EFFECTS OF WIND VERSUS HYDRAULIC FORCING ON THE DYNAMICS OF THE WESTERN MEDITERRANEAN SEA

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A numerical model is used to examine the relative effects of wind versus hydraulic forcing on the dynamics of the upper layer circulation within the western Meditteranean Sea.

Les effets relatifs des vents et des flux sur la circulation de la Méditerranée Occidentale sont examinés avec un modèle numérique.

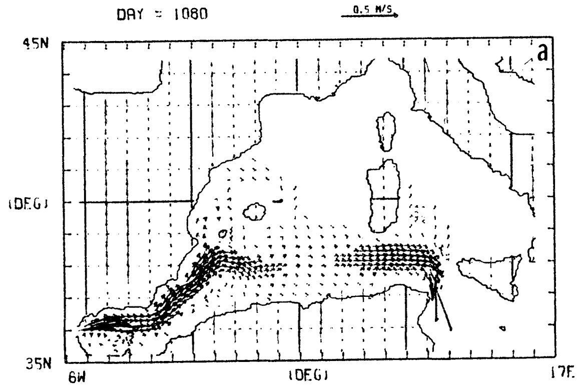
There are many physical factors which exert an influence on the circulation dynamics of the western Mediterranean; wind stress, hydraulic forced flow (inflow/outflow through the Straits of Gibraltar and Sicily), thermo/haline circulation, etc.. The purpose of this study is to examine the relative importance and interaction of the two possibly strongest forcing mechanisms for the western Mediterranean, those being the wind stress and hydraulic forced flow. These two mechanisms are relatively easy to study using a simple reduced gravity, hydrodynamic numerical model.

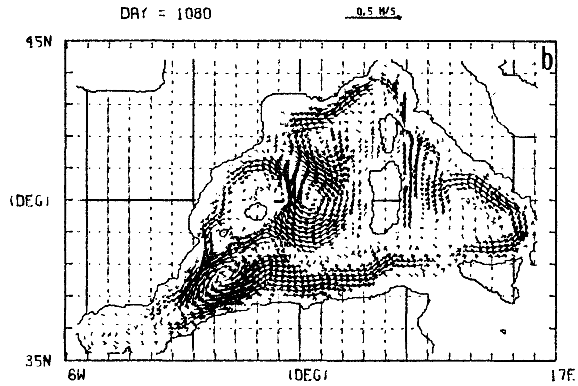
Many features of the general surface circulation of the western Mediterranean Sea (Allain, 1960; Bethoux, 1980; Ovchinnikov, 1966) appear to be either a hydraulic forced flow, e.g. the North African current, or wind driven, e.g. the circulations in the Tyhrennian, Ligurian and Balearic Seas and in the Provencal and northern Algerian Basins. While it is true that the thermodynamic effect of excess evaporation over precipation and river runoff plays an important role in the Mediterranean, this effect is much more important in the eastern Mediterranean than the western half. Thus the western half of the Mediterranean, divided at the Strait of Sicily, is more amenable to use of a purely hydrodynamic approach.

The numerical model used in these experiments is a one-active layer, reduced gravity, hydrodynamic, primitive equations model on a β-plane with a horizontal grid resolution of .1° by .05°. The one-active layer reduced gravity model is the simpliest model which can reproduce most of the prominent upper ocean features.

The model equations are solved using an explicit version of the Hurlburt and Thompson (1980) semi-implicit model with two important modifications: 1) the ability to handle realistic coastline geometry add by A. Wallcraft (personal communication) and 2) the outflow boundary condition used at the Strait of Sicily is a modified Orlanski (1976) radiation boundary conditiion.

The model was driven by specifying the inflow through the Strait of Gibraltar, or monthly mean wind stresses or a combination of both. The inflow velocity was chosen to yield an inflow volume transport on the order of 1.6 Sv (where Sv = 10^6 m^3/sec). The wind forcing was derived from monthly mean climatogical wind stresses on a 1° by 1° grid obtained from twenty years (1950-1970) of ship observations in the Mediterranean (May, 1982). The monthly averages were bilinearly interpolated to the model grid. The wind forcing is cyclic with a period of one year.





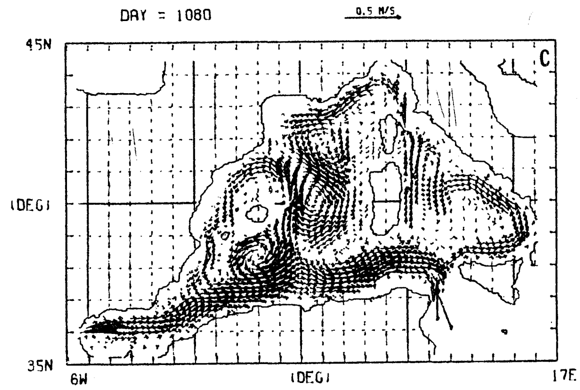


Figure 1. Upper layer depth averaged current velocity vectors.

a) Hydraulic forcing only.

b) Wind forcing only.

c) Combined hydraulic and wind forcing.

Figure 1 shows snap shots of the upper layer velocity vectors for day 1080 (January) of three-year simulations for each of the cases. The results from the case with hydraulic forcing only reveals a steady source/sink flow. We see in fig. 1a that the source/sink flow confined to the southern portion of the Algerian basin.

The wind only case yields quasiperiodic solutions in response the annual cycle of the wind forcing. In fig. 1b we see strong cyclonic circulations in the Tyhrennian and Ligurian Seas and a particularly strong circulation at the eastern extremity of the Alboran. During the summer, the cyclonic circulations weaken considerly with the flow in the Tyhrennian becoming weakly anticyclonic. The circulation east of the Alboran shinks in size and retreats to the northeast.

The combined case results reveal solutions which are almosts identical to the wind only case above 38°N and to the hyraulic only case in the western Alboran and Sardinian/Sicilian Straits region. The interactions between the two forcing mechanisms can be seen in the region from the Prime Meridian to 9°E along the African coast (fig. 1c). The steady current from the source/sink flow as seen in the hydraulic only case is modulated by the periodic forcing from the wind. During the summer as the wind driven circulation at the outflow of the Alboran retreats to the northeast the flow arcs towards the Balearic Islands before turning to the north African coast.

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