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Reply to comment by Ben-Zvi, A., D. Rosenfeld and A. Givati on the paper: Levin, Z., N. Halfon and P. Alpert, "Reassessment of rain experiments and operations in Israel including synoptic considerations," Atmos. Res. 97, 513–525. DOI: 10.1016/j.atmosres.2010.06.011

Zev Levin [a,*], Noam Halfon [b], Pinhas Alpert [a]

[a] Department of Geophysics and Planetary Science, Tel Aviv University, Israel
[b] The Israel Meteorological Service, Beit Dagan, Israel

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ABSTRACT

Levin et al. (2010; hereafter LHA) (Levin, Z., Halfon, N., Alpert, P., 2010. Reassessment of rain experiments and operations in Israel including synoptic considerations. Atmos. Res. 97, 513–525. DOI:10.1016/j.atmosres.2010.06.011.), reanalyzed the results of the operational seeding in northern Israel between 1975 and 2007 and the preceding Israel 2 cloud seeding experiment (1969–1975) and concluded that there is no net increase in precipitation over the target areas. Our analysis revealed that a synoptic bias during Israel 2 is one of the reasons for the apparent positive effect of seeding in the northern target area and the negative effect in the southern area both of which disappeared in the following experiment in the south (Israel 3; 1975–1995) and the operational seeding in the north.

Ben-Zvi et al. (2010;hereafter BRG) criticized our paper primarily on the ground that we did not consider the positive results of Israel 1 experiment (1960–1967). It should be noted that in Israel 1 different seeding lines were used from those in both Israel 2 and the operational period. In addition, its raw data is not accessible anymore for reanalysis. Furthermore, Israel 2 had been designed as a confirmatory cross-over experiment to Israel 1 and failed to reproduce its promising results with double ratio (DR) of ~1.00, namely, zero rainfall enhancements. The same DR values were also found in Israel 3 and in the operational seeding. Therefore, because of the differences in the two experiments, the lack of access to the raw data and the disappointing results of the confirmatory experiment, we decided to concentrate our analysis on the more recent seeding activities.

The attempt by BRG to explain the reduction of the DR to ~1.00 in the operational seeding period by the suppression due to pollution have been disproved by Alpert et al. (2008, 2009) and also fail to explain the sharp decline of the target/control ratio right at the beginning of the operational seeding period when the lucky draw in this area came to its end (see LHA).

1. Introduction

Levin et al. (2010) reanalyzed the cloud seeding experiments and operations in the north of Israel and concluded that after 32 years of operational seeding there is no net increase in precipitation over the target areas. To emphasize this conclusion, Levin et al. (2010) (from here on LHA) examined the "interior (target)/coastal (control)" rainfall ratios during the seeded and unseeded days in the northern area of Israel 2 and compared it with an unseeded adjacent area to the south of it (called Center). The results show that the ratio in the Center-unseeded area was the same and even slightly larger than in the seeded area. This was explained in

* Corresponding author.
E-mail address: zevlev@post.tau.ac.il (Z. Levin).

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part by the fact that the daily synoptic conditions during the seeded days in northern Israel were in favor of rain in the interior and hilly regions inside and outside the seeded area. Obviously, the origins for the synoptic variations are independent of the seeding processes.

2. Major points

1) Ben-Zvi et al. (2010) (from here on BRG) argued that we have not included Israel 1 (years 1960–1967) in our analysis, a cross over designed experiment that reported positive results.
   We did not address the Israel 1 experiment because our research was intended to examine the efficacy of the operational cloud seeding in the north of Israel. As our earlier results revealed that the operational seeding did not enhance precipitation we decided to re-analyze Israel 2 experiment (years 1969–1975) because it is the only experiment with the exact seeding lines in the north that could be analyzed by the same methodology used in the operational seeding period. Furthermore, it is the claim of success of this experiment that led to the operational seeding that has been going on since 1975.
   It is important to stress that Israel 2 was designed as a confirmatory cross-over experiment to Israel 1, a point that we are in agreement with BRG. Since Israel 2 was a confirmatory experiment, and its results do not confirm Israel 1 at all, it is sufficient to conclude that at least in Israel, the effectiveness of the seeding methods has not been proven. This is especially true since the Double Ratio, DR, of ~1.00 (no seeding effect) was found not only in the cross over analysis of Israel 2 (see Gabriel and Rosenfeld 1990) but also in Israel 3 (Rosenfeld, 1998) and in the operational period (Kessler et al., 2006 and LHA). The unique high statistical significant results of Israel 1 mentioned by BRG, only raises serious questions about the disappearance of these high values in both Israel 2 and in the operational period.
   Kessler et al. (2006), who tried to analyze the unique promising results of Israel 1 discovered that the raw data and the methodology that was used for calculating the daily average in each of the sub-areas to be no longer accessible (see P.17: "*Attempts to obtain the source data that were used for calculating the daily average in each of the sub-areas were not successful. The explanation that we got from the people connected to it is that these data were backed up on computer tapes and it is difficult, if not impossible, to reproduce them*"). Two other independent analyses of Israel 1 experiment which were carried out in the past by Rangno and Hobbs (1995) and Brier et al. (1973) revealed that most of its significant positive cross-over results came from the central area where seeded days were much rainier than unseeded ones. These results cannot be attributed to positive seeding effect since even more significant positive results were found by Brier et al. (1973) far beyond the central target area in Trans–Jordan (see also Fig. 14 in Rangno and Hobbs, 1995).
   It is worth noting also that in trying to explain the negative–neutral results in central Israel in Israel 2 and 3, Rosenfeld and Farbstein (1992) and Rosenfeld (1998) argued that "natural seeding" (abundance of dust particles) is sufficient so that additional artificial seeding has no positive effect. In view of these arguments, the only reasonable explanation for the significant results of Israel 1 is the conclusion of Rangno and Hobbs (1995) that the reported positive results are due to "type 1 statistical error" in which positive results are obtained by chance only. For all these reasons we decided to concentrate our analysis on the more recent seeding activities.
2) In our paper we pointed out that one of the reasons for the 15% decrease in precipitation amounts in the center and an equivalent increase in the north are differences in the synoptic conditions between seeded days in both areas. Using the semi-objective classification of the synoptic systems (Alpert et al., 2004) for the first time for seeding analysis, we found that seeded days in the north were characterized by deeper lows and the associated stronger winds at 850 hPa. For this reason during the seeded days in northern Israel the clouds moved more efficiently eastward to the hilly target producing enhanced orographic rainfall in the northern target area and far beyond it. Also, orographic rainfall exponentially increases with the 850 hPa wind speeds (Alpert and Shafir, 1991). In fact, most of the rain in Israel comes from convective clouds in which rain intensity varies rapidly in space and time. Such rainfall events are affected by interactions of both micro and meso scales that are difficult to monitor and cannot be highly correlated with, synoptic scale variables. For instance, Halfon (2008) showed that the correlation between coastal/hilly rainfall ratios and many synoptic variables in Israel reaches no more than 0.5. Even when multi-regression analysis with 20 synoptic variables at different pressure levels that was carried out on 420 rain events, only about 43% of the variance could be explained. This means that sometimes the hilly (target)/coastal (control) rainfall ratio can be much lower than expected by the synoptic analysis and sometimes it can be higher (as apparently happened in Israel 2). Any attempt as done by BRG, to resolve the synoptic effects on seeded and unseeded events to the accuracy of a single digit percentage is unrealistic and assumes correlation with zero variance between the synoptic conditions and the distribution of rain. If indeed one could be so accurate and able to separate the effects of seeding in the north to 5% due to synoptic bias and 8% due to seeding, then this rule should also apply to the decrease in rainfall in central Israel, since the two regions are both parts of the same cross-over equation. In this case, with the same reasoning, based on BRG, out of the 15% decrease in rainfall in central Israel (Gabriel and Rosenfeld, 1990 found a DR of 0.85 in the center, when they separated the analysis of the north from the center) 6% is due to the same synoptic bias and the rest (9%) are due to negative effects of seeding. This conclusion contradicts the results of Israel 3 that showed no effects at all due to seeding. Therefore, any attempts to claim that the negative results in the center are *all* due to bias and the positive effects (with the same magnitude) in the north are only *partly* due to the same bias are contradictory.
3) BRG argue that relying on historical rainfall ratios of unseeded days for computing DR values is not valid and make reference to the papers by Givati and Rosenfeld (2004, 2005) in which they suggested that aerosol pollution is responsible for a steady decrease in orographic rainfall ratio in Israel. In Fig. 4, LHA presented the ratios of target/control of equal segments of rainfall amounts from 1949 to 2007. This resulted in

overlap between parts of the historical period and the period of seeding. It can be seen that already in the first 3 years of operational seeding (1975–1978) the target/control rainfall ratio in the target area dropped to below the pre-seeding period. This means that DR results for this early periods drop below 1.00 when seeded days are compared to unseeded ones just less than 10 years prior (certainly this cannot be considered as "historical" data). This sharp decrease in the rainfall ratios cannot be attributed to a steady decay of orographic rainfall, but only to the fact that the lucky draw of the seeding days in the north ended at around the end of Israel 2 seeding experiment.

4) BRG assume that the decrease of the DR values to 1.00 in the operational period is not an evidence for the inefficiency of seeding but a result of two opposing factors (suppression of rain by pollution and enhancement by seeding) that in some magic way, perfectly neutralize each other. This assumption has been shown wrong by Alpert et al. (2008). See also Halfon et al. (2009) and further correspondence by Alpert et al. (2009). In the reply of Alpert et al. (2009) to the comment of Givati and Rosenfeld (2009), they demonstrated that all the results presented by Givati and Rosenfeld in their comments show no decrease in the ratio of rainfall on the "upwind slopes/coastal" rainfall, which is the essence of the pollution suppression theory.

3. Some minor points

BRG claim that we misquoted Kessler et al. (2006). In fact in the paper we never had a direct quote from Kessler et al. However, to set the record straight, on page 80 of their report Kessler et al. write (our own translation to English — in italics): "*The most general and most important conclusion is that the effectiveness of cloud seeding is still not proven beyond doubt. Question marks still exist about the effects of seeding on rainfall amounts (range of values of rain rates and spatial distribution), on the method of calculating the seeding efficiency (regression versus DR) and changes in time (climatic changes, air pollution etc.*). *The uncertainty that exists regarding the additional rainfall amounts are sufficient to put in doubt any attempt to estimate the additional water supplies into the Sea of Galilee* (the main catchment basis of Israel-LHA)" We fully agree with Kessler's et al. conclusions.

Furthermore, BRG chose to quote from Kessler et al. pages 80–81, but missed the first sentence: "*About the specific conclusions, different results were obtained in two independent statistical models*." This is another indication that confirms that there is no proof of positive effects of seeding on rainfall amounts, as claimed by BRG and by Givati and Rosenfeld (2004, 2005).

In the comment BRG mention a paper by Givati et al. (2010). We have no access to this paper since it is under review; however, we agree that it is advisable to use a good 3D model that simulates the atmospheric processes and includes detailed bin cloud microphysical processes, topography, and different synoptic scenarios that mimic the real conditions. In addition, we hope that in their simulations the authors will evaluate the effectiveness of the method of cloud seeding by airplane flying along a constant line, as it is done in Israel. This method of seeding has been shown by Levin et al. (1997) to be ineffective because most particles are washed by the rain and the few surviving ones, do not reach the proper levels in the clouds to affect ice formation in them.

4. Summary

BRG criticized our paper on the primary ground that we did not consider the positive results of Israel 1 experiment which differs in its seeding lines from both Israel 2 and the operational period and is not accessible anymore for reanalysis.

Since Israel 2 had been designed as a confirmatory cross-over experiment to Israel 1 and failed to reproduce its promising results, when the cross-over DR value dropped to below 1.00, we found those promising results that disappeared less relevant. DR Values of ~1.00 were found not only in Israel 2 experiment but also in Israel 3 and in the operational seeding. The unique high DR values of Israel 1 experiment that extended far beyond the target area (e.g. Rangno and Hobbs, 1995) and totally disappeared in Israel 2 were examined earlier when data was still accessible and were explained as error type 1, namely a bias or a lucky draw of seeded days.

BRG claim that synoptic bias can explain only part of the results of the seeding in Israel 2. If this is correct than the negative results of the seeding in the south (center) (see Gabriel and Rosenfeld, 1990) are not due to simple bias but are negative effects of seeding. This contradicts Israel 3 results which found no effect of seeding in this area (Rosenfeld, 1998).

The attempt to explain the reduction of the DR to ~1.00 in the operational seeding period by the suppression due to pollution have been disproved by Alpert et al. (2008; 2009) and also fail to explain the sharp decline of the target/control ratio right at the beginning of the operational seeding period when the lucky draw in this area came to its end.

References

Alpert, P., Shafir, H., 1991. On the role of the wind vector interaction with high-resolution topography in orographic rainfall modelling. Q. J. R. Meteorol. Soc. 117, 421–426 1991.

Alpert, P., Osetinsky, I., Ziv, B., Shafir, H., 2004. Semi-objective classification for daily synoptic systems: application to the eastern Mediterranean climate change. Int. J. Climatol. 24, 1001–1011.

Alpert, P., Halfon, N., Levin, Z., 2008. Does air pollution really suppress precipitation in Israel? J. Appl. Meteorol. Climatol. 47, 933–943.

Alpert, P., Halfon, N., Levin, Z., 2009. Reply to comment by A. Givati and D. Rosenfeld on the paper by Alpert, P., N. Halfon and Z. Levin: Does air pollution really suppress precipitation in Israel? J. Appl. Meteorol. Climatol. 48 (8), 1733–1746.

Ben-Zvi, A., Rosenfeld, D., Givati, A., 2010. Comments on "Reassessment of rain experiments and operations in Israel including synoptic considerations" by Z. Levin, N. Halfon and P. Alpert (Atmos. Res. This issue).

Brier, G.W., Grant, L.O., Mielke Jr., P.W., 1973. An Evaluation of the Extended Area Effects from Attempts to Modify Local Clouds and Cloud Systems. *Proc. WMO/IAMAS Scien. Conf. On Weather Modifictaion*, Switzerland. World Meteorological Org, Geneva, pp. 439–447.

Gabriel, K.R., Rosenfeld, D., 1990. The second Israeli rainfall stimulation experiment: analysis of precipitation on both targets. J. Appl. Meteorol. 29, 1055–1067.

Givati, A., Rosenfeld, D., 2004. Quantifying precipitation suppression due to air pollution. J. Appl. Meteorol. 43, 1038–1056.

Givati, A., Rosenfeld, D., 2005. Separation between cloud-seeding and air-pollution effects. J. Appl. Meteorol. 44, 1298–1314.

Givati, A., Rosenfeld, D., 2009. Comments on "Does air pollution really suppress precipitation in Israel?" by Alpert et al. J. Appl. Meteorol. Climatol. 48, 1733–1750 doi:10.1175/2009JAMC1902.1.

Givati, A., Lynn, B., Liu, Y., Rimmer, A., 2010. Coupling High-resolution WRF with a Hydrological Model for Operational Prediction of Jordan River Stream Flow. J. Applied Meteor. and Climate, In Review.

Halfon, N., 2008. Spatial Patterns of Precipitation in Israel and Their Synoptic Characteristics. PhD. Thesis, Dept. of Geography, University of Haifa, Israel, 185 pp.

Halfon, N., Levin, Z., Alpert, P., 2009. Temporal rainfall fluctuations in Israel and their possible link to urban and air pollution effects. Environ. Res. Lett. doi:10.1088/1748-9326/4/2/025001, 4.

Kessler, A., Cohen, A., Sharon, D., 2006. Analysis of the Enhancement Effect of Cloud Seeding in Northern Israel. Report to the Israel Water Commission by Environmental & Water Resources Engineering Co. Haifa, Israel, p. 117 (in Hebrew).

Levin, Z., Krichak, S.O., Reisin, T., 1997. Numerical simulation of dispersal of inert seeding material in israel using a three-dimensional mesoscale model. J. Appl. Meteorol. 36, 474–484.

Levin, Z., Halfon, N., Alpert, P., 2010. Reassessment of rain experiments and operations in Israel including synoptic considerations. Atmos. Res. 97, 513–525 doi:10.1016/j.atmosres.2010.06.011.

Rangno, A.L., Hobbs, P.V., 1995. A new look at the Israeli cloud seeding experiments. J. Appl. Meteorol. 34, 1169–1193.

Rosenfeld, D., 1998. The Third Israeli Randomized Cloud Seeding Experiment in the South: Evolution of the Result and Review of All Three Experiment. Preprints, *Conf. on Cloud Physics and 14th Conf. on Planned and Inadvertent Weather Modification*. Amer. Meteor. Soc, Everett, WA, pp. 565–568.

Rosenfeld, D., Farbstein, H., 1992. Possible influence of desert dust on seedability of clouds in Israel. J. Appl. Meteorol. 31, 722–731.