CYCLOGENESIS IN THE GULF STATES, JANUARY 1954

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INTRODUCTION

The Gulf States area (including the northern Gulf of Mexico) is a dependable source region for January storms. In this month there is an average of almost five cases of cyclogenesis, according to Visscher [1], compared with two per month in November and one per month in April.

These storms usually have a pronounced effect on the comfort and commerce of perhaps one-third of the population of the United States. For that reason alone the birth and growth of Gulf area cyclones is of primary interest and a fundamental problem for speculation and inquiry.

Most east coast winter Lows originate as unstable waves either in the Gulf of Mexico area or near the Atlantic coast. Miller [2] classified such storms on the basis of their genesis strictly in the Atlantic coastal region—some over land, others over or near the Gulf Stream. It seems probable that both types must occasionally result from Gulf-bred storms whose behavior is similar to that which George [3] calls "center jumps". Elliott [4], in his discussion of weather types, described type G (cyclogenesis in the Gulf). This type is subdivided into types Ga and Gb, both of which originate in the Gulf area and may eventually mature to east coast storms of major proportions. In his study of Texas-West Gulf cyclones, Saucier [5] suggested two synoptic patterns, the Great Plains trough and the Southwest cold-core Low, from which such cyclones form.

In January 1954 there were three instances of cyclogenesis in the Gulf States area in a period of less than 2 weeks. All three were responsible for widespread precipitation including rain, snowstorms or sleet, and attendant public inconvenience. From that standpoint alone each of those three Lows is worthy of comment. In this study, however, most attention will be given to antecedent synoptic patterns in the lower and mid-troposphere and those features associated with cyclogenesis.

CYCLOGENESIS ON JANUARY 10, 1954

The storm of January 10 (hereafter referred to as Storm I) was first detected at 0630 GMT on that date just south of Shreveport, La. (fig. 2). Twenty-four hours prior to the genesis of Storm I (fig. 1) the parent Low was over southeastern Wisconsin. The Low over west Texas moved southward, and was not associated with the cyclone development in Louisiana. That portion of the cold front south of 35° N. began slowing down. A strong ridge from a Canadian High extended south-southeastward into northern Texas. South of the front, a tongue of warm, moist tropical maritime air invaded the Gulf Coast States. By the time the first closed isobar was noted (fig. 2) rain had begun to fall from east Texas to lower Michigan.

Figure 3 shows the 850-mb. chart for 0300 GMT January 9. Vigorous cold advection took place from the Canadian

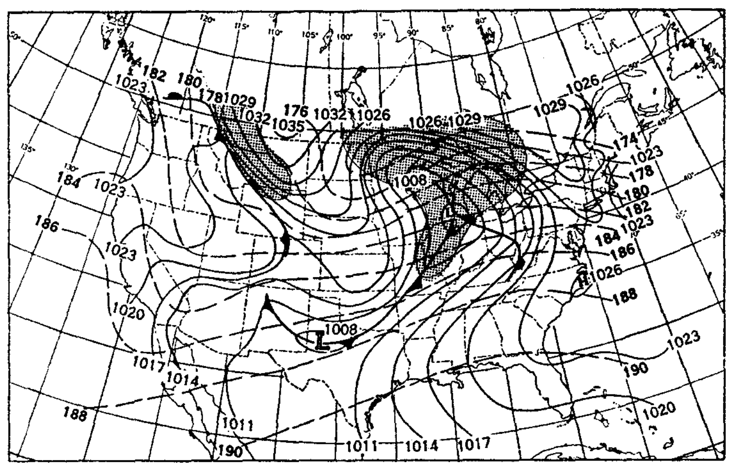

FIGURE 1.—Surface chart for 0630 GMT and 500-mb. contours in hundreds of feet (dashed) for 0300 GMT, January 9, 1954. Shading indicates areas of active precipitation.

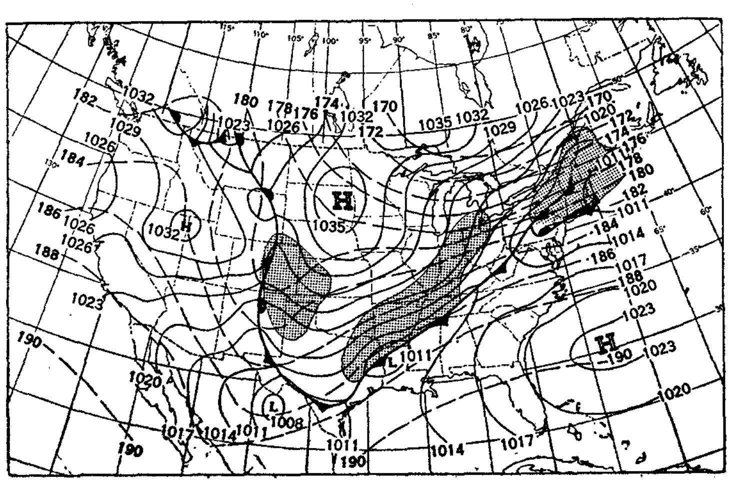

FIGURE 2.—Surface chart for 0630 GMT and 500-mb. contours in hundreds of feet (dashed) for 0300 GMT, January 10, 1954. Shading indicates areas of active precipitation.

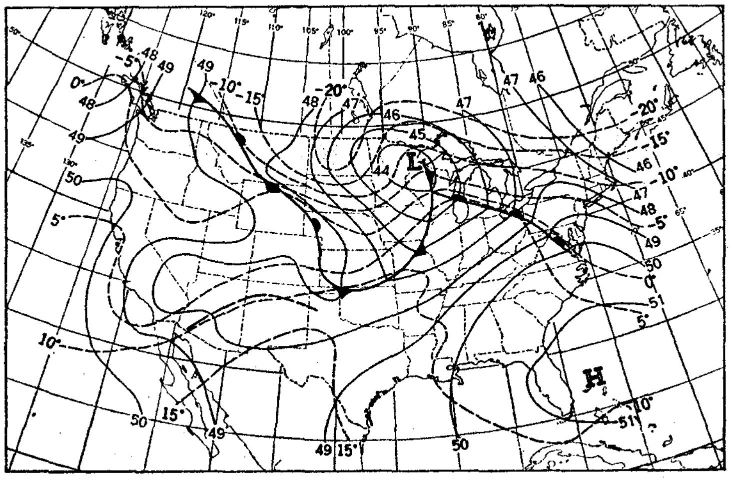

FIGURE 3.—850-mb. contours in hundreds of feet and isotherms in ° C. (dashed) for 0300 GMT, January 9, 1954.

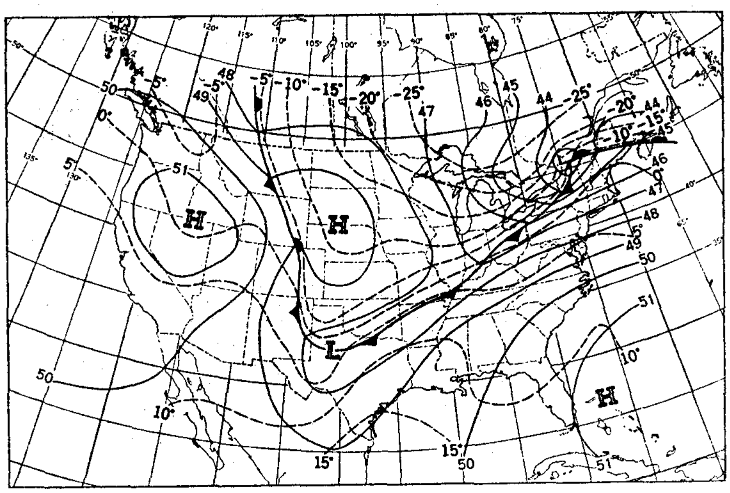

FIGURE 4.—850-mb. contours in hundreds of feet and isotherms in ° C. (dashed) for 0300 GMT, January 10, 1954.

border to central Kansas. South and east of the 850-mb. cold front there was warm air advection, but it was weak except from the Rio Grande to northern Arkansas.

By 0300 GMT, January 10 (fig. 4) a "cold injection" [3], prominent 12 hours earlier near Omaha, Nebr., had traveled to Oklahoma. North of the cold front winds veered to the northeast while winds south of the front remained from the southwest. Those southwesterly winds advected warm air from the Gulf to the Ohio Valley.

An inspection of the 500-mb. contours for 0300 GMT, January 9 (fig. 1) shows a minor trough oriented southwestward from Salt Lake City, Utah. By 0300 GMT, January 10 (fig. 2) the trough reached from Cheyenne, Wyo., southward to north-central Mexico. A pool of cold air associated with the trough was carried into the Denver, Colo.-Rapid City, S. Dak. area. A jet stream appeared along the Continental Divide, dipped into central Texas, then recurved northeastward into Virginia.

Rain began falling in Arkansas and Tennessee some 6 hours before the first closed isobar appeared at the surface. As the center deepened and moved slowly northeastward (fig. 5) the rain changed to freezing rain, sleet,

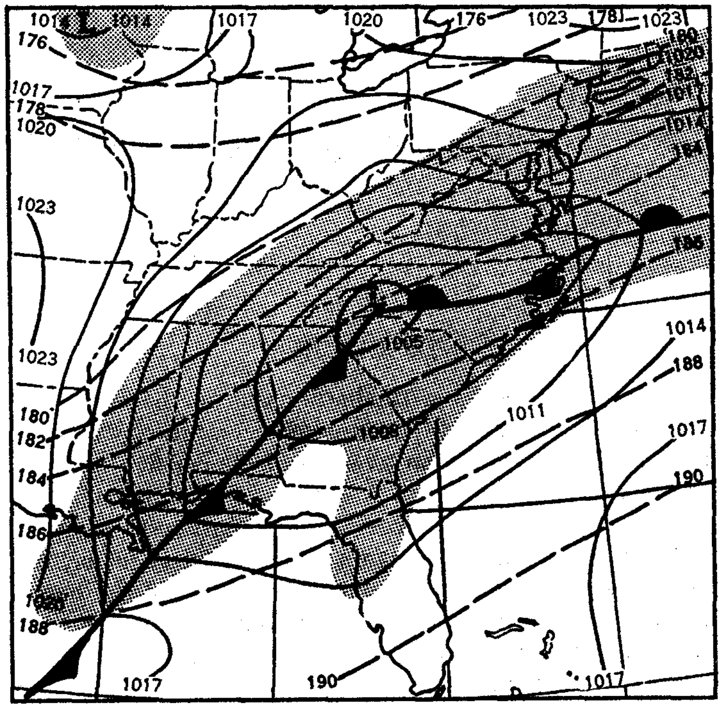

FIGURE 5.—Surface section for 0630 GMT and 500-mb. contours in hundreds of feet (dashed) for 0300 GMT, January 11, 1954. Shading indicates areas of active precipitation.

and snow north of the front. Thunderstorms and substantial rainfall were reported as the southern portion of the front moved eastward replacing and forcing aloft the moist Gulf air. Behind the cold front the surge of Arctic air caused temperatures to drop below freezing along the Gulf Coast from Corpus Christi, Tex., to Mobile, Ala. [6]. As the Low developed further, snow began accumulating. In the Atlantic Coastal States 6 to 10 inches fell from New Jersey northward. One to two inches were measured from West Virginia southwestward to Oklahoma.

CYCLOGENESIS ON JANUARY 15, 1954

On January 14, 24 hours prior to the development of Storm II the surface chart (fig. 6) shows that a quasi-stationary polar front twisted through the Gulf States and northeastward to the Atlantic seaboard. A cold outbreak similar to that found in Storm I was not readily apparent, although a weak cold ridge existed from Iowa to North Dakota. Next day (fig. 7) there was a cold outbreak following the formation of a new wave on the Arctic front, but it did not appear to be directly associated with the Low near Shreveport, La.

A pressure minimum in the Rocky Mountain lee trough (fig. 6) progressed rapidly eastward in 24 hours (fig. 7). Meanwhile the stationary polar front began to move as it was caught in this circulation. Twenty-four-hour pressure falls of 5 to 10 mb. were prevalent in the proximity of the 1,008-mb. center near Shreveport.

The 850-mb. chart for 1500 GMT, January 14 (fig. 8) shows a conspicuous absence of cold air advection east of the Rockies, except that of relatively minor magnitude

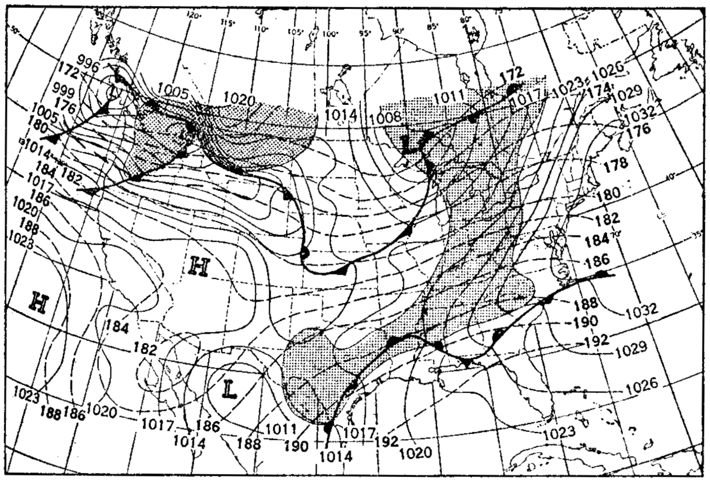

FIGURE 6.—Surface chart 1830 GMT and 500-mb. contours in hundreds of feet (dashed) for 1500 GMT, January 14, 1954. Shading indicates areas of active precipitation.

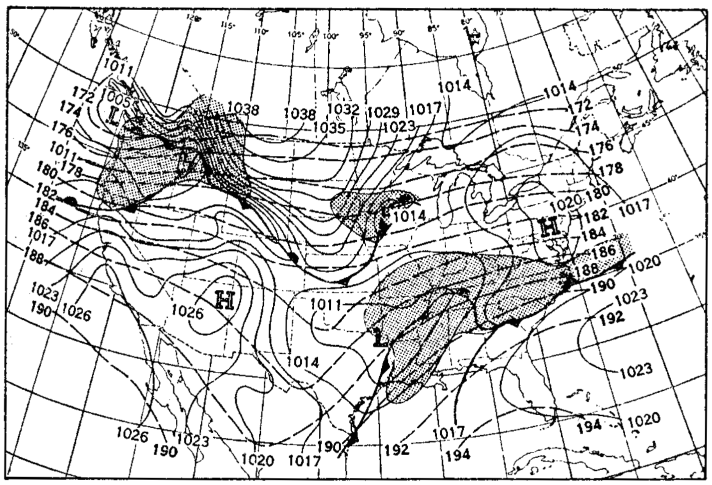

FIGURE 7.—Surface chart for 1830 GMT and 500-mb. contours in hundreds of feet (dashed) for 1500 GMT, January 15, 1954. Shading indicates areas of active precipitation.

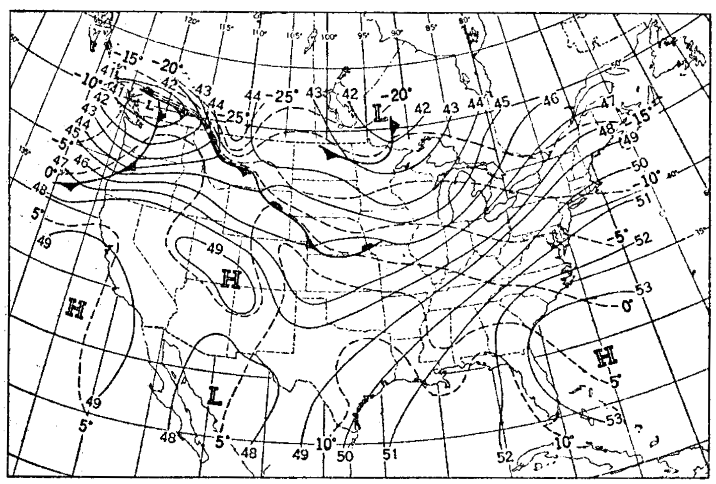

FIGURE 8.—850-mb. contours in hundreds of feet and isotherms in ° C. (dashed) for 1500 GMT, January 14, 1954.

in northern Minnesota and in the eastern Colorado-New Mexico region. A cold injection appears to be forming over northern Montana. Compared with Storm I, the 850-mb. level the day before cyclogenesis in Storm II

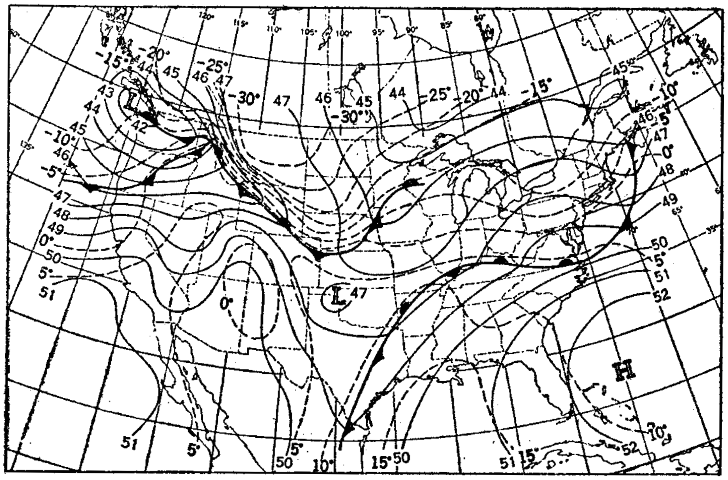

FIGURE 9.—850-mb. contours in hundreds of feet and isotherms in ° C. (dashed) for 1500 GMT, January 15, 1954.

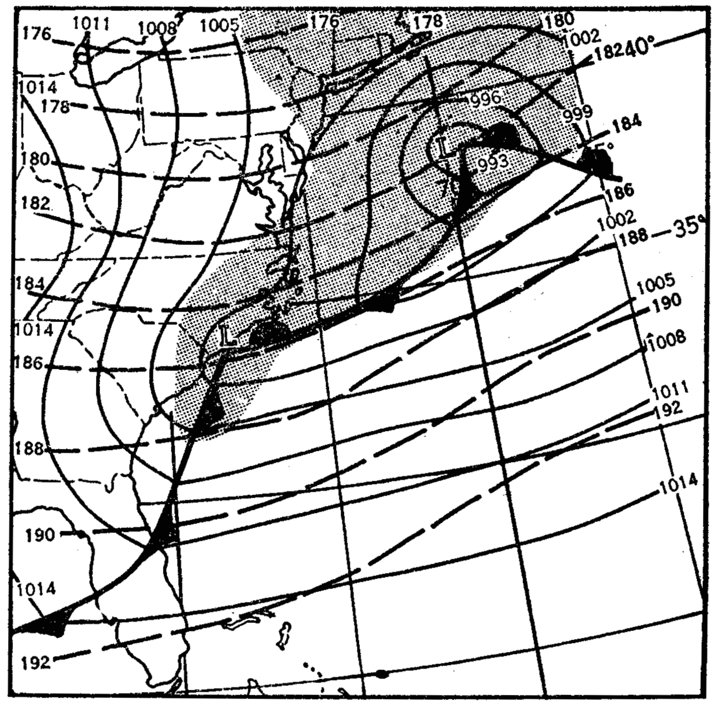

FIGURE 10.—Surface section for 1830 GMT and 500-mb. contours in hundreds of feet (dashed) for 1500 GMT, January 16, 1954. Shading indicates areas of active precipitation.

seemed to contribute little to the development except moderate, but widespread, warm advection.

By 1500 GMT, January 15 (fig. 9) a weak trough associated with the cold front had moved eastward from the Texas Panhandle. Advection of cold air was then quite apparent from Canada to central Nebraska, but was too far removed from the cyclogenetic area to have contributed much as a source of potential energy.

The 500-mb. chart for 1500 GMT, January 14 (fig. 6) shows a cold Low over the Gulf of California. The trough lying northeastward from the cold Low to Canada appeared to be strong enough and imbedded in such a flow that it would progress eastward. But the chart 24 hours later (fig. 7) shows that the northern portion of the trough disappeared in the strong westerly flow; the southern portion lay from Kansas to north-central Mexico. A jet stream around the cold Low on January 14 moved eastward and weakened. By January 15 it extended from south-central Texas northeastward into Virginia with a poorly defined isotach maximum from central Texas to Arkansas.

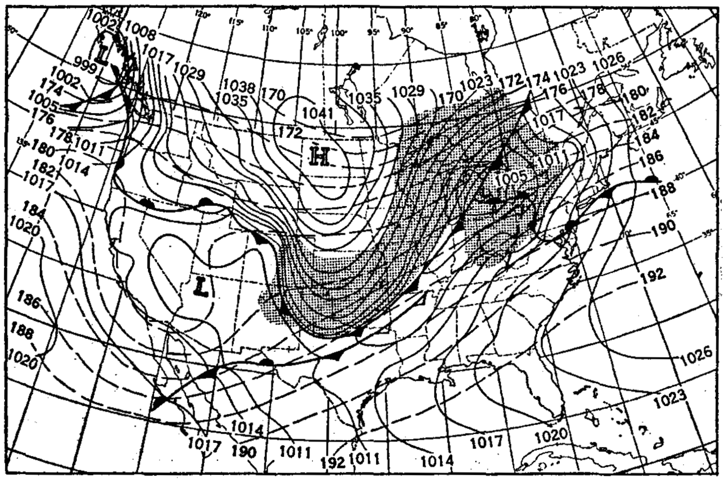

FIGURE 11.—Surface chart for 1830 GMT and 500-mb. contours in hundreds of feet (dashed) for 1500 GMT, January 20, 1954. Shading indicates areas of active precipitation.

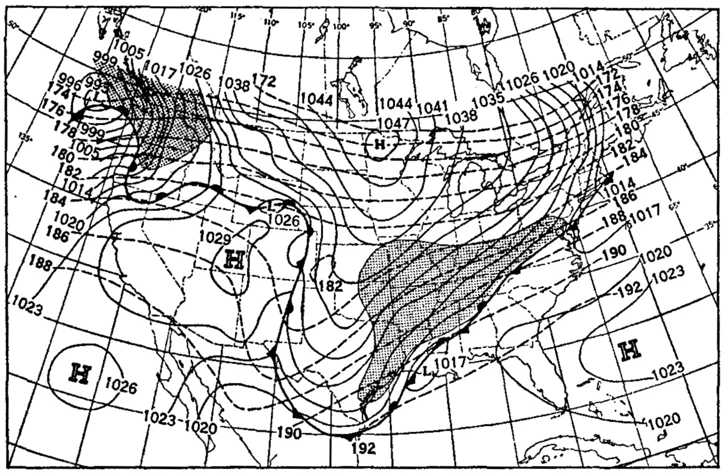

FIGURE 12.—Surface chart for 1830 GMT and 500-mb. contours in hundreds of feet (dashed) for 1500 GMT, January 21, 1954. Shading indicates areas of active precipitation.

The most significant difference in the 500-mb. patterns for Storms I and II was the absence in the second one of any nearby pronounced cold air advection before or at the time of cyclogenesis. Warm advection predominated in the area south of 40° N. The warming of the minor trough destroyed its thermal contrast.

In spite of its short life and obvious weakness, Storm II was responsible for considerable precipitation, most of which fell as rain. Floods in northern Alabama [6] resulted from heavy rains on January 16. In general, snow and sleet were confined to New York and New England. The Low deepened during the 24 hours following its development (fig. 10), then lost its identity as a new Low formed offshore.

CYCLOGENESIS ON JANUARY 21, 1954

Storm III originated on January 21 in much the same manner as Storm I. In both cases a wave formed on the polar front as it lost its momentum. As the parent Low moved rapidly across the Great Lakes the day before cyclogenesis (fig. 11), a cold wedge pushed southward behind the cold front. Temperatures fell 30°–40° F. in a 12-hour period in Oklahoma and northern Texas. By the time cyclogenesis occurred in southern Louisiana (fig. 12) temperatures south of the front were in the middle 70's; just northwest of the cold front temperatures in the low 20's were dominant.

The 850-mb. chart for 1500 GMT, January 20 (fig. 13) indicates that there was pronounced cold advection taking place from Kansas northward to the Canadian border. There was a cold injection over western Kansas. In view of the light winds at this level, advection may appear weak at first in spite of the strong isotherm ribbon. But winds below the 850-mb. level and nearer the gradient level over the isotherm ribbon averaged at least 20 knots. There was some warm air being advected east of the cold

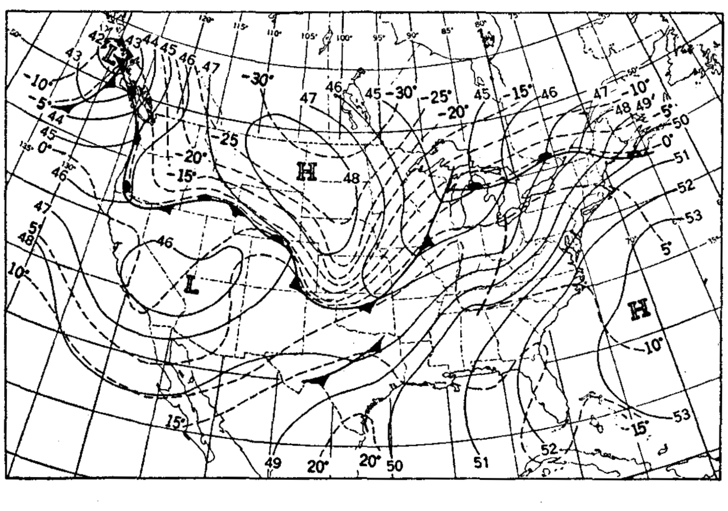

FIGURE 13.—850-mb. contours in hundreds of feet and isotherms in ° C. (dashed) for 1500 GMT, January 20, 1954.

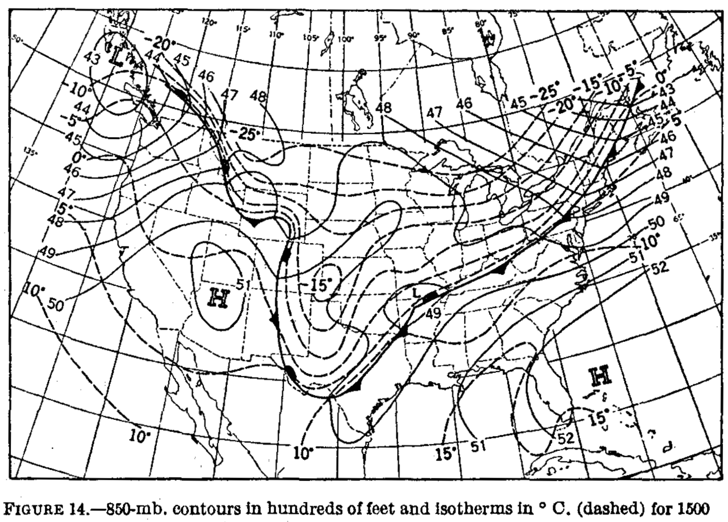

FIGURE 14.—850-mb. contours in hundreds of feet and isotherms in ° C. (dashed) for 1500 GMT, January 21, 1954.

front as shown in figure 13, but it appears considerably less intense than the cold advection.

In another 24 hours (fig. 14) a closed circulation formed over northwestern Arkansas as the cold air drove southward to the Rio Grande.

The pattern at 500-mb. the day before cyclogenesis is shown in figure 11. A cold Low was centered over southern California with a trough extending southward beyond 25° N. A jet stream in excess of 80 knots circled the southern half of the Low, then continued northeastward through western Texas, then across country to Pennsylvania.

By 1500 GMT, January 21 (fig. 12) the 500-mb. Low had filled about 400 feet as it moved to southwestern Kansas. But the trough and Low center contined to move eastward with a resulting fall in 500-mb. height and surface pressure.

The jet stream was oriented northeastward from northern Mexico across the Atlantic coast near Delaware. An isotach maximum of about 80 knots lay from central Texas to Tennessee.

Subsequent to the formation of Storm III (fig. 15) heavy snow fell northward from the Low to New Jersey. Heaviest amounts were observed in eastern Maryland [6] where totals ranged as high as 10 to 12 inches. The 500-mb. trough meanwhile had maintained its sharpness and eastward movement of about 30 knots.

SUMMARY OF SYNOPTIC CONDITIONS

In the discussion of antecedent synoptic conditions of the three storms an attempt was made to point out salient features of the lower and mid-troposphere. The contribution of higher levels doubtless has a considerable effect on the formation of cyclones as shown by Wulf and Obloy [7], Alaka, Jordan, and Renard [8], and others. But for forecasting winter cyclogenesis in the Gulf States area many feel that a detailed study of the middle and lower levels in the troposphere is probably an adequate approach to the problem if the forecasters' time does not also permit a thorough study of the upper troposphere and stratosphere.

By now the reader will have catalogued certain similarities and differences in the three storms presented above. In summary, then, the following statements should be emphasized:

1. A 500-mb. cold Low or trough was located over the southwestern United States at least 24 hours before cyclogenesis. The cold troughs moved eastward and were partially responsible for surface pressure falls (except in Storm II). Storms I and II were similar to Saucier's [5] cold-core cyclone formation.
2. An adequate supply of warm, moist, maritime tropical air was present before and at the time of storm formation.
3. The cold front in Storms I and III slowed down considerably before cyclogenesis; in Storm II a stationary front was present for wave formation.
4. Pronounced cold air advection took place at 850- and 500-mb. levels before Storms I and III formed; cold air advection was absent before Storm II formed.
5. The parent Low was well over 1,000 miles to the northeast of the cyclogenetic area.
6. 850-mb. winds in the lower Plains States veered to the northeast after the cold front passage as noted by Visscher [1]. The exception was Storm II.
7. Low index or relatively low index conditions prevailed. That low index is desirable for Gulf cyclogenesis was pointed out by Starr [9] and implied by Elliott [4] in his types Ga and Gb.
8. Bjerknes [10] has commented that it is necessary to have either "unstable frontal wave action or unstable growth of an upper trough" or both in order that cyclogenesis may proceed. Both factors existed in Storms I and III.
9. In all three cases a cold injection was present at 850-mb. before Lows developed. In Storm II, however, the injection appeared to be too far north to be of any importance in the subsequent wave formation.
10. 1,000-500-mb. thickness values increased over the areas of cyclogenesis (fig. 16) while 500-mb. heights generally decreased or were unsteady. The surface pressure falls were a reflection of the height falls and the thickness increases. (See next section.)

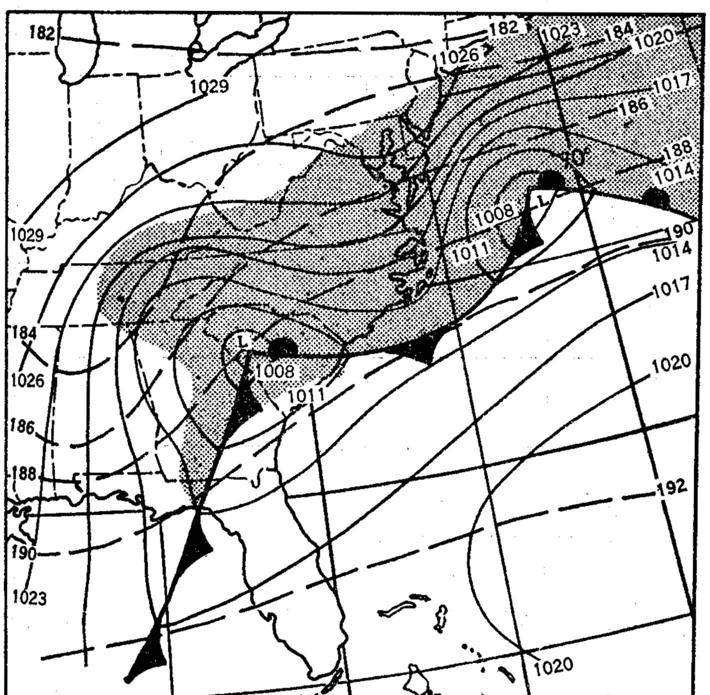

FIGURE 15.—Surface section for 1830 GMT and 500-mb. contours in hundreds of feet (dashed) for 1500 GMT, January 22, 1954. Shading indicates areas of active precipitation.

11. The activity of the jet stream was essentially the same in the three cases studied. An isotach maximum lay over or slightly to the north of the areas of surface development.

COMMENTS ON FORECASTING CYCLOGENESIS

THE GEORGE METHOD

A method proposed by George [3] was applied to the three January storms to determine whether cyclogenesis would occur and, if so, with what intensity. When used on Storm I the day before development, a center jump appeared likely and cyclogenesis was not favored. Actually, there was a center jump in addition to cyclogenesis of intensity 12 near Shreveport, La.

On Storm II this method indicated cyclogenesis of intensity 5 would occur in southwestern Kansas. A center of intensity 8 was found 24 hours later some 350 miles to the south-southeast even though the cold injection was far north of 38° N. (Cyclogenesis is most favored when the isotherm ribbon is below 38° N.)

In the case of Storm III a forecast development of intensity 6 in central Georgia compared favorably with the actual center of intensity 9 in central Louisiana.

1,000-500-MB. THICKNESS PATTERNS

The departure from normal of the 1,000-500-mb. thickness prior to the development of these storms was studied. A similarity of pattern was evident in all three cases. The greater than normal source of potential energy was delineated by the gradient and geographical location of the centers of plus and minus departures. In Storms I and III the gradient was largest northwest of the cyclogenetic areas; in Storm II the greatest gradient was to the southwest.

There are other ways in which thickness can be used effectively as an aid in forecasting cyclogenesis as proposed by Sutcliffe and Forsdyke [11]. A visual and subjective evaluation of vorticity can be made. If cyclonically curved thickness contours lie upstream from a region of suspected cyclogenesis, one could conclude that cyclonic development is more probable in view of the potential increase in cyclonic thermal vorticity. In the three cases studied here there was an increase in cyclonic curvature of the thickness contours (not reproduced) over the regions of Low formation which could have been projected downstream without apparent difficulty. It was felt that perhaps thickness mean flow charts would have been useful in forecasting the areas of thermal vorticity. Such charts were constructed, but their usefulness was not readily apparent. Linear extrapolation proved of most value.

Another tool can be derived from a consideration of the 1,000-500-mb. thickness patterns. A subjective determination of the greatest possible deepening in an area of likely cyclogenesis can be made by answering the question: What would be the lowest 500-mb. contour and the highest 1,000-500-mb. thickness contour in the suspected area in 24 or 36 hours? In short, a "reasonable" forecast of both thickness and 500-mb. values would result in a reasonable (and consistent) surface prognosis.

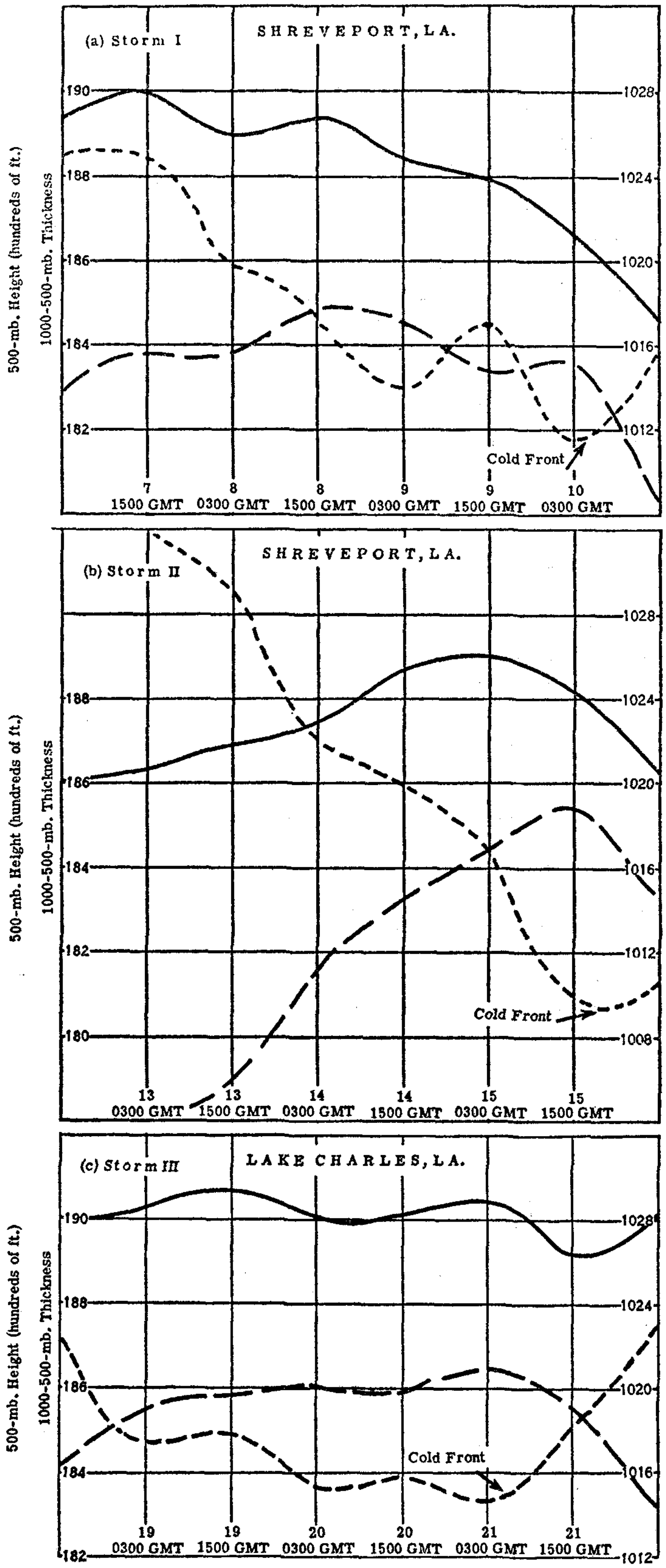

FIGURE 16.—Comparison of changes in 500-mb. height (solid lines), 1000-500 mb. thickness (long dashes), and sea level pressure (short dashes).

The combined contributions of the thickness and 500-mb. changes to the surface pressure changes in the three January storms are graphically illustrated in figure 16. Several prominent features of this figure are:

1. It shows best the effects which falling 500-mb. heights and rising thicknesses have on surface pressure falls
2. Thickness values and 500-mb. heights began falling or fell more rapidly after the cold front passed.
3. In general, thickness values increased as the cold front approached while 500-mb. heights fell.

CONCLUSION

It is felt that cyclogenesis in the Gulf States can be better understood and can be forecast with more confidence and certainty if the George method and thickness considerations are integrated into the pre-forecast synoptic study

ACKNOWLEDGMENTS

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