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Assessment of salt supply in different regions of the Eastern Mediterranean in response to changes in wind-driven circulation

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Introduction

Since the beginning of 90's a large climatic event, widely known as Eastern Mediterranean Transient, established in the Cretan Sea (Southern Aegean) an additional source of dense waters [Roether et al., 1996]. This event has been largely attributed to an increase of salinity in the Aegean Sea since the mid 80's [Theocharis et al, 1999]. The basic belief was that important meteorological anomalies acting in the Eastern Mediterranean changed the circulation patterns of the main water masses, which drive the salt distribution in the different sub-basins both at surface and intermediate layers [Malanotte-Rizzoli et al., 1999]. Concurrently, altered fresh water budgets and exceptional cold winters over the Aegean Sea might have played favourable conditions to move the predominant source of dense waters of the Eastern Mediterranean from the Adriatic into the Aegean Sea during the early 90's [Josey, 2003].

Basin-wide hydrographic observations performed since the late 80's in the Eastern Mediterranean exhibited unforeseen aspects of the upper dynamics, which were markedly different from the scheme depicted by Ovchinnikov (1966), who demonstrated the existence of three predominant divergence zones in the Ionian Sea, in the Cretan Passage and in the Levantine basin. The POEM Group (1992) traced a quite different scheme. In particular, the data gathered in the Ionian Sea have described the Atlantic-Ionian Stream that meanders in the western Ionian in a semi-permanent structure, which generally decreases in amplitude during the winter and transports Atlantic

Water into the Northern Ionian. The refined analyses of the POEM data sets (1985-1987) have described an inflowing jet with an intense northward meander looping a variety of multi-lobe Ionian anticyclones (Malanotte-Rizzoli et al., 1997) .

Strong connection between atmospheric forcing and dynamics was discovered by numerical simulations forced with real wind stress over the last 20 years, showing significant interannual fluctuations of the circulation pattern in the upper layer (Pinardi et al., 1997). Specifically, a winter anomalous forcing event occurred in 1986 over the Eastern Mediterranean induced changes in the circulation pattern. The Atlantic Ionian Stream, after exiting the eastern Sicily straits, branched northward into Ionian reversing the cyclonic motion in an anticyclonic rotation which was confirmed by observations in 1987.

A major outcome of the repeated hydrological observations performed in the Ionian Sea in 1988, 1990, 1991, 1992, and 1995, even if covering different periods of the year, was the persistent anticyclonic motion transporting large quantities of Atlantic Water (AW) into the Ionian interior. Moreover, the general flow pattern of the AW and the circulation of the underlying Levantine Intermediate Water (LIW) resulted altered. In fact, the fresh AW was entrained quasi-totally into the Northern Ionian and the LIW was confined into the Levantine basin, thus the exchange between the two basins was extremely reduced and these features were effective in increasing the salinity in the Aegean Sea (Malanotte-Rizzoli et al., 1999).

In this work we explore the status and the temporal evolution of the upper thermocline circulation patterns in the Northern Ionian on the basis of hydrological observations and current measurements conducted from 1997 to 2002, in relation to the climatic changes of the atmospheric forcing over the period of interest. The data considered are: (1) hydrographic observations from cruises specifically designed to monitor the status of the thermohaline circulation; (2) Wind fields from ECMWF reanalyses; (3) Altimetry data from TOPEX/POSEIDON; (4) Lagrangian measurements of surface circulation which show velocities and structures consistent with the circulation features inferred from hydrography.

Results and discussion

In 1999, a picture of the salinity minimum in the upper 250 m reveals the prevailing flow pattern of the AW toward the eastern end of the Levantine basin, further confirmed from the data collected in October-November 2001 and in March-April 2002. In parallel, the warm and saline LIW spreads at intermediate depths (200-400 m) from the formation region through the Cretan passage into the South Ionian.

The 10-m wind velocity fields from the ECMWF reanalyses span over a continuous

twenty years time series (1980-2002). Since the wind effect propagates into the ocean interior through its curl, such differential operator was applied to obtain the time series of the mean wind stress curl over the Ionian Sea and the Levantine basin. The atmospheric mesoscale activity was removed using appropriate low pass filter. The dominant signals integrated over the seasonal cycle have shown a yearly vorticity budget not balanced exhibiting a progressive shift from a prevailing cyclonic vorticity input in the early 80's to an anticyclonic vorticity lasting until the late 90's, when the wind stress curl inverts its sign to a cyclonic regime.

Clues of reduced transport of AW into the northern Ionian were also provided by the combined analyses of the low-pass filtered trajectories obtained from Lagrangian drifters spanning over a time period from 1995 to 2000. Besides the strong mesoscale activity in form of eddies, the meandering flow patterns include significant seasonal variations and persistent basin scale circulation features which have revealed the transition of the mean circulation from the anticyclonic to the cyclonic one in the Ionian interior.

0.0.1 Conclusions

The Ionian Sea interior dynamics show a sub-basin scale flow structure with a large anticyclone able to transport in the surface layer AW into the north after it enters the Sicily channel. Climate variations of the wind stress are proven to be important in determining not only the flow pattern of the main water masses at regional scale, but also in altering the temperature and salinity distributions and consequently shifting the prime ingredient for the dense water formation from one site to another. On the other hand, efficiently ventilated waters of the Mediterranean regions show relatively short residence time scale and therefore it is one of the primary area of the world ocean that displays large atmosphere and ocean variability being very sensitive and possibly influencing the climatic changes.

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