Reply

A. L. RANGNO AND P. V. HOBBS

Cloud and Aerosol Research Group, Department of Atmospheric Sciences, University of Washington, Seattle, Washington

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We thank A. Ben-Zvi (1997, hereafter B-Z97) for bringing to our attention articles that deal with runoff evaluations of the Israeli II cloud seeding experiment.

Ben-Zvi states that the number of rain days (461) in northern Israel for the Israeli II experiment quoted by Ben-Zvi (1988, hereafter B-Z88) was misinterpreted by us and that this number is not relevant to Gagin and Neumann's (1981) analysis, which uses subsets of 388 or fewer days. B-Z88 states, ''in the six years of the experiment there were 461 rain days, of which 165 were seeded and 181 were unseeded, and the rest of the days were excluded from the comparisons.'' However, we found numerous days (about 50) with measurable rain in northern Israel (between 1 November and 30 April), which, since they were assigned random a priori decisions for each season of Israeli II, should have been included in the target–control analysis. It is not permissible to exclude any day that was assigned a random decision from the primary analyses, let alone days with rain. In Israeli II, six November–April periods were assigned random decisions, or more than 1000 days. So far, results have been reported for only 388 days. The rainy days in Rangno and Hobbs (1995) (and those mentioned by B-Z97) that fall within the randomized cloud seeding experiment should have been included in the target–control evaluations of Israeli II.

When the primary crossover design was abandoned in the analyses of Israeli II, the buffer zone became a poor indicator of a ''dry day.'' This is because the target and control areas were located in northern Israel, and there are many more rainy days in northern Israel than in the buffer zone. Hence, the original reason for using three stations in the buffer zone, namely, to eliminate dry days in the ''crossover'' analyses, was no longer valid when they were used in the target–control analyses, which were limited to the north target area.

Ben-Zvi questions whether the results reported in B-Z88 were statistically significant. The runoff evaluations in B-Z88 were concerned with a subset of 165 seeded and 181 control days during the Israeli II experiment. B-Z88 reported that 26 seeded and 10 control days experienced runoff. Using the binomial test, one may reject the null hypothesis that seeding had no effect on runoff at the 0.004 level.

The B-Z88 finding concerning differences in rainfall intensities between seeded and control days is important in the discussion of the statistical results of Israeli II. Table 1, which reproduces the findings of B-Z88, shows that the amount of rain that fell within a certain rainfall intensity category was greater on seeded days than on control days in the north target area for all of the four intensity categories chosen by B-Z88. However, rather than providing support for a seeding effect, we believe that these results provide independent evidence that a type I statistical error (or ''lucky draw'') compromised Israeli II. To see why this is the case, we must first discuss the relationship between rainfall intensity and cloud-top temperature in Israel.

Using measurements from a recording rain gauge, a distrometer, a vertically pointed X-band radar, and an aircraft, Gagin (1980) found that rainfall rates greater than about 5 mm h^{-1} in Israel were produced by clouds with tops greater than or equal to 5 km MSL. Assuming a cloud-base temperature of 8°C at 0.8 km MSL, which is typical of Israeli clouds (e.g., Gagin and Neumann 1981), and a pseudoadiabatic lapse rate, the temperature at the tops of clouds that reach to 5 km MSL is less than or equal to −20°C. However, Gagin and Neumann (1981), and Gagin (1981, 1986) claim that such clouds are too cold to respond favorably to seeding. Recall also that later studies of Israeli clouds (e.g., Rangno 1988; Rosenfeld and Gagin 1989; Levin 1992; Rosenfeld and Farbstein 1992; Levin 1994; Rangno and Hobbs 1995) have shown that the formation of precipitation is much more efficient than indicated by earlier reports and that ice particle concentrations are likely to be considerably greater than previously believed, thus further diminishing the prospect of a favorable seeding effect for clouds with top temperatures less than −20°C.

Contrary to these expectations, Table 1 shows that

Corresponding author address: Prof. Peter V. Hobbs, Dept. of Atmospheric Sciences, Box 351640, University of Washington, Seattle, WA 98195-1640.
E-mail: phobbs@atmos.washington.edu

TABLE 1. Ratios of depths of rainfall on seeded and control days in Israeli II for four rainfall intensity categories (from Ben-Zvi 1988).

Rainfall station	Intensity category (mm h^{-1})			
	0–5	5–10	10–20	>20
(a) Control region				
Naharria (northern coastline)	1.05	0.99	0.89	1.06
Acco (northern coastline)	0.88	1.08	0.97	0.91
(b) Target region				
Har Kena'an (hill region, north target area)	1.19	1.41	1.46	2.00
Ayelet (hill region, north target area)	1.19	1.36	1.44	2.49

the amount of rain that fell with intensities greater than 5 mm h^{-1} was 1.36–2.49 times greater on seeded days than on control days in the north target region of Israeli II. This implies from Gagin's (1980) results (referred to above) that the higher rainfall on the seeded days with rain intensities greater than 5 mm h^{-1} was derived from cloud tops of 5 km MSL or greater (i.e., from clouds higher and colder than on control days). However, it is unlikely that cloud-top heights were increased by seeding, unless the ''static'' seeding mode employed in Israeli II produced a strong ''dynamic'' seeding effect. A dynamic seeding effect is unlikely, both from the standpoint of the cold wintertime polar air masses that bring precipitation to Israel and the relatively low rates of seeding employed in Israeli II. Dynamic seeding effects are generally confined to tropical cumuliform clouds with high cloud-base temperatures, which contain copious supercooled water and require very large seeding rates (e.g., Dennis 1980). This is one of the reasons for our contention that the differences between rainfall on seeded and control days in Israeli II were due to natural causes.

Another troubling aspect of the B-Z88 findings is that the north target area gauges that they examined were also studied (together with other gauges) by Gagin and Neumann (1976), Gagin (1986), and Gagin and Gabriel (1987), who found no apparent effects of seeding on rainfall *intensity* on north target area seeded days, but rather an increase in the *duration* of rainfall. This latter finding supported their static seeding hypothesis.

According to B-Z97, the differences between the findings of B-Z88 and those of Gagin and Neumann (1976), Gagin (1986), and Gagin and Gabriel (1987) are due to differences in definitions of the analyzed variables. However, the fact remains that B-Z88 obtained an entirely different result for seeded days in Israeli II than did Gagin and Neumann (1976), Gagin (1986), and Gagin and Gabriel (1987). Which result is correct, or are both correct? If there was a natural storm bias in the north target area on seeded days (i.e., a type I statistical error), as we concluded from our regional analyses (e.g., Fig. 17 in Rangno and Hobbs 1995), the frequency of heavier rainfalls *and* the duration of rain should have been greater on seeded days.

In view of the importance of any seeding effects on rainfall intensity and/or duration, we recommend that the recording rain gauge records for Israeli II be examined further in an effort to determine what happened on seeded and control days.

In the first sentence of the second paragraph of section 1 of Rangno and Hobbs (1995), we stated that the runoff analyses ''have generally been confined to local watersheds within the catchment region of Lake Kinneret.'' In fact, both Benjamini and Harpaz (1986) and Sharon (1990), two of the three studies we cited, examined runoffs from a wide area of the northern target, and BZ-88 examined only local watersheds. We noted the findings of Benjamini and Harpaz (1986) for the Lake Kinneret catchment region because the strongest seeding effects in daily rainfall in Israeli II appeared to be in that region (e.g., Gagin and Neumann 1981). Benjamini and Harpaz concluded, ''the fact that high runoff increments could not be identified, even in areas of reported high rainfall increases, calls for an explanation.'' We agree.

Finally, we note that none of the runoff analyses that have been published for Israeli II address whether the unusually heavy rainfall on control days in the south target area also produced runoff similar to that reported for the north target area by B-Z88 and Sharon (1990). If this were the case, it would be consistent with the findings of Gabriel and Rosenfeld (1990), who found that on days when the north target area was seeded, rain was significantly heavier than normal in the (unseeded) south target area. It would be consistent also with Rangno and Hobbs's (1995) findings of heavier rainfalls in Lebanon and Jordan on days when the north target area of Israeli II was seeded.

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