Comments on ''A New Look at the Israeli Cloud Seeding Experiments''

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Rangno and Hobbs (1995, hereafter RH95) note that for years many meteorologists believed that Israel I and Israel II were the only experiments providing confirmatory evidence of the ability of cloud seeding to stimulate rainfall and that Israeli winter clouds were seedable due to some unique characteristics, namely, a continental drop size distribution, with an attendant lack of a coalescence process, and a scarcity of natural ice crystals at temperatures above −15°C or so. RH95 provide convincing evidence that Israeli winter clouds sometimes produce drizzle or rain through coalescence and that significant ice particle concentrations exist in some of them at temperatures as high as −10°C. RH95 therefore conclude that they are ''not as conducive to rainfall enhancement by artificial seeding as previously believed.'' In doing so, RH95 mimic, albeit in a reverse sense, the scientists whose work they are criticizing. They judge the seedability of clouds in Israel with reference to a single, very simple concept of seedability and then allow that judgment to sway their interpretation of the Israeli statistical results.

The early descriptions of seedable orographic clouds (e.g., Mason 1971) concerned stratified orographic clouds with low cloud water concentrations and precipitation growth solely by the deposition of water vapor on ice crystals. They are inadequate for orographic clouds, including those in Israel, that contain embedded convective cells.

The presence of ice particles in a convective cloud does not guarantee absence of seedability. Substantial concentrations of supercooled cloud water can exist in the presence of ice particle concentrations of 10 or even 100 L^{-1}, provided that air is ascending to provide a fresh supply of condensate. The critical concept is one of production versus consumption of supercooled cloud liquid. Elementary calculations and many modeling results have shown that even very large amounts of graupel, snow, and smaller cloud ice particles cannot deplete all of the supercooled cloud liquid in a strong updraft (e.g., Cooper and Marwitz 1980; Orville and Chen 1982; Rauber and Grant 1986). One very noticeable microphysical effect in some model simulations is a rapid increase in graupel concentrations in updrafts as ice crystals formed around artificial (or natural) ice nuclei collide with supercooled raindrops formed by coalescence (Cotton 1972; Scott and Hobbs 1977). These graupel particles then rapidly sweep out the supercooled water. Microphysical effects change precipitation loading, and the rate and location of releases of latent heat, thereby affecting the dynamics of convective clouds (Orville and Chen 1982). Modeling studies show that the combined microphysical and dynamic effects can have a substantial influence, both positive and negative, on the timing and quantity of precipitation from convective clouds containing either or both natural ice particles and raindrops formed by coalescence.

Some model results even suggest that the temporary absence of significant amounts of supercooled liquid water does not disqualify a stratiform cloud from having cloud seeding potential (Orville et al. 1984, 1987). This has to do with the switch to saturation with respect to ice from saturation with respect to liquid and the attendant release of latent heat, which then stimulates updrafts and new condensation. To further confound the situation, Fritsch (1986) has argued that unfavorable seeding effects on individual clouds could be a positive contribution toward increasing rainfall from a mesoscale system.

Examination of the results of 10 years of winter cloud seeding in Santa Clara County, California, led Dennis and Kriege (1966) to conclude that seeding effects were limited to periods of convective instability and that the principal microphysical effect of seeding was the production of additional graupel particles in embedded convective cells. Elliott et al. (1971) seeded convective bands in a randomized experiment in Santa Barbara County, California, and found statistical evidence for increases of roughly 50% in band precipitation. They reported that, ''The effect was greatest in the case of the warmer and more unstable categories.'' In a more continental setting, Cooper and Marwitz (1980) found

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convective bands to be sites of substantial concentrations of supercooled cloud water over the San Juan Mountains of southwestern Colorado.

On the basis of the modeling studies and experimental data mentioned above, we believe that some Israeli winter clouds are seedable and that the statistical indications of rainfall increases obtained from Israel I *according to its original crossover design* should not be dismissed arbitrarily on the basis of the new microphysical data presented by RH95.

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