The EOF analysis of the Seasonal and Interannual variability of the Mediterranean General Circulation

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The purpose of this work is to study the seasonal and interannual cycle of the Mediterranean basin by analyzing the barotropic streamfunction's results of the Pacanowski, Dixon and Rosati version of Bryan and Cox's general ocean circulation model fitted to the aforementioned basin. The general idea is the separation of the time varying two dimensional streamfunction field stm(t,x,y) where x,y run all the model's grid points, in a temporal dependent and a spatial dependent component:

$$stm(t,x,y) = \sum_i T_i(t)\phi_i(x,y)$$

This target is achieved via an EOF analysis of the two dimensional streamfunction fields either for the Western or the Eastern sub-basin since these two areas can be considered as loosely coupled in the streamfunction field.

The practical computations aim at solving the eigenvalue problem $TG = GL$ where T is the nxn scatter matrix $T = DD^T$, G is the matrix of eigenvectors and L is the diagonal matrix of the eigenvalues. The data matrix D is a nxp matrix with elements stm(t,**x**) where t = 1,..,n indicates a time sampling scheme and **x** = 1 ,..,p a spatial sampling scheme.

The next step is the projection of D^T (the transpose of D matrix) onto the eigenvectors matrix G in order to obtain matrix B which contains the EOF's ($B = D^TG$). The reconstruction of the initial data matrix is now $D = GL^{1/2}K^T$ where $KL^{1/2} = B$.

The formula $D = GL^{1/2}K^T$ is also known as the singular value decomposition of D matrix.

For the seasonal variability studies we used twenty four snapshots (one every fifteen days) of the barotropic streamfunction's fields yielded from the perpetual year run of the model whereas for the interannual studies we used ninety six monthly snapshots of the eight years interannual run of the model. In both cases the data set was time-centered and each grid point was weighted by its temporal standard deviation in order to avoid the spatial patterns associated with the larger eigenvalues being dominated by grid points with high variance. A shapiro filtering scheme was also adopted for the elimination of small spatial scales noise.

In the Western basin and for the seasonal variability studies, the first two modes together explain around 89.7% of the overall variability. The first mode corresponds to a sinusoidal seasonal cycle while the second one which accounts for the 29.1% of the variability corresponds again to a seasonal cycle which is now $\pi/2$ out of phase with respect to the first mode. The spatial patterns connected with these two modes (the horizontal EOF's) reveal important information about the standing and propagating behaviour of this sub-basin. As a matter of speculation, the first EOF could be connected with the standing response while the second with the propagating response of the sub-basin to the time dependent forcing.

In the Eastern sub-basin the situation changes compared with that in the Western part a fact which supports our selection to treat them separetely which was based on our preconsumption that they are loosely coupled. The EOF analysis yields in this case that we need the first three EOF's in order to explain the 87.8% of the overall variability. The first mode (the one associated with the largest eigenvalue) corresponds to a seasonal cycle with some small asymmetry embedded on it and explains the 47.8% of the variability. The spatial patterns associated with it probably correspond to the standing response of the basin. The inspection of the horizontal spatial patterns associated with the second EOF points out the existance of small spatial scales and areas which change sign around their temporal average out of phase between each other. This kind of multipolar structure could be indicative of a dynamical system where wave propagation can take place. The second EOF explains 25.8% of the variability and corresponds to a seasonal cycle with a phase shift of $\pi/2$ with respect to the first one.

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Study of Levantine intermediate water formation processes, production rates and sensitivity to interannual variability with a 1-D mixed layer model

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A one dimensional modified Kraus-Turner mixed-layer model is used, to study the winter formation of the Levantine Intermediate Waters (LIW) in the Eastern Mediterranean. To force the model we use climatological heat fluxes and wind stress data (P. MAY, 1982 and 1983). The study is carried out in two stages: a) first we apply the model in the whole Levantine Basin and initialize it with climatological T and S profiles (DAVIS *et al.*, 1986). We define the LIW production zone and rate as well as its sensitivity to interannual variability of the heat fluxes. b) we then apply the model to a section of insitu POEM-2 cruise data (POEM GROUP, 1992), and identify the formation mechanism on a finer scale.

Climatological results

1.- **LIW formation area and production rate.**

The model is integrated for two years at each grid point of the Levantine Basin (185 grid points), and initialized with fall (November) climatological profiles. We use an exponential advection term, with a depth scale of 35m, to compensate for the non-zero heat and water budget at each location. An objective map of March mixed layer densities, produced by the model, is presented in figure 1. Densities within the range 28.85-29.10, generally accepted as typical of LIW, are concentrated in the broader area of the Northwestern Levantine during February and March. This area is occupied permanently by the Rhodes Cyclonic Gyre. The mean climatological production rate of LIW is calculated to be equal to 0.99 Sv, a value close to the 1.23 Sv suggested by OVCHINNIKOV (1983).

2.- **Sensitivity study to heat fluxes interannual variability.**

We simulate a severe and a mild winter by increasing and decreasing respectively the total winter heat losses by 300 W/m^2. In the first experiment the production zone of waters denser than 28.85 was significantly expanded. The LIW production rate was increased to 1.63 Sv while in the central part of the Rhodes Gyre 2.67 Sv of denser than LIW waters were produced with characteristics close to those of the deeper layers. In the second experiment no LIW was produced inside the basin. These experiments indicate a significant sensitivity of the LIW production area and rate to interannual variability.

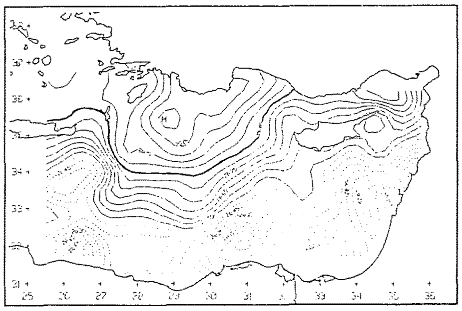

Figure 1

POEM-2 Results

The climatological study suggests LIW is produced inside the Rhodes Gyre area at the end of winter. We further investigate into the details of the production mechanism with the use of insitu POEM-2 cruise data. We use a meridional section of 8 stations running northward from the center of the Rhodes Gyre to the Asia Minor Current. The observations were taken from 27 March to 3 April 1986. The results of this experiment (figure 2), indicate that LIW is formed in the mixed-layer of the central part of the Rhodes Gyre, while at the periphery, a warmer and ligther winter mixed-layer overtops the LIW water mass which we assume has sunk isopycnally there.

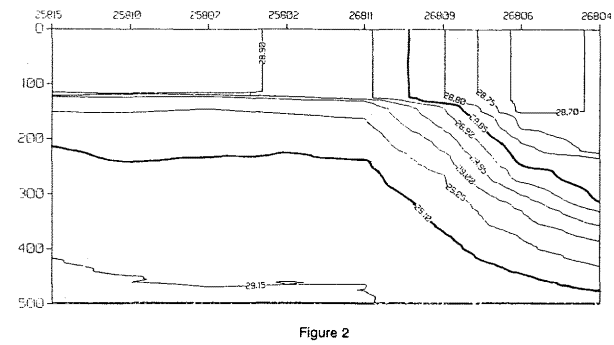

Figure 2

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