Record-high salinity and interannual dense water formation variability in the Aegean Sea coincide with reduced inflow of Black Sea Water

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Introduction

The observed warming and salinification of the Eastern Mediterranean Sea (EMed) during the last decades could impact dense water formation (DWF) and consequently the thermohaline circulation of the basin. The main drivers of interannual DWF variability in the EMed are the atmospheric heat fluxes, the internal redistribution of salt, and the exchange of heat and salt at its straits. Extremely high salinity has been observed recently in the Levantine and Adriatic Seas due to the superposition of the basin's decadal variability and long-term trend.

Considering the recent basin-wide thermohaline changes in the EMed, a combined analysis of in situ, satellite data, and model output was conducted to study the variability of mechanisms controlling the DWF in the Aegean.

Data and Methods

The long-term variability and recent DWF state of the Aegean were investigated using:

- A data set of in situ hydrographic observations compiled from data freely available on the internet,
  ☛ to investigate the long-term salinity variability and recent DWF events in the Aegean.

- A satellite-based product of Sea Surface Height (SSH),
  ☛ to create an index of BSW inflow in the Aegean and identify the long-term variability and present status of the North Ionian circulation Reversals (NIR).

- An in situ-based gridded hydrography reanalysis product,
  ☛ to investigate the relation of salinity between different subbasins of the EMed.

- An atmospheric reanalysis product,
  ☛ to compute the surface buoyancy fluxes over the study area.

- results from a Black-Sea box model system[1], a water budget estimation over the catchment area of the Mediterranean[2], and an SSH-based index coined in this study,
  ☛ to infer the long-term variability of Black Sea Water (BSW) inflow in the Aegean.

- A non-data-assimilating hydrodynamic model using variable BSW inflow[3] and a data-assimilating hydrodynamic model using climatological BSW inflow[4],
  ☛ to assess the variability of DWF in the Aegean.

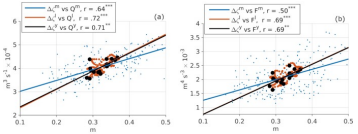

Figure 1. Evaluation of the SSH difference Δζ between the exits of Bosporus and Dardanelles as an index of BSW inflow in the Aegean. Δζ compared against the (a) volume inflow Q and (b) lateral buoyancy flux F of BSW in the Aegean, using the output of a box model[1] as reference.

Results

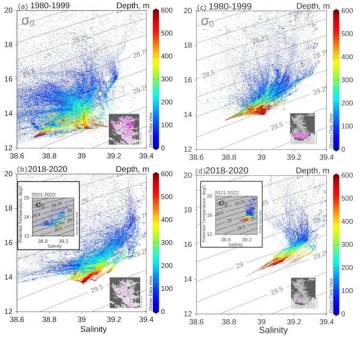

Figure 2. T-S diagrams of hydrographic measurements in the 0 – 600 m layer of the North and South Aegean Sea from 1980 – 1999 and from 2018 – 2022. Before 2018, the highest salinity has been observed during the EMT period (roughly 1986 – 1996).

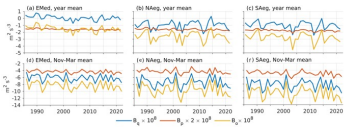

Figure 3. Thermal B_α, haline B_β and total surface buoyancy fluxes B_o over the (a, d) EMed excluding the Aegean and Adriatic, (b, e) North Aegean, and (d, f) South Aegean. The first row shows the year-mean and the second row the winter-mean fluxes.

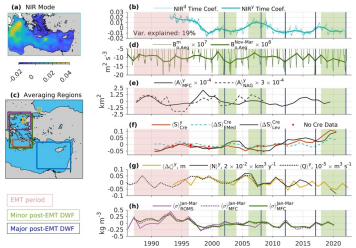

Figure 4. Relation of (a, b) first EOF mode of daily absolute dynamic topography anomalies showing the North Ionian circulation Reversals (NIR)[5], (d) total surface buoyancy fluxes B_o over the Aegean, (e) surface area A covered by BSW, (f) 0 – 250 m salinity S and salinity differences ΔS between the South Aegean and adjacent basins, (g) upper layer inflow Q, net inflow N and SSH-based inflow index Δζ of Black Sea Water in the Aegean, and (h) surface density σ from two hydrodynamic models. Brackets denote anomalies. Colored lines in time series plots denote the averaging over the area shown in (c). Shaded areas and vertical lines correspond to dense water formation periods in the Aegean. Time series in panels (e)–(g) have been scaled as shown in their legends to fit in the same y-axis.

Conclusions

- The BSW inflow in the Aegean has a negative trend reducing the salinity difference between the Levantine and Aegean Seas, especially after 2012.
- From 2017 to 2022 the Aegean has been in the most prolonged state of increased DWF since the EMT period.
- Post-EMT periods of minor DWF in the Aegean Sea coincide either with the anticyclonic circulation of the North Ionian Sea or with the increased surface buoyancy loss over the Aegean Sea, as a synchronous DWF-favouring phase of both drivers has not occurred yet.
- The common denominator of all major post-EMT DWF events in the Aegean -also true for the EMT period- is the reduced inflow of BSW.

Funding

This work was supported by the Project "Coastal Environment Observatory and Risk Management in Island Regions AEGIS+" (MIS 5047038), implemented within the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014-2020), cofinanced by the Hellenic Government (Ministry of Development and Investments) and the European Union (European Regional Development Fund), and by the Ypatia Scholarships for PhD studies of the University of the Aegean.

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