The Effects of Climatic Changes on the Availability of Water Resources in Israel – Atmospheric Section

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1. Introduction

The IPCC (2001) report was summarized with the suggestion that there are new and stronger evidence (as compared to the previous report of 1995) that most of the last 50 years warming is connected with human activity. One example for this is the almost complete melting of the tropical and sub-tropical ice capes (Alverston et al., 2001, Science, p. 47). The Kilimanjaro ice cape was reduced by 82% from the year of 1912 till 2000. If this will continue it is expected to completely vanish by the year of 2015. We still don't know what happens with the Hermon ice cape regarding the global warming. Preliminary estimations (Segal et al., 1994) show that the warming has a non-negligible potential influence on the Hermon snow. As a result the water balance of the Kinneret is also affected. Second example is that the average world wide near-surface temperature increased in the last decade to an unprecedented value during the last 150-200 years of the measurement data exist; probably it is also the highest level in the last 1000 years.

In this note we summarize the implications of past and future climate changes on the availability of water resources in Israel. Chapter 2 summarizes the observations and Chapter 3 the expected changes in the near future. Conclusions and recommendations are in chapter 4.

2. The observed Climatic changes in the E. Mediterranean and in Israel

2.1. Synoptic systems

The analysis of the typical synoptic systems in the Mediterranean Sea in rainy months according to NCAR/NCEP Reanalysis for 1958-1998 shows a considerable high pressure tendency over the western and central Mediterranean Sea, along with a southern migration of the low pressures to the SE Mediterranean.

In the E. Mediterranean, the low pressure anomaly center at 925 mb (about 750 m high) was over Turkey in the 1960s. In the 1970s it moved to be over Cyprus, while in the 1980s it moved further south to be over south Israel. The high pressure tendency over the western and central Mediterranean Sea along with the southern tendency of the low pressure over the eastern Mediterranean are statistically significant and connected with the intensification trend of the NAO index (North Atlantic Oscillation) since the 1970s. The NAO index is defined as the surface pressure difference between the regional sub tropical high at 35°N and the surface pressure at the central Iceland low at 55°N. During a high NAO index, North Europe is rainier and warmer, and south Europe and the Mediterranean Sea are relatively dry. The situation is reversed in low NAO index. In our research we have shown high-correlation between the NAO index and the temperatures and the pressure systems in Israel (Ben-Gai et al., 2001). On the other hand, the rain in Israel is correlated with the EA/WR (East Atlantic/West Russia) index (Krichak et al., 2001).

The idea that the NAO index intensification in recent years is associated with the world global warming was emphasized. In addition, this index is well connected with weather changes in the northern hemisphere, especially with exceptional cold and wind storms (Thompson and Walace, 2001). The connection with rain in Israel will be discussed in chapter 2.3.

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*This is based on the atmospheric section of the article by Alpert and Ben-Zvi (2001)

2.2. Temperature

Analyses of 40 stations in Israel (Ben-Gai et al., 1999) show that the **summer** temperature maximum and minimum increased over the period of 1964-1994 by an average rate of about 0.21, 0.26 degrees per decade, respectively. This fact fits well with the predicted trends of the greenhouse effect even when the daily amplitude is smaller (the minimum temperature increase rate is larger than that of the maximum temperature). Indeed, at the same time, we have found that the winter maximum and minimum temperatures in Israel are decreasing. This finding is in contrast with the world average winter temperature increasing trend as a result of the greenhouse effect. However, Alpert (2000) has explained the reason for this, suggesting that the Israel decreasing winter temperatures are highly correlated with the increasing NAO index. Therefore, the winter cooling trend is also a result of the global warming!

Ben-Gai et al., (2001) have found a highly negative correlation (about -0.90) between the NAO index and the winter temperatures in Israel. It should be mentioned, that there are other regions in the world that the temperatures show decreasing trends on certain seasons. However, these regions are in contrast to the general warming trend.

In summary, indeed the average annual summer & winter temperature analysis in Israel does not show increasing trend like in other regions in the world. However, this can be traced to be a greenhouse effect result.

Another interesting conclusion of the above result is the **increase** in the seasonal temperature amplitude i.e. warmer summer and colder winter. A distribution analysis of the maximum and minimum temperatures in Israel shows indeed a clear trend to higher probability of extreme values, i.e. higher trends for warmer/colder days (Ben-Gai et al., 1999). For example, the probability of summer days in Jerusalem with temperatures exceeding 35°C has increased by a factor of 3 in the 80-90s compared to the 60-70s. In the previous period such a day happened only once in three years in August, while in the second period such a hot day occurred on the average once about a year.

2.3. Precipitation

The high-pressure trend in central and western Mediterranean Sea, which was described earlier, has lead to a significantly 10-20% decrease in precipitation during the period 1950-1995. For example, the average value for south Italy has dropped from about 600 mm per year in the 1950s to only about 450 mm per year in the 1990s (Piervitali et al., 1998). Figure 1 shows the precipitation trends in the Mediterranean Sea based on the NCEP reanalysis for 1958-1998. A pronounced center of -12 mm/y exists over north Italy. This means an extraordinary annual rain decrease of 480 mm over the 40 year period. Other decreasing centers exist over Spain, Greece (-10 mm/y) and Turkey (-2 / -8 mm/y). It should be noted that this analysis values are somewhat exaggerated at the maximum centers (as compared to rain gauges), however, they represent quite well the last 40-years precipitation trends from global analysis of rain gauges (Dai et al., 1997).

In Israel, a somewhat increasing precipitation trend was also reported, especially over the center-south, along with an increasing trend over the north, west and east to Israel, Fig. 1. This exceptional increase as compared to the whole Mediterranean Sea is correlated with the southern direction trend of the low from Turkey on the 1950s to Israel on the 1990s (Ch. 2.1) along with the increasing NAO index (Ch. 2.2). The north Negev increase of rains was also partially explained by the intensive changes in land-use (Ben-Gai et al., 1993; Otterman et al., 1990; Steinberger and Yaari-Gazit, 1996; Paz et al., 1998).

The precipitation trends in 12 rain stations in Israel show no statistical significant trends (higher than 0.05) in any station. However, there are two regions: Lake Kinneret with negative trend and north Negev with positive trend (10-20 mm per decade). A maximum value of 19.8 mm/decade is found in Kibutz Negba (s. Israel). It should be noted that 1991/2 winter was exceptional with its high rainfall intensities. This turned the trend to positive over the north. This exceptional year was connected with the Pinatubo eruption (Rosenfeld and Yaari-Gazit, 1991; Kirchner et al., 1999) and with El-Nino effect (Price et al., 1998). A very interesting question is what the situation would have been without this exceptional year, and will be discussed in Chapter 4.

A negative climatic rain feedback connected to aerosol was recently suggested (Rosenfeld, 2000; Rosenfeld et al., 2001). The first reference shows negative influence of urban and industrial emissions on rain. The second show negative desert dust influence on Israel rains. It should be noted, that the increasing NAO index over the last decades was also connected with increasing dust emerging from the Sahara Desert (Moulin et al., 1997). These negative influences have not been investigated yet in Israel.

Alpert et al., (2001) recently showed that the total precipitation decrease over the Mediterranean region goes along with a paradoxical increase of high intensity rainy days (above 64 mm/d). In addition, an analysis of the annual rainfall distribution in Israel (γ-distribution, Ben-Gai et al., 1998) shows that in the last decades the trend is toward high probability of rainier years and drier years as compared to normal years, i.e. there is a trend toward extremes in the annual total values as well as the daily values. Of course, this happens along with a continuous decrease in both the normal daily and the median annual values.

2.4. Evaporation

Trend analysis of the daily average pan evaporation values usually shows a decreasing trend, although the summer temperature has increased. Some stations like Sedom do show a considerable evaporation increase (Alpert et al., 1997), however, it was explained by a local climatic change resulting from drying of the Dead-Sea.

It might be that the evaporation decrease, which is more common in Israel, results from intensive land-use/land-cover changes near the measuring stations. These changes can be due to urbanization or irrigation. Another possibility is the reduction in the solar radiation. Stanhill and Cohen (2001) have reported a global decrease of about $20W/m^2$, which they entitled as global dimming, and was connected to the anthropogenic aerosol increase in the atmosphere, the cloud growth and probably also the greenhouse effect.

3. The predicted climatic changes in Israel

3.1 The IPCC report

The IPCC report (Chapter 10) summarizes temperature and rainfall changes according to Regional Climate Modeling (RCM) resulting from greenhouse effect. It is worth noting that RCM simulations have not yet been performed in Israel. Recently, a project was approved; TAU group will perform RCM simulations for Israel. The project is part of the German GLOWA program in collaboration with the Israeli Ministry of Science.

This chapter of the IPCC report summarizes the climate implications in different regions in the world according to the global climatic models. The results for the Mediterranean Sea region (MED), Sahara region (SAM) and central Asia (CAS) are very short. Israel is included in all of the three regions. It should be noted, that these regions are quiet large, and significant deviations as compared to the central and the western Mediterranean were found in Israel (see above). However, these predictions are important in showing general trends over and around Israel, and are used as boundary conditions for RCM model future runs in Israel which are vital for our understanding of the predicted climatic changes in Israel.

The report notes the average deviations according to 10 model runs including models by Australia, Germany, Japan, England, etc. These deviations (in percents) are for different regions in the world for the historical period of 1961-1990. It was done in order to find the ability of the models to perform past climate simulations, and to identify the consistent biases for different areas for each model. The biases for the MED rainfall in the winter months are around zero, however, the extreme values in certain models are around ±20%. It should be noted that these temperature and rainfall biases in our region are very small as compared to other regions in the world. The models' predicted changes are for the years 2071-2100 (with expected doubling greenhouse gases), as compared to 1961-1990. They are for the temperature (degrees) and rainfall (%) for the winter (DJF) and summer (JJA) months.

The predicted temperature rise at the MED region in the summer is 3.2-5.5°C. Similar increases have also been found at the SAH and CAS regions. In the winter the temperature increases are smaller, about 3-4°C. All the models show precipitation decrease in the MED region. These decreases are between 3% to 35%. It should be noted, that this result is unusual as compared to other 23 regions in the world analyzed in the IPCC report. Usually rainfall increases are predicted in most regions in the world. It should also be noted that the predicted MED rainfall decrease fits well to the 20th century trends (see 2.3).

3.2 Preliminary experiments with RCM models over Israel

In a preliminary work by Segal et al. (1994), a regional model was applied for three rainfall events in the eastern Mediterranean and Israel. This was performed with the doubling of CO_2 in the atmosphere, and without it. Indeed, the input for the model was based on earlier (late 80s) greenhouse effect models. However, the predictions do not differ much from those reported in IPCC (2001), Ch. 3.1.

Segal et al., (1994) found that in 2 out of the 3 Cyprus low rainfall events investigated, there were increases in the rainfall in Turkey, and **decreases** in Israel. Only in the third event a small increase was found in Israel (13% increase in Tel Aviv, as compared to about 70% decrease in the other two events). Recently, preliminary experiments with RCM model were performed at Tel Aviv University. The run was for one month with good results. There is no doubt that a policy in Israel that will lead to scientific effort toward improving the resolution in dynamical and statistical models is required. This will ensure our better understanding of the downscaling results of the greenhouse effect in Israel.

4. Summary and recommendations

The global estimations according to the new IPCC report for our region are very severe:

a. A considerable rainfall decrease of 3-35% is expected and agreed by all the different models runs.

b. A regional temperature increase of 3-5°C is expected.

It should be noted that these are predictions to the years 2071-2100; however, these climatic changes are very acute. Analyses of the actual climatic changes over the last 50 years at the Mediterranean Sea region are in general in agreement with these trends. However, in the small area of Israel and the south-eastern Mediterranean the rainfall decrease which was observed in the other Mediterranean Sea regions has not been noticed yet. Also, the winter significant temperature rise has not been observed in Israel. However, the global trend toward extremism both in seasonal and daily rains as well as in temperatures is clearly noticed in Israel and the east Mediterranean.

The reasons for the rainfall decrease and the temperature increase which were found in most of the Mediterranean area but not in Israel are as follows:

First, the temperature rise in the summer was noticed to be about 0.21-0.25°C per decade. The decrease in the winter temperatures resulting directly from the NAO index rise, which is also a greenhouse effect result. This winter temperature decrease can partly explain also why the rainfall in and around Israel is not as expected in the other Mediterranean Sea regions (Striem, 1979).

However, it might be that the rainfall in Israel and the south-eastern Mediterranean regions is reduced since 1987; but it can't be noticed because of the exceptional rainy year of 1991/2. If indeed this blessing year is just a combination of the extraordinary Pinatubo eruption and an El-Nino effect, as certain studies suggest, these positive trends that we see in the second half of the 20th century have already changed their direction since the 1980s.

It should be noted that the examination of average rainfall trends from 5 years over north-eastern Israel (the Kinneret stations: Yiron, Kfar Blum, Dgania, Ayelet Hashahar and Kfar Giladi) without the exceptional year of 91/2 shows a drying trend since 1987. In this area the cumulative percent of the deviation from the normal (average for 1961-1990) of the average rainfall reaches an extreme value of -180% for the year of 2000. The previous extreme was -150% on 1965, which was after the dry series of late 1950s and early 1960s. However, in this period the water consumptions were low, and the drought period did not have such an effect as nowadays.

There are many open questions, especially with this special situation of Israel in the Middle East:

Are these exceptions of the rainfall and temperature in Israel going to continue?

Why is there a reduction in rainfall in north-eastern Israel? Is that connected with the southerly migration of the cyclonic anomaly in our region?

Why have rainfall increases been observed in the northern Negev at least till the 1990s? Have this trend been reversed?

What is the rainfall expected trend considering the enhancement of the greenhouse effect? And with the increasing of the NAO index?

What is the contribution of anthropogenic aerosols to the precipitation? What is the increasing dust contribution along with the NAO index?

Some answers may be given with the aid of regional climate simulations, along with advanced statistical methods for downscaling. These have not been done yet in Israel, although Israel is located in an especially sensitive area on the desert edge. Multi-disciplinary studies, which will attack these problems from different points of view, are urgently needed.

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References

Alpert P., 2000. "Why are winter temperatures decreasing in Israel?", Israel Met. Soc. Meeting, Awia Hotel, Lod.

Alpert P. and Ben-Zvi A., 2001. "The effects of climatic change on the availability of water resources in Israel". **Water**, *51 (Oct.)*, 10-16. (in Hebrew).

Alpert P., Shafir H. and Issahary D., 1997. "Recent changes in the climate of the Dead Sea Valley", **Climatic Change**, 7, 513-537.

Alpert P., Ben-Gai T., Baharad A., Benjamini Y., Yekutieli D., Colacino M., Diodato L., Ramis C., Homar V., Romero R., Michaelides C. and Manes A., 2001. " Evidence for increase of extreme daily rainfall in the Mediterranean in spite of Decrease in Total Values", **Geophy. Res. Lett**. (submitted)

Alverson K. et-al., 2001. "A global Paleoclimate observing system" **Science**, *293*, 47-48.

Ben-Gai T., Bitan A., Manes A. and Alpert P., 1993. "Long-term change in October rainfall patterns in southern Israel", **Theoretical and Applied Climatology**, *46*, 209-217.

Ben-Gai T., Bitan A., Manes A., Alpert P. and Rubin S., 1998. "Spatial and temporal changes in annual rainfall frequency distribution patterns in Israel", **Theoretical and Applied Climatology**, *61*, 177-190.

Ben-Gai T., Bitan A., Manes A., Alpert P. and Rubin S., 1999. "Temporal and spatial trends of temperature patterns in Israel", **Theoretical and Appl. Climatology**, *64*, 163-177 .

Ben-Gai T., Bitan A., Manes A. and Alpert P., 2001. "Climatic variations in the moisture and instability patterns of the atmospheric boundary layer at the east Mediterranean coastal plain of Israel". **Bound. Layer Meteor.**, *100*, 363-371.

Dai, A., Fung I. Y. and Del Genio A. D., 1997. "Surface observed global land precipitation variations during 1900-1988". **J. Climate**, *10*, 2943-2962.

IPCC, Climate Change, 2001. The Scientific Basis, Contribution of WG I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge Univ. Press, 2001.

Kirchner I., Graf H. F., Rodock A., Antuqa J. C., 1999. "Climate model simulation of winter warming and summer cooling following the 1991 Mount Pinatubo volcanic eruption". **J. Geophys. Res.**, *104*, 19039-19055.

Krichak S., Kischa P. and Alpert P., 2001. "Decadal trends of main Eurasian oscillations and the Mediterranean precipitation". **Theor. and Applied Climatology**, (submitted)

Moulin et al, 1997. "Control of atmospheric export of dust from north Africa by the North-Atlantic Oscillation". **Nature**, *387*, 691-4.

Otterman, J., Manes A., Rubin S., Alpert P. and Starr D., 1990. "An increase of early rains in Israel following land use change?" **Bound. Lay. Meteorol.** *53*, 333-351.

Paz S., Steinberger E. H. and Kutiel H., 1998. "Recent changes in precipitation patterns along the Mediterranean Coast". **2nd International Conf. On applied climatology**, Vienna, Austria, p. 79.

Piervitali, E., Colacino, M. and Conte, M., 1998. "Rainfall over the central-western Mediterranean basin in the period 1951-1995, Part I : Precipitation trends". **Nuovo Climento C**, *21*, 331-344.

Price C., Stone L., Huppert A., Rajagopalan B. and Alpert P., 1998. "A possible link between El-Nino and precipitation in Israel". **Geophys. Res. Letters**, *Vol. 25, No. 21*, 3963-3966.

Rosenfeld D. and Yaari-Gazit N., 1991. "The volcanic eruptions effect on the rainfall in Israel". **Meteorologia B'Israel**, *1*, 75-83 (in Hebrew).

Rosenfeld, D., 2000. "Suppression of rain and snow by urban and industrial air-pollution". **Science**, *287*, 1793-1796.

Rosenfeld, D., Rudich Y. and Lahav R., 2001. "Desert dust suppressing precipitation- a possible desertification feedback loop". **Proceedings of the Nat. Academy of Sci.**., *98*, 5975-5980.

Segal M., Alpert P., Stein U. and Mandel M., 1994. "On the 2xCO2 potential climatic effects on the water balance components in the Eastern Mediterranean", **Climatic Change**, *27*, 351-371.

Stanhill, G. and Cohen, S. 2001. "Global dimming: a review of the evidence for a widespread and significant reduction in global radiation with discussion of its probable causes and possible agricultural consequences". **Agricultural and Forest Meteorology**, *107*, 255-278.

Steinberger E. H. and Gazit–Yaari N., 1996. "Recent changes in the spatial distribution of annual rainfall in Israe"l. **J. Climate**, *9*, 3328-3336

Striem H. L., 1979. " Some aspects of the relation between monthly temperatures and rainfall, and its use in evaluating early climates in the Middle East". **Clim. Change**, *2*, 69-74.

Thompson, D. W. J. and Wallace J. M., 2001. "Regional climate impacts of the northern hemisphere annual mode". **Science, *293***, 85-89.

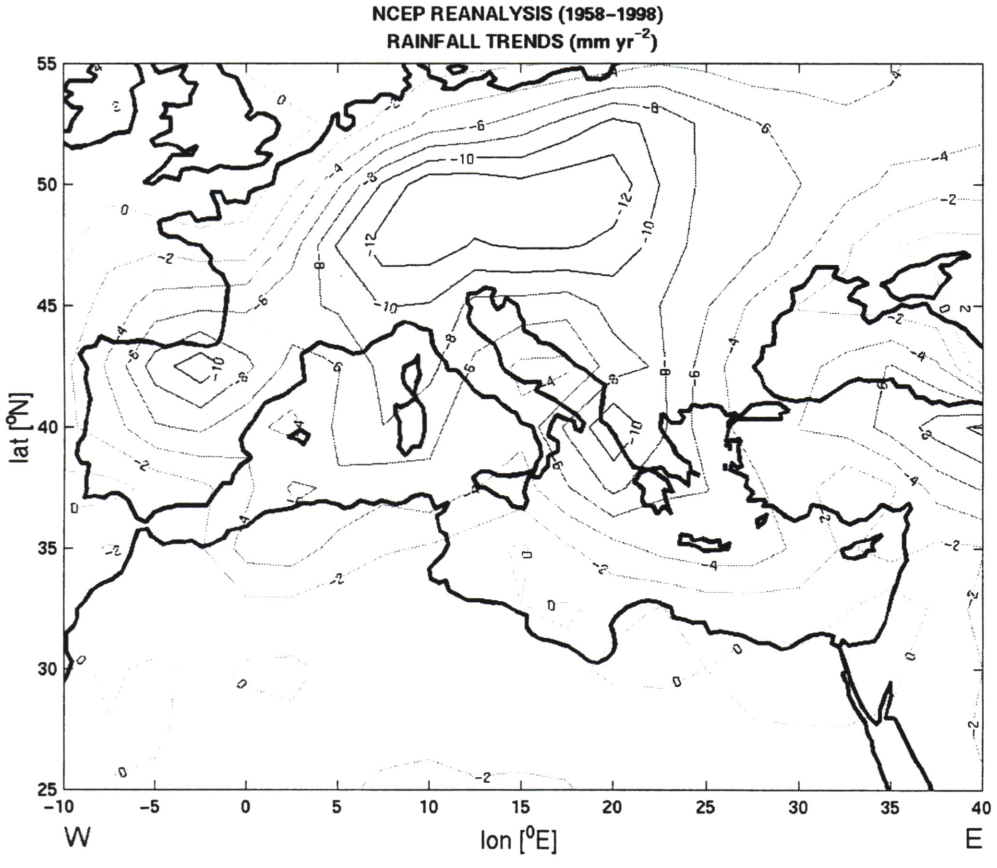

Figure 1: The precipitation trends in the Mediterranean Sea based on the NCEP reanalysis for 1958 – 1998.