SEASONAL TEMPERATURE AND SALINITY FIELDS IN THE MEDITERRANEAN SEA : CLIMATOLOGICAL ANALYSES OF AN HISTORICAL DATA SET

P. BRASSEUR, J.-M. BECKERS, J.-M. BRANKART and R. SCHOENAUEN

GHER, University of Liège, B5 Sart-Tilman, Belgium

Observations of temperature and salinity have been collected in the Mediterranean Sea for a long time, within the frame of national and international research projects. An effort to merge several existing data sets into a common file system has been undertaken in the perspective of climatological studies. Up to now, over 25000 CTD and STD profiles have been integrated in the so-called MED2 historical data base, covering the period 1900-1983. These profiles originate essentially from the French BNDO (Bureau National des Données Océaniques, Brest) and the U.S. NODC (National Oceanographic Data Centre). The spatial distribution of the MED2 stations is shown on figure 1. This preliminary effort is now pursued within the frame of the CEC MAST/MODB initiative for data and information management. In the near future, the data bank will be upgraded with more recent data collected, for instance, by the POEM Group or by regional institutions.

Seasonal and monthly objective analyses of the original data are performed using a variational inverse method (BRASSEUR and HAUS, 1991) as an alternate to the standard statistical procedure. The solutions are derived from a variational principle, taking into account the statistics of the observations to minimize the expected error on the fields. Error fields are estimated from the variance of the finite element solution. In addition, a kinematic constraint can be imposed to represent anisotropic correlations between the data, as a result of the advection of the scalar properties by the geostrophic circulation.

The numerical parameters of the scheme are adjusted according to the statistics contained in the MED2 data. The results, materialized as gridded data sets (horizontal resolution at 1/4 of degree), show some trends of the seasonal variability affecting the properties of the water masses. As expected, the upper layer is the seat of a well-marked seasonal variability affecting both the temperature and the salinity fields. The surface salinity reconstructed for the winter period is illustrated on figure 2. The Rhode gyre in the Eastern basin and the Gulf of Lions gyre in the Western basin represent the most robust features of the winter circulation. An inventory of the seasonal analyses performed at all depths is reported in BRASSEUR *et al.* (1994).

The MODB products have been prepared for general distribution among the scientific community. In addition, they are conceived as a basic support to more advanced studies, including: diagnostic calculations, initialization of dynamical models, assimilation of hydrological data into primitive equation models, planning of experimental surveys, ... A first attempt to assimilate these climatological analyses into a 3D primitive equation model is reported in BECKERS *et al.* (1994). New versions of the climatological fields will be released as additional data are validated and made available to feed the MED2 historical data set.

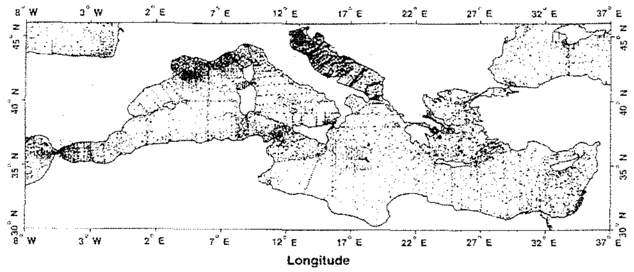

Fig. 1: Spatial distribution of the MED2 historical data during winter.

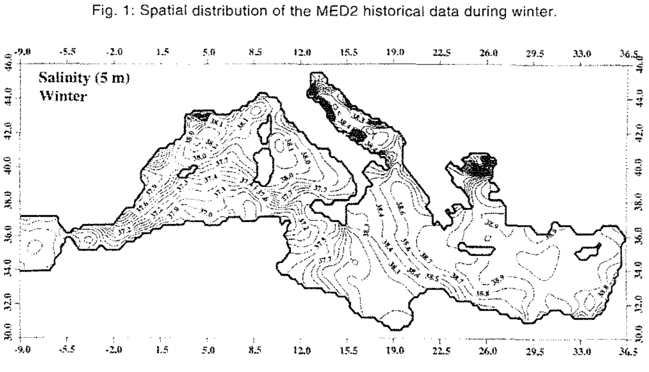

Fig. 2: Surface salinity representative of the winter season as reconstructed by the variational inverse method.

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EVALUATION OF HYDROLOGICAL BUDGET BY MEANS OF DIRECT CURRENT MEASUREMENTS IN THE STRAITS OF SICILY

G. BUDILLON, M. MORETTI, E. SANSONE, G. SPEZIE, E. ZAMBIANCHI

Istituto di Meteorologia e Oceanografia, Istituto Universitario Navale, Via Acton 38, 80133 Napoli, Italy

The meteorological events which force the dynamics of the individual subbasin of the Mediterranean yields variations in the stratification, which propagate at the typical speed of internal waves, i.e. very slowly. In other word, the Mediterranean is a system whose inertia acts so as to average the effects of a single meteorological situation and can be therefore considered as a sort of a climatological sensor.

Given the complexity of the Eastern Mediterranean basin, it is very difficult to identify criteria to quantitatively assess its variability. However, since the latter eventually expresses itself on the variability of AW (Atlantic Water) and LIW fluxes, it has proved convenient to look at it by measuring water mass transport in the Sicily Channel, where morphological characteristics make transport estimates easier.

The Sicily Channel represents the connection between the western and the eastern subbasins of the Mediterranean. At the surface in the western part of the Mediterranean, the flow is formed primarily by Atlantic Water which enters the Western Mediterranean through the Strait of Gibraltar and thereafter flows along the northern African coast, forming the Algerian Current.

The Algerian Current is characterized by intense associated mesoscale activity. This acts so as to divert a good portion of the AW from directly entering the Straits of Sicily, causing it to recirculate in the wide opening between Sicily and Sardinia, the Sardinia Channel. The path followed by the AW within the Channel exhibits considerable meandering, probably due to joint effect of direct dynamical forcing and conservation of potential vorticity in the surface.

The intermediate layer is, as can be expected, largely composed of Levantine Intermediate Water (LIW), which is always present in the region with a westward flow, slow but substantial in terms of mass transport. This has been clearly shown in the measurements collected by Istituto Universitario Navale over the last 8 years, which have revealed yearly variations with a quite well recognizable steady pattern through the maximum salinity topographies.

It is still not clear whether a presence of Eastern Mediterranean Deep Water is to be expected in the deepest region of the Channel : in particular, our measurements have not shown its presence, which might be confined, however, to relatively poorly sampled sub-areas.

As said above, the Sicily Channel is characterized by two layer situation, with the upper layer dominated by the AW flow towards South-East and LIW flowing in the opposite direction at lower depths.

In steady-state conditions, admitting salt and mass conservation in the Eastern Mediterranean, transport and mean salinities in the Channel are related to the water budget by :

$$Q(_{LIW}) = \frac{D}{\rho_{LIW}} \; \frac{\langle S\rangle_{AW}}{\langle S\rangle_{LIW} - \langle S\rangle_{AW}} \qquad \frac{Q_{LIW}}{Q_{AW}} = \frac{\rho_{AW} \langle S\rangle_{AW}}{\rho_{LIW} \langle S\rangle_{LIW}}$$

Our attention were consequently focused on a section North-East of the Pantelleria Island, perpendicular to the axis of the Channel. It is known that the knowledge of the hydrology along a section allows to estimate only the baroclinic component of transports taking place in correspondence of the section itself; therefore, in order to transform these relative measurements into absolute values it is necessary to make some assumptions concerning the actual dynamics, which be justified in terms of the thermohaline structure of the studied area.

In the Sicily Channel the reversal of the flow clearly yields that a level of no motion has to exist, to separate opposite flow regimes. Once identified, this level of no motion will enable to evaluate geostrophic transports.

Our procedure to estimate transport across the Pantelleria section consists first of all of a preliminary evaluation of water mass and salt transport assuming the level of no motion to coincide with the 38.0 isohaline surface; thereafter, an adjustment of the level of no motion which takes into account, if necessary, flux imbalances and anomalies in the distribution of the physical-chemical characteristics. This procedure proves to be extremely sensitive, as the vertical velocity gradients at the interface between AW and LIW are large. Moreover, transport patterns can be way more complex than hypothesized ones; this yields that reaching a perfect salt transport balance is not always feasible at this stage of the computations. However this is not so crucial, given the linear relationship between salt and water mass transport, which allows to achieve the sought-after flux balance.

Our results are around 0.5 Sv, i.e. almost half as much as the generally accepted estimates drawn from indirect measurements, and even less with respect to the fluxes determined with direct methods; they show also a clear, roughly linear bond between salt and mass transport. This is due to the fact that the salt transport is approximately the product between mass transport and average salinity. Using this relationship we can then correct our salt transport estimates and compute the correspondent mass transport values, which will be more accurate as they satisfy mass continuity criteria.

It has to be underlined, however, that the dynamics of the Sicily Channel are characterized by mesoscale structures such as meanders and eddies with typical time scales between 3 and 10 days. These structures clearly constitute a kind of noise superimposed to the climatic signal, so that it is difficult to establish whether our estimates can be considered an accurate assessment of the variability of the climatic forcing.

This noise, however, can be filtered even by means of direct measurements of current. We performed that with good results using direct current measurements collected by Istituto Universitario Navale during the last year. The current meter mooring was positioned in the deepest sill (430 mt) of the Straits of Sicily where the flow of the LIW is expected to be more concentrated.