A MULTI-LAYER MODEL FOR THE STUDY OF CIRCULATION AND EVOLUTION OF WATER MASS PROPERTIES IN MOST GENERAL CONDITIONS

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A multi-layer numerical model has been constructed which obeys the two basic flexibility criteria of being applicable to basins of quite different geometries and bottom topographies, like enclosed lakes, continental shelves open on one or more boundaries, completely open regions at sea etc. The further flexibility is that the model is capable of describing barotropic situations (constant density); baroclinic, mono-layer situations (vertically homogeneous fields of temperature, salinity, density corresponding to late fall-winter conditions in the Northern Adriatic); baroclinic, multi-layer situations (well-developed vertical stratification corresponding to spring-summer conditions).

The model thus predicts the space-time evolution of: sealevel - total horizontal transposrts, integrated throughout the water column - horizontal transports, hence velocities, for each considered layer - temperature, salinity, density distributions in each layer. Results and examples are shown and discussed.

A numerical model has been constructed to study the dynamical behavior of a water mass and its properties (temperature, salinity and density). This model satisfies the following fundamental flexibility criteria:

1) the model can be used for a most general basin, with closed or open boundaries, with quite different geometries and bottom topography distributions.

2) the model can be applied to quite different seasonal situations:

a) with temperature, salinity, density fields vertically homogeneous characterizing the phenomenology of late autumn-winter in the Northern Adriatic Sea. The model in its barotropic one-layer version reproduces this situation.

b) with a vertical stratification in the temperature, salinity, density distributions; this situation is typical of the phenomenology of spring-summer seasons in the Northern Adriatic Sea. The model in its baroclinic multi-layer version, with the superposition of n-interacting layers, reproduced this situation.

The model predicts the space-time evolution of

- sea level (sea surface around the mean sea level)
- total mass transports (integrated over the total depth)
- mass transports in each layer (integrated over the layer thickness)
- vertical velocities at the layer interfaces
- horizontal distributions of temperature, salinity and density anomaly for every layer.

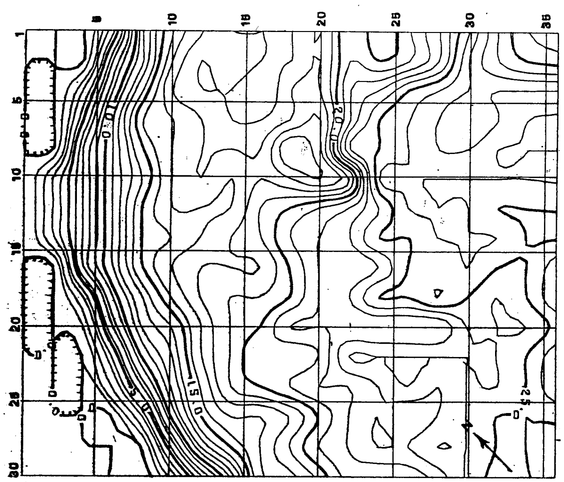

FIG. 1 COMPUTER - DRAWN BOTTOM TOPOGRAPHY MAP FOR THE TEST - AREA, IN FRONT OF THE LAGOON OF VENICE, WHERE THE SEA - TRUTH COMPAIGN OF PREVIOUS PANELS WAS CARRIED OUT : SCALE 1 : 100000

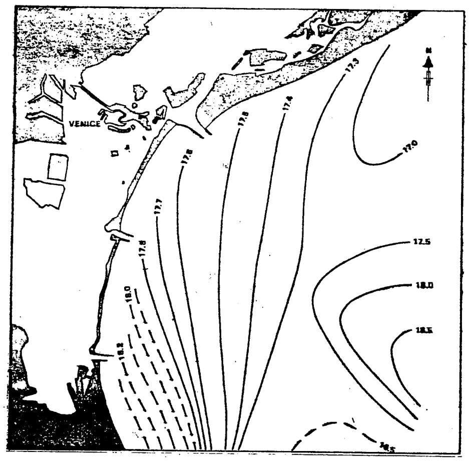

FIG. 2a TEMPERATURE DISTRIBUTION IN THE SURFACE LAYER (°C) AS DEDUCED FROM HISTORICAL DATE FOR LATE MAY - EARLY JUNE CONDITIONS.

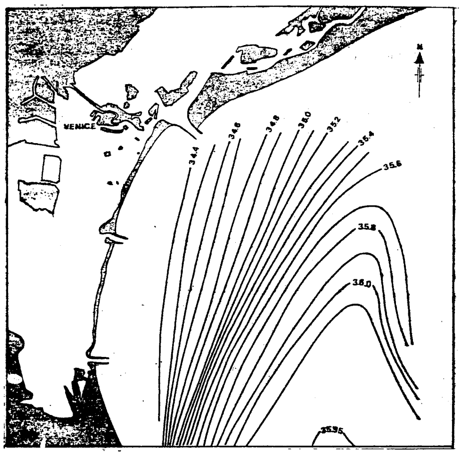

FIG. 2b AS FOR FIG. 2a, BUT FOR SALINITY IN ‰ .

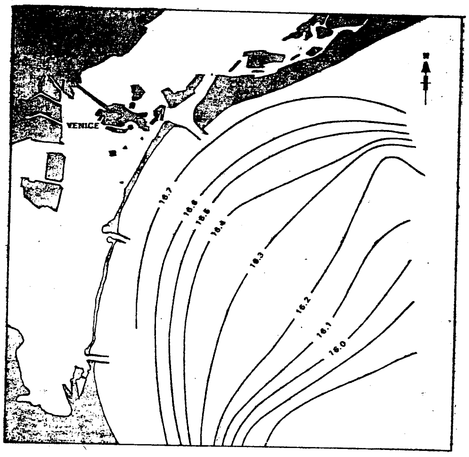

FIG. 2c TEMPERATURE DISTRIBUTION IN THE BOTTOM LAYER, ~~DEDUCED~~ AS FIG. 2a.

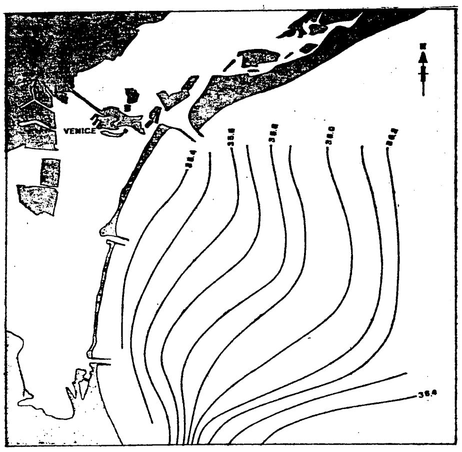

FIG. 2d AS IN FIG. 2c BUT FOR SALINITY.

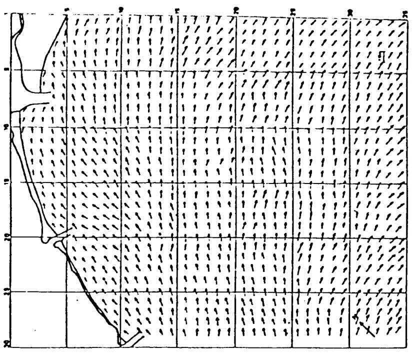

FIG. 3 COMPUTER DRAWN HORIZONTAL VELOCITY DISTRIBUTION IN THE SURFACE LAYER, AT 12h, JUNE 15, 1979.

VELOCITIES ARE NORMALIZED BY MAXIMUM VELOCITY VALUE.

$|V_{max}| \simeq 100$ cm/sec $|V_{min}| \simeq 5$ cm/sec

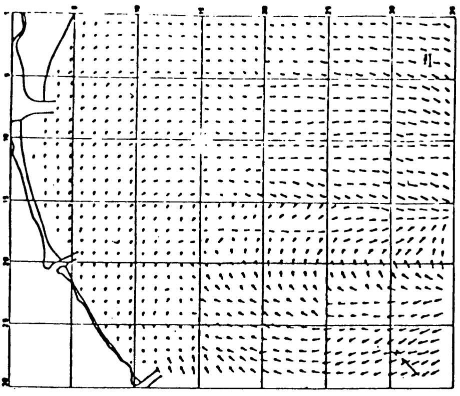

FIG. 4 AS FIG. 3 BUT FOR THE BOTTOM LAYER.

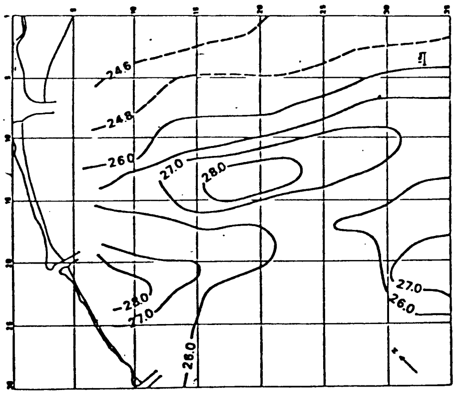

FIG. 5a TEMPERATURE DISTRIBUTION (°C) FOR THE SURFACE LAYER, AT 12h, JUNE 15, 1979.

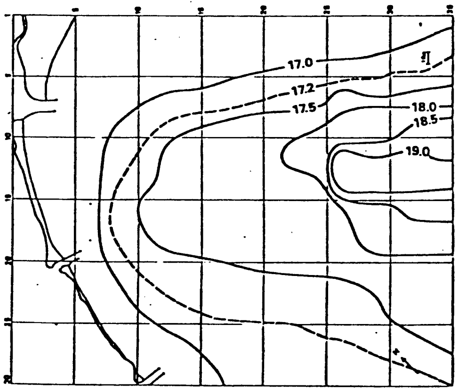

FIG. 5b LIKE IN FIG. 5a BUT FOR THE BOTTOM LAYER.

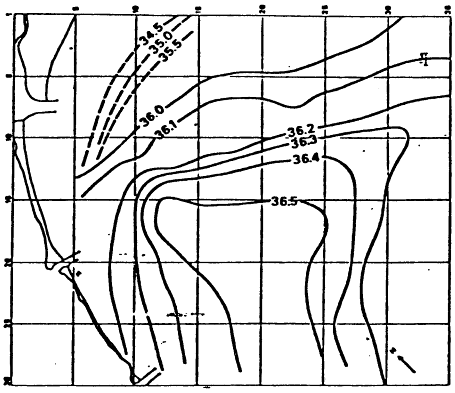

FIG. 6a SALINITY DISTRIBUTION IN ‰ FOR THE SURFACE SURFACE LAYER AT 12h, JUNE 15, 1979.

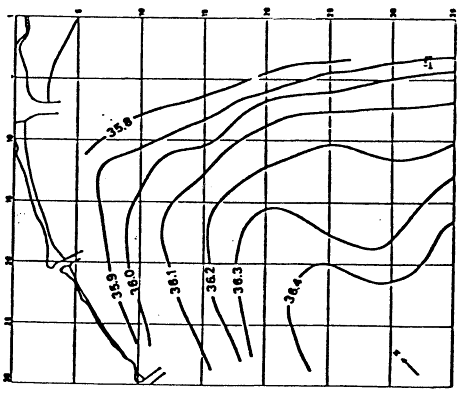

FIG. 6b LIKE IN FIG. 6a BUT FOR THE BOTTOM LAYER.

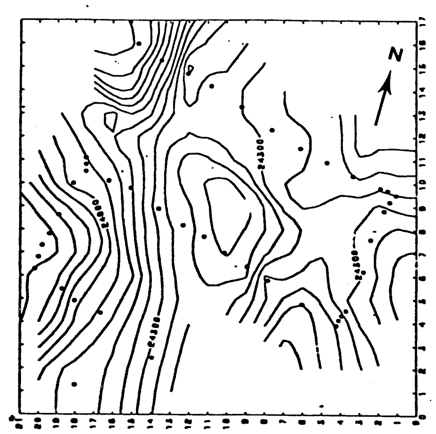

FIG. 7 SURFACE DISTRIBUTION OF TEMPERATURE AS OBTAINED THROUGH APPLICATION OF SURFACE II ROUTINE.

The model accepts as inputs the wind stress field at the surface,the thermal-evaporation fluxes at the air-sea interface, the coastal river outflows at coastal boundaries.

Without going into the numerical details, in this paper we show an application of the model. This is related to the satellite passage of June 15, 1979, the model has been used to simulate the sea-truth area in front of the Venice Lagoon, a 36 x 30 km^2 area with a spatial resolution of 1 km^2, and a time step of 60 sec. The bottom topography is shown in Fig. 1. All hydrological data historically collected for the months of May-early June were considered. From them the initial conditions shown in Fig. 2 were reconstructed. They are typical of late spring and allow to identify the surface layer thickness around 3-5 m. The model was therefore considered in its two layer version with the surface layer (fixed) thickness of 3 m.

The meteorological conditions during the first 15 days of June 1979, were sufficiently stationary, characterized by warm weather, so that local meteorological data were sufficient to reconstruct the time series of air-sea interface fluxes (surface wind stress, surface evaporation rate, conductive heat flux and latent evaporation heat flux). Since in the open basin the mass is not conserved, we give the sea level distribution, computed from the local harmonical constant.

The final run was started at midnight of June 11, 1979, until noon of June 15, 1979 time of satellite passage. Fig. 3 shows the velocity field in the surface layer. We can see a northward transport with the trend for the water mass to move towards the interior of the basin. This is principally determined by sea level focing, the wind and the thermohaline forces being negligible. Fig. 4 shows the corresponding velocity pattern in the bottom layer. The general northward flow is maintained. The tendency for the flux to turn towards the interior of the basin is enhanced in the bottom alyer, giving rise to a small circulation gyre, outwardly flowing at the eastern open boundary. This gyre pattern is evidently induced by the interaction with the bottom topography. Fig. 5 shows the temperature distribution in the surface layer and the bottom one. Correspondingly Fig. 6 shows the salinity patterns. As we see, the fields are smooth and they do not differ remarkably from the initial conditions. In fact being wind forcing negligible at the sea surface, the most important effect for these fields is advection through the open boundary, and vertical diffusion at the layers interface. But velocities are essentially tidally induced and therefore they do not change significantly the temperature and salinity patterns through advection. Also for salinity, air-sea interaction are very small. The only significant fluxes at the air-sea interface are the heat fluxes. The general trend of isotherms as well as predicted temperature values are in general qualitative agreement with the sea-truth map shown in figure 7.