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# Climate variability and deep water mass characteristics in the Aegean Sea

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ABSTRACT

The main objective of this study is to investigate the variability of the thermohaline characteristics of the deep-water masses in the Aegean Sea and the possible impact of the regional atmospheric forcing variability by analyzing the available oceanographic and atmospheric datasets for the period of 1960–2012. During this period the variability of the deep water characteristics of the Aegean sub-basins is found to be very large as well as the diversity of the deep water characteristics among the sub-basins. The Central Aegean seems to play the key role in the Aegean deep water formation processes. Due to its small size, the Aegean Sea surface responds rapidly to the meteorological changes and/or the variability of the lateral fluxes and this variability propagates in the thermohaline characteristics of the deep water masses of the basin through deep water formation processes. There are many episodes characterized by a tight coupling of the atmosphere and the ocean during the examined period, with the Eastern Mediterranean Transient (EMT) being the most prominent case. We suggest that deep water formation is triggered mostly by the combination of preconditioning during early winter and/or previous winters together with the number of subsequent extreme events during present winter and not only by the total amount of the extreme heat loss winter days.



## 1. Introduction

The Aegean Sea is a semi-enclosed basin located in the northeastern Mediterranean Sea covering an area of 240,000 km$^2$. The Aegean Sea communicates with the Ionian and Levantine basins through the Straits of the Cretan Arc and with the Black Sea through the Dardanelles Strait (Fig. 1). The total volume of the Aegean Sea is about 75,000 km$^3$ (Gertman et al, 2006; Vervatis, 2013) and the coastal and offshore topography is irregular and complex. The complexity of the shoreline and bottom topography is associated with the presence of a great number of islands (over 3000 islands and islets are present in the Aegean Sea) and in consequence the bottom topography is characterized by an alternation of shelves, sills and deep depressions. The Aegean Sea constitutes of three major basins; the North Aegean, with maximum depths up to 1500 m; the Chios Basin in the central part, with maximum depth of 1100 m; and the Cretan Sea in the south, the largest basin, with maximum depth of 2500 m. The above major basins are connected through channels shallower than 400 m. The exchange fluxes through the straits are not well known, especially at the intermediate and deep layers (Zervakis et al., 2003).

The annual evaporation exceeds the sum of precipitation and river runoff over the Aegean Sea, but the water balance is positive if we take into account the low salinity Black Sea Water (BSW) inflowing in the Aegean Sea. The annual net heat flux is estimated at - 26 W/m$^2$ (Poulos et al., 1997) and

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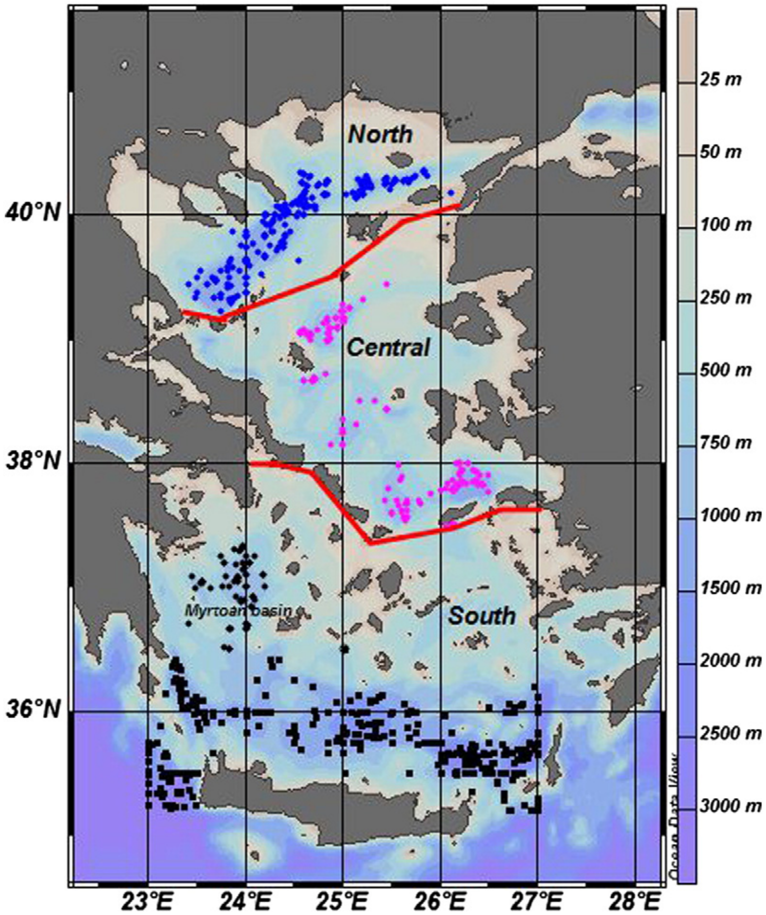


**Fig. 1.** Stations in the Aegean Sea with depth greater than 700 m (dots in blue and magenta for the North and Central Aegean) and 1000 m (southern Aegean—black dots). The South Aegean includes the Myrtoan Sea where depth greater than 700 m was selected.

consequently the Aegean Sea surface heat losses are balanced by the advection of warmer water masses through its open boundaries, mainly by the inflow of warm Levantine waters at the surface and intermediate layers. During summer (July–August) and winter (December–February) strong winds from northern directions blow over the Aegean Sea. These northerly winds bring relatively cool continental air from the region of southern Russia and the Caspian Sea, contributing to the decrease of surface temperature and the moderation of summer heat that lead to surface buoyancy loss (Poulos et al., 1997). Papadopoulos et al. (2012a, 2012b) and Josey et al. (2011) found a remarkable coupling between events of extreme surface cooling and the large-scale sea level pressure (SLP) configuration in the Mediterranean Sea. The patterns favoring abnormal heat loss are associated with the transfer of cold and dry air masses over the Mediterranean basin. In particular, SLP anomalies, related primarily to the East Atlantic/West Russian (EA/WR) pattern, are a prominent regulating factor of the air–sea heat fluxes over the Aegean Sea region especially during the cold season of the year.

The overall Eastern Mediterranean thermohaline circulation is driven by the air–sea buoyancy losses at the sea surface (Wüst, 1961). The classical pattern of the circulation in the Eastern Mediterranean is characterized by an inflow, through the Strait of Sicily, of low-salinity surface Atlantic Water (AW), by the formation of warm and of high-salinity intermediate waters in the Levantine Sea (LIW) and the Cretan Sea (CIW—Cretan Intermediate Water) during February and March, under the influence of dry and cold continental air masses (Bruce and Charnock, 1965; Lacombe and Tchernia, 1972; Georgopoulos et al., 1989) and by the production of Eastern Mediterranean Deep Water (EMDW) in the Adriatic Sea in the form of self and open sea convection. The warm, saline Levantine Surface Waters (LSW) can also be detected in most of the regions of the eastern Mediterranean (Lacombe and Tchernia, 1960). The intermediate layers between the LIW (200–500) and the EMDW (700–1600 m) are occupied by the Transitional Mediterranean Water (TMW) and are considered to be a transitional water mass (Pollak, 1951) with S and Θ lower than those of LIW (Theocharis et al., 1999a).

The circulation pattern of the Aegean Sea has been described analytically in the past through a series of observational and modeling studies and it can be summarized as follows. The northeastern region of the Aegean is characterized by the intrusion of the low salinity (24.0–35.0) surface Black Sea Water (BSW) through the Dardanelles Straits (Theocharis