THE ANTICYCLONE AND RECORD LOW TEMPERATURES IN CENTRAL AND SOUTHEASTERN UNITED STATES, APRIL 19–22, 1953

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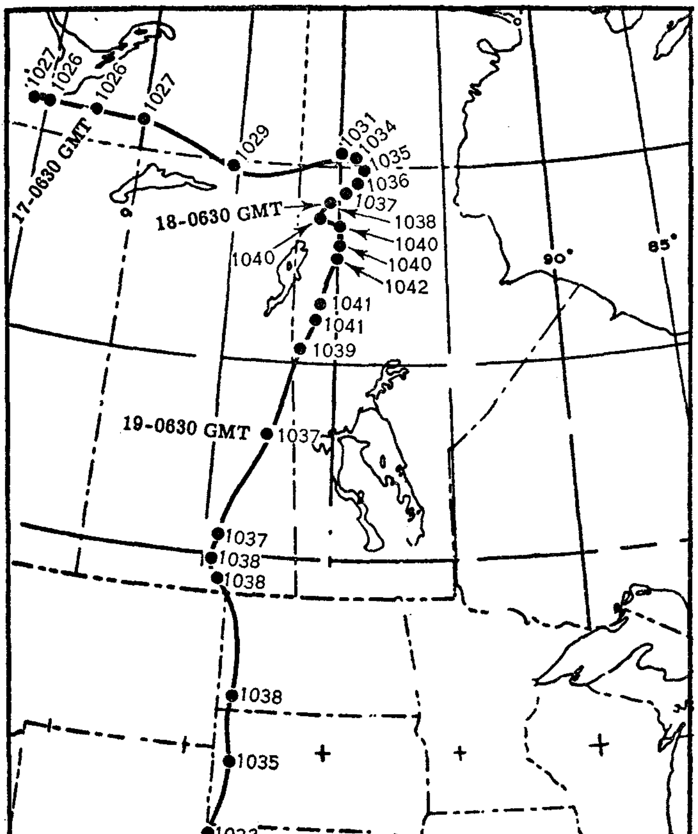
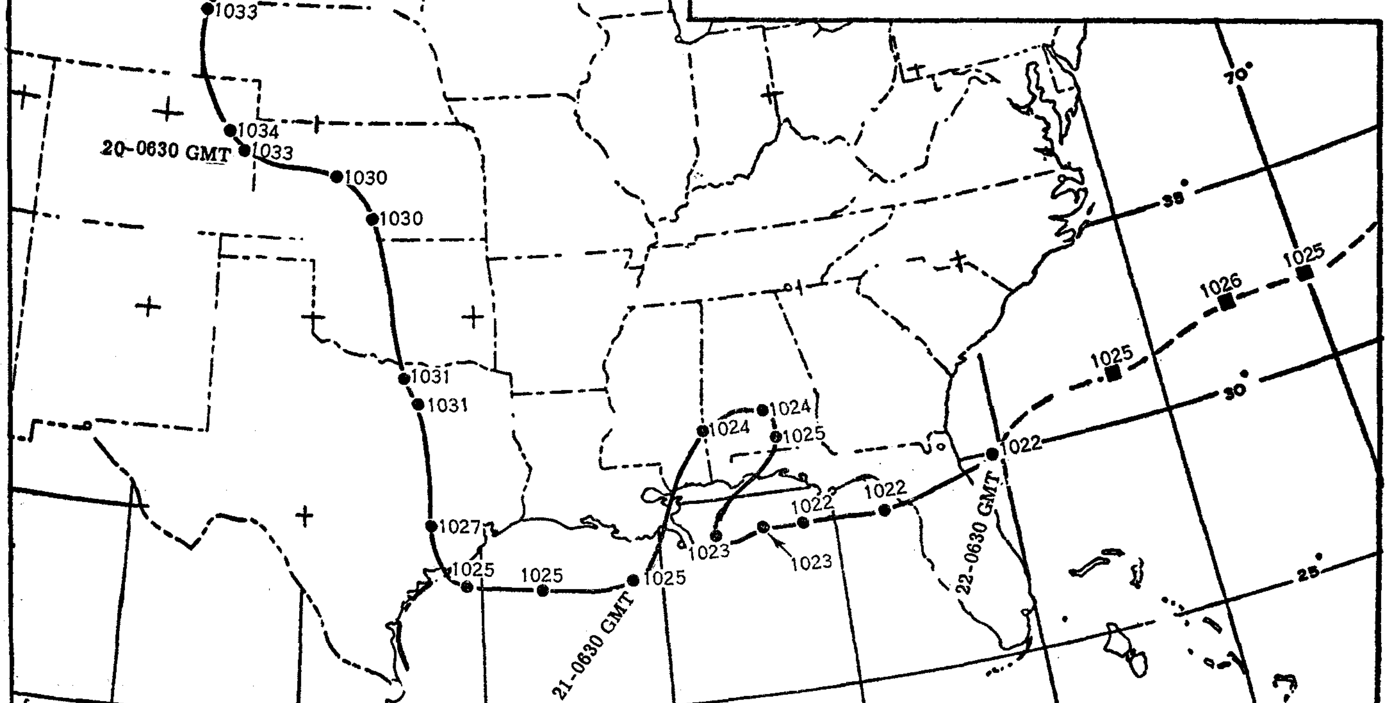

FIGURE 1.—The path followed by the center of Alfa. Central pressures and positions for every 3 hours are shown as dots, except over the Atlantic Ocean where positions are for every 6 hours and are indicated by squares. Reference dates and times are given for the 0630 GMT positions.

INTRODUCTION

The anticyclone of April 19–22, 1953, was the most intense of the month to invade the United States, at least with respect to the size of the area under its influence and the magnitude of the central pressure. It reached a maximum central pressure of 1,042 mb. in its life history although 1,038 mb. was the highest value observed within the United States. This high pressure system will, for purposes of euphony, frequently be referred to in the following by the name Alfa, taken from the ICAO phonetic alphabet. Alfa dominated the weather and circulation of April 19–22 inclusive, first in the central United States, and then in the southeastern States at the close of that period. Also in this same time interval, some near-record, record-equalling, and record-breaking low temperatures for these dates were reported by several stations in the Southeast. A study of the meteorological conditions associated with the movement and persistence of Alfa may prove of additional interest because this particular April was not characterized by anticyclonic circulation nearly as much as by persistently strong cyclonic circulation over the central and especially the northeast sector of the United States. Nor was anticyclonic activity in evidence over the West and Southwest, where flat pressure gradients prevailed for most of the month, with no formation of a Great Basin High in this period.

PATH OF CENTER

At 1830 GMT, April 17 a high center of 1,034 mb. was located at 60° N., 100° W., having evolved from an extensive north-south ridge that had moved slowly eastward through central Canada from 115° W. during the previous 2 days. This was Alfa. From this point it began a southerly movement that continued until the 21st and carried it to the Gulf Coast of Texas just north of Corpus Christi. Then Alfa turned east along the coast and by 0630 GMT of the 22d was centered in the Atlantic off northern Florida moving to the east-northeast and modifying to a warm High. This path is shown in figure 1.

Some representative views of Alfa, as seen on sections taken from the WBAN Analysis Center Northern Hemisphere sea level charts, are pictured in figures 2, 3, and 4. Figure 2 depicts Alfa soon after it had begun its southward movement, but while the center was still north of the border. The cold front, due to various circumstances preceding this date, had worked its way southward to just below Tampico, Mexico, resulting in an unusually great distance of some 30 degrees of latitude from front to High center. With the High center at this time moving essentially southward, northerly surface winds prevailed for many hours over the southern States behind the cold front, contributing materially to the lowering of surface temperatures. Thus we note (figs. 2 and 3) that along a line from Minnesota to southeast Texas, and over an area several hundred miles on either side of this line, the surface and gradient winds were predominantly northerly. This extensive field of northerly winds prevailed over most of the United States to the south of the Great Lakes for roughly a 2-day period beginning at 0630 GMT on the 19th and continuing to about 0630 GMT of the 21st.

The erratic portion of the track on April 21 is likely due to the effects of the diurnal pressure variations on the flat pressure gradients near the High center while the track was along the Gulf of Mexico coastline. With the diurnal pressure variations greater over land stations than over sea stations, we would expect the center to have oscillated between land and sea positions at the times of maximum diurnal change. Thus the 10 a. m. local time diurnal pressure rise made the center appear over land, while the 4 p. m. diurnal pressure fall caused it to move out over the Gulf. If corrections had been applied for the diurnal changes, the resulting track would probably have shown a far more regular path along the coastline.

The highest central pressure reached by Alfa was 1,042 mb. at 1830 GMT on the 18th, shortly after it had turned southward. Then a gradual decrease in pressure began, 1,038 mb. being its highest central pressure while within the United States.

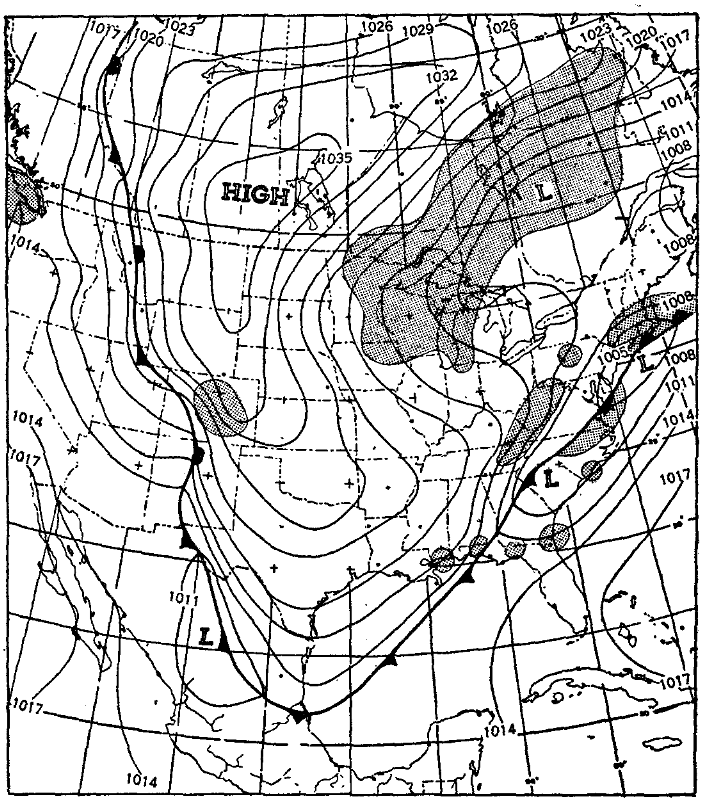

Figure 2.—Surface weather chart for 0630 GMT, April 19, 1953. Shading shows areas of active precipitation. Note northerly flow over eastern half of country on this map and figure 4. Lowest temperatures were experienced in the Southeast on the nights of April 19–22.

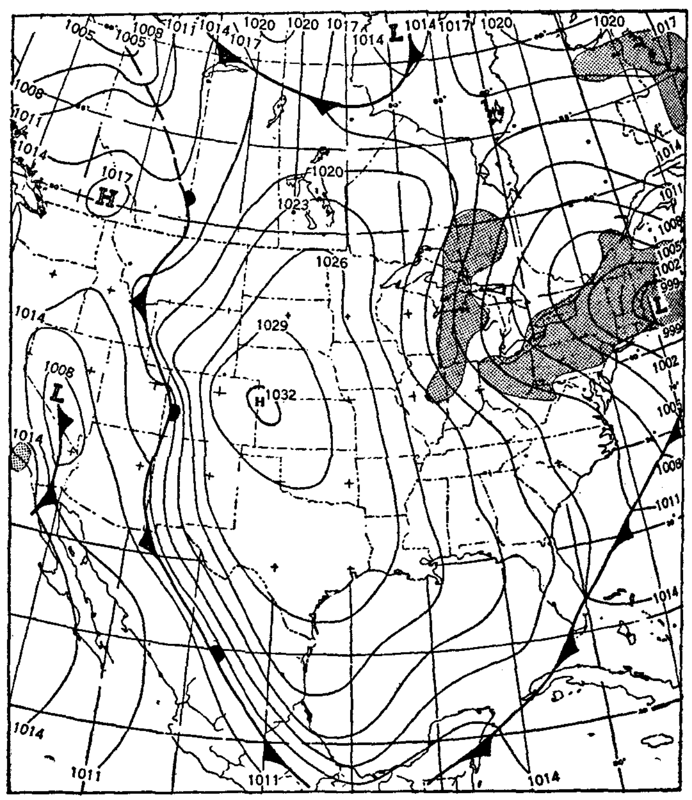

Figure 3.—Surface weather chart for 0630 GMT, April 20, 1953.

VERTICAL STRUCTURE

Of the Canadian stations making radiosonde observations regularly, Churchill was closest to the high center in the period from *1500 GMT of the 17th to 0300 GMT of* the 19th; it was sufficiently close that these soundings may be used *per se* to represent the vertical structure through the center of Alfa at these times. The soundings are shown as a composite in figure 5. In each of the soundings observe the weak inversion off the ground and, above this, an extensive, nearly isothermal layer to approximately 750 mb., which is characteristic of the lapse rate in cold, continental air masses near their source region [1]. The corresponding curves for dew point temperature were omitted from figure 5 for the sake of clarity. However, the respective mixing ratio values in the stratum below 750 mb. for all points on each of the soundings, ranged closely around 1.3 gm. per kg. Each of the soundings in figure 5, when plotted on a Rossby diagram and then compared with the characteristic slopes given by Showalter [2], clearly labels the air as having continental Arctic properties.

Further insight into Alfa's vertical structure is given by the time cross section over Rapid City, S. Dak. (fig. 6). The warm, low tropopause of the typical Arctic type is clearly in evidence at 0300 GMT of the 19th, but fades away rapidly after 1500 GMT upon the approach of Alfa's center. At 0300 GMT of the 20th, about 6 hours after the High center had passed the station, no tropopause point can be found to the top of this sounding, which only reached to 200 mb.; however, the existence of a tropical type tropopause is now suggested. The top of the cold dome was very flat throughout the 24 hours of the time section and was located very near the 700-mb. level.

While Alfa satisfied most of the specifications given by Wexler [3] to be classified as a cold or polar type anticyclone of North America throughout the time interval of this study, comments are in order on the weakness of its

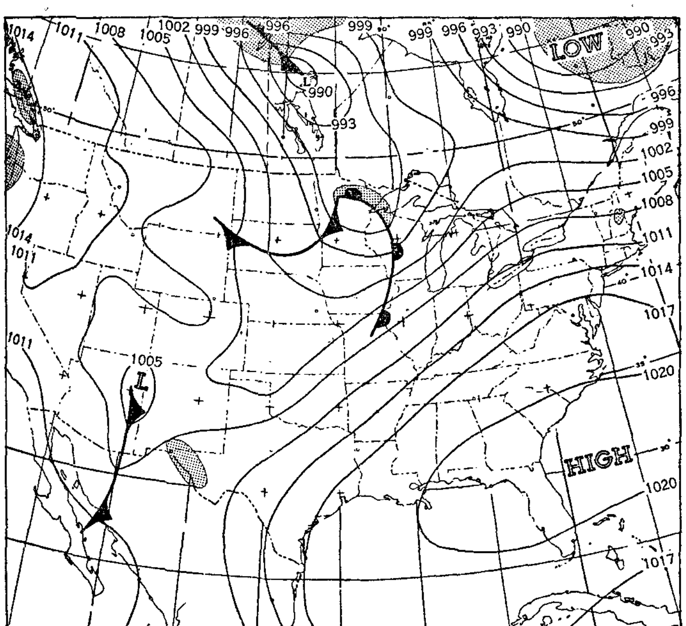

FIGURE 4.—Surface weather chart for 0630 GMT, April 22, 1953.

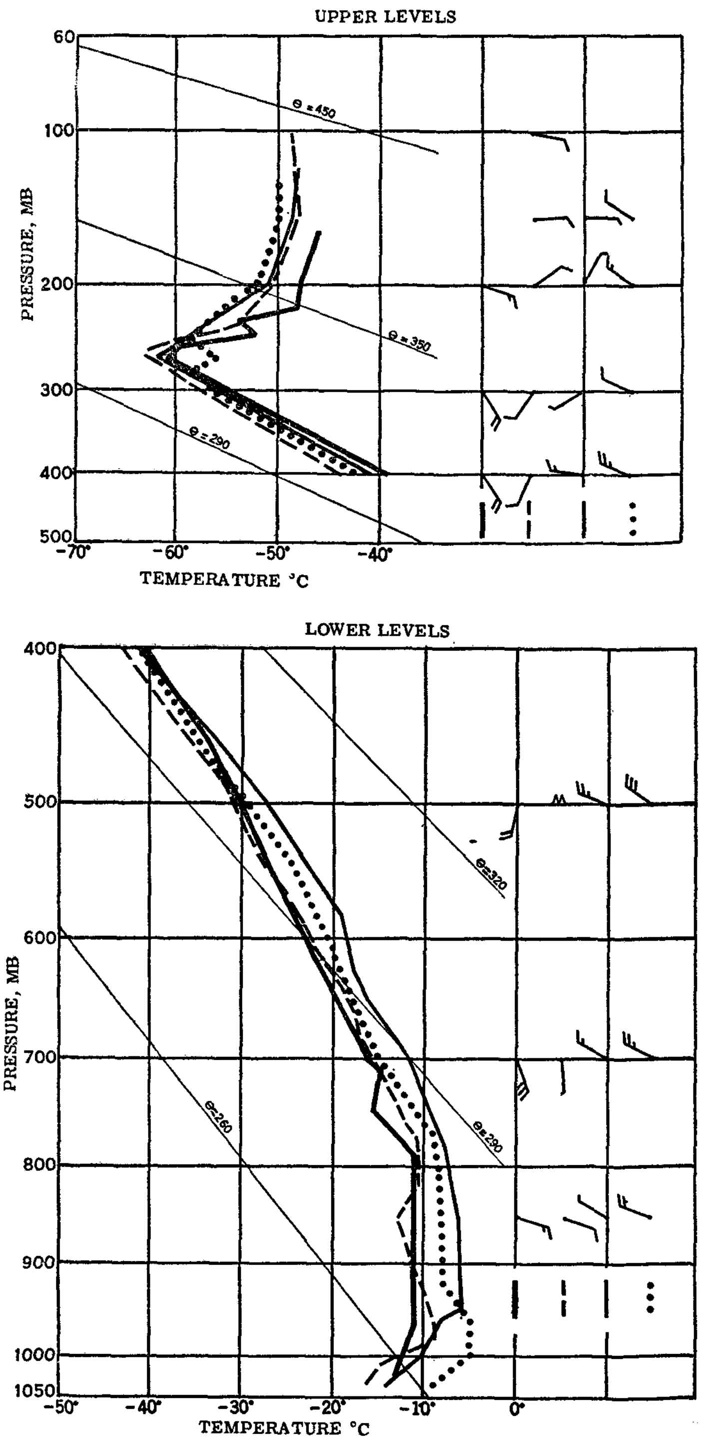

FIGURE 5.—Upper air soundings over Churchill, Manitoba at 1500 GMT, April 17 (heavy solid line), 0300 GMT, April 18 (dashed line), 1500 GMT, April 18 (thin solid line), and 0300 GMT, April 19 (dotted line). The winds are for the constant pressure levels at which they are plotted and correspond to the soundings as indicated by the key at the bottom right. A full barb indicates a speed of 10 knots.

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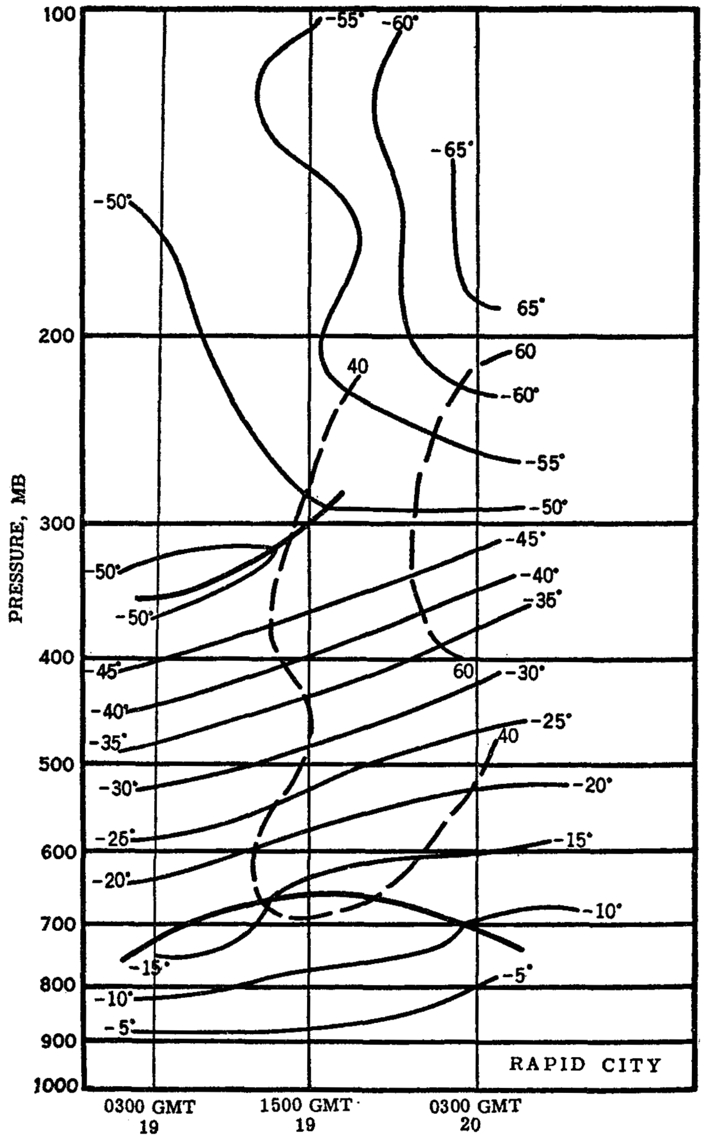

FIGURE 6.—Time cross section, Rapid City, S. Dak., showing soundings at 0300 and 1500 GMT, April 19 and 0300 GMT, April 20. Isotherms (solid lines) are in degrees Celsius (Centigrade). Isotachs (dashed lines) are in knots.

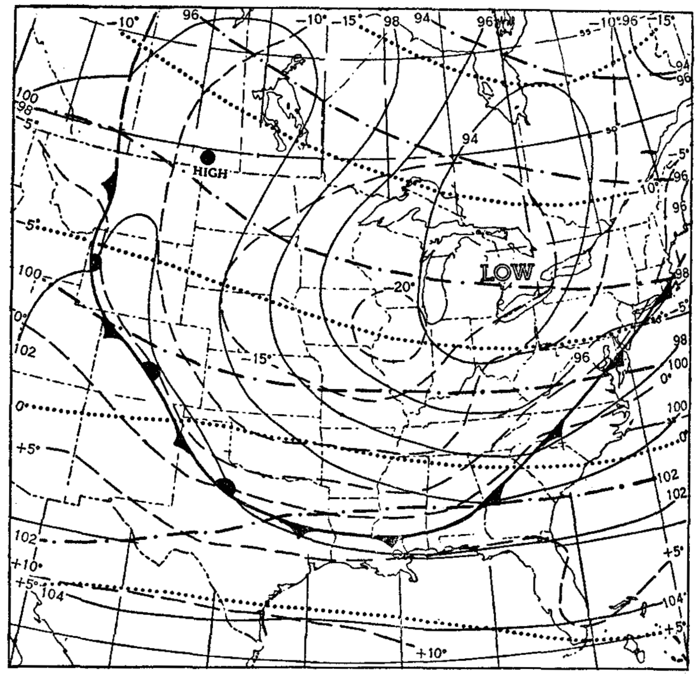

FIGURE 7.—700-mb. chart at 1500 GMT, April 19, 1953 superimposed on the normal April chart. Contours are in hundreds of geopotential feet; April 19 contours are given by solid lines and normal April contours by dash-dot lines. Isotherms are in degrees Celsius (Centigrade); April 19 isotherms are given by dashed lines and the normal April isotherms by dotted lines. The large dot over the word "High" shows the sea level position of Alfa.

exhibition of the required characteristics. In the lower troposphere, Alfa was colder than the environment, but only to about 850 mb.; its anticyclonic circulation failed to reach up to the 700-mb. level after 0300 GMT of the 20th. Its tropopause may be considered warm as it did fall within the temperature range, —50° C. to —65° C., given by Wexler, but the height of its tropopause, which was roughly 10 km. (fig. 5), exceeded the higher limit of the range, 5 to 8 km., to be classified distinctly as low. An examination of the 200-mb. and 150-mb. constant level charts corresponding to the times of the soundings in figure 5 showed that Alfa was distinguished, but weakly, for having a warm, lower stratosphere.

The apparent weakness of Alfa as a polar anticyclone, by the above criteria, was likely due at least partially to its immediate proximity to the quasi-stationary cyclonic circulation over the Great Lakes region. This cyclonic circulation was somewhat of the cold Low type, extending over a larger area than usual, and exhibiting colder temperatures than the environment at all constant levels in the troposphere up to and including the 500-mb. level, and was itself associated with a low, warm, polar type tropopause. On coming into close contact with such an environment already possessed of many of the properties generally attributed to a polar High, it is reasonable that Alfa would have suffered by comparison. Later we will again mention this close relationship between Alfa and the cyclonic circulation over the eastern part of the country in connection with some very low temperatures for the season recorded in this period.

THE COLD ENVIRONMENT OF ALFA

A vivid picture of the cold air that prevailed over most of the eastern United States ahead and to the left of Alfa's track is given by a comparison of actual temperatures with the normal [4] on some of the constant pressure charts in the lower troposphere. For instance, it was found that at 0300 GMT April 19, when Alfa had started to move southward but was still north of the border, the 700-mb. temperatures at Omaha, Nebr. and North Platte, Nebr., both located near the axis of coldest temperatures at this level, were some 15° C. below normal, and the heights of the 700-mb. surface, while not far below normal at North Platte, departed rapidly from normal in a steep downward slope toward a Low center near North Bay, Ontario. Simultaneously, the observed winds at 700 mb. over North Platte, Omaha, and stations in adjacent States to the north and east, had northerly components

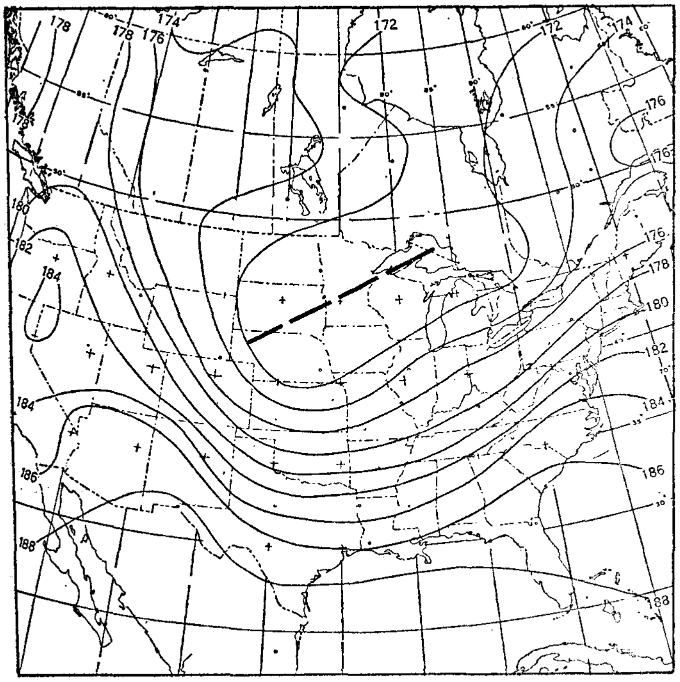

FIGURE 8.—1,000–500 mb. thickness chart at 0300 GMT, April 19, 1953. Thicknesses are in hundreds of geopotential feet. The heavy dashed line shows the axis of cold air. Note in figures 9 and 10 how this cold air axis moved east-southeastward ahead of the center.

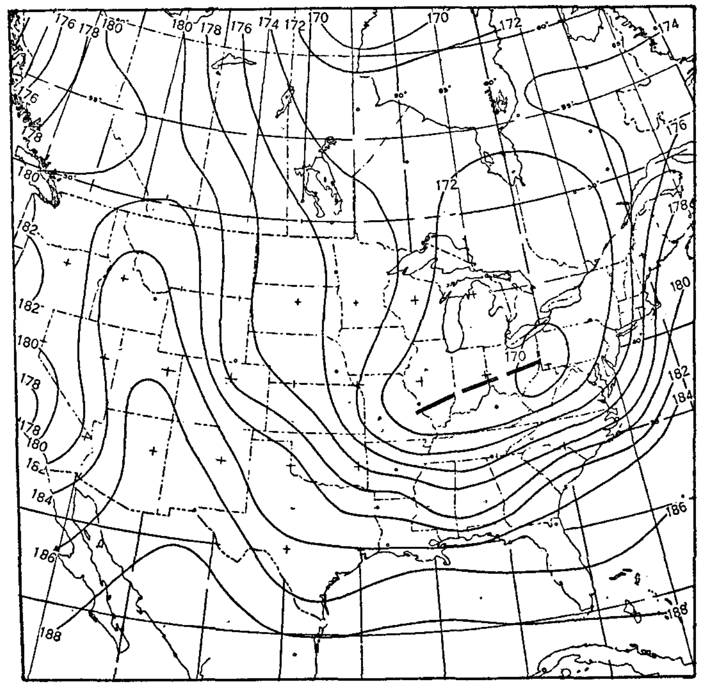

FIGURE 9.—1,000–500 mb. thickness chart for 0300 GMT, April 20, 1953.

distinctly greater than normal. This axis of low temperatures at 700 mb. moved steadily eastward and by 0300 GMT, April 21, was located along the Atlantic Coast. At this time the 700-mb. temperature at Cape Hatteras, N. C., for example, was 14° C. below normal and the height of the 700-mb. surface much lower than normal, with the wind having a slight northerly component as contrasted with the normal due west winds. A particular instance in this period, illustrating these departures from normal at the 700-mb. level, is shown in figure 7.

One of the outstanding features of the 1,000–500 mb. thickness charts in this period, three of which are reproduced in figures 8, 9, and 10, is the axis of cold temperature in this stratum, designated by a dashed line in the figures. This axis of low mean temperature moved east-southeastward with time, and when compared with the track of Alfa, is seen to have led the center at all times. A case study reported by Sutcliffe and Forsdyke [5] likewise made mention of a High center that was located west of a 1,000–500 mb. thermal trough. This condition is not unusual, but is mentioned as being indicative of the strong baroclinity of the lower atmosphere east of the High center. In superimposing the track of the High center on these thickness charts, we are also impressed by the fact that the center itself was associated with a fairly strong thermal gradient in this stratum.

The anomalies at the 500-mb. level were apparently similar to those at 700 mb. in this time interval, judging from the height departures from normal, temperature normals not being directly available. Some representative anomalies at the 500-mb. level were: 700 feet below

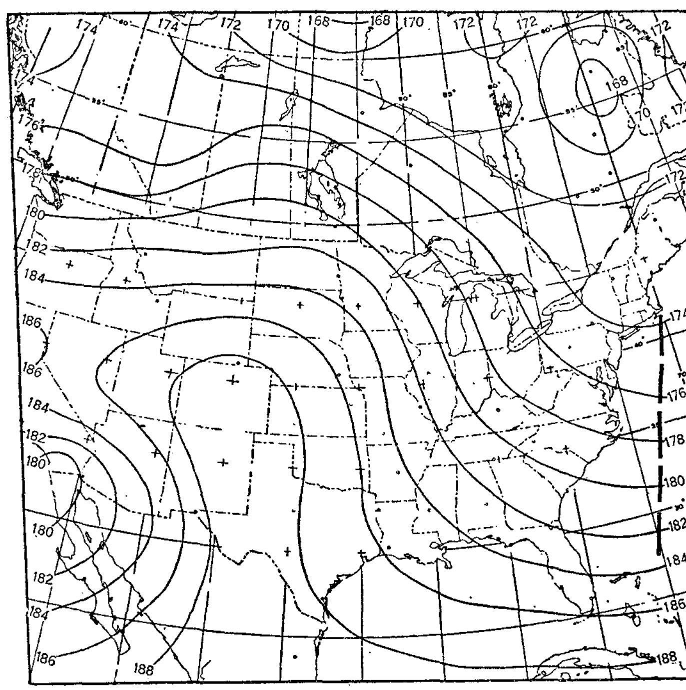

FIGURE 10.—1,000–500 mb. thickness chart for 0300 GMT, April 22, 1953.

normal at Omaha at 0300 GMT, April 19; 1,000 feet below normal at Rantoul, Ill. at 1500 GMT on the 19th; 1,000 feet below normal at Pittsburgh, Pa. at 0300 GMT on the 20th; 1,000 feet below normal at Washington, D. C. at 1500 GMT on the 20th; and about 1,000 feet below normal at both Mount Clemens, Mich. and Nantucket, R. I. at 0300 GMT on the 21st.

It is therefore apparent that in this period, as the

700-mb. Low center moved slowly east-northeastward through southern Quebec, the air at this level and also at 500 mb. over the East Central States remained colder than normal, heights of the constant pressure surfaces were generally lower than normal, while winds for the most part had a component from the north greater than normal.

RECORD MINIMUM SURFACE TEMPERATURES

We have seen how, as Alfa advanced eastward along the Gulf of Mexico coastline, the environment preceding it was already perceptibly colder than normal up to the 500-mb. level. The combination involving Alfa, a polar type High, and the cold environment ahead of it resulted in the rash of near-record, record-equalling, and record-breaking low temperatures reported from stations in Georgia and several adjoining States, mostly on the 21st of April. A tentative list of the record-breaking minimum temperatures for the particular date and month is shown in table 1. The table indicates that some records were established as recently as the 17th of April, but these occurred in conjunction with the passage of another High through the Southeast ahead of Alfa. By far the greater number of records were set with the passage of Alfa on the 21st.

Figure 11 shows the average observed temperature and also the average temperature departure from normal for the 4-day period, April 19–22, 1953 over the southeastern United States, except southern Florida. This area embraces all the stations included in table 1 at which records were established. Since the figure is based on 4-day averages the persistence of cold air over this section of the country is clearly indicated.

TABLE 1.—*Tentative list of near record, record-equalling, and record-breaking minimum temperatures at selected stations in the Southeast, April 1953*

Station	Min. temp.	Date	Remarks*
	(° F.)		
WBO, Anniston, Ala	29	21	Lowest.
	36	22	Do.
WBAS, Birmingham, Ala	31	21	Latest date of freezing temperatures since records began in 1896.
WBAS, Tallahassee, Fla	39	21	1 degree above record.
WBAS, Atlanta, Ga	36.6	20	Previous low 37.6 in 1901.
	33.4	21	Previous low 36.4 in 1914.
WBAS, Augusta, Ga	33	17	Lowest. Fifth consecutive April with sub-normal temperatures.
	34	20	
	30	21	Do.
	35	22	Do.
WBAS, Rome, Ga	27	21	Lowest.
WBAS, Savannah, Ga	36.3	21	Do.
WBAS, Spartanburg, S. C	35	20	
	34	21	
	36	22	
WBAS, Columbia, S. C	32	20	Do.
	29	21	Do.
WBAS, Charleston, S. C	34	21	Do.
WBO, Charleston, S. C	42	21	Lowest for so late in the season since 1910.
WBAS, Greenville, S. C	32	21	Latest freeze since records began in 1917.
WBO, Richmond, Va	33	21	
	34	22	
WBAS, Chattanooga, Tenn	29	21	Lowest (records began 1879).
WBAS, Nashville, Tenn	30.6	19	Lowest for this date.
WBAS, Wilmington, N. C	35	21	Lowest.
WBO, Raleigh, N. C	34	21	Record.
WBAS, Greensboro, N. C	29	17	Do.
	31	20	Do.
	31	21	Do.
	31	22	Do.
WBO, Asheville, N. C	33	19	Lowest for date.
	30	22	Do.

*Lowest, as used here, means lowest temperature ever recorded so late in the season; record means that the temperature equalled the previous low temperature record for so late in the season.

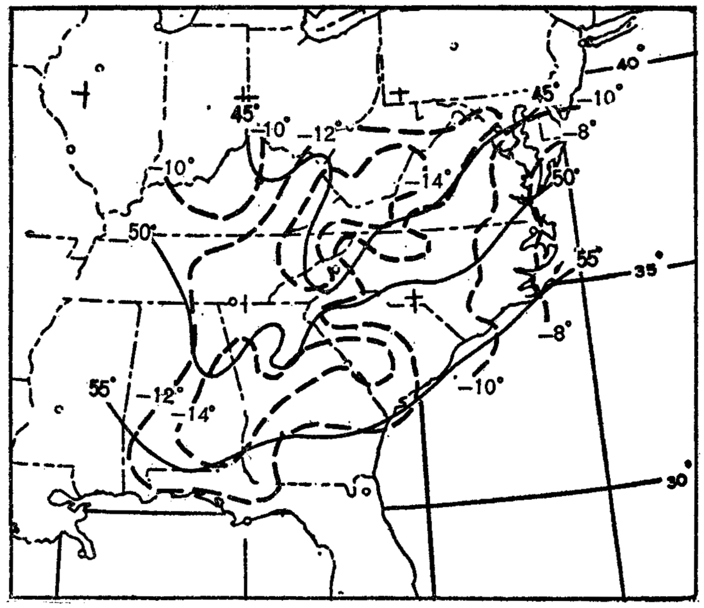

FIGURE 11.—Isopleths of average surface temperatures (° F.) and their departures from normal for the 4-day period April 19–22, 1953.

THE INTENSITY OF ALFA

Although Alfa was not solely responsible for the many record low temperatures that were established, on the sea level map (fig. 2 or 3) this High gave the impression of being a dominant pressure system and for a while covered an area somwehat greater than half of the United States. It might therefore be interesting to appraise the intensity of Alfa in its own right, if possible.

Intensity criteria for both Highs and Lows have been proposed by James [6] who has urged that objectivity be introduced into these evaluations. James computed the mean central pressures and standard deviations for both Highs and Lows in 5-degree latitudinal strips around the Northern Hemisphere. He then proposed, for example, that a High with a central pressure more than two σ (σ=standard deviation) higher than the mean of its corresponding latitude should be classed as very intense; a High with a central pressure greater than the mean for its latitude by an amount anywhere between σ and two σ would be rated intense, etc. But there may be a longitudinal aspect worthy of consideration in an evaluation of intensity, particularly some allowance for the climatic influences of continents, oceans, and extensive mountain areas. To illustrate this, consider latitude 32½° N., where, according to James, the mean central pressure of Highs in spring is 1,026 mb., σ^2 is 30, and a High with a central pressure of 1,040 mb., being more than 2σ greater than the mean, would be rated as very intense. Now on the basis of figure 12, showing maximum pressures for one of the spring months for the entire period of record, such a rating of very intense seems appropriate for central Texas but a value even 10 mb. lower, i. e., 1,030 mb. should deserve a very intense rating if observed in southern

Arizona. Illustrations like the above could be multiplied many fold. It therefore seems that longitudinal differences frequently deserve consideration in determinations of intensity. Until more complete studies are forthcoming, it may be possible to adjust James' ratings when they are seen to be inconsistent with extreme values based on a long period of record for the particular region.

TABLE 2.—*Intensity ratings of Alfa, following James [6]*

Latitudinal position of Alfa	Mean central pressure (mb.)	σ^2 (mb.)	Representative central pressure of Alfa (mb.)	Intensity rating
55-60° N	1, 030	53	1, 040	Intense.
50-55	1, 029. 5	37	1, 037	Do.
45-50	1, 028. 5	44	1, 037	Do.
40-45	1, 027	26. 5	1, 033	Do.
35-40	1, 025?	26	1, 030	Normal.
30-35	1, 026?	30	1, 028	Do.
25-30	1, 023	10	1, 024	Do.

The intensity ratings of Alfa at the respective latitudes according to James' criteria, are listed in table 2. Alfa fell into the intense, but not the very intense, category, until it passed south of 40° N., after which its rating was of normal intensity.

Another estimate of intensity may be had from the diagrams relating frequency to central pressures of anticyclones against latitude for the Northern and Southern Hemispheres, but only for the winter and summer seasons, as published recently by Gibbs [7]. Gibbs' diagrams indicate that Alfa was somewhat less intense than 50 percent of winter anticyclones throughout its track from south central Canada through the United States, but when compared with summer anticyclones, Alfa was of extreme intensity while the center was north of the United States border, but dropped off rapidly in intensity to reach approximately a median value while moving southward through central United States.

The modification of the James technique for estimating intensity, as suggested above, is applicable to Lows as well as to Highs. This method involves the use of monthly charts of sea level pressure extremes, with isopleths drawn as shown in figure 12, obtained from Lennahan [8], along with monthly charts of sea level pressure normals, as given in [4]. The intensity of a High (or Low) would then be judged by how far its central pressure departed from the normal in the direction of the extreme, both the normal and the extreme being dependent on the longitude as well as the latitude of the High or vortex center. Values of σ which would be useful in the same manner as in the James technique, are admittedly lacking and should be incorporated into any future refinement.

In figure 13 can be seen just where the central pressure of Alfa fits in between the highest April pressures ever recorded and the April normals for each respective position along its track. From the figure, note how Alfa plots about two-thirds of the way from normal toward the extreme in the period from 1230 GMT of the 19th until 1830 GMT of the 20th, after which its central pressure

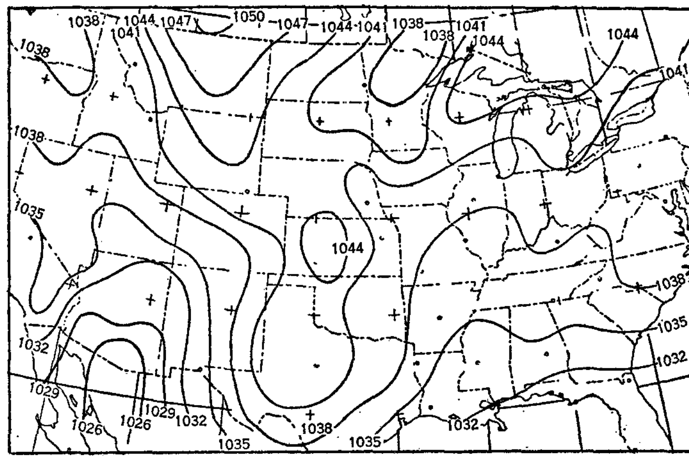

FIGURE 12.—Maximum observed sea level pressure (mb.) for April, based on entire period of record at each station. (After Lennahan [8].)

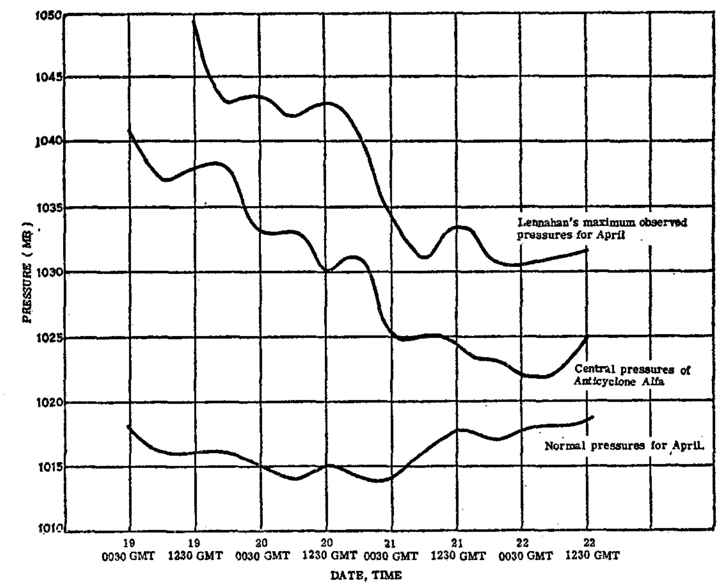

FIGURE 13.—Curves depicting normal April sea level pressure, highest pressure ever observed, and actual pressure of Alfa's center for successive 6 hourly positions along its track, with no corrections for diurnal variations.

plots closer to the normal by an amount less than half the spread between normal and extreme. Qualitatively, we conclude that Alfa was fairly intense until 1830 GMT of the 20th, after which it weakened and maintained about normal intensity. Certainly in this one case there has been close agreement concerning the intensity among the three methods.

DIFFERENTIAL TEMPERATURE CHANGES ALOFT OVER AND NEAR ALPHA

Figure 14 is essentially a space cross section showing the height profiles of selected constant pressure surfaces along the approximate major and minor axes of Alfa's sea level configuration at 0300 GMT, April 20. The center of the High at this time was about 2 degrees of longitude east of Denver, Colo. At 500 mb. Las Vegas, Nev. was

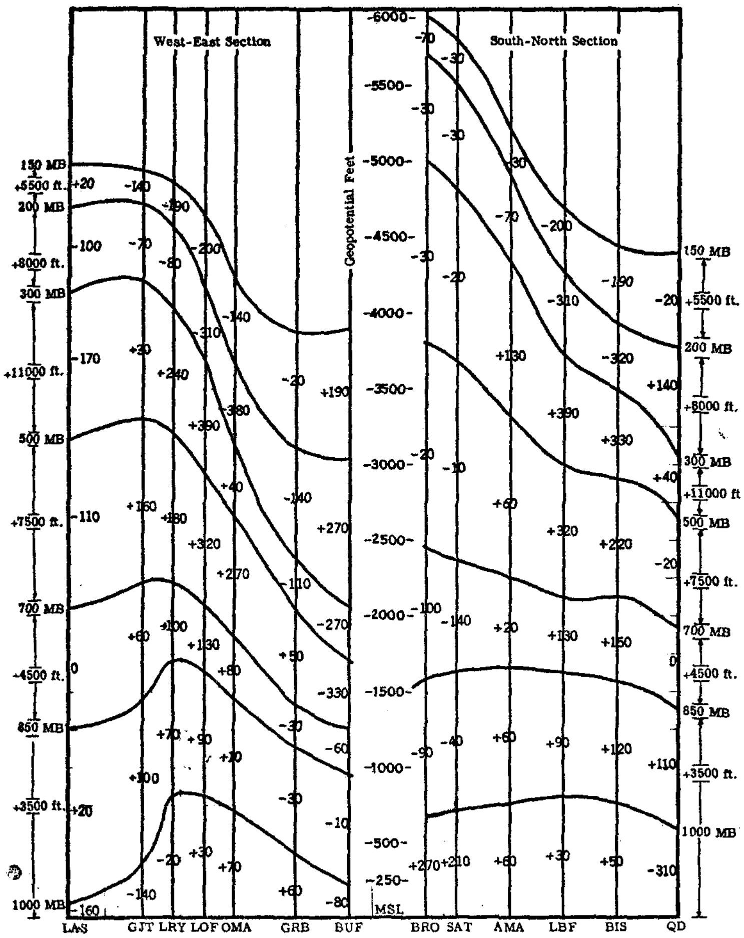

FIGURE 14.—Space cross sections at 0300 GMT, April 20, 1953 along the major and minor axes of Alfa, showing the profiles of constant pressure surfaces. Stations are those listed in table 3 and in that order. The figures midway between constant pressure surfaces are the 24-hour changes in feet of the thickness in each respective stratum. The numbers along both sides of the chart show the number of feet that were subtracted from the particular constant pressure profiles so that the chart would not be too large for reproduction. These numbers are the values that must be added to obtain the true thicknesses and heights.

just east of a cold Low along the Pacific Coast, and Green Bay, Wis. and Buffalo, N. Y. were under the influence of a cold Low centered near Buffalo. Brownsville, Tex. was in the direction toward which Alfa was moving while The Pas, Manitoba was in the area from which Alfa was rapidly departing.

In the chart, which extends to 150 mb., thicknesses between the various constant pressure surfaces (also sea level to 850 mb.) have been depressed by variable amounts as found to be expedient. The number of feet that should be added to the heights of the constant pressure surfaces, is indicated along the ordinate scale on both edges of the chart. If the actual height of, say, the 300 mb. level at Grand Junction, Colo. is wanted, it can be obtained by taking 4,250 feet read from the center ordinate scale, and adding 3,500 feet (depression of MSL–850 mb. thickness) plus 4,500 feet (850–700 mb. depression) and correspondingly, plus 7,500 feet, plus 11,000 feet to give a total of 30,750 feet. While the various strata have not been uniformly depressed, the differences in thickness for a particular stratum between stations are exact. Thus just a glance at the chart indicates that through the western section, Las Vegas to Denver, all strata from 1,000 mb. to 300 mb. were thicker than those through the eastern section, Denver to Buffalo. Contrariwise, above 300 mb. the strata between constant pressure surfaces were thinner in the west, thicker in the east.

TABLE 3.—*24-hour height changes of selected constant pressure surfaces and in thickness between selected constant pressure levels (assuming a constant height for the "0"-mb. level) at stations along the major and minor axes of Alfa during period ending at 0300 GMT, Apr. 20, 1953*

West-East Section

24-hour change in—	Las Vegas, Nev.	Grand Junction, Colo.	Denver, Colo.	North Platte, Nebr.	Omaha, Nebr.	Green Bay, Wis.	Buffalo, N. Y.
1,000-mb. height	−160	−140	−20	+30	+70	+60	−80
150-mb. height	−500	0	+300	+450	−50	−220	−290
1,000-150 mb. thickness	−340	+140	+320	+420	−120	−280	−210
150-0 mb. thickness	+500	0	−300	−450	+50	+220	+290

South-North Section

24-hour change in—	Brownsville, Tex.	San Antonio, Tex.	Amarillo, Tex.	North Platte, Nebr.	Bismarck, N. Dak.	The Pas, Manitoba
1,000-mb. height	+270	+210	+60	+30	+50	−310
150-mb. height	−70	−60	+230	+450	+360	−60
1,000-150 mb. thickness	−340	−270	+170	+420	+310	+250
150-0 mb. thickness	+70	+60	−230	−450	−360	+60

Along the west-east section Alfa was warmer in the west than in the east below 300 mb. and the reverse was true above 300 mb. In the south-north section some of the slope of the constant pressure surfaces downward to the north may be a normal latitudinal influence. Note how the mean temperatures associated with the various strata were generally higher in the south than in the north below 300 mb. while it was perceptibly colder in the southern section than in the northern in the 200–150 mb. stratum. More specifically, the 200–150 mb. thickness at Brownsville was 5,730 feet, equivalent to a mean virtual temperature of about −65.6° C., and at The Pas, it was 6,150 feet, which is equal to about −50.4° C.

Since changes in the 1,000-mb. height are very closely correlated with sea level pressure changes, it may be of interest to compare the 24-hour height changes of the 1,000-mb. level with the 24-hour net changes in thickness of the 1,000–150 mb. stratum for the stations in the cross section. Some of the computations are tabulated in table 3. Let us assume a constant height for the "zero"-mb. level and make a sample deduction. At Las Vegas the 1,000-mb. height fell 160 feet and the 150-mb. height fell 500 feet giving a net change in the 1,000–150 mb. thickness of −340 feet. Therefore, cooling below 150 mb. was more than compensated for by warming above 150 mb. to account for the decrease in sea level pressure. If now we examine the 24-hour changes in thickness near the center of Alfa at Denver and North Platte (fig. 14) we find that while warming had occurred below 300 mb., nevertheless sufficient cooling took place above 300 mb. to permit a small rise in the 1,000-mb. height at North Platte and only a very small fall at Denver.

Although this study has revealed some interesting features in the history, structure, and environmental interaction of the anticyclone Alfa, it has left unanswered many questions on the formation and evolution of the High. The authors conclude with Wexler [3] that "it is quite impossible to discuss the anticyclone as a separate entity, with respect to either its origin or its role in the general circulation".

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CORRECTION

MONTHLY WEATHER REVIEW, vol. 80, No. 3, March 1953, page 82: In column 2, in text beneath table 1, total March 1953 precipitation at Boston should be 11.00 in. instead of 11.69 as given. The next sentence should read "The 24-hour total of 3.10 in. for the period ending about 1900 EST, March 30 is 0.06 in. greater than any previous 24-hour total in March."