On the effects of pollution on precipitation in Israel

Zev Levin

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• The effects of aerosols on clouds have been studied for many years
• The role of aerosols in warm cloud formation is fairly well understood
• The role of ice in mixed phase clouds is less clear
• Ice formation in clouds remains a partial mystery
• The role of aerosols on precipitation is much more complex due to the various factors affecting precipitation.
• There is a long chain of processes and feedbacks leading to precipitation, which are not well understood
Aerosol Pollution Impact on Precipitation: A Scientific Review

Zev Levin, Chairman
William Cotton, Vice Chairman

Approved by the WMO - May. 2007
There were:

• 13 Lead Authors
• 27 Contributors
• 17 Reviewers
Effects of pollution on small warm clouds

Garrett and Hobbs [1995].

![Graph showing the effect of pollution on small warm clouds](image)
Impact of pollution on precipitation in urban environment (METROMEX)

Five year moving averages and time trend of Centerville (downwind of St. Louis) summer rainfall, 1941-1968. From Changnon et al. (1971).
The re-distribution of precipitation is in agreement with observations in Atlanta and in other urban regions.

CLEAN - POLLUTED accumulated surface precipitation.

Solid lines represent (-) pollution suppressing precipitation; 
Dash lines represent (+) the opposite. Contour interval is 5mm starting from 1 mm.
Most of the published results on the effects of pollution on precipitation relate to summer storms.

What about winter cyclonic storms, like the ones reaching the eastern Mediterranean that are the major water suppliers for many countries?
The eastern Mediterranean is affected by storms that interact with pollution (local and long distance) and by dust.
Interaction of a Dust storm with clouds – 28 January, 2003

1 – possible clouds without dust
2,3 – possible regions of interactions of dust and clouds

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Pollution interacting with dust particles

Sulfate coating on dust particles

Sea salt on dust particles

Levin et al, JAM, 1996

Levin et al, JRG, 2005
<table>
<thead>
<tr>
<th>Date</th>
<th>Altitude (ft)</th>
<th>Temperature (°C)</th>
<th>Max. drop conc. (cm⁻³) with diameter 2–47 μm</th>
<th>Max. ice crystal conc. (L⁻¹)</th>
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<tbody>
<tr>
<td>3 January 1990</td>
<td>13 500</td>
<td>−10</td>
<td>200</td>
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<td>(cloud B)</td>
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<td>3 January 1990</td>
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<td>6 February 1990</td>
<td>12 000</td>
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<td>8 January 1990</td>
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<td>−10</td>
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<td>(cloud A)</td>
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Levin et al, JAM, 1996
<table>
<thead>
<tr>
<th>Warm processes</th>
<th>Cold processes</th>
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</thead>
<tbody>
<tr>
<td>nucleation of CCN</td>
<td>drop freezing</td>
</tr>
<tr>
<td>condensation and evaporation</td>
<td>ice nucleation (Meyers et al, 1992)</td>
</tr>
<tr>
<td>collision-coalescence of drops</td>
<td>ice multiplication</td>
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<tr>
<td>Breakup (Low and List)</td>
<td>deposition and sublimation of ice</td>
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<td>riming</td>
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<td>melting of ice particles</td>
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<td>sedimentation of both drops and ice particles</td>
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<td></td>
<td>Aggregation of ice crystals</td>
</tr>
</tbody>
</table>

* Teller and Levin, ACP, 2005
The combined effect of GCCN and IN on total precipitation

Teller and Levin, ACP, 2005

From Deserts to Monsoons-Crete 2008
Zev Levin
Orographic precipitation

Orographic clouds can amplify precipitation over that which occurs for the prevailing weather systems over flat terrain.

Analysis of past data and modeling studies suggest that orographic clouds in some places are susceptible to modification of precipitation by pollution owing to:

– the modest liquid water contents in them
– the relatively short time the drops and ice crystals spend in the clouds
The effects of pollution on rainfall in the Sierra Nevada Mountains in California and in Israel.

Givati and Rosenfeld, 2004
Re-analysis of orographic ratio in Israel

Alpert, Halfon and Levin, JAMC, 2008
Precipitation ratio between the rainfall over the western slopes of Samaria mountains and coastal stations in the greater Tel Aviv area

\[ y = 0.006x + 1.088 \]

\[ R^2 = 0.176 \]

\[ p = 0.007 \]
Example of Trend analysis in annual precipitation in two stations in central Israel

**Trend analysis for Ben Shemen**
- Ending / Starting ratio = 566/466 = 1.26
- Regression equation: $y = -2969.5 + 1.781x$, $R = 0.21$, $P = 0.09$

**Trend analysis for Qiryat Anavim**
- Ending / Starting ratio = 681/735 = 1.08
- Regression equation: $y = -1253.5 + 1.001x$, $R = 0.09$, $P = 0.12$
The RATIO of annual precipitation between upslope and seashore stations in central Israel

\[ y = 0.006x + 1.088 \]

\[ R^2 = 0.176 \]

\[ p = 0.007 \]
The linkage between urban pollution and orographic rain in Israel

Rainfall temporal change 1952-2006

Topographic map of Israel

Alpert, Halfon and Levin, JAMC, 2008

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Examples of cross sections downwind of the two major urban centers in Israel

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Alpert, Halfon and Levin, JAMC, 2008
The northern cross section: differences between theory and observed rainfall values

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From Deserts to Monsoons-Crete 2008

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The graph shows the comparison of rainfall changes along the study period with topographic height. The lines indicate:
- Pink: rainfall temporal change - observed
- Blue: rainfall temporal change in theory
- Black: smooth topographic height
Results showing no apparent effect of pollution on precipitation

Alpert, Halfon and Levin, JAMC, 2008
The central cross section: differences between theory and observed rainfall values

rainfall change along the study period

longitudinal (km)

rainfall temporal change - observed
rainfall temporal change in theory
smooth topographic height

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Effects of cloud seeding

- Israel I 1961-1967 reported increases of 15% as compared to the Central part of Israel
- Israel II 1969-1975 Increase of about 12% as compared to the control on the coast
- Israel III (only in the South) no effects.

The hypothesis was that the clouds need more ice. But measurements we performed in the 1980’s and 1990 showed that the clouds contain abundance of ice (Levin et al, JAM, 1996)
Mean wind direction 245°

Rainfall ratio trends between the eastern Galilee and its upwind coastal plain

Givati and Rosenfeld, (2005) selection of stations and their results

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From Deserts to Monsoons-Crete 2008
Rainfall ratio trends between the eastern Galilee and its upwind coastal plain

Our selection of stations and results

Mean wind direction 245°

Halfon, Levin and Alpert, In preparation for JAMC, 2008
Recent re-evaluation by Kessler et al

• Showed-- on the average no effects.
• Stratifying the data based on <15 mm/day and >15 mm/day showed:
  – Increase of about 25% on days with <15 mm/day
  – Decreases by 10% on days with >15 mm/day
• However, about 70% of the rain in the target area is from days with >15 mm/day
• About 25% from days of <15 mm/day
– The average rain in the north is about 700 mm/yr.
– This means about 175 mm from <15 mm/yr
– About 490 mm/day from >15 mm/yr

– In other words, the **added water** from days with <15 is about **40 mm/yr**
– The **decrease** of rain from days >15 is about **50 mm/yr**

– Therefore the **net effect** is either a decrease in rainfall or no effect at all.

– **Conclusion**: If it is economical worthwhile, seed only on days with <15 mm/day
Conclusions

1) Orographic rain suppression in Israel due to pollution does not occur.
2) Although the effects of aerosols on cloud and precipitation cannot be ruled out, the urban effects and changes in synoptic conditions are stronger and more important.
3) The compensation effects on the lee side of the mountain has not been seen. In contrast a decrease in rainfall is observed in this areas.
4) The effects of cloud seeding in the target area in the north of Israel shows a decrease on seeded days.
5) It is possible that the decrease in rainfall on seeded days occur mainly on days with rain amounts of >15 mm/day.
A biblical example of how aerosols affect rainfall

Exodus, Ch. 9 (8-23)

- 9:8 And the LORD said unto Moses and unto Aaron, Take to you handful of ashes of the furnace, and let Moses sprinkle it toward the heaven in the sight of Pharaoh.

- 9:9 And it shall become small dust in all the land of Egypt, and shall be a boil breaking forth with blains upon man, and upon beast, throughout all the land of Egypt.

- 9:10 And they took ashes of the furnace, and stood before Pharaoh; and Moses sprinkled it up toward heaven; and it became a boil breaking forth with blains upon man, and upon beast.

- 9:18 Behold, tomorrow about this time I will cause it to rain a very grievous hail, such as hath not been in Egypt since the foundation thereof even until now.

- 9:23 And Moses stretched forth his rod toward heaven: and the LORD sent thunder and hail, and the fire ran along upon the ground; and the LORD rained hail upon the land of Egypt.
Acknowledgement

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Thank you