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A Numerical Investigation of the Circulation in the Mediterranean Sea

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ABSTRACT

A numerical model is used to obtain the stationary circulation pattern in the Mediterranean Sea for the winter season. The change of current velocity and direction with depth and some conclusions concerning the large-scale Mediterranean circulation were revealed.

INTRODUCTION

Despite the fairly clear picture of the general hydrographic regime of the Mediterranean Sea, a definite circulation pattern has not yet been set up using direct methods. This is mainly due to the technical difficulties involved in the problem of current measurements in the open sea.

Nevertheless, introducing the modelling approach to Marine sciences this difficulty has been circumvented and models have been recently devised to calculate the circulation pattern for different seas and oceanic areas.

The present investigation describes the results obtained by applying a numerical model of circulation to the Mediterranean.

THE MODEL

The model used here has been described in previous work (Gerges 1973: 1974). It is based on the linear hydrodynamic governing equations, and uses the observed density and wind fields with the real bottom topography, to obtain a 3-dimensional circulation pattern with an account for the joint effect of the barolinicity and real bottom relief as explained by Sarkisian and Ivanov (1971, 1972).

The stationary circulation pattern for the winter season has thus been obtained at a network of points at distance of half a degree latitude and longitude (about 40 km) for 12 standard levels from the surface to the baroclinic depth of 500 m.

RESULTS AND DISCUSSION

The surface circulation clearly reflects the wind field over the sea which is supposed to be the main factor driving the current system in the surface layer. Thus, the drift component of the current is dominating the surface circulation in the Mediterranean, except in the Gibralter region and in the eastern basin which are subjected to specific hydrographic and climatic conditions making the thermohaline effects play the main role in the circulation. This was explained (Gerges 1974) as due to the fact that the extreme wind velocities are greater over the western and central parts of the Mediterranean than over the eastern part (Klechenko 1970).

The velocities of the surface drift currents are ranging from 15 to 30 cm/sec, having a general cyclonic direction. Due to the narrowness of the Gibralter Strait, the velocities of the drift currents in this region are weaker (5-10 cm/sec). Meantime, the greater velocities are noticed in the Ionian Sea, where values exceeding 35 cm/sec. are obtained.

The total (drift plus gradient) current pattern (Fig.1) indicates the existence of six cyclonic gyres located as follows: in the Alboran Sea, around Corsica and Sardinia Islands, in the Ionian Sea, over the Crete-African sill, in between Crete and Cyprus Islands, and to the south of Cyprus Island. In addition, two local anticyclonic gyres were indicated. One in the Gibralter region with velocity 30-35cm/sec, and the other in the southeastern corner of the Eastern Mediterranean with velocity of about 40 cm/sec.

In the subsurface layer (50-100 m), the circulation patterns exhibit most of the features indicated at the upper levels. The general direction of currents still eastward. Some of the main gyres found at the surface and 20 m levels still could be traced down to the 100 m level.

However, due to the rapid decrease of the wind below the surface layer, the drift component of current decreases, and, hence, the velocities of the total current noticeably decrease with depth. They rarely exceed 20 cm/sec at the 100 m level.

One of the striking features of deep circulation in the Metiterranean is that the direction of currents in both the western and central basins is generally reversed at 150 m depth, indicating a clear transport of deep Mediterranean waters towards the Atlantic Ocean (Fig.2). Meantime, the deep currents in the eastern basin do not reverse direction. Here, the pattern exhibits one big gyre circulating the whole basin in a cyclonic fashion.

In the deeper layers, the velocity values continue to decrease and the indicated gyres weaken. At 400 m level, the velocities reach the value 2-5 cm/sec and the gyres practically disappear (Fig.3). Below 500 m depth, a nearly homogeneous deep water mass exists in the Mediterranean Sea. The density gradients are insignificant, and hence no appreciable change of the circulation pattern would be expected. The circulatory features at deeper levels are, thus, similar to those illustrated in figure (3).

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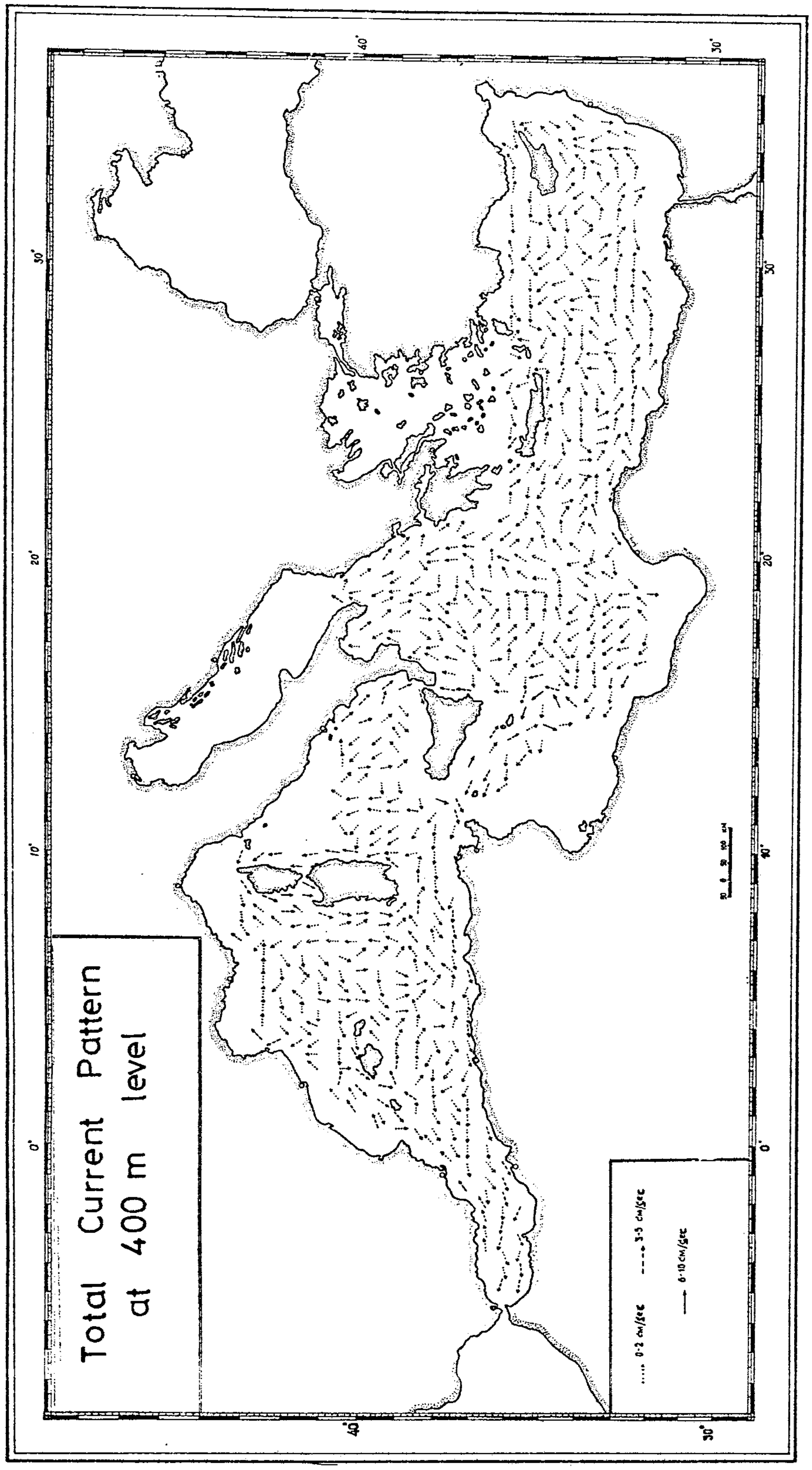
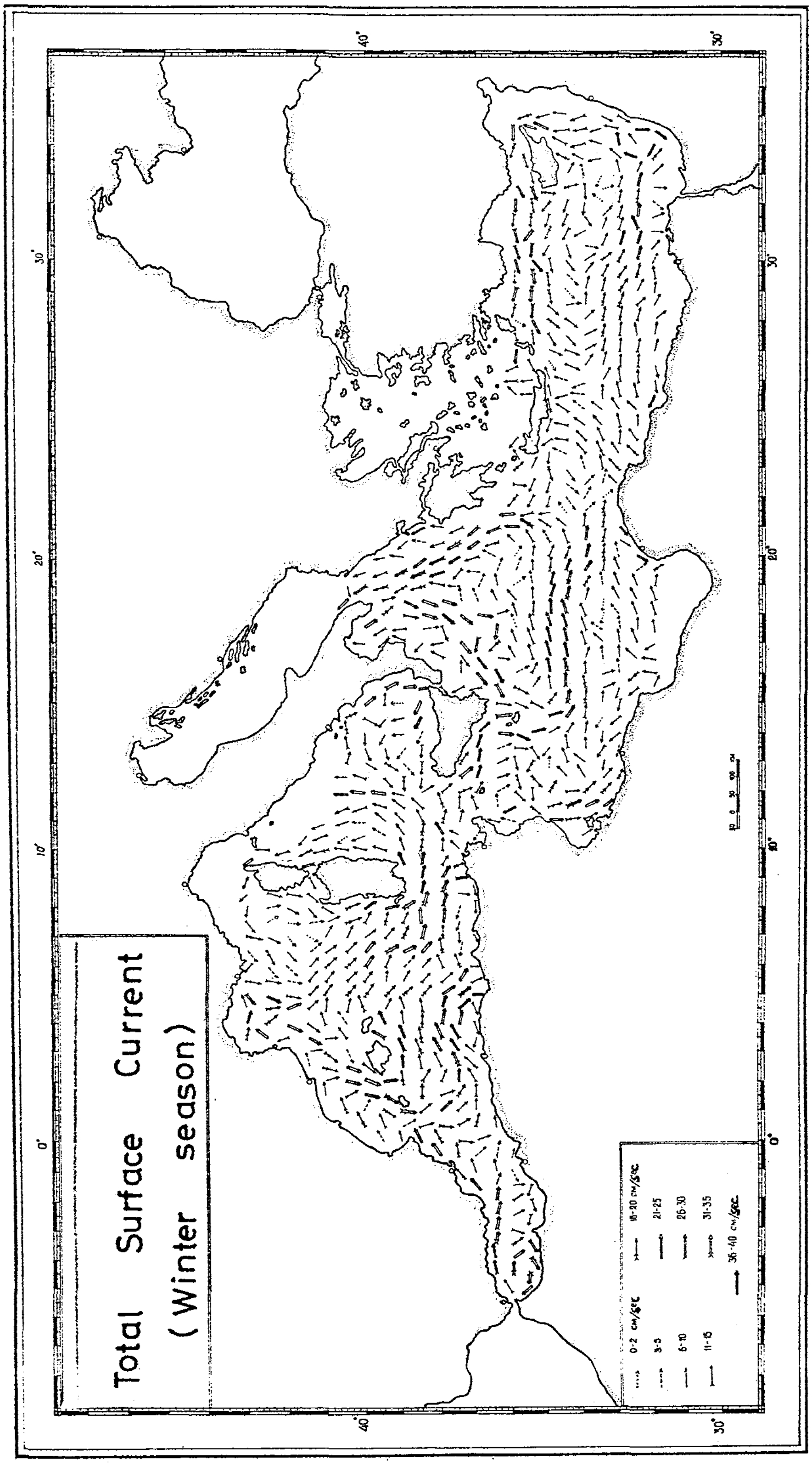
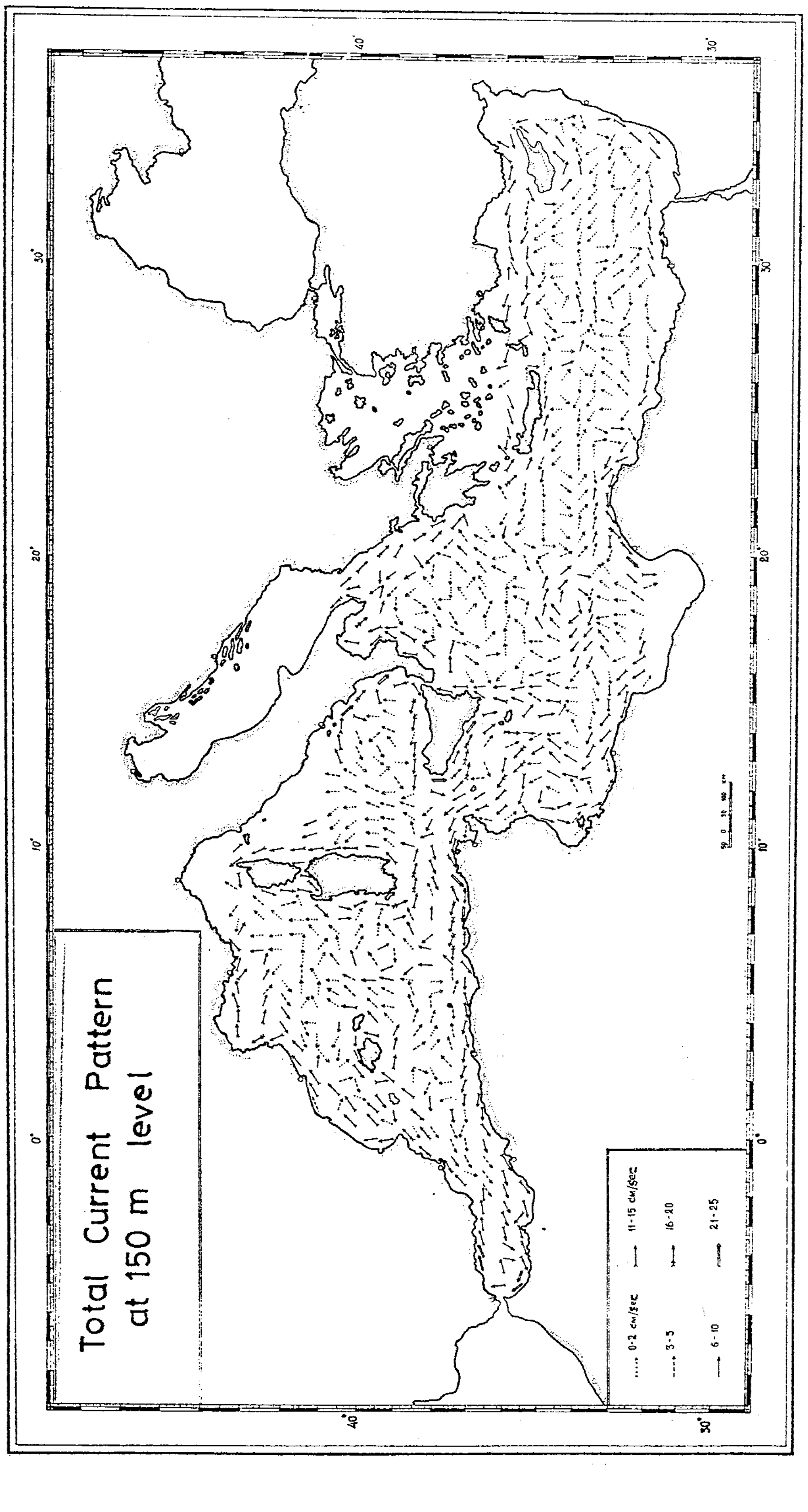

Total Current Pattern
at 400 m level
0-2 CM/SEC
3-5 CM/SEC
6-10 CM/SEC
40°
30°
20°
10°
0°


Total Surface Current
(Winter season)
0-2 cm/sec
3-5
6-10
11-15
16-20 cm/sec
21-25
26-30
31-35
36-40 cm/sec
0°
10°
20°
30°
40°


Total Current Pattern
at 150 m level
0-2 cm/sec
3-5
6-10
11-15 cm/sec
16-20
21-25