Basin scale dissolved oxygen interannual variability of the Mediterranean Sea: Analysis of long-term observations

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Introduction

Dissolved oxygen (DO) concentration is an important oceanic parameter for the marine ecosystem functioning. Both physical and biological processes such as the air-sea interaction, the ocean circulation, and the supply of bioactive trace nutrients to the ocean interior, regulate the DO distribution and its variability [1]. Understanding the related mechanisms and the variability of the above processes requires systematic oceanographic measurements over long periods and at high spatial resolution. The Mediterranean Sea is an interesting region for such a research effort because it is characterized by a combination of long-term trends and climatic shifts known in the literature as "transients", that impact the biogeochemical processes. However, its DO variability has been studied only partially, either on spatial or temporal scales. Taking advantage of the Mediterranean monitoring systems, we can examine the sensitive physical and biogeochemical processes in the Mediterranean ecosystem.

Scientific Questions

- Which is the spatiotemporal distribution of DO in the Mediterranean Sea?
- Are there any trends or shifts in the last decades explaining the Mediterranean Sea DO content?
- Which are the key mechanisms controlling the DO concentration in the water column?

Data & Methodology

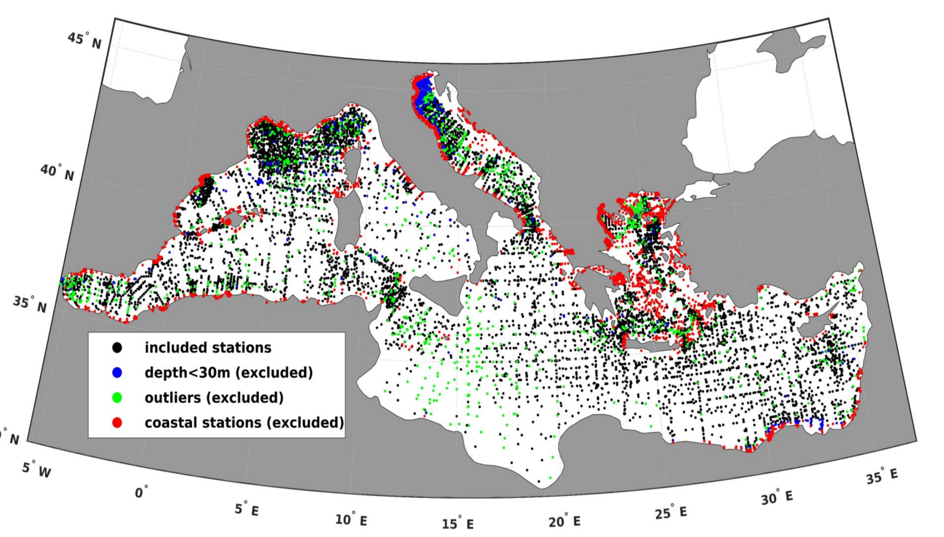

Figure 1: Study area and spatial distribution of sampling stations under quality controls. Excluded stations from the analysis are depicted with: red dots indicating coastal stations, green dots denoting outliers, blue dots corresponding to shallow stations with depths lower than 30m. Black dots indicate the included stations for the analysis.

The lack of good spatiotemporal coverage of in situ measurements does not allow for a direct and accurate evaluation of the interannual changes in the Mediterranean Sea. In order to investigate the variability of DO, a gridded dataset included DO, potential temperature and salinity, was constructed using Data-Interpolating Variational Analysis (DIVA) [2]. The data were used for the period 1960-2011 and, after a quality check (Fig.1), they interpolated into 1/8 x 1/8° grid for 32 standard levels.

Taking into consideration the region's dominant scales and applying spatiotemporal coverage optimization approaches available from DIVA software, especially in years with sparse data (Fig.2), we computed annual gridded fields.

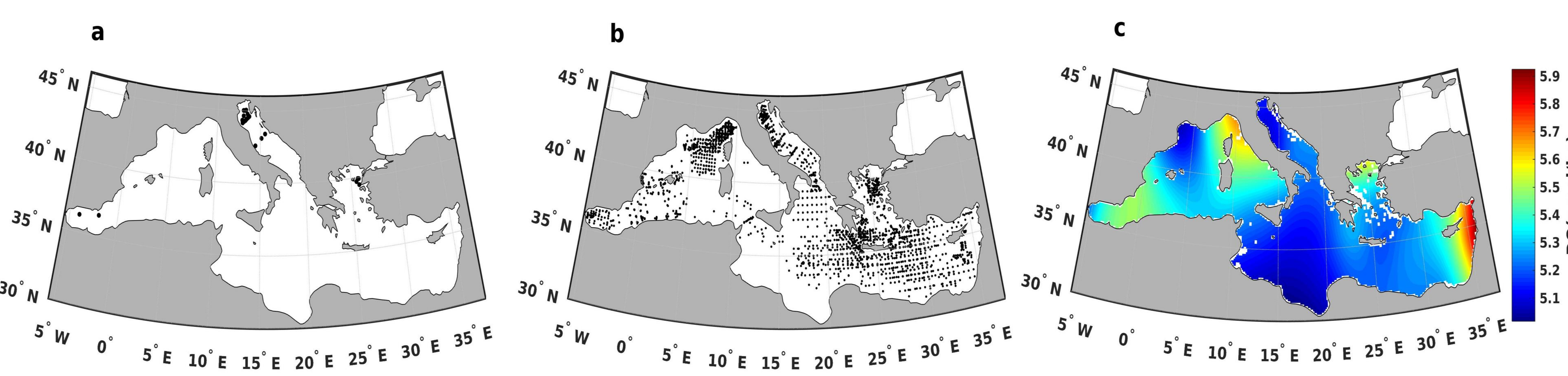

Figure 2: Example of coverage optimization. a) available stations to compute the annual field of the year 1984, b) available stations after optimized approach for the year 1984, d) the final gridded analyzed field (dissolved oxygen) for the year 1984.

Results

Temperature is one of the main factors controlling the oxygen distribution based on solubility, as the temperature increase leads to reduced solubility and depletion of surface oxygen concentrations [3]. The DO concentration at the surface layer appears to be sensitive to the temperature and the overall correlation coefficient is negative at the whole domain(Fig.3a).

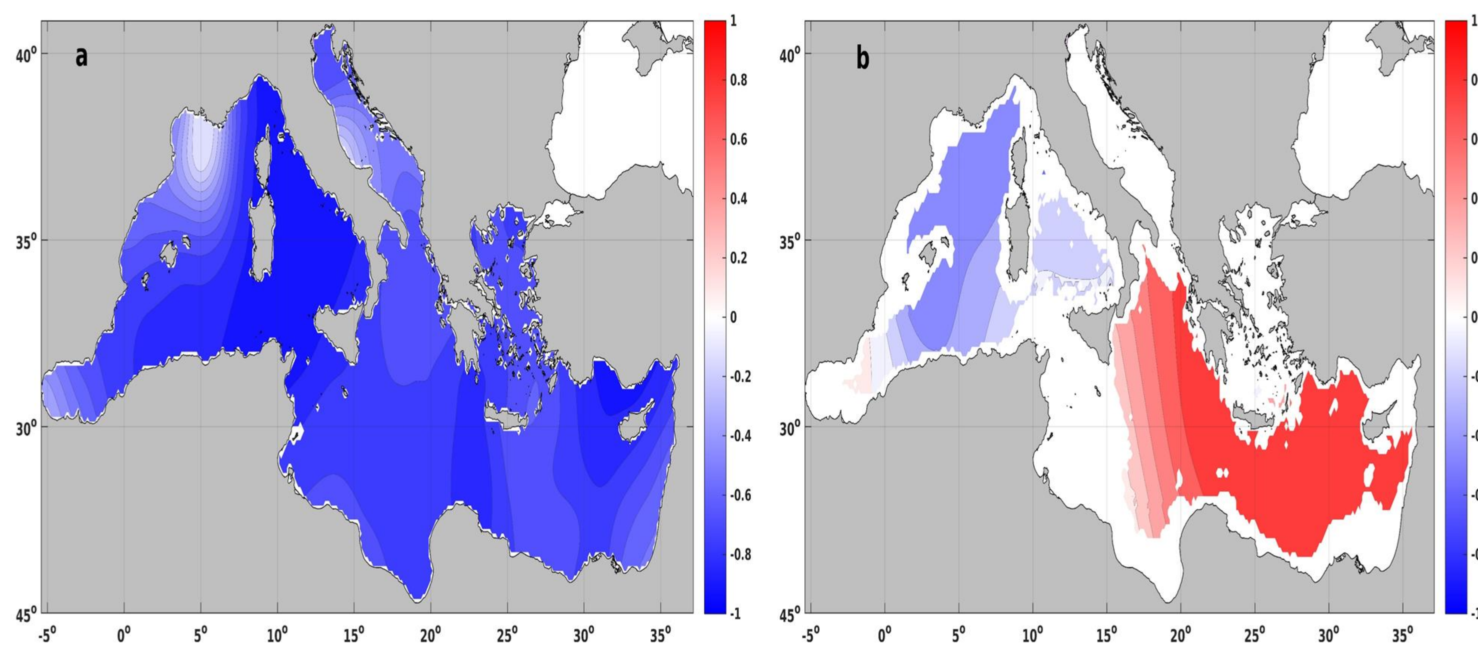

Figure 3: Correlation map between temperature and dissolved oxygen for a) surface layer, b) 1500m.

In the deeper waters the sign of the correlation between the two sub-basins is opposite (Fig.3b). The deep correlation in the Eastern Mediterranean does not follow the surface behaviour, which is an indication that there are dynamical processes (deep-water formation variability, transients, etc.) that are involved in the interannual variability of the DO.

The O_2 and O_{2sat} anomaly variations in the upper layer for the two sub-basins are also of the same magnitude, since the DO variability controlled by temperature changes (Fig.4a,b). The AOU as a metric, which separates the changes explained by solubility from other, more complicated mechanisms, is similar in magnitude to the observed O_2 variability in the deep layers(Fig.4c,d). This variability correspond to prominent shifts at specific periods.

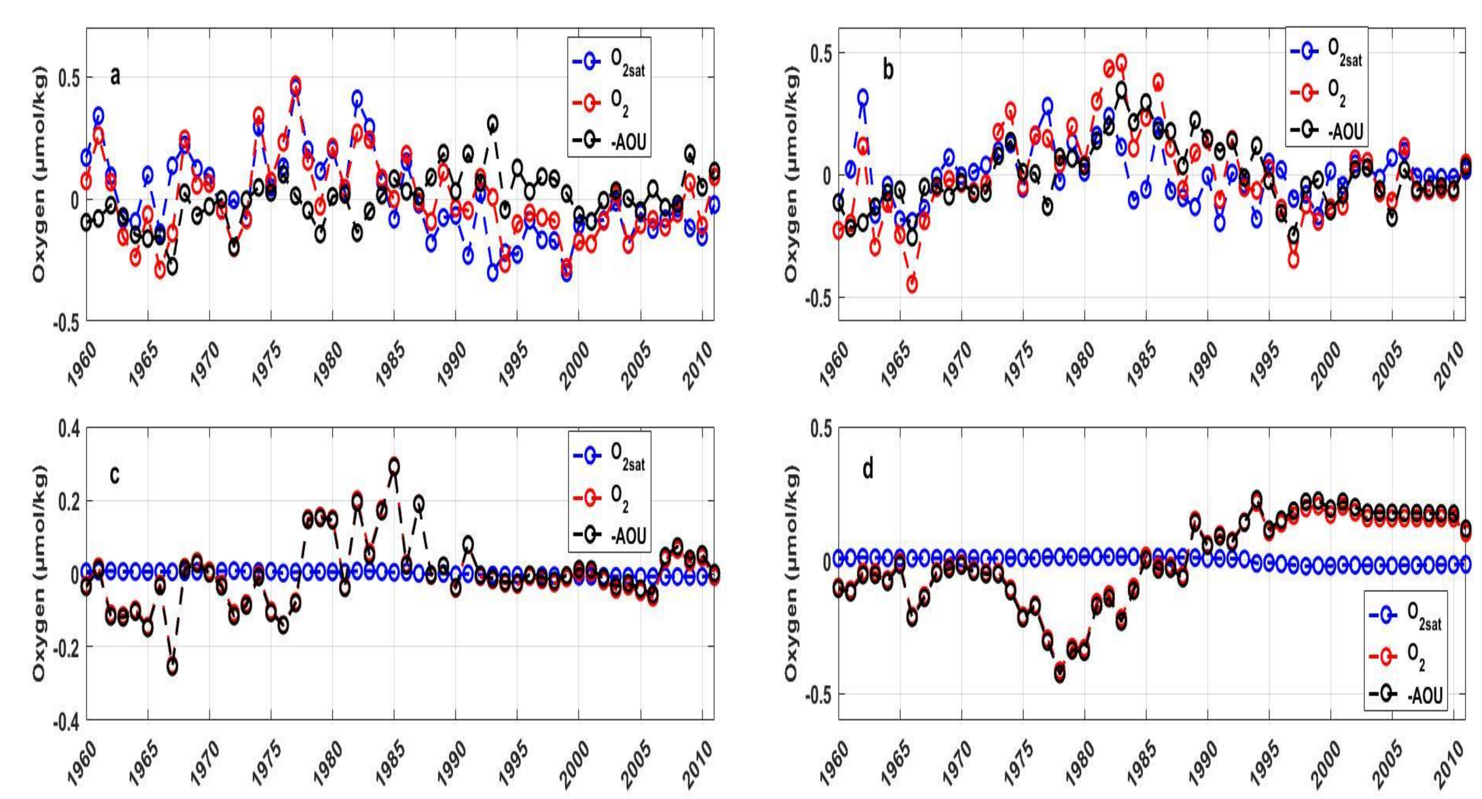

Figure 4: Mean annual anomaly of O_2 (blue line), O_{2sat} (red line) and negative AOU (black line) for the western basin at a) surface, c) 2000m and the eastern basin at b) surface, d) 2000m.

The vertical distribution of the DO also presents significant variability (Fig.5). Multidecadal shifts, rather than long-term trends, are observed for the dissolved oxygen and thermohaline characteristics and are associated with known episodic dense water formation events. The latter is true, especially for the EMT period, but to a lesser extent for the WMT. Results revealed also a marked difference between the two sub-basins in terms of minimum oxygen values and their observable depths. The different dissolved oxygen concentration in deep layers is closely associated with the rate of the mixing processes.

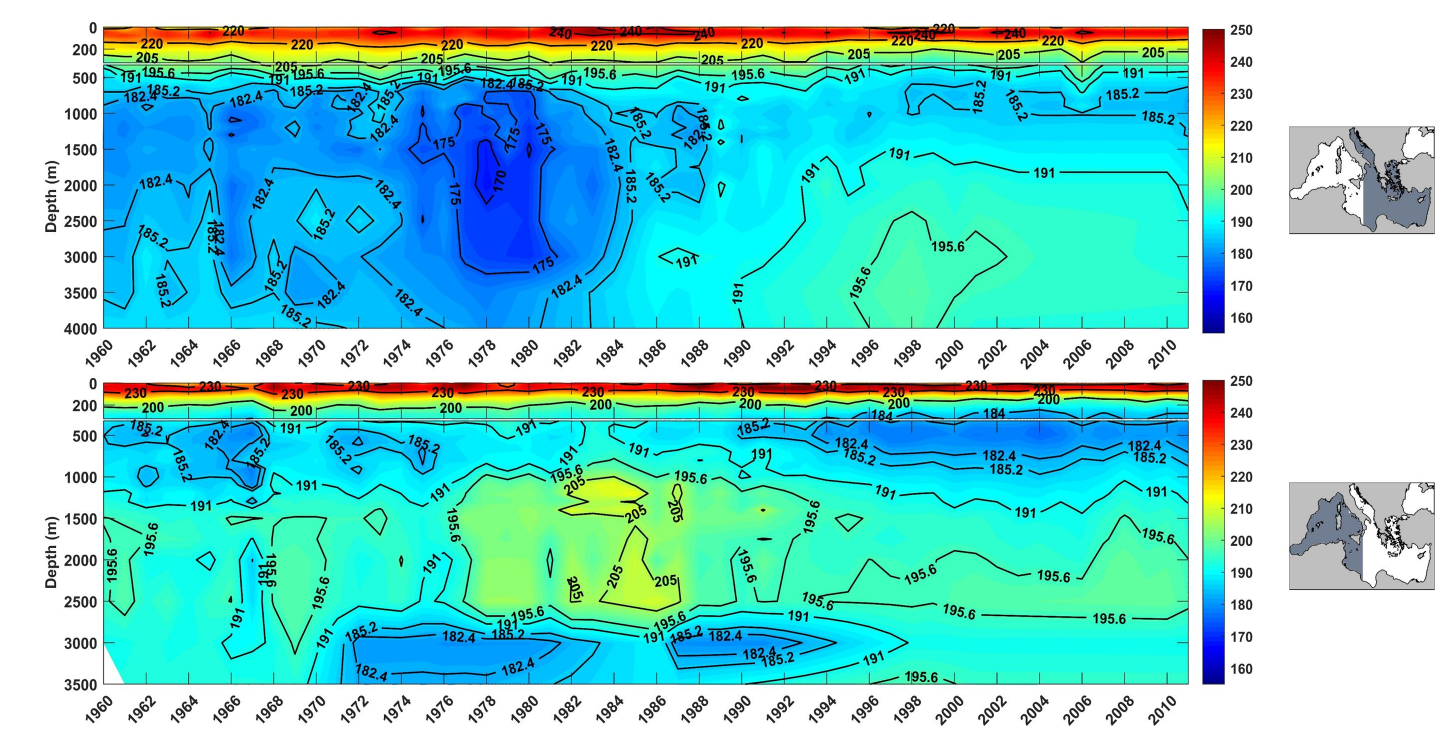

Figure 5: Hovmöller diagram of dissolved oxygen profiles for the Eastern Mediterranean (top) and the Western Mediterranean (bottom)

Their time scales have been estimated to be faster in the western basin in comparison to the eastern basin resulting to the weak ventilation of the latter. The EMT anomalous ventilation affected initially the deep layer and later the whole column.

Conclusion

In this study, we focus on the DO interannual to decadal variability in the Mediterranean Sea. The oxygen inventory is significant correlated with changes in temperature. The most prominent signal is the multiyear variability at the deeper layers, which is associated with changes in the deep water renewal pattern, mixing processes or decadal oscillations of the upper circulation of the Mediterranean Sea. The observed shifts instead of trends in the DO distribution of the Mediterranean Sea are also evidence of the faster response of the basin on transient changes compared to the open ocean [4]. The biogeochemical activity may also not be negligible and the attribution of the observed variability requires further analysis using modeling techniques and available operational tools.

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