PRECIPITATION OVER THE SEA IN THE COASTAL AREA OF ISRAEL; A POSSIBLE NEW SOURCE OF WATER

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1. BACKGROUND

The search for new water resources in arid and semi-arid regions like Israel is crucial (Margat at al. 2000, Gabbay 1998). Recent dry years in this region have demonstrated how critical these situations can become. One source of fresh water that has not been utilized is rainfall over the sea. Although precipitation in the eastern Mediterranean falls only in the late fall, winter, and early spring, the amount of water that falls over the sea, just a few kilometers to the west of the coast of Israel, for example, could potentially be used as a new and relatively inexpensive additional source of natural high quality fresh water. In this paper, we describe measurements that show the potential of this unexplored source and suggest a method for collecting rainwater over the sea.

2. RAIN OVER THE SEA VERSUS OVER LAND

Meteorological observations conducted in the area of Tel-Aviv during the rainy seasons in the last ten years, using the Tel Aviv University C-band meteorological radar show that the quantity of precipitation over the sea near the coast is sometimes similar, but often substantially greater than the quantity of precipitation over a similar area on the land just to the east of it. Moreover, even during dryer years over the land, the precipitation over the sea west of the coast of Israel is still substantial. The reasons for this stem from the fact that in the winter the Mediterranean Sea is warmer than the adjacent land, leading to land breeze from east to west in the lower elevations. This wind opposes the synoptic westerly winds, slowing the approaching storms and in some cases preventing the clouds from crossing the sea shores (Khain at al. 1993).

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In order to better quantify the difference between quantity of the rain falling over the sea versus that that is falling over land, we defined an area of a 60 km radius around the Tel Aviv University meteorological radar (northern Tel-Aviv). The analysis of the data indicates that in this area the ratio of the monthly average precipitation over the sea to that over the land ranges from 1:1 to 3:1 (Figure 1).

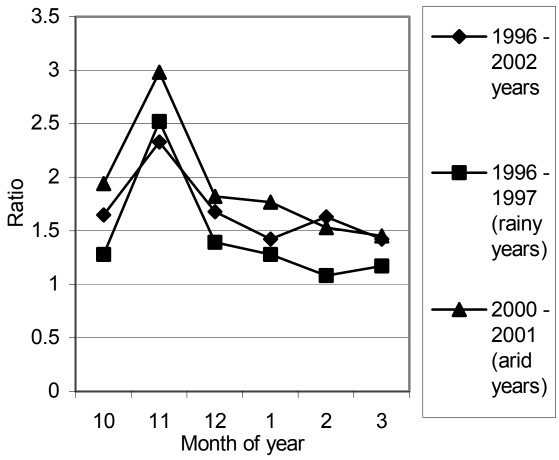

Figure 1. Sea / land precipitation ratio.

In other words, the amount of precipitation falling on the sea near the coast is as much as three times that falling over the adjacent land. In addition, the precipitation period in the costal sea area is often as much as two months longer then that over the adjacent land.

Figure 2 demonstrates the total precipitation amount in November 1996. In this month sea /land precipitation ratio was 2.5 and, as we can see, most of precipitation falls in the sea near the coastline of Israel.

In order to determinate the possible water harvesting time more qualitatively, we defined the effective precipitation region. That region is the compact region, were the precipitation rate exceeds a threshold value during fixed time. This is the time that we define as the potential water harvesting time. In our present evaluation we take into account only water harvesting regions with water harvesting time of more than two hours. We suggest that such regions could fit well our water harvesting technology.

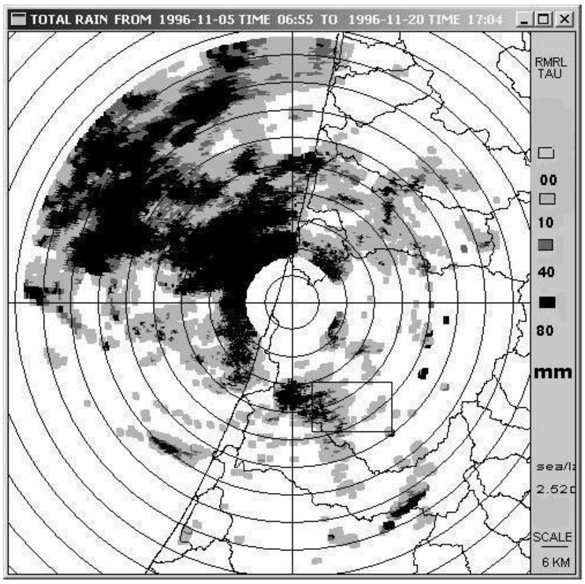

Figure 2. Radar integrated precipitation amount in November 1996.

Using archived radar data we calculate the harvesting time for effective precipitation regions having intensities of more than 35 mm / hour.

Taking into account that the data is not complete because of the radar technical problems, we have the following results.

Table 1 demonstrates the potential of harvesting time in effective regions with rain intensity threshold 35 mm / hour in the sea near the coastline of Israel in 60 km radius from the Tel Aviv University radar. It is about 400 hours for rainy and ordinary years and it exceeds 250 hours for dry years. Assuming that the characteristics of the rain is similar in adjacent areas of larger extend, the harvesting time may be enlarged accordingly. We estimate that the harvesting time could be enlarged by factor of 2 – 3 in 100 – 150 km region along the coastline of Israel.

Season (years)	Harvesting time (hours)	Type of season	Observation period (month)
1997 – 1998	396	Mean	1997:10,11,12 1998:1,2,3
2000 – 2001	248	Dry	2000:10,12 2001:1,2
2002 – 2003	387	Rainy	2002;10,11,12 2003:1,2,3

Table 1.Harvesting time in the sea near the coastline of Israel (60 km radius area) for different years.

Figure 3 demonstrates the monthly distribution of potential harvesting time in effective regions with rain intensity threshold 35 mm / hour in 60 km radius area from Tel Aviv University radar.

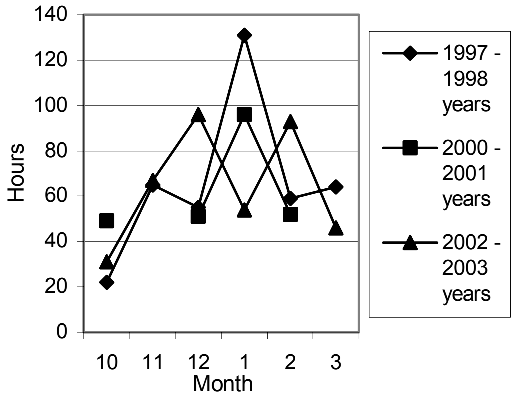

Figure 3. Distribution of potential water harvesting time.

Investigations conducted in Israel (Gabbay 1998, Mamane 1987, Singer 1994) also show that the quality of the rainwater falling over the sea near the coastline is higher (particularly with regard to PH) then that of rainwater over continental regions. This is primarily due to the degradation by pollution over the continent. This suggests that the rainwater over the sea might be of sufficiently high quality to make the proposed technology economically feasible not only due to the lower cost of water collection, but also due less expensive treatment to make it ready for human consumption.

3. THE PROPOSED METHOD FOR HARVESTING RAINWATER OVER THE SEA

The method consists of a ship or ships with relatively large rain collecting surfaces. Rainwater is collected by guiding the ship/s to the center of the rain shaft in the storm and by continuously remaining under it during the storm’s lifetime.

Important elements of the rainwater harvesting technology involve the use of long and short-range weather forecasting tools. These tools can be composed of numerical forecasting models for the longer-range prediction (MM5 (Grell at al.1995) or RAMS (Walko at al. 2001)) and radar tracking and forecasting tools (e.g. TITAN -Thunderstorm Identification, Tracking and Analysis (Dixon at al. 1993)). The role of these tools is to identify in advance the place, time and characteristics of the rain in real time, to accurately forecast the rain process development and to direct the ships to the area where the maximum rainwater can be collected.

In order to maximize rainwater production while minimizing the overhead costs, the routes of the collecting vessels have to be optimized. The optimization algorithms need to take into account that at any time there can be a number of regions with similar rain potentials and rain intensities. If a number of vessels for water harvesting are used, it is important to take into account the relative mutual positions of the vessels with respect to the rainy regions, and the costs versus expected benefits of deploying a specific vessel to a specific region for the next time window.

Therefore, to perform this work effectively the following components are needed:

- Radar-based estimation of maximal precipitation potential and maximal rain intensity over the sea, west of the coast of Israel.
- Forecasting of precipitation development and storm movement using both radar and numerical-statistical models.
- Choosing optimal routes for ships on which the potential for water harvesting is maximal.
- Navigating, managing and controlling the vessels used for water harvesting.

4. THE MANAGEMENT OF THE OPERATIONS

Although the system seems rather simple, it does require number of components in order to manage the operations and optimize the harvesting process. The basic system components are the management center, the meteorological radar, ships and the port quay.

The management center contains hardware and software for the meteorological radar data control system; the meteorological forecasting system; the ship control system; the radio communication system.

The meteorological radar is equipped with the special purpose hardware and software for presenting the information about the current precipitation rate and ship's location in real time. This information is used by the management center to navigate the ship towards, and within the water collection region.

The ship is equipped with special means for water collection, radio communication system, GPS system and active reflector for facilitating the recognition of the ship's coordinates on the radar.

In the port we need a quay being equipped for unloading and transporting the water from the ship to the storage places or for disseminating it to the users.

5. COST ESTIMATION

Although the precise evaluation of this method and the best ways to utilize it are still under investigation, it is worthwhile to estimate the cost of the proposed method. Characteristics of the modern vessels such as tankers and ocean barges that can be used for water harvesting, suggest that an area of water harvesting on the top of such vessels can reach a size of 6000 - 15000 m^2 per vessel (Marcon International).

From the statistics of the Israeli Meteorological Service (Shacham 1992) and from our radar measurements (Table 1) we know that during the rainy season there are about 400 suitable hours per year within effective precipitation regions with rain intensity threshold 35 mm /hour in the sea near the coastline of Israel in 60 km radius area from Tel Aviv University radar.

Therefore, potentially, 84,000 - 300,000 cubic meters of fresh water can be harvested per season using a single vessel. Of course, a number of such ships could be used simultaneously and special facilities for increasing the rain harvesting area on the ships can be designed to improve the collection by a factor of 1.5 – 2.

The method is economically affordable and not harmful to the environment. Using this method one can harvest natural high quality fresh water at the price of less than about 0.45 USD per cubic meter. This price is equivalent or lower than the current best estimates for desalination, but it could be reduced considerably if more than one ship is used and larger area is covered. It should also be remembered that the quality of water from the rain is much better than the water obtained from desalination, so that subsequent treatment is much cheaper. In addition, the presented method has no additional costs such as removal of salt or other complicated maintenance issues.

6. CONCLUSION.

In this paper, we describe measurements that show the potential of one unexplored source of natural fresh water, namely rainfall over the sea, and suggest a method for collecting this water. The method is economically affordable and not harmful to the environment. Using this method one can harvest natural high quality fresh water at the price of less than about 0.45 USD per cubic meter.

Although the proposed system seems rather simple, it does require number of components in order to manage the operations and optimize the harvesting process. The basic system components are the management center, the meteorological radar, ships and the port quay.

The proposed technology could be used not only in Israel but also in many other regions suffering from water deficiency and lying near the coastline. Such a system could be very useful for small islands with very little rainfall and not many underground resources. Examples of regions in which such a system could be effective include: Cyprus, Sicily, Crete, Crimea, Singapore, some of the Greek Islands and more. Investigation of the characteristics of these regions could provide information for optimal configuration of the proposed technology so that the local factors can be taken into account.

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