Monitoring, detection and attribution of thermohaline stability and variability in the Western Mediterranean Sea

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Introduction: observed thermohaline changes

The long-term monitoring of the hydrographic and circulation properties of water masses in the Sicily Channel and in other key positions of the western Mediterranean 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 western basin (Gasparini et al., 2005). During recent years, those changes were able to play a key role in the western Mediterranean deep water production (in terms of properties and volume), which induced a large renewal in the deep layer of that basin, an event that is comparable to the EMT, in terms of intensity and effects (Fig. 1).

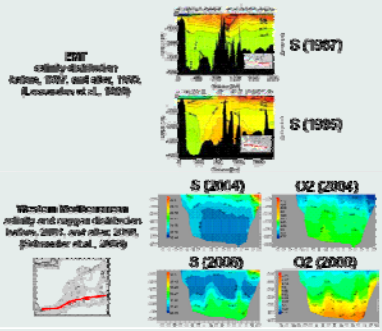

Figure 1: Comparison between observations of the EMT in the eastern basin and recent observations in the western basin

For this reason a continuous monitoring of the Mediterranean circulation would be necessary, to permit the detection of possible changes when they happen, to understand their time scales and to provide elements of comparison and verification to the models. A strategy to achieve this objective is proposed, addressing advances and gaps in current knowledge of the western Mediterranean deep-sea system and proposing priorities for future research.

The data collected in the deep western basin have revealed an abrupt change, with the appearance and spreading in the whole western basin of a new deep water, significantly warmer and saltier than previously, which has substantially substituted the resident deep water (Schroeder et al., 2008). This new deep water has been formed during massive convection events, that took place during winters 04/05 and 05/06 in the NW-MED. Between 2004 and 2008 the CNR-ISMAR (La Spezia) and the CNR-IAMC (Oristano) have jointly carried out an effort to monitor the anomaly at the basin scale, in order to obtain the most comprehensive picture of its evolution. A summary of the temporal evolution of the anomaly, and the consequent uplifting of the resident deep water is given in Fig. 2. The vertical profiles of potential temperature and salinity in a station south of the Balearic Islands clearly evidence the gradual uplifting of the resident deep water, replaced near the bottom by the warmer and saltier new deep water. A near-bottom salty and warm vein intrudes in 2005, and this layer has become 600 m thick in 2006 and almost 1000 m thick in 2008.

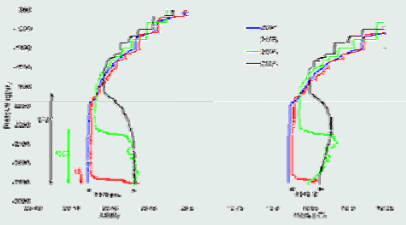

Figure 2: Vertical profiles of S and θ measured at a station in the Algerian basin (5 °E, 38 °N) in October 2004 (blue), June 2005 (red), October 2006 (green) and November 2008 (black). The vertical arrows indicate the thickness of the layer occupied by the nWMDW, while the black horizontal arrows indicate the total salinity and temperature increases at the bottom.

Priorities

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 but also biogeochemical, sedimentological and biological parameters. Priorities for future research on the dynamics of Mediterranean deep waters should include attempts to answer the following issues.

Reconstruction and monitoring of the transient event which is occurring in the WMED

Evolution in time and space: 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: 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 identify and quantify the effects that the anomaly observed in the western basin induces on adjacent areas (EMED and Atlantic Ocean).

Understanding of the climatic oscillations in the WMED, studying the physical tracers and the factors that modulate this variability

Internal variability: to set the background of the more recent changes, thus improving the interpretation and synthesis capability of the new available observations; to identify knowledge gaps and design of an observational system to allow critical considerations and to diagnose future changes.

Modulation of the variability: to define the relationship between exchanges through the straits and internal variability of the western basin; to formulate and test hypotheses on the possible mechanisms and causes of the internal variability in the western basin; to assess the possible feedbacks of the Mediterranean dynamics on the global climatic system.

References and Acknowledgements

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Investigative strategy

With the aim of monitoring, characterizing spatially and temporally and identifying causes and effects of the recent changes, the research should employ:

- ***Physical tracers*** *(temperature and salinity)*
- ***Chemical tracers*** *(nutrients, oxygen, CFC)*
- ***Hydrological and current data in fixed points***
- ***Numerical simulations***

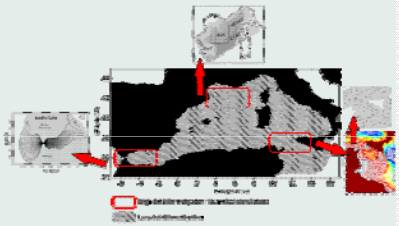

Figure 3: Investigative approach

In this context, we propose to carry out yearly cruises, to investigate both the western basin at large scale, in order to evaluate the evolution of the recently observed phenomenon, and three key areas: Sicily Channel, Gulf of Lions, Strait of Gibraltar. Finally, numerical simulations represent an useful tool to integrate observations and data collected during field activities (oceanographic cruises and mooring data). In particular, the models should be implemented in the three key areas (Fig. 3).

Conclusion

Even though the described event has several similarities with the EMT (Fig. 1) it has not received the same attention. The main knowledge gaps regarding this event are listed below.

Specific needs	General needs
• Identification of the causes that triggered the event (atmospheric forcings vs lateral advection?) • 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. • Availability of data to estimate the DWF relevance in the winters 06/07, 07/08 and 08/09.	• Better understanding of the thermohaline stability and variability in the Mediterranean Sea, as well as identification of the factors that modulate this variability. • Reconstruction and monitoring of the post-transient evolution, which occurred and is still occurring in the eastern Mediterranean Sea. • Reconstruction and monitoring of the event presently occurring in the western Mediterranean. • 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

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. Such monitoring could proficiently be done in coordination with the Special Observing Periods (SOP) and Enhanced Observing Periods (EOP), scheduled by HyMeX.