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Mesoanalysis of Hurricane Rainbands

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INTRODUCTION

Recent mesometeorological studies of severe local storms associated with squall lines revealed that the mesoanalysis techniques can also be applied to hurricane analysis. Unfortunately, at the present time no network data such as we collect from the severe storms network are available. Therefore, an attempt was made to utilize the existing station data, even though they are insufficient, in order to study mesometeorological characteristics of hurricanes.

HURRICANE DIANE OF AUGUST 17, 1955

This hurricane was born over the southern Atlantic about August 10, then moved west northwestward, landing near Wilmington, N. C. on August 17. Figure 1 shows the pressure traces from selected stations in the hurricane path. It is of interest to find that the pressure profiles are appreciably disturbed near the storm center. The dotted curves drawn by eliminating this disturbance and the diurnal variation of atmospheric pressure show the undisturbed pressure profiles of Diane. It is not the main object of this paper to investigate the cause of the disturbed pressure; however, the disturbance may result from the pressure filling which usually occurs when a hurricane lands. The undisturbed pressure profile for each station was estimated in order to obtain the undisturbed minimum pressures plotted in Figure 2. The isobars for these minimum pressures indicate that the hurricane moved over the map area along a very smooth path. The movement of the undisturbed hurricane center fixed by the path, and the times of the minimum pressure, appeared to be very uniform compared to the irregular movement of the radar center entered in the figure as a heavy line. The actual pressure center of the hurricane also showed a very irregular movement. The stations shown in the chart by black circles recorded appreciable filling.

A mesoscale chart for 0800 EST August 17, 1955, when the hurricane was near Wilmington, N. C. is presented in Figure 3. Inside the area of filling, surrounded by a heavy broken line, isobars are bent so as to give a positive deviation in pressure from the undisturbed pressure field which is characterized by circular isobars. Instantaneous isallobars in units of mb/hr are also drawn in the chart. The positive and negative tendency areas located along the storm path are the main feature resulting from the hurricane movement. Inside the area of filling, the tendency is such that it resists the pressure fall along the undisturbed pressure profiles.

Radar echoes are superimposed upon the previous chart (Figure 4). It is extremely interesting to find the existence of two centers of echo circulation; the one with a major circulation, and the other accompanied by a cyclonic hook. Both of them were located within 15 miles from the pressure center of the undisturbed hurricane. The true pressure center, namely the point of actual minimum pressure, was located about 20 miles west southwest of Wilmington (ILM). It will probably not be reasonable to evaluate the geometrical characteristics of hurricane rainbands with respect to radar centers, since two or more circulation centers may exist. The two major rainbands, extending from the northwest to the southeast sector, displayed a systematic spiral motion around the hurricane center. Several minor echoes along the rainbands and scattered elsewhere were picked up for accurate velocity computation. The vectors in the figure, ranging from 3 to 72 kts, are the velocity of individual echoes thus computed.

The movement of the rainbands in the period 0715 - 0845 is described in Figure 5. During that time the center of the undisturbed pressure moved as far as 30 miles north northwestward. Individual echoes attached to the rainbands showed the displacement indicated by heavy lines connecting echo centers. It will be found in the figure that a section of the rainband, between echoes 1 and 3 for instance, stretched appreciably as it moved northwest.

An attempt was made to know whether the rainband under discussion was expanding or shrinking. Figure 6, prepared for this purpose, will answer the question. It is true that the value $(\frac{\partial r}{\partial t})_{\theta = const}$ appears to be positive everywhere along the rainband. This value, however, does not indicate the rate of expansion if the rotation of the hurricane is taken into consideration. As one can easily imagine, a logarithmic spiral, as an example, drawn on a rotating disc, would expand not because of the real expansion, but because of the effect of the rotation which would give an apparent increase in radius vector at a constant direction angle. The rotating field of a hurricane, though the angular velocity of rotation may not be the same everywhere, would result in an expansion phenomenon if we observe the distance of the rainband at a constant direction viewed from the hurricane center.

True expansion of a rainband should be obtained by eliminating the rotation around the center. In order to do this, the corresponding features attached to the rainband must be followed as reference points. The circles in Figure 6 are the centers of these features -- echoes -- which furnish us with the suitable marks in knowing the movement of the various portions of the rainband. The figure shows that not a single echo was moving at constant θ; instead, all the echoes moved in such a manner as to decrease their direction angles with time -- that is to say, the motion was cyclonic. The radius r attached to these features on the rainband showed either increase or decrease. Evidently, the rainband to the east of the center was expanding while the other portion was shrinking. The rate of expansion and shrinking seems to be up to 6 kts in absolute value.

CONCLUSION

The center of hurricane Diane was obtained by analyzing the undisturbed pressure field. An appreciable difference in location was found between the centers of undisturbed pressure and echo rotation, respectively. The $r - \theta$ diagram of one of the Diane rainbands revealed that it expanded, so far as we observed it, at a constant direction angle when viewed from the hurricane center. Eliminating the effect of hurricane rotation by following the corresponding features on the rainband, it was found that one portion of the rainband was expanding while the other was shrinking. The rate of expansion or shrinking was up to 6 kts in absolute value. Physical explanation of these motions of the rainband so far remains unknown.

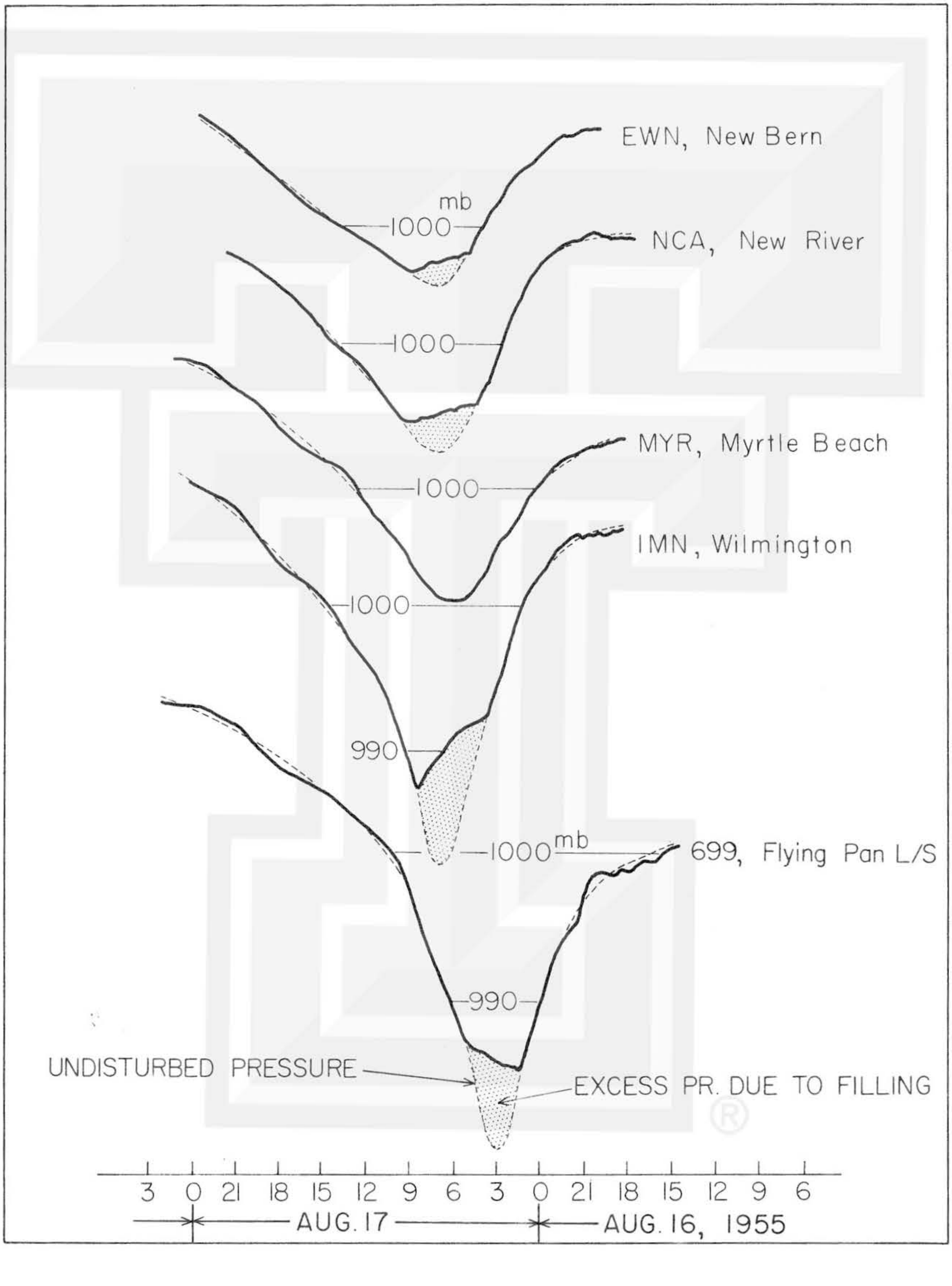
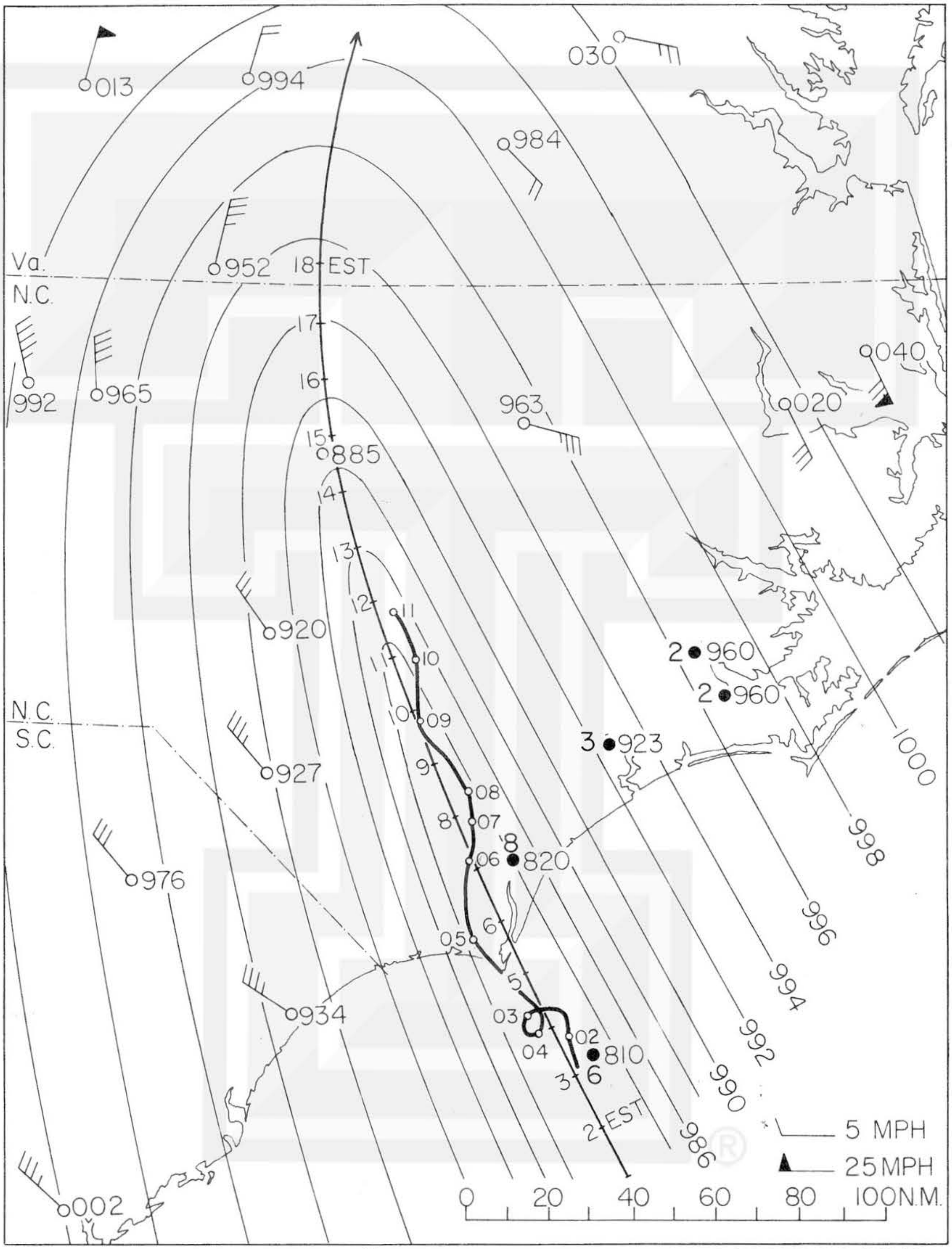
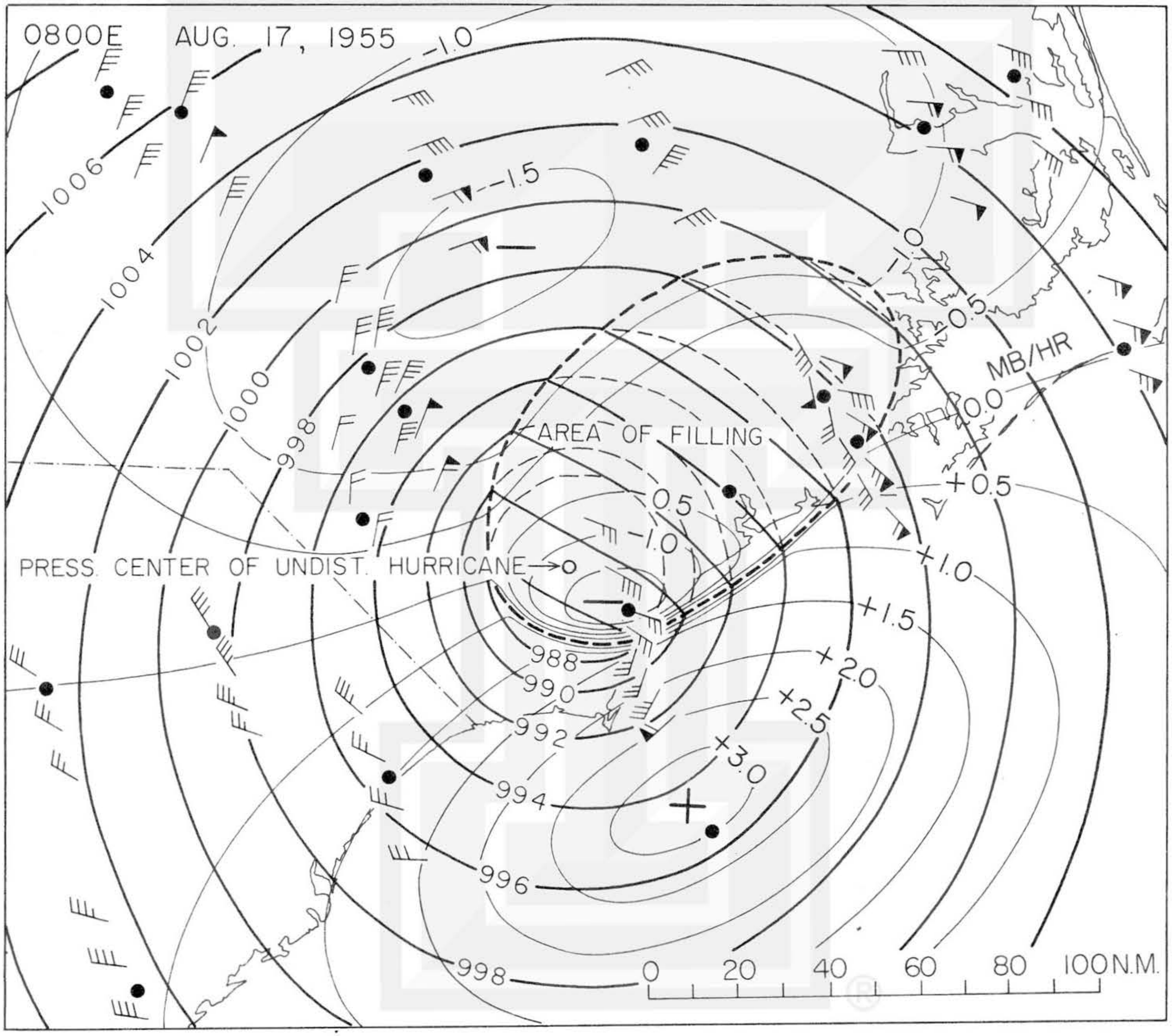

EWN, New Bern
mb
1000
NCA, New River
1000
MYR, Myrtle Beach
1000
IMN, Wilmington
1000
990
1000 mb
699, Flying Pan L/S
990
UNDISTURBED PRESSURE
EXCESS PR. DUE TO FILLING
3 0 21 18 15 12 9 6 3 0 21 18 15 12 9 6
AUG. 17
AUG. 16, 1955

FIG. 1



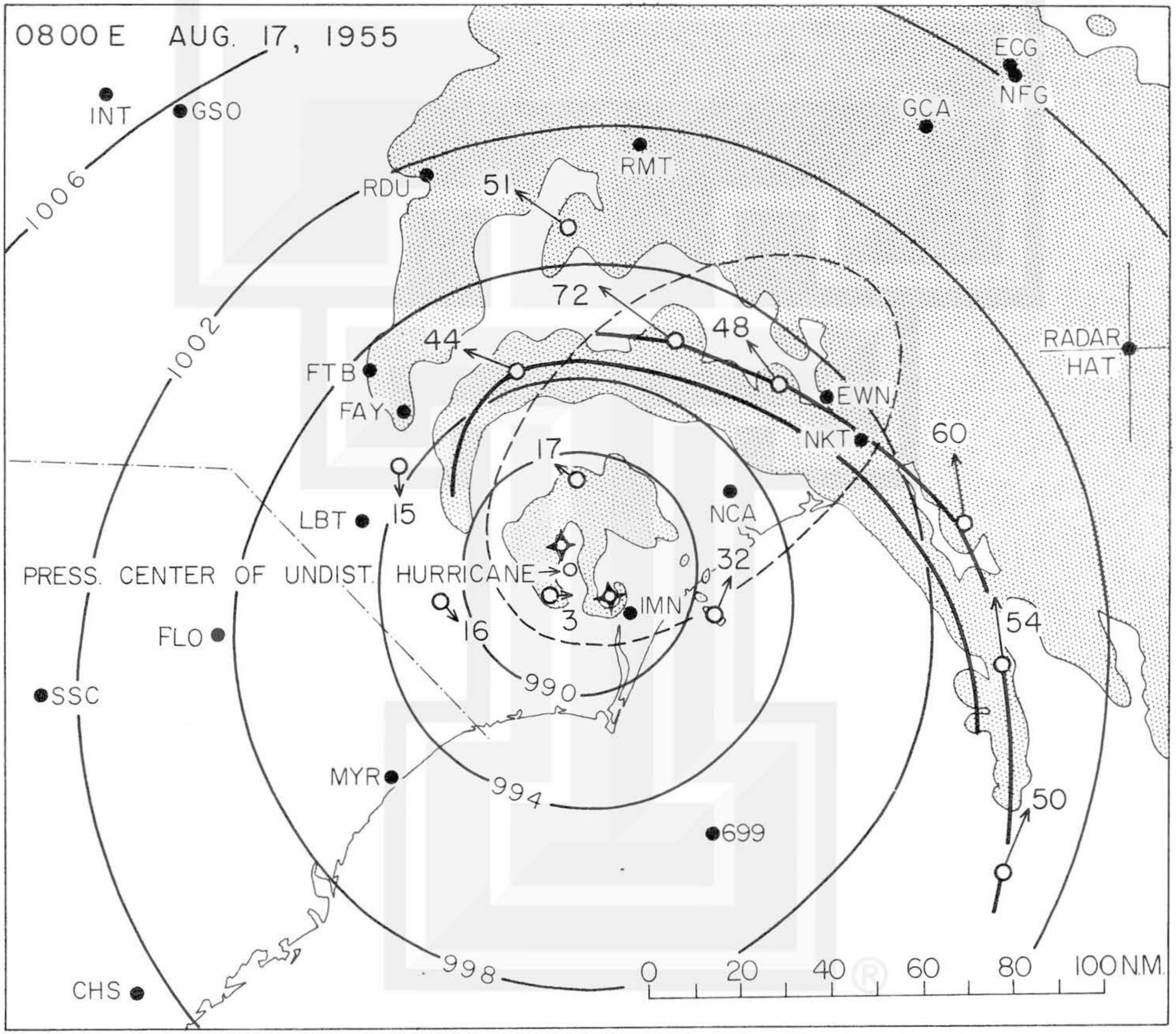
● 2 (2MB EXC. PR.), 96.3 MIN. PR. & CORRESPONDING WIND

FIG. 2



0800E AUG. 17, 1955
-1.0
-1.5
1006
1004
1002
1000
998
0
-0.5
MB/HR
0.0
AREA OF FILLING
-0.5
-1.0
+0.5
+1.0
+1.5
+2.0
+2.5
+3.0
PRESS. CENTER OF UNDIST. HURRICANE
988
990
992
994
996
998
0 20 40 60 80 100 N.M.

FIG. 3



25 ⟵○ ECHO VELOCITY (KTS), ✧ CENTER OF ECHO CIRCULATION

FIG. 4

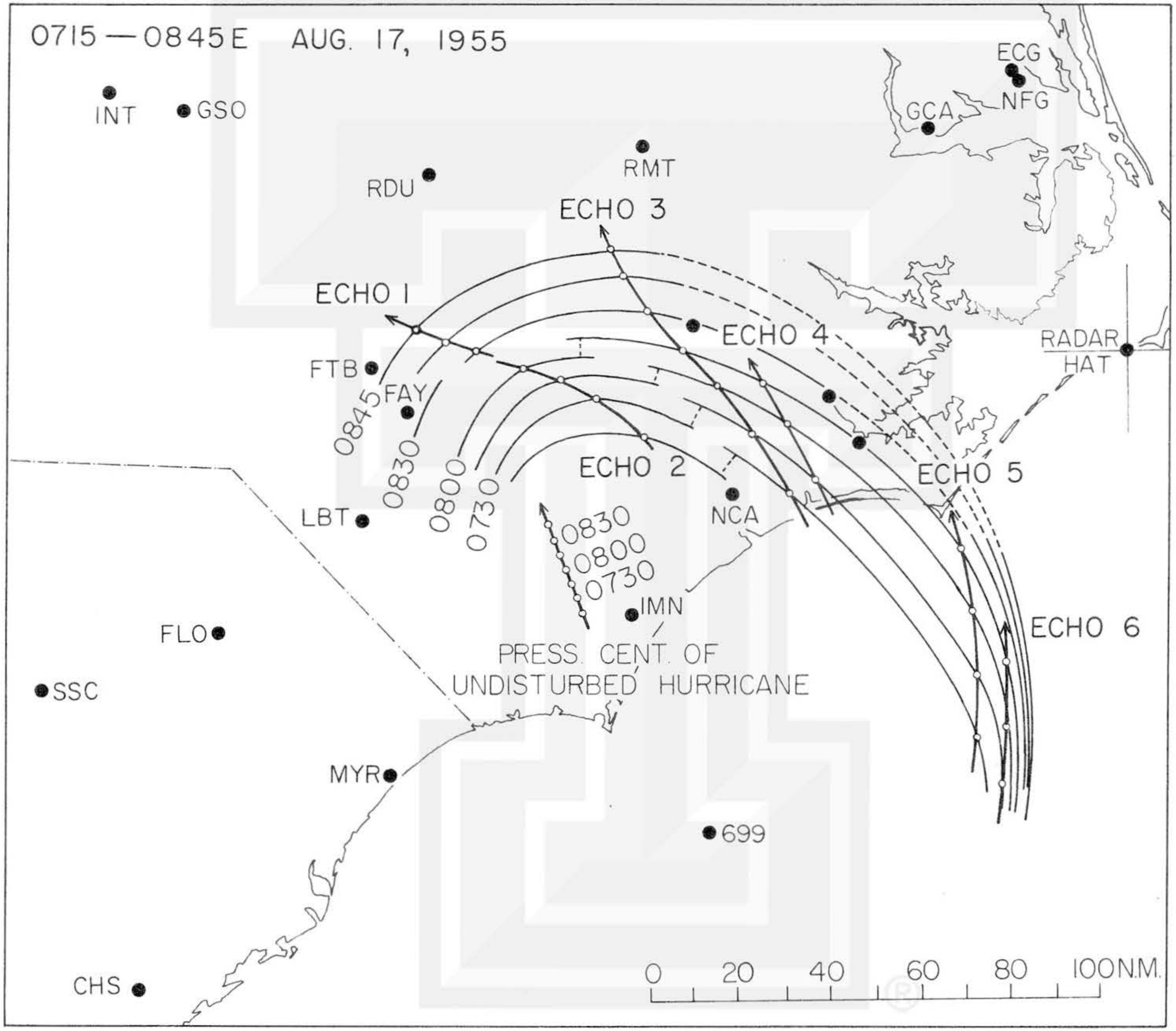
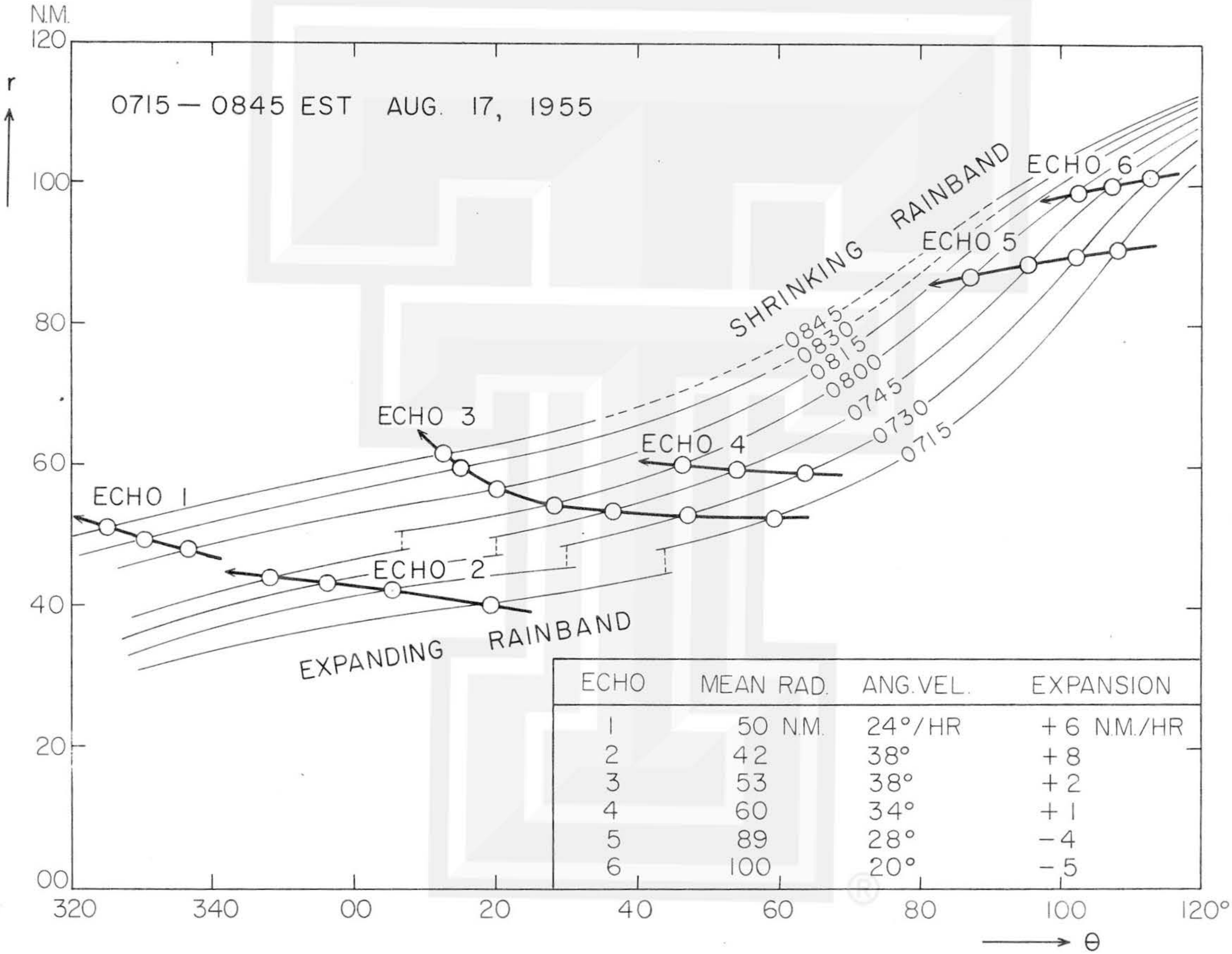

0715 — 0845E AUG. 17, 1955
INT
GSO
RDU
RMT
ECG
NFG
GCA
ECHO 3
ECHO 1
ECHO 4
RADAR
HAT
FTB
FAY
0845
0830
0800
0730
ECHO 2
ECHO 5
LBT
NCA
0830
0800
0730
IMN
FLO
PRESS. CENT. OF
UNDISTURBED HURRICANE
ECHO 6
SSC
MYR
699
CHS
0
20
40
60
80
100 N.M.

FIG. 5



ECHO	MEAN RAD.	ANG. VEL.	EXPANSION
1	50 N.M.	24°/HR	+6 N.M./HR
2	42	38°	+8
3	53	38°	+2
4	60	34°	+1
5	89	28°	−4
6	100	20°	−5

FIG. 6