5B.6 CHARACTERISTICS OF OCEANIC TROPICAL CONVECTION AT KWAJALEIN

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1. INTRODUCTION

Over tropical oceans precipitating clouds occur in ensembles that include a broad range of phenomena, from shallow isolated cells to large mesoscale convective systems with stratiform precipitation areas. Often one type or another of these clouds is investigated singularly. However, the precipitating clouds of this wide range of sizes and characteristics work in concert to redistribute the mass, heat, moisture, and momentum of the large-scale tropical circulation (Houze 1982, 1989, 1997). The ensemble properties of precipitating clouds over the tropical oceans are most readily characterized by measuring the properties of their radar echoes. Houze and Cheng (1977) and Cheng and Houze (1979) examined the radar echo population over the eastern tropical Atlantic using ship radar data collected in the Global Atmospheric Research Programme's Atlantic Tropical Experiment (GATE). They identified and tracked radar echoes occurring over a total of 44 days. This paper applies procedures similar to Houze and Cheng (1977) to determine the ensemble properties of the echo population described by a unique data set obtained over the tropical western Pacific Ocean. At the Kwajalein Atoll, an S-band research radar has been operating since 1998 to collect data in support of the TRMM satellite (Yuter et al., 2004). These radar data have high sensitivity, fine vertical and temporal resolution, and calibration matching with the TRMM satellite radar (Houze et al. 2004). An intensive field observation campaign, the Kwajalein Experiment (KWAJEX) supplemented the multi-year data set for the period 23 July through 15 September 1999. This study uses the KWAJEX radar data set to characterize the radar echo population in the vicinity of Kwajalein and compares the echo population at Kwajalein to that seen in GATE.

2. METHODOLOGY

At intervals of ~5 min, the radar at Kwajalein provided a low PRF base scan (max range 240 km) followed by a high PRF volume scan consisting of 24 elevation angles (Yuter et al., 2004). For this study, the volume scan data were interpolated to a Cartesian grid 2 km x 2 km in the horizontal, 1 km in the vertical. We characterized the echoes present at 00, 06, 12, and 18 UTC for 13 test dates scattered throughout the KWAJEX period. A reflectivity threshold of 15 dBZ was used to define the boundaries of echoes measured and tracked. No echo smaller than 5 km^2 was considered.

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The horizontal area of each echo present at 00, 06, 12, and 18 UTC was estimated by measuring a major and minor axis that when multiplied yield a rectangular area approximating the area covered by the echo (following Houze and Cheng, 1977). The orientation of the echo indicated by the major axis was also recorded.

Each echo was tracked backward and forward in time to determine its duration, speed and direction of motion, as well as its formation and dissipation modes (appearance, disappearance, split, or merger, following Williams and Houze, 1987).

The height of each identified echo was measured by moving up through the height levels of the Cartesian grid until the echo was no longer evident.

3. CHARACTERISTICS OF THE KWAJEX ECHO POPULATION

3.1 *Horizontal Dimensions*

The degree to which echoes were elongated was indicated by the ratio of the major axis to the minor axis, which averaged near 2.4.

The frequency distribution of echo area was approximately lognormal except for the largest 1% of echoes (Fig. 1). In the format of this figure, a lognormal distribution appears as a straight line. The deviation from a straight line at large echo area is characteristic of a truncated lognormal, and in this case truncation was evidently caused by the range limitation of the radar. The distribution was similar to that of the GATE echoes (Houze and Cheng, 1977) up through the truncation point, which is likely because the low PRF radar scan at Kwajalein has a larger maximum range than the GATE radars.

Close inspection of the curves in Figure 1 shows that the frequency distribution of echo area deviated slightly from a simple lognormal distribution in three ways: From 0 to 10^3 km^2, the distribution tended to follow a distinct straight line, whereas the distribution followed a different line from about 10^3 to 10^4 km^2. Above 10^4 km^2, the distribution began to truncate. These three deviations occurred at all four different analysis times.

3.2 *Echo Orientation*

If an echo was sufficiently elongated (i.e. the ratio of major to minor axis > 1.5), the orientation of the echo was determined by the major axis. *Small* echoes (< 10^2 km^2) tended to be oriented in either a north-south, east-west, or northeast-southwest direction. *Medium* (10^2-10^3 km^2) and *large* echoes (> 10^3 km^2) favored either a northeast-southwest or a southeast-northwest orientation.

3.3 *Echo Formation, Dissipation, and Duration*

The echo tracking showed that small echoes were more likely to form by appearing and to dissipate by disappearing. However, formation and dissipation were dominated by merging and splitting modes for medium echoes, and large echoes consistently formed and dissipated by merging or splitting. Houze and Cheng (1977) found similar results with the GATE echoes.

The average duration of the KWAJEX echoes was 72 min, and it was positively correlated with echo area, despite the lifetimes of the largest echoes being bounded by merges and splits. When plotted in log-probability format, the durations exhibited a lognormal distribution. This result has also been found in the eastern and western Atlantic (Houze and Cheng 1977 and López 1977).

3.4 *Echo Motion*

Average echo speeds of the KWAJEX echoes were 6-8 m s^{-1}, with the larger echoes moving faster than the smaller echoes. The average track angle was generally east-southeast to west-northwest, approximately aligned with the prevailing low-level trades. The smaller echoes were more likely to move in random directions, whereas the larger echoes were more likely to follow the east-southeasterly motion.

3.5 *Echo Height*

The average minimum detectable height for the small, medium, and large echoes was 5.9, 8.4, and 11.3 km, respectively. The 6 km level was associated with two interesting features of the echo heights: First, the mean height for the small echoes was near 6 km. Second, all of the large echoes extended up to or beyond the 6 km level. Although the exact mechanism for this is unclear at this time, the authors speculate that this was related to the height of the 0ºC level.

When plotted in log-probability format (Fig. 2), echo height displayed a lognormal distribution up through heights of 14 km, before quickly falling off at 15 km. The truncation compares well to that found in GATE by Houze and Cheng (1977) and López (1977). The deviation from lognormal is attributed to the fact that echo heights were limited to the height of the tropopause, which is at approximately 15 km in the Kwajalein region.

4. CONCLUSIONS

Radar echoes analyzed at Kwajalein appear to have similar characteristics to those in the eastern tropical Atlantic, as found in studies by Houze and Cheng (1977) and Cheng and Houze (1979). The echoes exhibited a lognormal, or truncated lognormal, distribution of all their temporal and spatial dimensions. Echoes tended to be elongated, with an average length/width ratio of 2.4. The elongated echoes exhibited a variety of orientations. Echo movement was related to the trade winds, but larger echoes moved somewhat faster than smaller echoes. Echo duration was positively correlated with echo area, and echo lifetimes were limited by merges and splits, especially for the larger echoes.

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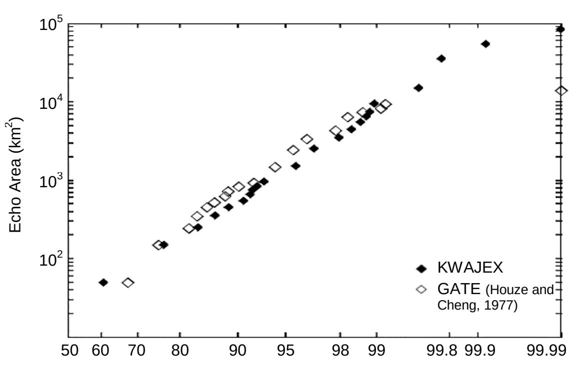

Figure 1. Accumulated frequency distribution of the areas of the radar echoes in KWAJEX compared with GATE.

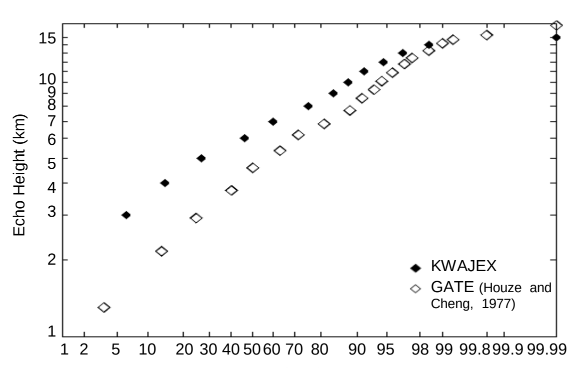

Figure 2. Accumulated frequency distribution of the heights of the radar echoes in KWAJEX compared with GATE.