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EFFECTS OF ARTIFICIAL SEA-MIXING ON OCEANOGRAPHIC AND METEOROLOGICAL PROCESSES

by

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Discussion Paper

on

Gad Assaf's

ENHANCEMENT OF PRECIPITATION VIA SEA MIXING

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INTRODUCTION

The idea of artificial mixing of the Eastern Mediterranean (EM) as a practical means of increasing heat storage and rainfall on the Middle East is based on the relationship found by Tzvetkov and Assaf (1982) between these two parameters. The technology of mixing consists in entraining deep cold water to the surface, and the profitability of the enterprise is guaranteed by the very high ratio existing between the amount of energy stored as heat accumulation and the amount of energy required for the mixing necessary to allow this heat accumulation (∿ 50,000). This very attractive technique, although designed at increasing overland precipitation, will affect many other parameters and processes. The purpose of this paper is to discuss the most prominent effects of the artificial sea-mixing on oceanographic and meteorological processes.

SEA-MIXING AND NUTRIENT RECIRCULATION

The EM is a stratified water body having a "permanent thermocline" around 300 m and a "seasonal thermocline" approximately at 100 m in summer. During the winter mixing, the upper 200 m are fairly homothermal at a temperature of 16 to 17°C.

The oxygen profiles of the EM are very informative of the mixing conditions, since a slight decrease in mixing rate is always accompanied by a drastic decrease of oxygen, a substance which is incessantly consumed by the oxidative processes. Deep oxygen profiles measured by Oren (1970) show two important features:

1. a drastic decrease of concentration below 300 m in all seasons, confirming the presence of a permanent thermocline.

2. the presence of at least 3 mg l^{-1} oxygen in deep water, indicating that a slow but constant exchange of water exists between the upper layers and the water masses below the permanent thermocline.

An inverse pattern is found for the main nutrients: nitrogen, phosphorus and silica. In contrast with oxygen, these substances accumulate with depth. The low productivity of the EM is related to the poor recirculation of these nutrients. The high photosynthetic potential of the area, due to the highly favorable radiation situation, does not materialize into high productivity because of the lack of phosphorus, nitrogen and silica.

Deep profiles measured by Oren (1970) down to 1800 m show a net increase of concentrations of phosphorus at 200 m (0.2-0.3 μg at l^{-1} in comparison with 0.05 μg at l^{-1} at the surface). The concentration of phosphorus continues to increase with depth (0.4 μg at l^{-1} at 400 m and 1.0 μg at l^{-1} at 1000 m).

The artificial mixing of the upper 300 m of the sea will enhance photosynthetic activity and algal production by two mechanisms:

1. the redistribution of a given amount of nutrients stored in the layer between 200-300 m at a given time. A very crude calculation shows that by mixing an area of 300 km x 300 km we can recirculate as much as 30×10^{12} mg phosphorus stored in the 200-300 m layer. The redistribution of this phosphorus into the upper 300 m of the considered area would increase the phosphorus concentration by 60% were the recirculated phosphorus to remain in the considered mixing area. Taking into account losses by advection, the local increase will be much less but its effect will be felt on a wider area.

2. the recirculation at a faster rate of the dead organic matter sinking as a constant rain to the 200-300 m layer. This permanent recirculation will accelerate the mineralization of the organic phosphorus (P) and nitrogen (N) into inorganic forms assimilable to algae. In other words the turnover time of phosphorus and nitrogen will be shortened, and a given amount of P and N atoms will allow the formation of more biological material.

These processes will lead to a significant increase of primary productivity which is the first link of any terrestrial or marine food chain. In the EM it is the sine qua non step of fish production. The many EM countries depending on sea fisheries for their protein supply should see this increase of productivity as a very positive by-product of the artificial mixing. It is also a non-negligible fringe benefit for the project for those who will have to look at it from the purely economic point of view.

SEA-MIXING AND SURFACE TEMPERATURE

The Levant summer climate is dominated by the breeze regime: landward breeze during daytime and seaward breeze at night. This characteristic regime is due to the very different thermal capacity of seas and continents. During daytime the land is more rapidly heated by the sun than the sea. Consequently the air mass above the land masses expands rapidly and rises, initiating a landward flow of cooler marine air. At night, the continental air becomes rapidly cooler than the marine air mass and flows seaward.

Since the air flows are governed by the difference of temperature of the land and sea surfaces, it is clear that artificial mixing which will decrease the temperature of the sea surface will affect the breeze regime.

Mahrer (1982), utilizing a model developed by Segal et al. (1982) to simulate the diurnal variation of the sea and land breezes, investigated the possible effect of the decrease of the Mediterranean sea surface temperature which will result from artificial mixing. Two numerical simulations were carried out, one with the July average of the Mediterranean sea surface temperature (27.5°C) and one with a sea surface temperature of 24.5°C. The effects of the lowering of the sea surface temperature are as follows:

1. The changes in flow pattern mainly concern the coastal area.
2. With a sea surface at lower temperature, a stronger westerly wind will prevail

during daytime (an approximate increase of 15% of wind velocity at noon is predicted for the given 3°C difference of sea surface temperature).

3. At night the seaward breeze is reduced since the difference of temperature between land and sea diminishes.

4. A cooler temperature will prevail during daytime.

It is difficult to estimate the effect that a substantial increase of wind velocity will have on the human activities in the coastal areas (fisheries, tourism). A more positive aspect of this modification could be envisaged were the wind energy on the Israeli coast utilized on a large scale.

As far as the decrease of daytime air temperature is concerned, this may be considered as a fully positive side effect.

SEA-MIXING AND WINTER CLIMATE

The weather modification project has already generated considerable research concerning cloud formation in the EM. Outstanding results in this field have been obtained.

1. The clouds producing rain over the Levant are not born over the whole EM on the path of displacement of cold air masses, but they are rather formed along the African coast and near the Levantine coast (Tzvetkov et al., 1982). This is in perfect agreement with the finding by Hecht et al. (1982) that, in September 1980, high heat storage was concentrated at the eastern edge of the EM forming a thermal front near the Levantine coast. A similar feature having been reported earlier by Levine and White (1972), it seems that this accumulation of warm water near the Israeli coast represents a permanent feature strongly correlated with the formation of rain clouds in the EM.

2. Dry years and wet years do not differ by the number of rain events but by the duration of each event (Tzvetkov et al., 1982).

These observations indicate that the artificial sea-mixing will affect the winter climate in the following way:

1. intensification of cloud formation in an area of 200 km off the Israeli coast.

2. increase of duration of the storm events with an overall increase of number of rainy days.

This first examination of the side effects of artificial mixing is far from being exhaustive, and more research should be done to assess their effect on human communities and economic activities.