Comparison of Reflectivity Measurements by Radar and by Disdrometer

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ABSTRACT

Average reflectivities of the rain falling on a ship, measured with a shipborne radar by observing at close range and high elevation angle, are compared with values computed from drop size measurements on the ship. Agreement is good and the technique appears to hold promise as a routine calibration check in locations where sidelobe echoes from nearby ground targets are not too predominant.

1. Introduction

Strictly speaking, the radar reflectivity factor $Z=\Sigma nd^6$ can only be calculated from measurements of drop-size distributions, whereas the reflectivity obtained from radar measurements, and generally denoted Z_e, is a deduced quantity. Comparison of Z_e values from a sampling volume above a disdrometer with Z's measured with the latter has long been recog-

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TABLE 1. Characteristics of WR73 radar.

Wavelength	5.3 cm
Antenna gain	40 dB
Beam width	1.5°
Range resolution	300 m

nized as a potentially ideal way to calibrate, or check the calibration of, a weather radar.

Joss *et al.* (1968) calibrated their vertically pointing radar in this way with excellent results. They compared the Z_e value obtained from the radar at a height of 200 m above a disdrometer with the Z value calculated from the disdrometer whose accuracy had been verified by comparison with raingages. Subsequently, in 46 intervals, averaging 14 min each, the standard deviation of the quotient Z/Z_e was $\pm 6\%$. Practical limitations of this method as employed by Joss *et al.* are 1) the difficulty in measuring radar signals at very close range (Joss *et al.* used two antennas, one for transmission and one for reception) and 2) the obvious undesirability of tying up a radar in a vertically pointing mode.

Martner (1977) also considered the possibility of calibrating with this type of comparison but at long ranges, 70 km and well over 100 km in the two cases shown. His results showed quite reasonable agreement between the radar and disdrometer reflectivities if differences in sampling volume and the possible presence of hail for part of the time are taken into account. Although there was considerable scatter in the measurements by the two methods, there was no consistent bias and he concluded that this type of comparison (at large distances from the radar) could serve as a crude check on the radar calibration but not as a calibration per se.

In this note, reflectivities measured with a disdrometer on the R/V *Gilliss* during GATE are compared with close-in reflectivities measured with a radar on the ship. These comparisons were not intended to serve as a calibration but rather to provide some measure of the degree of confidence which could be assigned to both sets of data.

2. Radar measurements

The pertinent characteristics of the WR73 radar that was operated aboard the R/V *Gilliss* during GATE are given in Table 1.

Full 360° maps were taken in stepped-elevation sequence every 15 min. The signals were digitized, averaged and range-normalized in a programmable digital integrator (Yeager, 1975). The data were then recorded on magnetic tape in units proportional to dBZ. The methods of calibrating the radar and of compensating for system drift have been described by Geotis (1975). The standard error in the measurements of reflectivity is estimated to have been approximately 1 dB.

The best approximation of the reflectivity of the rain on the ship was taken to be the average signal at a range of 2 km at each elevation angle greater than 5°. The range limitation was dictated by the time required for receiver recovery after transmission and the elevation limit was imposed to avoid sea clutter. The reflectivity values were first anti-logged so that the averaging could be done in Z_e rather than log Z_e. Results were then converted to dBZ for plotting.

The data were in the form of integrator output, the average of 16 pulses in time, every degree in azimuth. These were then averaged over the full circle for each elevation angle. Nearly a minute was required for a complete azimuth scan and the results from each elevation angle could thus be plotted separately. In this way, several samples were obtained within each 15 min period rather than only one.

3. Disdrometer

The drop-size measurements were made with a Joss-type disdrometer (Joss and Waldvogel, 1967). This disdrometer is a momentum exchange device which produces a pulse whose magnitude is a function of the size of the impacting drop. It is also sensitive to accoustic noise, and special circuitry is incorporated which precludes the counting of noise as drops. To accomplish this, a threshold (proportional to the noise) is established which must be exceeded by the voltage produced by real drops if they are to be counted. Unfortunately, the noise on the R/V *Gilliss* was quite high and, as a consequence, most drops with diameters <1.5 mm were lost and the counts of drops as large as 2 mm were affected. Fortunately, since it depends on the sixth power of drop diameter, Z is heavily weighted toward the larger drops which were counted reliably.

Before calculating Z and the other parameters from the data, the distributions were first corrected (or reconstructed) by anchoring them at the reliable, large-diameter end and fitting a smooth curve such that the calculated rain matched that recorded in a gage a few centimeters away.

The duration of each sample was 1 min and all samples included in the analysis contained at least 100 drops each before correction. In all, drop-size data were taken during eight of the periods when rain fell on the ship. On four of these occasions enough data were obtained to allow a fair comparison with the radar measurements.

4. Results and discussion

Z_e from the radar and Z from the disdrometer are plotted in Fig. 1 for the four times when a sufficient number of drop measurements were available. The agreement is quite good, and there is no sign of any

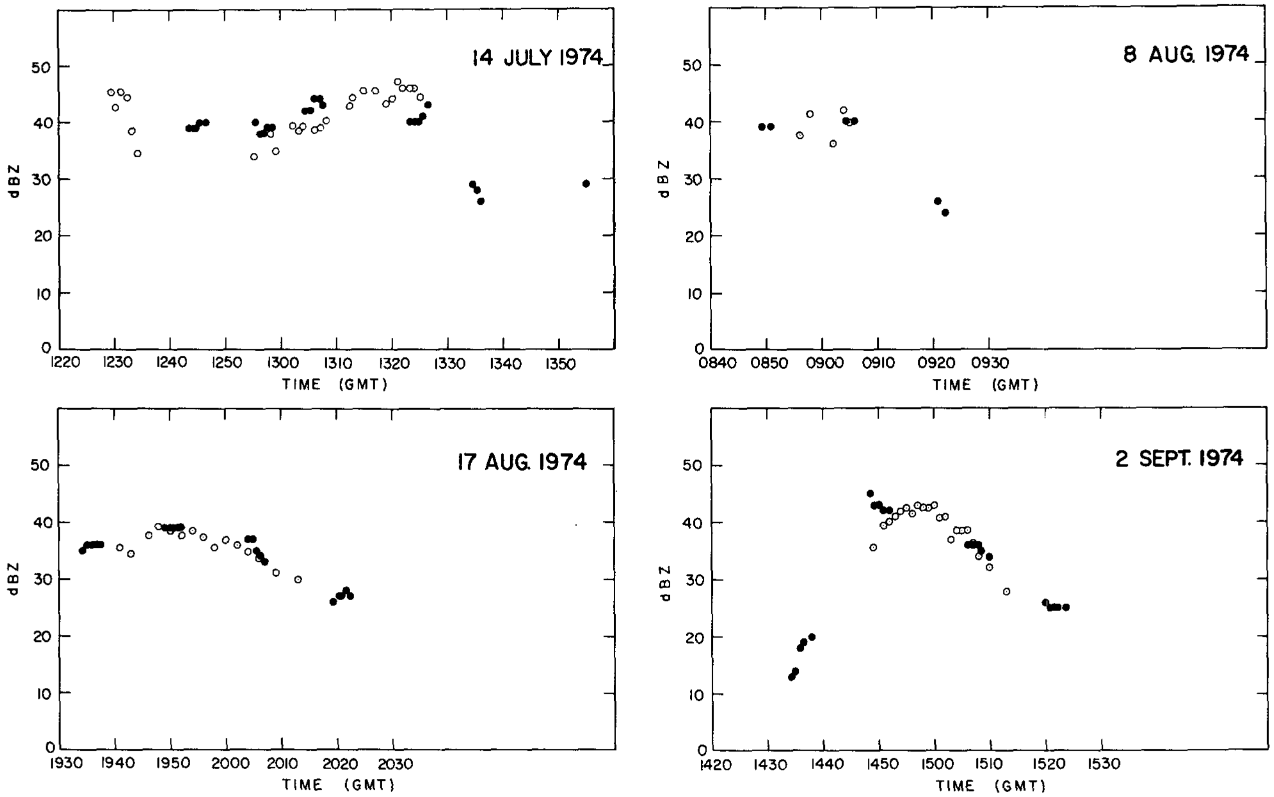

Fig. 1. Comparison of Z_e from radar (solid circles) and Z from disdrometer (open circles) for four rain periods during GATE.

bias, in spite of the differences in sample size and location.

Although this type of test may not be suitable as a stand-alone calibration procedure, it is certainly useful as a check. Discrepancies of more than a decibel or two should easily be detected, especially if extended averages are compared. The agreement is especially encouraging if we consider that extensive adjustments were made to the disdrometer data, although the strong dependence of Z on the larger drops, which were unaffected by the noise, was certainly a helpful factor.

The procedure described here is feasible only if the signal from the rain is considerably stronger than that of the nearby ground clutter in the side lobes. This was, of course, not a problem aboard ship.

5. Conclusions

Disdrometer-derived Z values were compared with near-in radar reflectivities at high elevation angles and agreement was found to be quite good. We have suggested that this procedure is useful as a calibration check.

Echoes from the side lobes were not a problem aboard ship but this may not be true in the case of nearby ground clutter. Tests of the feasibility of using this procedure with land-based radar are planned. If such feasibility could be established, a great advantage would be that the procedure could be used routinely as a calibration check whenever stepped-elevation data beginning at close range are taken. The needed radar data would be acquired automatically as part of the total set being recorded, as was the case in GATE.

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