Reply

JOHN B. CUNNING AND ROBERT I. SAX

National Hurricane and Experimental Meteorology Laboratory, NOAA, Coral Gables, Fla. 33124

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We appreciate the comments by Jones, and we are grateful for the opportunity to elaborate on a few points which, for the sake of brevity, we did not discuss in our original paper. We chose to regress Z as a dependent variable on R as an independent variable to make the calculations compatible with those of previous workers. Merceret (1974) addressed the need to state clearly the choice of variable dependence used in the regression technique, and Jones correctly points out that the selection of R as the independent variable often results in a larger coefficient and a smaller exponent than when Z is taken as the independent variable. Table 1 gives the GATE Z–R relationships derived from the daily and total drop distribution data sets (as in Cunning and Sax, 1977, Table 2) calculated with both R and Z as independent variables (the latter after appropriate transposition from the form $R=cZ^b$). It can be seen that in all cases the coefficient is smaller and the exponent is greater when Z is chosen as the independent variable. However, the differences between each set of calculated Z–R relationships are very small, a result which could have been deduced from the very high correlation coefficients given in Table 2 of the Cunning and Sax (1977) paper.

We agree that the Z–R relationship data presented in our paper are strongly weighted by the heavy precipitation in the core regions of the penetrated shafts, and we pointed out that application of the results to the periphery of showers may not be a valid procedure. It is not possible, however, to further stratify the data within a given shower because the sampling volume then becomes too small for reliable representation of the tail of the true drop size spectrum.

We would like to address briefly what we perceive to be the main thrust of Jones' comments—namely, the precipitation formation mechanism operating within the tropical clouds investigated as part of the GATE Z-R study. Although we certainly concur with his comments regarding the complexity of the precipitation formation mechanisms operating in midlatitudes, it is our opinion that the apparent high correlation of the GATE Z-R relationships from day to day and as a function of stratification by rainfall rate does not necessarily preclude the possibility of a complex precipitation formation process operating within those tropical clouds. Indeed, since the precipitation shafts frequently occurred from clouds with tops extending well above the melting level (Kelley, 1974), the possibility of an ice-phase-induced precipitation process working in complement with an effective coalescence mechanism cannot be ruled out and, in fact, seems likely. The lack of significant variability in the drop distribution data *at cloud base* may well be due to a smoothing of the spectra by natural processes (such as drop breakup) within the rather large depth (4 km) of warm cloud. It is our experience in Florida (Cunning, 1976) that the drop size distribution within rainshafts from clouds receiving a pronounced impulse of ice at

TABLE 1. Cloud-base Z–R relationships as a function of choice of independent variable.

Date (1974)	Number of raindrop spectra	Z–R Relationship: R independent variable	Z independent variable
12 July	7	$Z=164R^{1.54}$	$Z=163R^{1.55}$
29 July	9	$Z=146R^{1.55}$	$Z=142R^{1.57}$
3 August	15	$Z=261R^{1.34}$	$Z=222R^{1.41}$
5 August	19	$Z=176R^{1.45}$	$Z=162R^{1.49}$
10 August	12	$Z=211R^{1.47}$	$Z=187R^{1.52}$
11 August	5	$Z=163R^{1.58}$	$Z=126R^{1.68}$
13 August	12	$Z=291R^{1.38}$	$Z=254R^{1.43}$
14 August	3	$Z=150R^{1.44}$	$Z=145R^{1.47}$
17 August	3	$Z=116R^{1.63}$	$Z=110R^{1.65}$
30 August	5	$Z=179R^{1.38}$	$Z=171R^{1.41}$
6 September	10	$Z=164R^{1.54}$	$Z=146R^{1.58}$
14 September	7	$Z=118R^{1.66}$	$Z=106R^{1.69}$
Total combined raindrop spectra (all days)	107	$Z=170R^{1.52}$	$Z=155R^{1.56}$

the $-10°C$ level (due to the massive infusion of silver iodide nucleant) did not differ detectably from those in rainshafts from unseeded clouds of similar size. In other words, the adjustment of the drop-size distribution in precipitation falling through a great depth of warm cloud proved to be so effective that no seeding signature could be detected at cloud base. This serves to point out that considerable caution must be exercised in drawing inferences regarding precipitation formation mechanism(s) when sampling in regions far removed from (in this case, much below) the effective zone of precipitation formation.

Although we are not convinced that there is any fundamental difference between the precipitation formation processes operating in midlatitude and tropical clouds with similar depths and base temperatures, we do feel that Jones has raised some very pertinent points which could be addressed in future research. We wholeheartedly agree with his statement that tropical clouds provide a valuable natural laboratory for experimentation in cloud physics.

REFERENCES

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