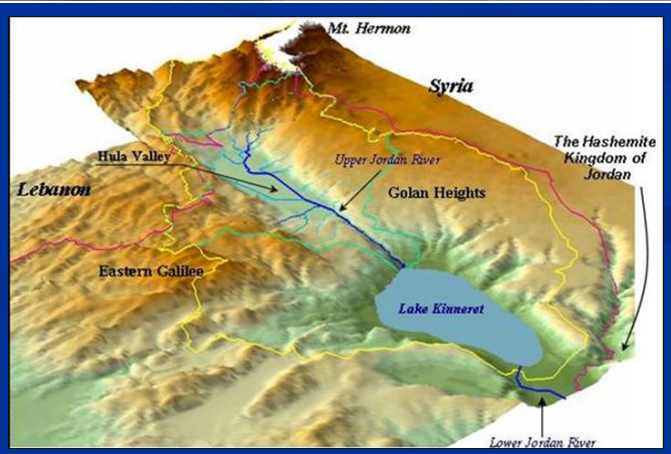
WATER AUTHORITY

Planning the Israel-4 Cloud Seeding Experiment

Amir Givati, Israeli Hydrological Service - Water Authority

Danniel Rosenfeld, Nati Glick, Yigal Herell, Uri Shamir,

Baroch Ziv, Davied Stainberg, Yoav Bengamini



The Israeli water Authority is about to conduct new cloud seeding experiment in the coming rainy seasons

- The experiment will focus on orographic clouds.
- New target area in the Sea of Galilee basin.
- The statistical experiment will be done along with microphysics measurements and chemical analysis.
- New statistical analysis will be use in order to evaluate the seeding effect in the target area: Using simulations from high resolution numerical models.

The methodology of the Israel-4 experiment:

Shifting emphasis from seeding convective to orographic clouds at the catchment of Sea of Galilee: Golan and Hermon

- New target area (The Golan heights and the Hermon).
- Adding new seeding line inland.
- Ground generators on the Galilee range mountain tops with double burners.
- Cloud physics experiments (aircraft measurements) and numerical simulation of the seeding.
- Chemical measurements (including Ag) in rain water at the target and control areas.
- Hydrometric measurements at small basins in the target area to evaluate the seeding effects on water resources.
- Using the high resolution WRF model forecast (1.3 km) in order to improve the seeding targeting.
- Using the high resolution WRF model calculated precipitation as control for the formal statistical analysis of the experiment.

Seeding Effects in Israel

Seeding Period	Seeding type	% Enhancement	Significant	Source
1961 - 1967	Experimental (Israel-1)	15	0.009	Gabriel (1967,1970)
1969 – 1975	Experimental (Israel- 2)	13	0.028	Gagin and Neuwmann, (1981)
1975 - 1990	Operational seeding	6-11	0.05	Nirel and Rosenfeld (1995)

Israeli-1 Experiment : 1961-1967

Seeding line 30 minutes upwind the coastline

Cross-Over random seeding allocation for the North or South target

Seeding effect **E=1.15**

$E=(TNs/TNu * TSs/TSu)^{0.5}$

Where:

TNs: Rainfall in Target North when seeded

TNu: Rainfall in Target North when un-seeded

TSs: Rainfall in Target South when seeded

TSu: Rainfall in Target South when un-seeded

Significance=2%

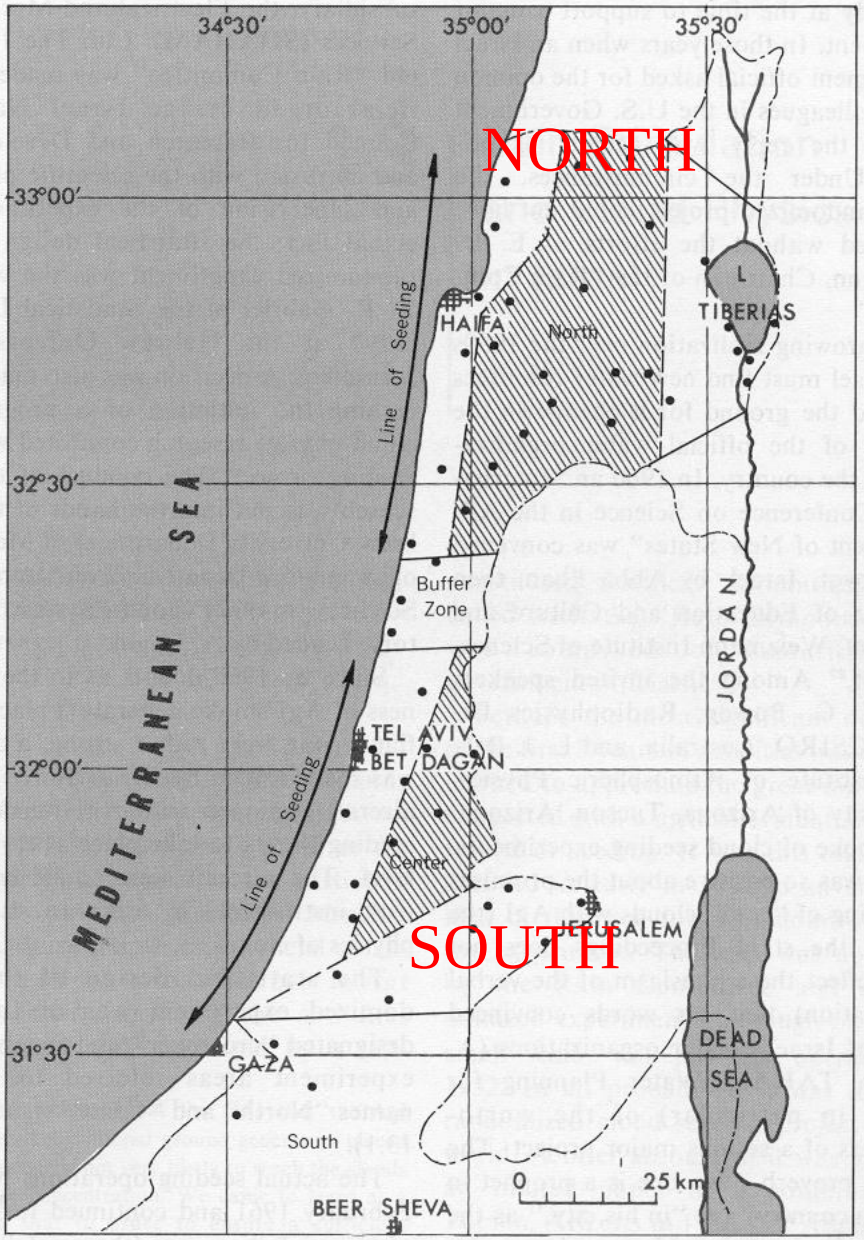


Figure 13.1 Map of Israel, showing the two experimental areas and their interior parts (shaded), for the 1961–1967 experiment. Dots indicate location of rainfall gauges used in the statistical analysis.

Gagin and Neumann, 1976

Eexp. Israel-2: 1969-1975

Seeding effect in the North: **E=1.13**

E=(TNs/TNu) * (CNs/CNu)

Where:

TNs: Rainfall in Target North when seeded

TNu: Rainfall in Target North when un-seeded

CNs: Rainfall in Control North when Target North seeded

CNs: Rainfall in Control North when Target North un-seeded

Significance=2%

Gagin and Neumann, 1981

Seeding line in the south was extended along the coastline, leaving no control for evaluation the effect in the south alone.

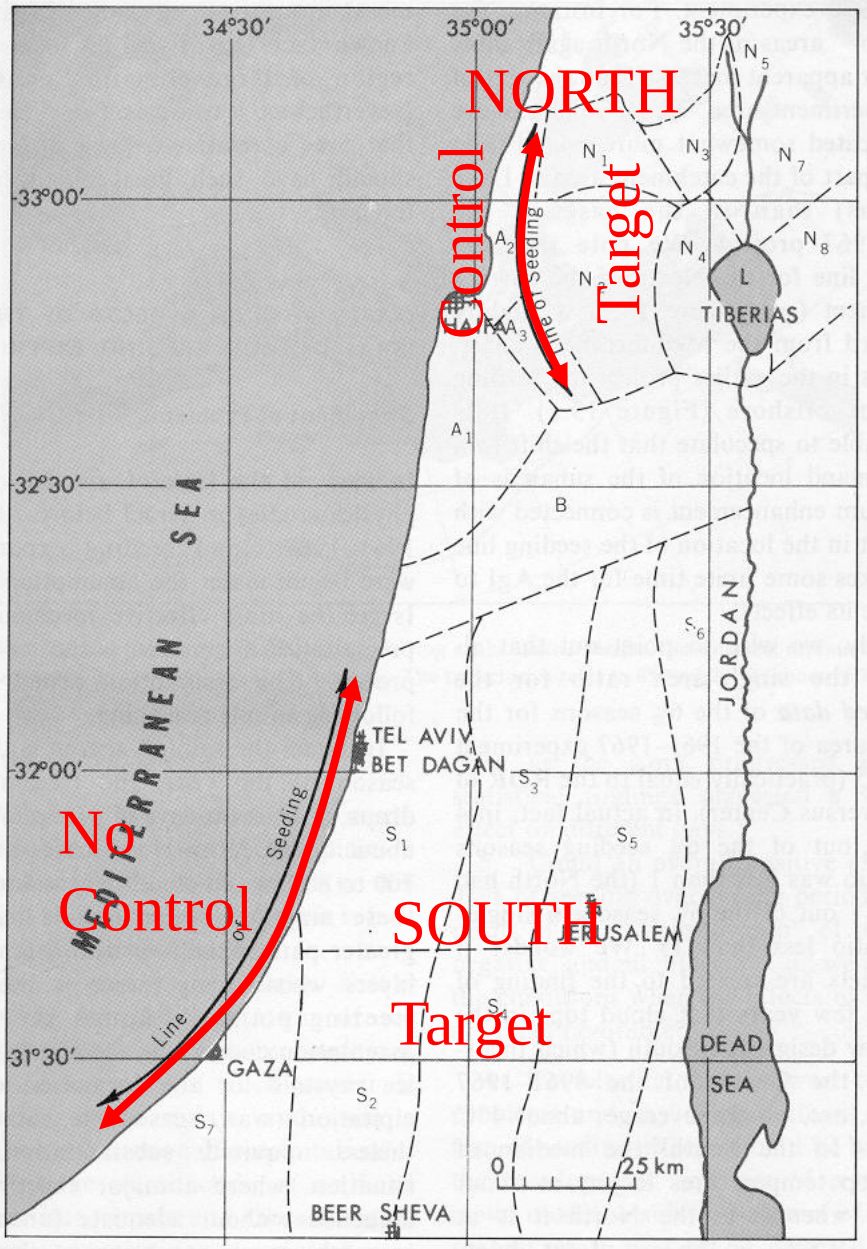
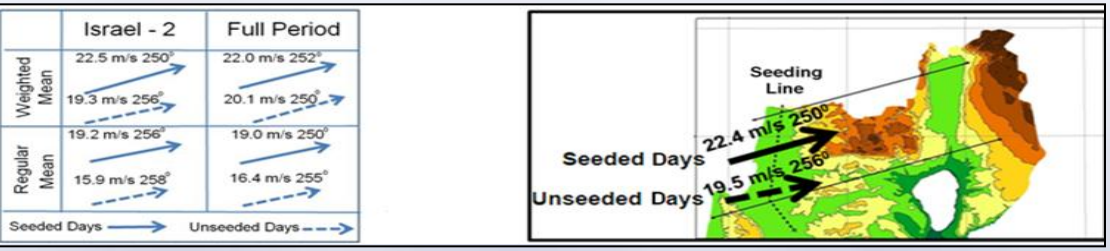


Figure 13.2 Map of Israel, showing the two experimental areas and their subareas (N_i, S_i), the contro areas (A_i), and the buffer zone (B), for the second experiment (beginning in 1969–1970).

Ben zvi et al. 2010



ARTICLE IN PRESS

ATMOS-02331; No of Pages 4

Atmospheric Research xxx (2010) xxx–xxx

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmos

Comment on "Reassessment of rain experiments and operations in Israel including synoptic considerations" by Zev Levin, Noam Halfon and Pinhas Alpert
[Atmos. Res. 97 (2010) 513–525]

Arie Ben-Zvi [a,b,*], Daniel Rosenfeld [c], Amir Givati [b]

[a] Sami Shamoon College of Engineering, Beer Sheva, Israel
[b] Israel Hydrological Service, Jerusalem, Israel
[c] The Hebrew University of Jerusalem, Jerusalem, Israel

ARTICLE INFO

Article history:
Received 13 October 2010
Received in revised form 11 November 2010
Accepted 2 December 2010
Available online xxxx

Keywords:
Cloud seeding
Israeli experiments
Precipitation trends

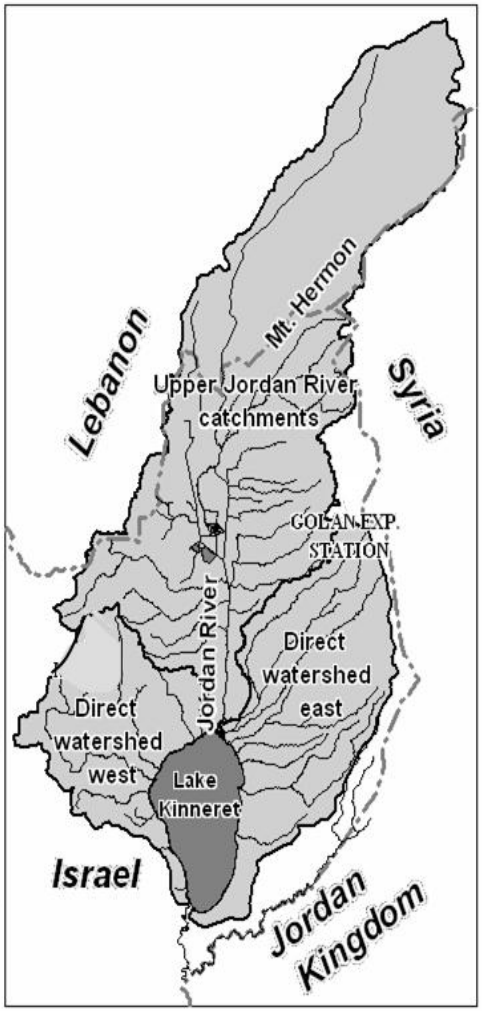
ABSTRACT

Levin et al. (referred here as LHA) made a sweeping conclusion that cloud seeding has been ineffective in Israel. They claimed that the results of the Israeli-2 experiment could be fully ascribed to synoptic bias. However, the cross over analysis of Israeli-2 has shown the same already in 1990 by Gabriel and Rosenfeld. While LHA only showed differences in the 850 hPa winds being stronger in the north seeded days of Israeli-2, Rosenfeld and Farbstein had already shown quantitatively in 1992 that this synoptic bias explains less than half of the indicated seeding effect in the north. Furthermore, accepting that a cross over design protects against synoptic bias means that the highly positive and statistically significant indicated seeding effect in Israeli-1, which was based on a cross-over design, cannot be explained by such synoptic bias. Instead, LHA completely ignored the Israeli-1 experiment.
LHA's evaluation of the operational seeding used implied assumption that amounted to historical comparisons that have already been shown to be invalid, especially for the Israeli situation due to the decreasing trend of target–control ratio, especially over the eastern upper Galilee. For all of the above reasons, the conclusion of LHA that cloud seeding is ineffective in Israel is not supported by the data. Given the uncertainties, both physical and statistical, the Israeli water authority has embarked on the Israeli-4 randomized cloud seeding experiment, which is aimed at testing the hypothesis that cloud seeding might be affecting mainly the precipitation in the orographic clouds developing over the hills in the catchment of the Jordan River.

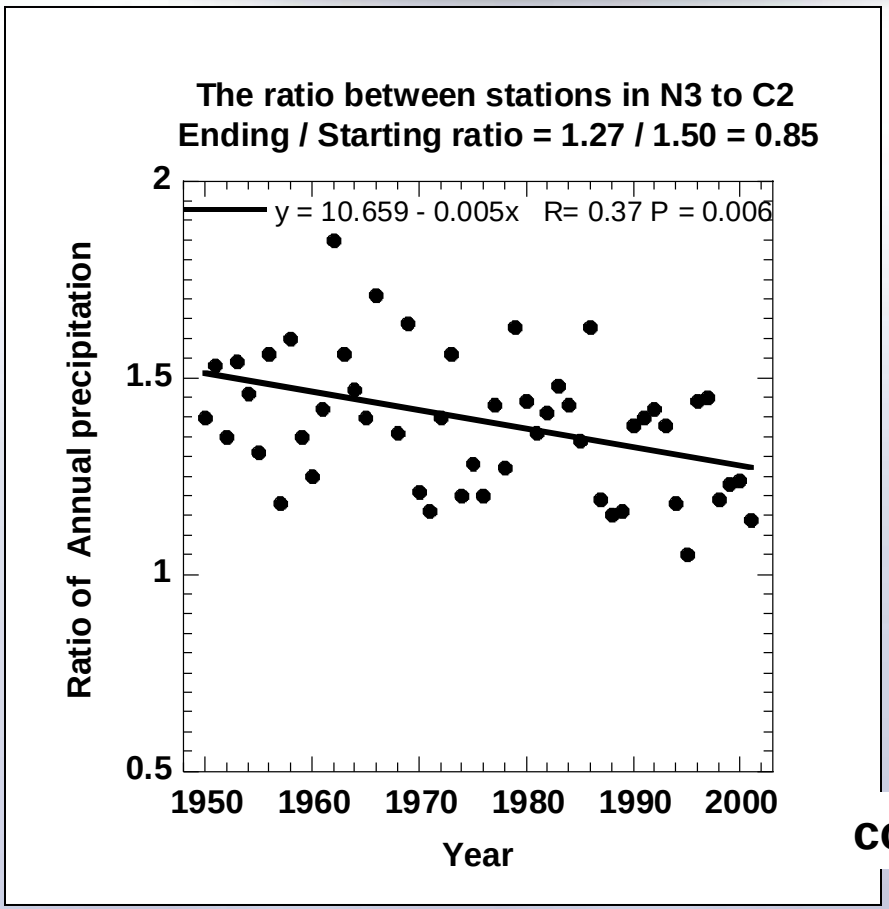
© 2010 Published by Elsevier B.V.

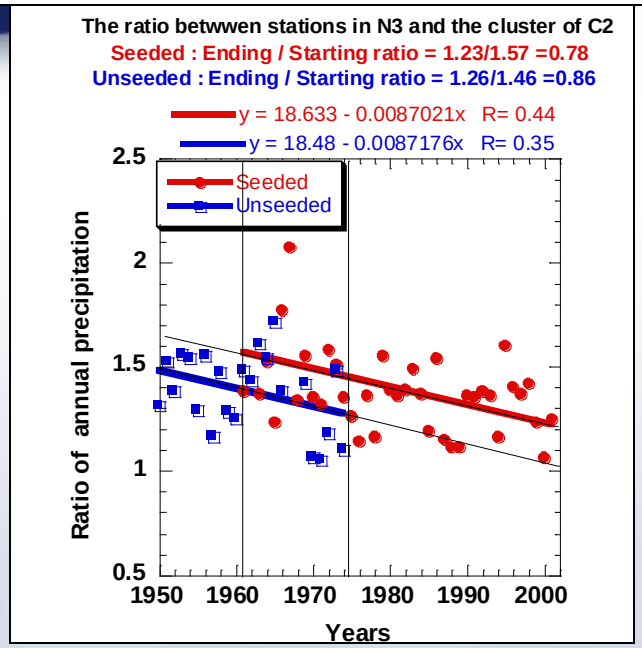
Levin et al . 2010

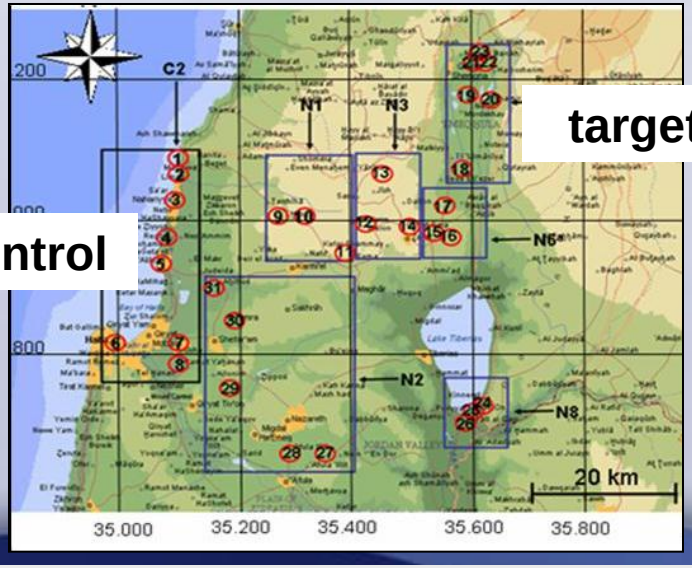
The Kinneret basin



Decreasing trend between precipitation in target vs. the control areas



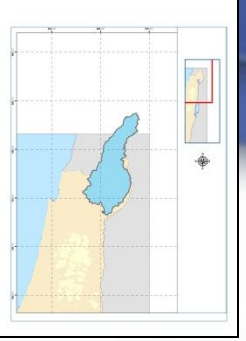




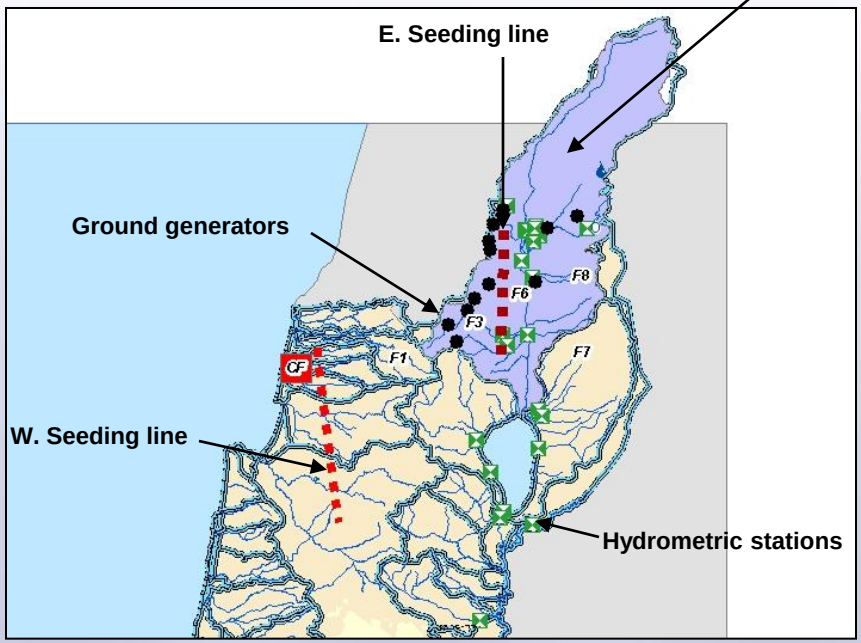
target

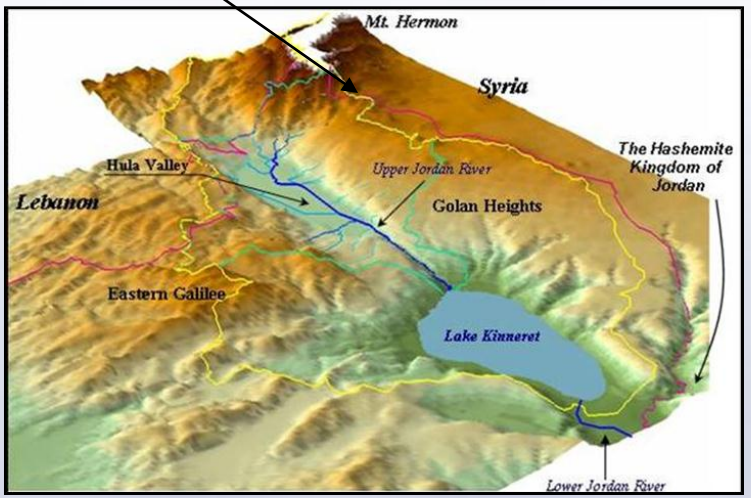
control

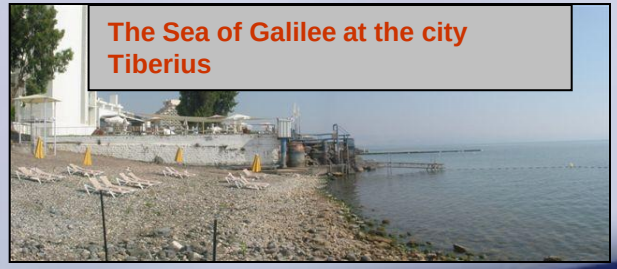
Givati and Rosenfeld (2005): Separation between Cloud Seeding and Air Pollution Effects, J. App. Met., 44, 1298-1398

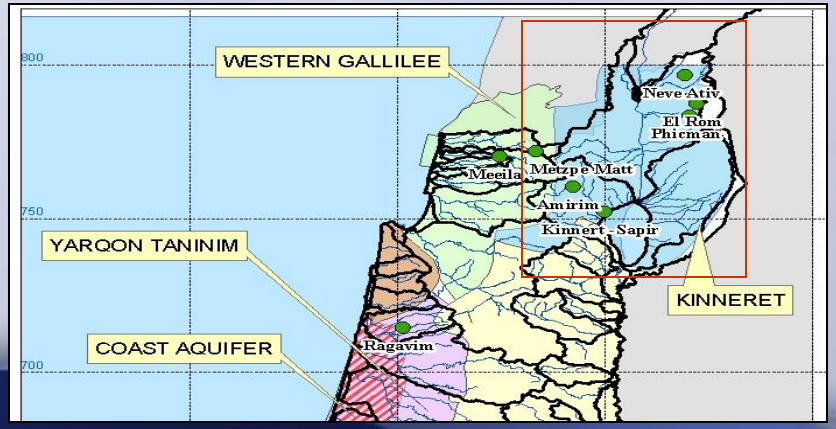


The seeding areas in Israel-4: Upper Jordan River basin and the Lake of Galilee

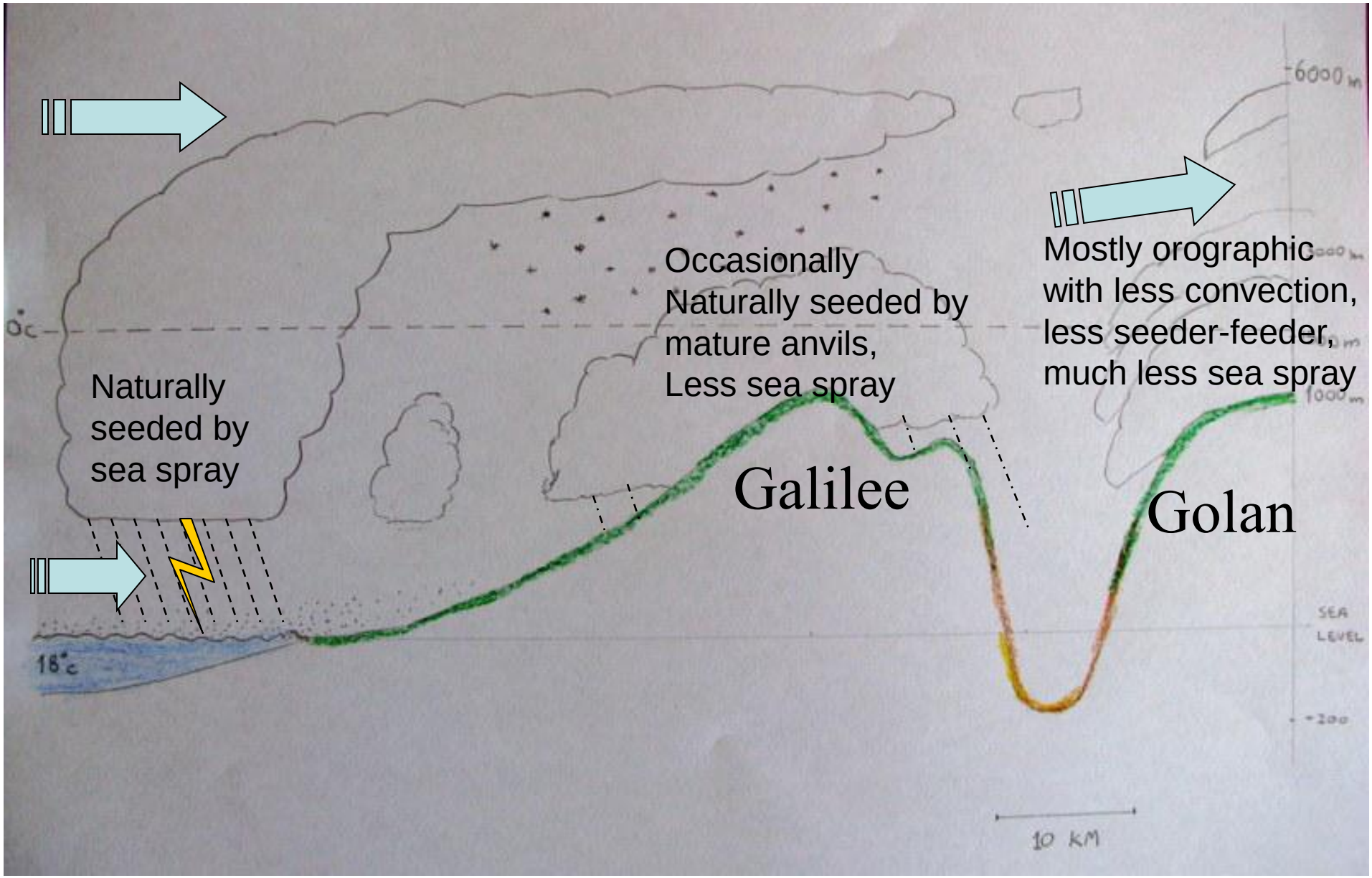




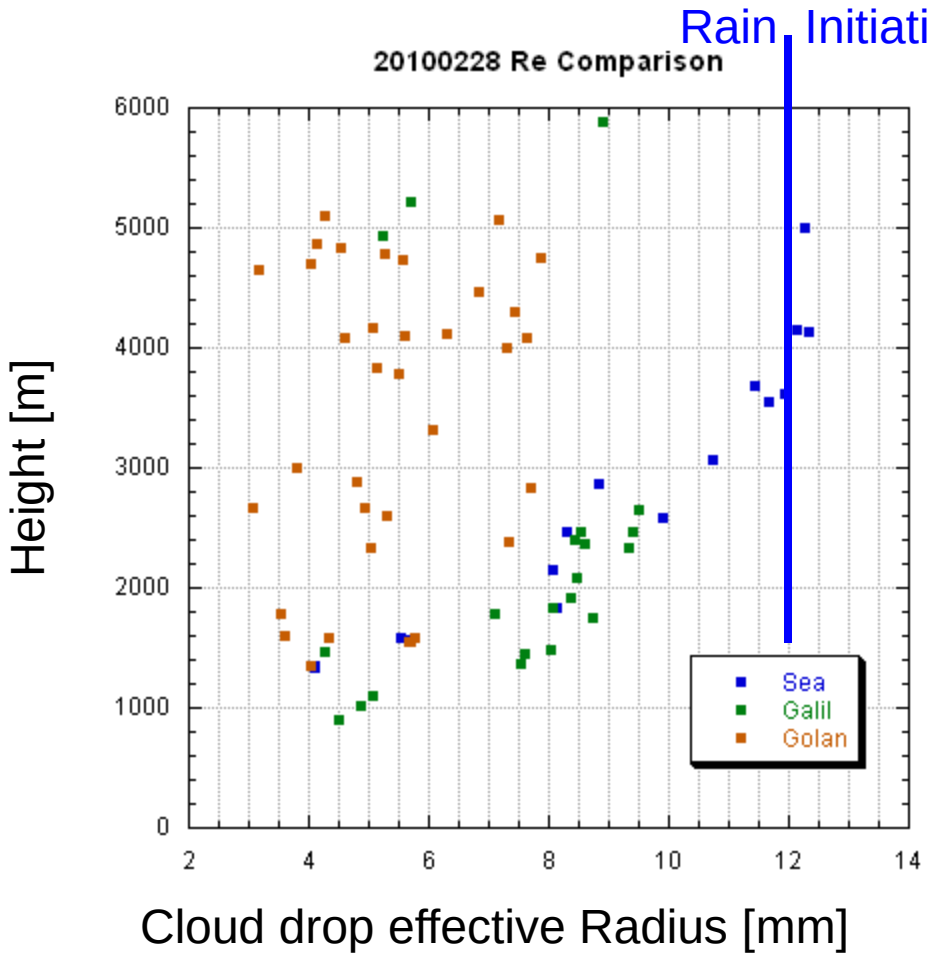

The Sea of Galilee at the city Tiberius

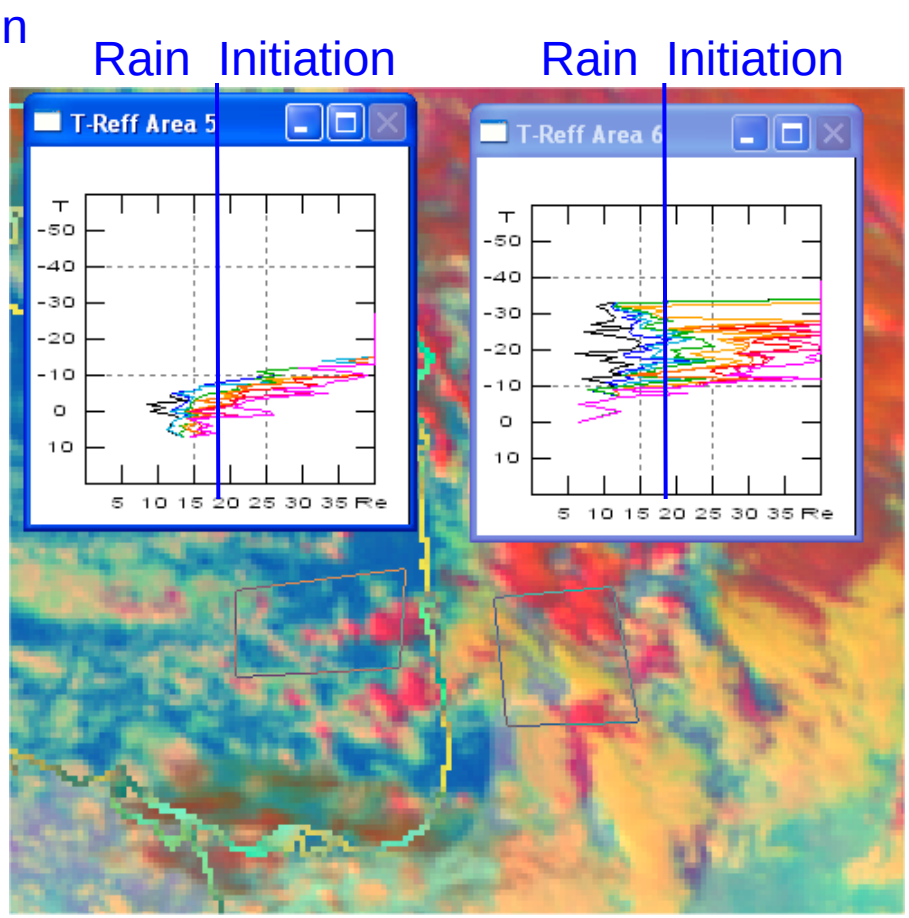


A typical winter rainy day in Northern Israel



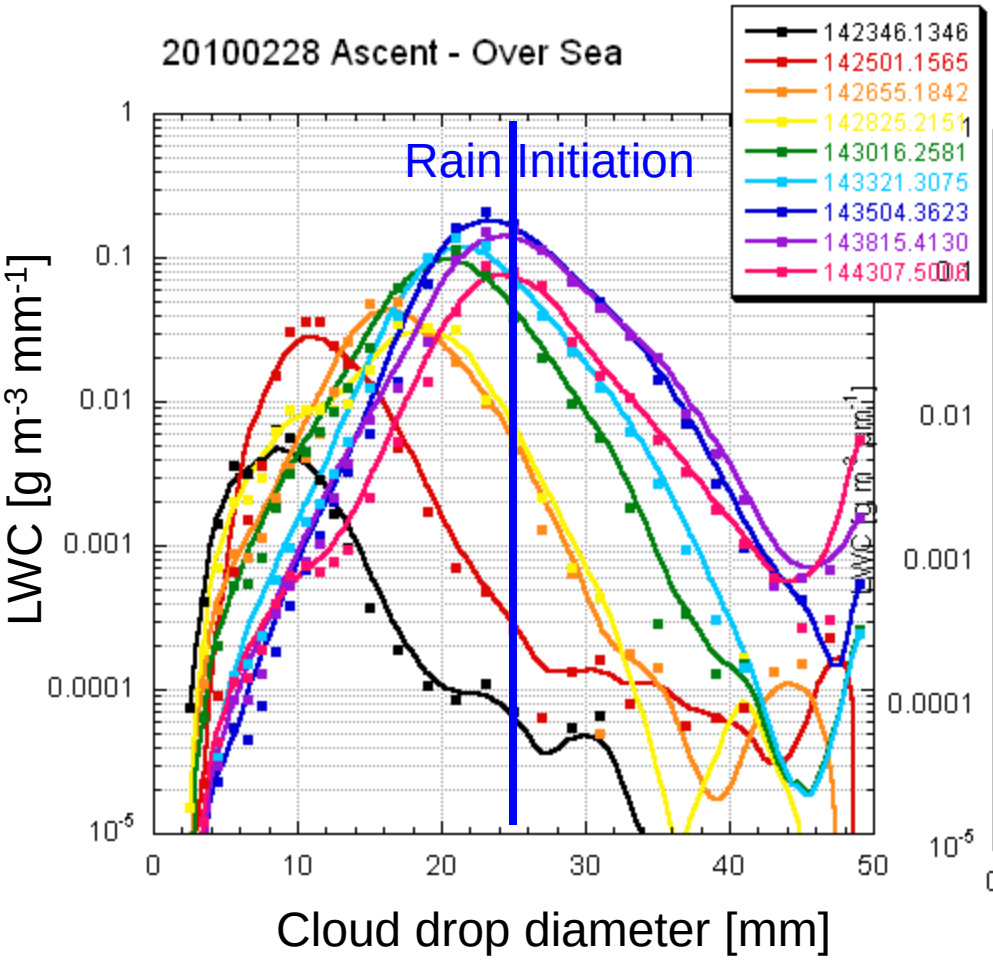
Sharp contrast between sea&coastal and orographic cloud microstructure

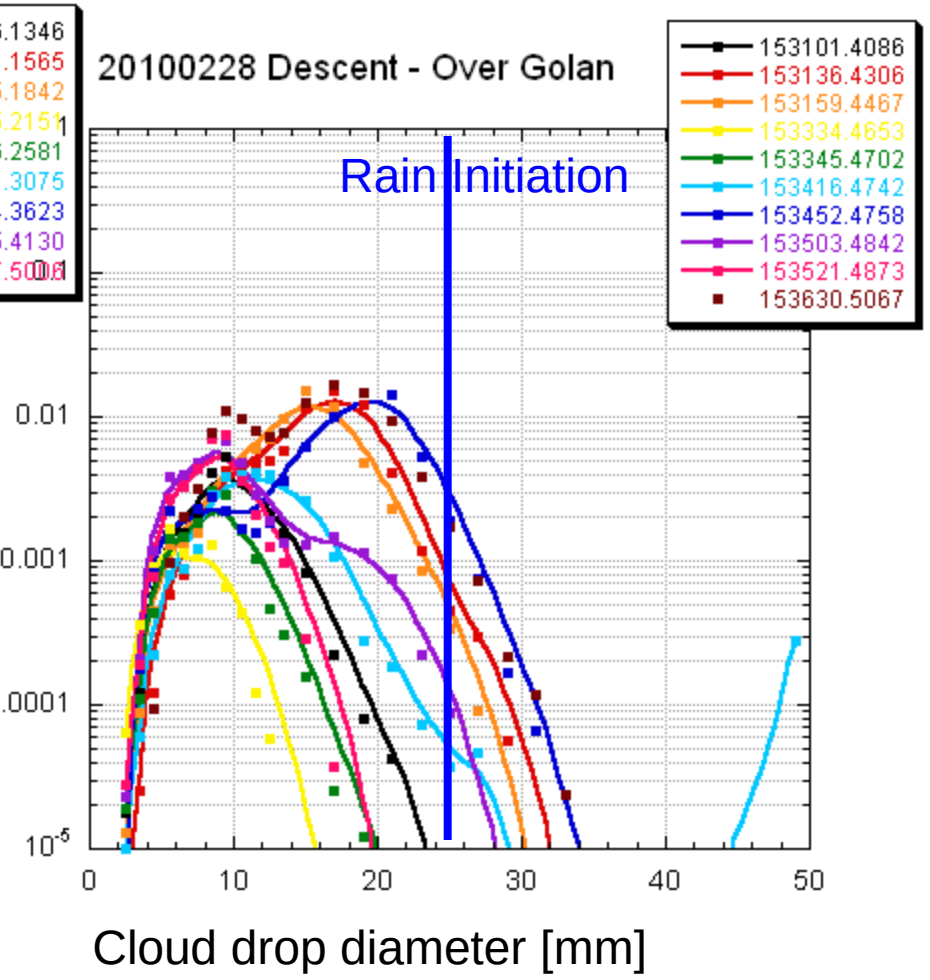


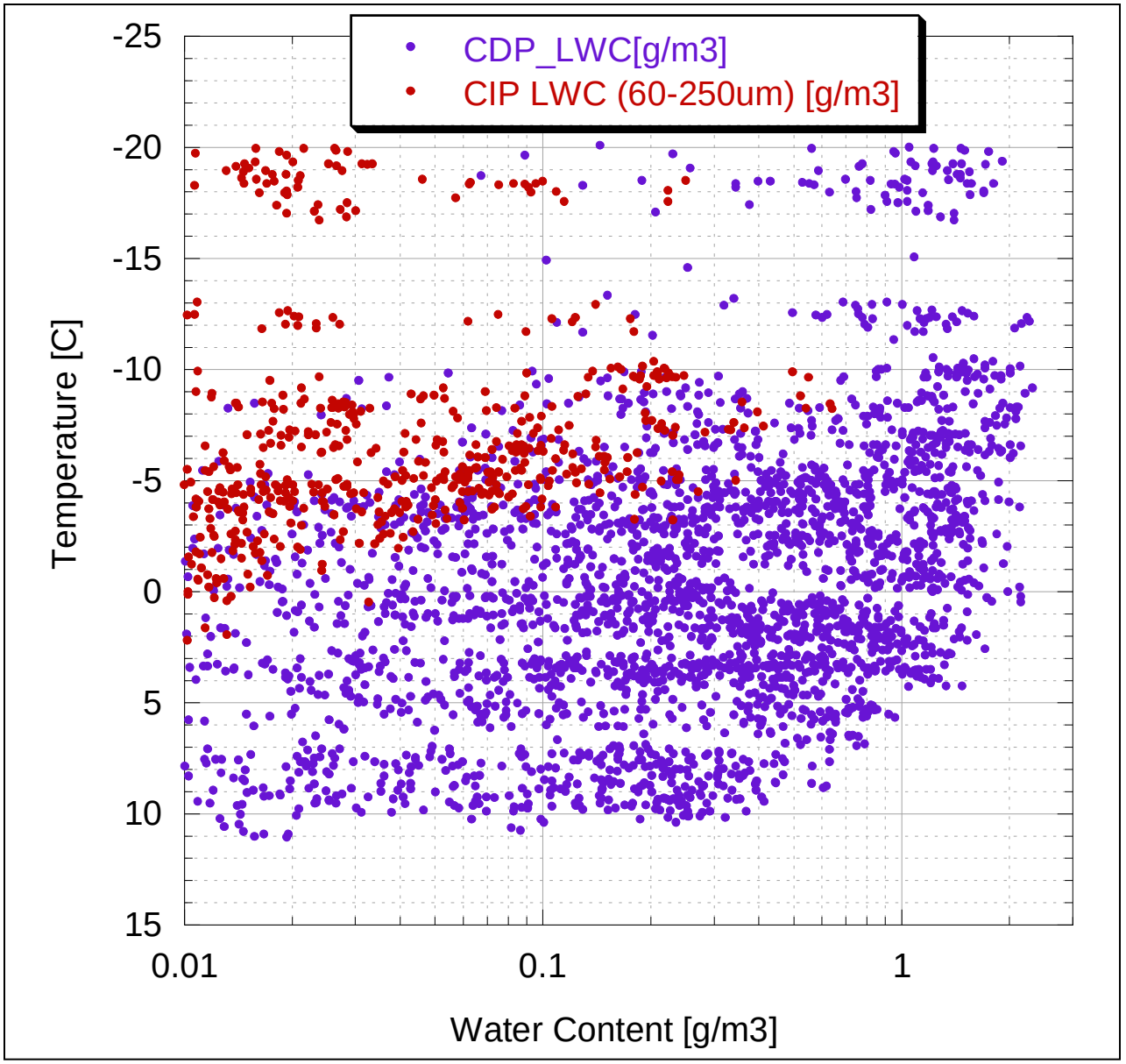


Sea & coastal

Orographic






CDP_LWC[g/m3]
CIP LWC (60-250um) [g/m3]
-25
-20
-15
-10
-5
0
5
10
15
Temperature [C]
0.01
0.1
1
Water Content [g/m3]

Summary – cloud measurements

1. Convective clouds over sea are seeded hygroscopically naturally by sea spray during the winter storms.
2. During weak winds the convective clouds do contain much supercooled water, but in these infrequent situations they move slowly and do not penetrate much inland.
3. The strong winds during the winter storms create orographic clouds that are not as affected by sea spray, mainly over the eastern upper Galilee, Golan and Hermon.
4. The cloud drop effective radius and phase can be detected in real time with the MSG geostationary satellite.
5. We still need additional measurements for characterizing the amount of supercooled water in the various synoptic situations.

Chemical analysis in rain water at the target area

Time series from Neve Ativ during the storm of 23-24 March 2009. The green line is three times EF_{Ag}. The light green (D.L. Ag (X3)), represents times where the Ag concentration was below Detection Limit (≈3ppt), where 3 ppt was applied. CH09-CH07 represent the satellite-retrieved cloud top phase. The blue line is the cloud top temperature and the pink line marks the aircraft seeding time corrected for wind drift. High EF_{Ag} values were measured when the rain fell from mix phase clouds. Lower EF_{Ag} value were measured when the rain fell from mostly warm clouds.

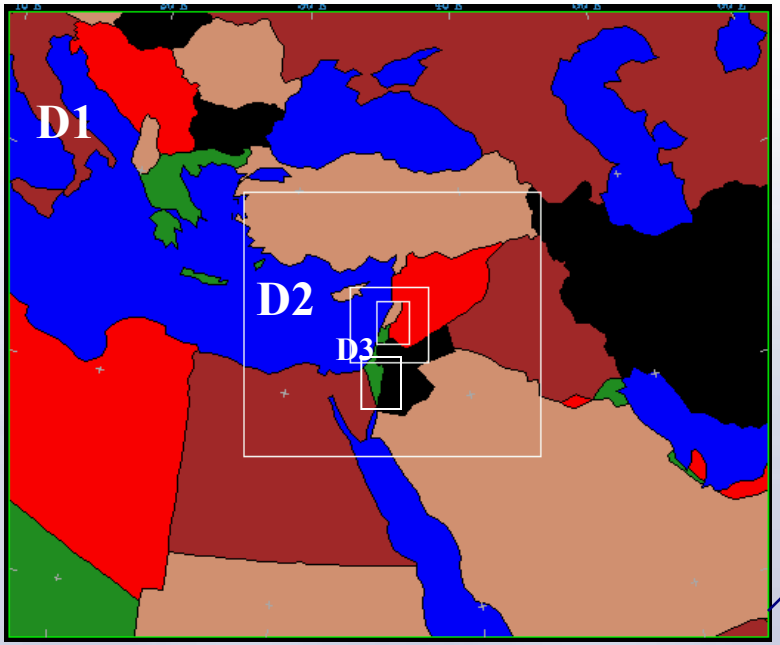
- AgI is transported to the catchments area of the sea of Galilee as suggested by the Wilcoxon test and by a principal component analysis (not shown here).
- AgI is taking an active role in the mixed phase precipitation process.
- The use of satellite microphysics analysis in combination with careful chemical measurements is a powerful technique which can improve the efficiency of cloud seeding activities.

Y. Erel, A.Zipori and D. Rosenfeld

Using calculated precipitation from the WRF high resolution model

WATER AUTHORITY

WRF Climo - FDDA Domains



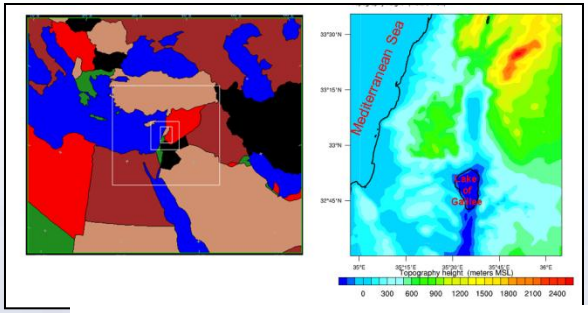
D1 98x84x37, DX = 40.5 km

D2 106x115x37, DX = 13.5 km

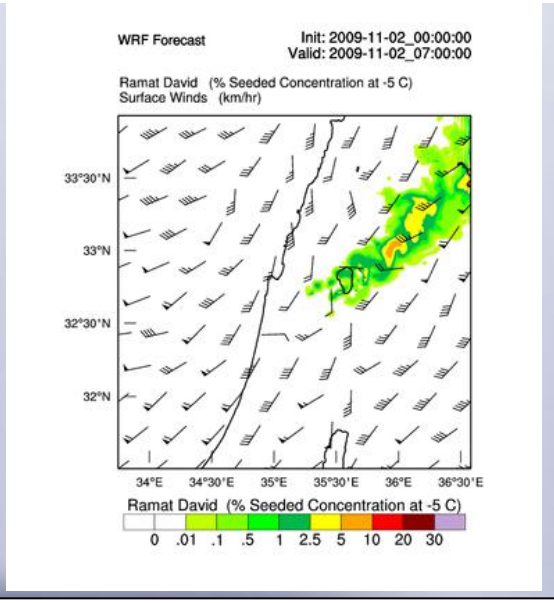
D3 91x91x37, DX = 4.5 km

D4 112x154x37, DX = 1.5 km

D4

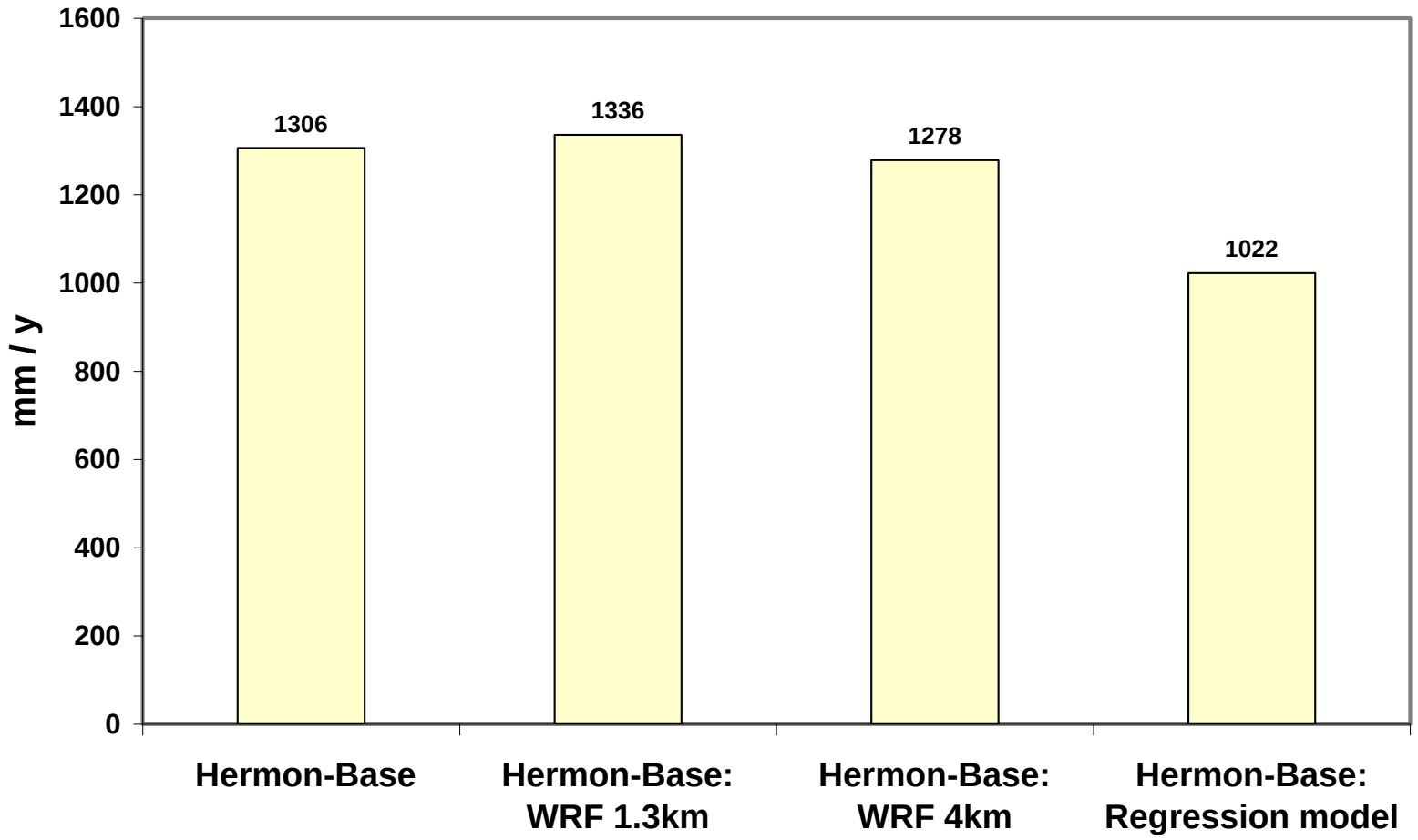


WRF simulation of the material dispersion



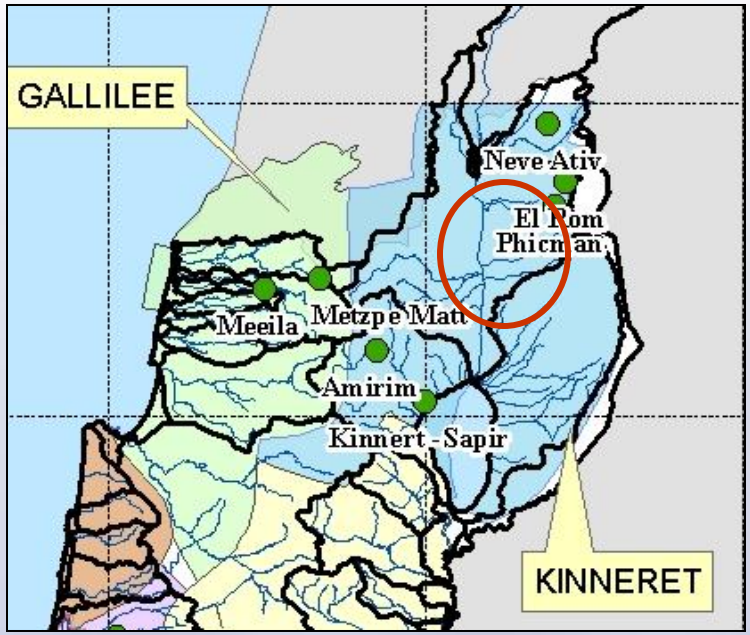
Rostkier-Edelstein□, D., Y. Liu, G. Roux, A. Givati, A. Pietrkowski, M. Ge, A. Hahmann, J. Pinto, T. Warner and S. Swerdlin, 2009 :**High Resolution WRF-RTFDDA seasonal precipitation over complex terrain,** *Proceedings of the 10th Annual WRF User's Workshop, 23-26 June 2009 ,Boulder ,CO.*

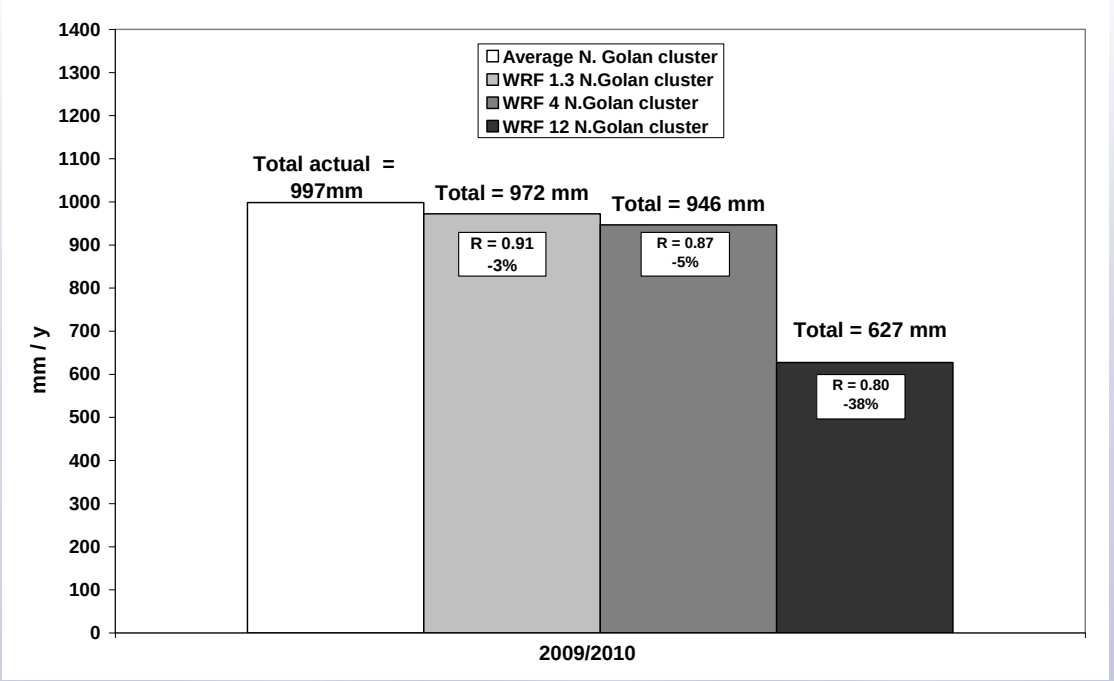
: Annual precipitation at 2009 -10 at the Hermon base rain gauge vs. calculated precipitation from the WRF model at 1.3 km resolution, WRF 4 km and according the regression model used by Rimmer and Selinger (2006)



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.

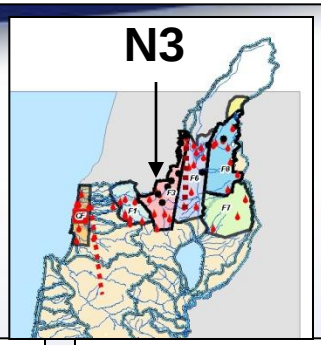
Observed accumulated precipitation at 2009-10 for the cluster of 4 rain gauges in the upper part pf the Kinnert basin vs. the WRF forecasted precipitation run at 1.3 km, 4 km and 12 km grid spacing .





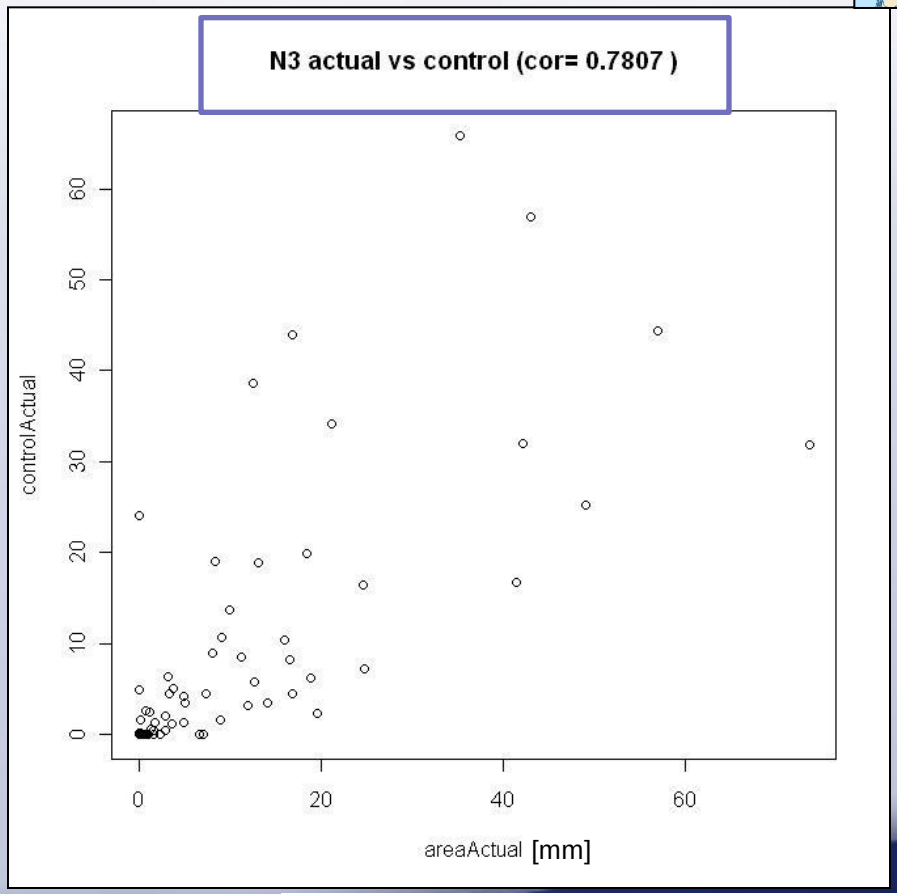
Givati et al. 2011, Using the high resolution WRF model for calculating stream flow in the Jordan River, *J. Applied Meteorology and Climate*, In Review.

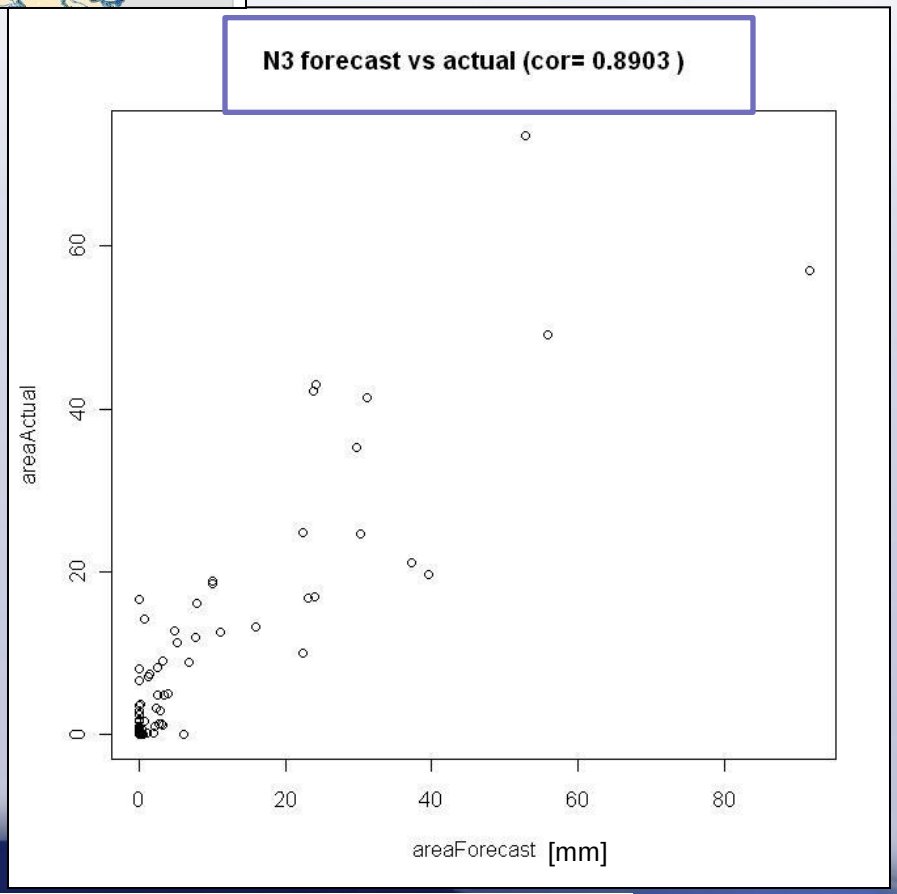
comparisons between actual to calculated precipitation in the target and control areas: The 2009 – 2010 rainy season



Actual Daily precipitation in the target (N3) vs. the control (C2)

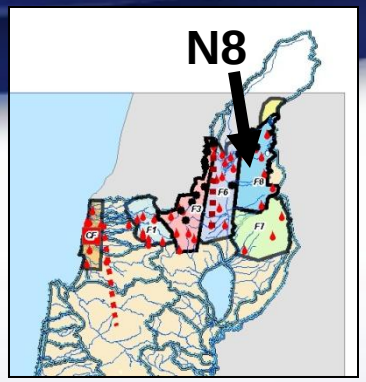
Calculated daily precipitation in the target (N3) vs. actual



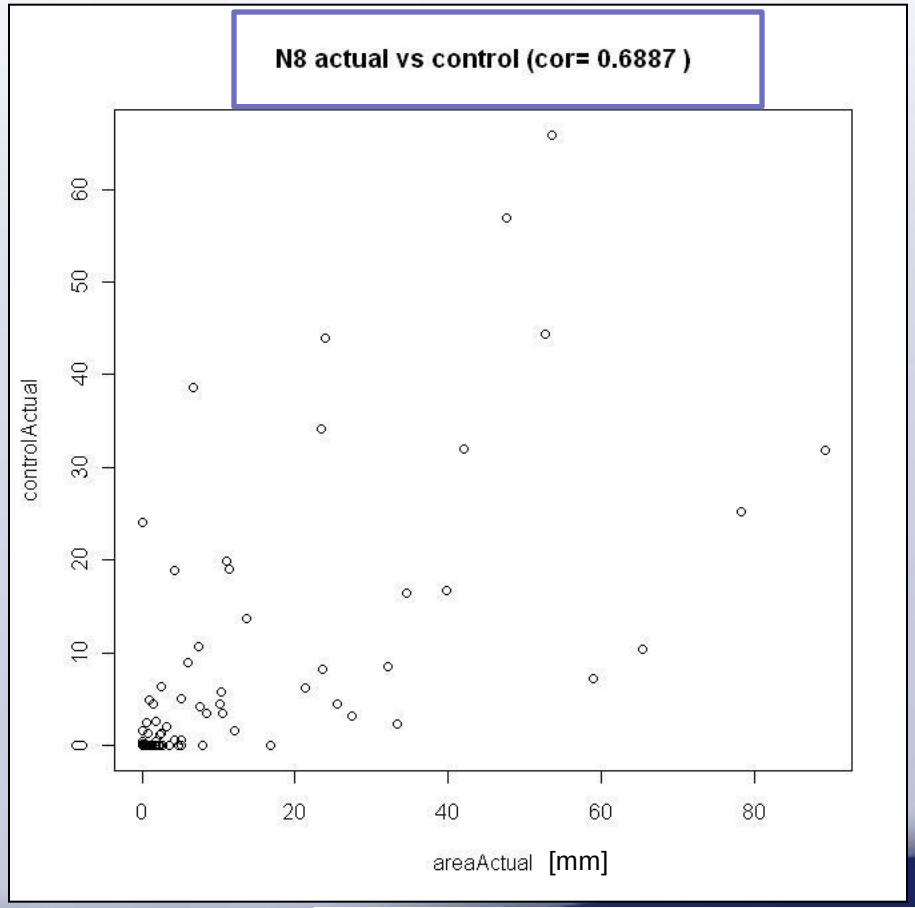


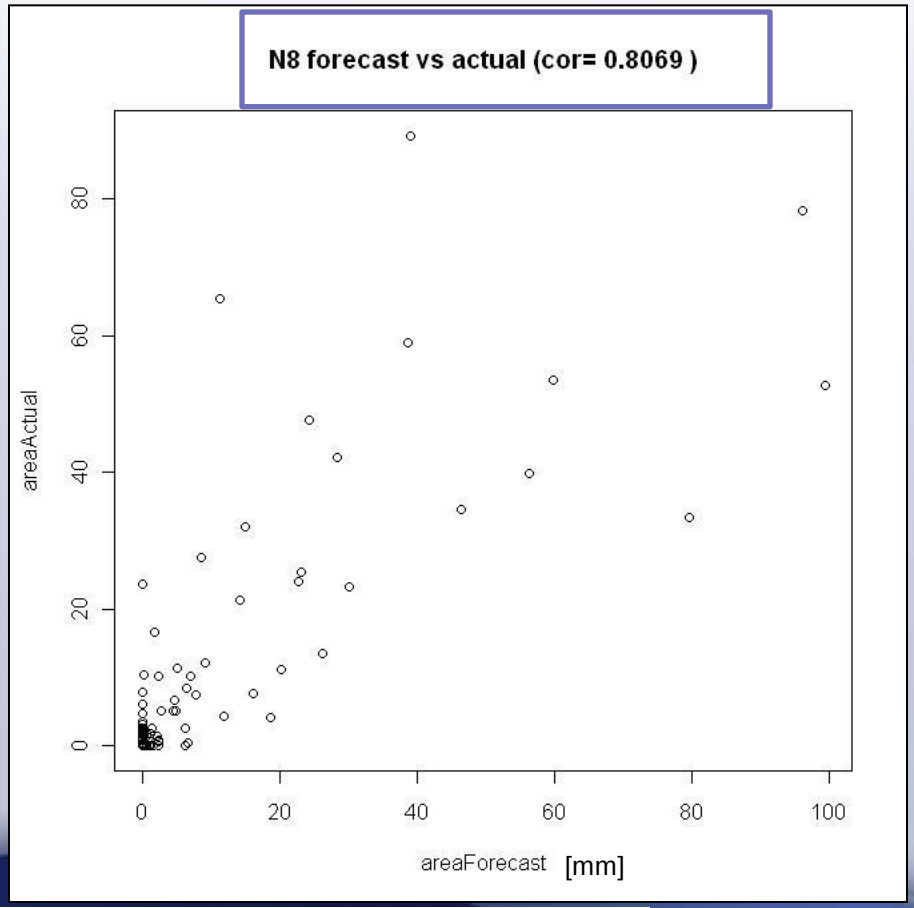
Steinberg, Binjamini and Givati, 2010, Special report for the Water Authority

Daily precipitation in the target (N8) vs. the control (C2)



Calculated daily precipitation in the target (N8) vs. actual





Stainberg, Binjamini and Givati, 2010, special report for the Water Authority

Summary

- **Aircraft measurements show seeding potential in the orographic clouds in north - east Israel.**
- **Chemical analysis reveal that the seeding material reachs the target area and takes part in the precipitation formation process in the clouds.**
- **Cloud seeding in Israel-4 will focus on orographic clouds located in the upper Galilee, Golan heights and the Hermon ranges, and not on convective clouds that come from the Mediterranean Sea.**
- **New methodologies will be used to conduct the seeding activities and also to evaluate their effects: WRF for dispersion simulations, evaluating with double ratio based on high resolution meteorological models, microphysical analysis of cloud properties from satellite and chemical analyses of rain water.**