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SQUALL LINES OBSERVED IN THE VICINITY OF THE RESEARCHER DURING PHASE III OF GATE

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1. INTRODUCTION

Tropical squall lines have been described previously by Hamilton and Archbold (1945) and Zipser (1969, 1971). According to Zipser (1971), "The structure of these squall lines is characterized by active cumulonimbus clouds on the leading edge, in which low level air overtaken by the squall rises to the upper troposphere, and a large area of downdraft air, with mid-tropospheric origin, occupying the rain area and forming a micro-cold front advancing in the direction of propagation of the squall line." During Phase III of GATE (August 30 - September 19, 1974), four squall lines fitting this description passed over the U.S. National Oceanographic and Atmospheric Administration (NOAA) ship Researcher, located at 7°N and 23°W. This paper briefly summarizes the characteristics of these four systems as they were observed by the author on board the Researcher.

2. DATA

On shipboard, the only weather information available was data from the NOAA quantitative weather radar (characteristics in Table 1) and ship-based surface and upper air observations.

Table 1

Characteristics of NOAA Radar
On Board the Researcher in GATE

Wavelength	5600 MHz (C-band)
Peak Power	250 Kw
Antenna Beamwidth	1.9 deg

Data from the radar were in the form of Polaroid photographs of the PPI display of quantized range-corrected reflectivity taken once each hour, and digital magnetic tapes of three-dimensional conical scan sequences recorded once every 15 minutes. The conical scan sequence consisted of complete azimuthal sweeps of the reflectivity pattern at elevation angles ranging from 0.5° to 22.5° in 2.0° increments.

Each day during Phase III, the radar data were monitored in a systematic manner. The Polaroid photographs were examined and compared and motions of prominent echo patterns determined. A computer program was written and utilized on shipboard to examine the vertical structure of echoes. The program constructed and printed out selected RHI displays from the digitally recorded three-dimensional scan data. Although this computer program only took into account the curvature of the earth in positioning the reflectivity data in the vertical, it proved to be a versatile tool for monitoring the vertical structure of echoes.

The radar data were supplemented by over 400 cloud photographs taken by the author, and a written log was maintained of all relevant weather events.

3. DESCRIPTION OF SQUALL LINES

Many lines of radar echoes were observed in the vicinity of the Researcher during Phase III of GATE. In fact, the PPI almost always contained echoes arranged in lines. The echo lines referred to here as squall lines were typically 25 to 40 km in width, over 150 km in length, and were distinct from other lines of echoes in that they moved steadily across the area of radar coverage at speeds of 5 to 20 m s^{-1}. Other lines of echoes typically moved more slowly, if at all, and much more erratically. Characteristics of the four squall lines which were observed are listed in Table 2. The propagation speeds of the squall lines observed in this study are similar to those reported by Zipser (1971) who noted squall line speeds of 12 to 15 m s^{-1}.

Table 2

Summary of Squall Line Characteristics

Squall Line	Date	Direction of Movement	Speed ($m\ s^{-1}$)	Maximum Echo Top (km)	Maximum Reflectivity (dbz)	Windshift ($m\ s^{-1}$)	Shape	Stratiform Precipitation behind Squall Line
1	4 Sept. 74	NE to SW	10	13	42-50	SE/5 to ESE/10	Arc	Yes
2	11 Sept. 74	NE to SW	20	12	42-50	NE/5 to ENE/15	Arc	Yes
3	12 Sept. 74	NE to SW	8	11.5	42-50	W/5 to ENE/ 10	Arc	Yes
4	16 Sept. 74	N to S	5	12	42-50	SSW/6 to WSW/12	Straight	No

The squall lines clearly exhibited a convective nature as each contained cores of intense echo extending vertically to 11-13 km. The two squall lines which passed over the Researcher during daylight hours (squall lines 3 and 4 in Table 2) were each visually observed to consist of a continuous line of cumulonimbus cloud preceded by a pronounced low-level roll cloud.

The squall lines were also distinct from other lines of echoes by the fact that the passage of each squall line was immediately preceded by a sudden shift of wind direction and an increase in wind speed (see Table 2). This windshift apparently occurred along the leading edge of downdraft air which was spreading under the line of convection, providing uplift to release instability and thus maintain the squall line, as suggested by Zipser (1969).

The first three of the squall lines listed in Table 2 were arc-shaped with a convex leading edge. The arc-shaped band in each case was followed by a zone of stratiform precipitation extending over 80 km behind the line of active convective cloud. Zipser (1969) noted a similar structure in his case study and showed

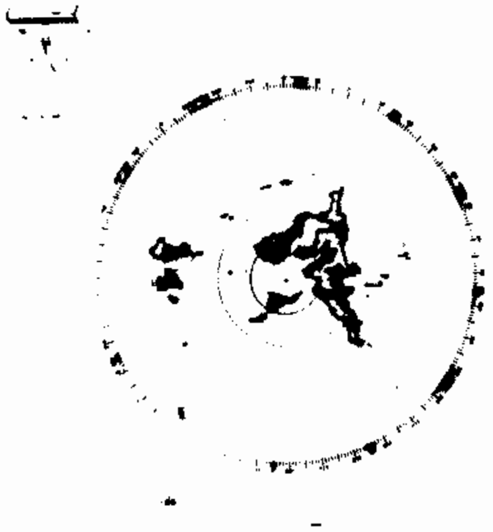

Figure 1. Quantized PPI display of Researcher radar, 1656 GMT, September 4, 1974. Contours of reflectivity are shown by three gray shades. Thresholds are: gray 18 dbz, black 26 dbz, white 34 dbz, gray 42 dbz. Range markers are for 37 km intervals. True north at top of page. Ships heading 298°.

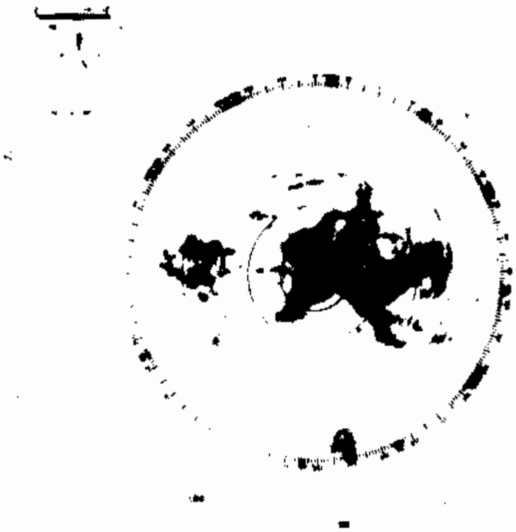

Figure 2. PPI display of Researcher radar's log receiver output, 1659 GMT, September 4, 1974. Format same as in Fig. 1. Ship's heading 299°.

that the stratiform region behind the arc-shaped squall line was occupied by unsaturated downdraft air.

Figure 1 shows Squall Line number 1 of Table 2 when it was located just east of the Researcher. (In all PPI displays an 18° sector is blocked in the direction of the ship's heading by ship superstructure.) This quantitative display shows the cores of intense convective echo in the squall line. The same echo pattern is shown again in Fig. 2 with the PPI showing the non-quantized, log receiver output. This display was found to be more sensitive to weak echoes and in Fig. 2 it shows the region of light stratiform rain behind the squall line.

The vertical structure of squall line phenomena is well illustrated by the RHI patterns shown in Figs. 3 and 4. Figure 3 is a cross section through the squall line shown in plan view in Figs. 1 and 2. It is evident from Fig. 3 that the squall line itself was composed of deep convective towers. The stratiform nature of the precipitation behind this line is shown by the RHI pattern in Fig. 4 which was obtained after the intense arc-shaped squall line in Figs. 1 and 2 had moved southwest of the Researcher and while the stratiform zone was located over the ship. A very pronounced radar bright band, a typical characteristic of stratiform precipitation, is observed just below the 0°C level in Fig. 3.

4. CONCLUDING REMARKS

The further study of squall line echo patterns will be an important aspect of the overall interpretation of GATE radar data. The

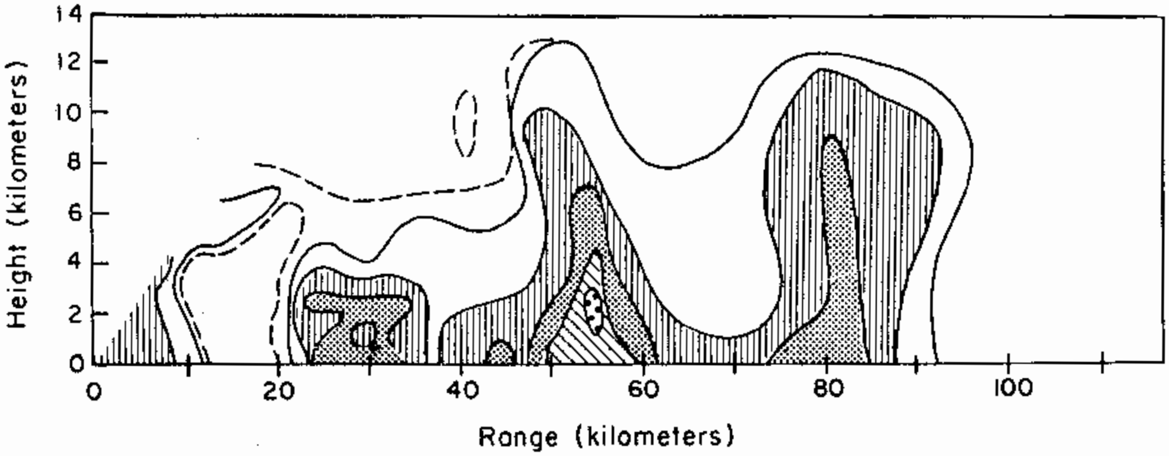

Figure 3. RHI display for azimuth 042° derived from Researcher radar conical scan sequence made at 1700 GMT, September 4, 1974. Contours of reflectivity have values of 11 (dashed), 18, 26, 34, 42, and 50 dbz.

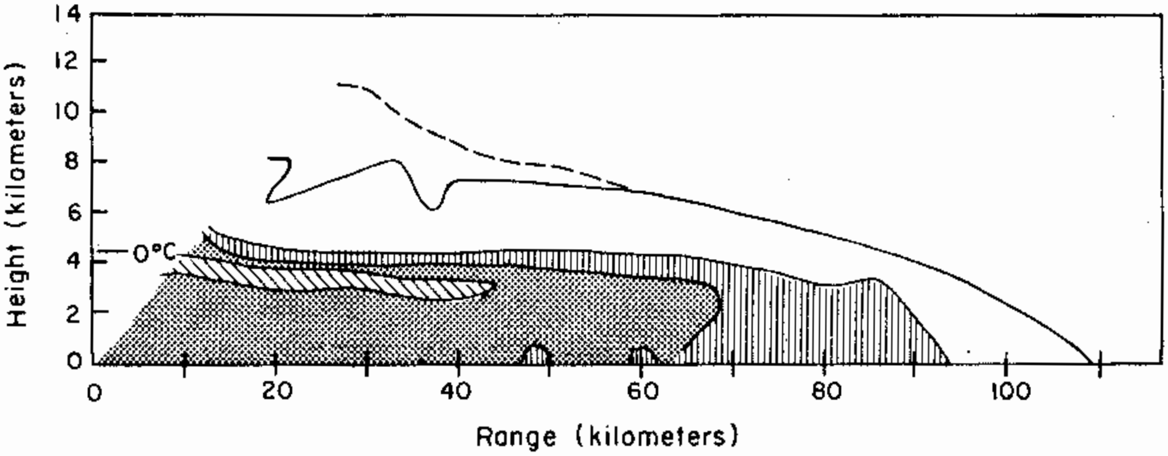

Figure 4. RHI display for azimuth 100° derived from Researcher radar conical scan sequence made at 2100 GMT, September 4, 1974. Contours of reflectivity same as in Fig. 3.

probable significance of squall lines in tropical dynamics and energetics is indicated by the observation that the four squall systems described above accounted for 50% of the total precipitation recorded on the Researcher during Phase III. The highly organized dynamical structure of squall lines suggests that they probably account for much of the overall vertical transport of mass, heat and momentum from lower to upper troposphere over the tropical Atlantic.

From careful study of the quantitative radar patterns over the GATE area, it will be possible to learn much about the relative role of squall lines in convective transport processes. At the University of Washington a research effort is currently underway to develop methods for computing vertical transports by convective cloud groups from quantitative radar data. One goal of this work, which is an extension of that of Austin and Houze (1973) and Houze (1973), is to determine from GATE radar data the proportion of total convective transport in tropical disturbances which is due to squall lines.

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