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Circulation and water exchange between the Mediterranean Sea and the Nile Delta Lakes

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Most of the energy driving nearshore processes along the Nile Delta coast comes from the Mediterranean Sea, in the form of winds, waves and currents. During the flood tide, Mediterranean waters enter the lakes for some distance, mixes with the brackish water and return back during the ebb tide. Besides the tidal effect, the prevailing winds and the drainage waters which are poured into the lakes, plays an important role in the water exchange between the sea and the lakes.

The Nile Delta lakes include Idku, Burullus, Menzala and Bardawel. The water exchange between the Mediterranean Sea and the lakes, as well as the Rosetta and Damielta estuaries of the River Nile has been affected considerably during the last thirty years.

From the hydrographic and geological surveys taken in front of the Nile Delta coast, in particular at the mouth of the lakes during the period 1960 - 1983, a few remarks can be summarized:

1. The circulation pattern along the coastal areas in front of the lakes indicate that the current direction might be the main reason for the erosion process.
2. The pattern of the mean size distribution of sediment indicates the erosion and accretion areas at the sea - lake connection.
3. The water exchange between each lake and the Mediterranean Sea has a considerable effect on the lake sediment dispersion at sea.

One of the most important features of the circulation of the southeast sector of the Mediterranean Sea before 1964, was the effect of the annual Nile Flood. Before completion of the dam, during the flood period, estuarine circulation pattern was a two layer flow at the mouth of the two estuaries, Rosetta and Demietta.

The general oceanographic conditions in the offshore region beyond the continental shelf did not change noticeably before and after 1964. The hydrographic conditions over the continental shelf in front of the Delta showed considerable change after 1964. Also, since 1964, almost no sediment has been discharged from the Nile. This has produced an imbalance in the near coast sediment budget, increasing erosion at the two mouths of the river Nile and shifting sediments along the coast.

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Levantine Basin circulation - An historical perspective

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The first map of the circulation in the upper and in the intermediate layers of the Mediterranean Sea is due to Nielsen (1912) who computed it from the data collected by the Norwegian ship Thor. In his data, the Levantine basin, investigated by the Thor in 1910, was represented by nine stations: four of them in the Cretan straits close to the shores of Cyrenaica and the other five across the basin roughly from Mersa Matruh to Rhodes. Thus, Nielsen's Levantine basin anticyclonic circulation, is based on continuity and geostrophic principles as well as on some plain common sense.

The Thor was followed by the American Atlantis in 1948 and by the French Calypso in 1956. The additional stations provided new details but, at least as far as the Levantine basin is concerned, the circulation is still depicted as generally anticyclonic and resembling Nielsen's description of almost half a century earlier. Thus, the Nielsen map became the established representation of the Levantine basin circulation and even as late as the end of the 70's one can find this map still quoted in the scientific literature.

Between 1959 and 1963, the Russian ship Vavilov carried out six detailed cruises in the Mediterranean Sea. Consequently, it was for the first time that the seasonal changes in the Eastern Mediterranean circulation were described. In particular, it was shown that the Ionian gyre reverses from anticyclonic in the summer to cyclonic in the winter. This reversal also appeared to induce a reversal in the current patterns in the Cretan straits. In the Levantine basin, the circulation in the upper layers is still depicted as cyclonic and with no significant seasonal changes. Finally, in the entire basin, the horizontal circulation in the deeper layers resembled closely that in the upper layers.

The validity of the cyclonic pattern of the circulation in the Eastern Levantine basin was supported by the tracing of the fresh waters of the Nile floods. These were shown to hug the Eastern Mediterranean coast and could be observed sometimes as far as Beirut. Nevertheless, some contradicting data began to appear. During the summer of 1963, the Sea Fisheries Research Station of Haifa began a series of detailed cruises in the Eastern Levantine Basin. To our surprise we found in the region a warm core edddy and anticyclonic currents along the coast of Israel. Towards the end of the sixties, S. Friedman from the IOLR, tried to determine the seasonal pattern of the currents over the Israeli continental shelf by tracing the paths of a series of free floating buoys. Acording to his reports, most of his buoys move persistently southward for a number of days. At the beginning of the seventies the IOLR carried out a long series of current measurements from current meters moored on the Israeli continental shelf. Once more we observed persistent southward flow although northward flow appears to be just as prevalent. Towards the end of the seventies, the IOLR started to carry out the MC cruises - a detailed investigation of the Eastern Levantine basin. Preliminary results indicated, once more, the presence of a warm core eddy south of Cyprus and subsequent southward flow along the Israeli coast.

At the beginning of the eighties, a group of scientists from various countries (Cyprus, France, Germany, Greece, Egypt, Italy, Israel, Turkey, U.S.A., and Yugoslavia) prepared a detailed plan for the cooperative investigation of the Physical Oceanography of the Eastern Mediterranean - POEM. So far five POEM coordinated cruises were carried out. During the first two - POEM01 and POEM02 - the Turkish ship Bilim and the Israeli ship Shikmona covered almost the entire Levantine basin with a dense grid of CTD stations. During those two cruises, the Shikmona augmented its data in the Eastern Levantine basin with even denser XBT casts. The objective analysis of this very dense set of measurements (Robinson et al., 1987) revealed a complex structure of mesoscale eddies, jets and filaments and indicated the presence of some larger features. Moreover, the analysis of a "coarse grid subsample" of this data set showed that the important features of this region can still be properly resolved. Thus, one could confidently apply the same methodology to the entire Levantine basin data set and expect meaningful results.

Subsequently, the data obtained by the Bilim and by the Shikmona were combined and objectively analyzed. The resulting maps indicate that the entire Levantine basin is populated by a wealth of mesoscale deformation. By and large, as previously stated by Ovchinnikov and his collaborators, there does not seem to be a significant difference between the summer and winter maps, and the surface features seem to persist throughout the deeper layers. Moreover, some features, such as the Rhodes gyre or the cyclonic circulation in the Cretan straits, resemble those described by the Russian investigators. On the other hand there are some features which differ significantly from any previous description. For instance, the flow in the Cicician basin appears to be far more meandering and disorganized than previously envisaged. Or, the large and intense anticyclonic gyre in the southwestern Levantine basin, near Mersa Matruh, which appears to have a smaller and weaker counterpart in the Russian maps. But, most of all, the intense anticyclonic eddy, or eddies, in the eastern Levantine basin, which appear to be the cause of southward flow along the coast of Israel. The eddies appear to be well established features both in the winter as well as in the summer. Between them they produce a general anticyclonic circulation pattern which appears to transport the Atlantic waters from the Cretan straits, through the center of the Levantine basin, southward along the coast of Israel and westward along the coast of Egypt, in the opposite direction to the one described in previous investigations.

Finally, before we replace one myth with another, we must realize that this description is based on incomplete information and that it is just one realization of the circulation pattern. In fact, objective analysis of the MC data base (Hecht et al, 1988) show occasional flow reversals and the presence of cyclonic edies close to the Israeli coast.