sounding of Tatoosh Island (798) were constructed to further explain the cloud mass. The deep moisture supply up to 400 mb is shown by the sounding as well as by the blue zone in the cross section, where temperature and dew point differences do not exceed 5°C. The potential temperature surfaces (shown in orange on the cross section) give a lifting mechanism to produce saturation. The peak of isentropic upslope is at the point where the arc is observed. Saturation may be present up to 370 mb if complete upslope motion is assumed. Consequently, clouds up to 20,000 ft. appear likely. In the region north of 57°N subsidence and lack of moisture make clouds, if any, rather thin.

In summary, the curved band of clouds is in a region of considerable lifting of a deep moist layer. The strong flow aloft, as shown by the streamline analyses, carries these clouds into the arc that is observed.

The second series of pictures covers an area near $95^{\circ}W$ over the upper midwest of the United States. A surface weather depiction chart was prepared from the hourly aviation observations, and the pictures were used to improve this depiction chart. The surface observations aided in the interpretation of the pictures.

The surface analysis for 1500 GMT shows that the area of concern is dominated by the western extremity of an east-west ridge with two weak fronts. The surface flow was weak and fog and stratus clouds had developed over much of the area.

The surface weather depiction (Figure 5) was analyzed without reference to the TIROS pictures. The pictures were then compared with this analysis and corrections were made in red. Areas "A" and "C" show regions which were analyzed without low clouds, but which are in reality overcast. Areas "B" and "D" are shown as cloudy but are really cloud-free. Area "E" is less defined in the picture but appears to have less middle cloudiness than was shown in the analysis. It is difficult to find evidence in the picture of the position of the edge of the stratocumulus clouds in southern Canada; it is likely that this is obscured by middle cloudiness above.

It is evident that in this case the cloud pictures provided significant detail which could not be obtained even with a dense surface observation network. The improvement in detail would be quite valuable for the aviation forecaster both in pilot briefing and also in terminal forecasting.

At the same time, the surface observations not only aided in the interpretation of the pictures but also provided important additional information. With the surface observations there is no doubt that the bright clouds over Iowa are stratus. They also indicate that the cloudiness farther north is middle level cloudiness; a fact not evident from the TIROS pictures.

The conclusion reached from this part of the study is that it is essential to combine the standard surface observations with the cloud photographs if the maximum information is to be obtained.

From these two case studies several general conclusions can be reached: First, a knowledge of the geography and terrain is essential. For example, in the first case what was originally thought to be the coastline of North America, turned out to be the snow line of the mountains. What was originally interpreted as water turned out to be low lying coastline and islands off the coast, thus it was impossible to distinguish between the water and the vegetation of the low lying land areas.

Second, surface observations should be used as much as possible to "calibrate" the picture. If features over land stations are properly identified, similar features may be used to interpolate over data sparse regions. Without surface observations, for example, it would be difficult, if not impossible, to distinguish between snow and cloud cover.

Third, high contrast in the picture is desirable to maximize differences in shading.

Finally, if the pictures were to be used on a daily operational basis, it would be extremely valuable to have the same view of the same area at the same time every day. Then the analyst would become used to this view and could do a quicker, more accurate analysis. For this purpose, the sun synchronous satellite would be ideal.

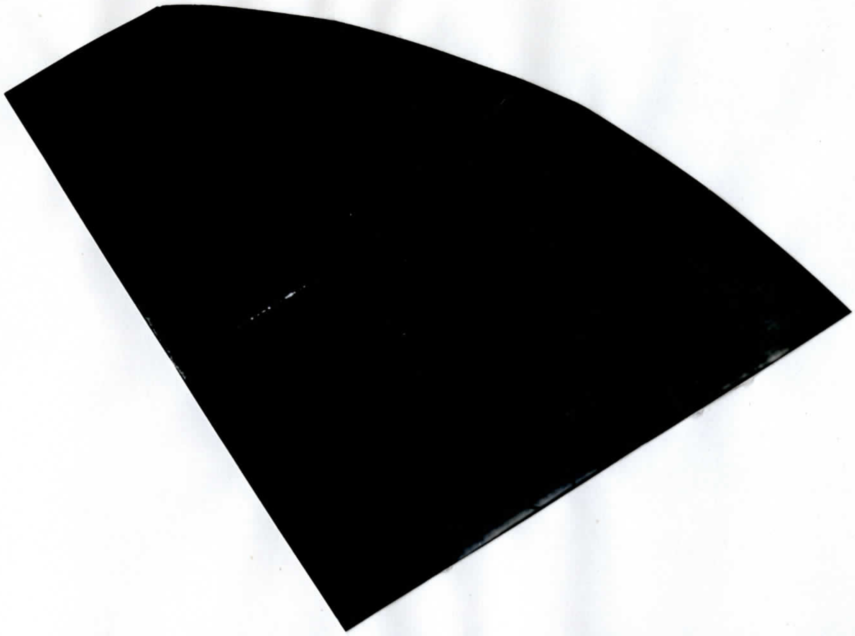


Figure 1a Western Coast of North America

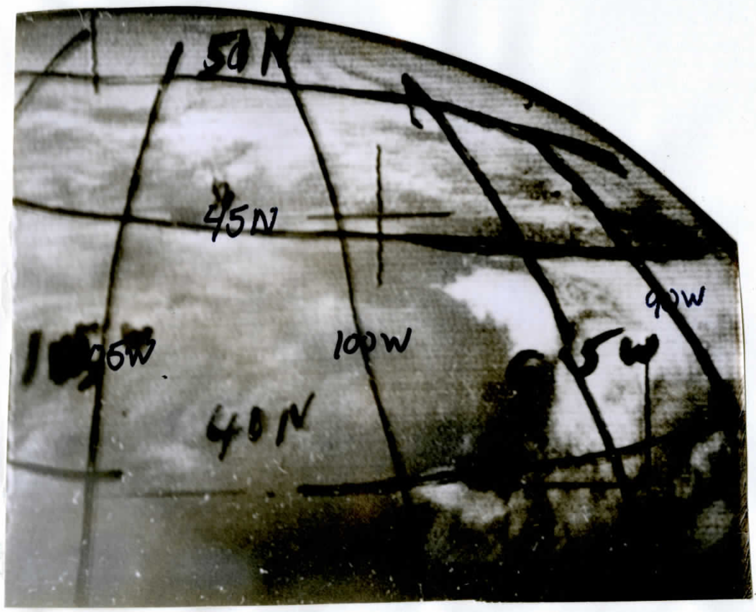
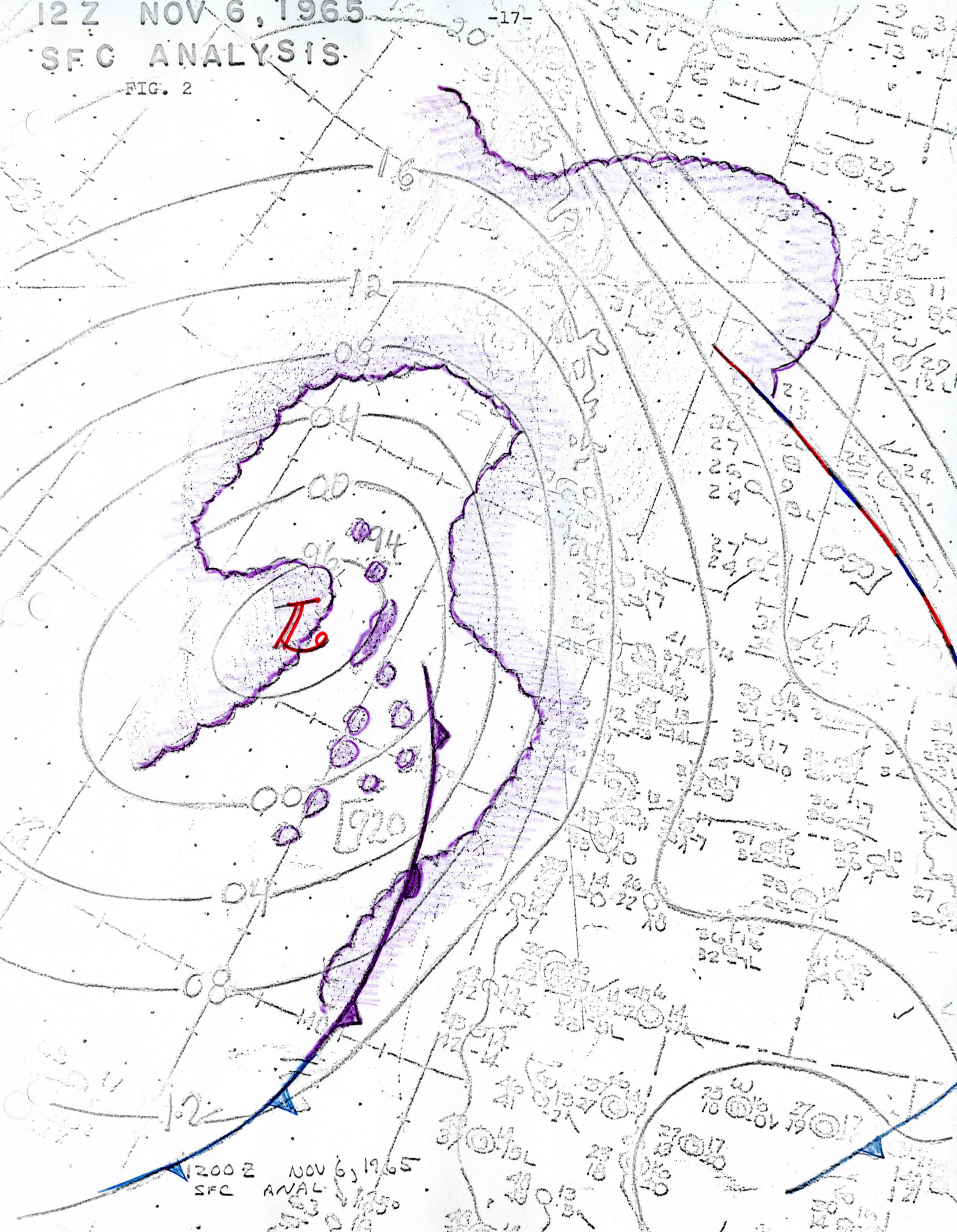


Figure 1b Central United States

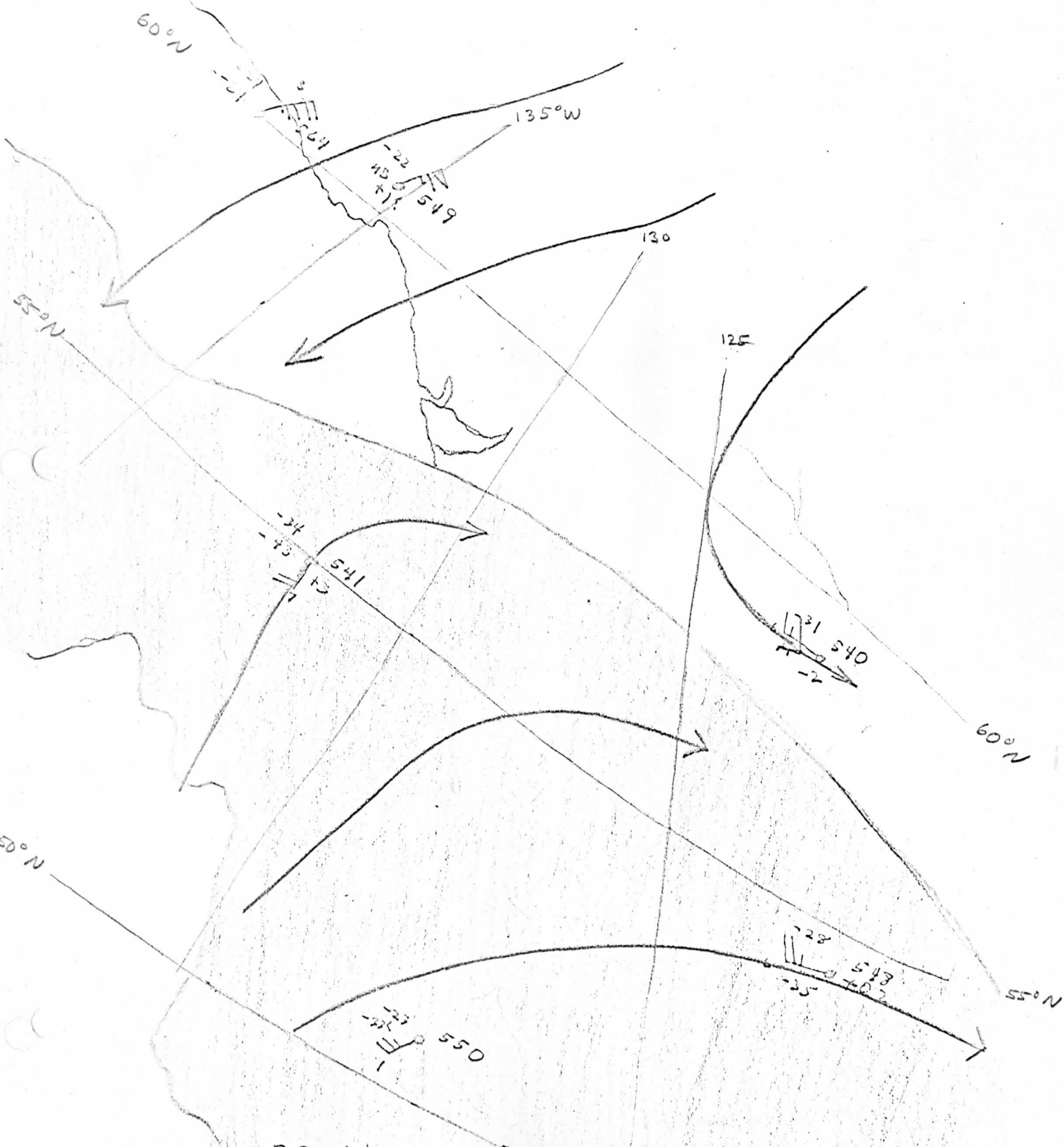
12 Z NOV 6, 1965
SFC ANALYSIS

FIG. 2



500 MB STREAMLINE

FIG. 3

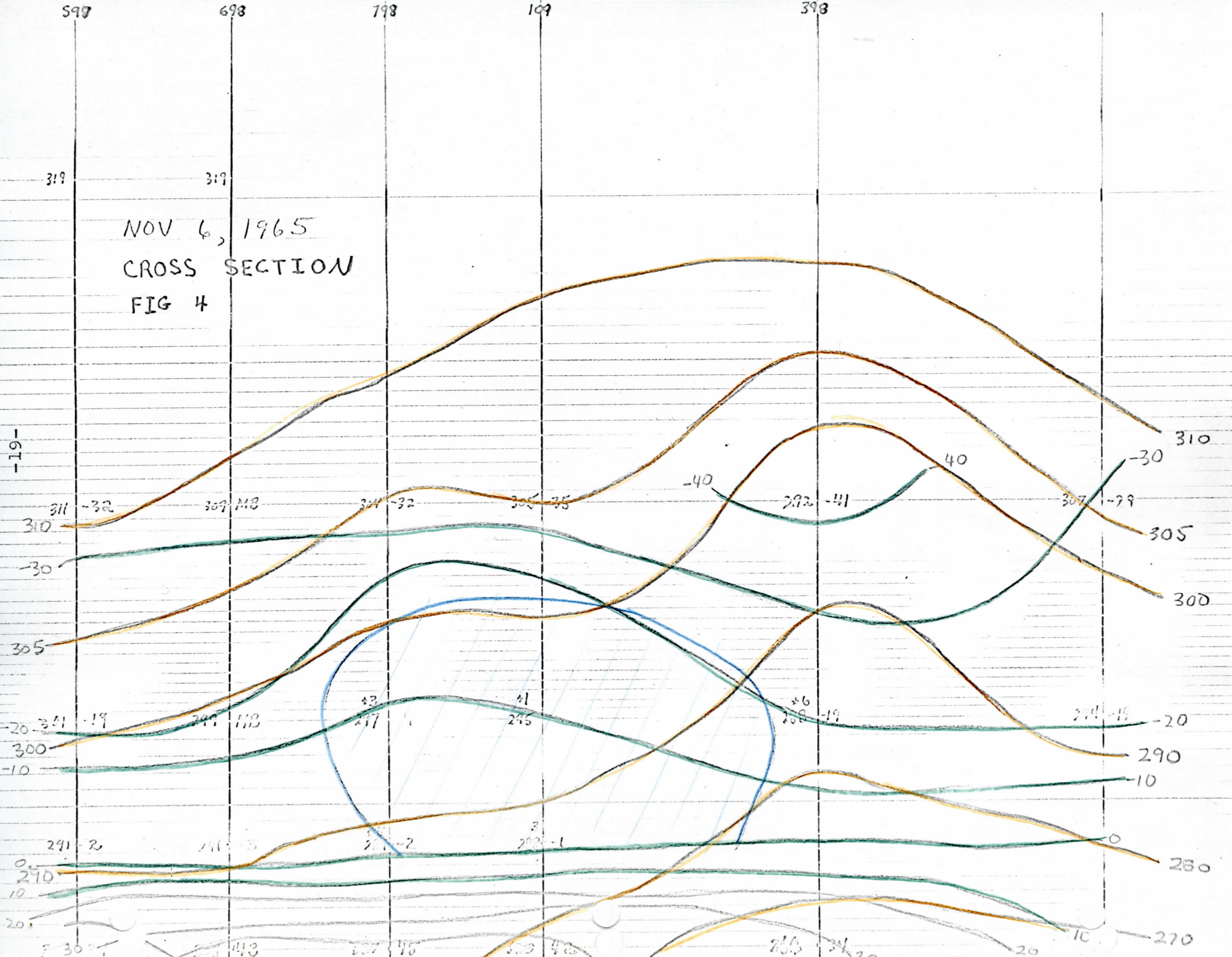


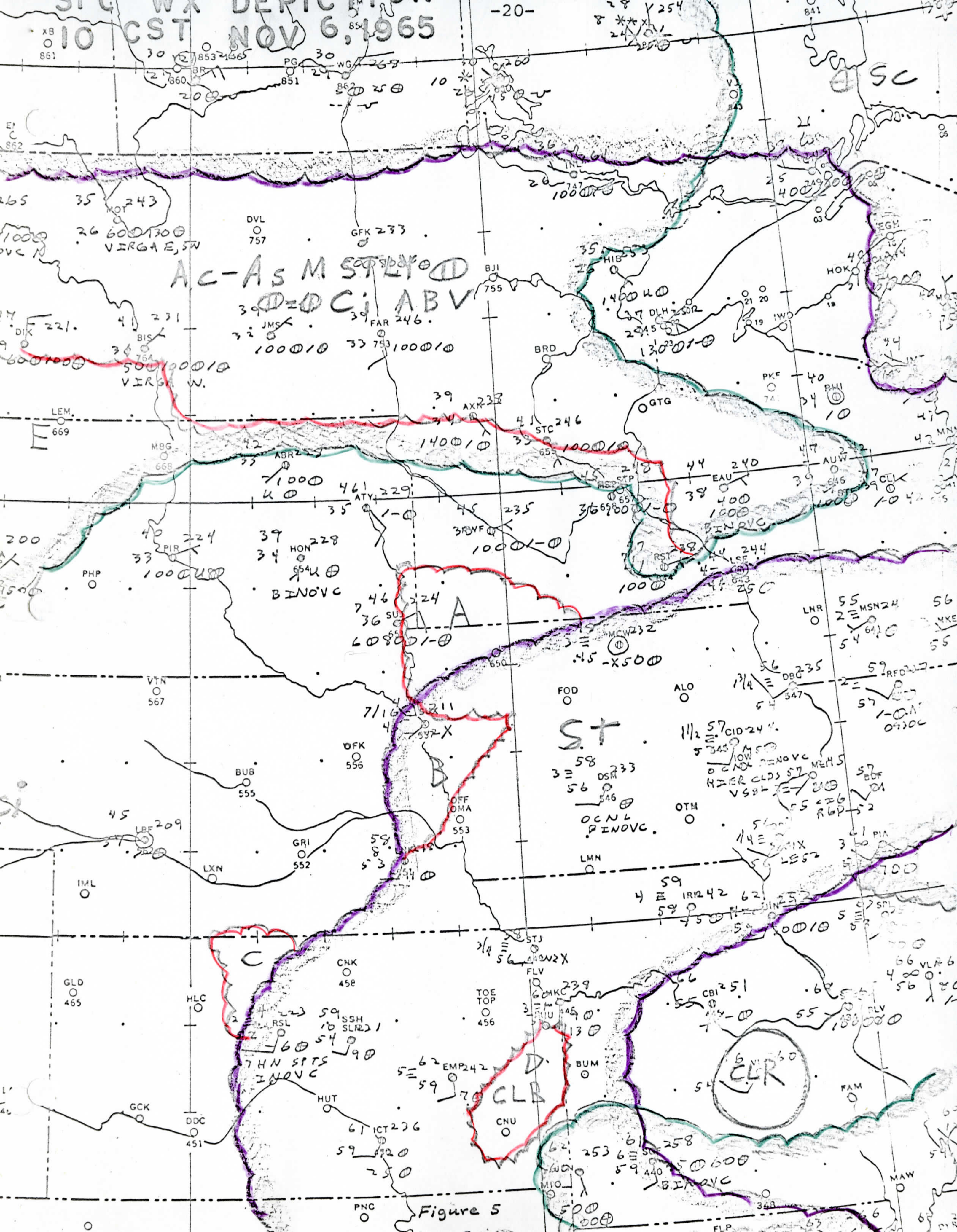
500Mb 1200Z

NOV 6, 1965

CROSS SECTION

FIG 4





10 CST NOV 6, 1965
SC
Ac-As MSTLY
Ci ABV
VIRGA E, SW
VIRGA W.
BINOVC
A
St
B
OCNL BINOVC
C
D
CLR
THN SPTS INOVC

Figure 5

CASE STUDY III

November 7, 1965

CASE I.

A member of this group was on duty at the U.S. Weather Bureau at Madison, Wisconsin on Sunday, November 7, 1965. It was his duty to prepare a forecast for Madison and vicinity at 1030 LST. At forecast time, most of the state was covered by low stratiform clouds except for some clearing that was taking place along the shore of Lake Michigan. With a high pressure ridge centered north of Lake Superior, and an east-west orientated stationary front lying just south of the state (Figure 2), we find an east to northeasterly flow in the lowest layers. Surface wind speeds were five to twelve miles per hour. With this flow pattern, and with the clearing near Lake Michigan, it seemed logical to call for some clearing or at least partial clearing during the afternoon. As a result, the state forecast was for "partly cloudy this afternoon" and the Madison and vicinity forecast was "becoming partly cloudy".

During the course of the afternoon, the clearing remained confined to the extreme eastern portion of the state. The forecast "becoming partly cloudy" never materialized.

Now the question that arises is: "If the forecaster had a satellite picture available at forecast time, would he have been able to put out a better forecast?".

The TIROS picture does very distinctly show clearing over part of Lake Michigan (Figure 1). This clearing was also shown on the weather depiction chart and on the hourly weather sequences. The big difference was in the detail of the clearing. The satellite picture suggests that this clearing is more intimately associated with the lake than do the more conventional sources of information.

A streamline analysis of the surface winds shows a very distinct divergence pattern along the lake shore (Figure 3).

Figure 1

The 0000Z November 8, Green Bay Raob shows an adiabatic lapse rate in the lowest layer (Figure 4). This indicates that there could have been considerable turbulence near the surface of the lake as a result of the incoming air being cooler than the lake. This might have resulted in a greater roughness or frictional drag over the lake, than over the land, in turn, producing the divergence near the lake shore.

We cannot definitely say, "If the forecaster had the satellite pictures he would have made a better forecast". It is quite certain, however, that the key to the broken forecast is more evident in the satellite pictures than in the more conventional sources of information.

Another interesting feature of the picture (Figure 1) is the sharply defined western edge of the fog and stratus. No synoptic feature was evident that could explain the sharp and unusually shaped boundary.

A closer inspection and a comparison of the picture with a relief map indicated the western boundary followed very closely the Mississippi and St. Croix River Valleys.

The available surface data and weather depiction chart did indicate the approximate western boundary but not with the exactness of the TIROS picture.

Surface Analysis 1800Z Nov 7, 1965

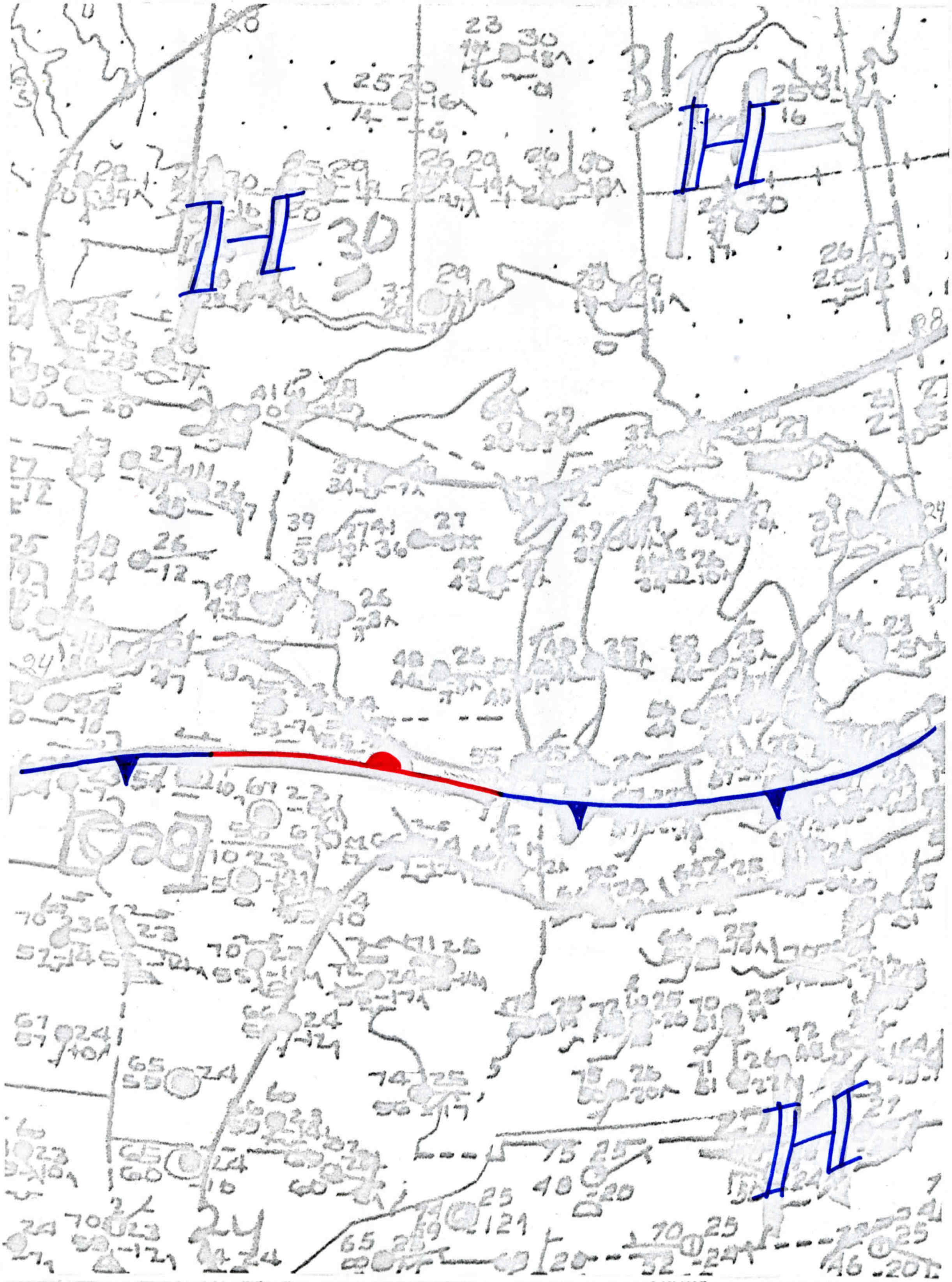
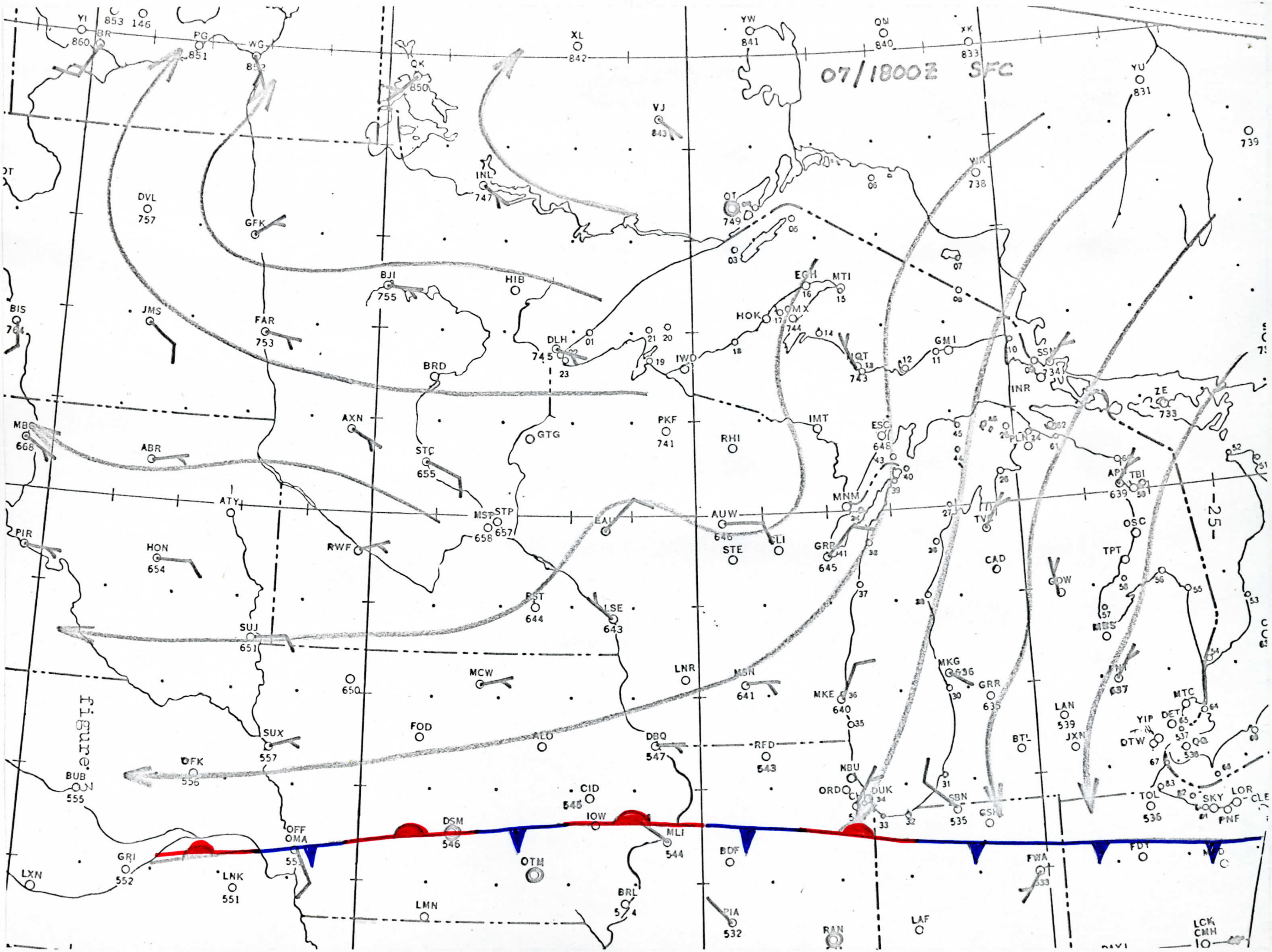


Figure 2



figure

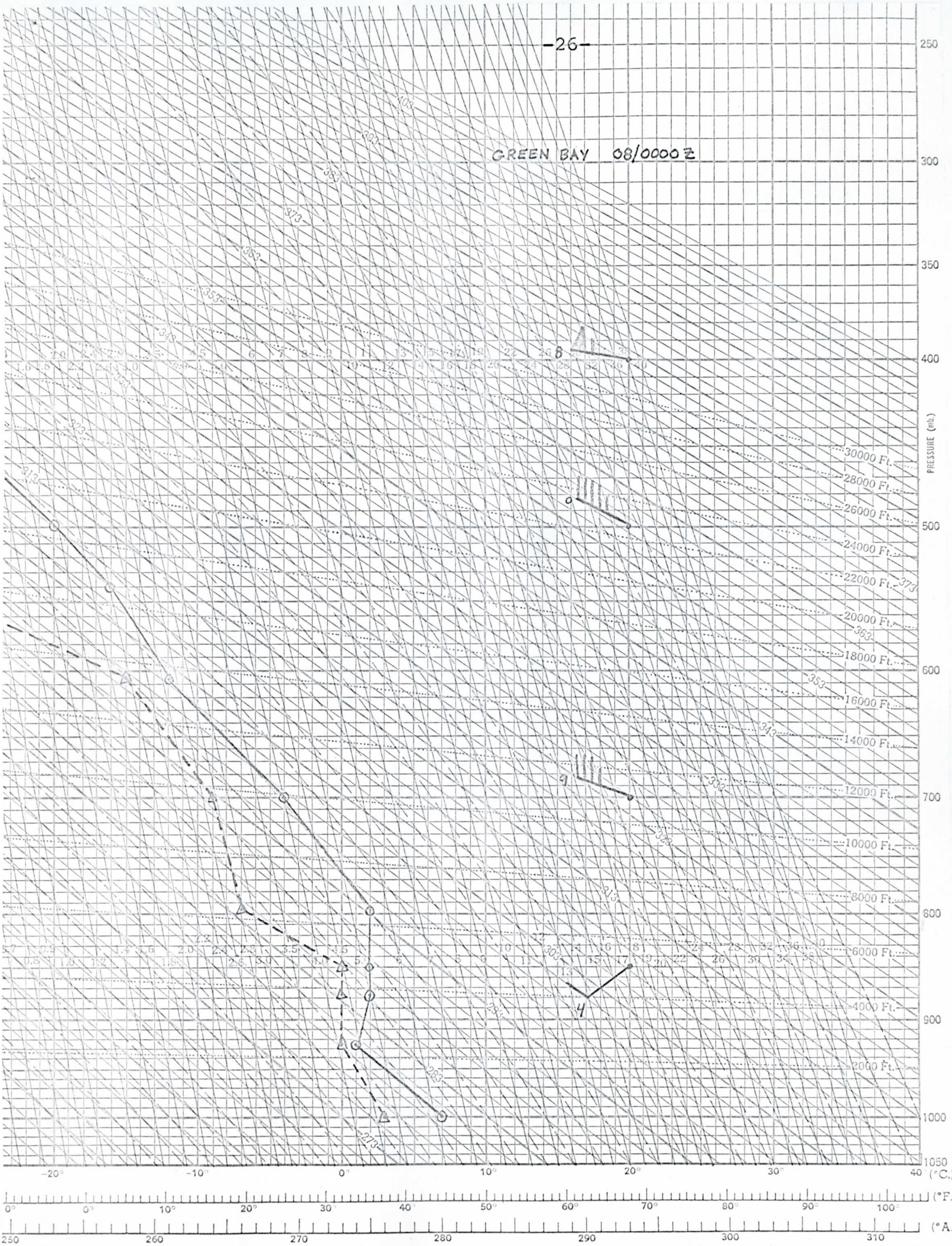


figure 4

CASE II.

The general synoptic situation involves a closed low at both the surface and 500 mb level located about 43°N, 135°C. A diffuse high pressure area or ridge extends northwest from Idaho. Finally, a warm front extends across Northern California. (Figure 6)

It is obvious even to the novice that there is an extensive band of clouds associated with the low. The weather depiction chart also shows these clouds, but one cannot determine the westward extension of this band. Supplementing the surface observations with the TIROS picture (Figure 5) the band is seen to be about four degrees wide with a scattered clear area following.

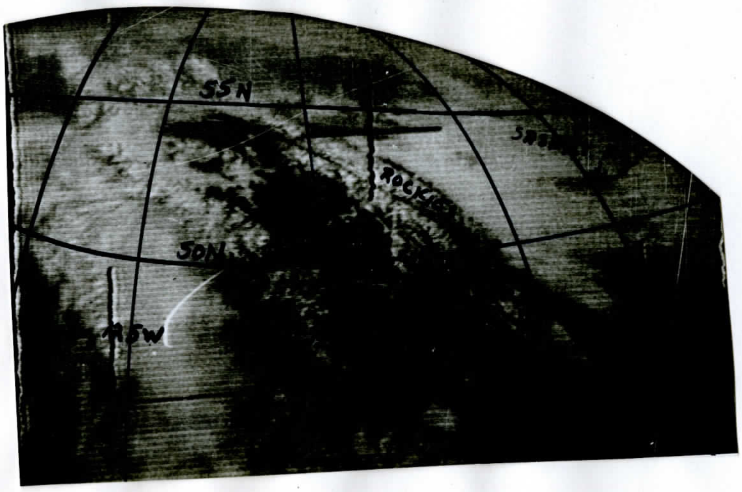


Figure 5

Now with infrared pictures of this cloud band one would have not only the horizontal extension but also the vertical development of the clouds approaching the west coast. This certainly would aid a forecaster.

The Canadian Rockies are seen by the snow while the valleys appear as narrow dark lines. The horizontal weather depiction chart and TIROS show the area east of the Canadian Rockies covered with stratiform type clouds. The Saskatchewan River Valley appears darker than its surroundings. The weather depiction chart does not indicate any breaks in the stratus.

Surface Analysis 1800Z Nov 7, 1965

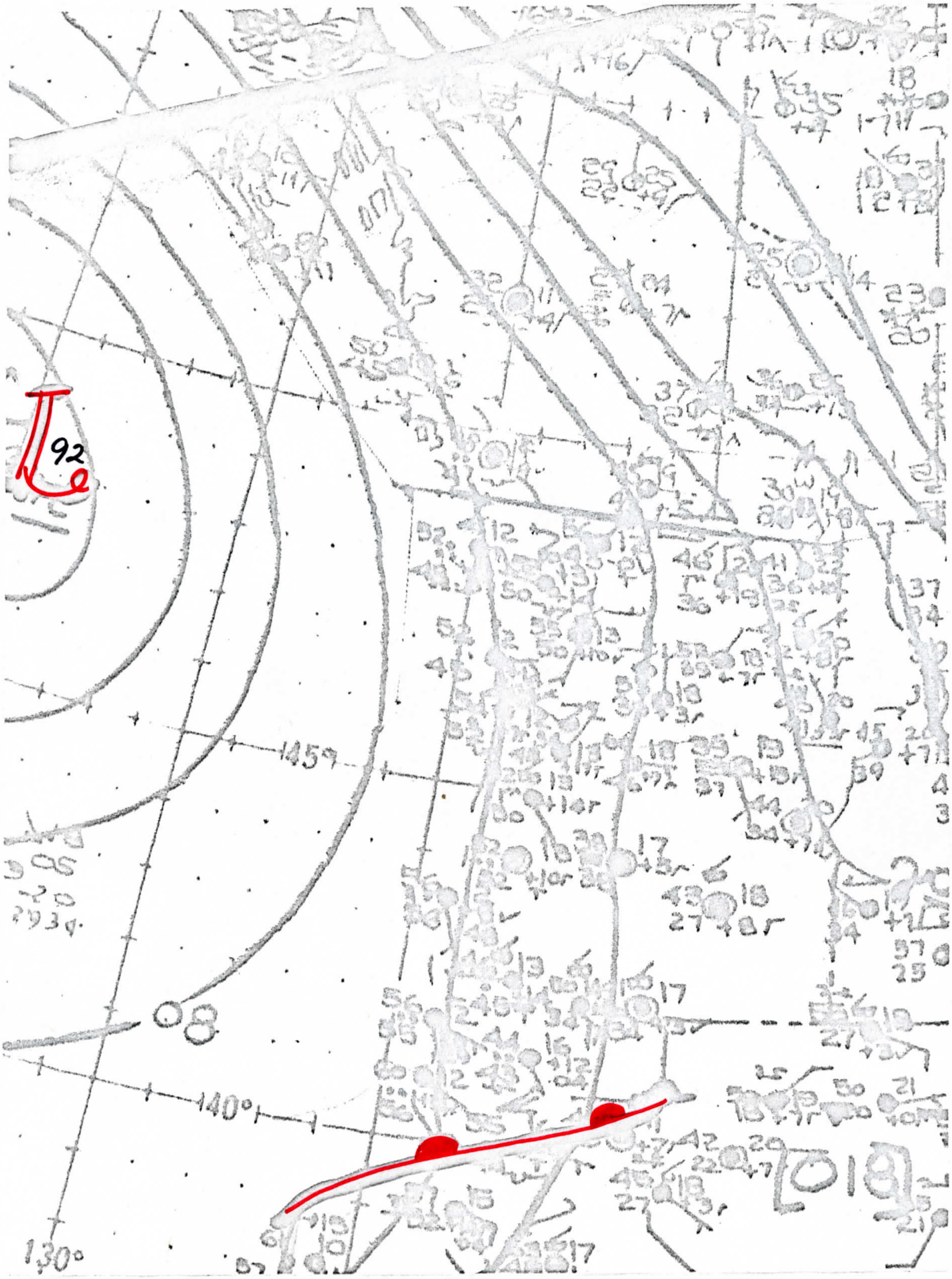


Figure 6

Problems confronting the field forecaster in his daily use of satellite pictures.

First--it is most important that the forecaster not have to use valuable time in gridding the pictures. The data for gridding should be available to the field in advance of the pictures. Accuracy of gridding is of course most important.

Second--there needs to be good contrast between light and dark features and the resolution of the picture should be known to determine the size of the features in the picture. Shadows are often prominent and can be used to determine cloud stratification. Thus, the forecaster needs to know where the sun is in relation to the picture.

Third--it is very important to have a good knowledge of topography. Lakes, mountains, river valleys, and various types of vegetation appear in the pictures but often not as obvious features. A relief map would be an excellent aid to visualize the three-dimensional aspect of the picture. Information as to the snow cover, particularly in winter would be a valuable aid as it is difficult to distinguish snow cover from fog or stratus.

In conclusion, satellite pictures are of great aid in interpreting conventional synoptic data and for observing features over regions with few observing stations. However, these pictures must be used as an aid or supplement to other synoptic data and not just as isolated information. It could be said that the conventional synoptic data should be interpreted in terms of the picture and not vice-versa.

COMMENTS & CONCLUSIONS

Problems Obscuring Satellite Information

1. Background. A knowledge of the topography (or background) is essential in evaluating satellite pictures. A relief map of the region being considered is more helpful in this evaluation than a geographic contour map. An atlas of reflectivity would be very helpful for interpretation of topographic features and seasonal changes in vegetation and snow cover.

2. Quality of Reproduction. It is desirable to have as much contrast as possible between light and dark areas of the photo. Some indication of the resolution of the picture should be given to aid in determining size of features in the picture.

3. Gridding of Photos. It would be helpful to have TIROS pictures with grids. Some indication of the error in gridding should be given with each picture.

4. Lack of Related Information. It would be very beneficial to have the track of the suborbital point and also the track of the camera center readily available to an analyst--preferably accompanying the grid. It would also be very beneficial to have the "local" longitude of the sun at picture time and also the zenith angle of the sun for at least one point on the picture--preferably the camera center.

5. Picture Distortion. There is distortion at the outer edges of the TIROS pictures. The problem of distortion can be minimized by the construction of a picture mosaic.

6. Conclusions. The value of having available on a TIROS picture the information mentioned above (2 through 4) cannot be over-emphasized. Such information relieves the analyst from tackling these computations. In fact, the necessity of doing such computations would often discourage the analyst from proceeding. This information is available from the computer programs of gridding and could be supplied with the pictures after having been computed once--instead of many times by analysts.

Synoptic Applications of Satellite Information

1. Comment on Nephanalysis. The nephanalysis is usually not as completely descriptive of the cloud cover as that from the TIROS picture. However, detecting thin cirrus clouds from TIROS pictures is very difficult. In certain cases, the nephanalysis was inadequate for pilot briefing.

2. Data Sparse Regions. It is obvious that TIROS picture provide valuable information in data sparse regions where little or no information is available.

3. Isolated Weather Phenomena. Many weather phenomena that do not show up from the surface and upper air observation networks are easily seen on TIROS pictures. Examples are gravity waves, vorticity-maximum centers, fog (particularly fog in geographic basins), eddy patterns due to surface disturbances, and semi-radial cloud patterns over tropical and subtropical areas.

4. Supplementing Synoptic Data. The TIROS picture is extremely beneficial when used as a supplement to the synoptic information. This is because the two are mutually beneficial. The synoptic information essentially calibrates the TIROS picture, whereas the TIROS picture fills in the blanks left in the synoptic network. Used together, the two are very much more beneficial than either one used independently.

   The positioning of cold fronts is aided by TIROS pictures; however, warm fronts are very difficult to find on the pictures. In one case, streamline analysis at 700 mb was much more descriptive of the cloud pattern seen in TIROS pictures than the surface pressure analysis. The streamline pattern shows areas of convergence and divergence, while this is not apparent on surface pressure analysis. In the case mentioned above, the convergence areas on the 700 mb streamline analysis were in good agreement with cloudy areas on the TIROS pictures at that time.