Past and Future of cloud seeding experiments in Israel

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The WMO guidelines for experiments and operations:

For cloud seeding to be accepted as a viable source of rainwater three main things have to be fulfilled:

- There should be a proven physical hypothesis that seeding is affecting clouds and precipitation development

- There should be separation between experimental designers, operators, and independent evaluators of the statistical results.

- There should be evidence for increased water on the ground.

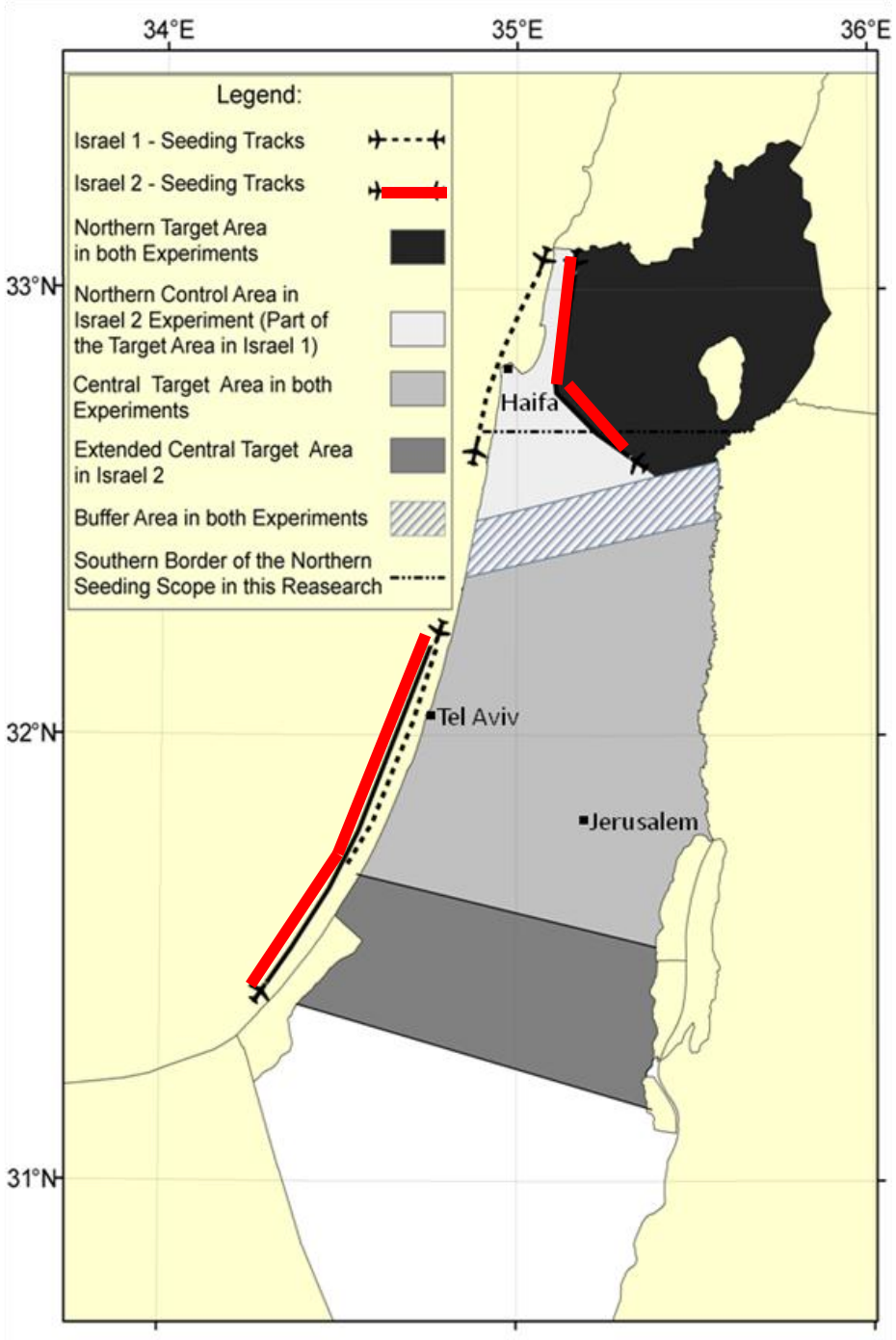
Historical perspective of the first two Israeli experiments

For many years the Israeli cloud seeding experiments were considered a unique success story:

1. **The hypothesis: the clouds are convective continental and thus should respond to seeding.**
2. **Some statistical results indicated that seeding succeeded in increasing rainfall.**
3. **There was some supporting evidence of increased water on the ground.**

• **However**, since the mid 1990s the validity of the physical hypothesis have been questioned (***Levin et al 1996; Hobbs and Rangno 1997 etc.***) and even the statistical evaluation of Israel 1 and 2 have been challenged (***Kessler 2005; Levin et al 2010***).

• In spite of these questions, an operational cloud seeding was initiated immediately after the termination of the Israel 2 and it has been going on continuously since 1975.



the seeding lines used during Israel 1, 2 and the operational period.

Note that seeding lines in Israel 1 are different from the rest.

A recent example of the re-evaluation of the Israeli cloud seeding experiments

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Reassessment of rain enhancement experiments and operations in Israel including synoptic considerations

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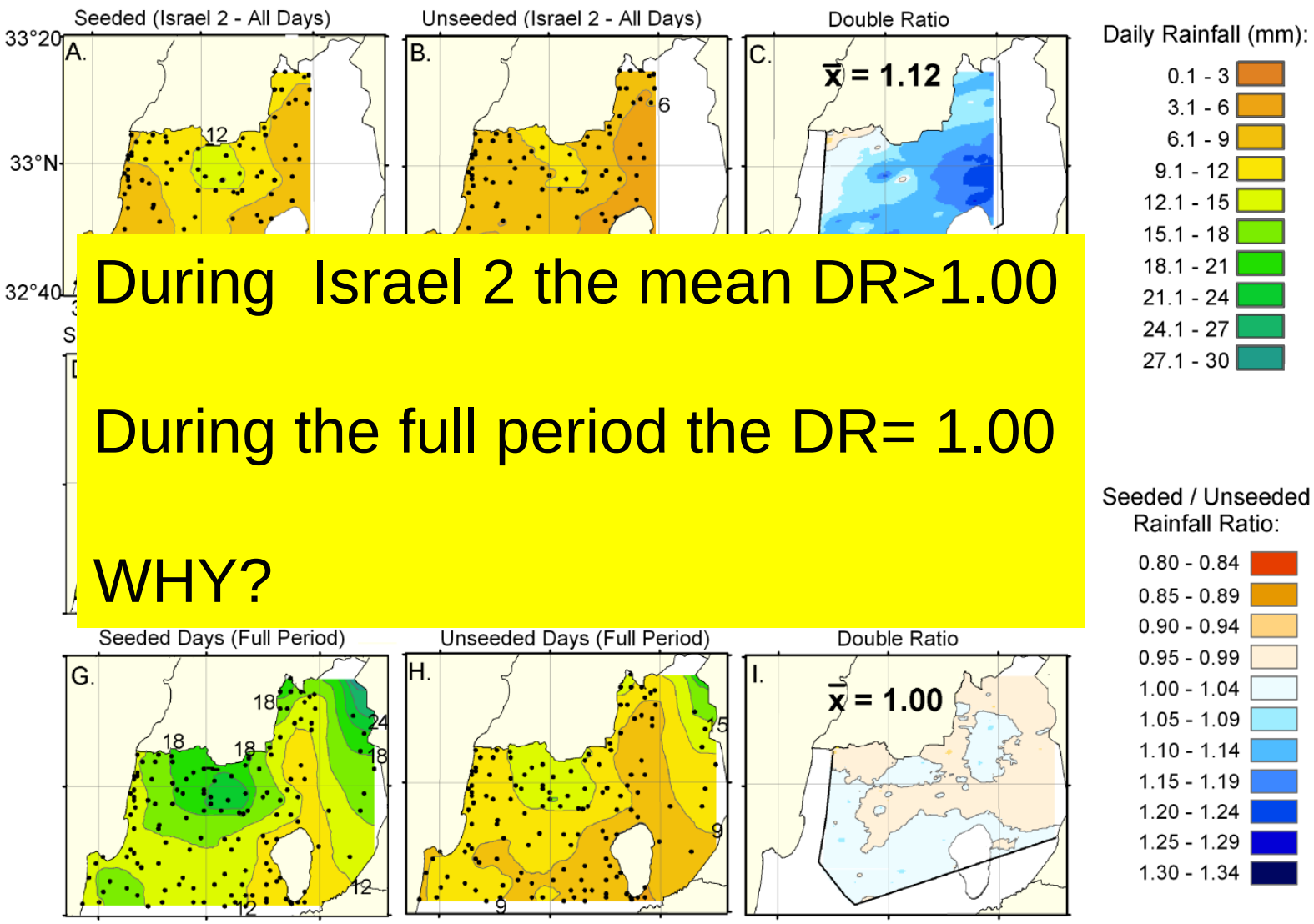
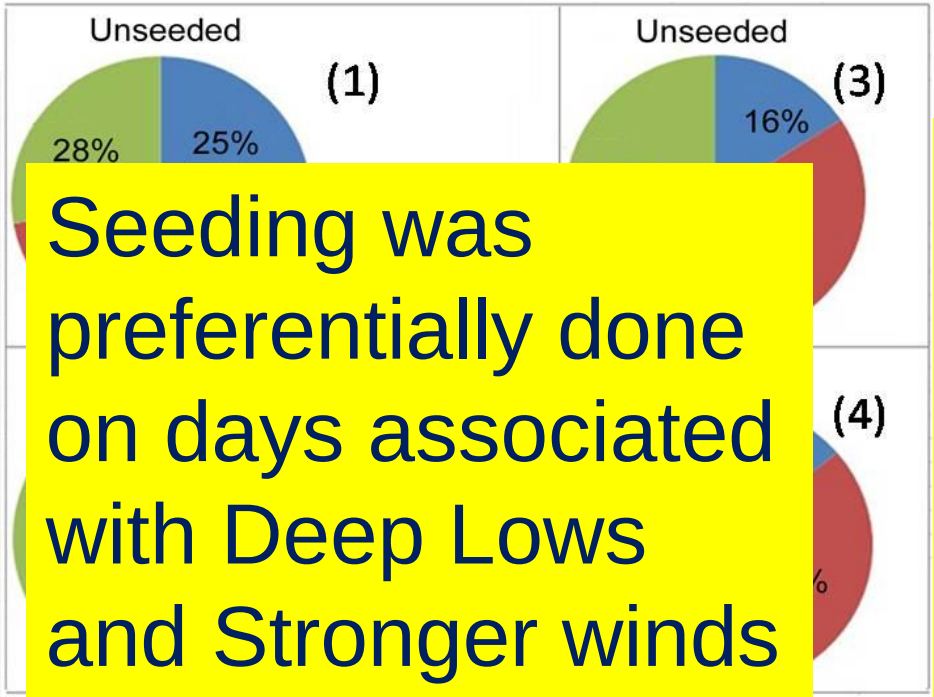
The average daily rainfall on seeded (A, D, G) and unseeded (B, E, H) days. The Double Ratios are shown in (C,F,I).



Frequency distributions of the Synoptic conditions during

"Israel 2" **"full period" (1950-2007)**

A.



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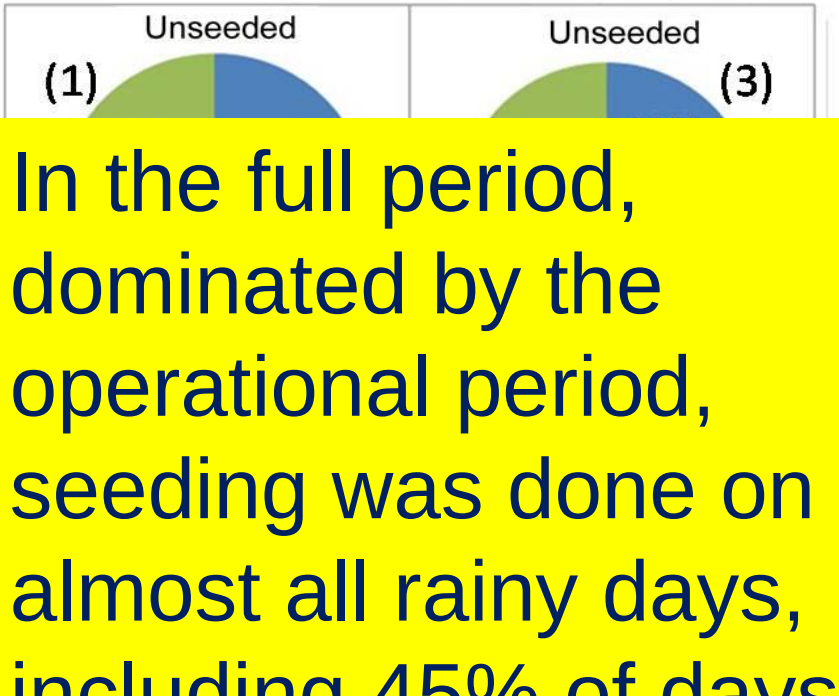


Seeding was preferentially done on days associated with Deep Lows and Stronger winds

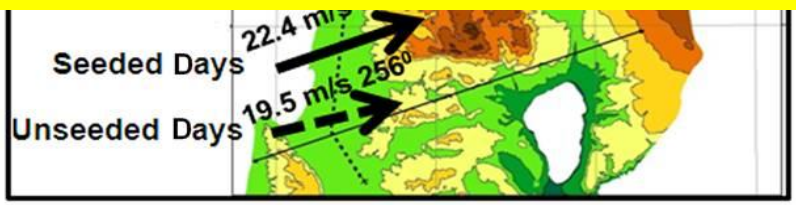
In the full period, dominated by the operational period, seeding was done on almost all rainy days, including 45% of days with Shallow Lows, leading to DR~1.00

C.

	Israel - 2	Full Period
Weighted Mean	22.5 m/s 250° → 19.3 m/s 256°	22.0 m/s 252° → 20.1 m/s 250°
Regular Mean	19.2 m/s 256° → 15.9 m/s 258°	19.0 m/s 250° → 16.4 m/s 255°
Seeded Days →	Unseeded Days --→	

Stronger winds on seeded days

D.



Microphysical evidence that the convective clouds over the Galilee are not suitable for extensive cloud seeding

TABLE 3. Measurements of drop concentrations at cloud bases in Israel.

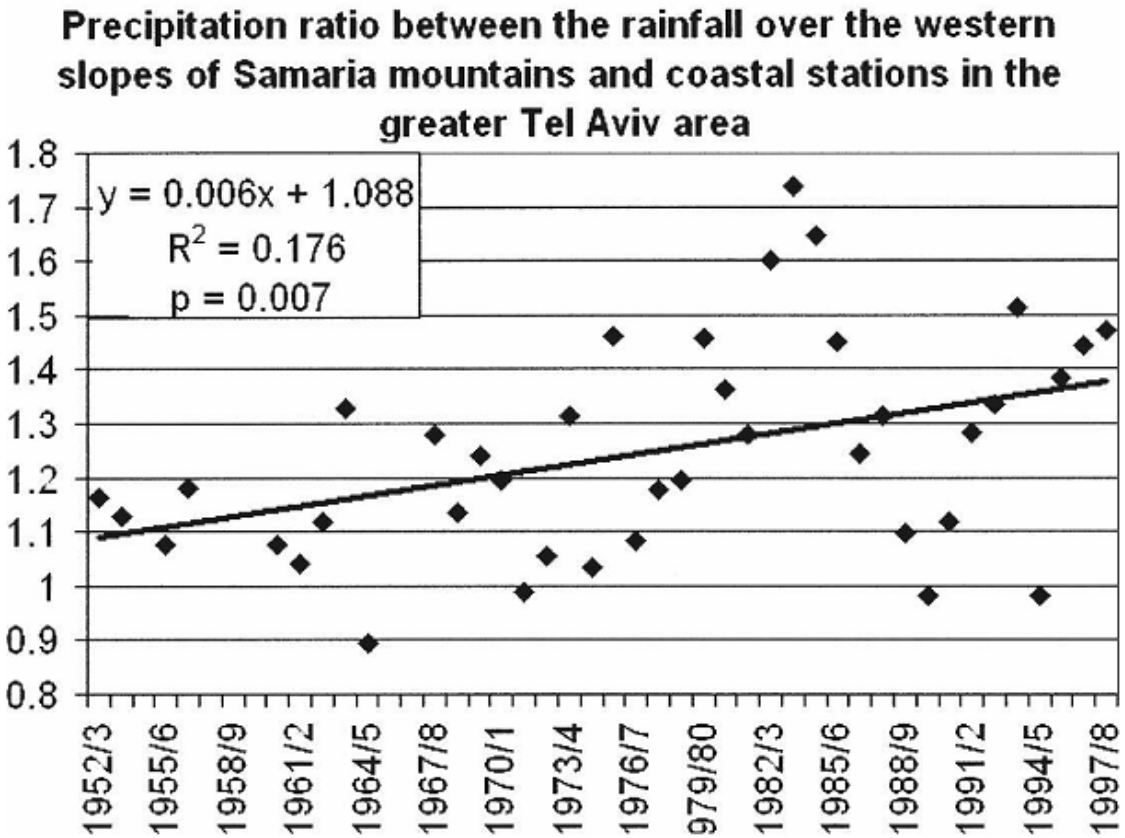
Date (cloud No.)	Altitude (ft)	Temperature (°C)	Max. drop conc. (cm^{-3}) with diameter 2–47 μm	Max. drop conc. (cm^{-3}) with diameter 20–47 μm
3 January 1990 (cloud D)	5000	4	70	2
3 January 1990 (cloud E)	5000	0	80	0.1
6 February 1990 (cloud A)	3000	5	100	0.4
6 February 1990 (cloud E)	3000	7	500	8
6 March 1990 (cloud A)	3500	5	500	10
6 March 1990 (cloud A)	3500	6.5	400	8
22 February 1995 (cloud A)	3000	3.5	170	0.3
22 February 1995 (cloud C)	3500	10	254	0.7
3 March 1995 (cloud A)	4000	3.8	291	2.7
3 March 1995 (cloud B)	4000	3.5	236	0.3
3 April 1995 (cloud A)	4000	4.7	560	1.5
3 April 1995 (cloud B)	3880	4.2	525	5.8
3 April 1995 (cloud D)	4400	3.6	557	7.9
3 April 1995 (cloud J)	5000	2	740	21
3 April 1995 (cloud M)	4800	3.9	638	130

TABLE 4. Measurements of drops and ice crystal concentrations near cloud tops in Israel. Only crystals larger than 90 μm were counted.

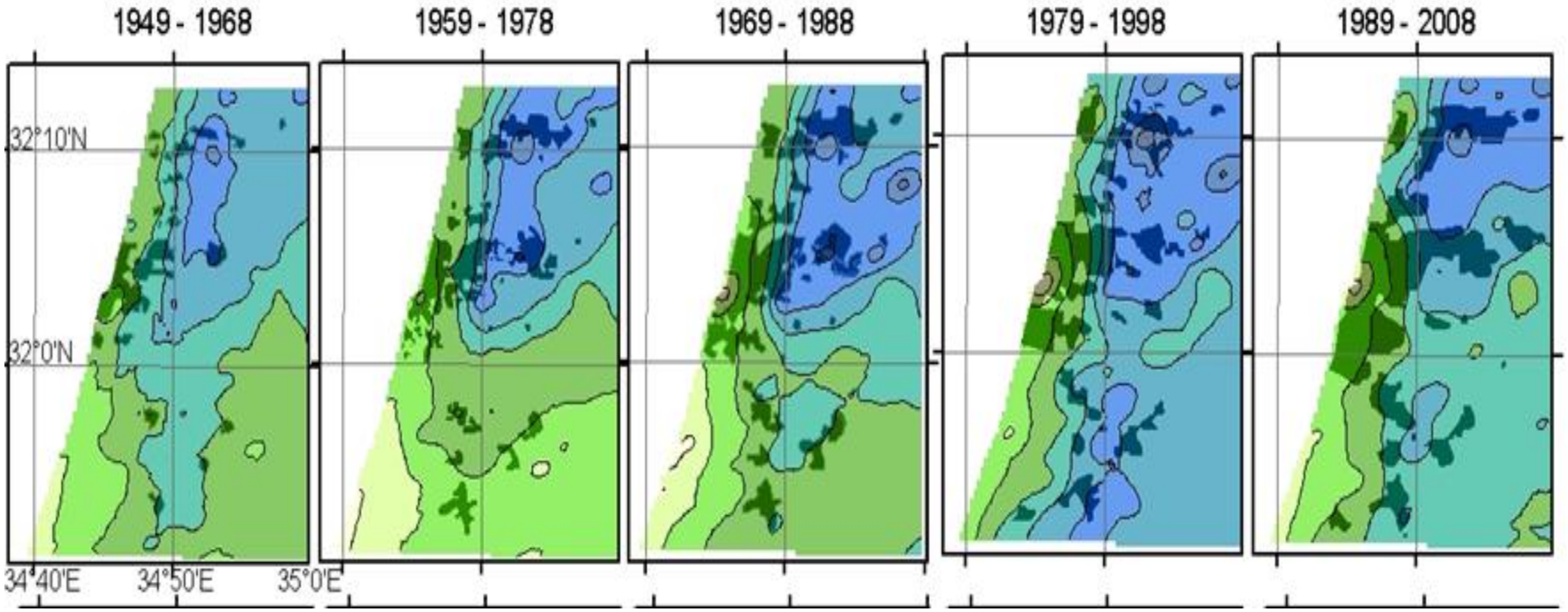
Date (cloud No.)	Altitude (ft)	Temperature (°C)	Max. drop conc. (cm^{-3}) with diameter 2–47 μm	Max. ice crystal conc. (L^{-1})
3 January 1990 (cloud B)	13 500	−10	200	60
3 January 1990 (cloud C)	12 000	−6.5	450	50
1 February 1990 (cloud C)	14 000	−13	200	300
1 February 1990 (cloud D)	12 000	−10	400	100
6 February 1990 (cloud C)	12 000	−11	500	20
8 January 1990 (cloud A)	9500	−10	300	50

It has been suggested that urban air pollution reduces the effects of cloud seeding due to the increased concentrations of condensation nuclei from urban sources *(Givati and Rosenfeld, 2005)*

Our results *(Alpert, Halfon and Levin, 2008)* do not support this claim, at least not for Israel.



Urban development effects on winter precipitation in Israel



Rainfall (mm):

451 - 475	551 - 575	651 - 675
476 - 500	576 - 600	676 - 700
501 - 525	601 - 625	
526 - 550	626 - 650	

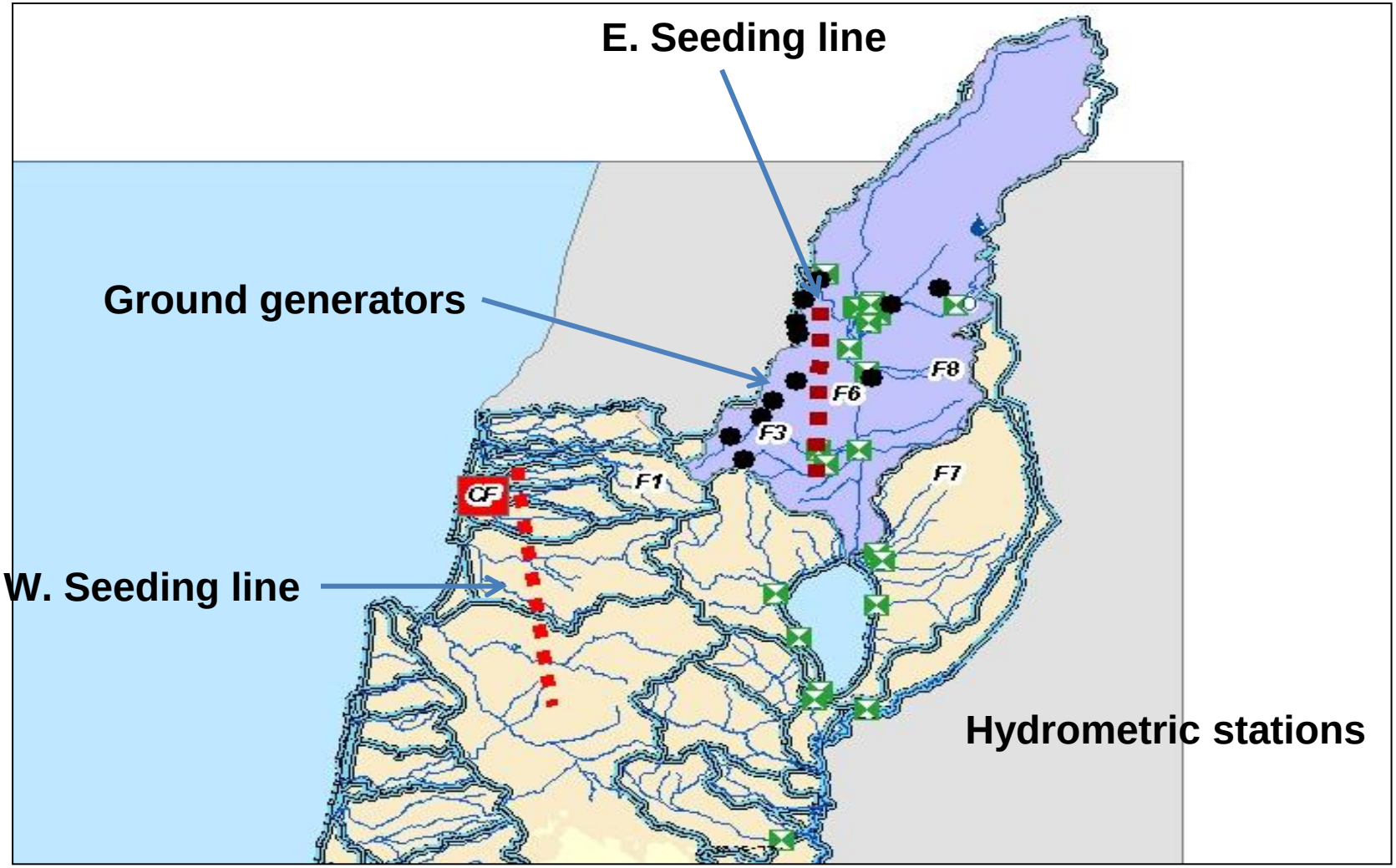
Conclusions from past experiments

- In Israel, the convective cloud seeding experiment and operations have not produced the expected rain enhancement and the original hypothesis has been refuted.

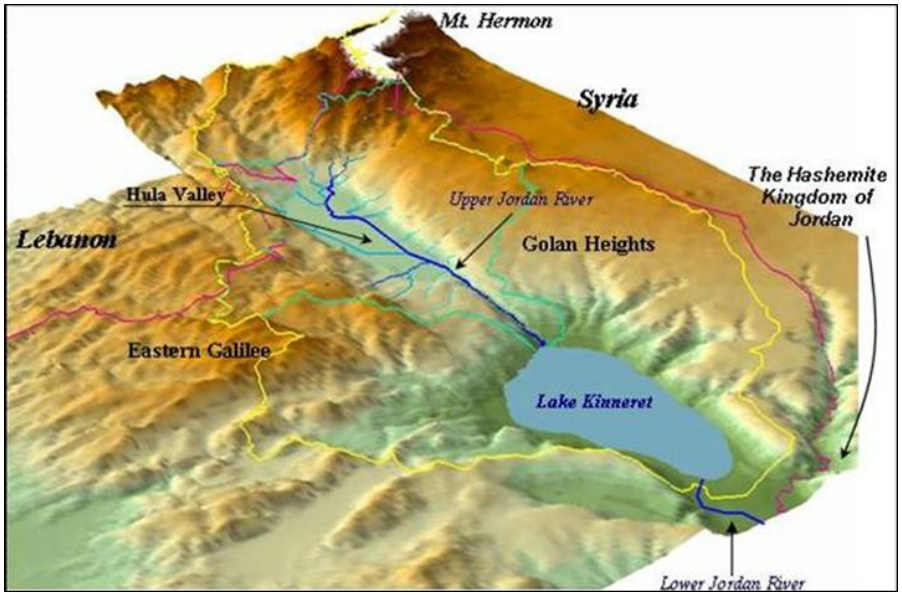
- However, the experiment did suggested that seeding clouds that develop under conditions of DEEP LOWS could produce some positive results– ***indicating that dynamics plays a crucial role in the success of cloud seeding.***

- The fact that the values of the DR were higher in the eastern part of the country suggests that orographic enhancement could have played a role in this enhancement.

Israel 4 cloud seeding experiment

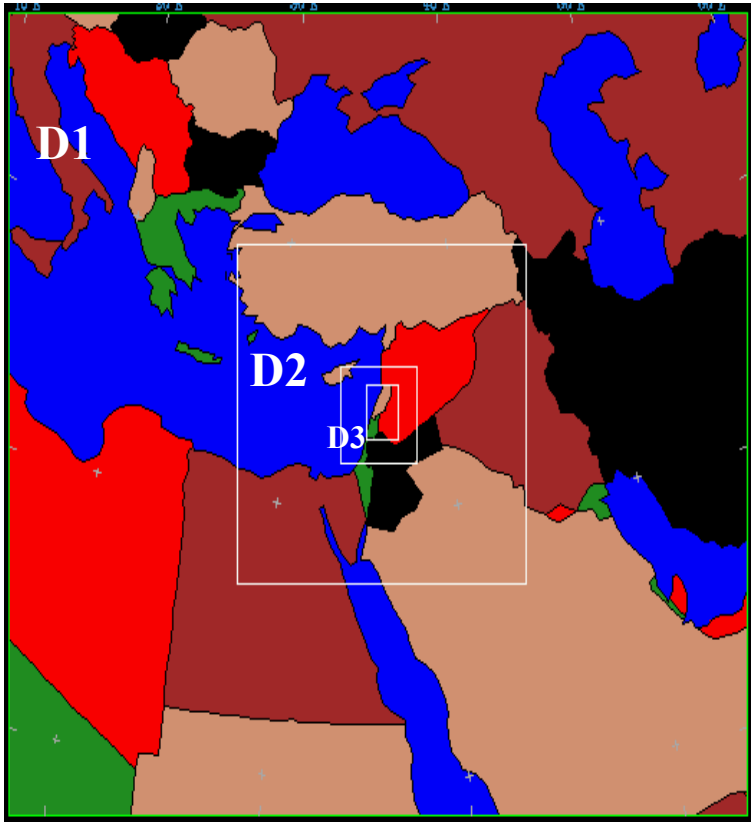


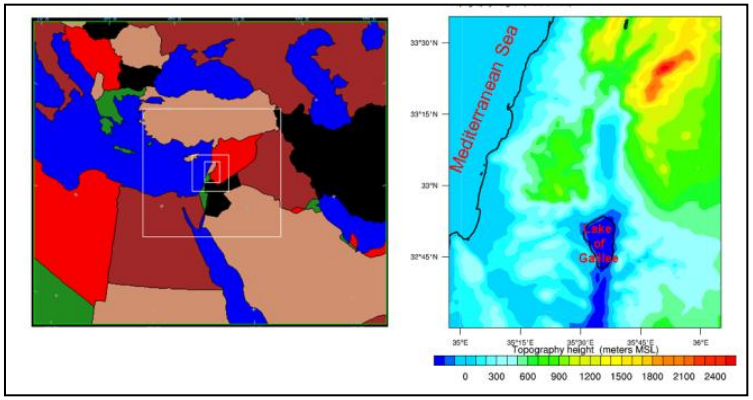

4X-DZT
CHIM-NIR


Mt. Hermon
Syria
The Hashemite Kingdom of Jordan
Hula Valley
Upper Jordan River
Lebanon
Golan Heights
Eastern Galilee
Lake Kinneret
Lower Jordan River

- DR will be used between the Golan Heights (Target) and the coast (control) as well as between the Galilee and the coast (as it was done during Israel 2).

- In addition, the results from a WRF model with 1.3 km resolution will be used to compare with rain gages. *Recent analysis showed good correlation between WRF model results and rainfall in the Golan Heights, suggesting that the model could be used as an additional tool for evaluating seeding results.*





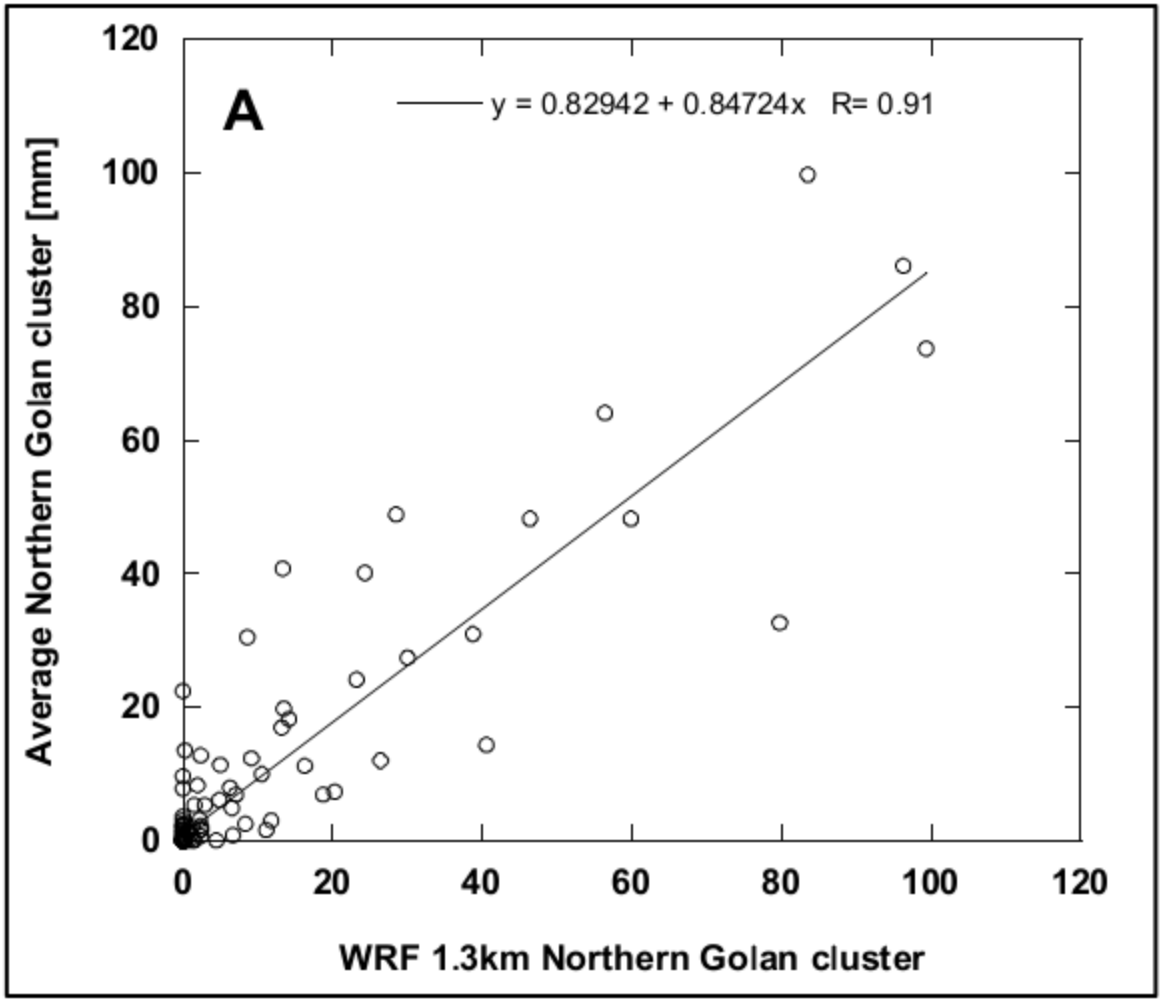
D1 98x84x37, DX = 40.5 Km

D2 106x115x37, DX = 13.5 Km

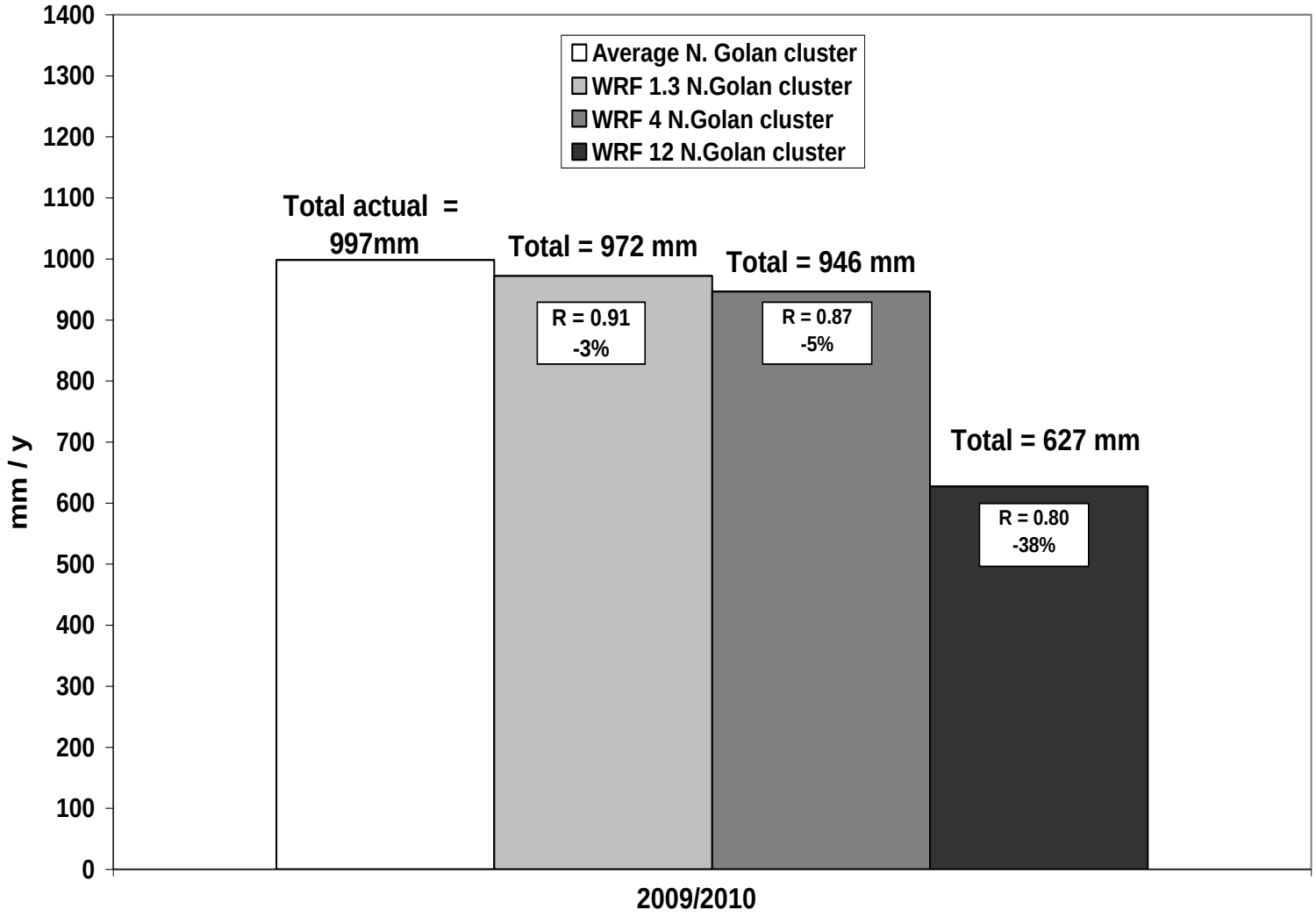
D3 91x91x37, DX = 4.5 Km

D4 112x154x37, DX = 1.5 Km

Rostkier-Edelstein et al 2009 :**High Resolution WRF-RTFDDA seasonal precipitation over complex terrain,** *Proceedings of the 10th Annual WRF User's Workshop, 23-26 June 2009 ,Boulder ,CO.*


A
y = 0.82942 + 0.84724x R= 0.91
Average Northern Golan cluster [mm]
WRF 1.3km Northern Golan cluster
0
20
40
60
80
100
120

Observed accumulated precipitation at 2009-10 for the cluster of 4 rain gauges in the upper part pf the Kinnert basin vs. the WRF forecasted precipitation run at 1.3 km, 4 km and 12 km grid spacing .



Givati et al. 2011, Using the high resolution WRF model for calculating stream flow in the Jordan River, *J. Applied Meteorology and Climate*, In Review.

Conclusions

- **Cloud seeding in Israel- 4 will focus on orographic clouds in the upper Galilee, Golan heights and the Hermon ranges, and not on convective clouds that come from the Mediterranean Sea.**

- **Airborne seeding will be done along two seeding lines, thus producing two target areas and one control. In addition, ground generators will be used closer to the eastern area where orographic effects are maximum.**

- **Results will be evaluated using DR and will be complemented with high resolution WRF model simulations.**

- **Cloud microphysical measurements will continue throughout the experiment.**

Thank you