DEPARTMENT OF COMMERCE
SINCLAIR WEEKS, Secretary

WEATHER BUREAU
F. W. REICHELDERFER, Chief

MONTHLY WEATHER REVIEW

JAMES E. CASKEY, JR., Editor

Volume 84
Number 1

JANUARY 1956

Closed March 15, 1956
Issued April 15, 1956

ON THE FORMATION OF HURRICANE ALICE, 1955

With Notes on Other Cold-Season Tropical Storms

JOSÉ A. COLÓN
U. S. Weather Bureau, San Juan, Puerto Rico
[Manuscript received December 29, 1955]

ABSTRACT

The occurrence of hurricane Alice in January 1955 was a meteorologically unseasonable event. The synoptic history of the storm during its genesis over the warm waters of the tropical Atlantic, its intensification while drifting west-southwestward, its passage over the Leeward Islands, and its decay in the eastern Caribbean is reviewed. Its formation is attributed to a rare combination of favorable circumstances. These included anticyclogenesis and blocking in the middle latitudes of the western Atlantic and strong, deep easterlies to the south. This prolonged pattern of circulation effectively isolated the tropical regions from polar air invasions and caused an incipient cyclone that had formed at the point of fracture of an extended Atlantic trough to move west-southwestward over relatively warm waters where it was transformed into a warm-core storm of hurricane intensity. The wind and thermal structure is analyzed and land observations and damage estimates are presented. Finally, some comparative notes on other cold-season storms in the Tropics are given.

1. INTRODUCTION

Hurricane Alice of 1955 gave rise to considerable speculation at the time of its formation due to its unseasonable occurrence. This storm had its genesis in a low pressure center which formed during December 29, 1954, around latitude 21° N., longitude 49° W. (fig. 1). It then drifted west-southwestward, gradually developing warm-core properties, and intensified to hurricane proportions by the afternoon of January 1, 1955. During January 2 the storm passed over the Leeward Islands causing considerable damage.

The formation of storms of this type in the Atlantic Ocean in winter is so infrequent that the events leading up to their formation must constitute a coincidence of favorable circumstances very seldom duplicated. The main purpose of this report is to describe those conditions that led to the formation of Alice. In addition, a discussion of the wind and thermal structure of the storm is given and some remarks on other cold-season tropical storms are made.

The analysis of Alice is based on the surface maps, the low-level wind charts, contour charts at the standard isobaric levels, and time cross-sections at key stations. Low-level wind maps were obtained by combining ship wind reports and Pibal winds at 2,000 feet at land stations. This procedure for the combination of wind data has been used previously by the writer with good results. Upper-air charts at 850, 700, 500, and 200-mb. levels were available, but only the 500-mb. charts are illustrated here. The analysis over the ocean is mainly dependent on ship reports and the best coverage is usually available during the daytime. As a consequence, the surface analysis is presented for 1230 GMT and the upper-air maps for 1500 GMT, although for upper-air analysis in these regions the 0300 GMT observations are generally recommended.

The upper-air analysis over the ocean is based to a large extent on extrapolations from ship observations. Extrapolations were made first from the surface to 700 mb. by estimating the 700-mb. temperature and assuming that the mean temperature of the layer was equal to the

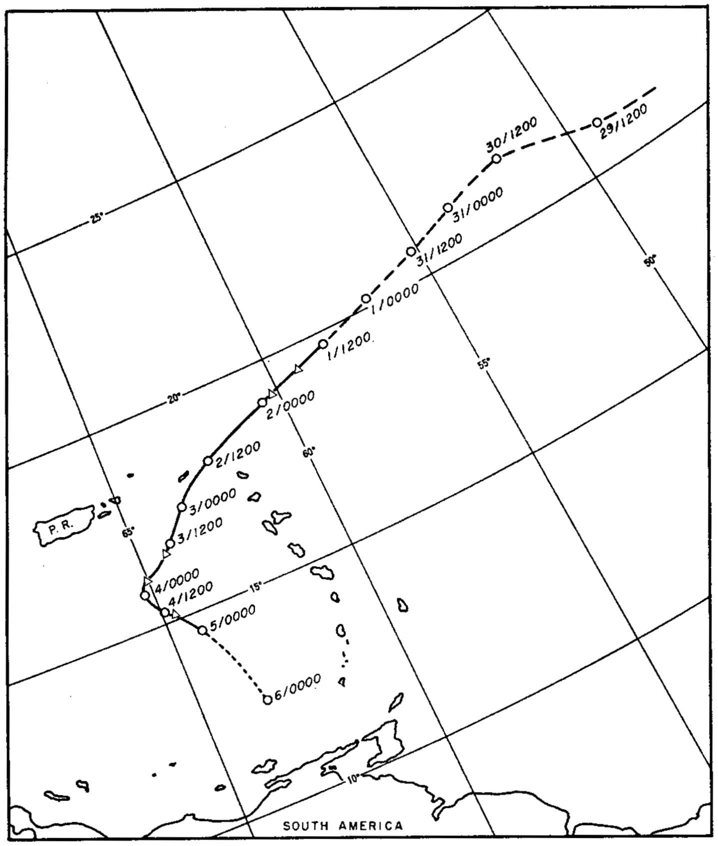

FIGURE 1.—Track of hurricane Alice, December 29, 1954–January 5, 1955. Dates and times (GMT) are indicated.

arithmetic average of the surface and 700-mb. temperatures. The 700-mb. chart was then analyzed and necessary adjustments made. The 500-mb. heights were extrapolated from the 700-mb. level using the same procedure.

2. SYNOPTIC HISTORY

The beginnings of what eventually led to the formation of Alice started around December 25–26, 1954, from a typical wintertime picture. The charts for December 26 (fig. 2) show a frontal system extending southwestward from an extratropical Low (centered around 45° N., 45° W.) and becoming an E-W quasi-stationary front in the region of the Bahama Islands. This front had moved rapidly southeastward from the continent in the previous 48 hours and passed Bermuda around 1230 GMT, December 25. On the 26th a pertubation existed in the trade easterlies around longitude 53°–54° W. extending southward from the frontal trough in the north. This type of formation, which is frequent in this area during the cold season, has been described in the literature [1]. Although the wind structure is similar to that of the summertime easterly waves, these cold-season perturbations form in connection with a polar system and move to the east against the trade winds. One other system that predominated on the 26th was the anticyclone behind the cold front (fig. 2). The behavior of this high cell was of particular significance in the events that followed. At this time the anticyclone had a well-defined NNE–SSW elongated axis centered along the coast.

At upper levels (fig. 2B) the flow was dominated by the extended polar trough associated with the surface system. The extension of the trough into the Tropics was clearly defined by the winds at San Juan, Guadeloupe, and Trinidad. To the west of the trough a well-defined ridge extended northward along the east coast.

During the next 2 days the polar system and associated tropical perturbation moved steadily eastward steered by the westerlies. On December 27 (fig. 3A) the extratropical Low was located around longitude 40° W. The tropical trough moved to around longitude 49° W.—an eastward speed of around 12 knots. As there were not many data near the position of the trough, the analysis indicated on this and other charts was based on consideration of the intermediate maps, on the analysis of the low-level wind charts, and also on proper continuity.

Significant changes took place in the shape of the anticyclone. The center of the cell moved very slowly south-southeastward and the major axis turned to a more E-W orientation. The polar front moved slightly southward in the region north of Cuba and Hispaniola. The temperature discontinuity was not too clear, but there was a wind speed discontinuity with higher speeds north of the front. Showers were reported along the frontal zone in the eastern Bahama Islands. At the 500-mb. level (fig. 3B) the polar trough moved eastward and passed Ship Echo (35° N., 48° W.). At the same time a sharp ridge spread into the region north of Bermuda. Contour rises were observed at Bermuda and particularly at Sable Island. The Bermuda winds became more northerly; ordinarily they should turn to westerly with the normal approach of a ridge. A secondary trough formed between Bermuda and San Juan in an ENE-WSW orientation.

By December 28 (fig. 4A) the transformation of the High into a well-developed E-W oriented anticyclone was completed. This anticyclone dominated the flow from longitude 40° W. westward to the Eastern States and easterly flow prevailed south of latitude 35° N. The polar Low and tropical wave continued moving eastward at about the same speed. The actual position of the southern section of the tropical perturbation was uncertain, but its northern portion was well delineated by a series of ship observations around latitudes 22°–27° N. and longitudes 36°–46° W. The large amplitude of the 1016-mb. isobar suggests the presence of a small low center. Considerable cloudiness and weather were observed over this area.

Along the quasi-stationary front no temperature discontinuity was discernible any more, except in the region north of latitude 25° N. A wind speed discontinuity was still present, but as it generally occurs in this area the polar front was gradually losing its properties.

The low-level wind map (dashed pattern in fig. 4B) shows the frontal trough and tropical wave as an extended

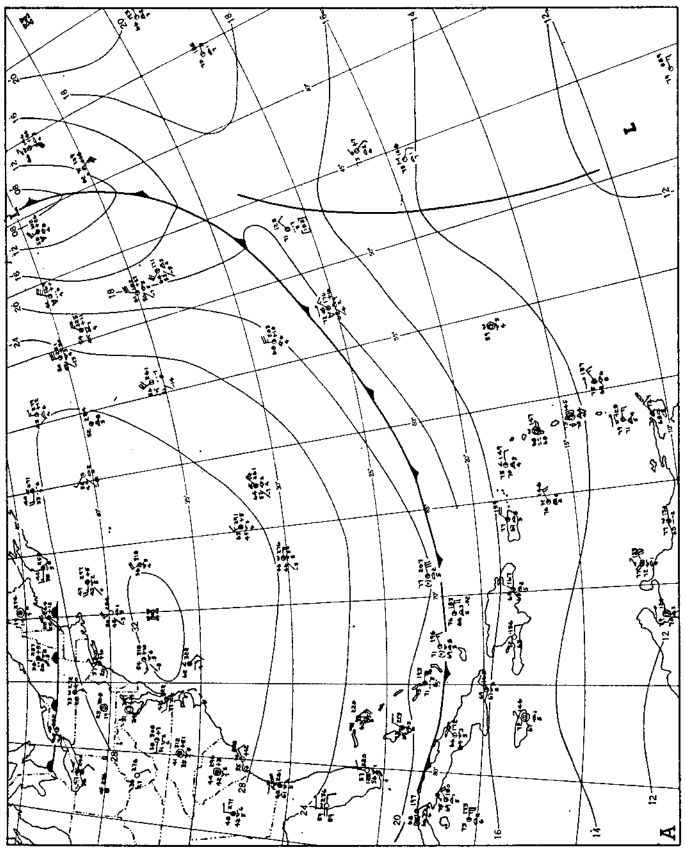

FIGURE 3.—December 27, 1954. (A) Surface map, 1230 GMT. (B) 500-mb. map, 1500 GMT.

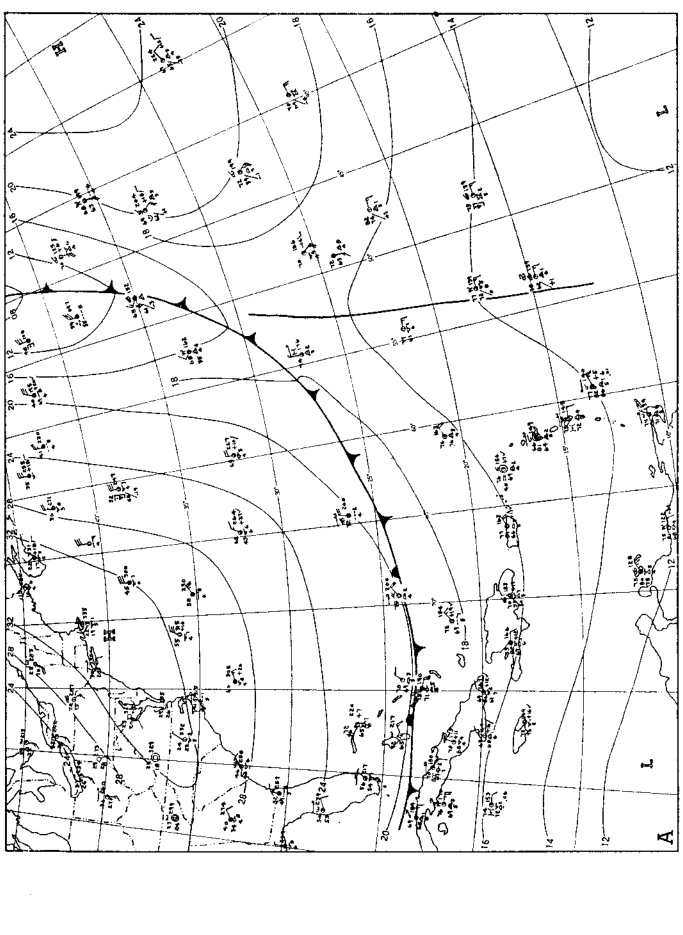

FIGURE 2.—December 26, 1954. (A) Surface map, 1230 GMT. (B) 500-mb. map, 1500 GMT.

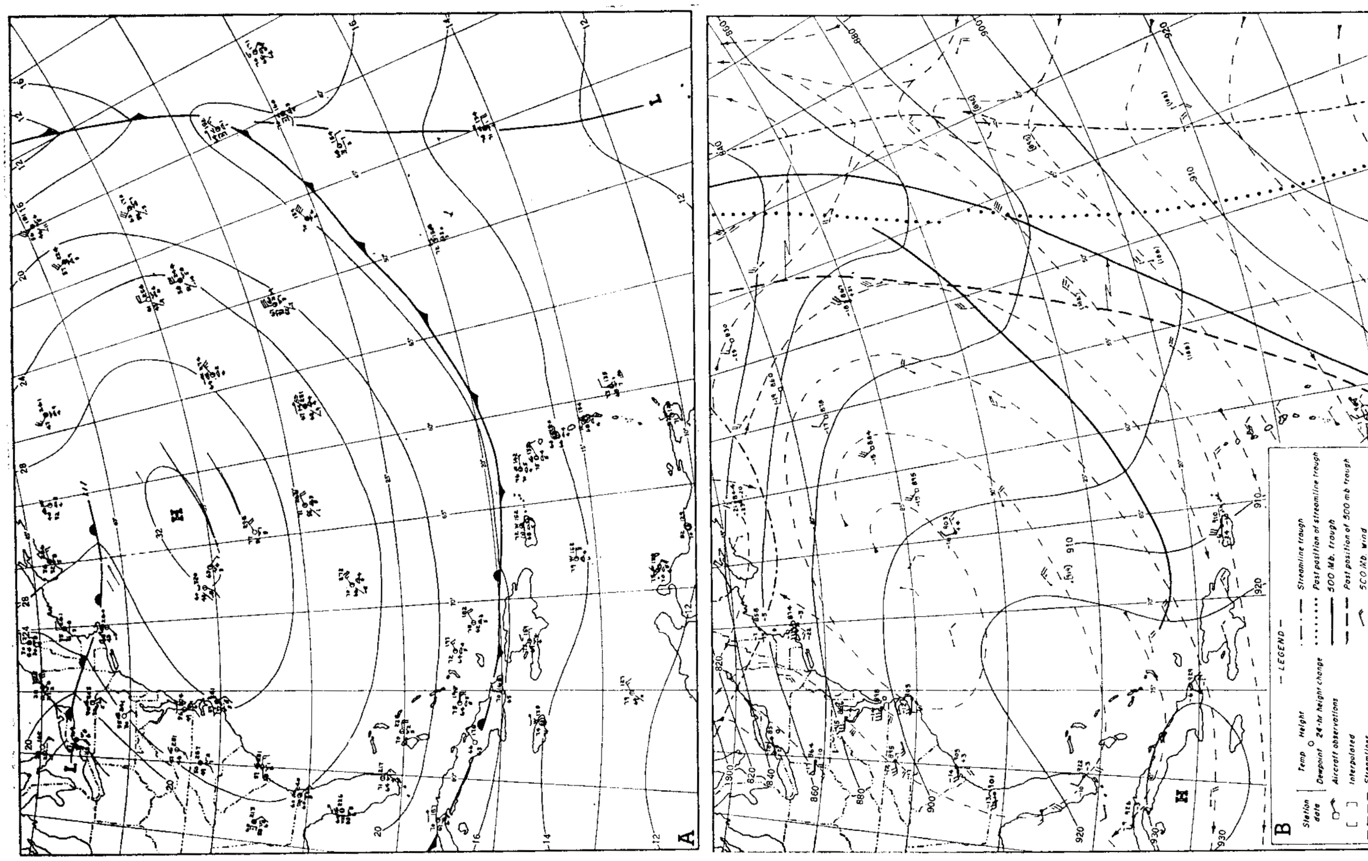

FIGURE 4.—December 28, 1954. (A) Surface map, 1230 GMT. (B) 500-mb. map with 2,000-foot streamlines, 1500 GMT.

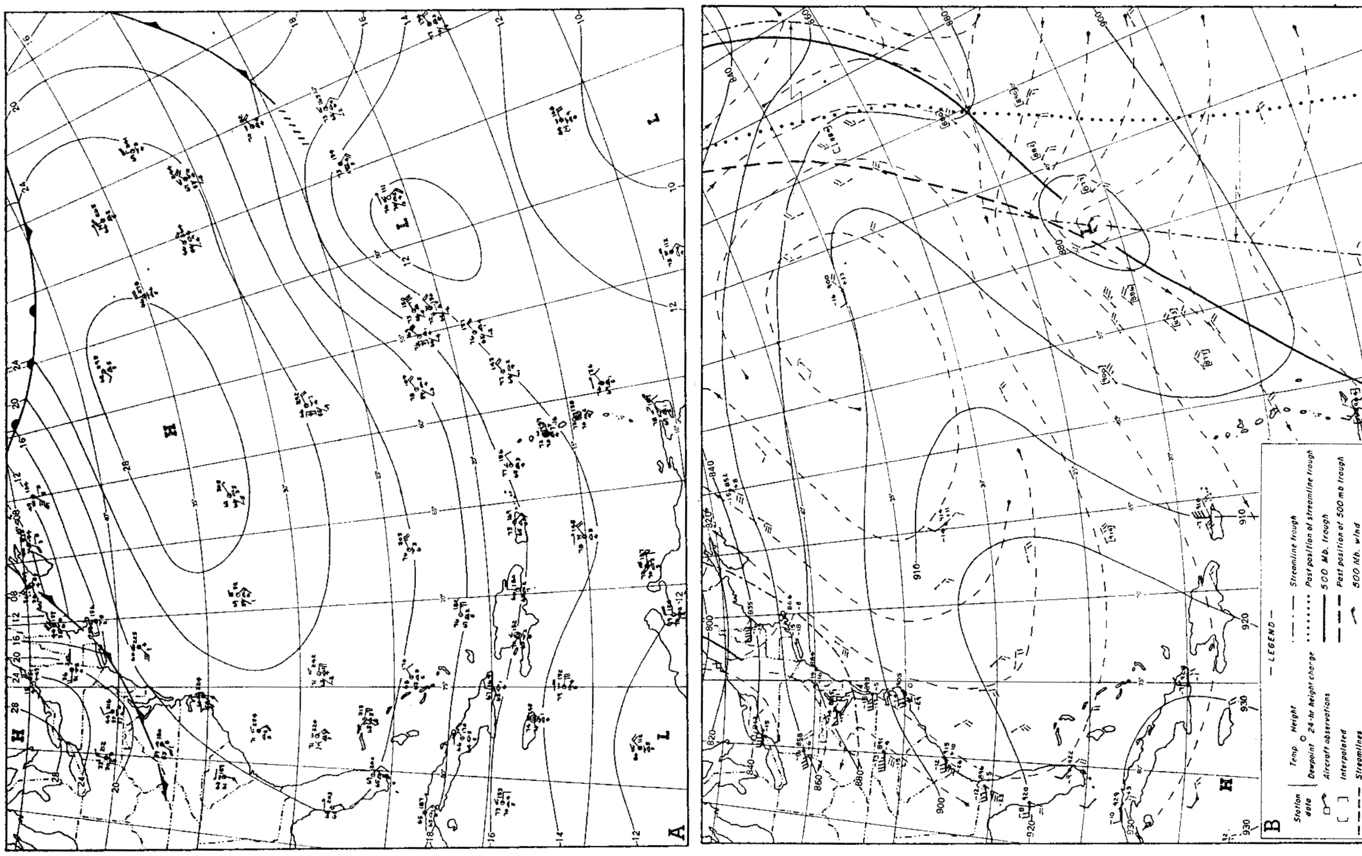

FIGURE 5.—December 29, 1954. (A) Surface map, 1230 GMT. (B) 500-mb. map with 2,000-foot streamlines, 1500 GMT.

trough. There was no wind discontinuity along the polar front in the Atlantic, except in the vicinity of the extratropical Low. The SW wind at 24.5° N., 40° W. suggested a closed circulation in the northern end of the tropical perturbation. After careful inspection of this wind report, there was no obvious reason for disregarding it. It gives the first indication of the ensuing cyclogenesis in this area.

Over the Caribbean area, a fairly deep and strong easterly current prevailed at this time. At San Juan (fig. 12) the east flow was 12,000 feet deep with speeds of 20–30 knots. At Bermuda (fig. 11) easterlies prevailed up to 25,000 feet, while 48 hours before no east components were present.

At high levels (fig. 4B) the anticyclogenesis continued over the western Atlantic; rises were still being observed at Bermuda and also at Ship Echo. The main trough in the westerlies continued its eastward progression, but the tropical section stayed behind close to the Antilles. In the belt of the westerlies the strong current persisted over the New England-Newfoundland region. Rapid motion of weak migratory troughs in these strong westerlies was observed throughout this period.

After December 28, cyclogenesis began in the tropical Atlantic. Already at 1230 GMT, December 28 (fig. 4A) a closed circulation was indicated in the junction of the extended trough. By 0030 GMT, December 29, the fracture of the extended trough was completed and a closed Low formed in the northern portion of the tropical wave. This tropical Low then came under the influence of the anticyclone and reversed its motion to the west. The polar section of the trough continued its steady motion to the east in the belt of the westerlies. At 1230 GMT, December 29 (fig. 5) the closed Low was centered at approximately 21° N., 49° W., already embedded in the easterly current. This position gave a westward motion of around 14 knots from the position of the wave 24 hours earlier; this suggests that the chart of December 28 marked the easternmost position of the extended trough and that fracture and cyclogenesis started at that time.

A comparison of figure 5B and figure 4B shows the changes that took place in the low-level wind flow during the process of fracture of the extended trough and cyclogenesis. The position of the disturbance was considerably farther south and west of the incipient closed circulation indicated on the previous day. Such things occur sometimes during the first stages of cyclogenesis; the process is probably dissolution of one center and reformation in another section of the wave rather than continuous motion of the same circulation.

No fronts have been analyzed in this Low. There was no evidence of a frontal wave in the process of formation. Cyclogenesis seems to have occurred by a process similar to that observed sometimes during the summer. During the summer, extended troughs are usually formed by the junction of an easterly wave travelling westward and a trough in the westerlies moving eastward. Cyclogenesis in the easterly current in the manner indicated by figures 4B and 5B occurs on occasions during fracture of the extended trough.

At the 500-mb. level (fig. 5B) the analysis is based almost entirely on extrapolations. The observations at Bermuda, Ship Echo, and San Juan, together with the extrapolated heights, provide a consistent and plausible analysis. An upper Low formed in the tropical section of the trough. With the continued extension to the northeast of the anticyclonic nose, this Low was practically isolated from the westerlies. The indications were that the upper Low formed simultaneously and in connection with the surface Low as part of the same cyclogenetic process. In the belt of the westerlies a strong jet current persisted; a trough was present in Canada around longitude 65°–70° W., which was evidently associated with an intensifying wave cyclone present at the surface over Newfoundland.

From this time on the story of the tropical Low was one of steady motion westward and gradual warming and transformation into a warm-core type of circulation. At 1230 GMT, December 30 (fig. 6A) three ship observations in the periphery of the Low pinpointed the circulation around 22° N., 52° W. and also gave the first indications of a closed circulation in the wind field. The central pressure was approximately 1008 mb. and wind speeds of 30–35 knots were reported. Cloudiness and bad weather were observed over the entire area.

In the belt of the westerlies intense cyclogenesis occurred. The frontal Low that was located the previous day over Newfoundland intensified considerably and moved rapidly eastward at a speed of around 37 knots. At the same time another frontal wave moved into the New York area. As a result of this cyclogenesis the anticyclone was squeezed into a flat two-cell structure. Nevertheless, it held its position and blocked the southward motion of the cold front.

The ridge line persisted also at high levels (fig. 6B) and the tropical Low was already isolated from the westerlies. The old trough in the westerlies moved away and a new rapidly moving trough associated with a surface cyclone was centered along longitude 45° W. Another rather intense system was observed over the region of Lake Ontario.

The surface analysis of the tropical Low on December 31 (fig. 7A) is based on continuity. No data were available at this time, but observations received 6 hours later indicated the Low, with central pressure of around 1007 mb., was moving westward at about 8 knots. Wind speeds of about 35–40 knots continued to be observed.

Strong cyclogenesis occurred once again in the belt of the westerlies. The previous cyclone continued the rapid motion and disappeared from the picture, but another occluded Low developed in the New England-Newfoundland area. The cold front advanced into central Florida and toward Bermuda, but it stayed far from the tropical Low. The ridge line was maintained E-W along latitude 32° N., although the high pressure cell was gradually

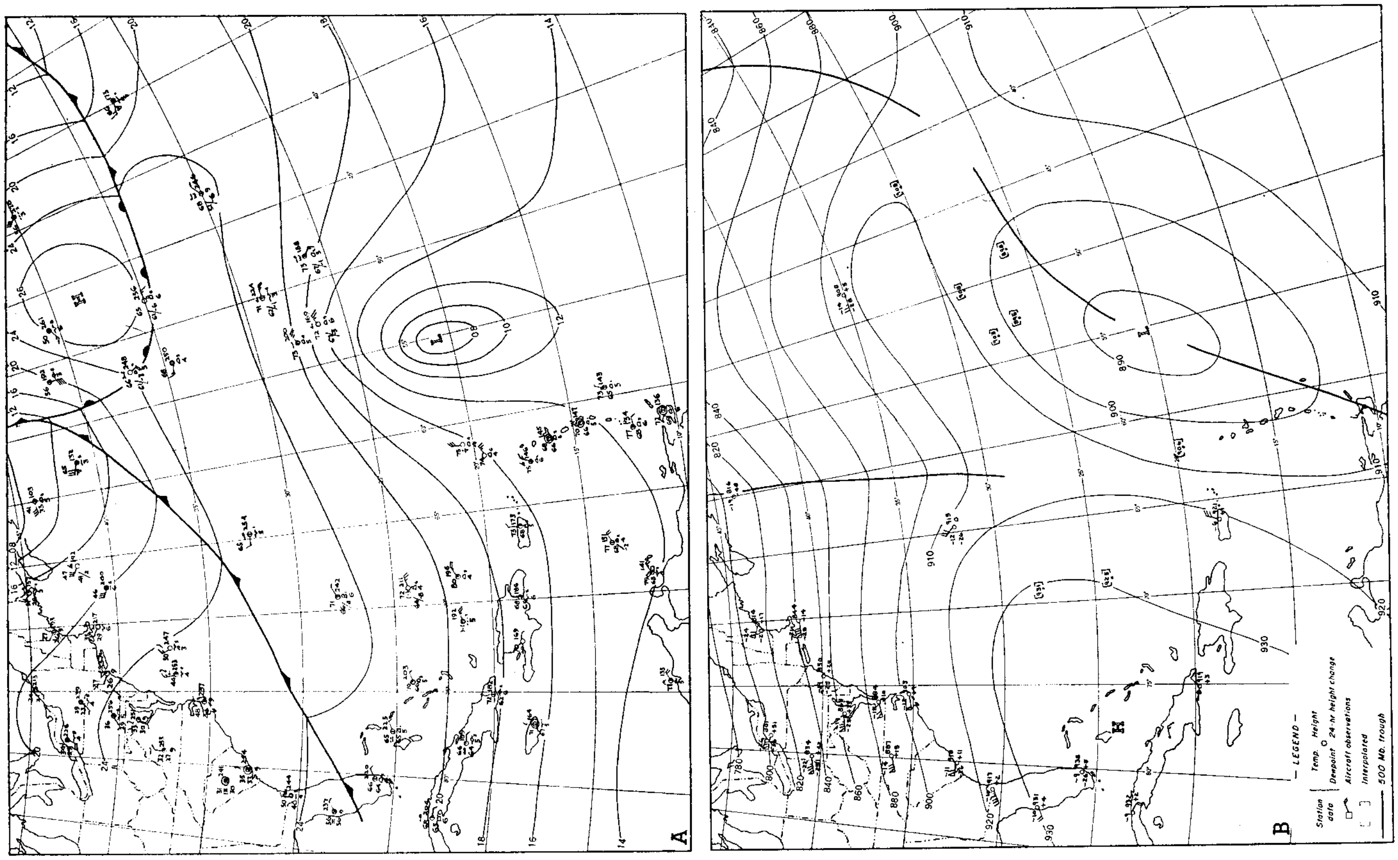

FIGURE 7.—December 31, 1954. (A) Surface map, 1230 GMT. (B) 500-mb. map, 1500 GMT.

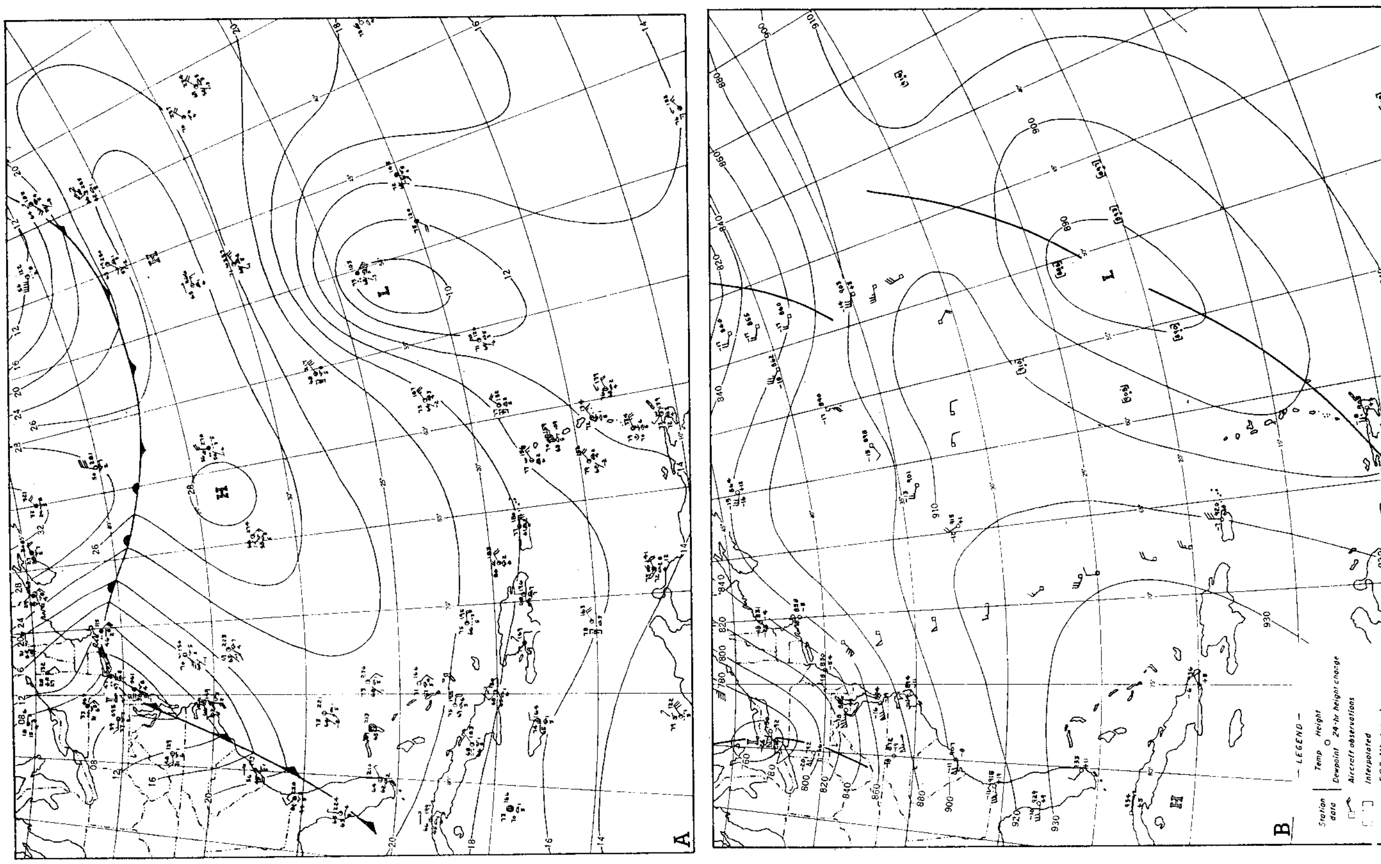

FIGURE 6.—December 30, 1954. (A) Surface map, 1230 GMT. (B) 500-mb. map, 1500 GMT.

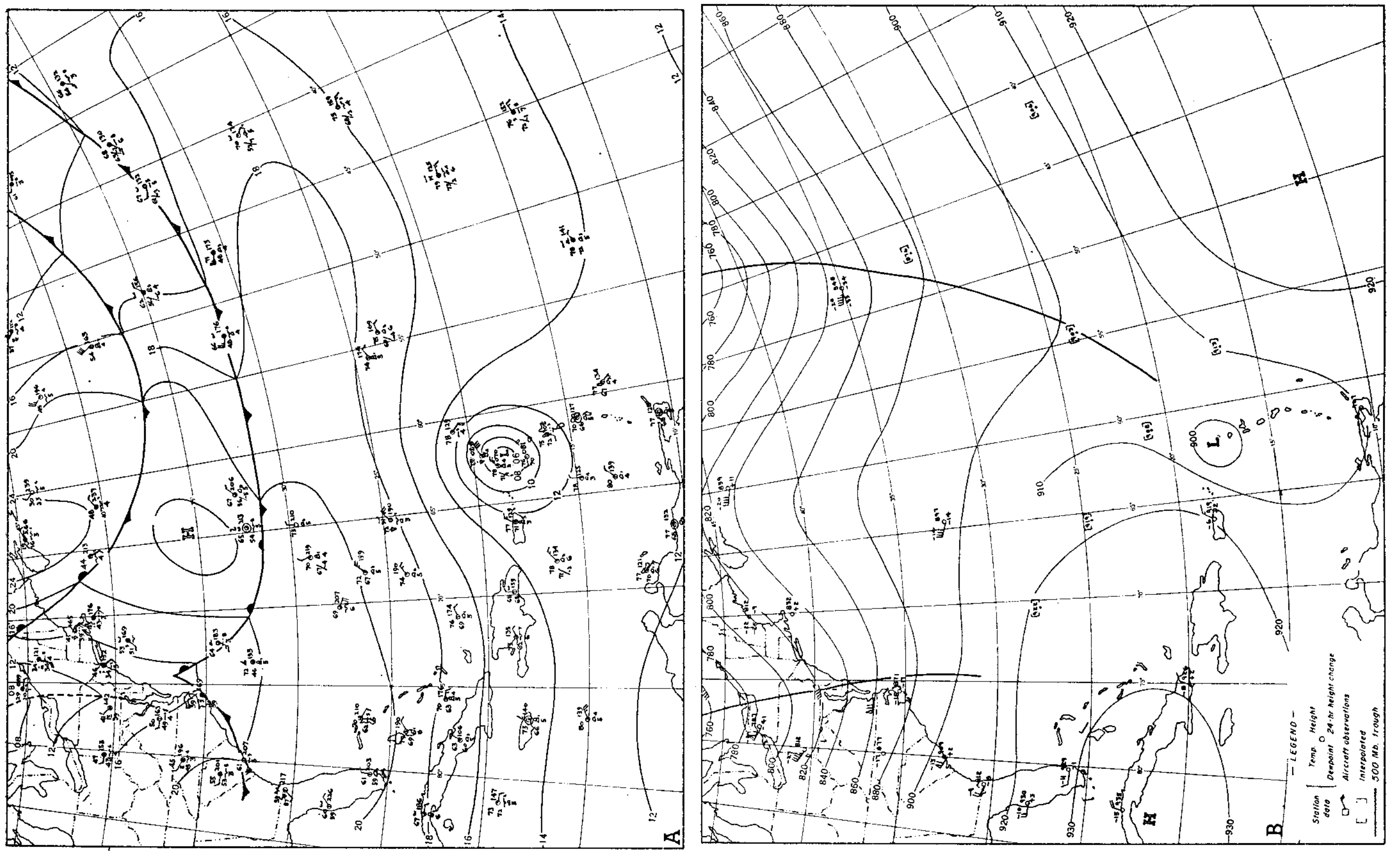

FIGURE 9.—January 2, 1955. (A) Surface map, 1230 GMT. (B) 500-mb. map, 1500 GMT.

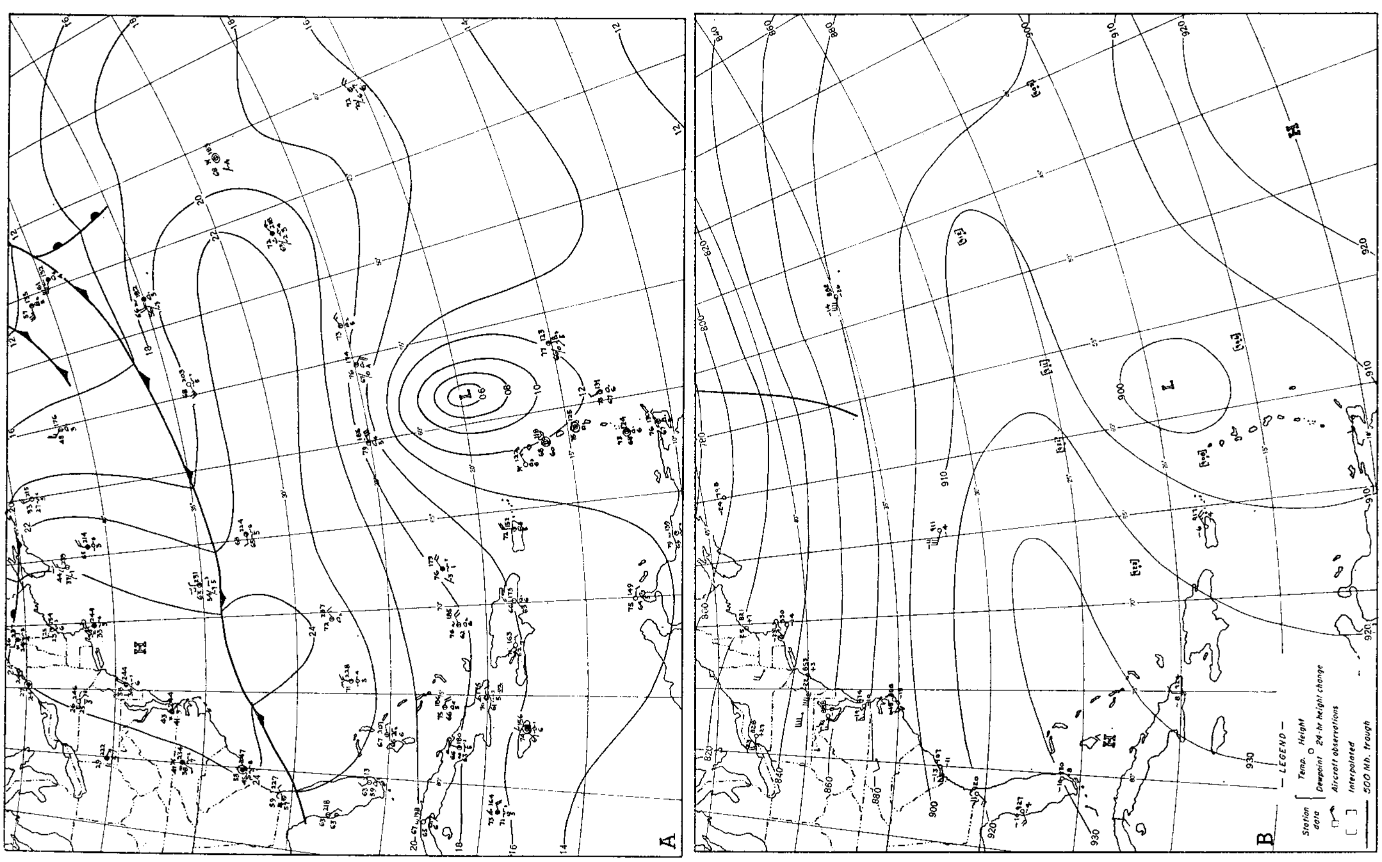

FIGURE 8.—January 1, 1955. (A) Surface map, 1230 GMT. (B) 500-mb. map, 1500 GMT.

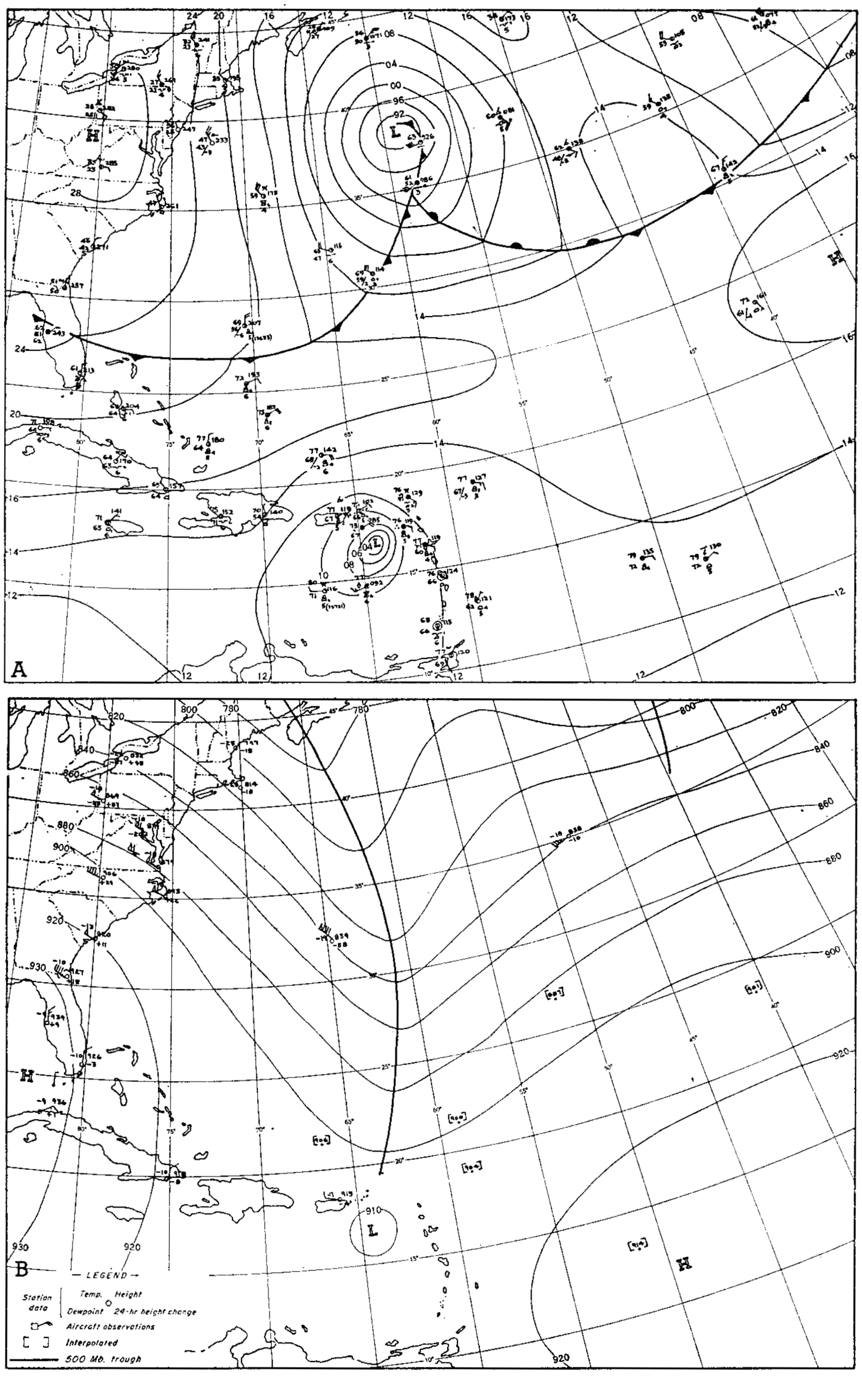

FIGURE 10.—January 3, 1955. (A) Surface map, 1230 GMT. (B) 500-mb. map, 1500 GMT.

collapsing. At upper levels (fig. 7B) the strong westerlies spread southward into the region of Bermuda, but still the E-W ridge line persisted secluding the tropical Low from the westerlies.

Intensification of the Low into a tropical storm was apparently completed by January 1. The analysis of the Low indicated in figure 8A is based on continuity. A series of observations after this time indicated the presence of the tropical storm. As for developments in the westerlies, the high pressure belt was maintained north of the center and the cold front stayed well to the north. Again, the occluded cyclone moved rapidly out of the picture. At upper levels (fig. 8B) the tropical Low was still disconnected from the westerlies as the ridge line persisted to the north.

During the afternoon of January 1 a series of observations indicated the presence of a tropical storm circulation. The ship *Arawak* reported at 1919 GMT, January 1, at a position 19°15′ N., 59°10′ W., "West wind 12, barometer 987, temperature 66, visibility nil." Soon afterward a

United States Navy ship with radar facilities reported the center "located at 19°07′ N., 60°07′ W. moving 255° at 17 knots, diameter of center 20 miles, scattered showers, surface wind NW 47 knots, seas very rough, swell 040° 15 feet 6 seconds, sea level pressure 1000.1 mb." Other ship reports along the same line followed in quick succession.

The islands to the east of Puerto Rico were immediately warned against winds of storm intensity and high seas. Initially the circulation was referred to as a tropical Low, but reports received during January 2 from the land areas affected confirmed winds bordering on hurricane intensity. At 1900 GMT on January 2 an additional bulletin from the San Juan office officially named the system "Alice" and operations continued as for a summertime hurricane.

Hurricane Alice entered the Caribbean Sea late on January 2. Aircraft reconnaissance was made into the storm twice on January 3 and once on January 4. Maximum winds of 50–55 knots were reported by both flights into the storm on January 3.

The charts for January 2 (fig. 9) still show the persisting ridge line to the north of the storm. The polar front moved south of Bermuda but it still was outside the area of the storm. Much deeper troughs were then observed in middle latitudes. At the surface another frontal system was approaching the east coast. The 500-mb. chart shows one deep trough in the central Atlantic and another, also very intense, over the east coast.

On January 3 (fig. 10) the picture began to change radically. Strong cyclogenesis occurred in the Atlantic north of Bermuda. This new cyclone was in a more southern position than the previous ones and also much more intense. The ridge line was practically gone and the *cold air moved southward into the Caribbean area.* At high levels a deep trough moved to the east of Bermuda and the middle latitude troughs extended into the Tropics again after an interval of about 8 days. After this time, the circulation of Alice began to dissipate rapidly. The storm recurved to the south in the afternoon of January 3 (fig. 1) as the westerly flow was established over the area. Aircraft reconnaissance into the storm on January 4 reported only a wide area of squally weather with maximum winds of 35 knots. Soon afterward the circulation disappeared in the southeastern corner of the Caribbean Sea.

3. REMARKS ON FORMATION

As mentioned before, for a type of storm that occurs so infrequently the conditions for the formation must be a rare combination of favorable circumstances. Such was the case in this study. The main factor was the establishment and maintenance of the blocking High. This anticyclogenesis initiated and maintained a series of favorable conditions for the formation and intensification of the tropical Low. It maintained for a prolonged period a fairly strong, deep, and extensive easterly current. The spreading of the anticyclonic surge eastward over the western Atlantic ended in the isolation of the tropical section of the extended trough with the ensuing cyclogenesis during the fracture process.

Once the Low was formed and moving in the easterly current, the determining factor was the continued isolation from the polar air, which again was accomplished by the persistent high pressure belt. During the period there were two strong cyclones forming in the westerlies (see charts for Dec. 30 and 31) neither of which could extend its influence into the tropical latitudes. The presence of the strong High forced the cyclones into a path far to the north and the rapid motion in the westerly current did not allow time for interaction with the Tropics. Under ordinary circumstances any one of these cyclones would have been able to push the cold air southward into tropical latitudes.

The warming process that took place over the whole region after December 26 can be followed in the observations at Bermuda and San Juan. The temperature changes throughout the troposphere were determined by computing the 24-hour change in the thickness of the standard isobaric levels, which is a direct measure of the temperature change. The changes at Bermuda (fig. 11) indicated warming in the whole troposphere from December 27 until December 30. During December 31 cooling started at high levels with the extension of the strong westerlies southward into the region. (See fig. 7B.) This cooling spread downward to lower levels during January 1 and 2. At San Juan (fig. 12) cooling occurred at lower levels during December 28 and 29 with the advance southward of the E-W quasi-stationary cold front, while warming took place at high levels after the passage of the upper trough. During December 30 warming started at low levels probably due to the warmer air approaching from the Bermuda region—at this time the tropical Low was still far out in the Atlantic. Warmer air spread through the lower troposphere during December 31 and January 1 and 2. Part of the warm air in this later period was undoubtedly due to the warm current from the tropical storm. The new influx of cold air reached San Juan on January 3. This cooler air extended into the eastern Caribbean and started the dissipation of Alice.

While these temperature changes were taking place in the San Juan-Bermuda region, the tropical Low was moving westward embedded in a strong easterly current, disconnected from the cold air, and advancing over warm ocean waters. A total of 53 observations of water temperatures were available in the area 15°–30° N. and 40°–60° W. during the period. These gave an average water temperature of 76.6° F., which is about 1° warmer than the mean January water temperature for this area given in the Climatic Charts of the Oceans. Similarly, air temperatures for the same area averaged 74.6° F.; that is about 2° cooler. The air was thus advancing over warmer waters. At the same time the storm was isolated from

376303—56——2

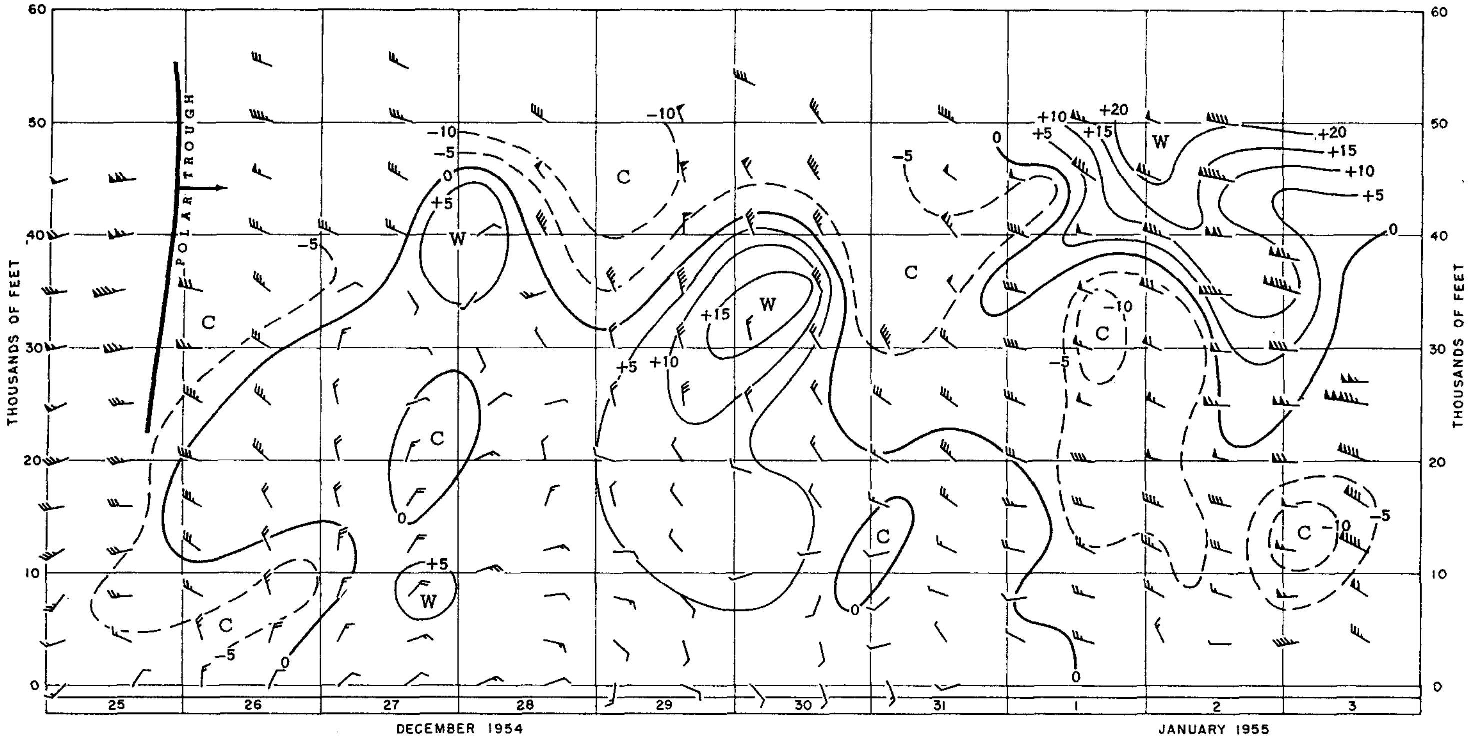

FIGURE 11.—Time section at Kindley Field, Bermuda, December 25, 1954–January 3, 1955, showing analysis of the 24-hour change in the thickness between the standard isobaric levels (in 10's of feet). W stands for warming, C, for cooling. Wind speeds in knots. Analysis displaced to center of period.

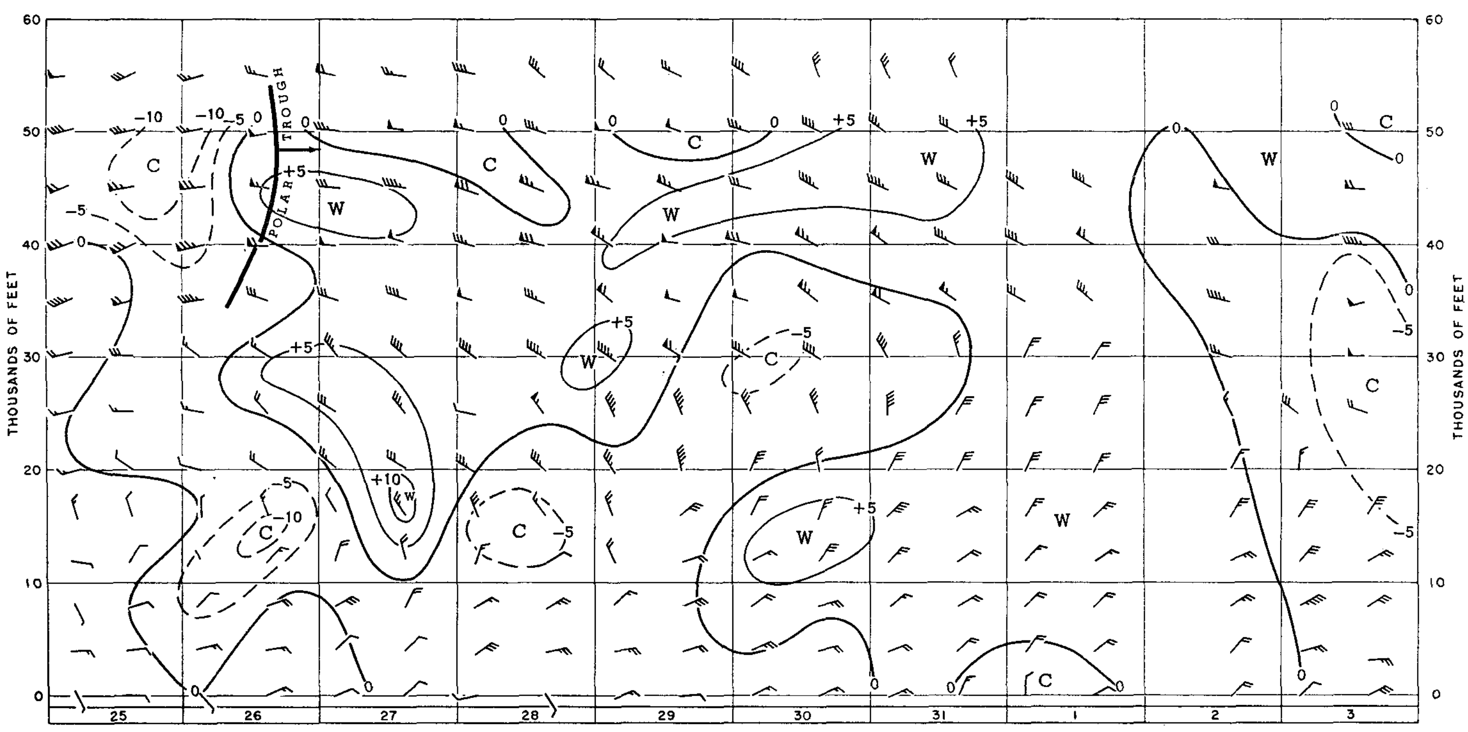

FIGURE 12.—Time section at San Juan, P. R., December 25, 1954–January 3, 1955.

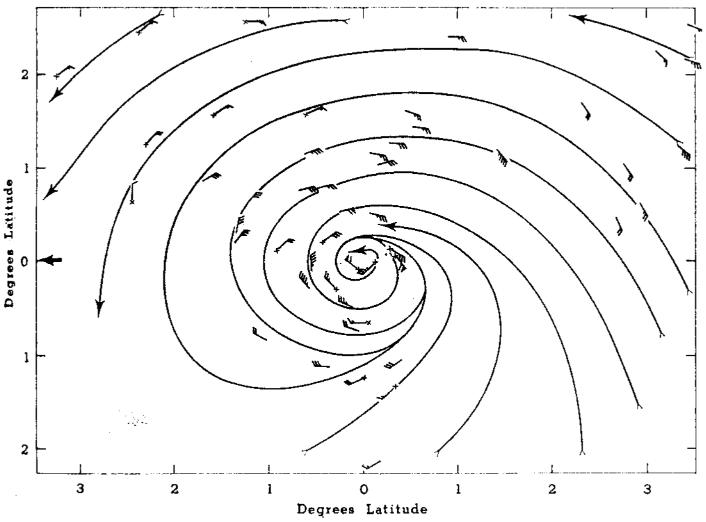

FIGURE 13.—Composite wind map and streamlines for January 2, 1955. Wind observations (in knots) between 0000 and 2100 GMT are plotted relative to storm position with direction of motion indicated by heavy arrow at left side of chart. Land observations marked by X; aircraft observations, by square; others are ship observations. Wind speed in knots. Units of distance in degrees of latitude.

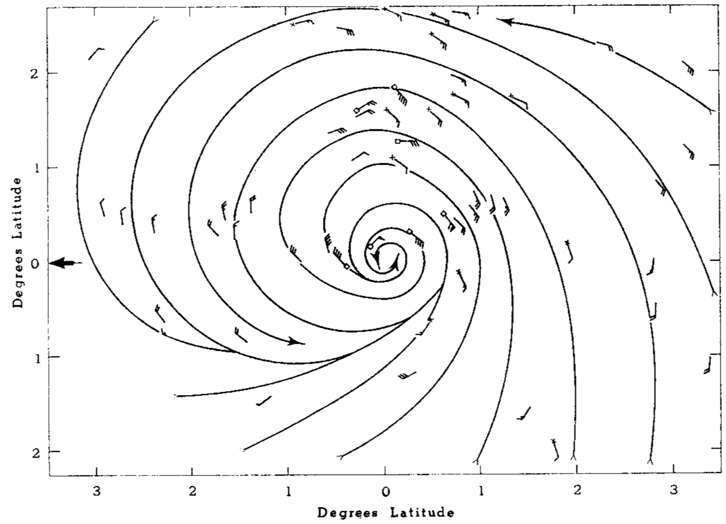

FIGURE 14.—Composite wind map and streamlines for January 3, 1955.

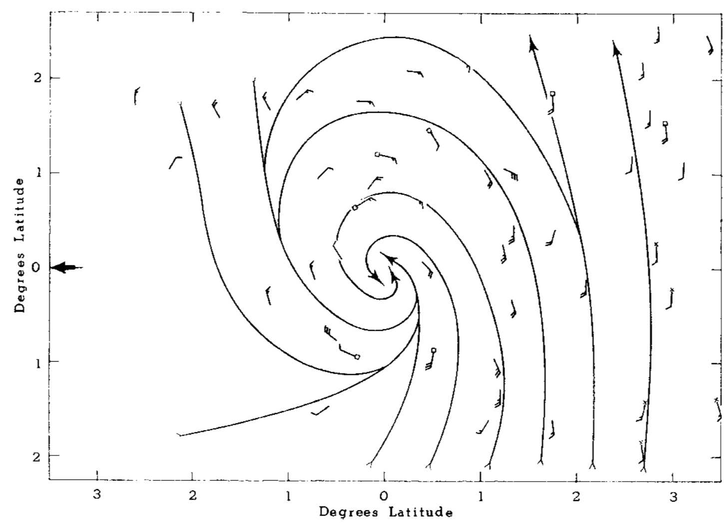

FIGURE 15.—Composite wind map and streamlines for January 4, 1955.

the source of polar air and instead a current from the SE from the tropical Atlantic entered the circulation of the storm. Considerable cloudiness and widespread shower activity prevailed over the area from the beginning thus giving another source of heat by the release of latent heat. Favorable thermal conditions were thus established for the transformation into a warm-core type of circulation.

An unsuccessful attempt was made to determine the influence of the high tropospheric flow (200-mb. level) in the formation of Alice. Unfortunately, the observations at San Juan, Bermuda, and Ship Echo alone did not suffice for a satisfactory analysis in the area of the storm. The time cross-sections of San Juan and Bermuda (figs. 11 and 12) give an indication of the flow prevalent at high levels during the period. The polar trough aloft passed Bermuda around 0000 GMT, December 26; the tropical extension passed San Juan around 1500 GMT, December 26. It moved eastward and passed Ship Echo around 1500 GMT, December 27. It was established in the region to the east of Ship Echo extending southwestward to the region of the Lesser Antilles around December 28 and 29 at the time that fracture and cyclogenesis occurred at lower levels. After the passage of the trough a strong west to west-northwest current prevailed over the tropical latitudes (see the San Juan upper winds). It was impossible to determine the presence of any jet structure in the flow, but the maximum wind speeds at San Juan were all the time at least 50 knots.

4. WIND AND THERMAL STRUCTURE

Observations obtained during January 1–4, 1955 indicate that Alice developed true hurricane properties. There are two essential characteristics that may be considered as typical of tropical hurricanes. One is the organization of the wind system with the maximum winds in a ring close to the center and speeds decreasing radially outward. The other is the warm-core type of thermal structure. Both of these properties were attained by Alice in its relatively short life.

For a better picture of the wind field, composite wind maps were prepared. These charts were obtained by plotting all available wind observations relative to the center of the storm for the period 0000 to 2100 GMT each day. Figures 13, 14, and 15 indicate the composite charts for January 2, 3, and 4. The charts for January 2 and 3 reveal the typical circulation of a tropical cyclone. The strong winds of 50–60 knots were all observed very close to the center. Winds of 30–40 knots were recorded within 75 miles from the center. The right semicircle apparently was the strongest in accordance with results found in tropical storms. The streamline field was also typical of

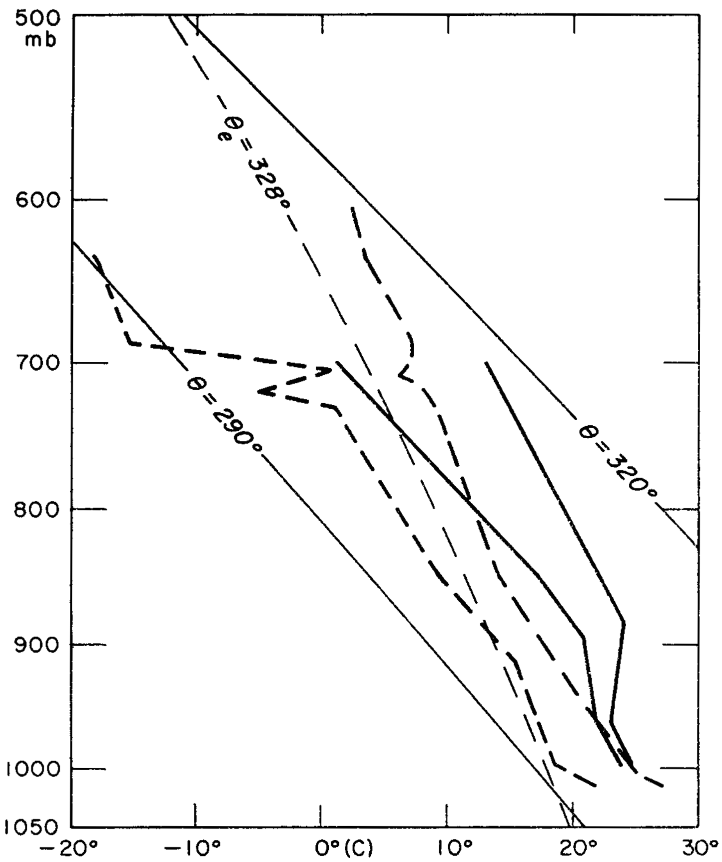

FIGURE 16.—Dropsonde observation (temperature and dew point, solid lines) in eye of hurricane Alice, January 3, 1955, 1345 GMT at position 16.5° N., 64.4° W. Dashed lines show radiosonde observation at San Juan, P. R., January 3, 1955, 1500 GMT.

hurricane charts. The current into the center of the storm was exclusively from the tropical latitudes of the Atlantic.

The chart for January 4 shows a different picture. During this day the storm was already in the dissipating stage. Wind speeds of 15–25 knots prevailed over most of the area. Only three winds of 30 knots were recorded: two from ships and one from the reconnaissance plane.

An Air Force reconnaissance report on the storm on January 3 described the eye as horseshoe shaped, poorly defined, 15 miles in diameter, with minimum pressure of 999 mb. A sounding in the eye obtained by this flight is plotted in figure 16 together with the observation that was made at San Juan about the same time and which was representative of the outside air. The warm-core properties of the storm are evident. The air of the eye was only slightly warmer than the outside air in the layer near the surface, but averaged about 6°–7° C. warmer from the 950-mb. level up. A nearly dry-adiabatic layer existed near the surface topped by a fairly deep stable layer. The lapse rate above the stable layer was slightly more unstable than the moist adiabatic. The eye conditions indicated by this sounding agree quite well with those found in the eye of summertime typhoons in the Pacific Ocean [2]. The mixed conditions in the surface layer, the stable layer above, and the considerably warmer air at higher elevations are typical of eye soundings in well developed typhoons.

5. LAND OBSERVATIONS AND DAMAGE

The reconstructed path of the storm between January 1 and 3 (fig. 1) indicates that the center passed during January 2 between the islands of St. Martin and St. Barthélemy. The winds at St. Martin changed from north to east with a near calm wind reported at the time of minimum pressure. The winds at Gustavia, St. Barthélemy indicated the center passage to the north of the station. The center passed also within 10 miles to the north of the Island of Saba, with a lull and gradual wind change observed between 1600 and 1900 GMT. Estimates of the maximum winds were not available at all places. At the Island of Saba an unofficial estimate of 75 m. p. h. was reported. A summary of the wind observations and damages is given in table 1. This is based on post-storm reports received from the governments of these islands. Most of the damage occurred within 50 nautical miles of the center. At St. Croix, which came within 65 nautical miles of the center, the effects of the storm were nil. The same occurred at the Island of Nevis, 50 nautical miles on the east side (left-hand semicircle of the storm).

The rainfall amounts were quite excessive in most places. The maximum report was made at Saba where orographic effects played a significant part. Readings of 6 to 8 inches were made at some of the other islands. The report of 2.48 inches at St. Martin looks surprisingly low, compared to the others. However, since the rainfall distribution in such storms is not uniform, the report is within the realm of possibility.

TABLE 1.—*Summary of wind, pressure, and rainfall observations and damage estimates in the Leeward Islands during hurricane Alice, January 1955*

Station	Average distance from center (miles)	Wind observations	Minimum pressure (mb.)	Rainfall (inches)	Estimated losses
St. Martin (Dutch section).	5	7½ hours of winds over 38 m. p. h.; no estimate of maximum.	991.2	2.48	
Gustavia, St. Barthélemy.	8–10	Maximum wind: south at 35 kt.	991.0		$43,000.00
Saba	6	Maximum wind: (estimated) 75 m. p. h.	982.5 at station, 1,500 ft. elev.	11.27 in 48 hr.	280,000.00
Anguilla	14	12 hours of winds over 38 m. p. h.		6.75 in 20 hr.	244,500.00
St. Eustatius	22		1001.4	8.00 in 40 hr.	31,000.00
St. Kitts	40	SW, force 6–8	1002.4	6.05 in 23 hr.	25,000.00
Nevis	52			3.60 in 19 hr.	Nil
Antigua	78	South, force 5	1007.1	2.00 in 8 hr.	Nil
Barbuda	52		1005.8	2.95	Nil
St. Croix	66				Nil
Total					623,500.00

Estimates of damage totalled over $600,000. The damage was mostly to shipping facilities and to crops. According to reports, the damage was caused mostly by the effect of rainfall and the action of the sea and not by the direct action of the wind. These total damages, although relatively small, represented a severe blow to the economy of these small islands.

6. OTHER COLD-SEASON TROPICAL STORMS

Alice of 1955 was the first tropical storm ever recorded officially during the cold season in the Caribbean-Atlantic area of tropical storms. As a result of its formation, several reports about previous wintertime tropical storms in history were revived. All such reports which have come to the attention of the writer referred to storms in the North Atlantic and most of them were very uncertain and indefinite. One particular report that received wide distribution in the newspapers concerned the storm experienced by Christopher Columbus during February 12–15, 1493. This storm, however, apparently was not a true tropical storm. At the time, Columbus was well advanced on the return leg of his first voyage to America. He sighted the Azores Islands on February 15, 1493; therefore, Columbus experienced the stormy weather in the region immediately to the west of the Azores. C. F. Brooks [3] made a detailed study of this storm and of another that affected Columbus on the same trip during February 26–March 4, 1493 and concluded that the weather and wind changes described by Columbus could have been produced by an extratropical storm with frontal boundaries such as occur frequently in that region today. Columbus had several experiences with hurricanes in his later voyages, but all were during the so-called regular hurricane season.

Although Alice, 1955, has been recorded as the first wintertime tropical storm in modern times, a closer study revealed that it was not the first one of its kind. In fact, one doesn't have to go very far in history to find a previous case of a storm of tropical characteristics during the cold season. Alice of 1955, for one thing, provided ample proof that they do occur.

During January 1951 a storm that occurred in the tropical regions of the Atlantic Ocean north of Puerto Rico gave all the indications of being as good an example of a tropical storm as Alice was. Figure 17, the surface chart for 1230 GMT, January 6, 1951, shows the storm centered at 21° N., 61.5° W., with a minimum pressure of around 1004 mb. and a wind report of force 8 (37 knots). Six hours after this map a ship reported winds of force 10 (48–55 knots) close to the center. This storm started as a frontal wave cyclone during January 1 around 34° N., 69° W. It moved first eastward and then curved southward toward tropical latitudes. By January 3 it was already isolated from the polar air and no fronts were distinguished in the circulation after this date. It continued in a southward track reaching latitude 20° N. on January 6. A recurvature to the west occurred at this point, just in time to prevent the storm from striking land. This storm later turned northward, joined a polar front. on January 10 and became again an extratropical storm.

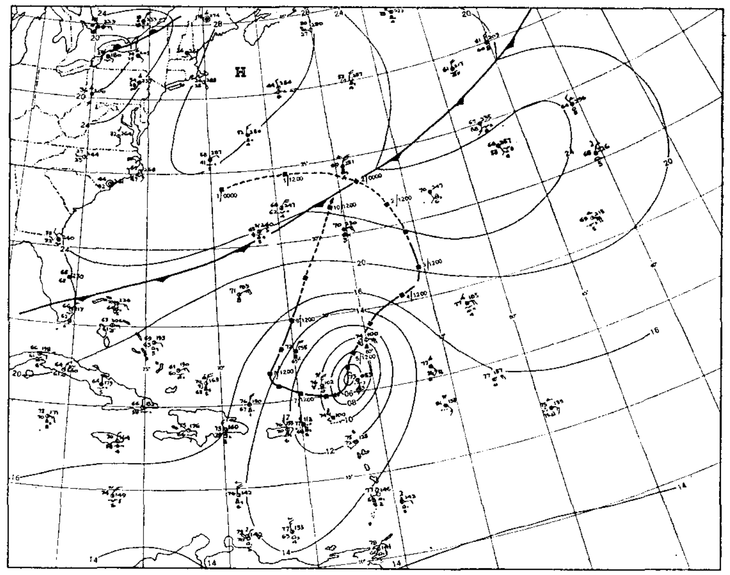

FIGURE 17.—Surface map, January 6, 1951, 1230 GMT. Track of the storm during the period that it exhibited frontal boundaries (extratropical characteristics) is indicated by dashed lines; track while it exhibited tropical characteristics is solid.

Between January 4 and January 9, 1951, this storm exhibited properties resembling a true tropical storm. Winds of force 7 to 10 (28–55 knots) were reported, the stronger winds generally observed closer to the center. The central pressure ranged from 1000 to 1005 mb., perhaps lower. The wind and pressure fields indicated a warm-core structure. Had aircraft observations been made in this storm, they undoubtedly would have shown a tropical warm-core circulation; and if the storm had struck land, it would have taken first honors as a cold-season hurricane instead of Alice of 1955.

A cursory investigation of the conditions for the formation of the storm of January 1–10, 1951 revealed some of the favorable circumstances present in the case of Alice 1955. Isolation of the Low from the belt of the westerlies both at the surface and at the 500-mb. level was also accomplished in the 1951 case. (See the *Daily Series Synoptic Weather Maps, Northern Hemisphere* for January 1951.) A blocking ridge to the northwest of the storm prevented subsequent intrusions of cold air while the storm wandered southward over warmer ocean waters and attained apparent warm-core characteristics. The original formation, however, was different from the 1955 case. In the January 1951 storm the initial Low was definitely formed as a frontal wave. Then the fronts vanished gradually and left a tropical type of Low. In the case of Alice, the initial formation occurred through a cyclogenetic process in the easterly current. The storm formed and moved all the time in tropical latitudes.

There has been some attention lately to subtropical storms of cold-core characteristics that occur mostly during the cold season and which may sometimes transform into warm-core types of circulation. Simpson [4] made an extensive study of these storms in the region of Hawaii, where they are known as Kona storms. He describes two main processes of formation: one by the transformation of middle-latitude frontal cyclones, like the case of the January 1951 storm described above; and the other, by a cyclogenetic process in the trade easterlies that is usually triggered by the building down of a preexisting cold upper Low. He found evidence of storms of the same type in the North Atlantic Ocean; they occurred mostly in the region 15°–35° N., 30°–60° W. during the months of November, December, and January. Moore and Davis [5] described the formation of the May storm of 1951, which, although occurring closer to the regular summertime season, can also be considered in this same class.

7. CONCLUSION

In summary, Alice of 1955 was a small storm. Its maximum winds barely reached hurricane intensity; its diameter reached no more than 50–60 nautical miles; it resembled to some extent some of the preseason and postseason storms, that is, the May and June storms and some of the October–November storms. The vertical extent was also very limited. It is perhaps significant that intensification occurred in a region which is also preferred for formation during the summer season. Alice represents a type of storm for which we have to watch more closely in coming years. Such storms are not as infrequent as we have been inclined to believe. It is important that forecasters recognize their true nature at the earliest time. The forecasting of their motion and intensity and issuance of adequate warnings to threatened areas would be a lot easier if we recognize them for what they really are.

ACKNOWLEDGMENT

The encouragement and assistance received from Mr. Ralph L. Higgs, United States Weather Bureau, San Juan, Puerto Rico, during the course of the study and preparation of this report is gratefully acknowledged.

REFERENCES

1. H. Riehl, *Tropical Meteorology*, McGraw-Hill Book Co., 1954. See p. 269.
2. C. L. Jordan, "On the Low-Level Structure of the Typhoon Eye," *Journal of Meteorology*, vol. 9, No. 4, Aug. 1952, pp. 285–290.
3. C. F. Brooks, "Two Winter Storms Encountered by Christopher Columbus in 1493 Near the Azores," *Bulletin of the American Meteorological Society*, vol. 22, No. 8, Oct. 1941, pp. 303–308.
4. R. H. Simpson, "Evolution of the Kona Storm, A Subtropical Cyclone," *Journal of Meteorology*, vol. 9, No. 1, Feb. 1952, pp. 24–35.
5. P. L. Moore, and W. R. Davis, "A Preseason Hurricane of Subtropical Origin," *Monthly Weather Review*, vol. 79, No. 10, Oct. 1951, pp. 189–195.