THE EVOLUTION OF THE AEGEAN WATER'S INFLUENCE IN THE DEEP THERMOHALINE CIRCULATION OF THE EASTERN MEDITERRANEAN (1986-1995)

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Abstract

The significant changes of the Cretan Sea (S. Aegean) water mass characteristics during the last 8-9 years have considerably influenced the deep thermohaline circulation of the Eastern Mediterranean. Observations indicate that this change evolved in two phases. The first phase (1987-1991) is characterized by a pronounced increase of salinity (more than 0.1), while the second (1992-1995) by a dramatic drop of the deep waters' temperature (0.4°C). Both changes resulted in an increase of the Cretan deep waters' density of almost 0.2 and in a massive outflow of these waters towards the deep parts of the Eastern Mediterranean. This major climatic shift seems to be related to important meteorological anomalies in the area.

Key-words: Cretan Sea, Straits and Channels, water transport, Deep Waters

Introduction

The Adriatic sea has been historically considered as the main contributor to the Eastern Mediterranean deep waters [1]. Until the beginning of this decade, the horizontally homogeneous temperature and salinity values at deep layers have indicated an almost perfectly repeating cycle in both water mass characteristics and formation rates. The Aegean Sea has also been reported as a possible secondary source of intermediate and deep waters [2] but its contribution has been considered rather sporadic. The relatively warmer and more saline waters of the Cretan Sea (S. Aegean), were usually observed [2, 3] outside the Cretan Arc, just below the Levantine Intermediate Water (LIW) and above the Eastern Mediterranean Deep Water (EMDW) of Adriatic origin loosing rather quickly their characteristics due to mixing. Since the beginning of this decade, a number of observations indicate a major change in this picture of the Eastern Mediterranean deep thermohaline circulation: the deepest parts of the basin have been filled by denser and young waters with modified characteristics (warm and saline) outflowing from the Aegean Sea. The older deep waters of the basin, together with the newly formed dense waters of the Adriatic Sea, which still contributes to the deep waters, are lifted up several hundreds of meters, enriching with nutrients the intermediate depths of the basin [4].

The Cretan basin, the largest in volume and deepest basin of the Aegean Sea, communicates with the Levantine and the Ionian seas through the six "Cretan Arc" straits. The Antikithira Strait to the West (sill depth 700 m), and the Kassos & Karpathos Straits to the East of Crete (sill depths 1000 and 850 m respectively) are the most important for the deep water exchanges. The Rhodes strait is relatively narrow and shallow (250 m deep) but quite important for the upper layer exchanges between the Aegean and the Levantine Seas.

We present hydrological observations from the period 1986-1995 that describe the evolution of this climatic "shift" and the modification of the Cretan water mass characteristics which, as will be seen, occurred in two phases (1987-1991 & 1992-1995). The currentmeter data show the corresponding variability of deep water mass exchanges through the straits. The preliminary analysis of the meteorological conditions over the south Aegean gives some first indications for the mechanisms responsible for this transient.

Data analysis and results

We use hydrological and currentmeter data collected in the framework of the Greek national project "Open Sea Oceanography", the international project POEM "Physical Oceanography of Eastern Mediterranean" and the EU funded international research project PELAGOS/MTP-1. During the period 1986-1995 16 cruises were carried out in the south Aegean and the surrounding seas (E. Ionian and NW Levantine). The hydrological data were collected with a "SeaBird Electronics" CTD profiler on board the R/V Aegaeo. During the same period, currentmeter data were collected at the straits of the Cretan Arc: one array (P1) was deployed in the strait of Rhodes, two in the Karpathos strait (P2 east, P3 west), two more in the Kassos Strait (P4 east, P5 west) and one array in the Antikithira strait (P6). All deep current-meters were deployed within a depth range of 50 to 300m from the bottom. For each period, deep transports were computed at each strait and the data were compared with the hydrological structure of the area in order to estimate water mass exchanges through the straits.

The meteorological data (air temperature and precipitation) were collected by the National Meteorological Service at 9 stations of south Aegean islands for the period 1984-1995. The time series of precipitation clearly marks the extended period of dryness that lasted for more than 6 years (1988-1993). During this period we had a 40% decrease of the precipitation over the south Aegean compared to the period 1984-1987 (25 instead of 42 cm/yr). A second anomaly in these time series is related to the significant drop (DT > 2°C) in winter mean temperature during 1992 that has been attributed to the atmospheric dust from the Pinatubo eruption in 1991 [5]. The corresponding buoyancy loss caused deep overturning and mixing of the entire water column in the Cretan Sea.

The evolution of Cretan water mass properties

The typical hydrological structure in the Cretan Sea during the period 1986-1989 was composed by two water masses with T/S properties similar to the Levantine Intermediate Water (LIW). In the upper layers (50-400m) we meet the Cretan Intermediate Water (CIW) slightly colder (~14.5-15.5 °C) and saltier (S~38.95-39.10) and hence denser (σ_θ ~29.15) than the LIW. In the deeper layers (below 600m) we meet slightly colder (θ~13.9-14.2°C) and fresher (38.85-38.95) water with maximum density of 29.20 near the bottom. This means that the stratification was, in general, weak during this period and the water mass properties rather uniform but quite different from those of the Eastern Mediterranean at respective depths.

In March 1987 we first observe $\sigma_\theta > 29.2$ below 1000m in the western Cretan Sea while in March 1989 we also observe these densities in the eastern deep basins. During 1989 we must have a significant formation rate since the 29.2 isopycnal was raised from 2000 to 1000m between March and September. In the same period we first observe dense water of Cretan origin outside the Straits at depths 700-1600m with σ_θ ~29.17-29.18. The increase of density was continued for the following years and during the first period was mainly attributed to increased salinity. During the period 1989-1992 we had an almost 0.1 increase of the salinity (fig 1) and a small

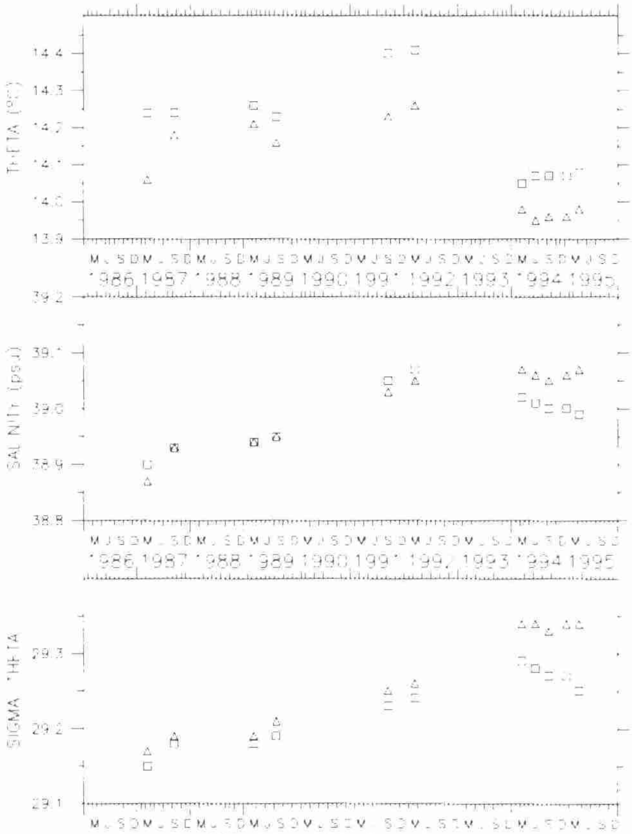

Figure 1: Time series of mean water mass properties in the Cretan Sea (squares: 600-1000m averages, triangles: 1000-2500m averages)