Modal Decomposition Analyses of POEM–I–85 and POEM–II–86 Experimental Data In the Levantine Basin

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I. Introduction

Two coordinated surveys of the Levantine Basin were completed during October-November 1985 (POEM–I–85) and March-April 1986 (POEM–II–86) by the Turkish ship BILIM and the Israeli ship SHIKMONA. Based on the average profiles of the stability frequency obtained from these data sets, we use the experimentally calculated values of geopotential anomaly to estimate the relative contribution of the dynamical modes to the observed field of motions.

II. Mean Stratification and Vertical Modes

The surface streamlines of the flow field for the two cruises (Figs. 1a and 1b) indicate the presence of gyres, eddies and jet flows of various scales.

The mean profiles of temperature, salinity and density in summer (Fig. 2a) indicate strong vertical gradients and high static stability at the thermocline. In winter (Fig. 2b), the density gradients are decreased and the stability frequency decreases uniformly with depth. The Brunt-Vaisala frequencies computed from the mean density profile and those calculated by horizontal averaging of individual N^2 profiles of stations were compared and no appreciable differences were found.

The vertical structure equation

$$\frac{1}{\rho_s}\frac{d}{dz}\left(\frac{\rho_s f^2}{N^2}\frac{d\phi}{dz}\right)+\lambda^2\phi=0 \qquad (1.a)$$

with the boundary conditions

$$\frac{d\phi}{dz}=0 \text{ at } z=0, \text{ and } z=-h \qquad (1.b)$$

was solved for given stratification parameters, and assuming an average basin depth of $h=$ 2000 m. The first three vertical modes for each cruise are shown in Fig. 3. The amplitudes of the modes are largest within the upper 300 m, with relatively deeper structure in winter. The first mode internal Rossby radius for the October-November 1985 case was 12.3 km, while it was calculated as 10.4 km for the March-April 1986 cruise.

III. Modal Decomposition

The mean vertical distribution of the geopotential anomaly is obtained by suitably averaging the vertical profiles at all stations. Then the contribution of each baroclinic mode to this experimental profile is obtained by minimizing the mean square difference

$$\Delta=\int_{-h}^{0}\rho_s(\phi-\hat{\phi})^2\,dz \qquad (2)$$

between the experimental profile $\hat{\phi}(z)$ and the eigenfunction expansion of the computed profiles

$$\phi(z)=a_1\phi_1(z)+a_2\phi_2(z)+\cdots \qquad (3)$$

with respect to the unknown amplitudes a_i : i.e. $\partial\Delta/\partial a_i=0$, yielding

$$a_j=\int_{-h}^{0}\rho_s\hat{\phi}\phi_j\,dz \;\Big/\; \int_{-h}^{0}\rho_s\phi_j^2\,dz\,. \qquad (4$$

Since the experimental geopotential anomaly has been obtained with respect to ar assumed reference level, it has non-vanishing vertical integral over the total depth. In orde to accommodate this difficulty, the decomposition was made with respect to the vertica derivative of the experimental profile expressed in terms of the vertical derivatives of th eigenfunctions, which is identical to requiring minimal mean square difference between th observed and reconstructed functions. Using the orthogonality relations and boundar conditions we have

$$a_j=\int_{-h}^{0}\frac{\rho_s f^2}{N^2}\frac{d\hat{\phi}}{dz}\frac{d\phi_j}{dz}\,dz \;\Big/\; \int_{-h}^{0}\frac{\rho_s f^2}{N^2}\left(\frac{d\phi_j}{dz}\right)^2 dz\,. \qquad (6$$

The contribution of each mode to the vertical structure and to the available potenti energy can also be determined

$$APE=\frac{1}{2}\int_{-h}^{0}\frac{\rho_s f^2}{N^2}\left(\frac{d\phi}{dz}\right)^2 dz=\sum_{j=1}^{N}\frac{a_j^2}{2}\int_{-h}^{0}\frac{\rho_s f^2}{N^2}\left(\frac{d\phi_j}{dz}\right)^2 dz$$

$$=\sum_{j=1}^{N}APE_j\,.$$

The eigenfunction expansion with a truncated sereis of $N = 5$ modes was used to calculate the modal amplitudes and the relative contributions to APE (i.e., each term of 7) normalized with respected to the first mode, which are presented in Table 1.

Table 1

October - November 1985			March - April 1986		
Mode(i)	a_i	APE_i	Mode(i)	a_i	APE_i
1	1.00	1.00	1	1.00	1.00
2	0.02	0.004	2	0.20	0.19
3	0.07	0.08	3	0.001	0.00
4	0.09	0.28	4	0.01	0.004
5	0.07	0.18	5	0.005	0.005

In the summer survey it is found that the first baroclinic mode dominates the observations, with the higher modes having negligible influence. In winter, the first two modes are important, with the second mode contribution being about 20% of the first mode, and negligible contributions being attributed to higher modes.

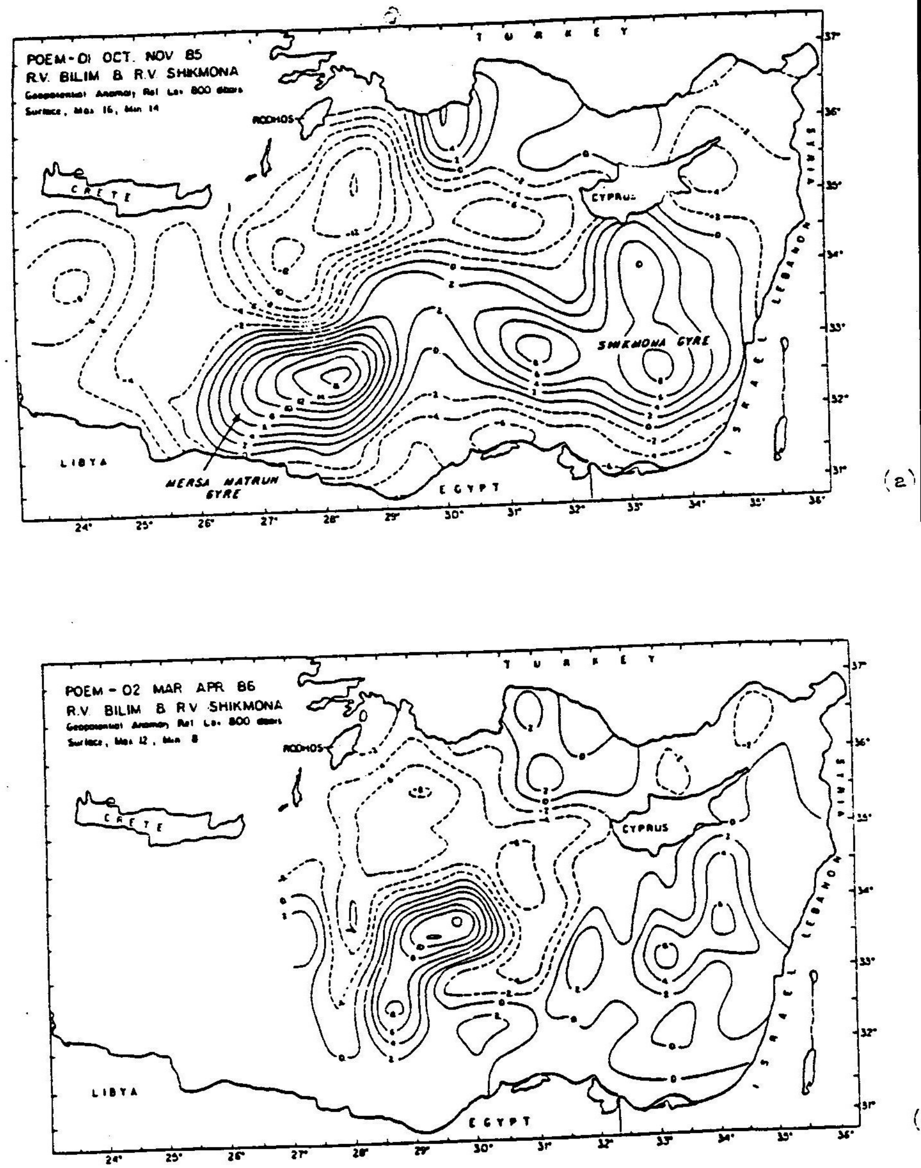

Fig. 1 Surface circulation maps obtained from the experiments of (a) October-Novemb 1985 and (b) March-April 1986.

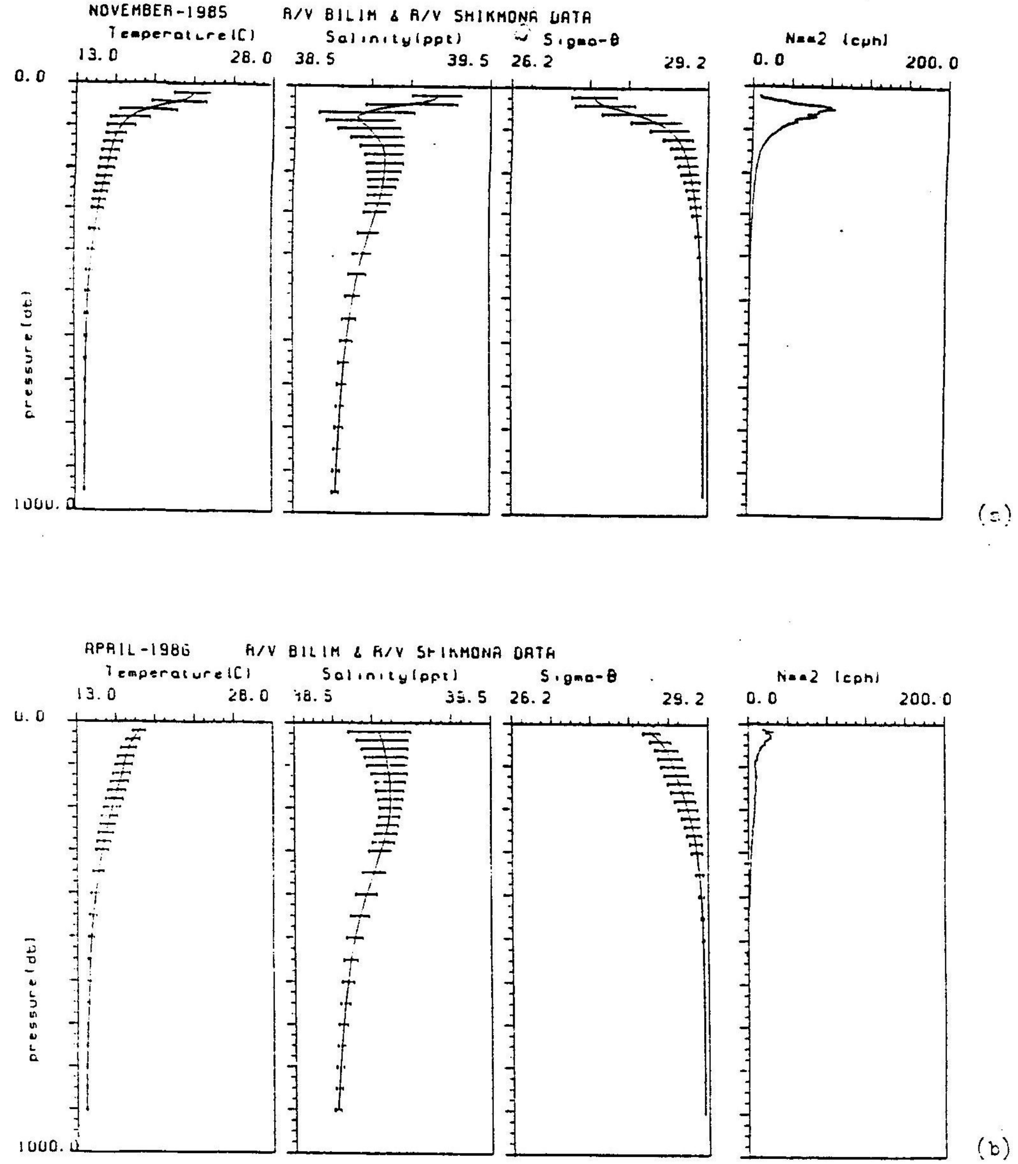

Fig. 2 Horizontally averaged profiles of temperature, salinity, sigma-θ and static stability (N^2) in (a) October-November 1985 and (b) March-April 1986. Horizontal bars mark one standard deviation.

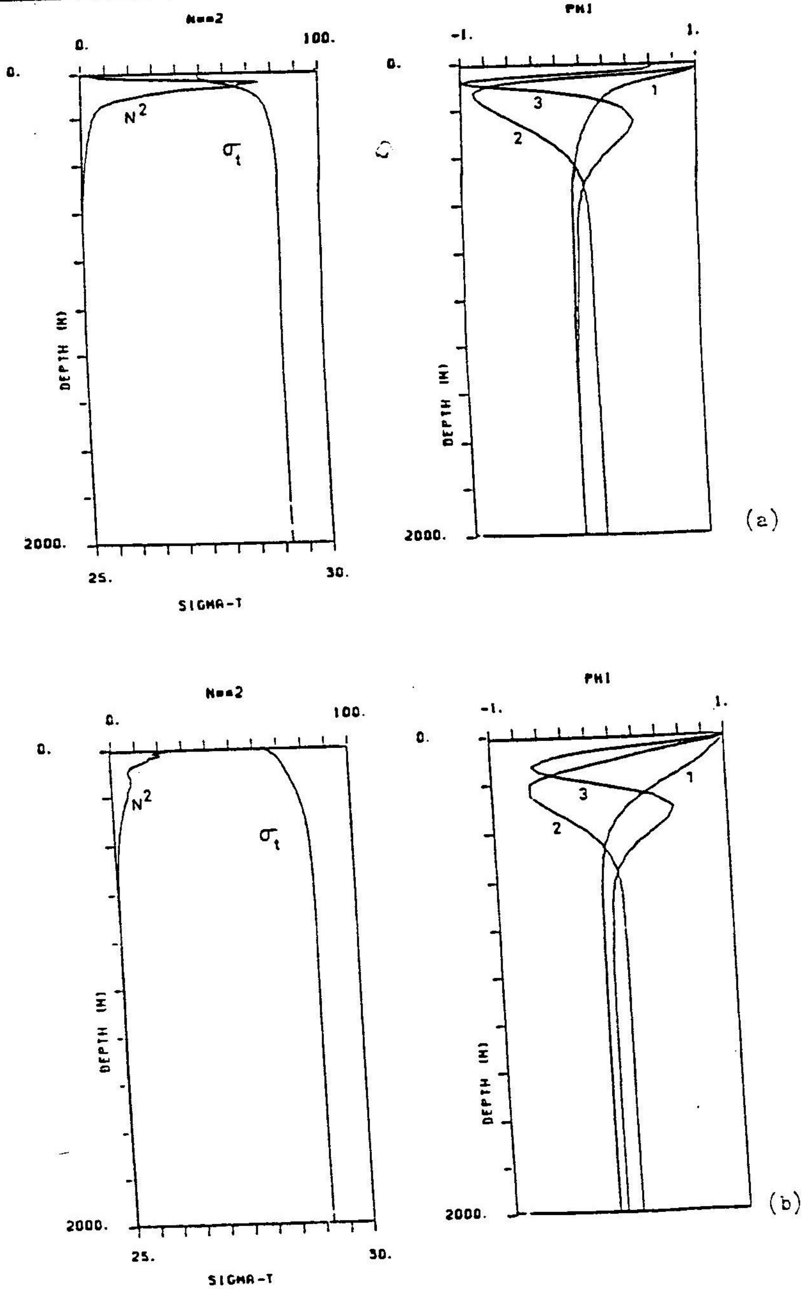

Fig. 3 The density stratification and the first three modes of the vertical structure equatio (a) October-November 1985 and (b) March-April 1986.

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