shift in convection during El Niño. The high values over Indonesia in October 1997 are related to biomass burning and the suppressed convection and change in dynamical transport in the region. The induced dry conditions over Indonesia during El Niño produced a large amount of uncontrolled wildfires. Recovery of the El Niño is seen for October 1998. The CCD data have also been used for studying seasonal and interannual variabilities in tropical tropospheric ozone to delineate the relative importance of biomass burning and large-scale transport (Ziemke and Chandra 1999).

4. Obtaining the data

The CCD, TCO, and SCO data may be obtained via the World Wide Web (http://hyperion.gsfc.nasa.gov/Data_services/Data.html) or direct ftp over the Internet: ftp jwocky.gsfc.nasa.gov; logon: anonymous; password: (your e-mail address); cd pub/ccd.

Because these are small datasets, the data can also be obtained via electronic mail from ziemke@jwocky.gsfc.nasa.gov

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Comments on "A Review of Cloud Seeding Experiments to Enhance Precipitation and Some New Prospects"

Bruintjes (1999, hereafter B99) has done a commendable job of providing a summary of recent developments in cloud seeding, the scope of present day commercial seeding programs, and pointing out some pitfalls that need to be avoided. This writer shares his cautious optimism about the future of cloud seeding, particularly due to the developments in hygroscopic seeding that he describes, with his caveat, "if we do not oversell."

However, some commentary beyond that supplied by B99 is required regarding two sets of cloud seeding experiments he describes. These are the experiments that took place in Israel, conducted by scientists at the Hebrew University of Jerusalem (HUJ) and those conducted at Climax, Colorado, by scientists at Colorado State University (CSU).

About the experiments in Israel, B99 states that "the original thought that clouds in Israel were continental in nature and that ice particle concentrations in these clouds were generally small for cloud tops warmer than −12°C with neither coalescence nor an ice multiplication process operating has also been questioned."

The cloud-top temperature above which the HUJ researchers reported low concentrations of ice crystals was −21°C, not −12°C as stated by B99. In fact, HUJ researchers claimed that *no* detectable ice formed in clouds with tops warmer than −14°C (e.g., Gagin and Neumann 1974; Gagin 1975, 1986). These claims gave wide credibility to the HUJ experimenters' statistical results suggesting that seeding had increased rainfall in the cloud-top temperature range of −12° to −21°C because few natural ice crystals, they claimed, formed in such clouds (e.g., Gagin and Neumann 1981). Also, the lack of seeding effects below cloud top temperatures of −21°C was because ice crystal concentrations in those clouds averaged 10 or more per liter (e.g., Gagin and Neumann 1981).

While B99 notes that the HUJ cloud reports have been questioned by Rangno and Hobbs (1995) and Levin (1992), he states that these measurements are "limited." On the contrary, Rangno (1988) used 10 seasons of rawinsonde data to infer that there were problems with the HUJ cloud reports: rain often fell from clouds with much higher top temperatures than could be accounted for by their reports. Further, the HUJ reports that ice concentrations of one per liter did not appear, on average, until cloud-top temperatures had reached −17°C, have been found to deviate substantially from a summary of ice-forming behavior in continental convective clouds around the world (Rangno and Hobbs 1988, 1995).

Further, Levin et al. (1996) provided additional information on the flight data gathered by Levin 1992, a study mentioned by B99. In only five days of sampling (six measurements) scattered over two winter months, Levin et al. (1996) found maximum ice particle concentrations of 60, 50, 300, 100, 20, and 50 per liter in clouds with tops "near" −10°, −6.5°, −13°, −10°, −11°, and −10°C, respectively. Recall that the HUJ researchers asserted over many years that ice did not form at all in clouds with these top temperatures. All of these concentrations except one are also higher than the maximum concentration reported in a cloud for *any* cloud-top temperature by the HUJ researchers.

While the Levin et al. (1996) sample can be considered small in the absolute sense, the implications are nevertheless mighty. The situation is analogous to a resort owner who has told tourists in his many brochures over the years that it has never rained at his resort in the winter. A tourist goes to this resort on five different days one winter and it rains on every day. How confident can we be that the resort owner made exaggerated claims about the good weather at his resort? The answer is obvious (cf. Brier and Panofsky 1965). When B99 inadvertently discounts such results as "limited," he misses their profundity.

Last, B99 makes no mention of perhaps the most astounding cloud seeding results yet in Israel, those from a recently reported third randomized experiment that consumed 18 years of seeding in central and southern Israel beginning in 1975. In this experiment, the seeded days averaged about 9% *less* rainfall than the control days (Rosenfeld 1998)! Cloud tops are, on average, lower and warmer in this region than in northern Israel (Gagin and Neumann 1974; Rangno and Hobbs 1995) making such negative results even more unexpected. It is probably fair to say that all of the disparate results have more than "somewhat" eroded the confidence in the HUJ cloud seeding experiments.

B99 also describes some conclusions about the CLIMAX (sic) experiments based on Rangno and Hobbs (1987, 1993). B99's description, however, was incomplete. While the *combined* result of the Climax I and II experiments was, as B99 reports, about 10% (Rangno and Hobbs 1987), our main conclusion was that Climax II had not replicated Climax I, a fact not mentioned by B99. This same important conclusion had been reached earlier by Rhea (1983). Replication, in particular, *independent replication,* is essential for the credibility of experimental results.

In fact, even the Climax I result, which contained the only statistically significant seeding results of the two experiments, is suspect. The reason for this is that when the results of Climax I are examined after the date the controls were selected by the experimenters, about midway through that experiment, no further seeding effects were observed (Grant and Mielke 1967; Rangno and Hobbs 1993). This inevitably raises the issue of whether "post-selection bias" (Dennis 1980)—"cherry-picking"—crept into the choices of control stations to show a seeding effect that the experimenters were sure was there. If the seeding effect is, in fact, illusory, and only the product of an extensive search, then it is extremely unlikely that it will be seen after the date the controls are chosen. This problem is analogous to a researcher finding historical climate "cycles" after a long search which then fail to appear in future data. This is what was observed in Climax I; a very large apparent seeding effect followed by no effect.

It should be pointed out, however, that the results of Rangno and Hobbs (1987, 1993) for the Climax experiments are based solely on the Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) cooperative recording gauge at Climax 2 NW. The data for this independently maintained recording gauge was reduced and published by employees of the National Climatic Data Center in Asheville, North Carolina, who of course had no knowledge of the random seeding decisions in the Climax experiments.

On the other hand, the researchers who conducted the Climax experiments have continued to claim, however, that a real seeding effect did fall on their own snowboards and gauges in these experiments (Mielke 1995)—while somehow avoiding the NOAA gauge located near the center of the target. This assertion by the experimenters, which cannot be independently verified, stresses the critical importance of having an independent collection *and archiving* of key data during cloud seeding experiments.

Further, the CSU researchers' claims of seeding effects in the Climax experiments are not backed by any viable evidence that the high 500-mb temperature stratifications in which they partitioned their seeding effects are related to any cloud microstructure property having great seeding potential. In fact, *unsuitable* conditions for ground seeding have been reported for the very stratification (high 500-mb temperatures) that they used on several occasions (e.g., Rangno 1979; Hobbs and Rangno 1979; Mielke 1979; Cooper and Marwitz 1980; Cooper and Saunders 1980; Rangno and Hobbs 1993). This was not mentioned by B99.

The same now appears to be true concerning the cloud microstructural foundation of the experiments in Israel.

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