# HYDROGRAPHIC AND CIRCULATION PROPERTIES IN THE CRETAN SEA FROM THE M3A DATA

Cardin V.[1*], Kovacevic V.[1], Nittis K.[2]

[1] Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy

[2] National Centre for Marine Research, Athens, Greece

## Abstract

The sub-inertial variability of hydrological and circulation properties in the Cretan Sea is studied, using upper thermocline data from a prototype multi-parametric ocean observing system. The EOF analysis indicates a highly coherent and barotropic variability of temperature (T) and salinity (S) during the winter period. The two parameters are less correlated during spring and more variance is explained by higher modes, probably as a result of the developing stratification. The baroclinicity of the flow field is also increased during spring indicating a decoupling between the upper 300m and the deeper layers. Finally, the T and S variability is partially explained by advective processes with stronger coherence at the synoptic time scale.

*Key-words: temperature, salinity, currents, time-series, Cretan Sea*

### Introduction

Current, T and S time series obtained at M3A buoy site (Mediterranean Moored Multi-parametric Array) make part of an extensive multidisciplinary monitoring in the southern Cretan Sea, which has been conducted almost continuously since March 2000 within the framework of MFSPP (Mediterranean Forecasting System Pilot Project). The buoy is situated in an area characterised by the presence of quasi-permanent anti-cyclonic and cyclonic gyres [1].

A sub-inertial variability of the three properties within a 400 m water column for the two time intervals as indicated below, is summarised using an EOF (Empirical Orthogonal Function) analysis.

### Data and methods

T and S are measured at three levels: at nominal depths of 40, 65 and 115 m below the surface. Current measurements are obtained every 10m from an upward looking 75 KHz ADCP, and sub-sampled at 11 levels, unequally spaced in the range between 45 and 445 m. Original data, collected every three hours, are smoothed by a moving average in order to filter out high-frequency (daily) variability. EOF analysis has been applied to a normalised data, which were organised into two sets: the first contains all meridional current component (north-south) of 11 levels and the other consists of T and S at the three depths. The main reason that only meridional (v) component is included lies in the fact that the mooring is presumably located in the boundary region between Cretan cyclonic and anticyclonic gyres primarily characterised by the north-south flow (Fig.1). The investigated time series is divided into two parts: part A related to the period Apr. 15 - May 14 and part B relative to the period May 18 - Jun. 30.

### Results and Conclusions

For period A, the principal characteristics of the EOF eigenvectors (Table 1) show the prevalence of a barotropic structure, especially between 65 and 355 m (with 81% of the total variance [t.v.] explained), and a variability of the T and S being coherent at all three depths (72% of the t.v.). The second mode of the v component (8%) exerts baroclinic-like variability: upper layer (down to 360 m) is out of phase with respect to a lower one (below 360 m), while that of the TS (18% ) reflects primarily T variability at 40 m i.e. at the level of the seasonal thermocline.

**Table 1 – EOF eigenvectors and t. v. explained for the v-current component and the TS during period A.**

| MODE | t.v. | Depth (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ( % ) | 45 | 65 | 95 | 115 | 155 | 255 | 325 | 355 | 375 | 405 | 445 |
| 1 | 81 | 0.28 | 0.31 | 0.31 | 0.32 | 0.32 | 0.32 | 0.31 | 0.30 | 0.30 | 0.29 | 0.24 |
| 2 | 9 | -0.45 | –0.24 | –0.19 | –0.18 | –0.15 | –0.14 | 0.01 | 0.30 | 0.30 | 0.26 | 0.63 |

For period B (Tables 2), the first mode of the v component (84 %) resembles the structure observed during period A. For the T and S parameters the most important features are reflected in the first and the third modes. The structure of the first TS mode is again characterised by a relatively coherent variability of the T and S along the water column, while the total variance explained is much lower (56 %) than during period A. The third mode is probably associated to the vertical mixing which induces the increase of the water temperature in deeper layer and the out-of-phase behaviour of the surface water temperature.

A comparison of the amplitudes of the modes and time-series of both T and S data (not shown here) indicates that the peaks of the first TS mode mainly correspond to a temporary increase of both temperature and salinity, probably due to some advective processes or down-

**Table 2 – EOF eigenvectors and t. v. explained for the v-current component and the TS during period B.**

| MODE | t.v. | T/S Depth (m) | | | | | |
|---|---|---|---|---|---|---|---|
| | (%) | T-40 | T-65 | T-115 | S-40 | S-65 | S-115 |
| 1 | 72 | 0.04 | 0.44 | 0.44 | 0.43 | 0.46 | 0.46 |
| 2 | 18 | 0.94 | 0.23 | –0.10 | 0.08 | –0.15 | –0.14 |

welling. In order to determine to which degree the variability of the hydrographic properties is linked to a variability of the current field, a correlation coefficient between current and TS modes has been calculated (Table 3). Relatively significant correlation coefficients indicate a wide variety of their possible interconnections. The correlation between the first mode of the v current (V1) with either first or second TS mode for both periods, indicates that an increase in a northward flow is associated with a decrease of T and S at all three levels. In other cases the same increase of the flow is coherent with an increase of temperature at the thermocline depth and a decrease of it below that layer. The baroclinic-like mode (V2) is significantly correlated only with the first TS mode (TS1).

**Table 3 – Correlation coefficient between the v component EOFs' (V1 and V2) and TS EOFs' (TS1, TS2, and TS3).**

| MODE | t.v. | Depth (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ( % ) | 45 | 65 | 95 | 115 | 155 | 255 | 325 | 355 | 375 | 405 | 445 |
| 1 | 84 | 0.29 | 0.29 | 0.31 | 0.31 | 0.31 | 0.32 | 0.32 | 0.30 | 0.30 | 0.29 | 0.29 |
| 2 | 13 | -0.34 | –0.40 | –0.30 | –0.26 | –0.20 | –0.02 | 0.18 | 0.31 | 0.32 | 0.36 | 0.38 |

**Table 4 – EOF eigenvectors and t. v. explained for the TS during period B.**

| MODE | t.v. | T/S Depth (m) | | | | | |
|---|---|---|---|---|---|---|---|
| | ( % ) | T-40 | T-65 | T-115 | S-40 | S-65 | S-115 |
| 1 | 56 | 0.33 | 0.41 | 0.44 | 0.42 | 0.40 | 0.45 |
| 2 | 19 | -0.25 | –0.06 | –0.46 | 0.53 | 0.58 | –0.33 |
| 3 | 17 | -0.67 | –0.47 | 0.34 | 0.03 | 0.15 | 0.44 |

**Table 5 – Correlation coefficient between the v component EOFs' (V1 and V2) and TS EOFs' (TS1, TS2, and TS3).**

| | Period A | Period B |
|---|---|---|
| V1 : TS1 | - 0.28 | - 0.20 |
| V1 : TS2 | 0.30 | - 0.10 |
| V1 : TS3 | - | - 0.16 |
| V2 : TS1 | - 0.34 | 0.17 |
| V2 : TS2 | 0.01 | 0.02 |
| V2 : TS3 | - | - 0.03 |

### Reference

1 - Theocharis A., Balopoulos E., Kioroglou S., Kontoyiannis H., and Iona A., 1999. A synthesis of the circulation and hydrography of the South Aegean Sea and the Straits of the Cretan Arc (March 1994-January 1995). *Prog. Oceanogr.*, 44: 469-509.