The South Adriatic Sea as a deep water convection site in the Mediterranean Sea

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Ritmare – La ricerca italiana per il mare

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Abstract

The South Adriatic Sea is a deep water convection site in the Mediterranean Sea. In the last 4 years a peculiar double salinity maxima (DSM) is evident along the water column. This specific feature was never observed before in the historical dataset of the area. Several glider campaigns were carried out in the area from 2013 to 2019. Glider data were analyzed along with heat flux products, observations of river discharges and Argo float salinity data of the last 8 years to shed new lights on the dynamics of the area.

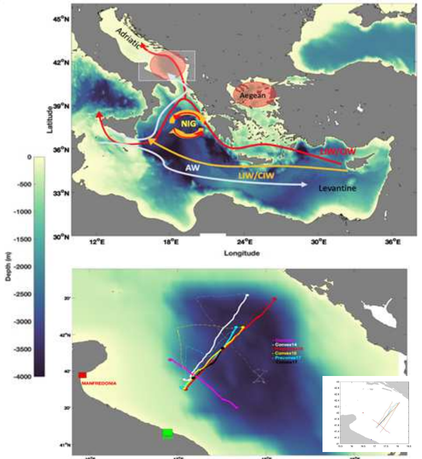

Fig.1: a) Diagram of the Central Mediterranean Sea circulation and water masses in the top 500 m: Atlantic Water (AW), Levantine Intermediate Water (LIW), Cretan Intermediate Water (CIW), north Ionian gyre (NIG). Red lines depict the circulation during the NIG cyclonic mode and yellow lines during the NIG anticyclonic mode; b) zoom of the south Adriatic Sea with glider tracks.

Introduction

The Adriatic Sea (Fig.1a) is the northernmost sub-basin of the Mediterranean Sea connected to the Ionian Sea through the Otranto Strait. The bathymetry is shallow in the north, while a deep pit characterizes the south Adriatic pit (SAP). During the winter, the surface water of the basin cools and evaporates because of strong easterly dry winds, triggering the deep water formation in the northern and the southern areas.

The hydrological characteristics of the SAP are determined by the local climatic conditions, the water flowing from the northern basin and the water exchange with the Ionian Sea.

The waters entering in the Adriatic depend on the North Ionian Gyre (NIG) mode, that undergoes to a periodical reversal from cyclonic to anticyclonic and viceversa, influencing the upper thermohaline cell (Fig. 1a). The reversal happens on about a decadal cycle and seems to be correlated with alternations of Adriatic and Aegean Seas as Dense Water Formation sites. When the NIG is in anticyclonic mode the Atlantic Water (AW) pathway deflects to the north Ionian and when the NIG is in cyclonic mode, the Ionian Surface Water (ISW) / Levantine Surface Waters (LSW) enters in the SAP. The deeper layers are influenced by the Levantine Intermediate Water (LIW) and the Adriatic deep waters flowing on the bottom layer.

The flow from the north Adriatic is composed of the cold deep North Adriatic Water (NAdW), formed during the winter and moving to the south on the bottom along the Italian coast and by the Western Adriatic Current (WAC) carrying riverine low salinity water.

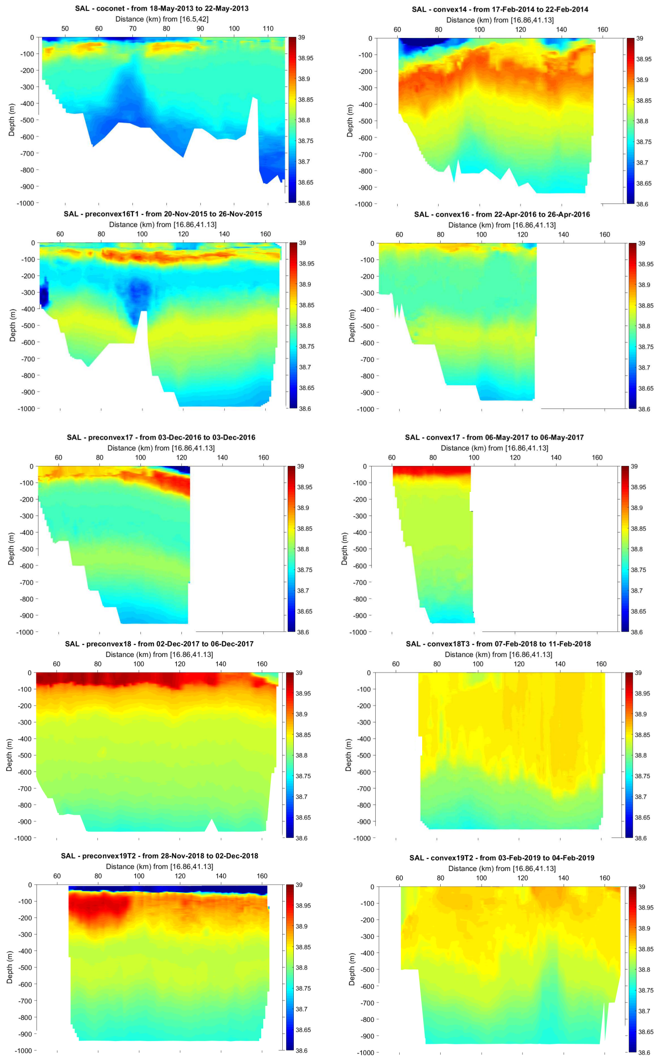

Fig. 2: Salinity data along the Bari-Dubrovnik transect from 2014 to 2019, the x-axes shows the distance from Bari (blue dot). In 2013 the track followed the Italian coast and the distance is computed from the red dot reported in Fig 1b.

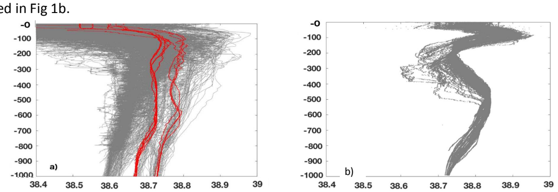

Fig. 3: a) Historical salinity profiles collected in the SAP between 1984 – 2013. The DSM profiles are superimposed in red relative to December 1990, June 1994, December 2005 and May 2006; b) salinity profiles collected during November 2015. (SeaDataNet products catalogue at https://www.seadatanet.org/Products#/).

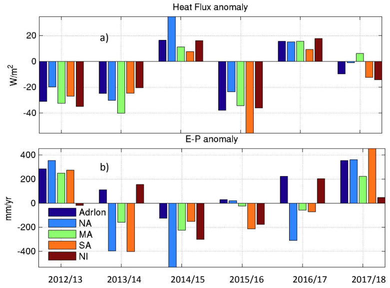

Fig. 4: a) Anomalies of the water and heat fluxes in different regions of the Adriatic-Northern Ionian area: Northern, Middle, and Southern Adriatic and North Ionian were computed over the time period 1912-2016. The anomalies of the winter months from December to March are evaluated with respect to the 1987-2016 mean; b) Water balance is computed as evaporation minus precipitation and runoff. Evaporation is derived from the latent heat flux. Data from Mediterranean Sea reanalysis dataset (doi:10.25423/medsea_reanalysis_phys_006_004).

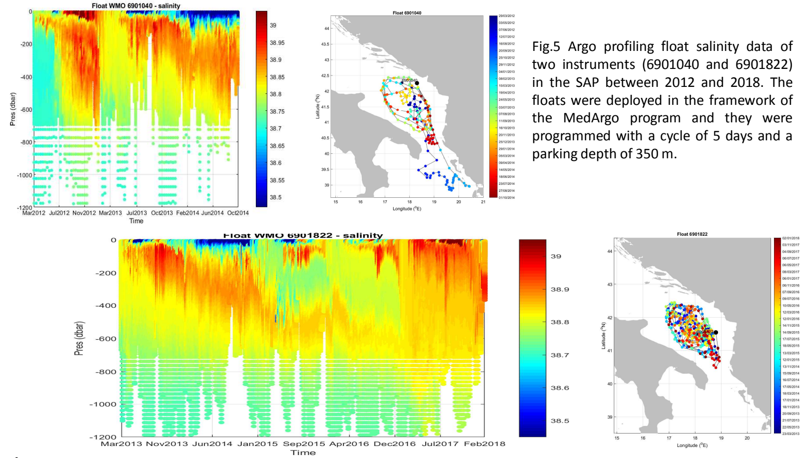

Fig.5 Argo profiling float salinity data of two instruments (6901040 and 6901822) in the SAP between 2012 and 2018. The floats were deployed in the framework of the MedArgo program and they were programmed with a cycle of 5 days and a parking depth of 350 m.

Results

The salinity data of the Bari-Dubrovnik transect collected by gliders during 10 campaigns from 2013 to 2019 are displayed in Fig. 2. A peculiar DSM profile is evident in some sections (November 2015, April 2016, December 2016, November 2018, see Fig. 2). This feature is not present in the historical (1984 – 2013) dataset of the area. Fig. 3a shows 1445 historical salinity profiles in gray and a few DSM profiles in red, that represent much less than 1% of the total profiles.

To study the temporal evolution of salinity in the SAP, data of 3 Argo floats were analyzed starting from 2012. The Argo floats evidence the DSM starting from May 2015, it disappears only during the convection phase persisting through December 2016, when winter 2016/17 convection canceled it out. A new DSM appeared again in November 2018.

A synthetic description of the water masses evolution along with heat flux and evaporation – precipitation anomalies product (Fig. 4) and mixed layer computation (not displayed) can be reassumed as follows:

- **Winter 2012/13** was characterized by a dry and cold winter. The deep convection in 2012/13 reached **700 m** favored also by a high salinity water mass present in the surface layer. The dense water produced in the northern part (NADW) and it was captured during the 2013 glider mission.
- The next year **(2013/14),** even if the heat loss was similar to the year before, the winter was rainy and in the top 50 m layer a low salinity layer was present, preventing a strong convection that reached only **100 m**.
- **Winter 2014/15** shows positive heat flux anomaly producing a convection to **200 m**. The north part of the basin was characterized by extremely mild and wet conditions, which produced a water mass moderately dense. The newly formed water flow a few months later to the south, invading the 200-500 m layer of the SAP. This water was captured during the November 2015 glider mission. During the summer a salty water mass intruded from the Ionian Sea in the top 200 m created the DSM.
- **Winter 2015/16** was cold and rainy in the south precluding a high salinity mass at surface, precondition for a deep convection. That year the convection reached **400 m.** The less salty water mass in the intermediate layer was mixed during winter, but still visible in the DSM. During summer a salty water at the surface intruded again at the surface.
- **Winter 2016/17** was warmer of the average, but quite dry and the convection reached **700 m,** induced by short and favorable cold events.
- **Winter 2017/18** was very dry and cold and a high salinity mass in the surface layer was present as in winter 2012/13 creating a quite deep convection.