HURRICANE AUDREY, 1957

ROBERT B. ROSS AND MAURICE D. BLUM
National Weather Analysis Center, U. S. Weather Bureau, Washington, D. C.

1. INTRODUCTION

On the morning of June 27, hurricane Audrey swirled across the Gulf coast near the Texas-Louisiana border. Communications were disrupted, and as reports dribbled in it was some time before a shocked nation learned the full extent to which the hurricane had devastated the coastline. The death toll mounted to 100—then 200—and finally over 500. Property damage was estimated at 150 to 200 millions of dollars [1, 2]. Entire communities in the tidal region of Louisiana were demolished. Even after the storm had assumed extratropical characteristics, ten lives were lost and property was destroyed in Indiana, Illinois, and New York due to heavy rains and high winds. The storm's influence extended even into Canada, were four persons were killed and winds of 80 m. p. h. were recorded.

During the period June 20 to June 25, an ill-defined easterly wave had moved across the Caribbean Sea to a position at 22.5° N., 93° W., in the Gulf of Mexico, where a tropical depression developed. This easterly wave was difficult to follow as it progressed westward due to the uneven distribution of reports from this area. In correspondence with the Weather Bureau office in New Orleans, La. [2], regarding the formation of hurricane Audrey, the following was received:

> Light westerly winds aloft (mid-levels) were reported from Carmen (Mexico) on June 24th. This was the first definite indication of circulation over the southwest Gulf. That evening the following message was received from Brownsville (Tex.):
>
> CKT 7062 ABRO 250230Z SHRIMP DOCK AT PORT BROWNSVILLE REPORT ONE SHRIMP BOAT IN GULF OF CAMPECHE IN ROUGH WEATHER AT 2230N 9430W WIND STEADY AT 35/40 KTS G55 IN SQUALLS BAROMETER READING THIS MORNING 2990 THIS EVENING 2978 STRONG SEA SENT 0233 HRR

An investigation by Klein [3] on the formation of this tropical depression which developed into Audrey is reported in this issue. He discusses the importance of the broad-scale flow patterns and the sea surface temperature.

2. TROPICAL PHASE

At 0430 GMT on June 25, the first bulletin from the New Orleans Weather Bureau Office [4] was released on the tropical depression which had formed over the Bay of Campeche in the southwestern Gulf of Mexico. Highest winds were estimated to be about 35 to 40 m. p. h. The depression remained nearly stationary for several hours and showed signs of rapid intensification. On the basis of a Navy reconnaissance flight and an earlier excellent report from the SS *Terrier*, the first hurricane advisory was issued by the Weather Bureau at 1800 GMT June 25, stating the tropical depression had reached hurricane strength and was centered near 22.5° N., 93.0° W., or about 380 miles southeast of Brownsville, Tex. The storm was forecast to move northward at 5 m. p. h. and to increase slowly in size and intensity. As the storm moved northward, the winds near the center increased in speed from 75 to over 100 m. p. h., and by 1200 GMT on the 26th it had moved to a position 250 miles east-southeast of Brownsville. At this time the storm was moving northward at about 10 m. p. h. This rate gradually increased until it reached 15 m. p. h. early on the 27th. By 1300 GMT on the 27th the storm was centered just off the Texas-Louisiana coast south of Port Arthur, Tex. Up to this time the highest winds reported on the coast were 75 m. p. h. and the highest tide reported was 7 ft. m. s. l. These were the last reports received from Sabine, Tex., before their communications failed.

At 1530 GMT on the 27th a report from Orange, Tex., stated that after having experienced winds of over 100 m. p. h., the town was now in the dead calm associated with the eye of the storm and awaiting the return of strong winds. The maximum winds at Lake Charles, La., as the storm passed just to the west were 105 m. p. h. Having entered the mainland, the storm rapidly increased its forward momentum and recurved toward the northeast.

The major portion of the damage in the Gulf coast region resulted from high water. Normal diurnal range of the tides for this region is from 1 to 2 ft. Increased heights of the water as a result of Audrey were apparent as early as noon on the 26th at Galveston, Tex., and reached a peak there of 6.2 ft. m. s. l. at 1030 GMT on the 27th. The area affected by tides of 6 ft. m. s. l. or over extended from Galveston to a point 330 miles eastward.

At Cameron Coast Guard Station, La., the water began to rise prominently by 1000 GMT on the 27th and rose at the rate of 1.5 ft. per hour for several hours, reaching a peak in Cameron of 10.6 ft. m. s. l. between 1600 and 1700 GMT on the 27th. This peak was reached after the initial impact of the high winds of the hurricane and before the rise of the secondary winds associated with

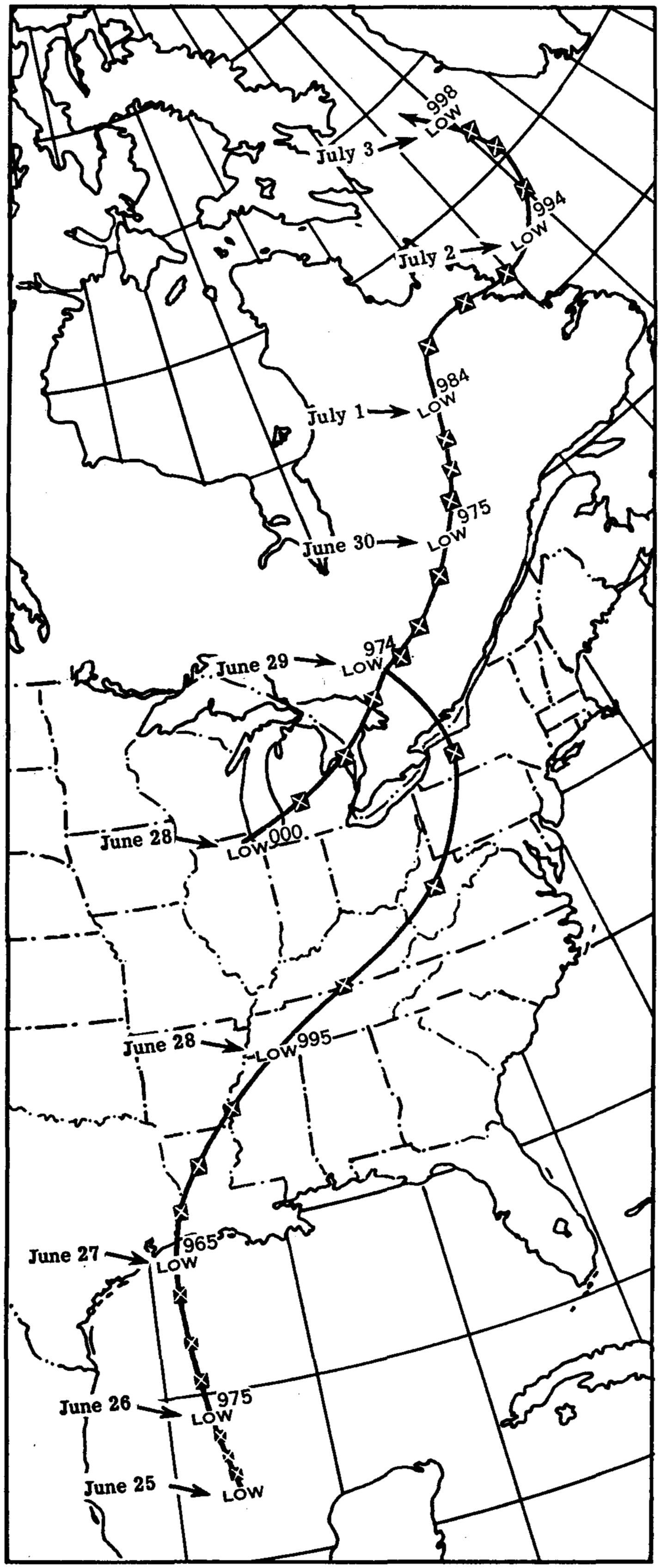

FIGURE 1.—Track of hurricane Audrey, 1957. Positions shown are at 6-hour intervals.

the passage of the eye of the storm on shore some 23 miles to the west of Cameron. Waves of between 4 and 5 ft. with a few peaks possibly reaching 8 to 10 ft. were superimposed on this high water. The water remained high until around 2000 GMT, at which time the winds shifted to an offshore direction and the water began to recede.

The highest tides occurred about 40 miles to the east of the region where the center of the hurricane crossed the coast. They were highest on the coast and decreased somewhat inland. At Lake Charles, La., a tide of 7 ft. m. s. l. was recorded. The tidal region along the Gulf coast affected by the high water is quite extensive, being near sea level, and in some instances below sea level, for considerable distances inland. For the period of high water, these tidal regions were inundated as far as 10 to 20 miles inland.

Some of the reported low barometric readings and the times of their occurrence on June 27 are as follows:

	(*mb.*)	(*GMT*)
Galveston, Tex	986	1200
Cameron, La	959	1430
Port Arthur, Tex	966	1523
Beaumont, Tex	971	1528
Lake Charles, La	972	1740

On the morning of the 28th the storm, which was centered over west central Tennessee, had lost its hurricane strength winds and had entered its extratropical phase. As the storm was moving from the coast to this position, several tornadoes developed in Mississippi, Louisiana, and Alabama. In Mississippi and Louisiana, one life was lost and several buildings were damaged. In Alabama 14 people were injured and property damage was estimated at $600,000 as a result of these tornadoes [1]. For Audrey's track and associated surface features, see figures 1 and 2.

Between 0000 GMT and 1200 GMT on the 25th, a polar trough at the 200-mb. level moved eastward through the Mississippi Valley. An extension of this trough produced a shear line through south-central Texas (fig. 3). The northern portion of the polar trough continued its eastward movement, while the shear line through Texas was accentuated and slowly retrogressed. By 1200 GMT on the 25th, the 200-mb. winds at Brownsville and Corpus Christi, Tex., which had been north-northwesterly, had backed sharply and were blowing from 210°. These winds continued to back slowly as Audrey moved northward. At this time a weak anticyclonic circulation in the eastern Gulf region, which had become more pronounced, facilitated the outflow above the storm and favored the further development of the hurricane [5].

3. EXTRATROPICAL PHASE

The extratropical phase of the storm presented some noteworthy dynamic aspects in conjunction with the

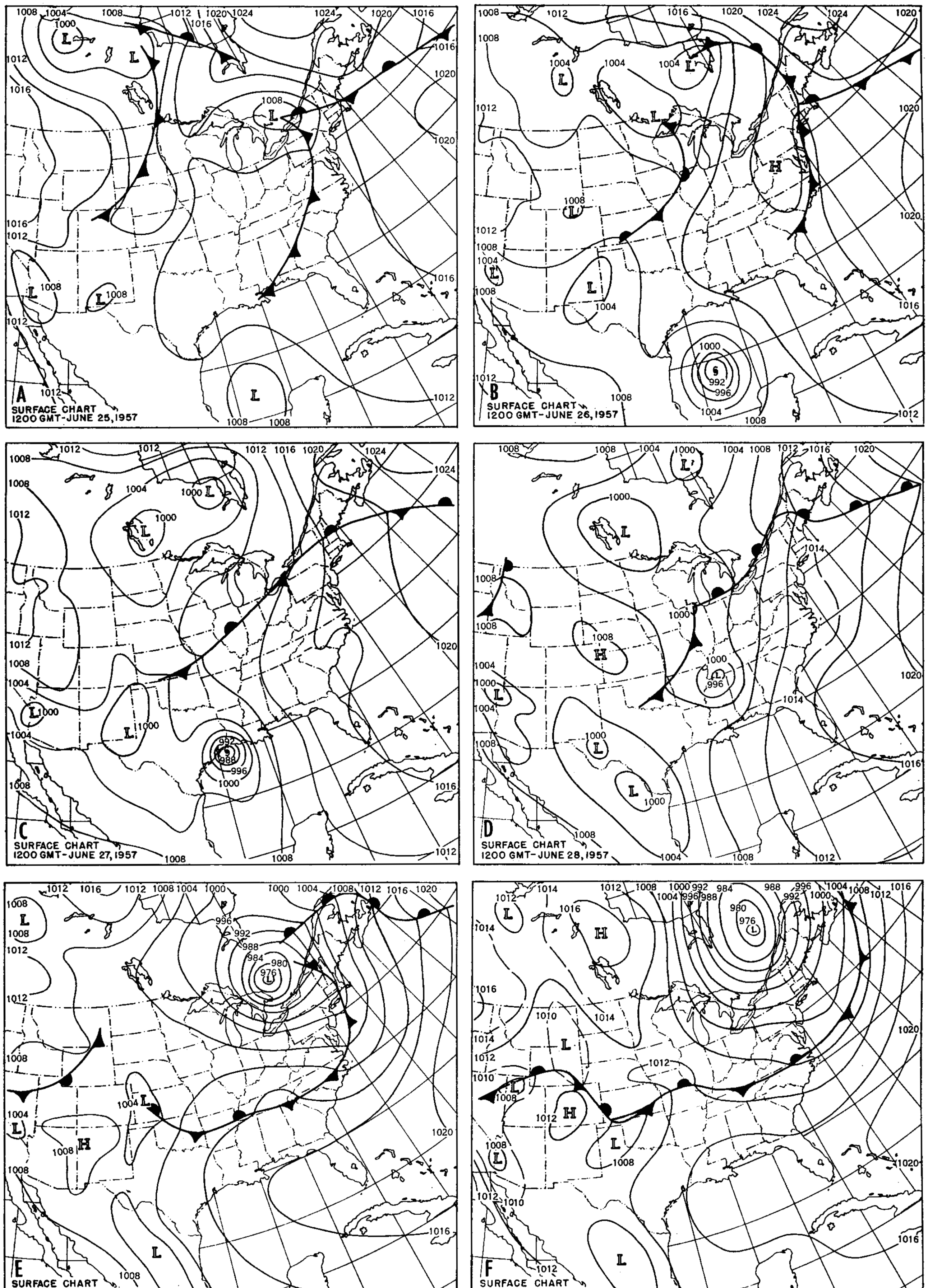

Figure 2.—Surface weather charts for 1200 GMT June 25–30, 1957.

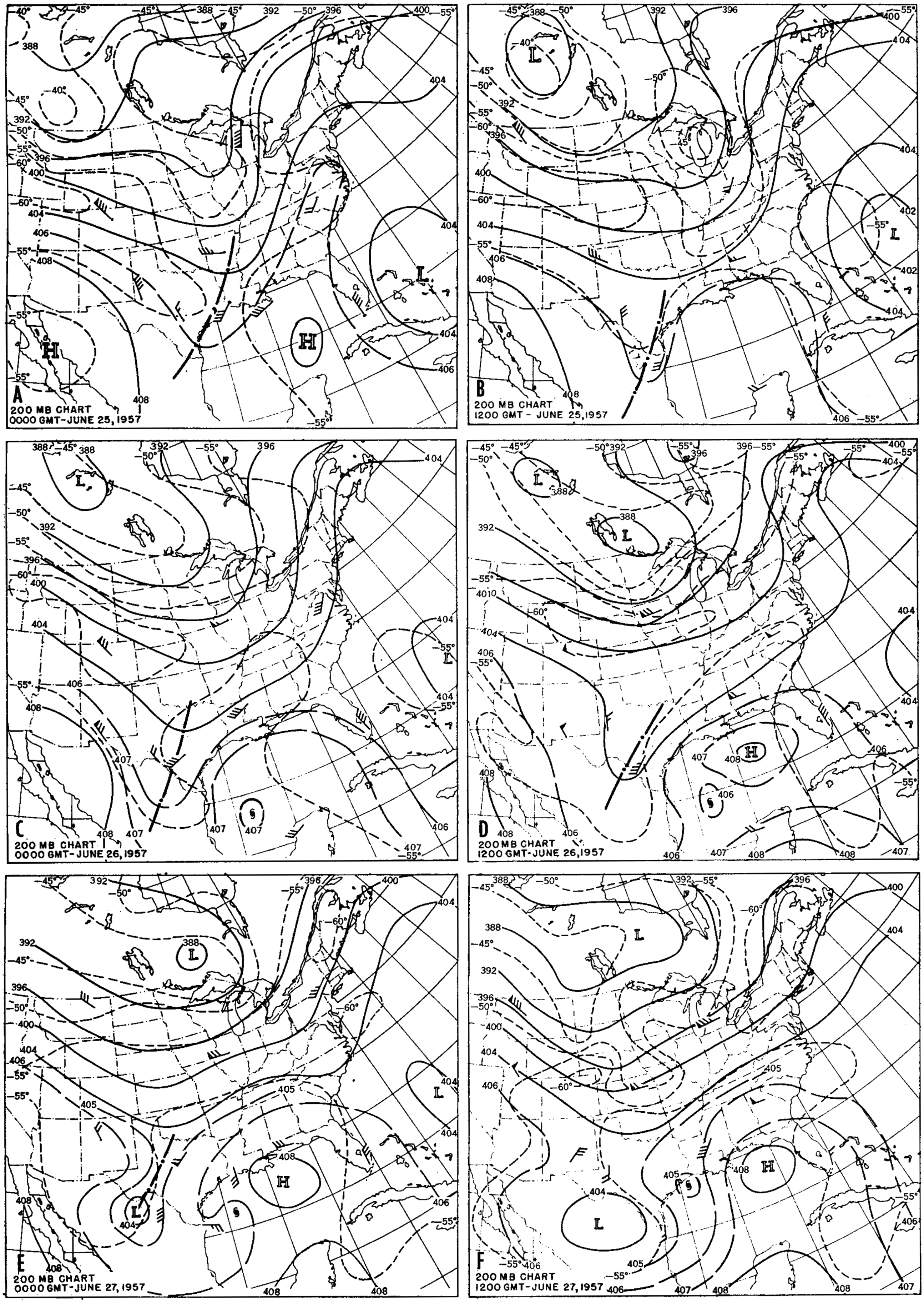

FIGURE 3.—200-mb. charts shown at 12-hour intervals from 0000 GMT June 25 to 1200 GMT June 27, 1957. Contours (solid lines) are in hundreds of geopotential feet; isotherms (dashed lines), in ° C.

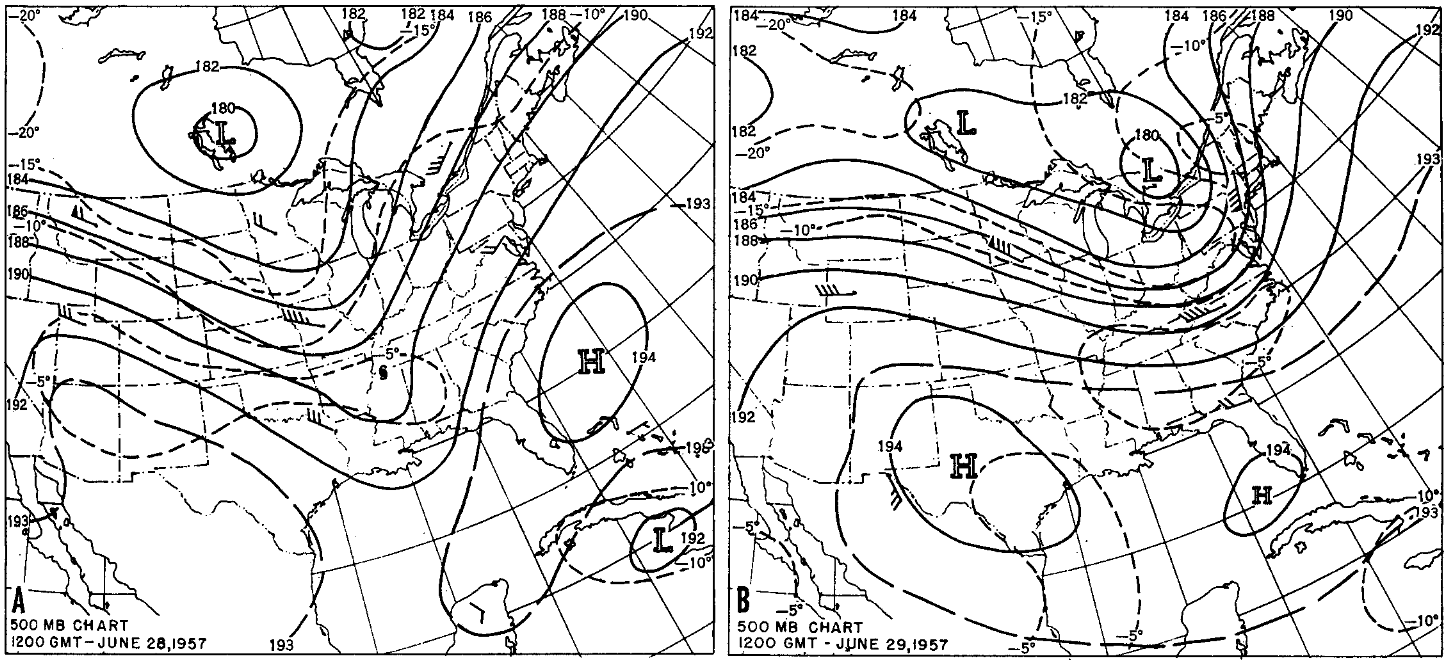

FIGURE 4.—500-mb. charts for 1200 GMT, June 28 and 29, 1957. Contours (solid) are in hundreds of geopotential feet; isotherms (dashed), in ° C.

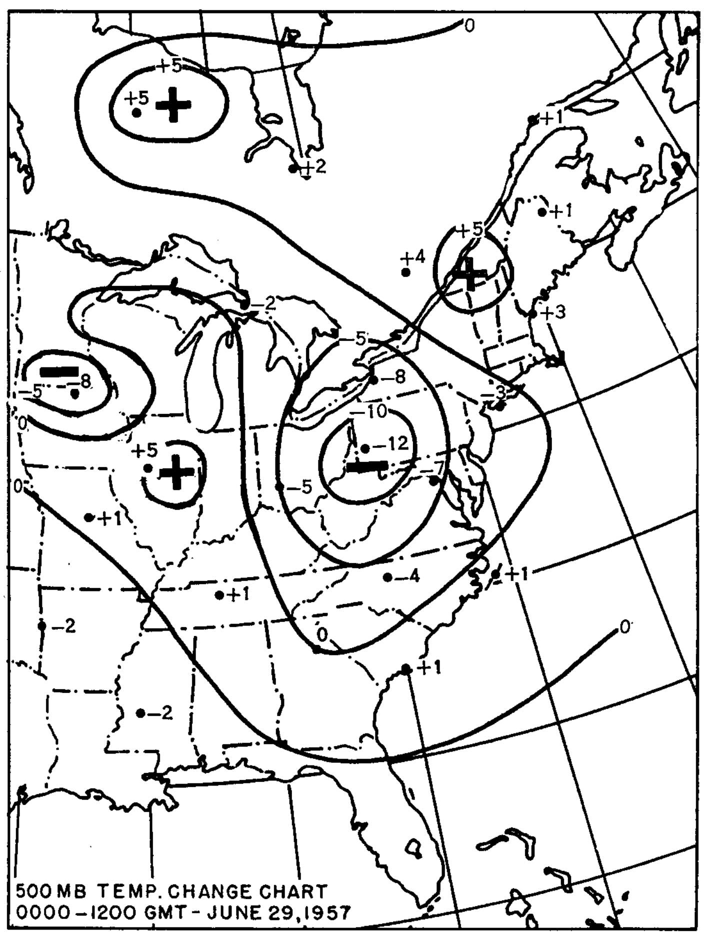

FIGURE 5.—500-mb. 12-hour temperature change chart for the period 0000 GMT to 1200 GMT June 29, 1957. Isolines of temperature change are at 5° C. intervals.

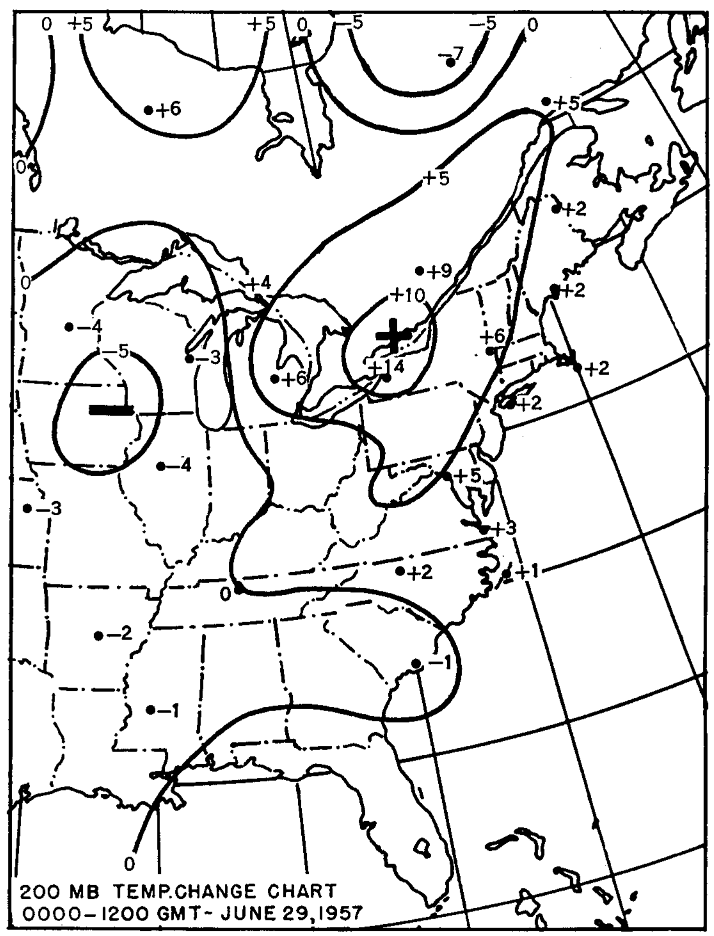

FIGURE 6.—200-mb. 12-hour temperature change chart for 0000 to 1200 GMT June 29, 1957. Isolines of temperature change are at 5° C. intervals.

433988—57——3

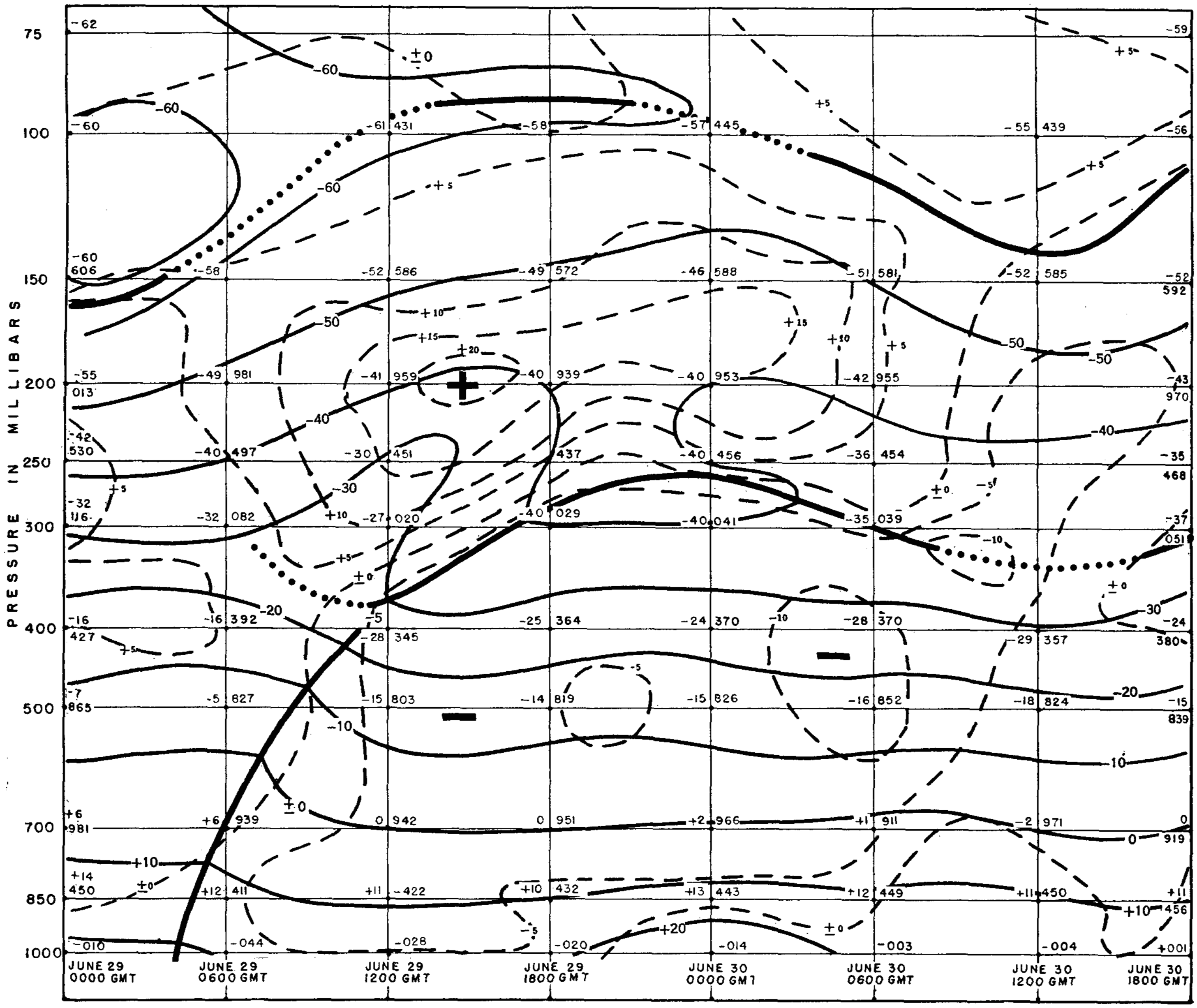

FIGURE 7.—Time cross section for Buffalo, N. Y., from 0000 GMT June 29 to 1800 GMT June 30, 1957. Isotherms in ° C. are light solid lines. 24-hour temperature changes at 5° C. intervals are dashed lines. Fronts and tropopauses are heavy solid lines, heavy dotted where indistinct.

amalgamation of Audrey with a polar wave. This union resulted in a storm of major proportions which affected much of the Mississippi-Ohio Valley region, eastern United States, and eastern Canada. In the Mississippi-Ohio Valley region most of the storm damage resulted from heavy rains, while high winds accounted for nearly all the damage in the eastern United States and Canada. The heavy, flood-producing rains which occurred in the Mississippi-Ohio Valley on June 27, 28, and 29 cannot be attributed completely to Audrey. These rains were frontal in nature. However, there is little doubt that Audrey augmented the available precipitable moisture contributing to the heavy rains [1].

On the 28th, when Audrey was in the process of assuming extratropical characteristics, a wave formed on a polar front in the vicinity of Chicago, Ill. At 1200 GMT on the 28th, the central pressure was 995 mb. for Audrey and 1,000 mb. for the wave on the polar front (fig. 2D). Just 24 hours later the union of these storms was complete, with the storm centered about 140 miles north of Buffalo, N. Y., in southwestern Quebec, Canada. At this time, the storm had reached maximum intensity as an extratropical storm with a central pressure of 974 mb. This approached the lowest pressure associated with Audrey in its tropical phase. It was this rapid intensification of the storm which resulted in the high winds observed in the eastern United States and Canada. Winds of 95 to 100 m. p. h. were reported at Jamestown, N. Y. [1].

In the deepening of the polar wave, it was difficult to differentiate between the contribution made by the remnants of Audrey and that made by cyclogenesis in the westerly flow aloft. As Audrey moved inland she became aligned with, and eventually absorbed into, an intensifying polar trough progressing eastward. At the 500-mb. level, the warm air moved rapidly northeastward, which resulted in an intensifying thermal gradient over the northeastern United States (fig. 4). In the 24-hour period between 1200 GMT on the 28th and 1200 GMT on the 29th, maximum cooling in the troposphere was centered near Pittsburgh, Pa. (fig. 5), where at the 500-mb. level 9° C. of cooling occurred; 8° of this cooling was in the last 12 hours. In the stratosphere during the same interval, maximum warming at the 200-mb. level was centered near Buffalo, N. Y. (fig. 6), where 16° C. of warming occurred, 14° of which took place in the last 12 hours of the period. The time cross section for Buffalo (fig. 7) graphically shows the temperature change which occurred in the troposphere and stratosphere.

Maximum intensification of the surface storm ensued when the upper-air low pressure center became nearly vertical with the surface feature. In conjunction with this intensification, a low tropopause formed as shown on the time cross section (fig. 7). The baroclinic nature of this development, which contributed to the rapid intensification of the storm, can be seen by an inspection of the isotherm field on the 500-mb. chart shown in figure 5. The 24-hour change shown in the temperature field with the intensification of the thermal gradient in northeastern United States is quite spectacular.

It appears that even without the influence of Audrey the baroclinic structure in the westerlies would have been sufficient to develop a storm of major proportions. Stratospheric warming is considered to have been of prime importance in the extratropical cyclogenesis. Vederman [6] has discussed the importance of stratospheric influences to cyclogenesis at the surface. Haurwitz [7] relates the stratosphere to the troposphere in the development of cyclones. The time cross section for Buffalo (fig. 7), with the 24-hour temperature changes, shows the spectacular magnitude of the stratospheric warming just above the formation of the low tropopause in relation to the cooling which took place in the troposphere.

Audrey's contribution cannot be ignored—certainly with the absorption of the tropical Low into the polar trough cyclonic vorticity was added and the thermal distribution was affected, contributing to the baroclinicity of the development. The limited time allotted to the preparation of this article, however, precludes any attempt to assign quantitative values to the tropical influences adding to the development of the extratropical storm.

ACKNOWLEDGMENTS

The authors wish to express their thanks to the staff of the National Weather Analysis Center for their aid in the preparation of this report. We are also indebted to Messrs. Robert H. Simpson, Gordon E. Dunn, Stephen Lichtblau, and their staffs for information supplied and for their review of this article; also to Mr. D. Lee Harris for his assistance in the preparation of the section on tides.

REFERENCES

1. U. S. Weather Bureau, *Weekly Weather and Crop Bulletin, National Summary*, vol. XLIV, Nos. 26 and 26a, July 1, 1957.
2. Stephen Lichtblau, Personal correspondence.
3. William H. Klein, "The Weather and Circulation of June 1957—Including an Analysis of Hurricane Audrey in Relation to the Mean Circulation," *Monthly Weather Review*, vol. 85, No. 6, June 1957, pp. 208–220.
4. U. S. Weather Bureau, *Hurricane Audrey, June 24–27, 1957*, Preliminary Report, Washington, D. C., July 8, 1957.
5. U. S. Navy, Bureau of Aeronautics, Project AROWA, "Intensification of Tropical Cyclones Atlantic and Pacific Areas," *Fourth Research Report, Task 12*, Oct. 1956, 28 pp.
6. Joseph Vederman, "Changes in Vertical Mass Distribution over Rapidly Deepening Lows," *Bulletin of the American Meteorological Society*, vol. 30, No. 9, Nov. 1949, pp. 303–309.
7. Bernhard Haurwitz, *Dynamic Meteorology*, McGraw-Hill Book Co., Inc., New York and London, 1941. (See pp. 320–334.)