# NEW HYDROGRAPHIC SCENARIOS IN THE WESTERN MEDITERRANEAN: A POSSIBLE MONITORING STRATEGY

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## 1. ABSTRACT

Recent studies suggest that the deep western Mediterranean is undergoing a drastic change, comparable to what happened in the eastern basin during the mid-80s and 90s, the Eastern Mediterranean Transient (EMT). An alteration of the stratification, associated to an abrupt temperature and salinity increase, has been observed, which extension, causes and effects are still largely unknown.

## 2. INTRODUCTION

Recent studies have evidenced that significant changes in the climate conditions are not always related to centenary or millenary time scales, but may also happen in much shorter periods. This is particularly true for the Mediterranean, where space/time scales are one order of magnitude less than in the ocean and where, starting from the 80s, a rapid and extended change in the thermohaline circulation of the eastern Mediterranean (EMED) has been observed. An important task is to define a realistic survey strategy, focalized on a continuous monitoring of key regions, and to capitalize the existing time series, to understand the time scales of variability and to provide elements of comparison and verification to models.

## 3. RECENT CHANGES

The properties of the WMDW began to change after two winters in which new deep water has been formed by deep convection: winter 2004/2005 and winter 2005/2006 [1, 2]. In winter 2004/2005 the deep water formation (DWF) events that lead to this salty and warm new deep water mass occurred mainly in the Gulf of Lions and the Catalan subbasin, over an usually large area. The event has probably been triggered by strong atmospheric forcings and a very high salt content in the intermediate layer. In the following winter 2005/2006, the deep water has been formed mainly in the Ligurian Sea. The deep water properties and their variability are due to the hydrographic preconditioning (heat and salt content and structure of the water column before the onset of convection), and to the atmospheric forcings (heat, freshwater and buoyancy fluxes). The deep convection is sustained by the combination of surface heat and freshwater losses and the lateral convergence of heat and freshwater. In a steady state it is supposed that there is a balancing between the removal of heat and freshwater by the atmosphere and the supply of those properties by the ocean.

The long-term monitoring of the hydrographic and dynamic properties of water masses in the Sicily Channel and in other key positions of the western Mediterranean (WMED) during the last 20 years permitted to follow the interannual variability of the east-west exchanges, considering the propagation of the Eastern Mediterranean Transient (EMT) signature toward the WMED.

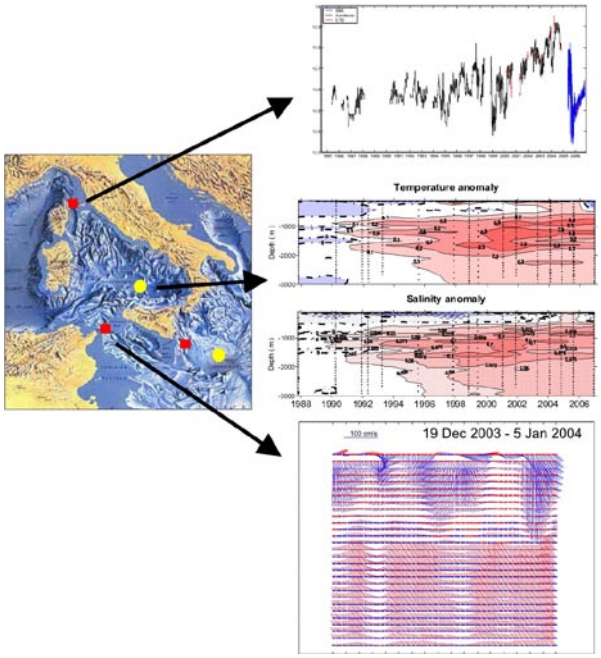


*Figure 1. Location of moored chains (red squares) and sites of special interest (yellow circles). Examples of data collected: time series of potential temperature in the Corsica Channel (moored instruments since 1985), T and S anomalies in the central Tyrrhenian basin (repeated CTD casts since 1988), current profiles in the Sicily Strait (moored instruments since 1994).*

The changes produced by this event in the deep thermohaline circulation of the EMED modified the properties of the Sicily Channel outflow and deeply influenced the hydrographic structure of the WMED water. More specifically, an acceleration of the increasing temperature and salinity trends in the deep

and intermediate layers has been produced. During recent years, those changes were able to play a key role in modifying the WMED deep water production. The abrupt increase of the heat and salt contents in the deep layer of the basin can be largely attributed to an increased heat and salt lateral advection.

## 4. APPROACHES

A continuous monitoring of the Mediterranean circulation is necessary to detect possible changes when they happen and to understand their time scales. Straits and channels form an important network inside the basin. Their monitoring permits to determine, at a basin scale, the evolution of the water mass characteristics and the transport variability. Therefore an adequate survey strategy would consist in (Fig. 1):

1. Long-term monitoring of Mediterranean straits, to define the main inter-basin exchanges, and some few regions characterized by relevant processes (moorings in the Straits of Sicily and Corsica since 25 years)

2. Repeated observations in sites of special interest, to maintain a deep-basin monitoring with repeated CTD casts at fixed stations in deep basins (Ionian and Tyrrhenian since more than 20 years, 1-2 casts per year)

3. Large-scale monitoring, through basin wide hydrographic surveys, a necessary tool for budget calculation, e.g. by means of box models (Fig. 2), to initialize and validate general circulation models, and to be assimilated in models to improve their forecast capability.

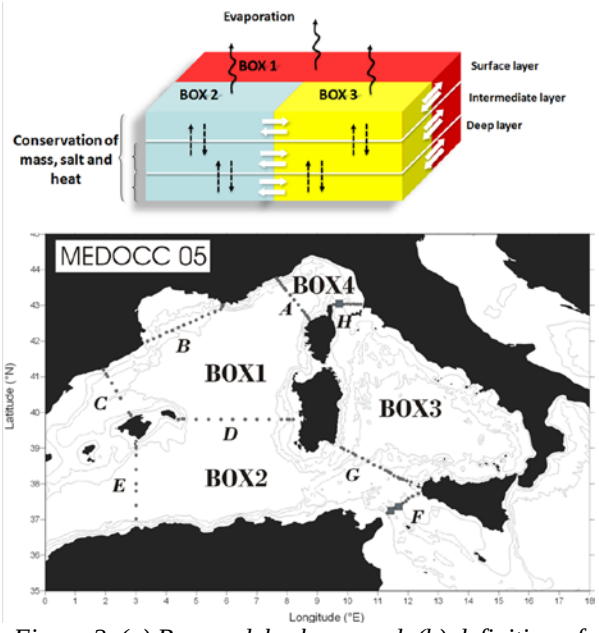


*Figure 2. (a) Box model scheme and (b) definition of real boxes using data of a cruise in the Western Mediterranean [3]*

Recently, wide-ranging dedicated field experiments have been carried out to get a quasi-synoptic view of the circulation in the WMED (Fig. 2b). A first comprehensive estimate of water fluxes in the WMED was obtained by means of a physically robust approach, aimed to an inter-comparison of differently achieved results. Three approaches have been adopted to describe the WMED circulation and velocity field, resolving different spatial–temporal scales and components of the motion, in order to evaluate their degree of accordance: a geostrophic approach, a direct approach and a modeling approach. The results confirm the qualitative overall circulation pattern, providing a solid quantitative basis to be used for budget estimates of different chemical/biological properties [3].

| Specific needs | General needs |
|---|---|
| Identification of the causes that triggered the event (atmospheric forcings vs lateral advection?) | Better understanding of the thermohaline stability and variability in the Mediterranean Sea, as well as identification of the factors that modulate this variability. |
| Determination of the origin of the greatly increased salt and heat transports across the Strait of Sicily (Cretan Intermediate Water, Levantine Intermediate Water…?), which is still continuing. | Reconstruction and monitoring of the post-transient evolution, which occurred and is still occurring in the eastern Mediterranean Sea. |
| Availability of data to estimate the DWF relevance in the winters 06/07, 07/08 and 08/09. | Reconstruction and monitoring of the event presently occurring in the western Mediterranean Sea. |
| | Assessment of the degree to which a relevant deep water production in one year may influence the production of the following years (*memory* of the system). |

*Table 1. Specific and general needs of further investigations*

Despite several advances in the recent years, there are still huge gaps in current knowledge, as well as the need of a monitoring effort of the anomaly, including not only physical parameters, but also biogeochemical, sedimentological and biological. The main knowledge gaps regarding this event are both specific and general (Table 1).

Priorities for future research on the dynamics of Mediterranean deep waters should therefore include attempts to answer the following questions:

**1. Reconstruction and monitoring of the transient event which is occurring in the western Mediterranean Sea.**

- *Evolution in time and space*: Which is the extent of the event occurring in the western Mediterranean, in terms of salt and heat contents increases in the deep layers and in terms of uplifting of the resident deep water? Which are the involved mixing processes? What are the ventilation times and the ages of the involved water masses?
*Achievements*: to contribute to the knowledge of the evolution of this climatic event, reconstructing its spatial and temporal variability, the transit times and the mixing fraction of the involved water masses, both resident and newly formed.

- *Causes and forcings*: Which forcings have determined the observed anomaly in the deep western basin?
*Achievements*: to identify processes at different time-scales and to test hypotheses on the mechanisms and causes of the abrupt alterations in the physical properties of deep water masses, by using on-purpose models and the time-series of observations.

- *Possible impacts and repercussions*: To which degree the anomaly will contribute to the general warming and salinification of the Mediterranean basin? How fast is the anomaly propagating in the interior of the basin? To which extent the straits control this propagation? Which might be the possible repercussions on the Mediterranean Outflow? Which are the involved temporal scales?
Achievements: to identify and quantify the effects the anomaly observed in the western basin induces on adjacent areas (eastern Mediterranean and Atlantic Ocean).

**2. Documentation and understanding of the interactions between the western and the eastern Mediterranean, studying the physical tracers and the factors that modulate their variability.**

- *Internal variability*: Which is the degree of variability of the thermohaline circulation and the physical properties of each basin?
*Achievements*: to set the background of the more recent changes, thus improving the interpretation and synthesis capability of the new available observations.

- *Modulation of the variability*: Which are the mechanisms that modulate the internal variability in each basin? How do the feedbacks between Strait of Sicily – Strait of Gibraltar – deep water formation areas act?
*Achievements*: to define the relationship between exchanges through the straits and internal variability of the basins; to assess the possible feedbacks on the Mediterranean dynamics on the global climatic system.

## 5. COONCLUSIONS

The interannual variability of the hydrographic conditions evidences how the influence of the EMT in the Mediterranean is far to be concluded. Recent observations (since 2006) in the Sicily Channel suggest the arrival of new dense waters from the EMED. The experience of the propagation of the EMT demonstrates that straits and channels are suitable points to provide early warning of anomaly propagation.
The long-term monitoring of the straits of Sicily and Corsica permitted to detect important changes in the circulation and hydrography at basin-scale, giving important information concerning the investigation strategy for the basin interior. This is done by providing time-series of repeated CTD casts in the deep layers of both the western (Tyrrhenian) and the eastern (Ionian) Mediterranean, as well as performing basin-wide surveys, that provide quasi-synoptic views of the hydrographic and dynamic features.
New available technologies are able to significantly improve the present monitoring in term of space/time resolution and extending the coverage to biogeochemical parameters. The important task of data transmission needs to be evaluated to permit a real time monitoring and the consequent possibility to make the acquired data available for forecasting purposes.
Even though the recent western anomaly has several similarities with the EMT, in terms of intensity and effects, it has not received the same attention. Therefore the future research priorities should aim to make up for this lack, scheduling the monitoring of the event and addressing the study of the causes (remote or local) that may have induced it and of the possible repercussions.

## 6. REFERENCES


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