THE LOW LEVEL DIVERGENCE IN HURRICANE "GRACIE" 29th SEPTEMBER 1959

by

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I. ABSTRACT

Wind and temperature data are utilized to present the thermal pattern at 700 millibars and the divergence pattern at 1000 millibars in the tropical cyclone - "Gracie", at 1200 z, 29 September 1959. This pattern is compared with the mean patterns presented by Banner I. Miller in his report for the National Hurricane Research Project. (1) The pattern of divergence in "Gracie" at the specified time is compared with the corresponding pattern twelve hours earlier (2).

II. HISTORY OF "GRACIE"

Hurricane "Gracie" was the most intense tropical cyclone to cross the coast of the southeastern United States since Hurrican "Hazel" in 1954 . After forming in an "easterly wave" near the island of San Salvador in the southeastern Bahamas on the 22nd of September 1959, her erratic movement for the next few days defied prediction. From the 22nd through the 24th of September, the circulation pattern in the upper troposphere was one of a very complex nature, consisting of a number of cyclonic and anticyclonic eddies. This circulation pattern began to consolidate into a more clear-cut pattern. Thus, from 1200 z on the 24th of September through 1200 z on the 25th of September, a rapidly propagating, but intensifying 700 millibar trough extending from a position off the eastern shore of Hudson Bay south-south westward over Chicago moved to a position extending from Goose Bay, Labrador to near Washington, D. C. As this trough moved eastward the southern end assumed an east-west orientation.. As a result of this orientation, Gracie became involved in the westerly flow preceeding the trough. This attempted recurvature was frustrated by rapid development of anticyclonic circulation to the rear of the trough. This development led to the establishment of a sufficiently strong easterly flow at low levels to result in the reversal of "Gracie's" motion.

The anti-cyclonic circulation developed a warm core so as to allow extension of the anticyclonic flow into the middle and high troposphere. As a result of this anti-cyclonic circulation "Gracie" was moving in the west-northwest direction by 0000 z on the 29th of September. "Gracie" continued to move around the periphery of this anti-cyclonic in such a manner that the direction of her motion veered from 280 degrees at 000 z on the 29th to 320 degrees at 1200 z of the same date. At the time of our investigation the storm was centered some 80 miles south-southeast of Charleston, South Carolina. Her motion was toward 320 degrees at 17 knots.

III. TECHNIQUE

By assuming a steady-state we could utilize all of the data available from 0000 z on the 29th through 1200 z on the 30th; thus it was possible to obtain coverage within 300 miles of the center of "Gracie", with a density of approximately 2 observations per 2500 square miles. The off-time reports were plotted in their position relative to the center.

All of the wind vectors were resolved into orthagonal components. The component velocities (u, which is the component of westerly wind, and v, which is the component of southerly wind) were then plotted on two separate maps. Analyses of the u and v components were then made upon these two maps.

A fifty-mile grid was then placed over each analysis, in such a manner so that one of the grid points coincided with the center of the storm. The values of u and v were tabulated at each grid point. From this tabulation it was easy to compute $\frac{\partial u}{\partial x}$ and $\frac{\partial v}{\partial y}$. The sum of these terms divided by the grid distance, 50 miles, and the number of seconds in an hour, 3600, is equal to the divergence of the wind. The values on pages 9, 11 and 12 are in 10^{-5} per second.

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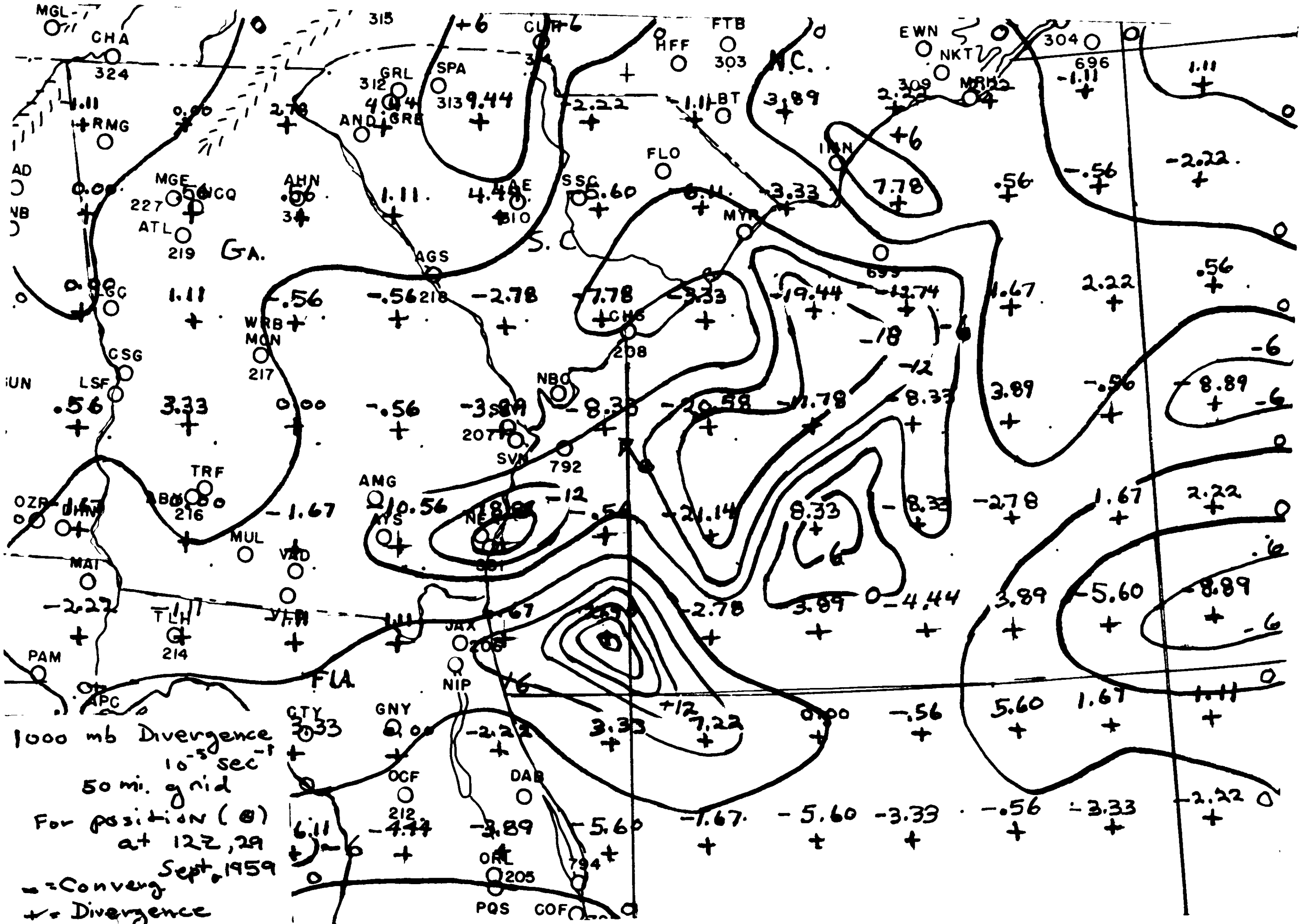
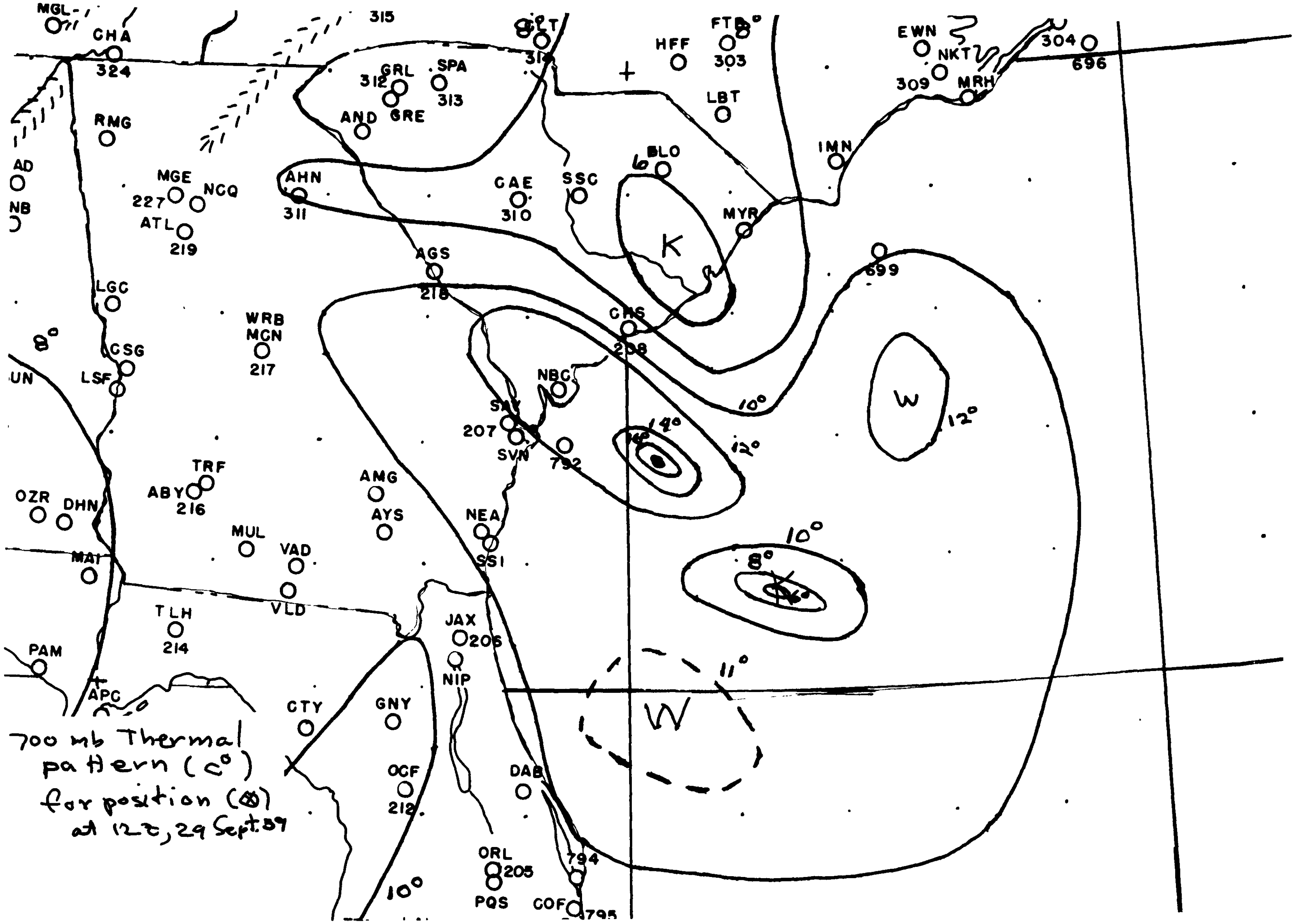
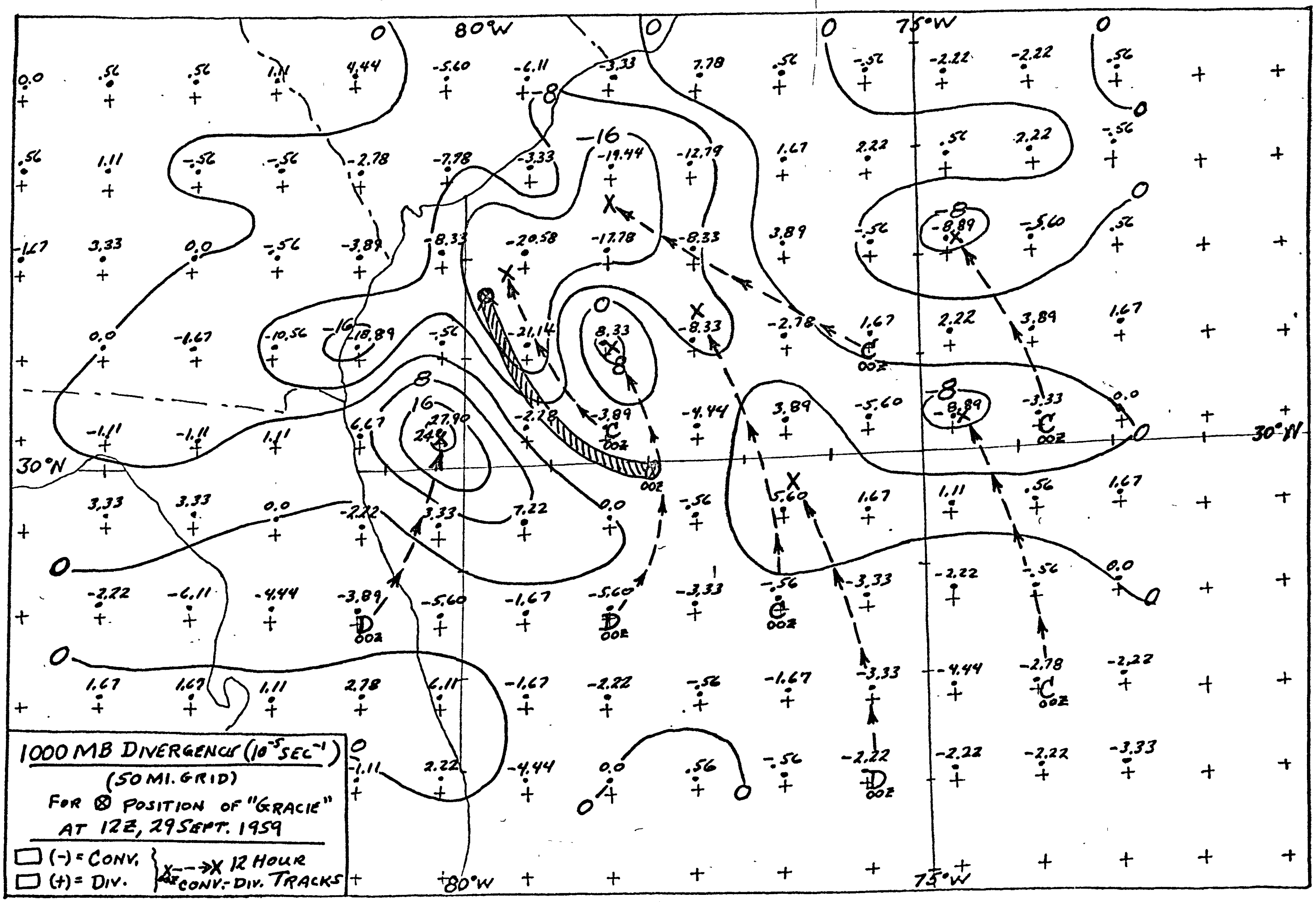
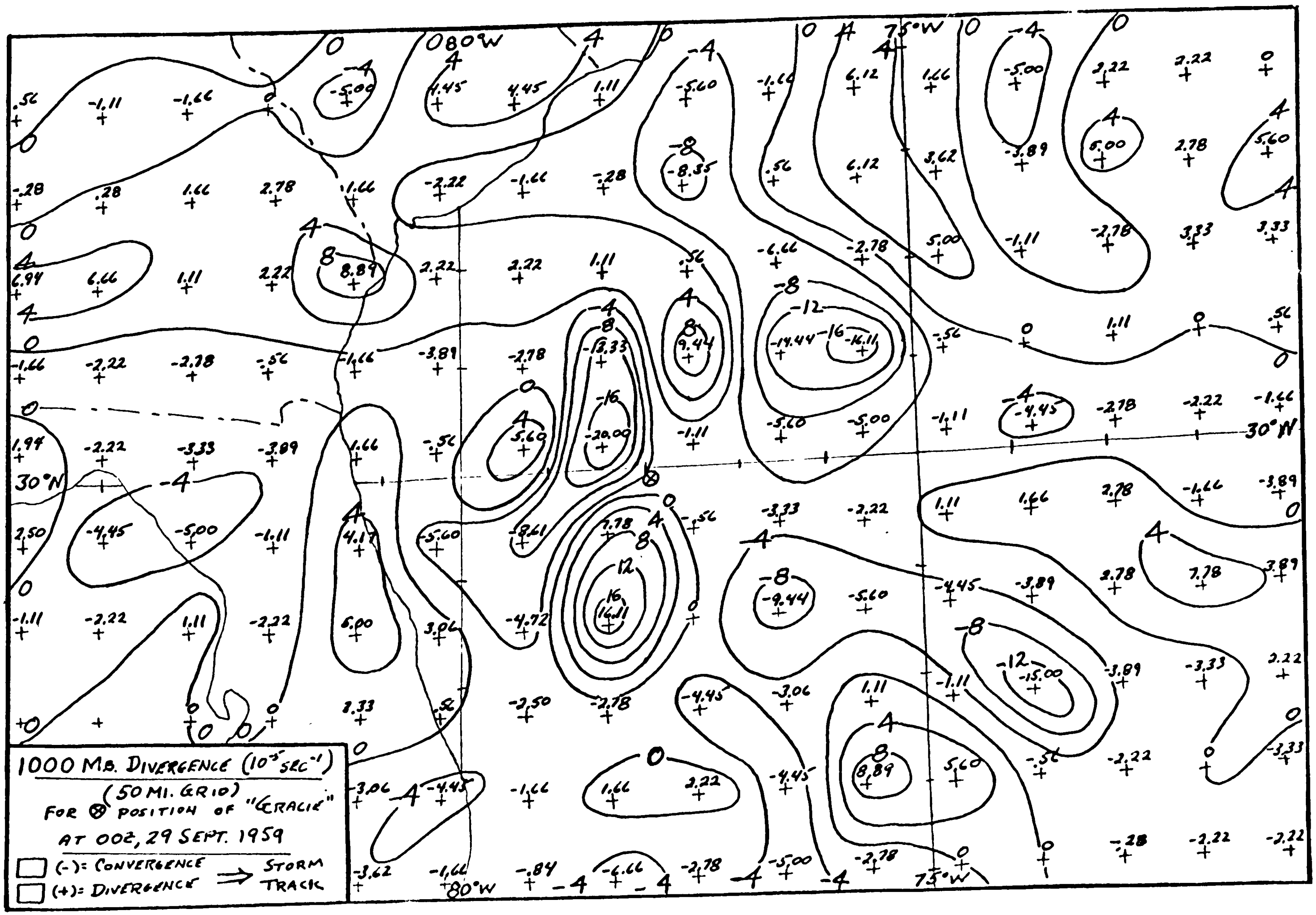

1000 mb Divergence
10⁻⁵ sec⁻¹
50 mi. grid
For position (⊕)
at 122,29
Sept, 1959
– = Converg
+ = Divergence
GA.
S.C.
N.C.
FLA



700 mb Thermal pattern (C°) for position (⊗) at 12Z, 29 Sept. 59



1000 MB DIVERGENCE (10^{-5} SEC^{-1})
(50 MI. GRID)
FOR ⊗ POSITION OF "GRACIE"
AT 12Z, 29 SEPT. 1959
(−) = CONV.
(+) = DIV.
X- - →X 12 HOUR CONV.-DIV. TRACKS
80°W
75°W
30°N



1000 MB. DIVERGENCE (10-5 SEC-1)
(50 MI. GRID)
FOR ⊗ POSITION OF "GRACIE"
AT 00Z, 29 SEPT. 1959
(-): CONVERGENCE
(+): DIVERGENCE
STORM TRACK
080°W
75°W
30°N
80°W

IV. RESULTS

A. Comparison with the mean

The pattern of divergence at 1200 z (see map on page 9) resembles the means tabulated by Miller (1) in three gratifying respects:

1. the divergence located at 34.5 N and 81.5 W is nearly identical in position as that shown by Miller's fig. 14a of the work cited (1);

2. the convergent area at 31.5 N and 79 W corresponds to the location of Miller's main convergent area;

3. both the mean and "Gracie" had secondary maximums of convergence although the mean position seems to lie approximately 60 miles toward the rear of the position in "Gracie".

The most striking variation from the mean was the position of the divergent zone of "Gracie", located at 31.5 N and 78.5 W, which falls in the strongly convergent rear right quadrant of Miller's model.

In comparison to the mean Gracie possessed values of greater magnitude, this is, of course, is to be expected. Two significant magnitudes were found.

1. The convergent located 90 miles to the north-east is as strong as the convergent area located only 25 miles to the east

2. The extreme strength of the divergence to the south-southwest is a curious phenomenon. This large value, for the most part, is due to a very strong wind from the south reported by reconnaisance aircraft. The wind, located some 40 miles northeast of the maximum divergence, was from 17^0 degrees at 120 knots.

B. Comparison of Divergence at 1200 z with that of 0000 z

The divergence patterns presented on pages 9 and 12 are similar in many respects. In both patterns there are two convergent areas to the right and rear of the path. There is a striking similarity between the divergent areas to the south in both maps.

The one major dissimilarity is the absence at 1200 z on the 29th of the divergent area between the two convergent areas as observed 12 hours previous. In its stead we now observe a minimum of convergence.

As illustrated in the map on page 11, Major Smith (2) and the author have theorized the motion of the predominate areas of convergence and divergence.

The most important feature on this map is the apparent joining of the two main convergent areas of the South Carolina coast. From the trajectories it is estimated they would have joined approximately 4 hours after the time of the map. It was at approximately that time that the storm moved inland. The indicated point of joining is approximately the same area where winds in excess of 160 miles per hour were estimated.

It can be seen from the map on page 11 that the areas of divergence and convergence moved relative to the storm in the same sense as the low-level winds, counter-clockwise. It appears that the farther the area is from the center the more its motion resembles that of the low level winds.

C. <u>Comparison of Temperature and Divergence</u>

There are two basic considerations involved when discussing temperatures at a level such as the 700 millibar level. The first is that the air may be heated by the latent heat of condensation, or colled by evaporation. Condensation would be expected to occur in the updrafts associated with the convergence, and evaporation in the downdrafts associated with the divergence. Second, air will be cooled adiabatically as it rises and heated as it sinks. In what ratio these two mechanisms effect a given location cannot be determined without some information concerning the water vapor content of the air.

When the map on page 10 is inspected, it can be seen that there are five areas of temperature maximum or minimum. The first area to be considered is the warm area located perpendicular to the Georgia-South Carolina coast line. The center of this area is located 70 miles south of Charleston or exactly at the "eye" of the storm. The maximum temperature reported at 700 millibars was 19°C. This maximum is orientated approximately southeast to northwest line. This orientation lies almost parallel to the direction of motion, which was 310°. This warm area is most likely due to a combination of the descending air in the "eye" and the extreme condensation in the converging wall cloud.

The cold area located just northeast of Charleston is not as easily explained as the previous area. It is located in the same area relative to the storm, that twelve hours previous was rather divergent (see page 12). This divergence could have been associated with descending air, which may have been so lacking in condensation that it appears cold with respect to its surroundings, which are being heated by condensation. A second alternative is possible, that this cold area is associated with the maximum of convergence whose present location coincides closely with that of the cold area (see page 9).

The third area of interest is the warm area located at approximately 37.5 N and 77.5 W. This area is located some 40 miles east of a strongly convergent area. This eastward displacement could be due to the distribution of cloud formation.

The fourth area is located 100 miles southeast of the center and is cold in nature. It is situated midway between a convergent and a divergent area. The exact cause of this cold area is impossible to determine without detailed information of the cloud distribution.

A fifth area, located at 30° N and 80° W, is situated just southeast of an extremely strong divergent area. The cause of this warm area is most probably the adiabatic heating of the air which would tend to descend into a strong divergent area.

V. REFERENCES

(1) Miller, Banner I. "The Three Dimensional Wind Structure Around a Tropical Cyclone", National Hurricane Research Project Report No. 15, January 1958.

(2) Smith, James E., Maj. U.S.A.F., Divergence Vertical Motion and Moisture Distributions in Hurricane "Gracie" - September 1959, S. M. Thesis, M.I.T. 1960.