An Up-To-Date Version of the Levantine Basin Circulation

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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 mainly from the data collected during the 1910 cruise of the Danish ship THOR. In the Levantine basin, the THOR occupied 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. For his computations in the Levantine Basin, Nielsen also included data from the 1911 and 1912 cruises of the Danish ship PANGAN, as well as relying on the results of the 1890 expedition of the Austro-Hungarian ship POLA (Luksch and Wolf, 1892). Even so, the datat were hardly sufficient, but basing himself on continuity and geostrophic principles as well as on some plain common sense, Nielsen (1912) concluded that both the upper layer as well as the intermediate layer of the Levantine basin are flowing cyclonically (Fig. 1).

Generally speaking, the circulation of the Levantine basin did not preoccupy the scientific community, and the next extensive cruise in that region was carried out almost forty years later by the USA ship ATLANTIS in 1948, and was followed in 1956 by the French ship CALYPSO. The additional data provided new details, but at least as far as the Levantine basin was concerned, the circulation was still depcited as generally cyclonic and resembling Nielsen's description of almost half a century earlier. Thus, the Nielsen map became established representation of the Levantine basin circulation and, with minor modifications, one can find this map (Fig. 2) still widely quoted in the scientific literature even as late as the end of the 1970s (e.g. Lacombe, 1975).

Between 1959 and 1963, the Russian ship VAVILOV carried out six detailed cruise in the Eastern Mediterranean Sea. Subsequently, for the first time the seasonal changes in the Eastern Mediterranean circulation were described (Ovchinnikov and Fedoseyev, 1965). 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 indue a reversal in the current patterns in the Cretan straits. In the Levantine basin, the circulation in the upper layers is still depcited as cyclonic and with no significant seasonal changes (e.g. Fig. 3). Finally, in the entire basin, the horizontal circulation in the deeper layers is depicted as closely resembling that in the upper layers.

Additional evidence in support of the validity of the cyclonic pattern of the circulation in the Eastern Levantine basin was found in the drift pattern of the sand along the Mediterranean coast of Israel (e.g. Emery and Neev, 1960), or by tracing the fresh waters of the Nile floods (e.g. Fig. 4 from Hecht, 19643), which were shown to hug the Eastern Mediterranean coast and could be observed sometimes as far as Beirut. Unfortunately, the investigators appeared to ignore the fact that both processes are nearshore shallow water effects and not part of the Levantine basin criculation.

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 a warm core eddy in the region and anticyclonic currents along the coast of Israel (Fig. 5). This observation was far too revolutionary and we buried it in an internal report in Hebrew (Oren *et al.*, 1963). Toward 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. Friedman reports that most of his buoys moved 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 (Fig. 6). Toward the end of the seventies, the IOLR started to carry out MC cruises — a detailed investigation of the Southeastern Levantine basin. Preliminary results indicated, once more, the presence of a warm core eddy south of Cyrpus (Fig. 7) 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 (Malanotte-Rizzoli and Robinson, 1988). So far six POEM coordinated cruises have been carried out. During the first two, POEM 01 and POEM 02, 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 Southeastern 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 (Fig. 8). 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 even on a half-a-degree station grid. Thus, one could confidently apply the same methodology to the entire Levantine basin data set and expect meaningful results (Hecht *et al.*, 1988).

Subsequently, the data obtained by the BILIM and by the SHIKMONA were combined and objectively analyzed (Ozsoy *et al.*, 1989). The resulting maps (Fig. 9) indicate that the entire Levantine basin is populated by a wealth of mesoscale features, compatible with the local internal Rossby radius of 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 the winter maps, and the surface features appear 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 Cilician 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, 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, appear(s) to be the cause of southward flow along the coast of Israel. These 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 ub previous investigations. An analysis of the POEM V data (Pinard, 1988), although somewhat incomplete in the Levantine basin, supports the conclusions of Ozsoy *et al.* (1989).

Thus, we feel that at present, we have a very good description of the Levantine basin circulation. Nevertheless, 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) shows occasional flow reversals and the presence of anticyclonic eddies close to the Israeli coast. Thus, we can see that it is absolutely imperative to continue our quest for the verification and enhancement of our understanding of the Levantine basin circulation.

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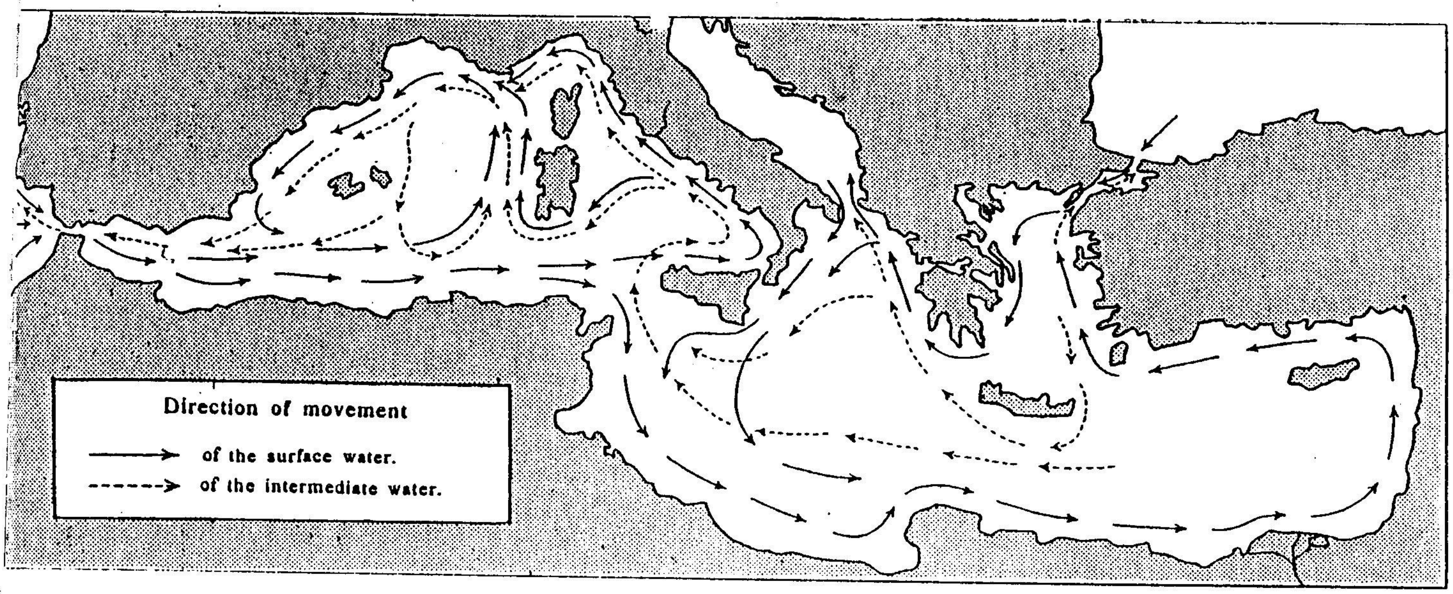


FIG. 1

Fig. 1 The Nielsen (1912) Mediterranean circulation map.

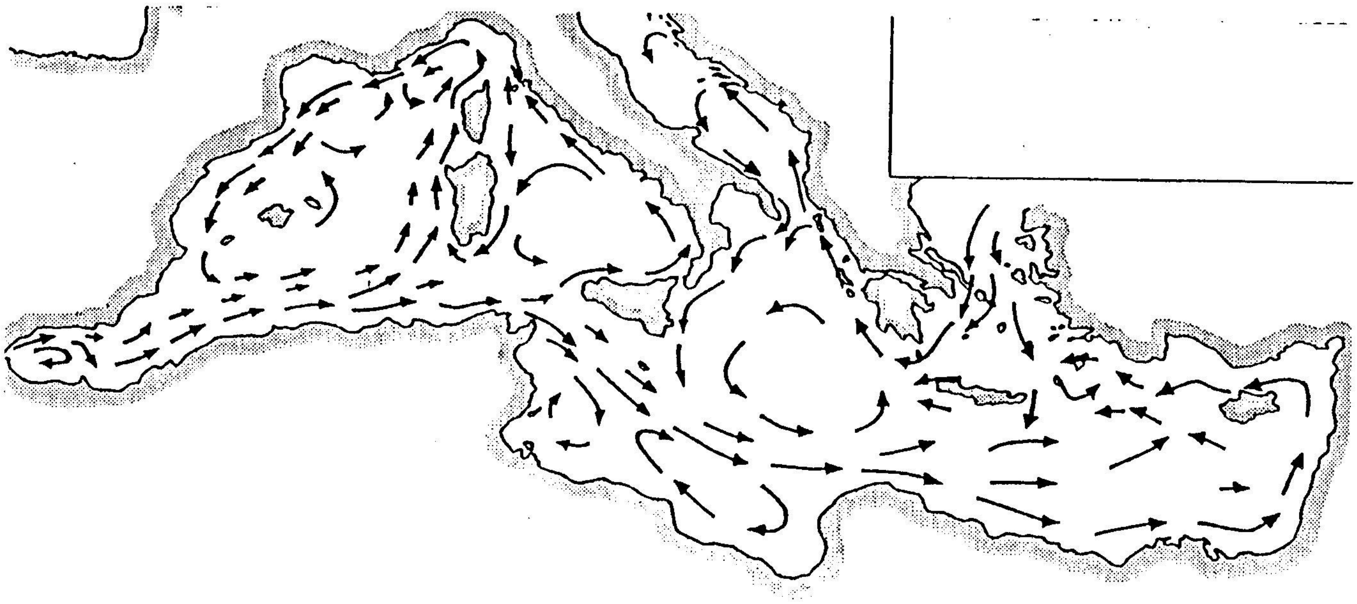


FIG. 2

Fig. 2 Mediterranean surface circulation in the summer, adapted from Nielsen by Lacombe (1975).

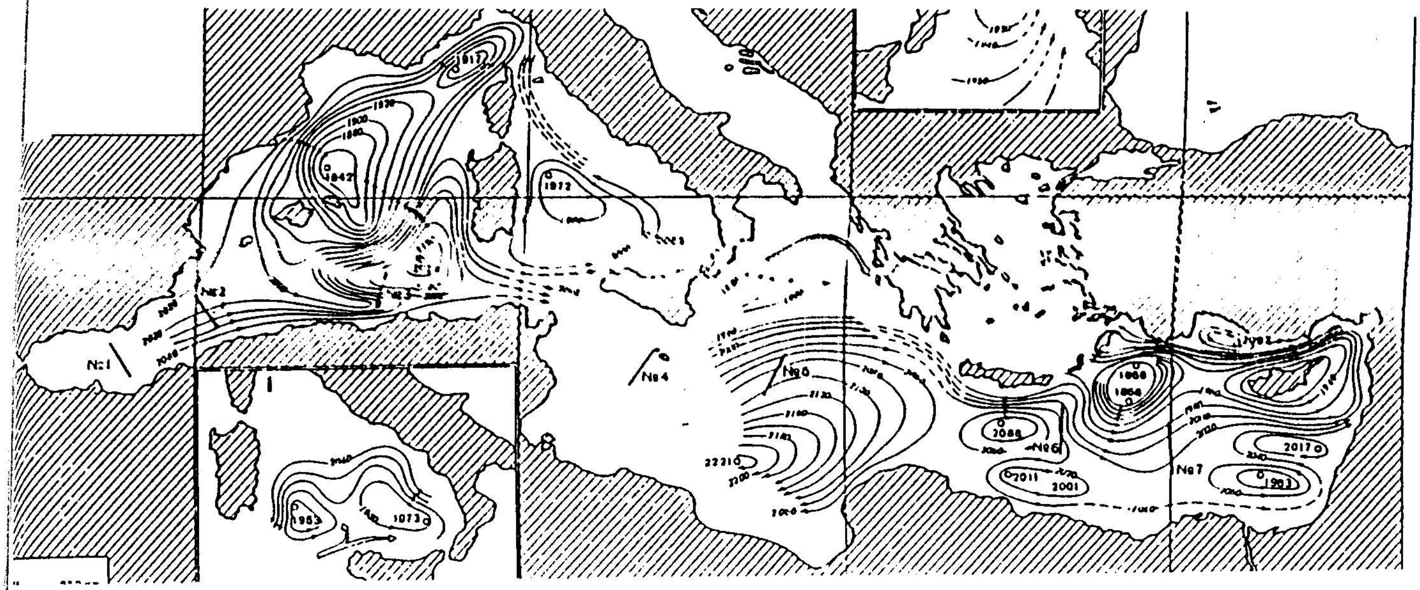


FIG.3

Fig. 3 Mediterranean surface circulation in the summer according to Ovchinnikov and Fedoseyev (1965).

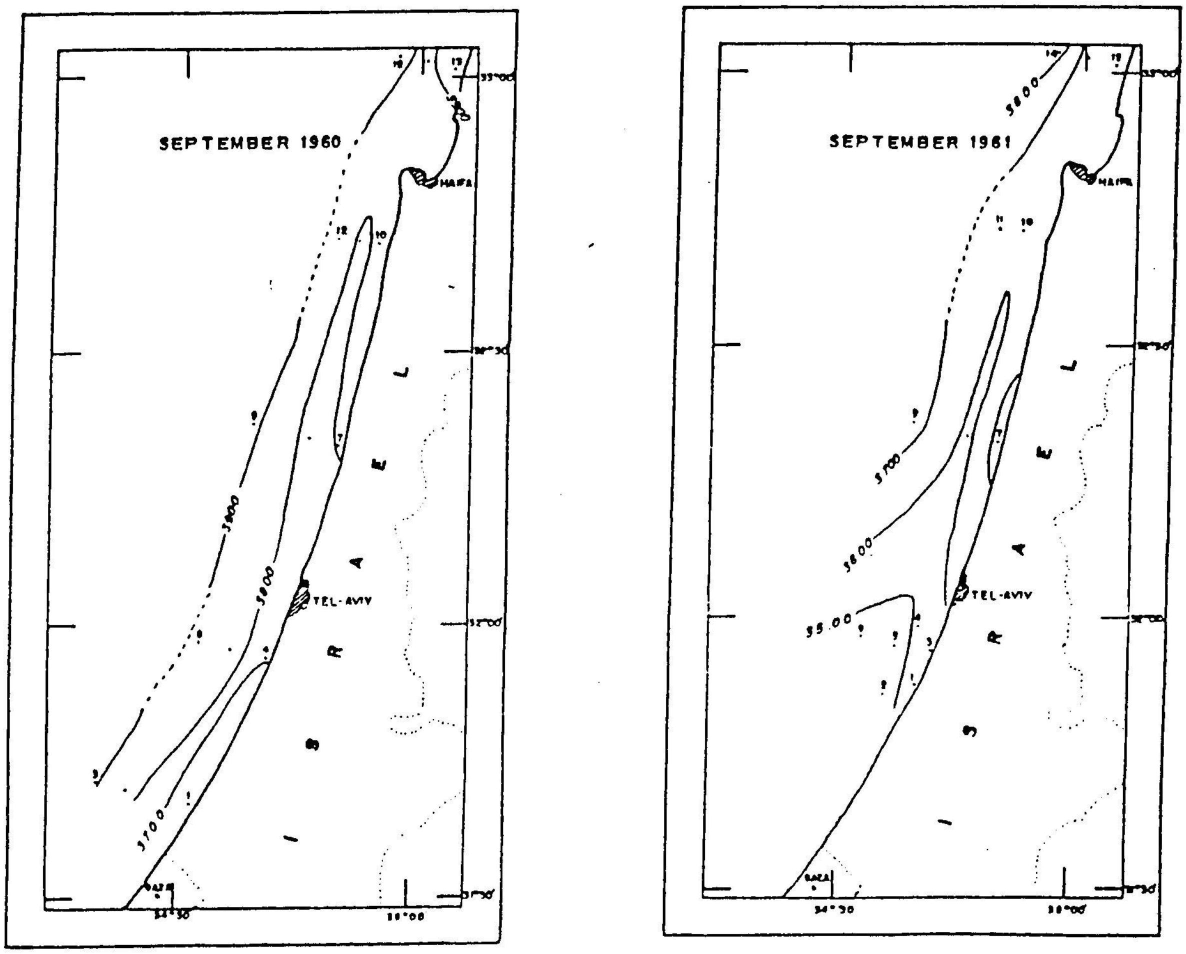


FIG.4

Fig. 4 The tongue of the Nile flood waters along the coast of Israel.

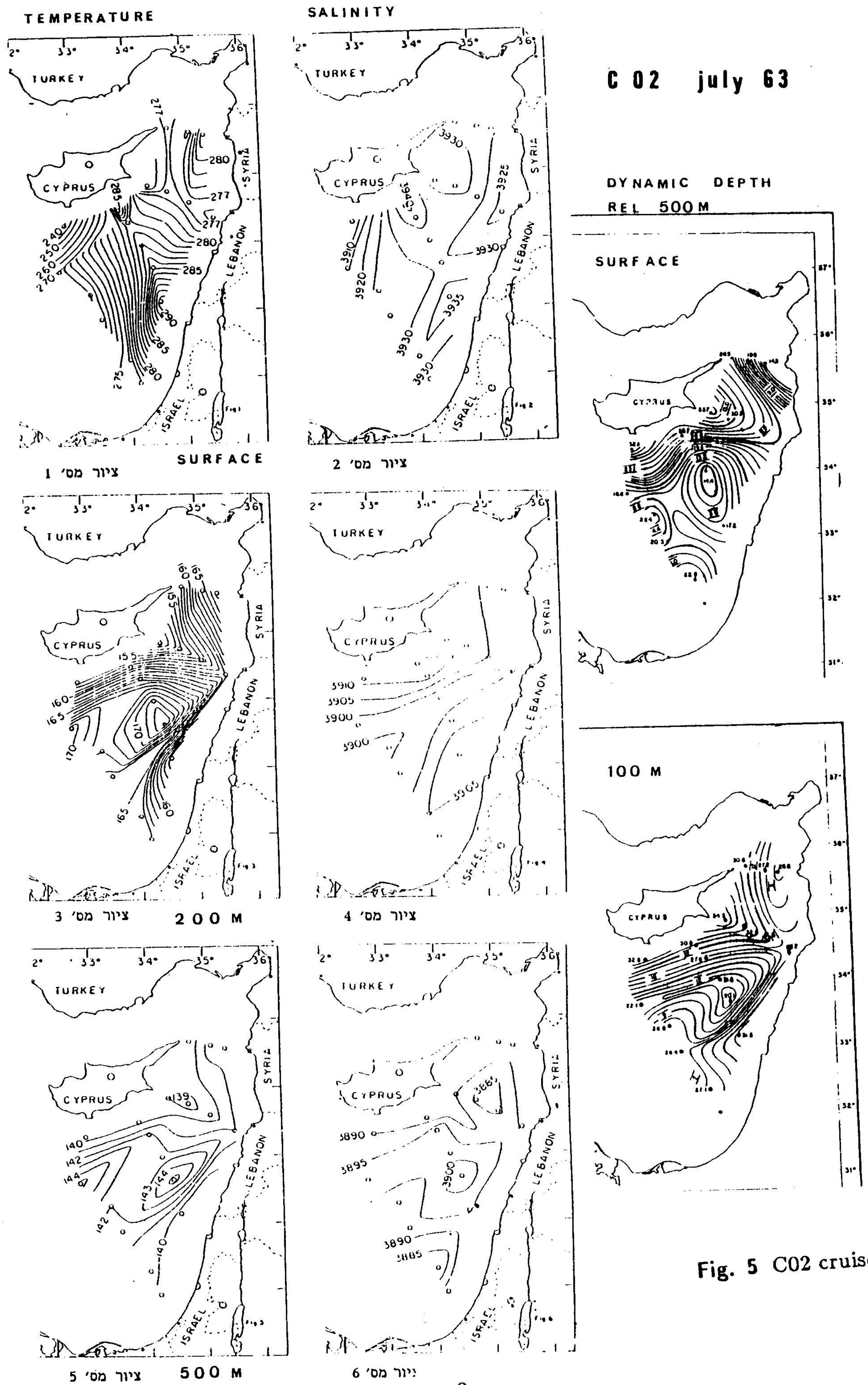


Fig. 5 C02 cruise results.

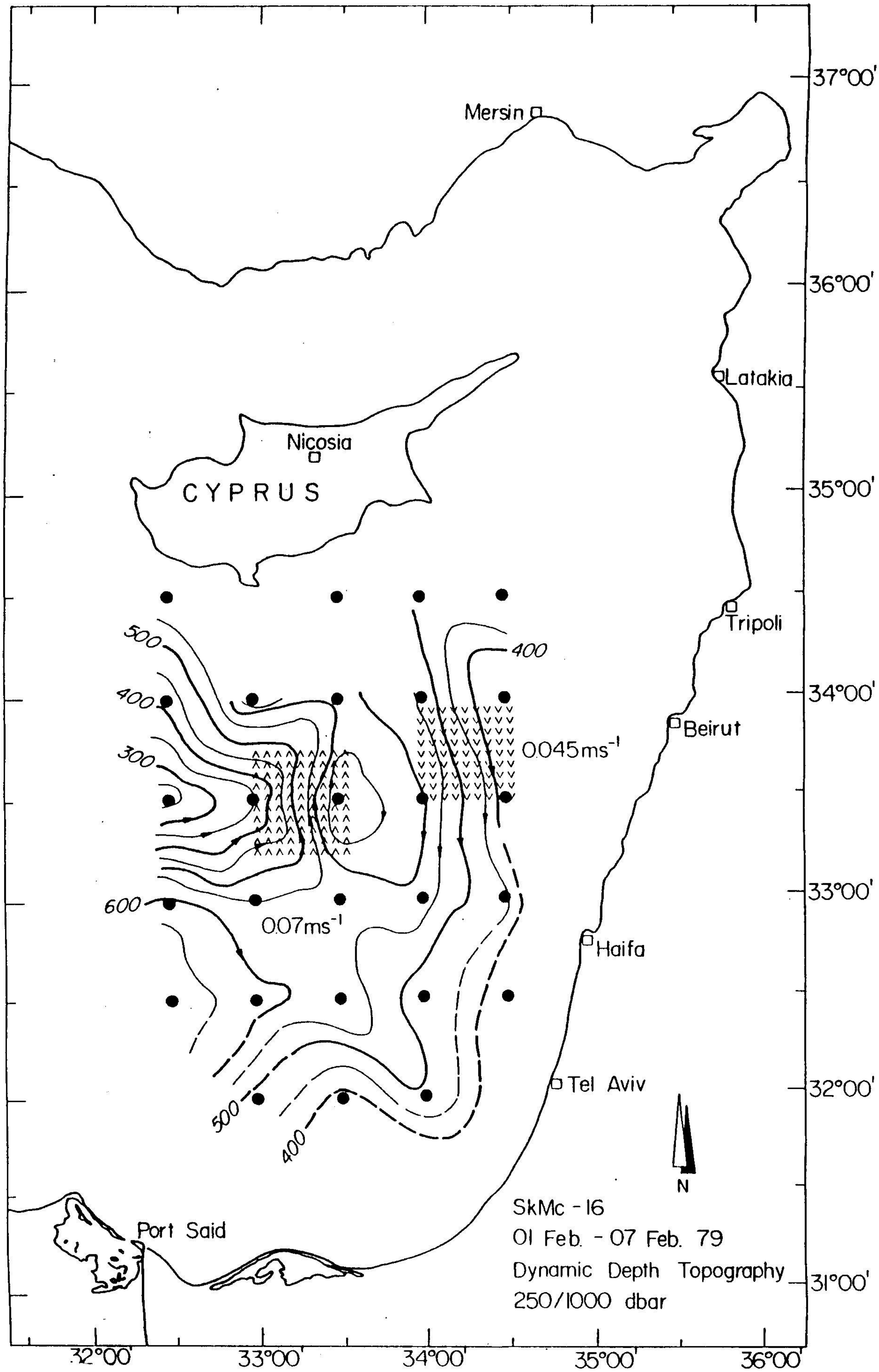
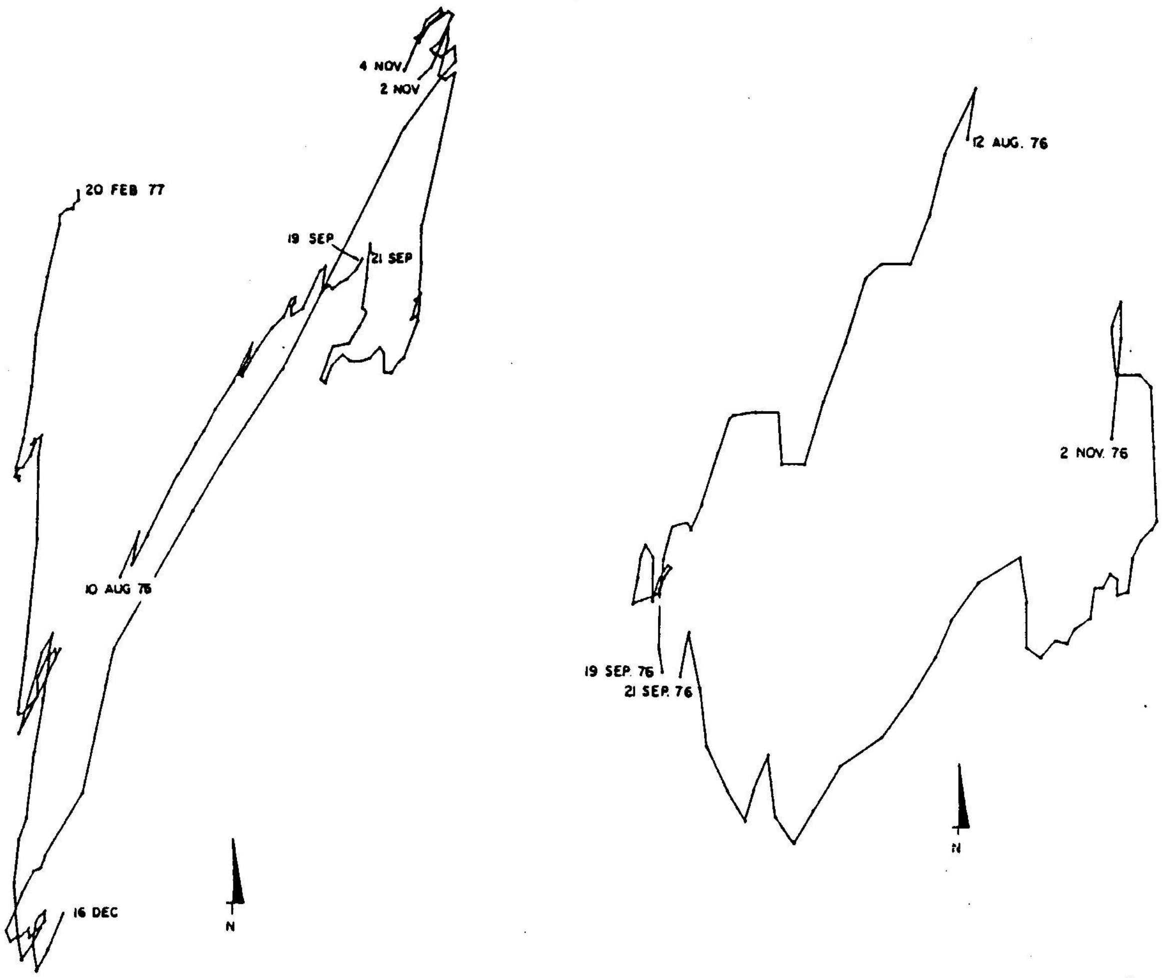


Fig. 6 A preliminary analysis of the MC16 data.



1.3 km offshore in 16m of water. Measured at 15m below average sea level.

2.6 km offshore in 24m of water. Measured at 15m below average sea level.

Fig. 7 Progressive vector diagram of currents on the continental shelf of Israel.

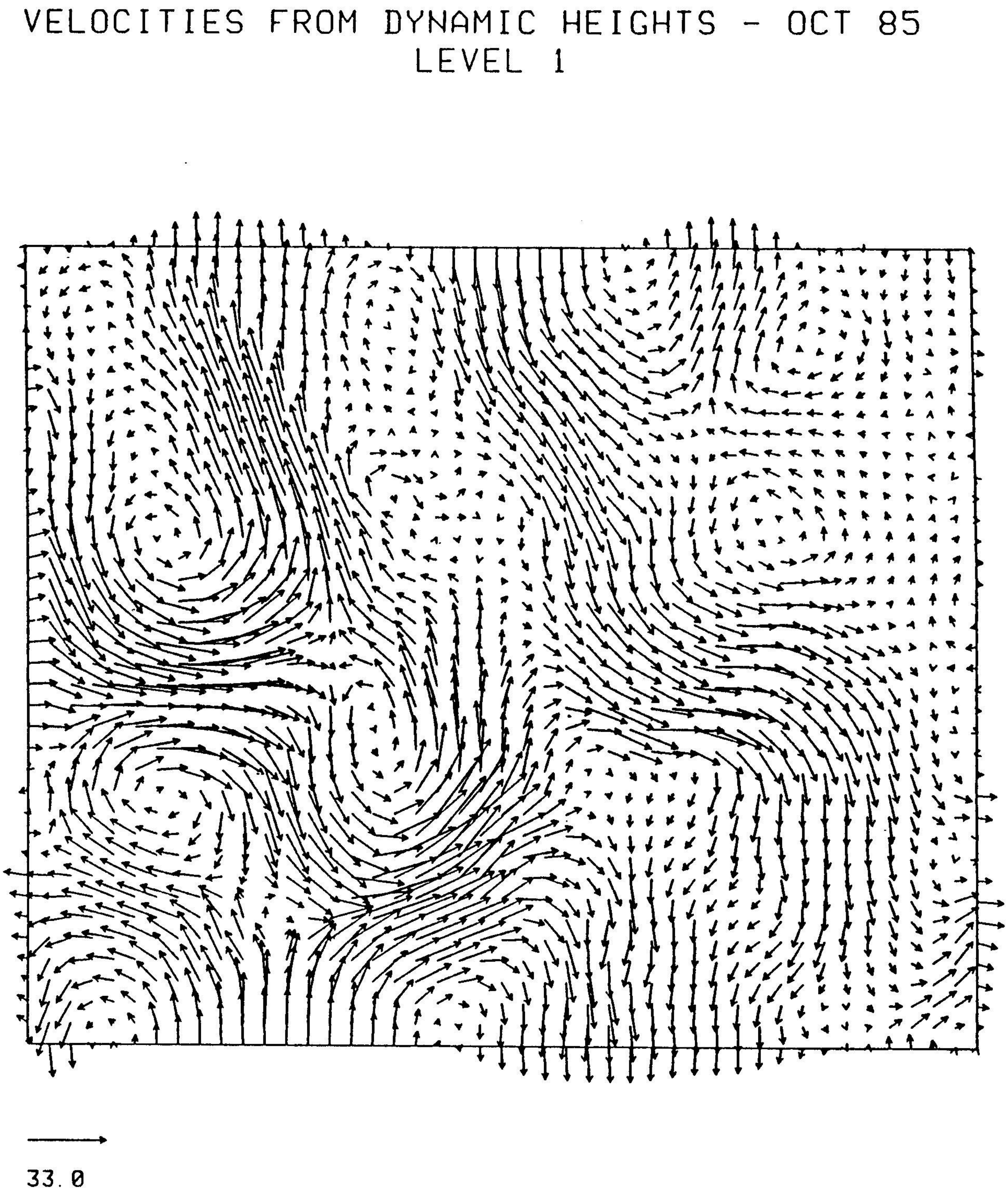


Fig. 8 Currents, eddies and jets in the southeastern Levantine basin.

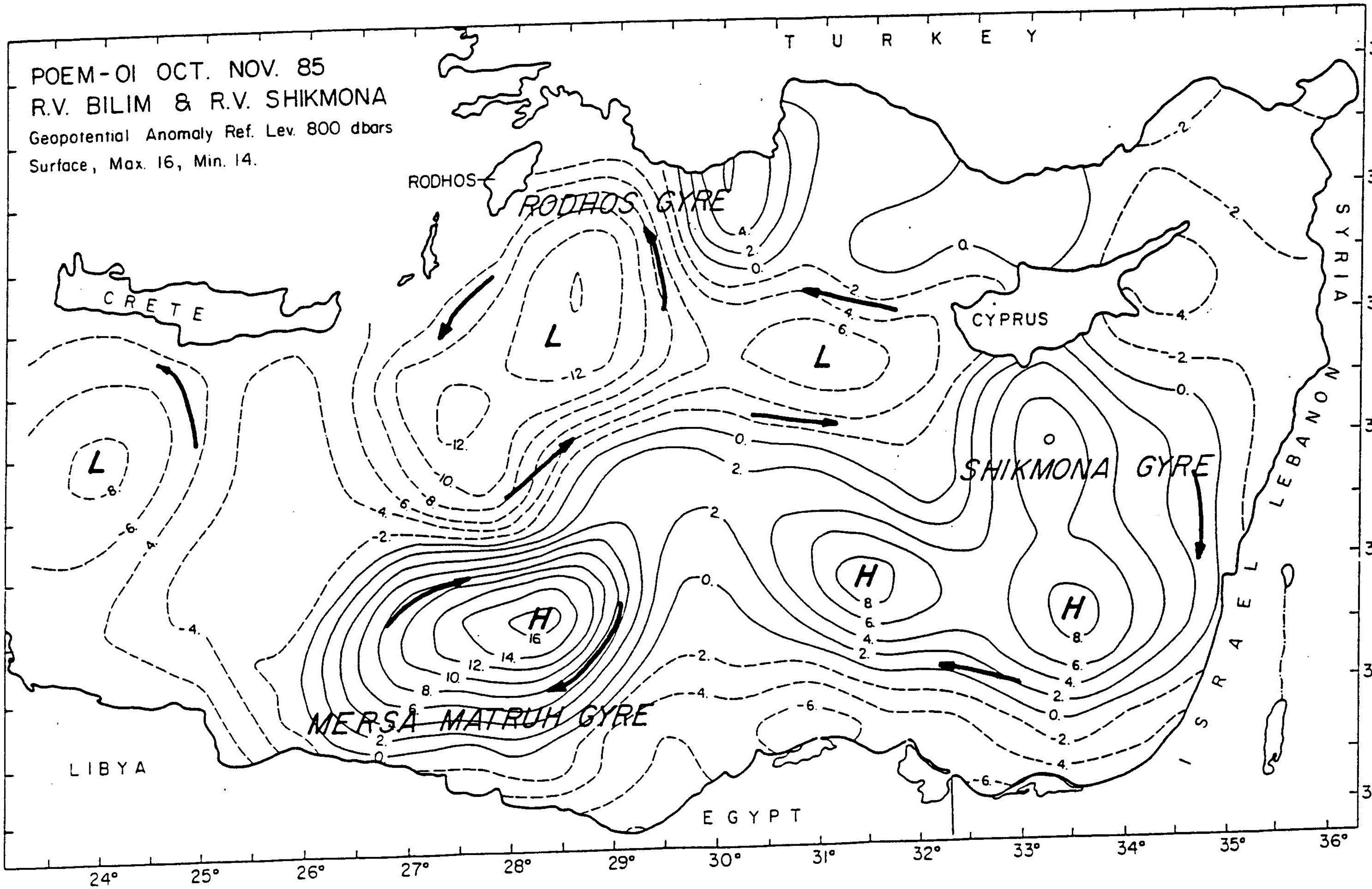


Fig. 9 Summer surface circulation in the Levantine basin according to the data from POEM 01.

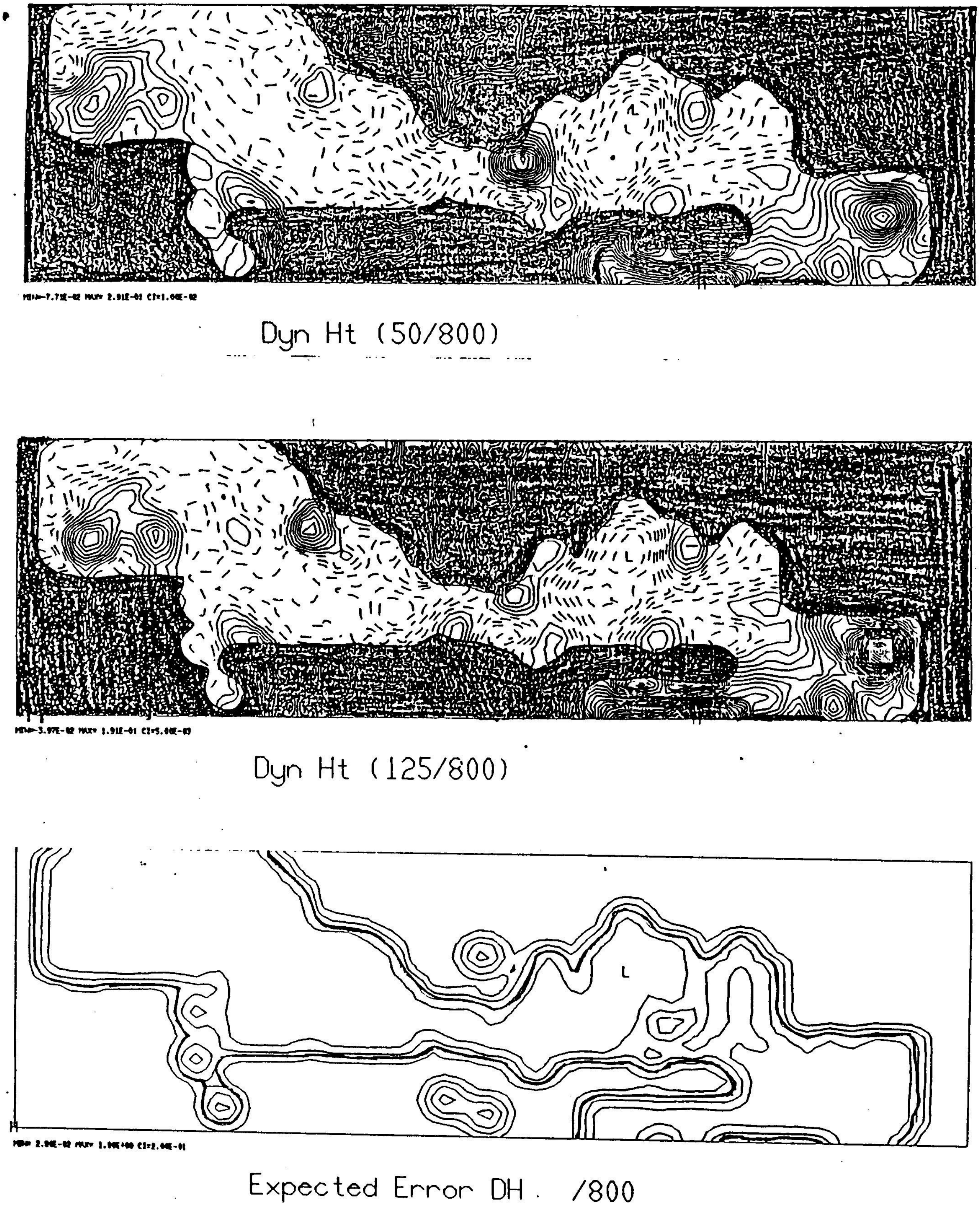


Fig. 10 Surface circulation of the Eastern Mediterranean Sea according to the data from POEM 05.

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