The Levantine Intermediate Water in the eastern Mediterranean Sea

by

Pierre-Antoine Lamer, Elena Mauri,

Giulio Notarstefano and Pierre-Marie Poulain

Approved for release by: ………………………………

Dr. Cosimo Solidoro
Director, Department of Oceanography

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I. Introduction

Due to the small size of the Mediterranean Sea, the re-circulation of the basin is of the order of hundreds years, while the global circulation take thousands of years. The Mediterranean is for this reason a good candidate to study the changes induced by the climate change. The Mediterranean Sea can be divided in two basins: one east of the Sicily Channel (SC), the Western Mediterranean and the other west, the eastern Mediterranean. The Levantine Basin is the easternmost sub-basin of the Mediterranean.

The Mediterranean circulation includes the intake of the cold and less salty water from the North Atlantic Ocean at the Gibraltar strait, which has a width equal to 13 kilometers and a depth around 300 meters. The **Atlantic water (AW)** less salty, colder and with a density around 36.2 PSU enters in the surface layer in the Mediterranean Sea. Two different water masses, deep and intermediate water, exit from Mediterranean Sea at Gibraltar. Figure 1 shows a schema of the Mediterranean circulation. The AW flows along the African coast changing gradually its properties (Goffredo and Dubinsky, 2014). It becomes saltier and warmer proceeding to the east. When the AW reaches the SC (width equal to 35 km and depth about 300 m), the salinity becomes close to 37.5 PSU. The AW bifurcates, flowing along the west part of Italy to the Lion's Gulf where the **Western Mediterranean Deep Water (WMDW)** is formed. The other branch continues its way along the continental shelf of Africa. Flowing along the African coast, the water mass properties vary, due to the mixing with the surrounding waters, this water mass is identified as **Atlantic Modified Water (AMW).** The surface water of the Levantine basin is called **Levantine Surface Water (LSW).** During winter, around February and March in the Rhodes Gyre, due to the strong Etesian wind, it cools and evaporates, becoming denser and it sinks to a depth of about 200-400 m forming the **Levantine Intermediate Water (LIW)**. Another site, where in winter the deep water is formed, is the Adriatic Sea: a strong katabatic cold and dry wind called Bora, causes a large seawater heat loss producing dense water, which sinks to the bottom of the basin and flows into the Ionian contributing to the **Eastern Mediterranean Deep Water (EMDW)**.

The main aim of this study is to identify the LIW across the Eastern Mediterranean and analyze possible trends using the Argo float dataset from 2001 to 2018.

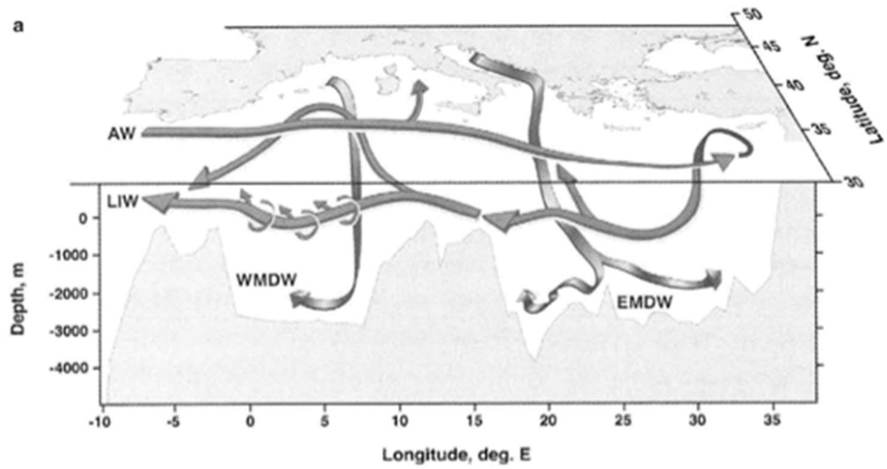


***Figure 1**: Brief resume of the water masses circulation in the Mediterranean Sea.*

II. Material and methods

In this analysis we use data from Argo profiling floats. These instruments are able to follow water masses in which they are deployed and perform profiles along the water column.

Floats

An Argo float (Figure 2) is a subsurface profiling instrument; it profiles down to 2000 m depth measuring conductivity-temperature-depth. Floats change their buoyancy in order to profile the seawater column by changing the volume of an external bladder. After the deployment the floats descend to a parking depth, where they drift for 5 days, then they dive to the maximum depth and they sample during the ascent to the surface, with a speed of about 10 cm s^{-1}. When the float is at surface the data and the position are sent to satellites and then to land stations. Usually, this cycle takes place every 5 days. In order to check the accuracy of collected data, there are two steps: real time quality control (RTQC) and delayed mode quality control (DMQC). The RTQC removes outliers of the positioning system and of the measurements, but the drift of sensors (in particular the conductivity sensor) is detected only by the DMQC. The QC assigns, a number to each datum from 0 to 9, where for example, 0 corresponds to the absence of quality control, 1 is good data and 4 is bad data. The real time data are identifiable by "R" in the file name and the delayed mode ones by "D". For each parameter there are two arrays of data: real-time data and adjusted data.

***Figure 2**: Left: a float. Right: sticker of United Nations World Climate Research Program*

In this work we used:

The **potential temperature**, that is the temperature resulting from an adiabatic displacement at a reference pressure and the **potential density,** that is the density overcoming pressure effects at a reference pressure. The EOS 80 Equation was used. From now on, only the potential temperature and potential density are used. The geographic distribution of the float data is reported in Figure 3, while salinity, temperature and density profiles divided by years are presented respectively in Figures 4, 5 and 6.

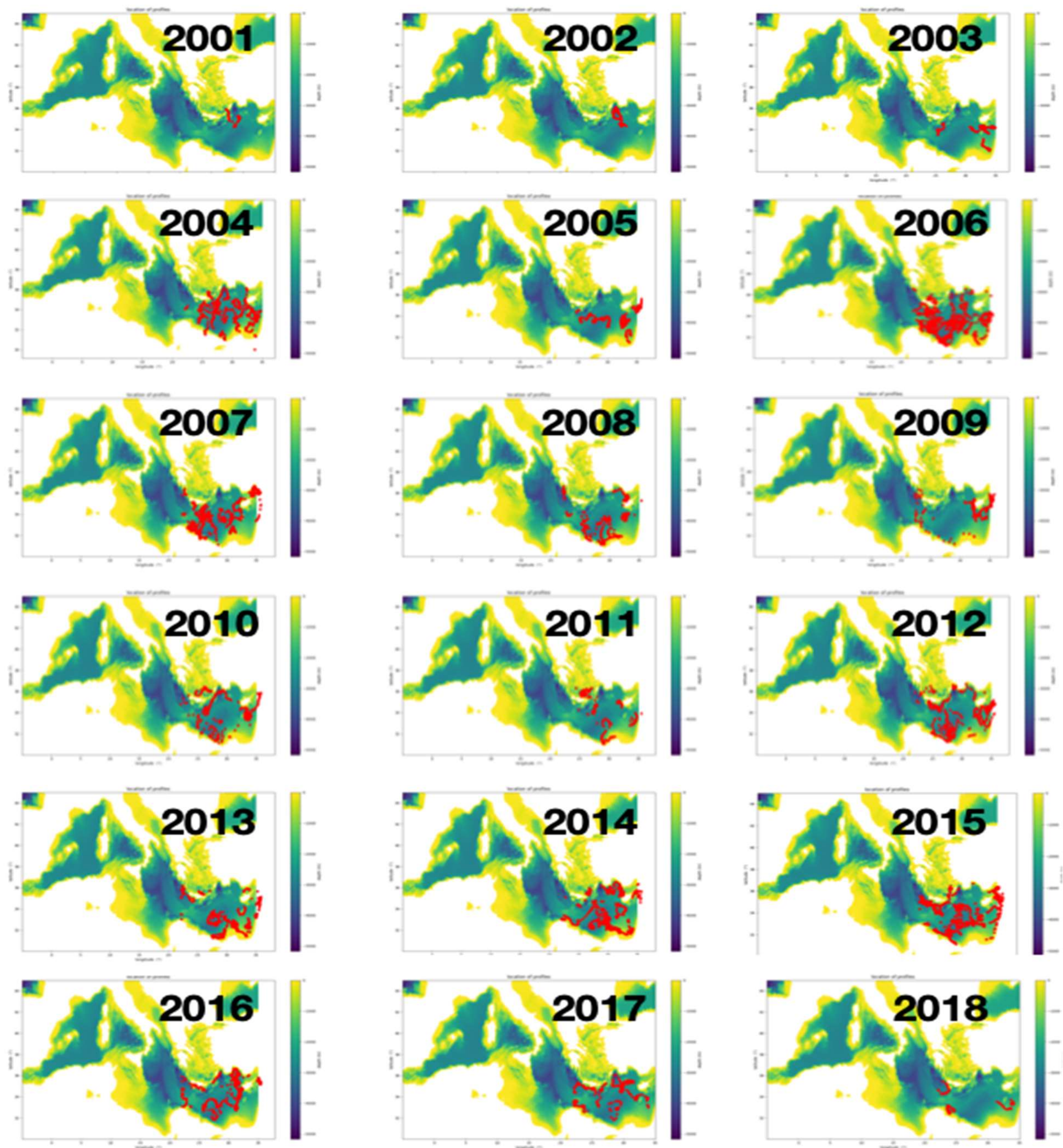


Figure 3*: Float data distribution in the Eastern Mediterranean.*

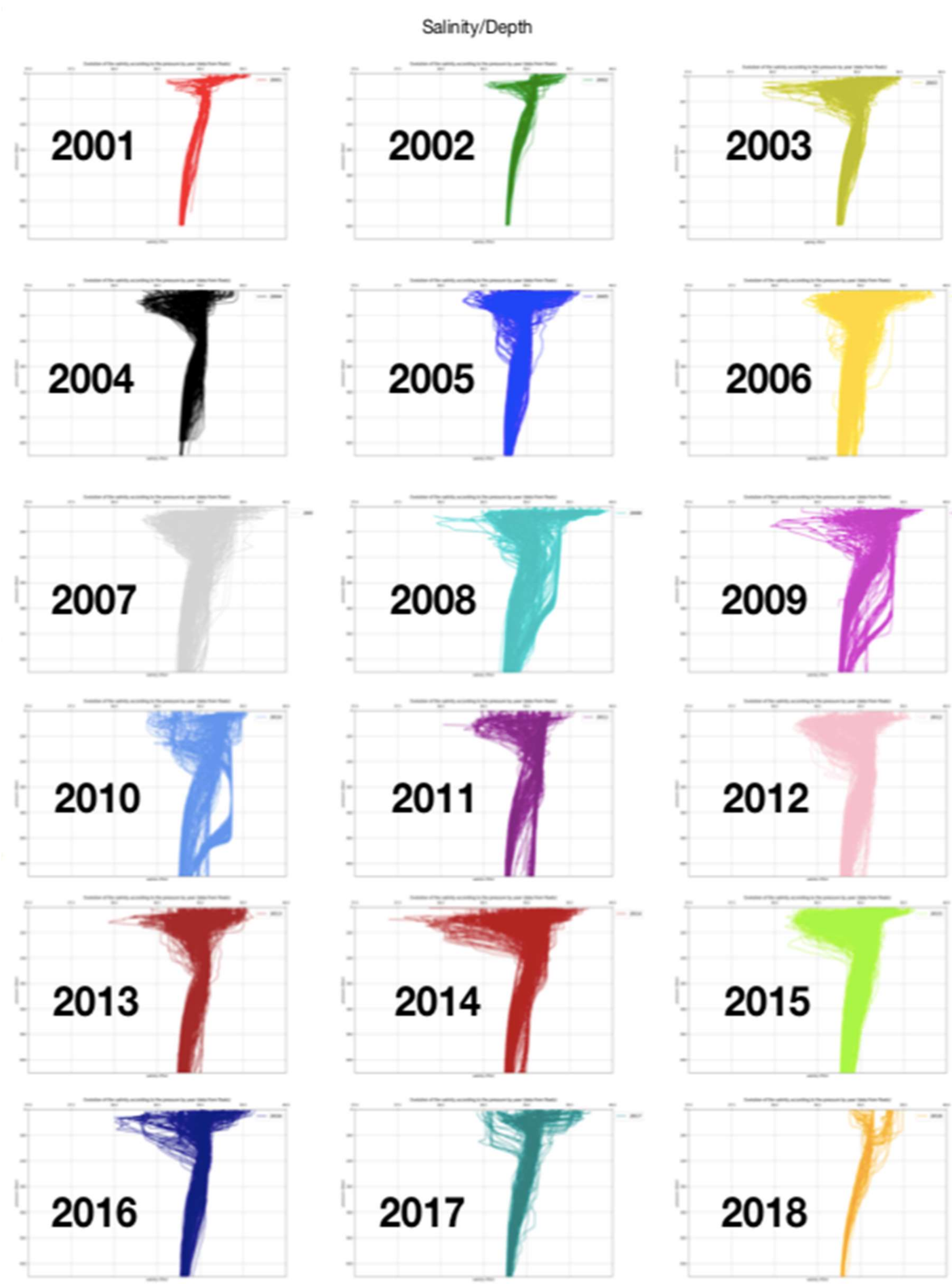


***Figure 4**:*

The float salinity profiles in the Eastern Mediterranean over time.

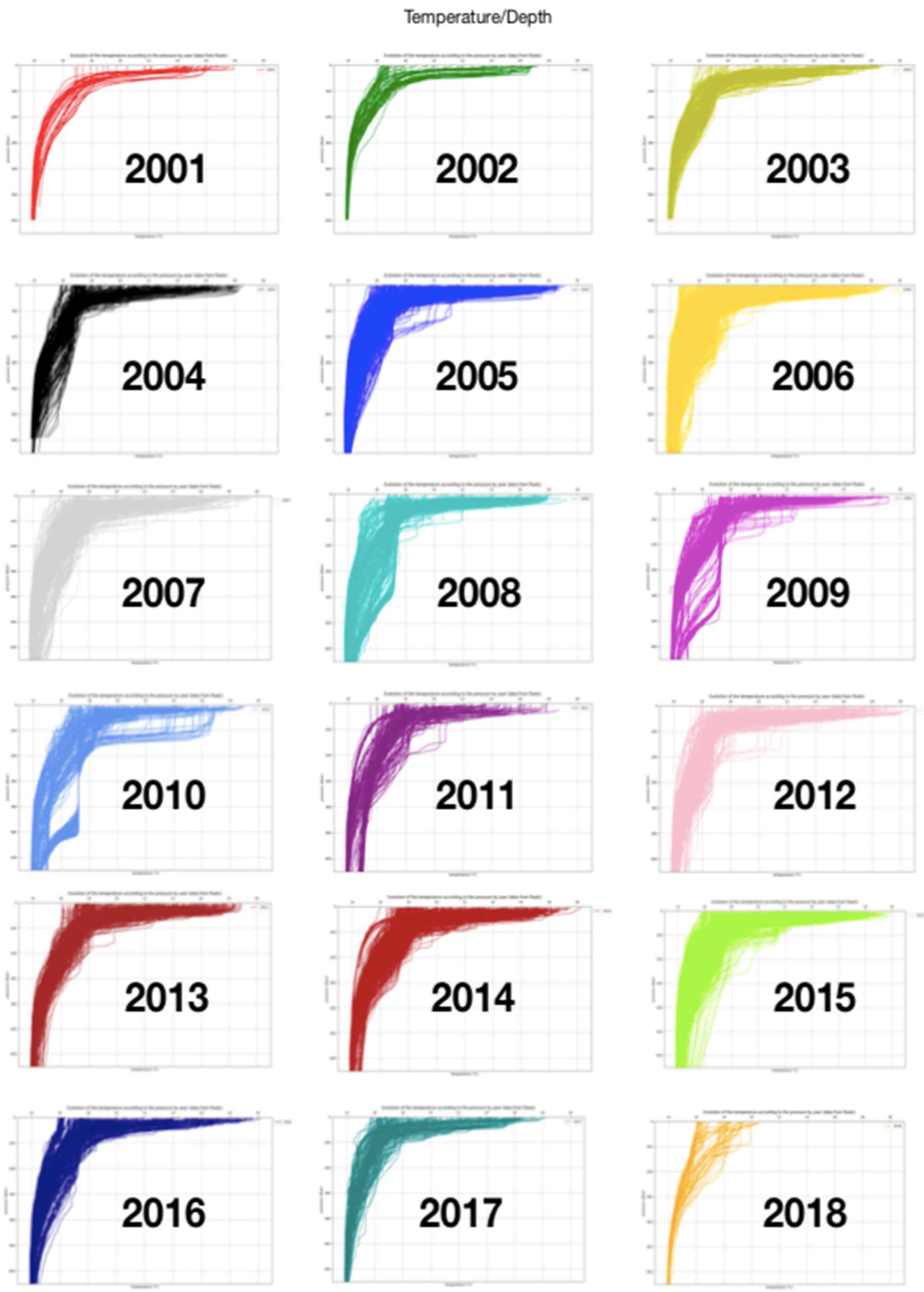


***Figure 5**: The float potential temperature profiles in the Eastern Mediterranean over time.*

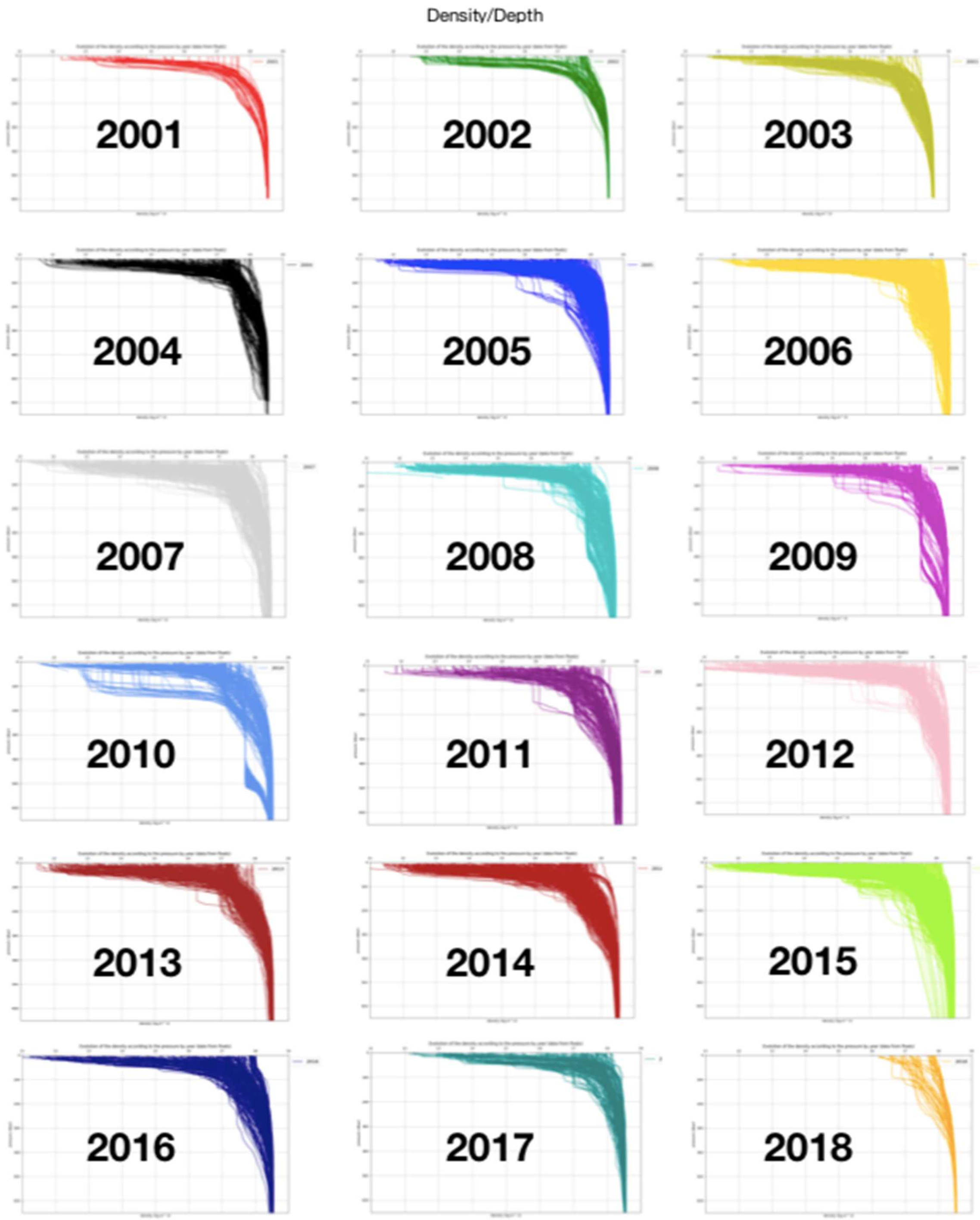


Figure 6: *The float potential density profiles in the Eastern Mediterranean over time.*

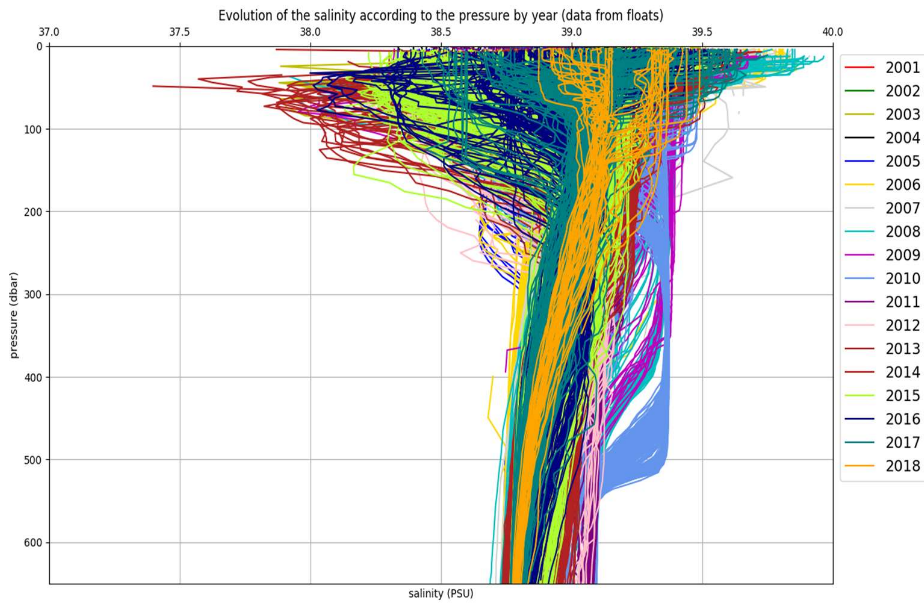


***Figure** 7: Profiles of salinity in the Eastern Mediterranean color coded by year.*

Some temperature profiles in Figure 5 exhibit mixing layers, visible in first 200 m layers; these mixing layers are associated to the seasonal thermocline. A few profiles have different behavior, in which the homogeneous layer reaches 400 m and below it, the temperature converges towards 14°C. In salinity we see a mixing in the top 200 m and below it the value of salinity stays around 39 PSU. Some profiles follow a different behavior, because the profiles are located in eddies.

The density (Figure 6) increases with depth. At surface, the density varies a lot (between 25 and 29 kg m^{-3}) due to variations of temperature and salinity. Below 300 m, profiles converge towards a value around 29 kg m^{-3}.

The Figure 7 displays all the salinity profiles for the different years together showing a wide range in the top 200 m, some profiles show the mixing to 500 m, at 600 m there is still a wide range of salinity from 38.7 to 39.1 PSU.

II.1 T/S diagrams

To further analyze the data, T/S diagrams were plotted. After a first attempt to use the data of the whole eastern Mediterranean to identify a single criterion, the data were split in different basins because of the high variability of the parameters. The reason of this approach is due to the need of understanding the variability of the basin, the changes in properties and depths of the LIW through the basin. The Eastern Mediterranean was thus divided in 4 areas (Figure 8) and T/S diagrams were produced for each of them:

- **Levantine basin**
- **Rhodes basin**
- **African basin**
- **Ionian Sea**

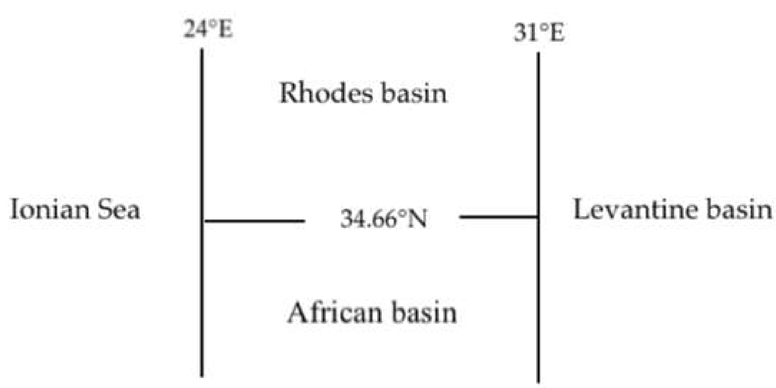


***Figure 8**: Arbitrary geographical coordinates of the 4 basins.*

The data set was also divided by year; as an example Figure 10 shows the T/S diagram of the **Levantine basin** in 2012. In Annex 1 are reported the T/S per basin of all the years. The red points represent data of the top 100 m characterized by high salinity (not related to the LIW), high temperature and the lowest density. The blue dots represent measurements below 100 m, they form a u-shape. The LIW is represented by the bending where the salinity is high below the surface 100 m layer.

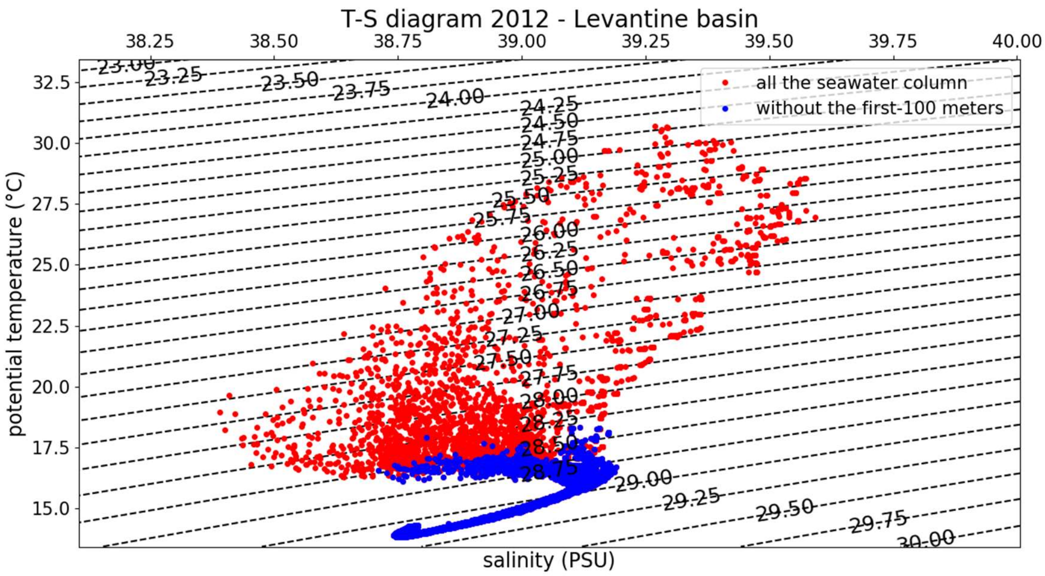


***Figure 10**: T/S diagram without the first 100 m for the Levantine Basin in 2012*

Below 100 m, the salinity maximum in the Levantine Sea is between 39.1 and 39.2 PSU. Higher salinity is registered between 2007 and 2014. Potential density ranges between 28.3 and 28.8 kg m^{-3}.

In the **Rhodes basin** the data on the TS diagram exhibit a different shape, the maximum of salinity is not too marked as in the Levantine Basin, there is not a clear u-shape in all the years. In some years there is a double maximum 2007, 2011,2013, 2014, 2017. At the bending density ranges between 28.75 and 29, the temperature exhibits a wide range 15 - 17.5 through the years and the salinity around 39 -39.2 PSU and even higher.

In the **African basin**, the salinity maximum is around 39.25 PSU, but can reach 39.5 PSU in a record (temperature higher 26 °C and density of 26 kg m^{-3}). The temperature at the salinity maximum is about 17°C and the density is around 28.75 kg m^{-3}.

In the **Levantine basin** the T/S diagrams exhibits a V shape but not in all the years. The temperature at which the maximum salinity is visible the temperature is much lower and ranges around 15 °C but from 2015 the temperature increases by one degree. The salinity reaches 39- 39.1 PSU, while the density ranges between 28.75 and 29 kg m^{-3}.

II.2 Program to detect the salinity maximum along the profile

A program to recognize the maximum of salinity along a profile was created and checked single profiles were inspected manually. An automatic program does not always discriminate the LSW from the LIW, therefore an interactive program enabled to check the effective salinity maximum detection and the correspondent density. During the test, if the same profiles, in a close range of depth, showed more than one maximum of salinity, we took in the depth average of salinity maximum.

II.3 Definition of the criteria to detect the LIW and work flow

A. Density, salinity and temperature criteria

The chosen criteria are based on Goffredo and Dubinsky (2014):

- Maximum of salinity
- A value of potential density around 29.10 kg.m^{-3}
- A value of potential temperature between 15 and 16°C

To avoid detecting salinity maximum close to the surface the first-100 meters were removed therefore the maximum of salinity was search only between 100 and 600 m. Using those criteria only a few maxima along the profiles were detected. The temperature is more variable then the suggested range in the eastern basin: an interval of 15-17°C does not help to discriminate and after a careful inspection the criterion was removed.

B. Density criterion

Other criteria uses wide density criterion, as in *Hayes et al., 2019* (Figure 10) with density of 29.1 kg m^{-3}. Other studies like Tanhua et al. (2012) also used a range of density instead of a single value therefore in our study the density was set between 28.5 and 29.1 kg m^{-3}. Out ranges of density between 28.85 and 29.1 kg m^{-3} are comforted also by the study of Tanhua et al, 2012 shown Figure 11.

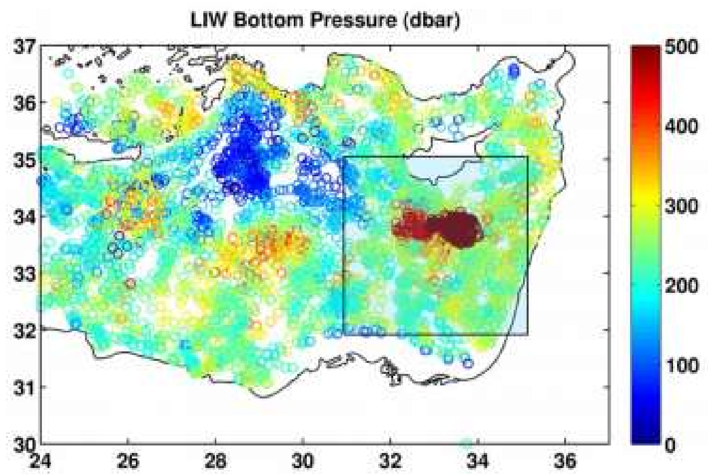


Figure 10*: Map of pressure (dbar) of 29.0 kg m-3 isopycnal from Argo floats from 2002 to 2014, recent years are plotted on top of previous. The box indicates the region included in the time series. Glider results inset for years 2009-2014 from Hayes et al., 2019.*

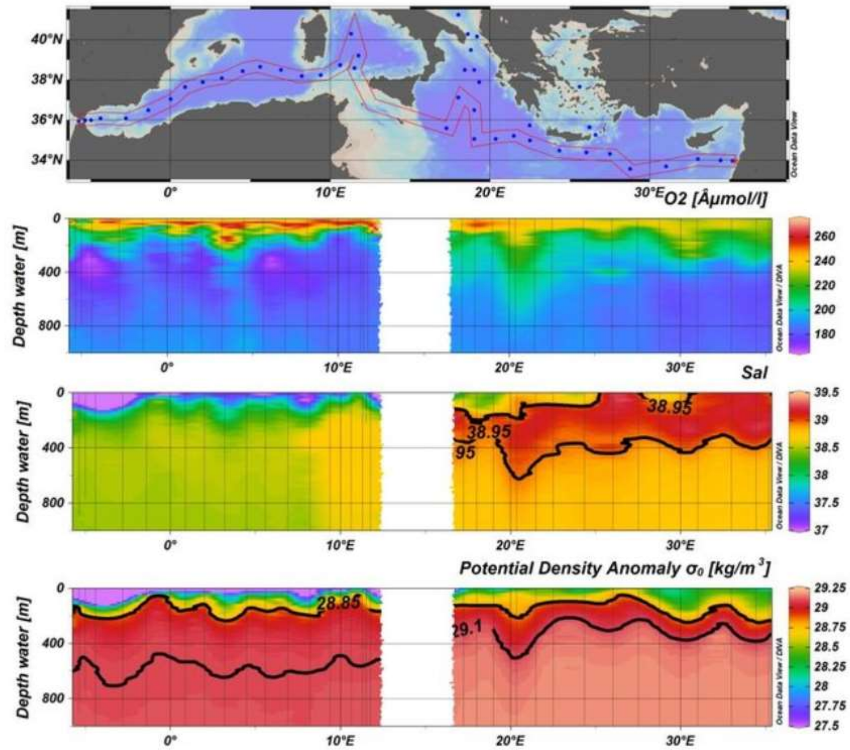


Figure 11: *Levantine Intermediate Water spreading from East to West (indicated by potential density anomaly between 28.85 and 29.1 kg m $^{-3}$) (data plotted from Tanhua 2012).*

Density between 28.5 and 29.10 kg m^{-3} , salinity maximum detection and depth constrain: depth between 100 and 400 m

- ✓ **products**: maps depth, salinity, density, temperature (ANNEX 2)

  The criteria adopted seems too wide.

C. Density and salinity criteria

Density between 28.8 and 29.10 kg m^{-3} and salinity between 38.9 and 39.1 - salinity maximum detection and depth constrain: depth between 100 and 400 m

- ✓ ***products****: maps depth, salinity, density, temperature (*ANNEX 3)

These are some results of the analysis.

- Depth maps

  - The maximum depth of the LIW is in the anticyclones area, like Pelops, Ierapetra, Cyprus gyres.
  - The Marsa Matruh eddy seems to move from a permanent geographical position, it is present in different geographic positions in different years. Interaction with anticyclonic eddies or the presence of other eddies in that area might be possible.
  - In 2006, 2008, 2009 a peculiar anticyclonic structure is evident in the south Ionian in which the maximum salinity is as deep as 300-350 m.

- Salinity maps
  - The highest salinity of the LIW is found in the Cyprus eddy with salinity close to 39.25 PSU.
  - The entire area of the north Levantine and Aegean Sea also exhibit high salinity.
  - The salinity of the LIW is higher in the east part of the basin and gradually decreases toward the west.
  - It is evident an increase in time of salinity all over the eastern basin maintaining an east-west gradient. The increase is more evident in the center of the basin.
- Density maps
  - Highest density of about 29.1 kg m^{-3} is evident in the northern Ionian Sea at a depth of around 200-250 m.
  - In the area of intermediate water formation (LIW) the density is around 28.8-28.9 kg m^{-3} with salinity of 39.10-39.15 PSU at a depth of 200-300 m.
- Temperature maps
  - Also in the temperature maps is evident an east-west gradient and an increase of temperature in the center of the eastern basin is evident.

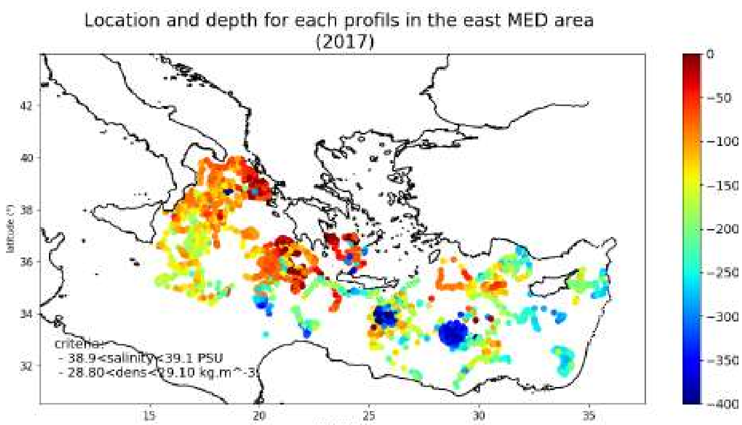
The same criteria were applied in 2 different seasons winter (Nov-Apr) and summer (May-October) and 4 plots were created:

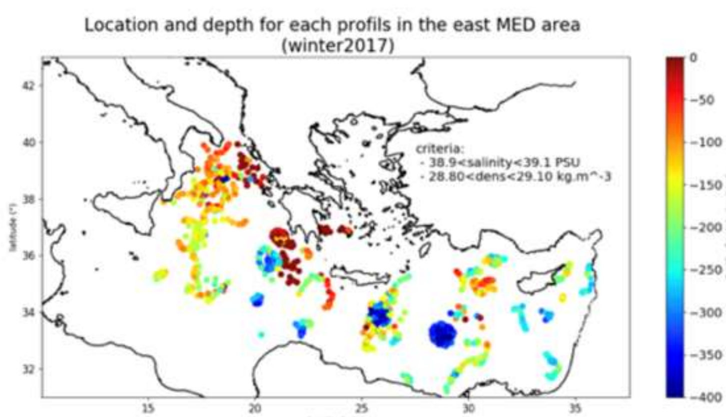
- maps of depth at which the criteria are met (Figure 13)
- maps of the correspondent density (Figure 14)

- maps of the correspondent salinity (Figure 15)
- maps of the correspondent temperature (Figure 16)

Figure 13, 14, 15, 16 report the plots for 2017. In each figure the whole year is presented in the top panel, winter in the middle panel and summer in the bottom one.

The criteria are met at deeper depth in specific gyres in the Levantine and depth does not show a clear seasonality (Figure 13). Higher density is visible in the Rhodes Gyre in all seasons (Figure 14). Salinity exhibits an east west gradient lower salinity is present in the Ionian and higher in the Levantine (Figure 15). Eddies and gyres are marked by higher temperature and no clear seasonality is visible (Figure 16).





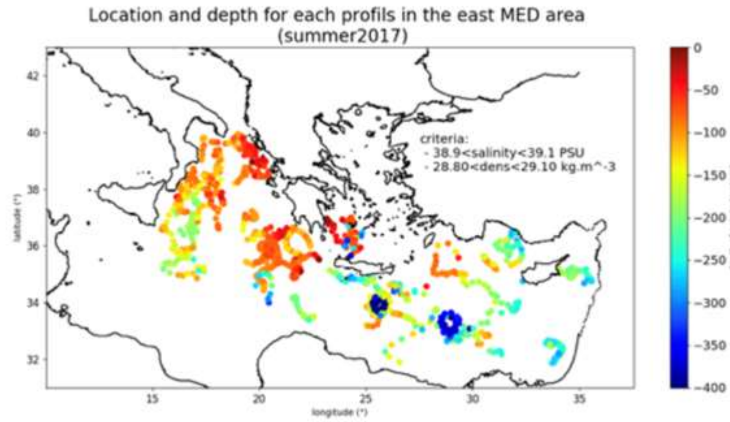
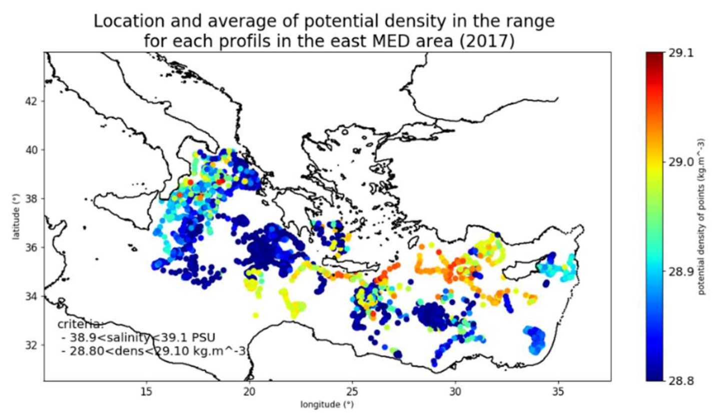
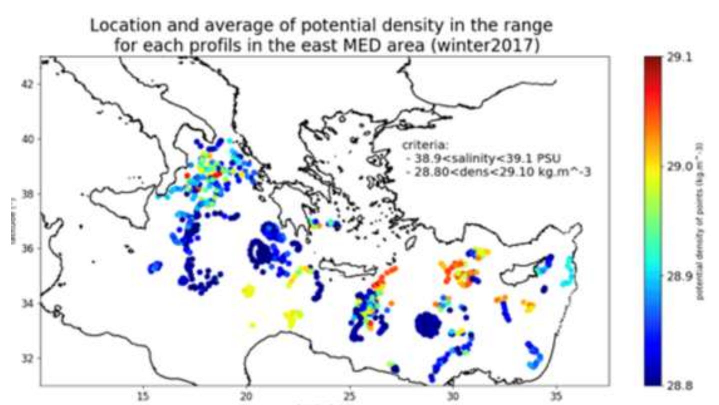


***Figure 13**: Depth at which the criteria of salinity and density are met during the 2017. The whole year (top), winter (middle), summer (bottom).*





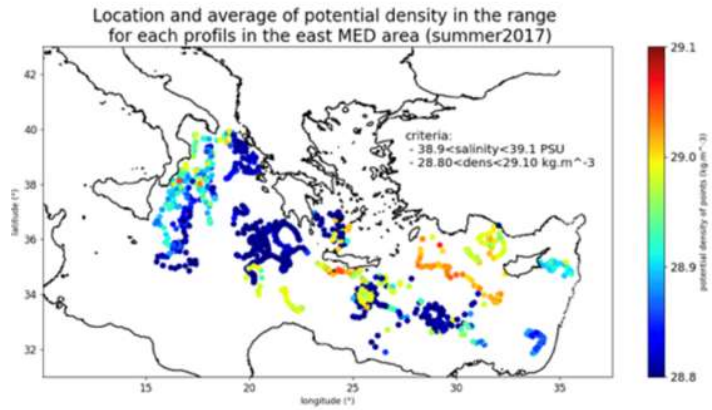
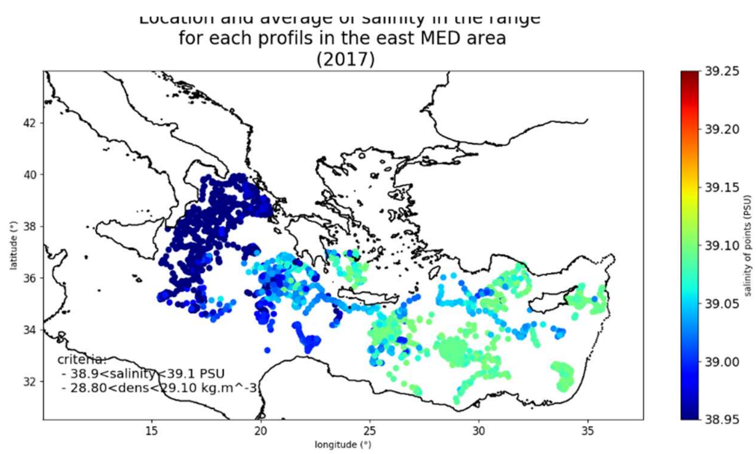
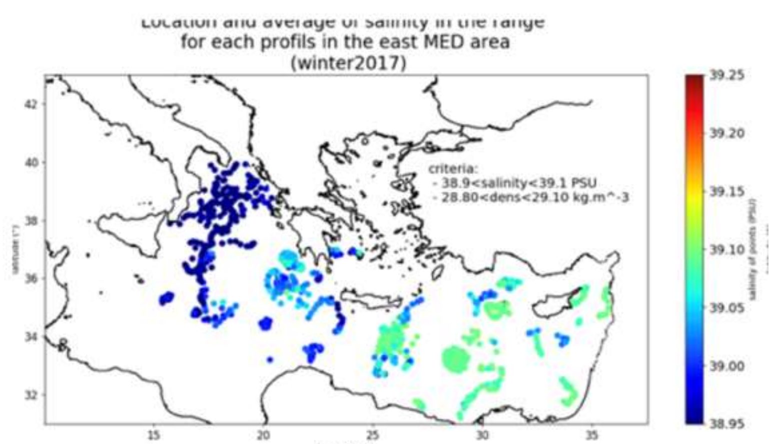


***Figure 14**: Density at which the criteria of salinity and density are met during the 2017. Year (Top), Winter (middle), summer (bottom).*





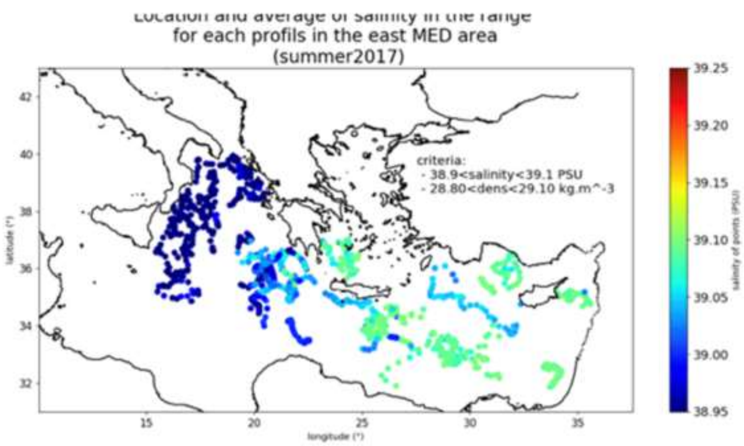
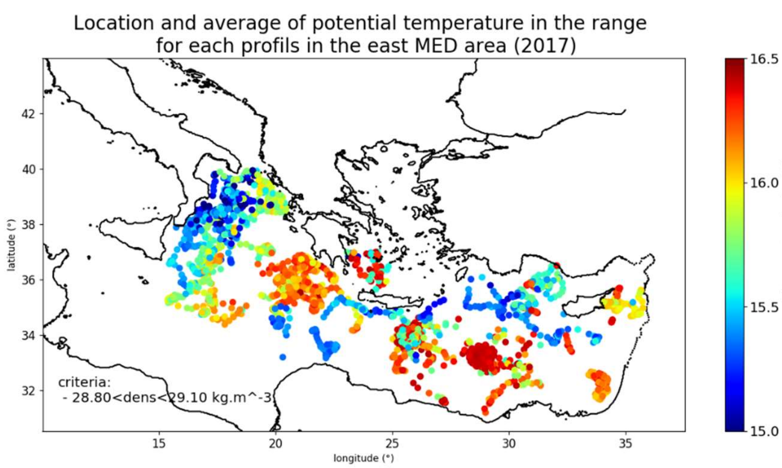
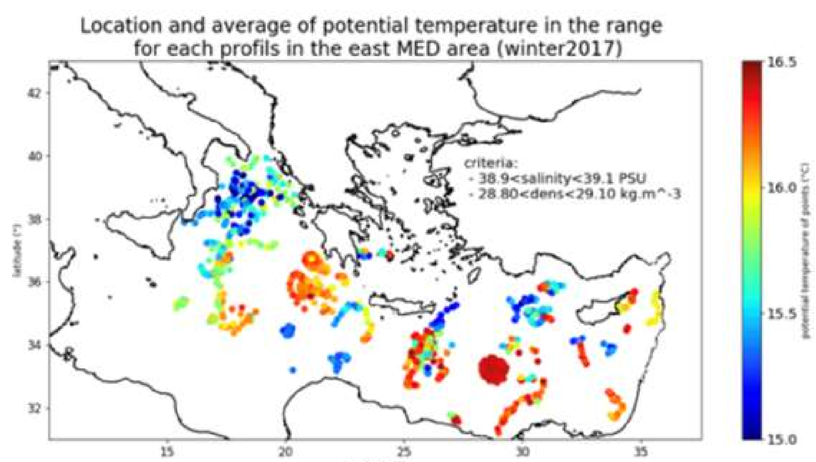


Figure 15: *Salinity at which the criteria of salinity and density are met during the 2017. Year (Top), Winter (middle), summer (bottom).*





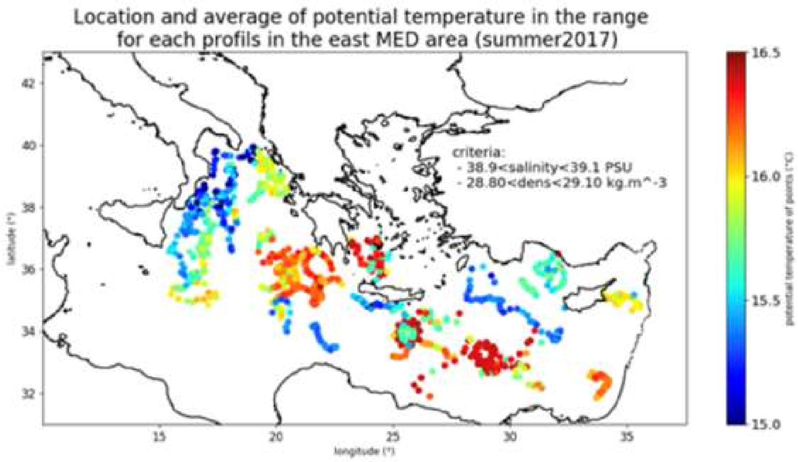


***Figure 16**: Temperature at which the criteria of salinity and density are met during the 2017. Year (Top), Winter (middle), summer (bottom).*

II.4 TRENDS in different layers of the basins

Since in our study and in literature (Schroeder et al., 2017) an east west gradient is visible in temperature and salinity , trends were calculated for each basin and different layers . The computation was performed on layers of 100 m interval. The result was a bit confusing because of the large heterogeneity of the whole eastern basin, therefore we separated again the data in basins.

The yearly mean temperature, salinity and density and a linear regression were computed and shown in the plots, the trend per year is present in the legend (Annex 5).

In the final figure of the Levantine basin, the data of the big gyres, like Cyprus eddy, were averaged before the computation of the mean, to balance the different amount of data. In 2010 and 2018 the different amount of data in specific areas was particularly evident. Yearly standard deviations per layer were added.

Hereafter in table 1 and Figure 17 the increase of temperature salinity and density per year at the different layers are reported.

	Levantine	**Rhodes**	**African**	**Ionian**
	Salinity			
0-100	-0,00580	0,00230	-0,00450	0,00238
100-200	-0,00070	0,00550	0,00020	0,01460
200-300	0,00550	0,00770	0,00690	0,00720
300-400	0,00540	0,00810	0,00690	0,00630

400-500	0,00400	0,00720	0,00540	0,00570
	Temperature			
0-100	-0,00190	0,01030	-0,07390	-0,03630
100-200	0,05610	0,01080	0,04300	0,02960
200-300	0,04520	0,05000	0,04890	0,03270
300-400	0,02860	0,04220	0,03770	0,03020
400-500	0,02090	0,03170	0,02480	0,02750
	Density			
0-100	-0,00250	0,00000	0,01630	-0,03910
100-200	-0,01460	-0,00540	-0,01060	0,03860
200-300	-0,00650	-0,00540	-0,00640	0,02640
300-400	-0,00240	-0,00320	-0,00310	0,01510
400-500	-0,00160	-0,00150	-0,00310	0,00910

Table 1: the increase of temperature salinity and density per year at the different layers.

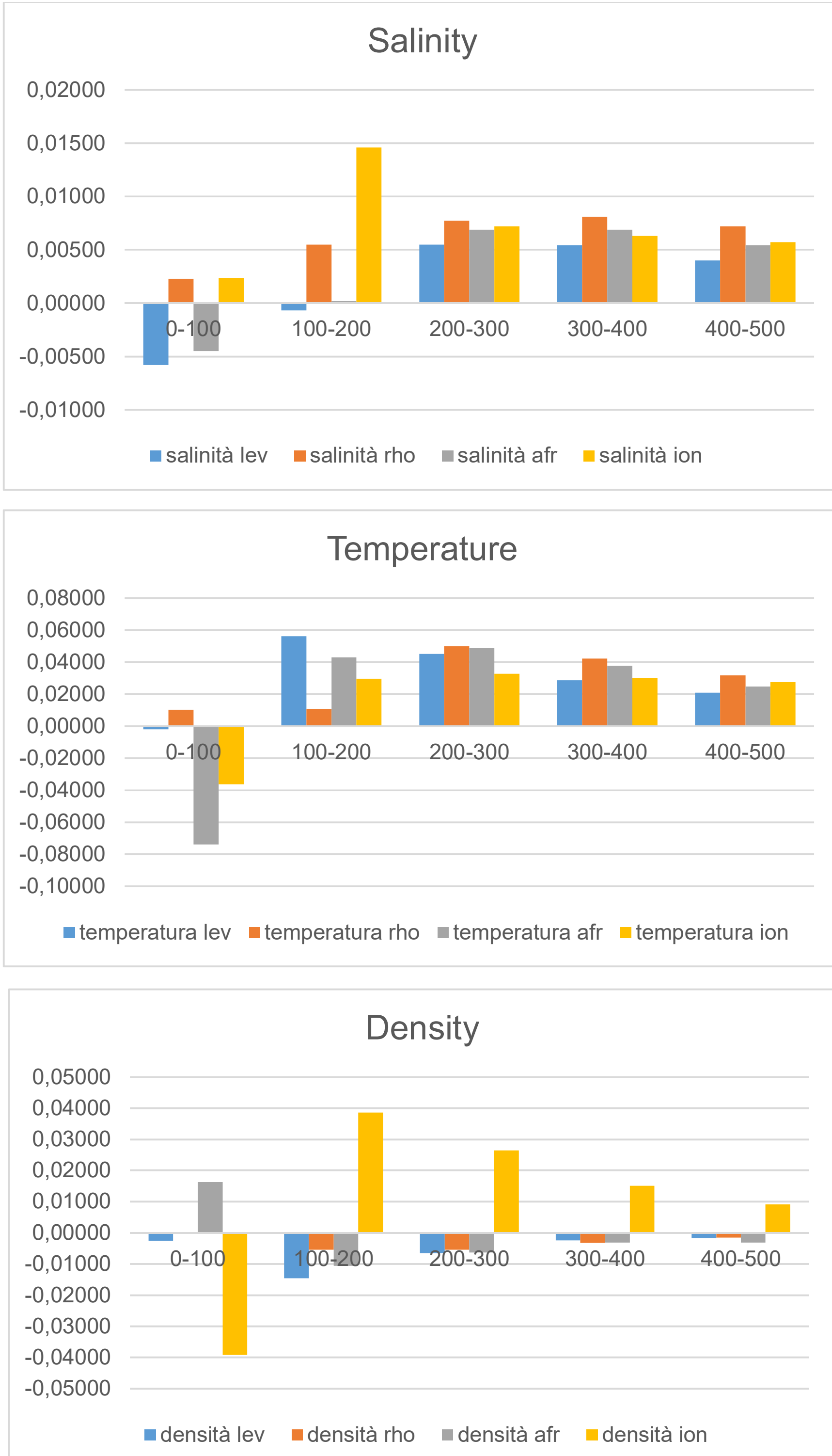


Figure 17*: Salinity (PSU), Temperature °C, density (kg/m^{-3}) trends in different basins.*

Figure 17 shows a clear rising trend in salinity and temperature below 100 m in all basins. Temperature presents a slightly lower increase in all layers compared to Schroeder et al. (2017). In the paper the increment in temperature from 2011 at 400 m is 0.064°C/yr. Salinity in our study increase is half of the reported rate that is 0.014 PSY/yr.

The density decreases in all the basins below 100 m with the only exception of the Ionian basin.

III. Conclusions

These are very preliminary results, a more accurate analysis based on stronger statistics has to be performed before publishing

- The detection of the salinity maximum based on salinity criterion only seems to work better for the detection of the LIW. We see east-west gradient in salinity temperature and density and also trends over the period of time. Permanent eddies stand out because the water masses are affected by the dynamics of the eddy.
- The top 100-200 m has to be removed from the profile otherwise it is difficult to discriminate the LSW or the ISW (Ionian) from LIW the maximum in salinity is at the surface.
- From 2012 more floats are present in the Ionian, showing high salinity at surface with high density.

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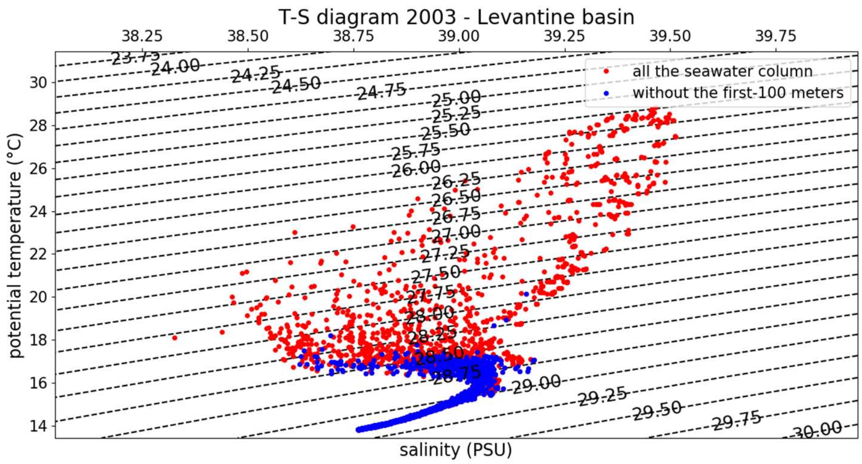
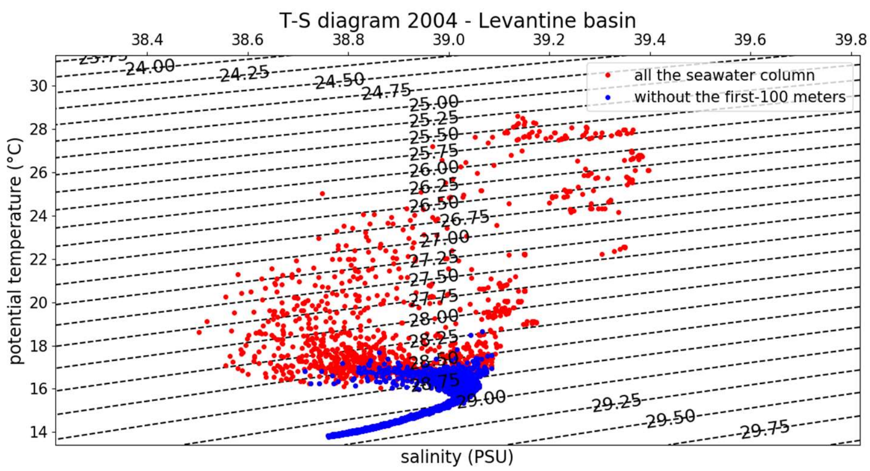
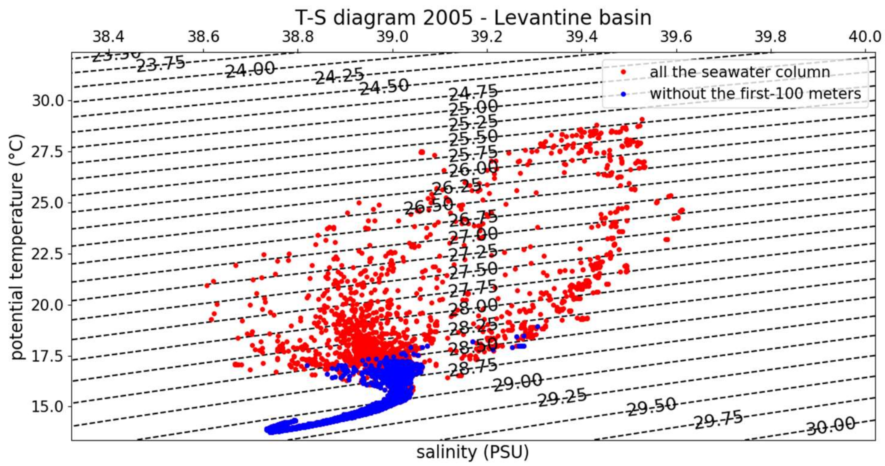
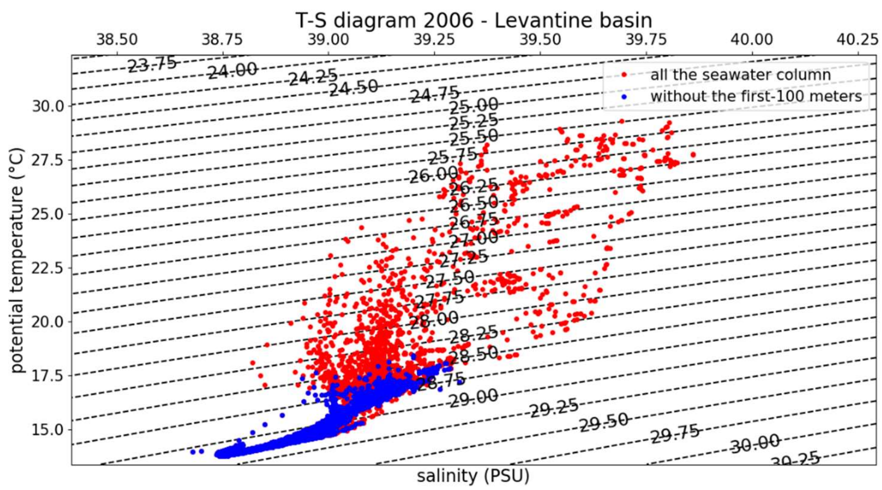
APPENDIX 1

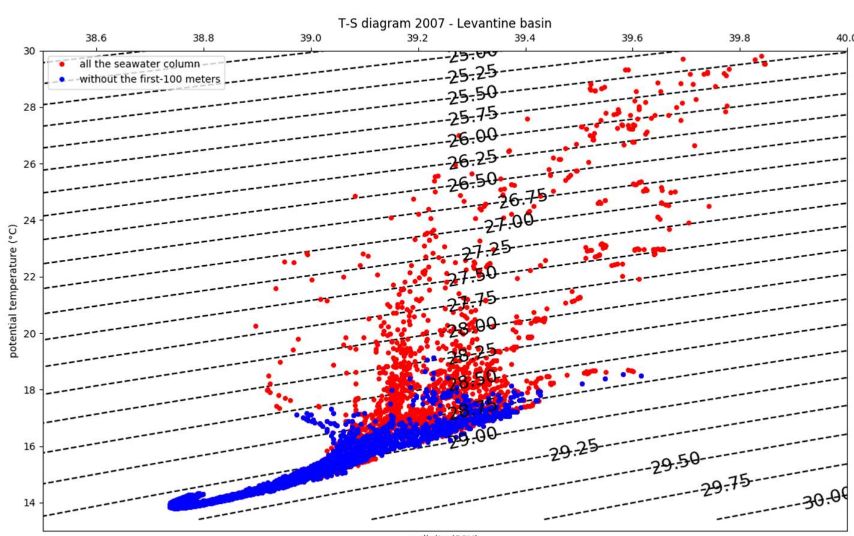
THE LEVANTINE BASIN

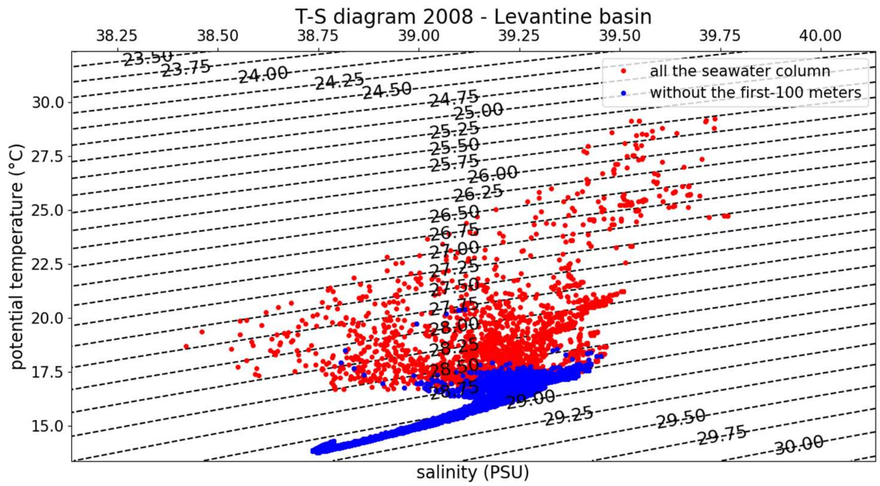


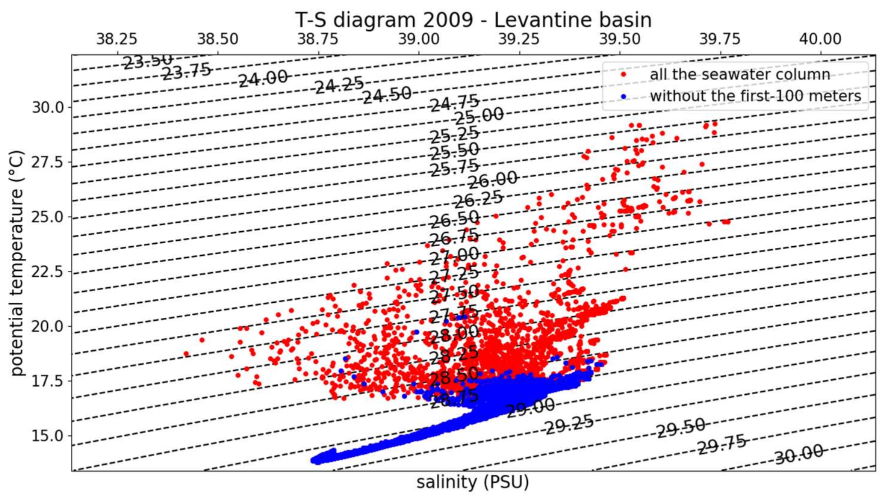


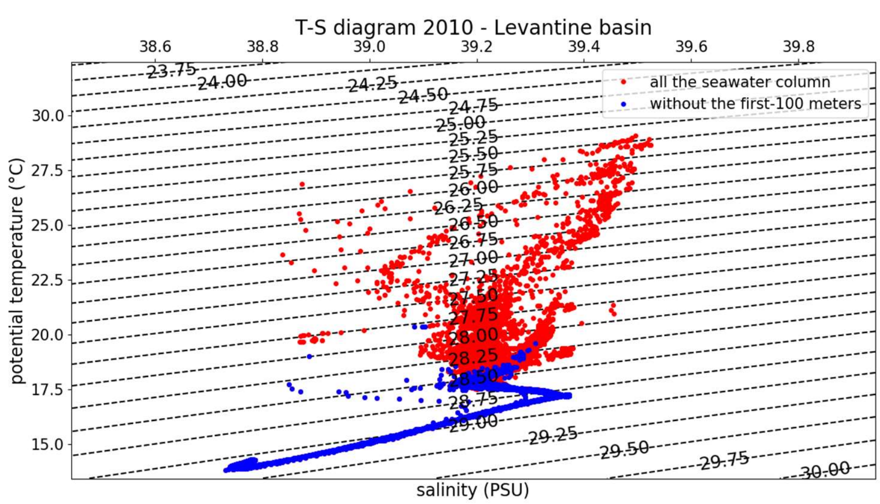

T-S diagram 2005 - Levantine basin
38.4
38.6
38.8
39.0
39.2
39.4
39.6
39.8
40.0
all the seawater column
without the first-100 meters
potential temperature (°C)
30.0
27.5
25.0
22.5
20.0
17.5
15.0
salinity (PSU)

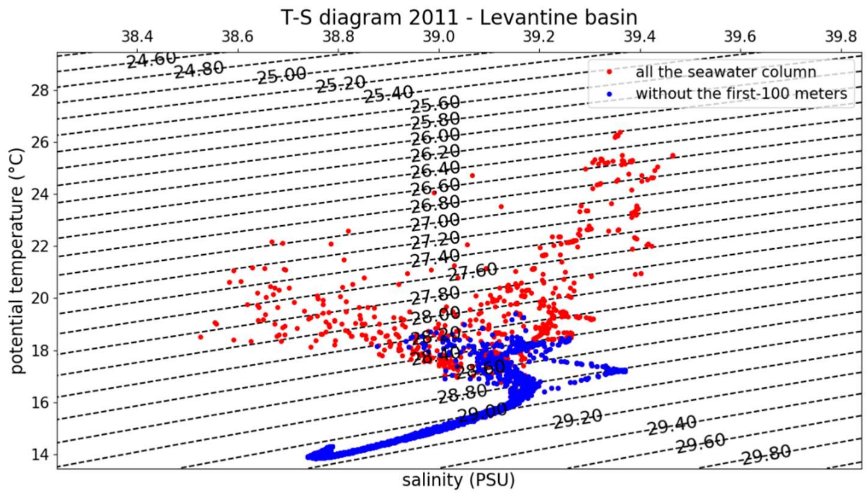

T-S diagram 2006 - Levantine basin
38.50
38.75
39.00
39.25
39.50
39.75
40.00
40.25
all the seawater column
without the first-100 meters
potential temperature (°C)
30.0
27.5
25.0
22.5
20.0
17.5
15.0
salinity (PSU)

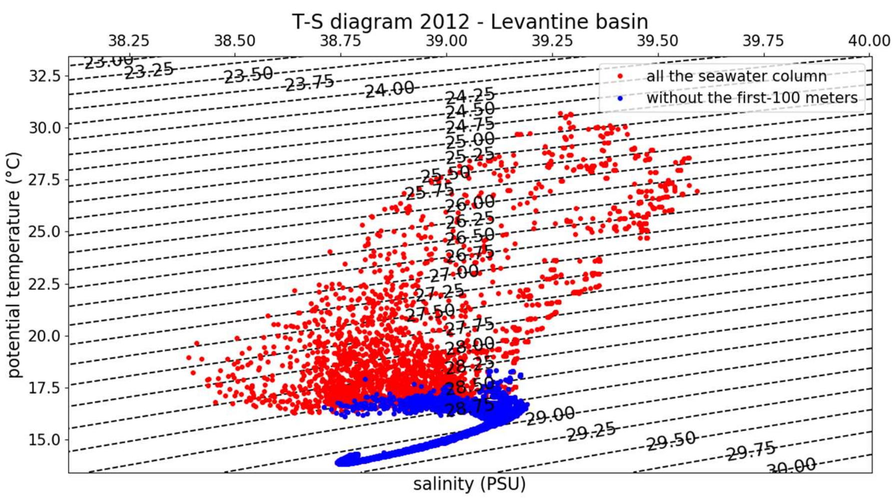

T-S diagram 2007 - Levantine basin
38.6
38.8
39.0
39.2
39.4
39.6
39.8
40.0
all the seawater column
without the first-100 meters
potential temperature (°C)
30
28
26
24
22
20
18
16
14
salinity (PSU)

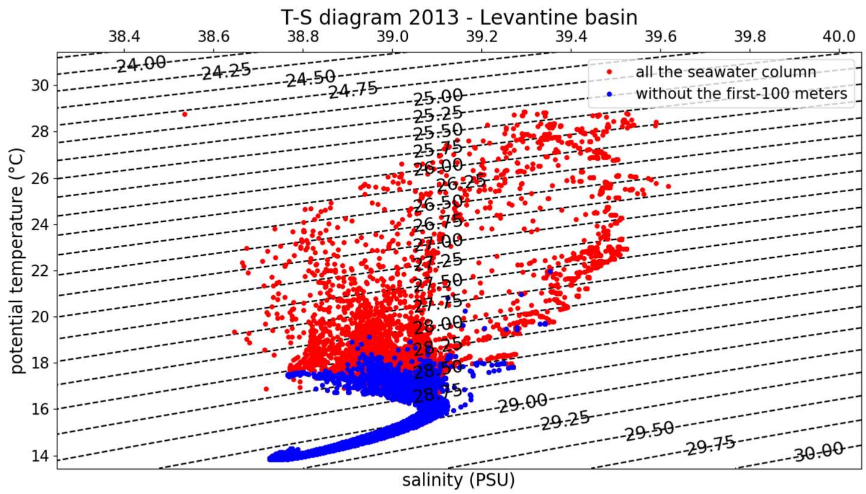

T-S diagram 2008 - Levantine basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

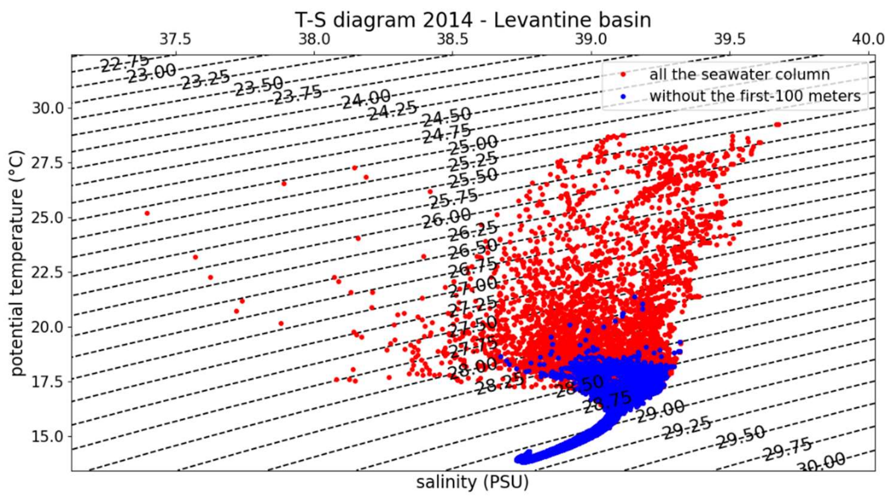

T-S diagram 2009 - Levantine basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

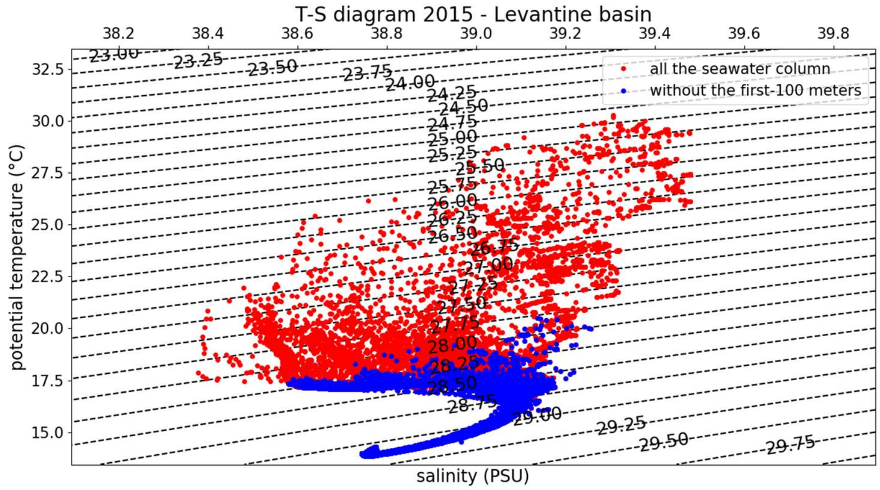

T-S diagram 2010 - Levantine basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

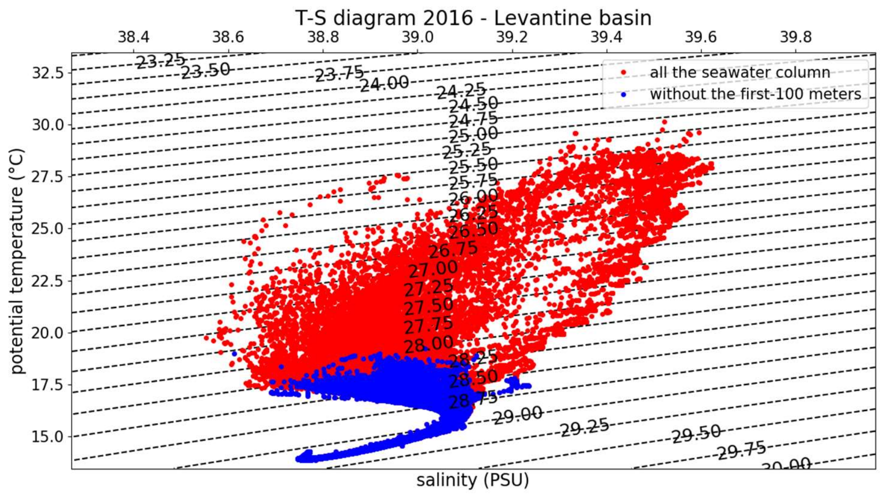

T-S diagram 2011 - Levantine basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

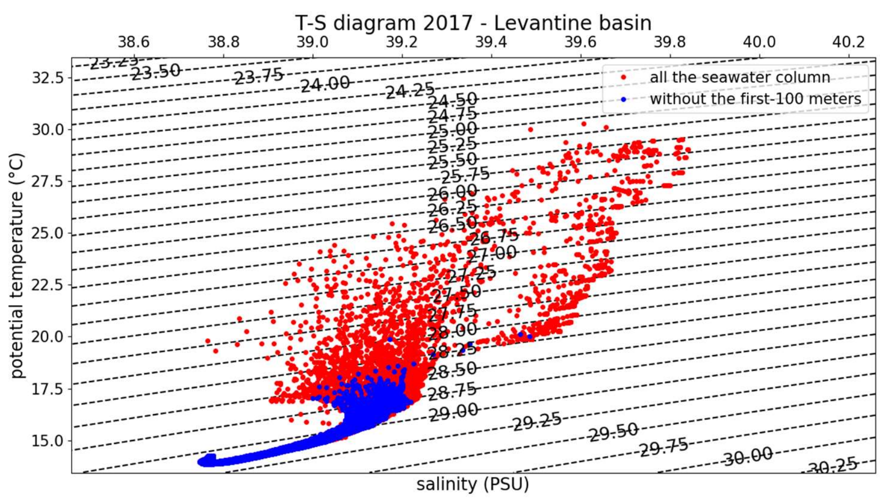

T-S diagram 2012 - Levantine basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)


T-S diagram 2013 - Levantine basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

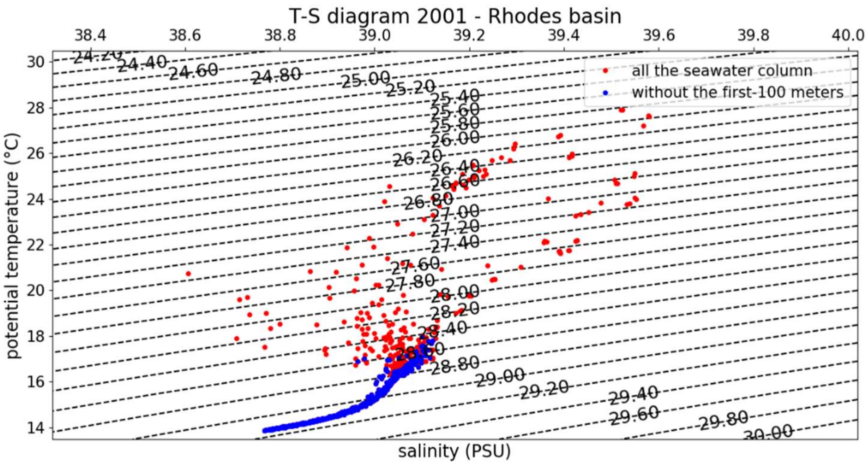

T-S diagram 2014 - Levantine basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

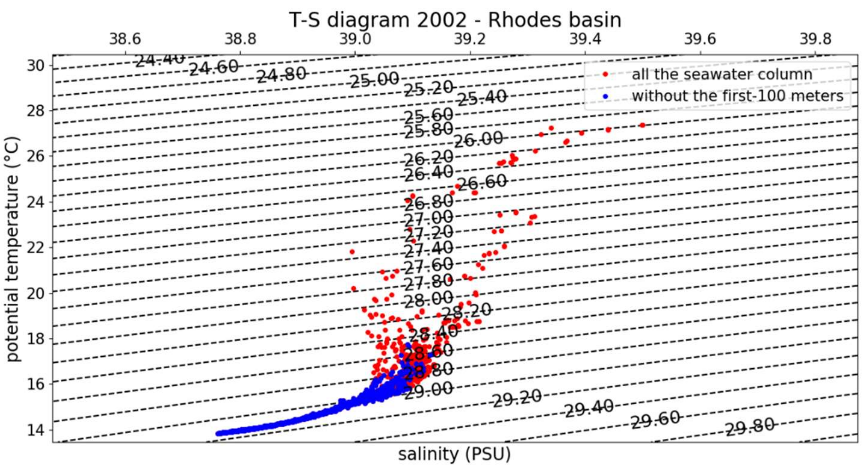

T-S diagram 2015 - Levantine basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

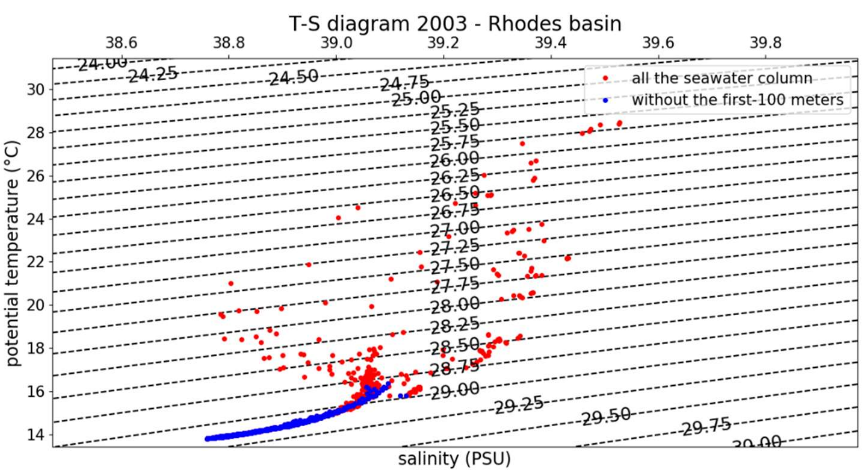

T-S diagram 2016 - Levantine basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

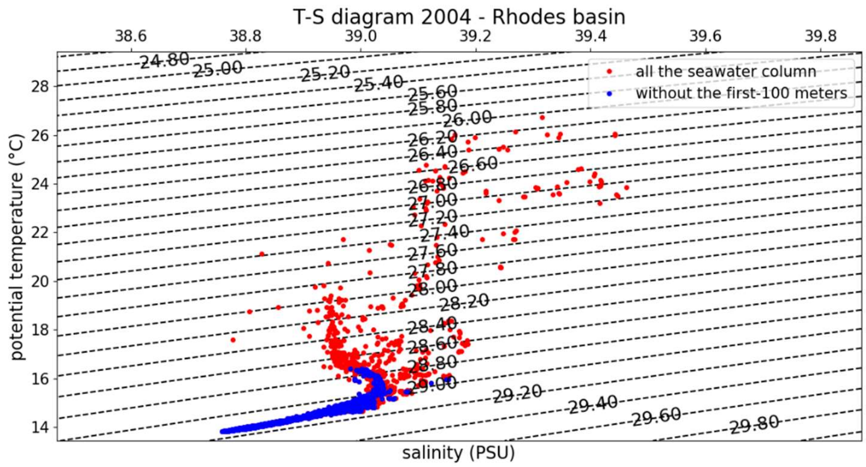

T-S diagram 2017 - Levantine basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

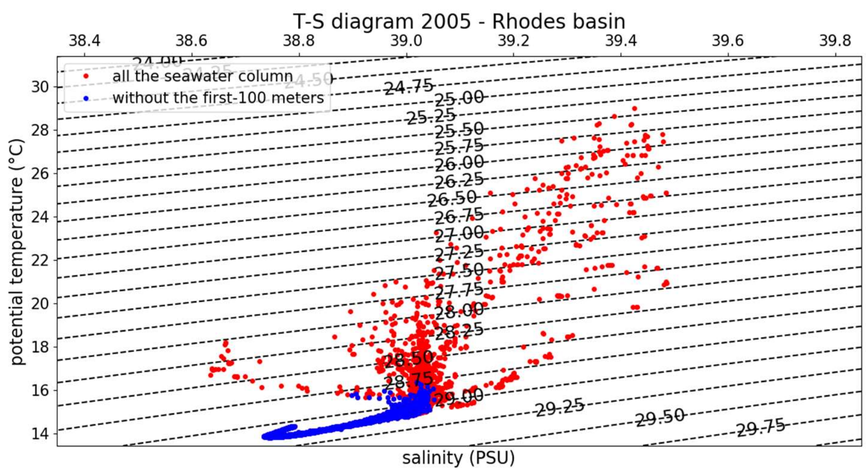
THE RHODES BASIN

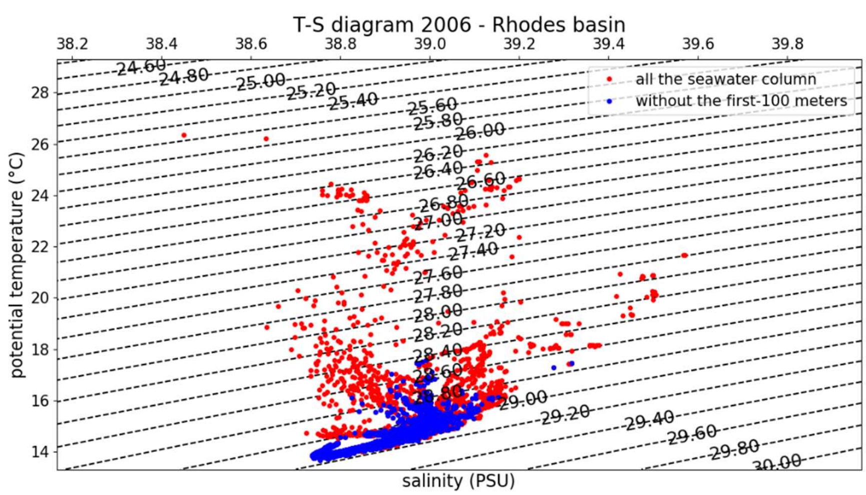


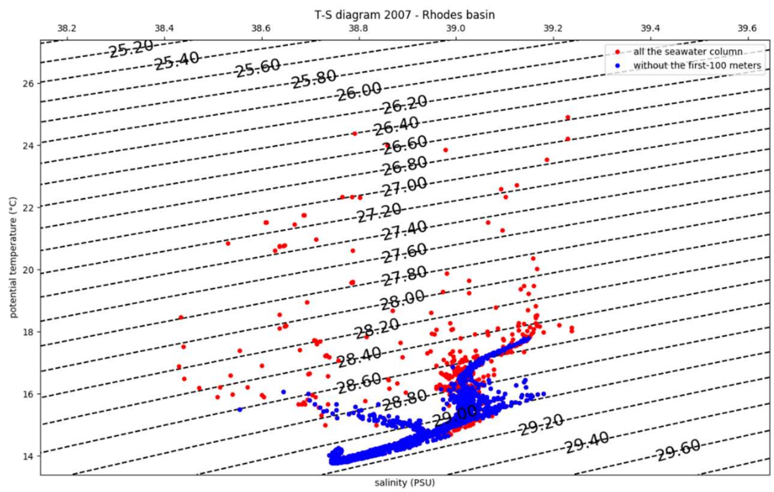


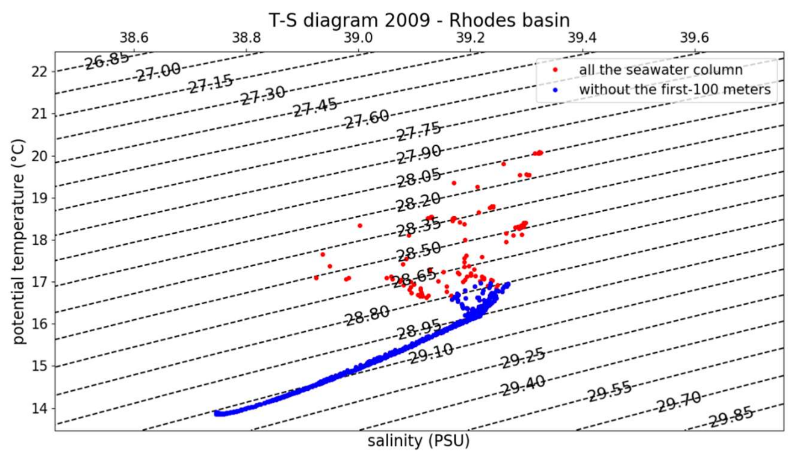


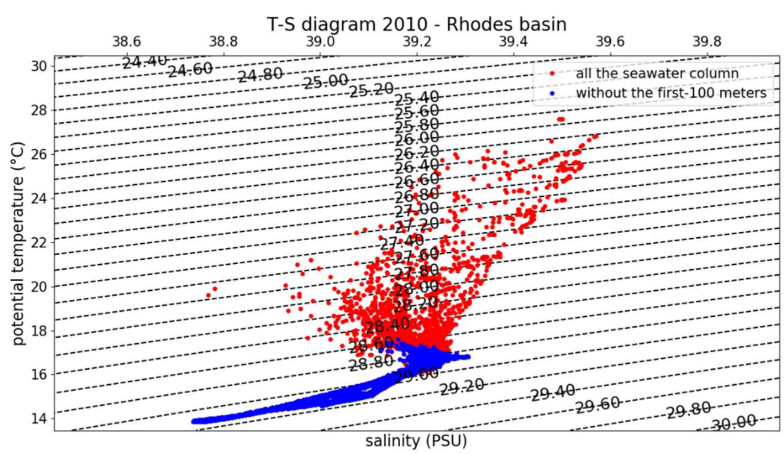

T-S diagram 2004 - Rhodes basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

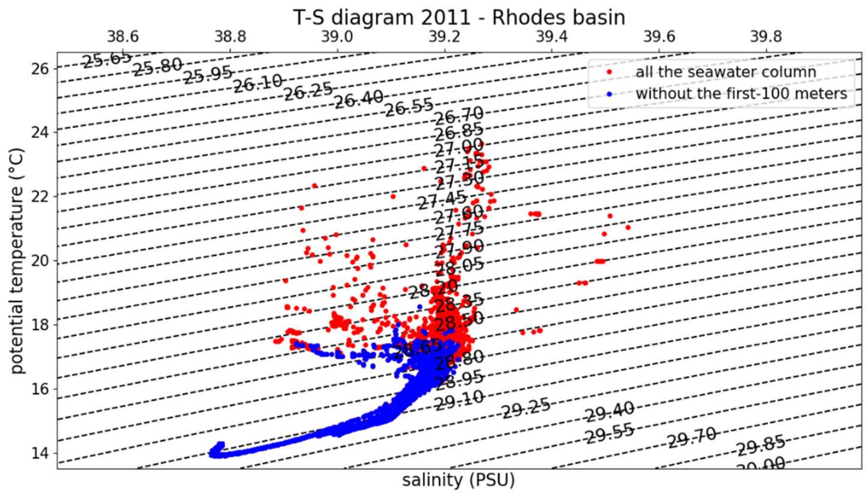

T-S diagram 2005 - Rhodes basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

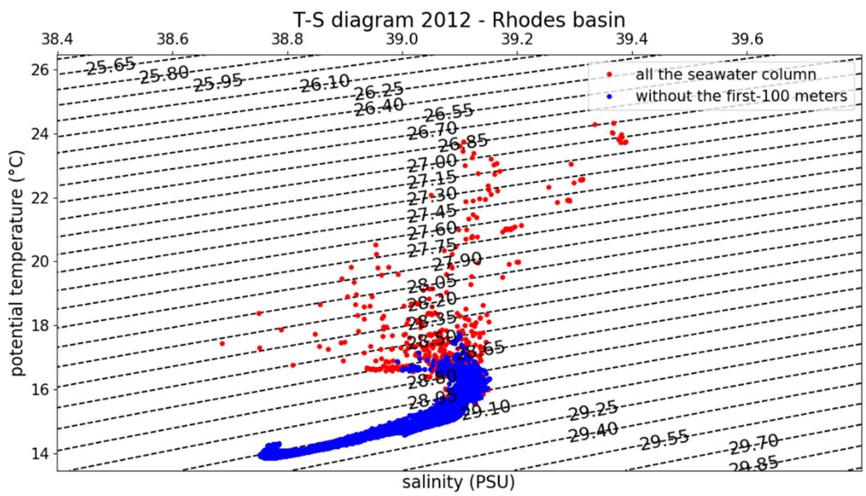

T-S diagram 2006 - Rhodes basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

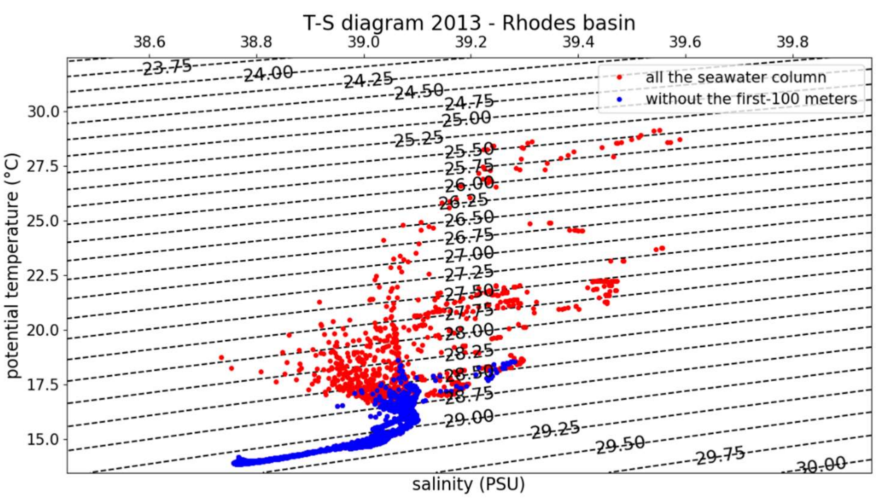

T-S diagram 2007 - Rhodes basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

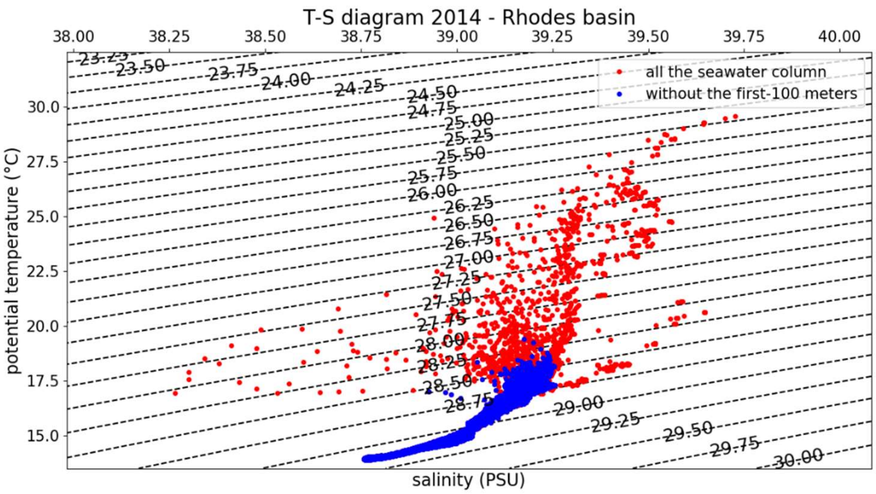

T-S diagram 2009 - Rhodes basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

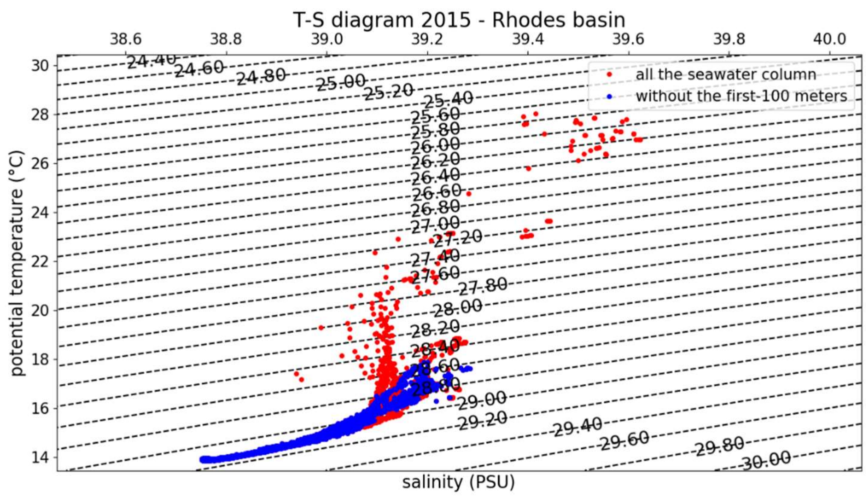

T-S diagram 2010 - Rhodes basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

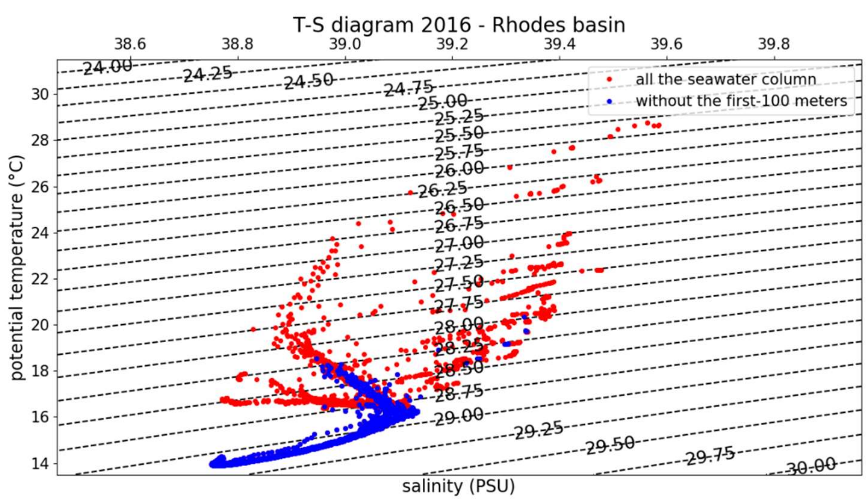

T-S diagram 2011 - Rhodes basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

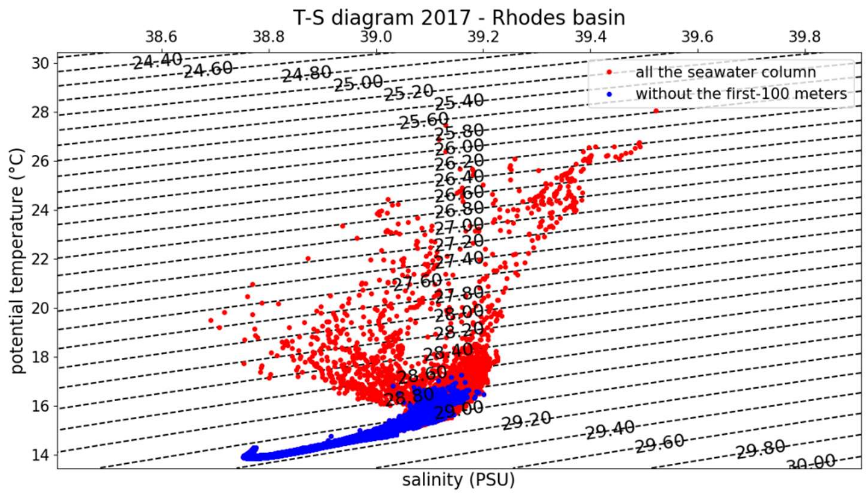

T-S diagram 2012 - Rhodes basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)


T-S diagram 2013 - Rhodes basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

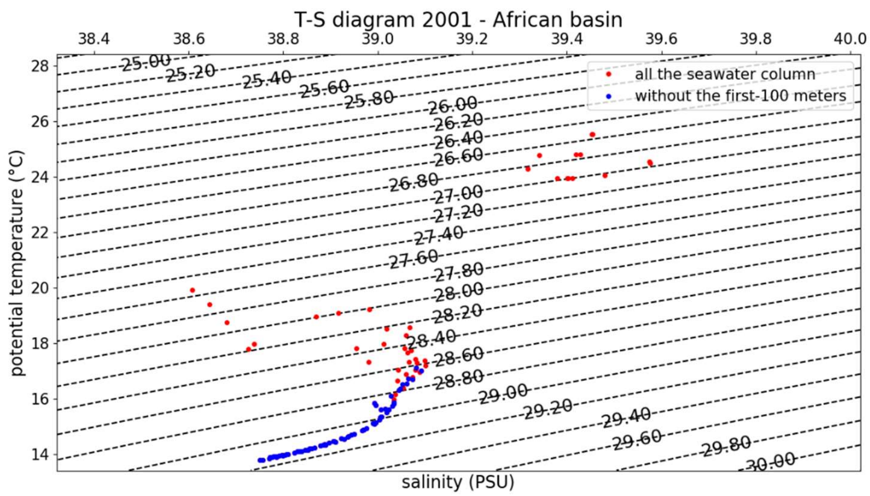

T-S diagram 2014 - Rhodes basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

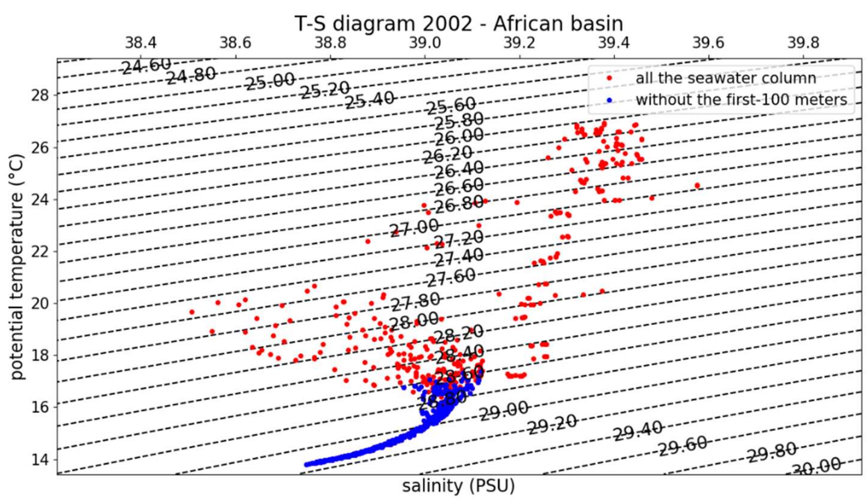

T-S diagram 2015 - Rhodes basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

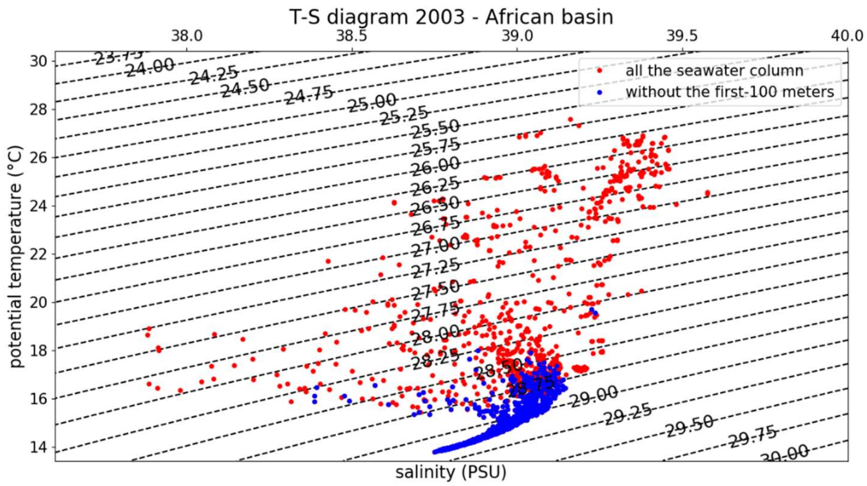

T-S diagram 2016 - Rhodes basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

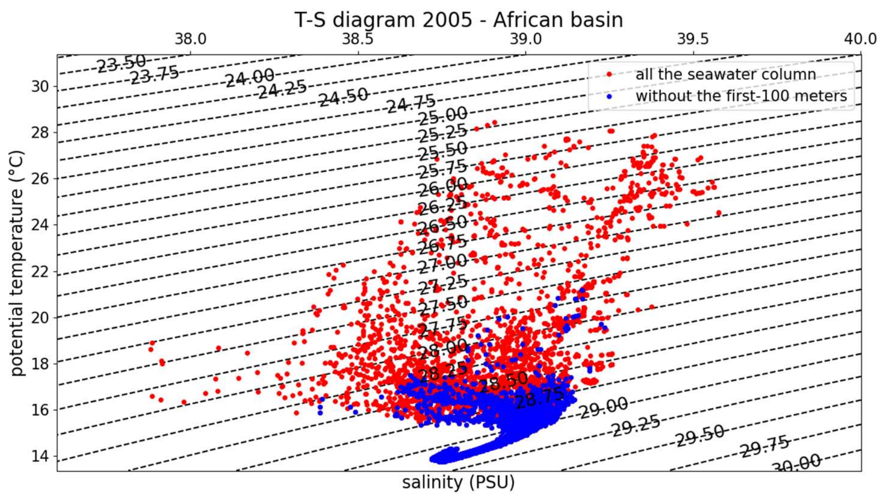


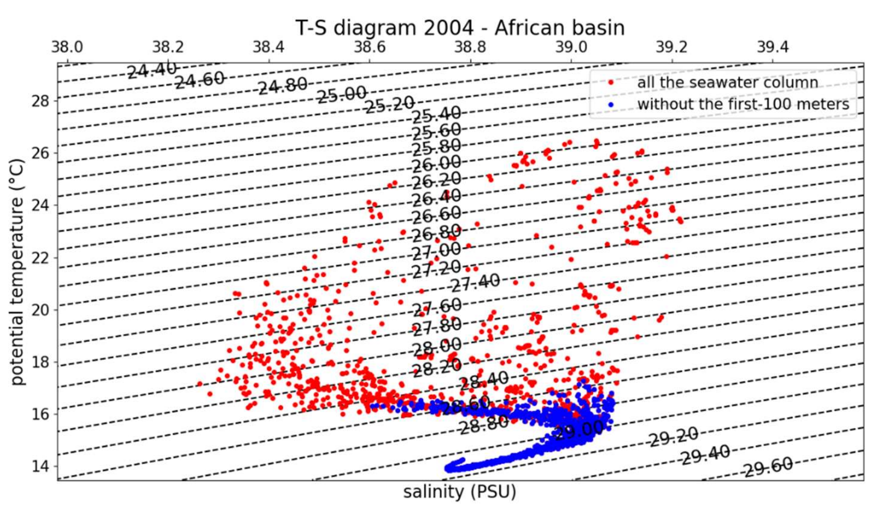
THE AFRICAN BASIN

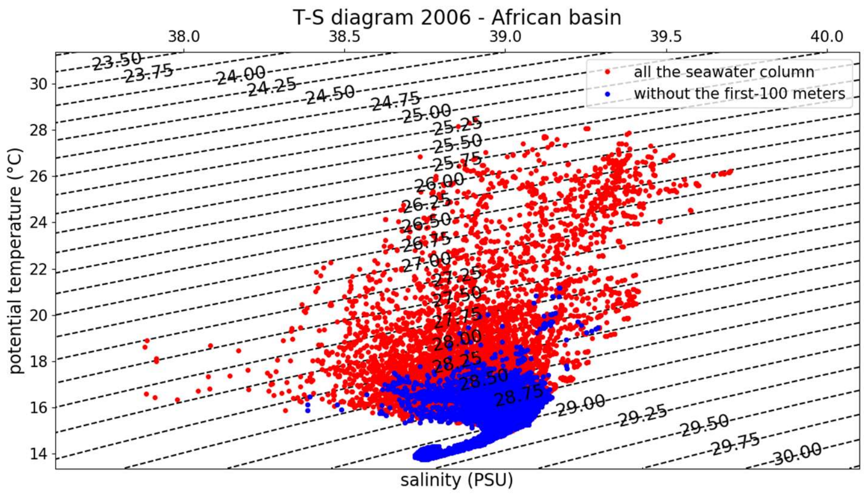


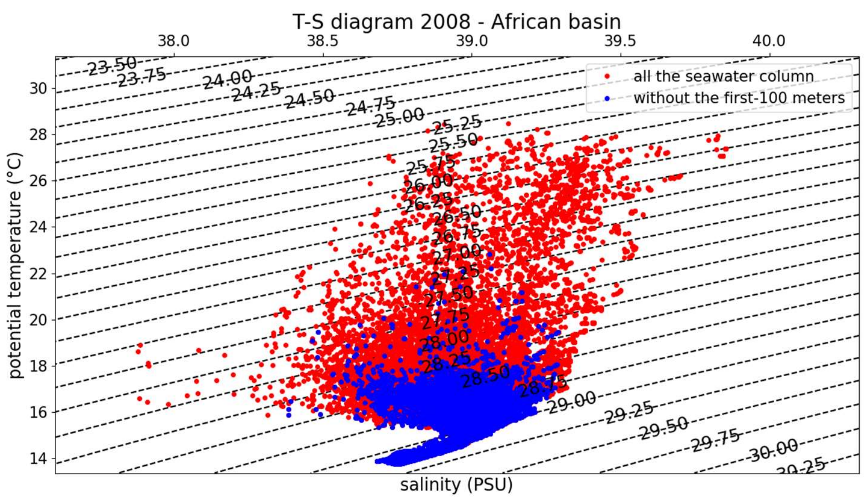


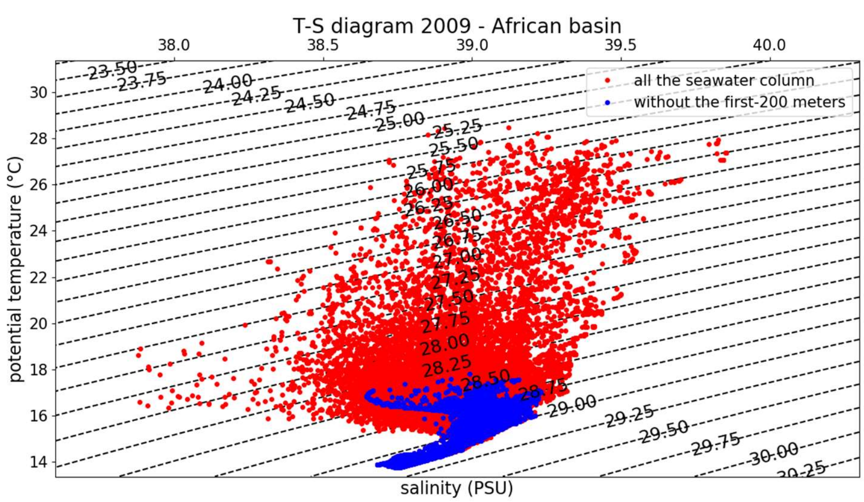

T-S diagram 2003 - African basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

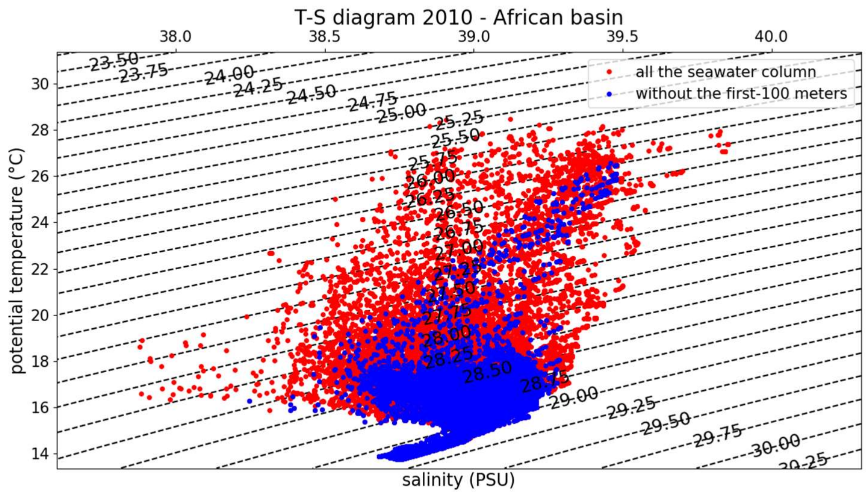

T-S diagram 2005 - African basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)


T-S diagram 2004 - African basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

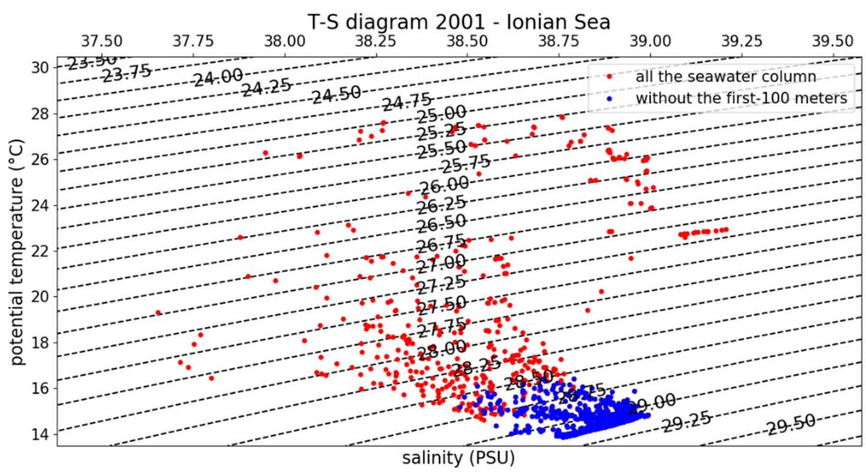

T-S diagram 2006 - African basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

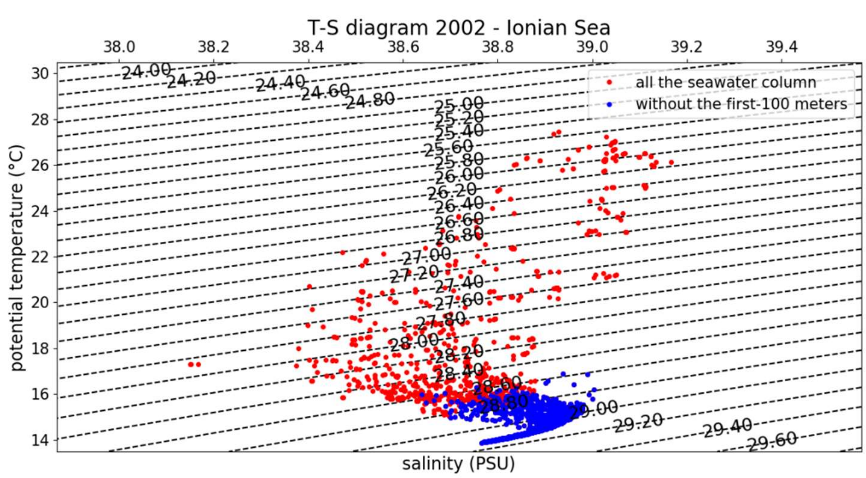

T-S diagram 2008 - African basin
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

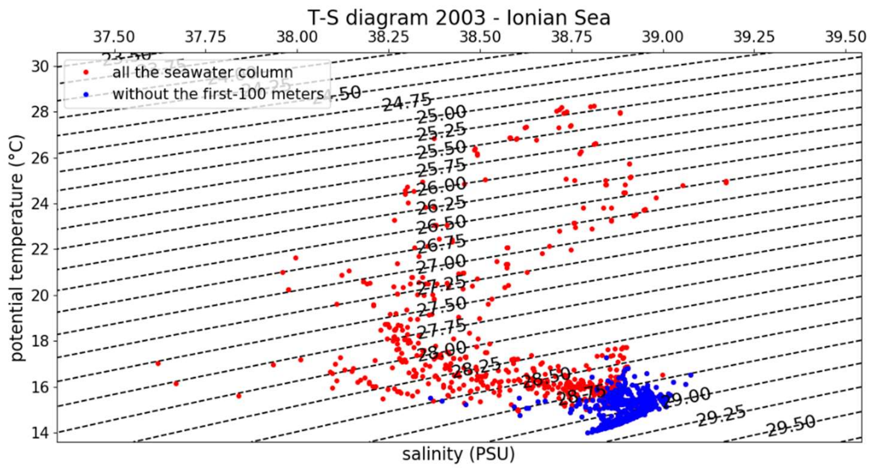

T-S diagram 2009 - African basin
all the seawater column
without the first-200 meters
potential temperature (°C)
salinity (PSU)

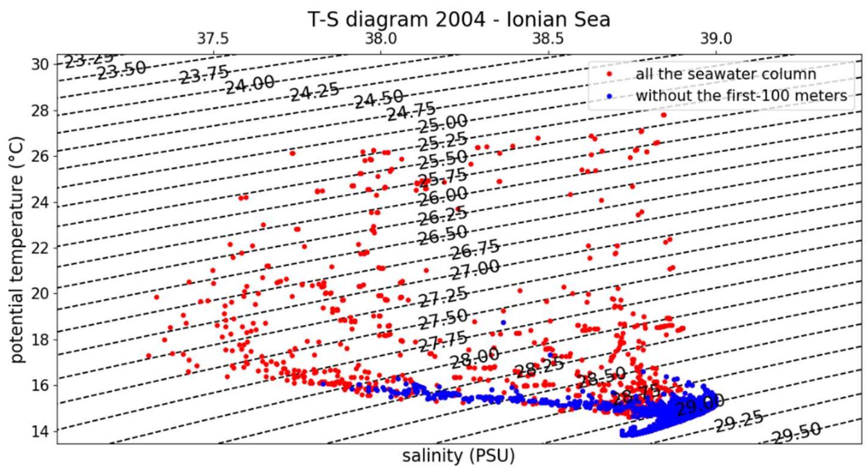


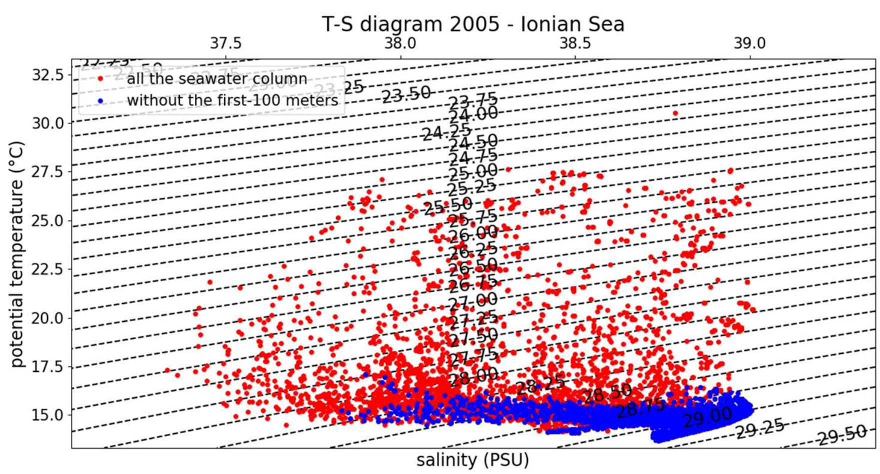
THE IONIAN BASIN

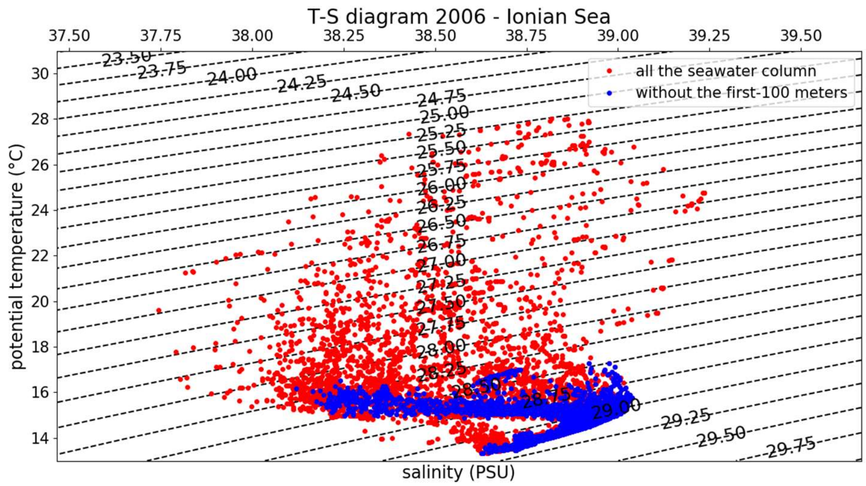


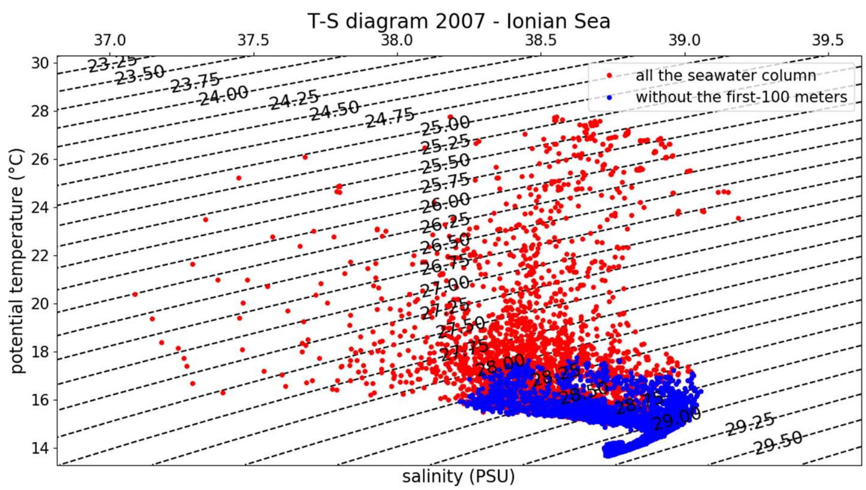


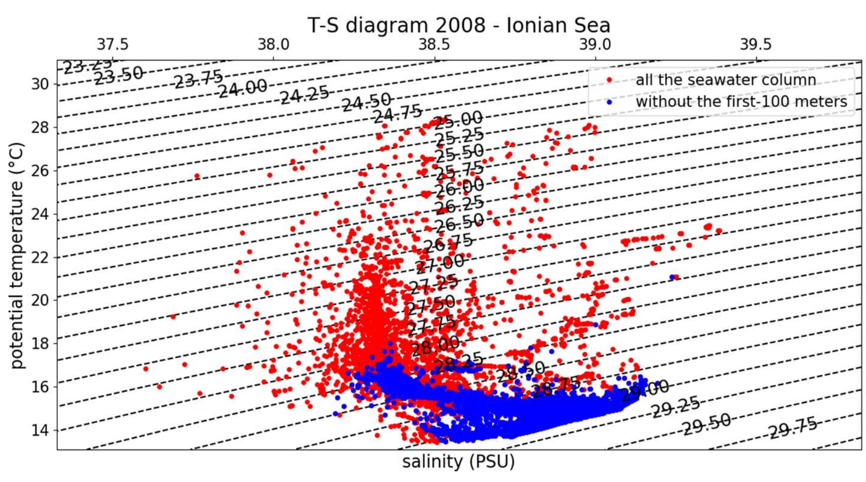

T-S diagram 2003 - Ionian Sea
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

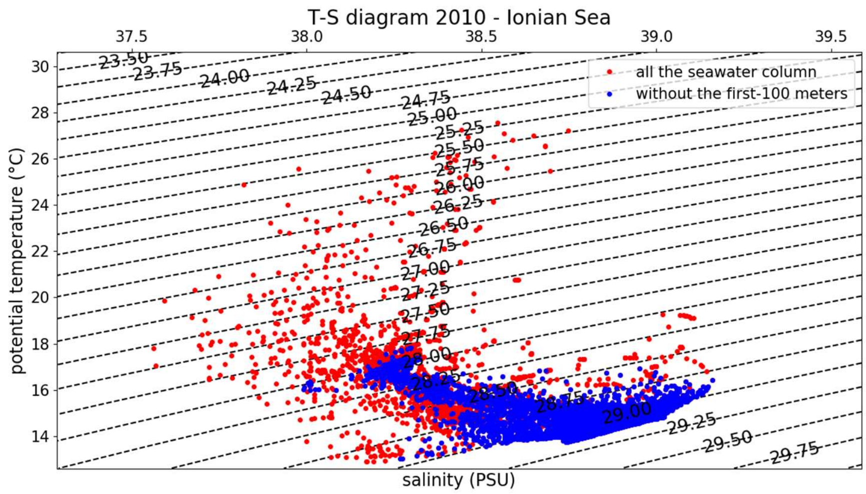

T-S diagram 2004 - Ionian Sea
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

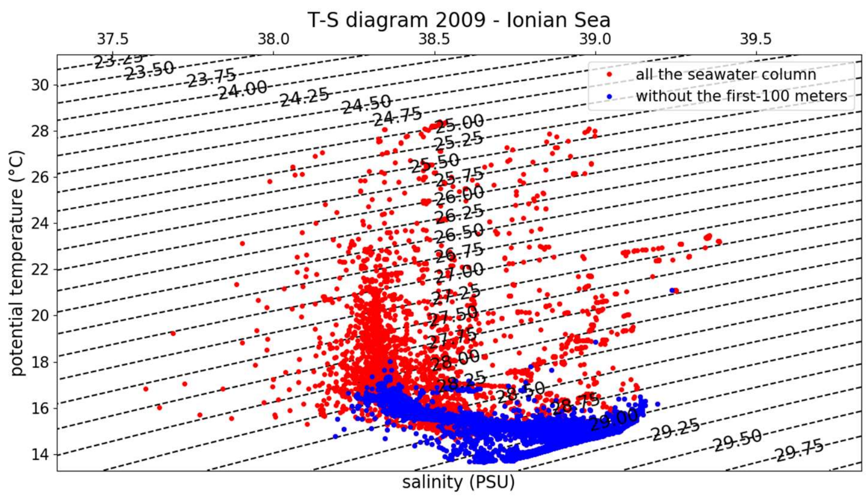

T-S diagram 2005 - Ionian Sea
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

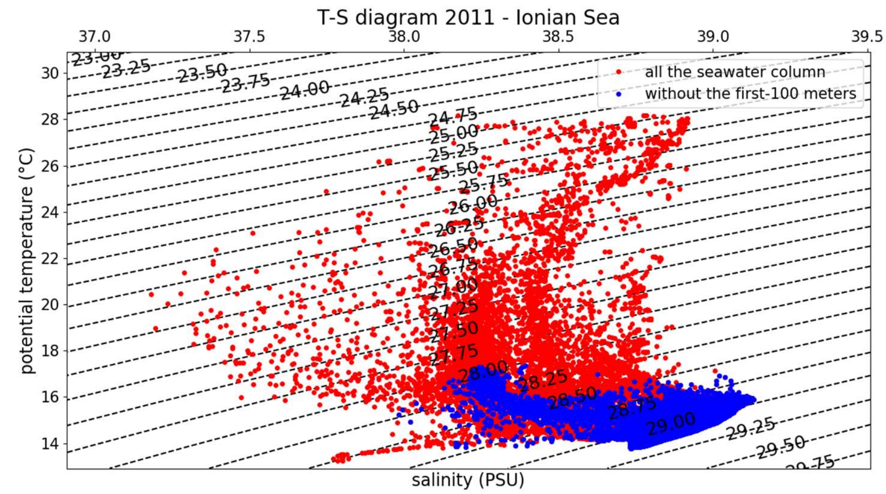

T-S diagram 2006 - Ionian Sea
potential temperature (°C)
salinity (PSU)
all the seawater column
without the first-100 meters

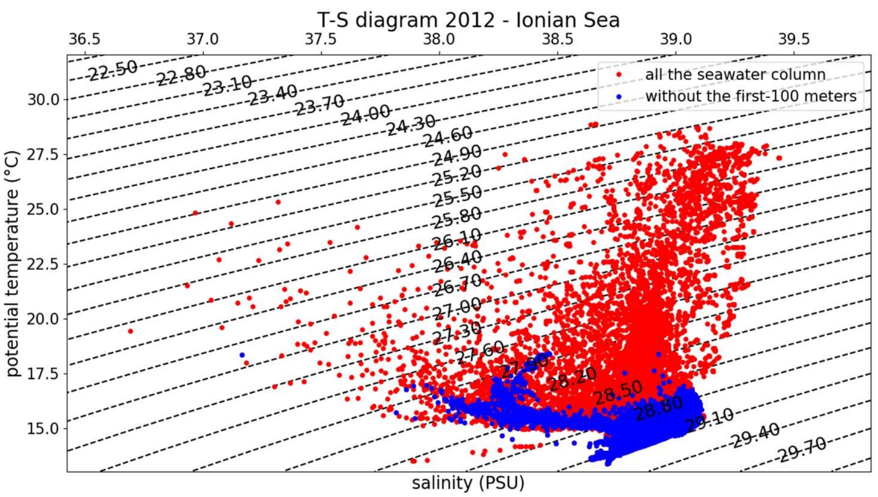

T-S diagram 2007 - Ionian Sea
potential temperature (°C)
salinity (PSU)
all the seawater column
without the first-100 meters

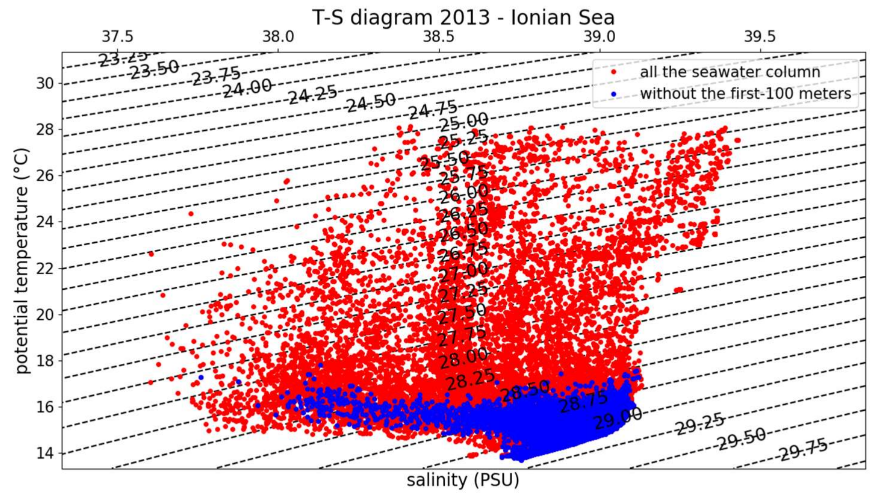

T-S diagram 2008 - Ionian Sea
potential temperature (°C)
salinity (PSU)
all the seawater column
without the first-100 meters

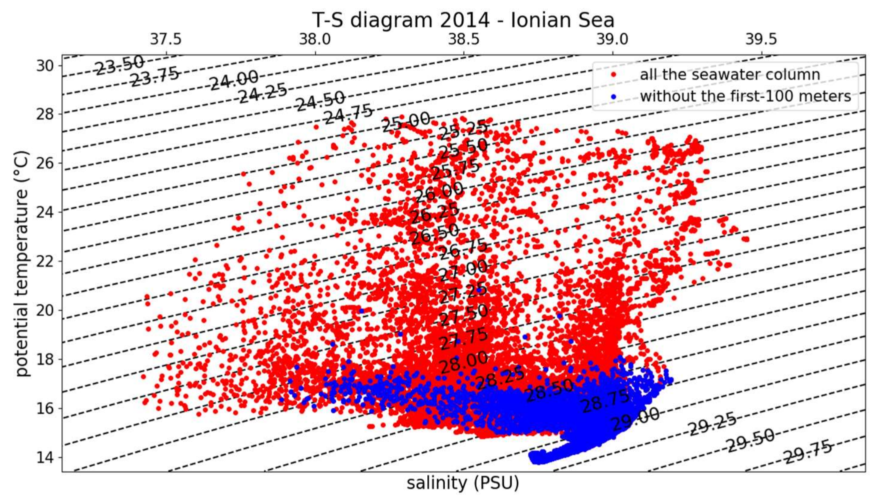

T-S diagram 2010 - Ionian Sea
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

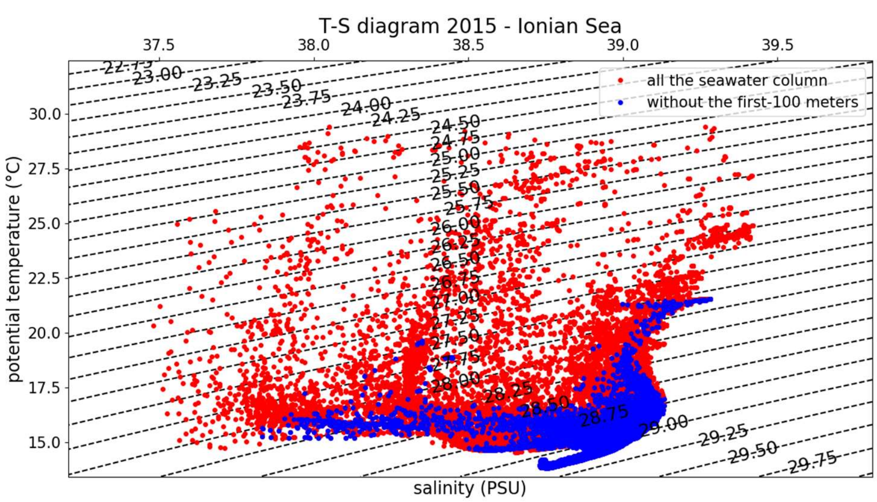

T-S diagram 2009 - Ionian Sea
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

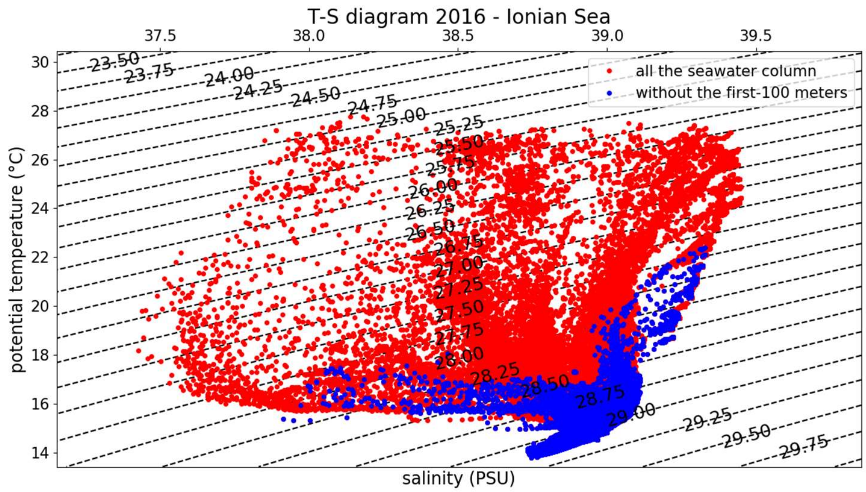

T-S diagram 2011 - Ionian Sea
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

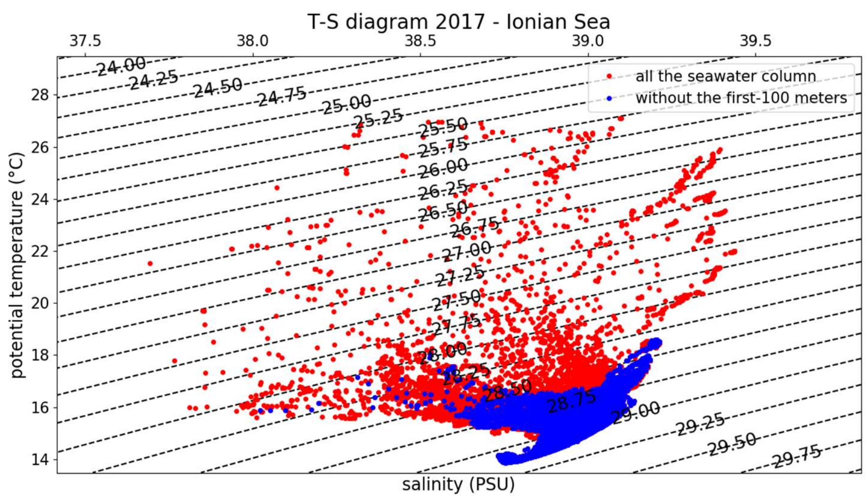

T-S diagram 2012 - Ionian Sea
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

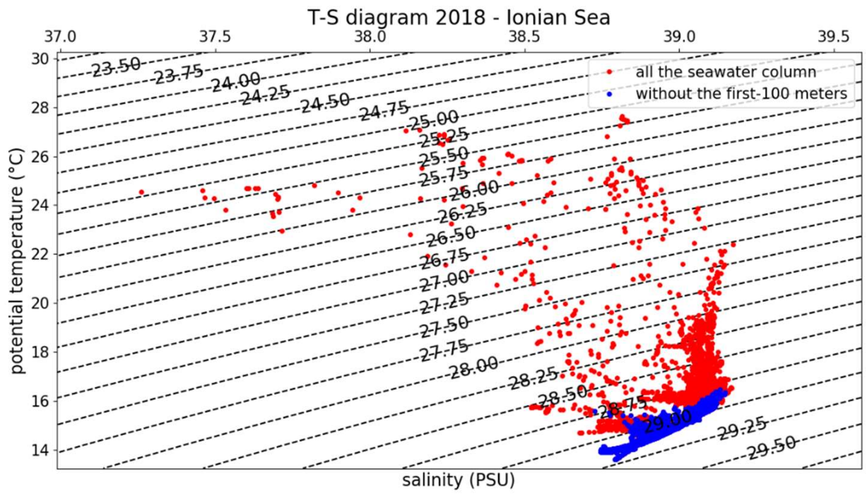

T-S diagram 2013 - Ionian Sea
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)


T-S diagram 2014 - Ionian Sea
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)


T-S diagram 2015 - Ionian Sea
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)


T-S diagram 2016 - Ionian Sea
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)

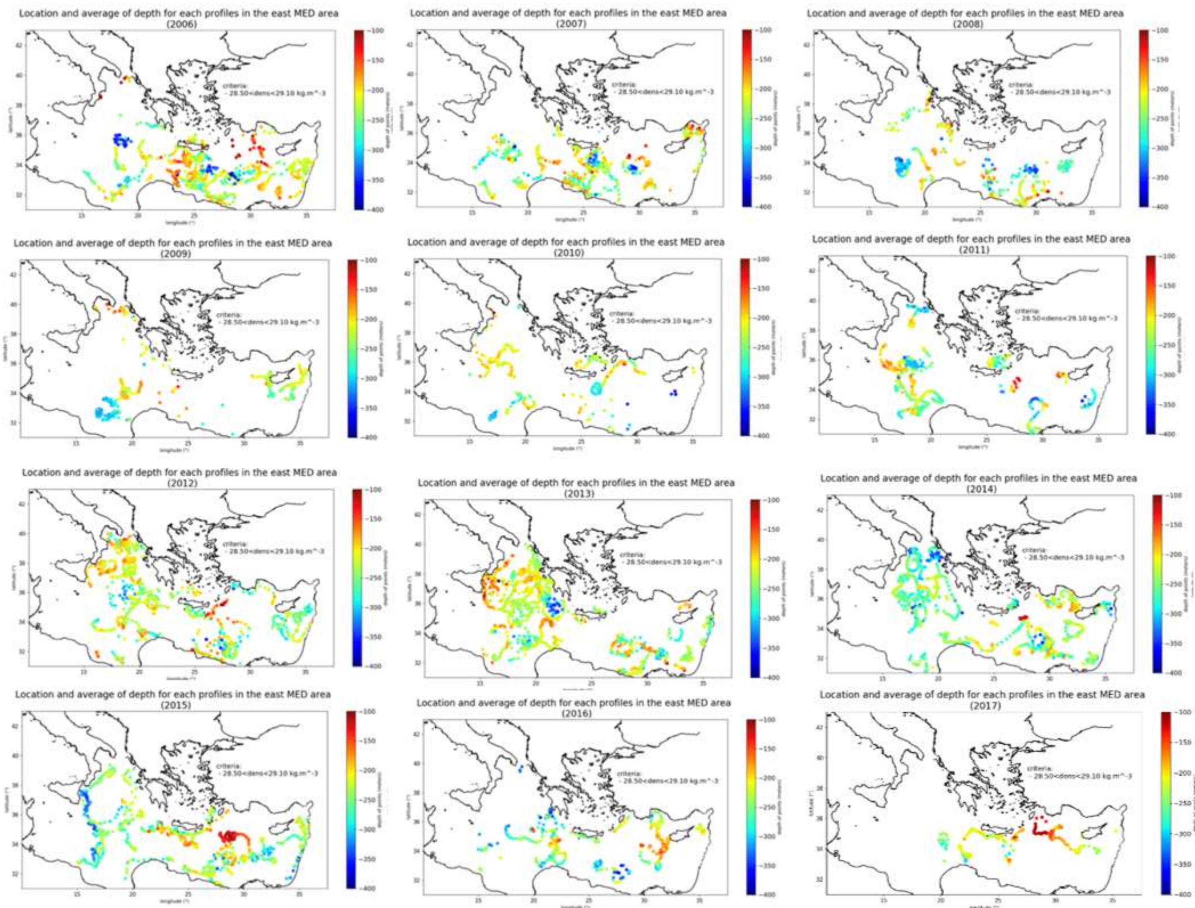

T-S diagram 2017 - Ionian Sea
all the seawater column
without the first-100 meters
potential temperature (°C)
salinity (PSU)


T-S diagram 2018 - Ionian Sea
37.0
37.5
38.0
38.5
39.0
39.5
30
28
26
24
22
20
18
16
14
potential temperature (°C)
salinity (PSU)
all the seawater column
without the first-100 meters
23.50
23.75
24.00
24.25
24.50
24.75
25.00
25.25
25.50
25.75
26.00
26.25
26.50
26.75
27.00
27.25
27.50
27.75
28.00
28.25
28.50
28.75
29.00
29.25
29.50

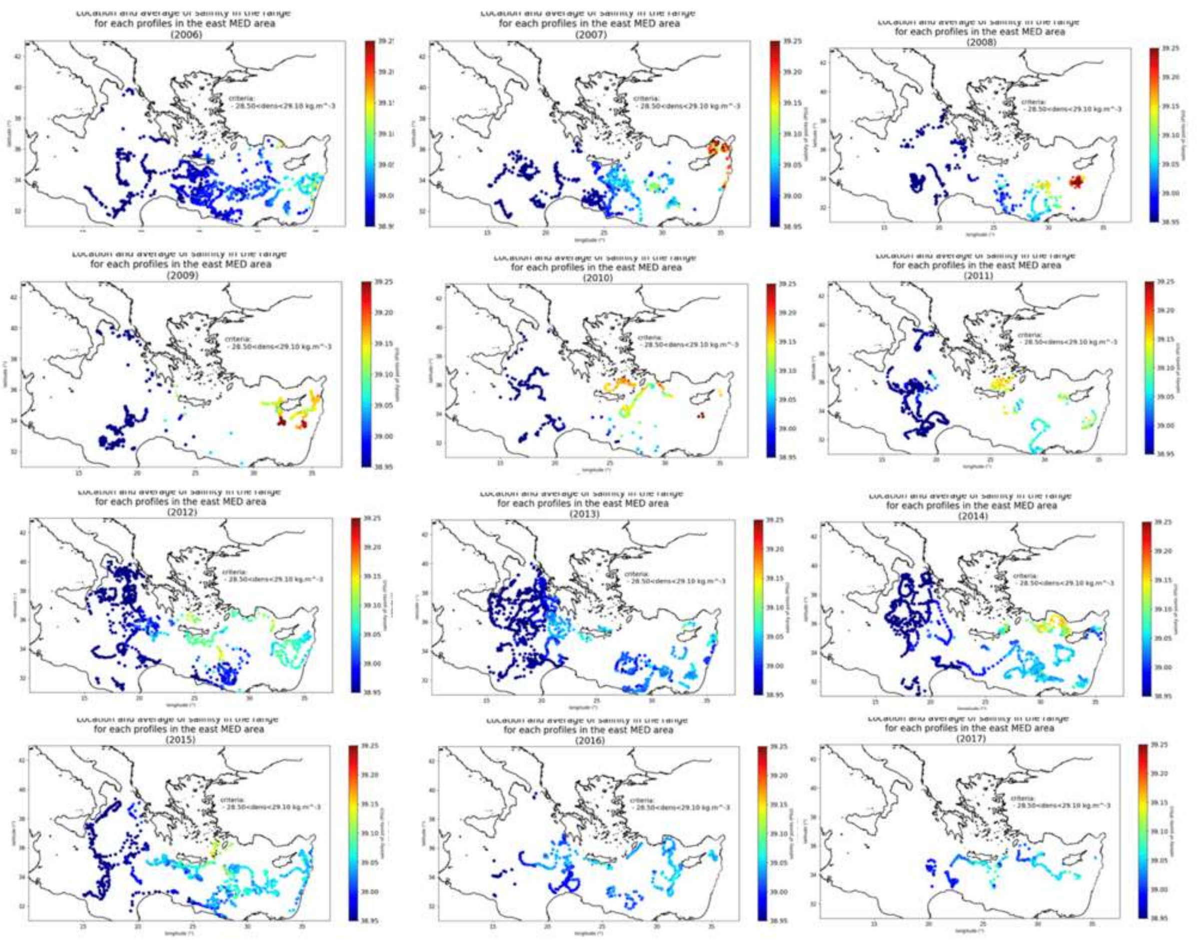
APPENDIX 2

- *density between 28.5 and 29.10 kg m^{-3} and depth between 100 and 400 m*

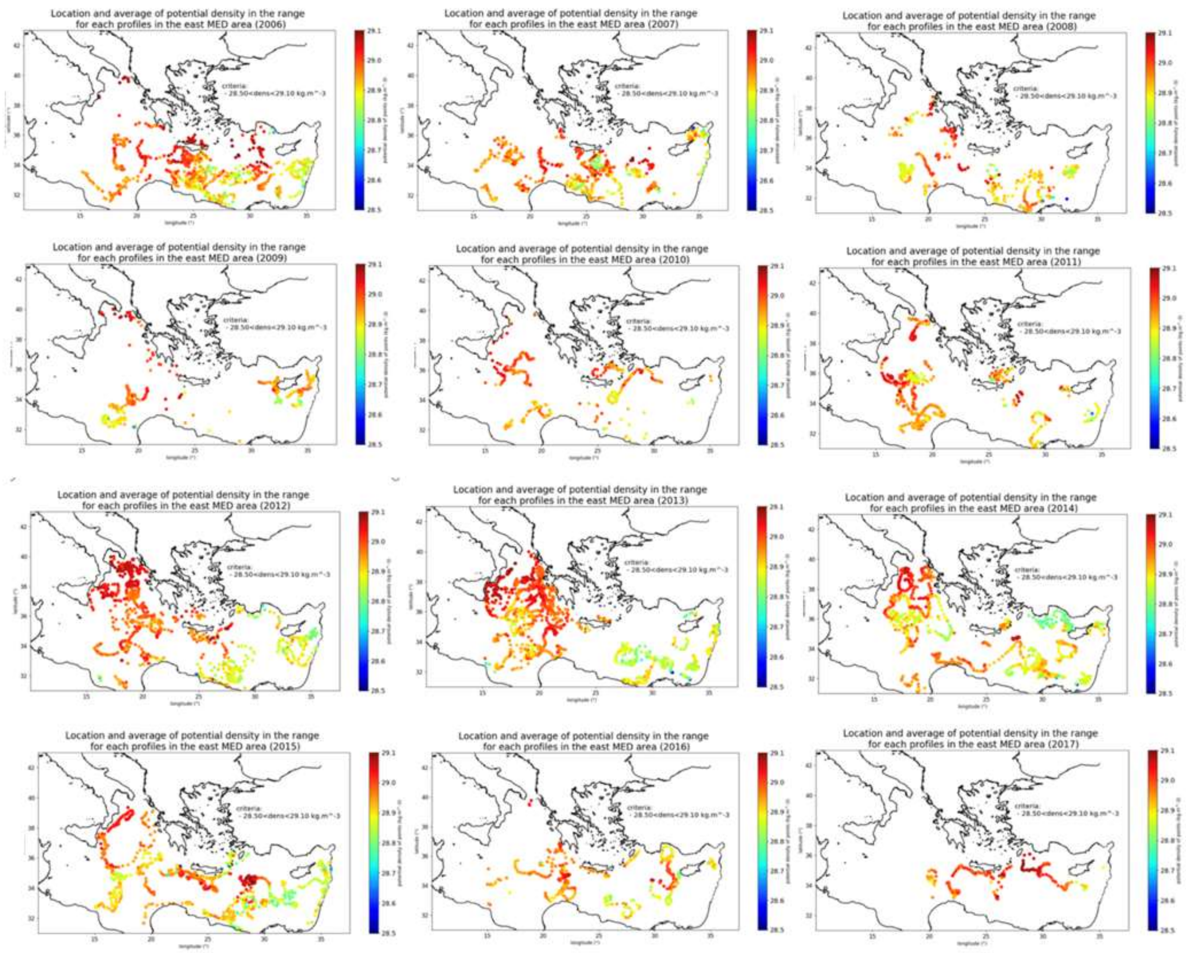
Depth of max salinity



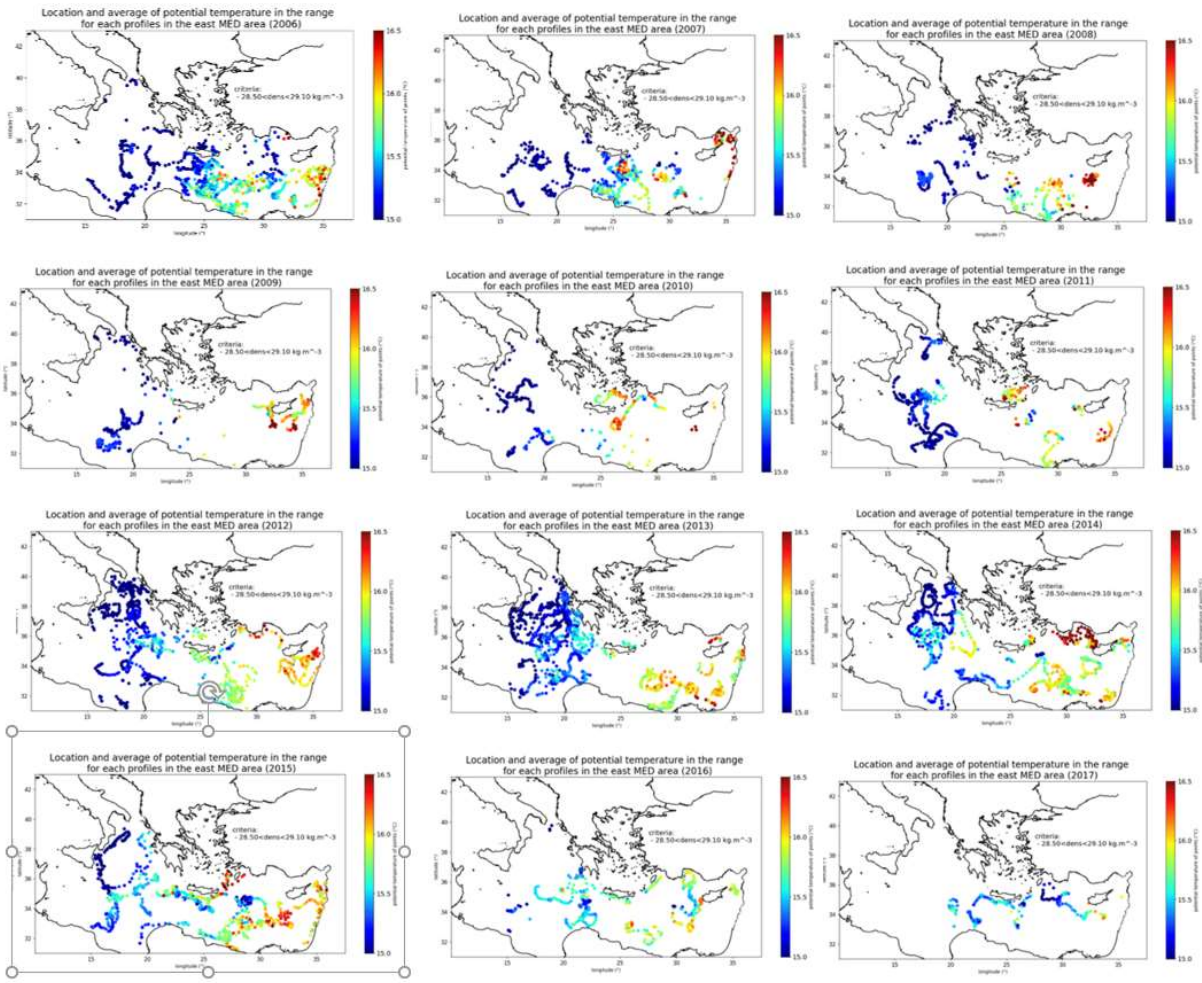
Salinity max



Density

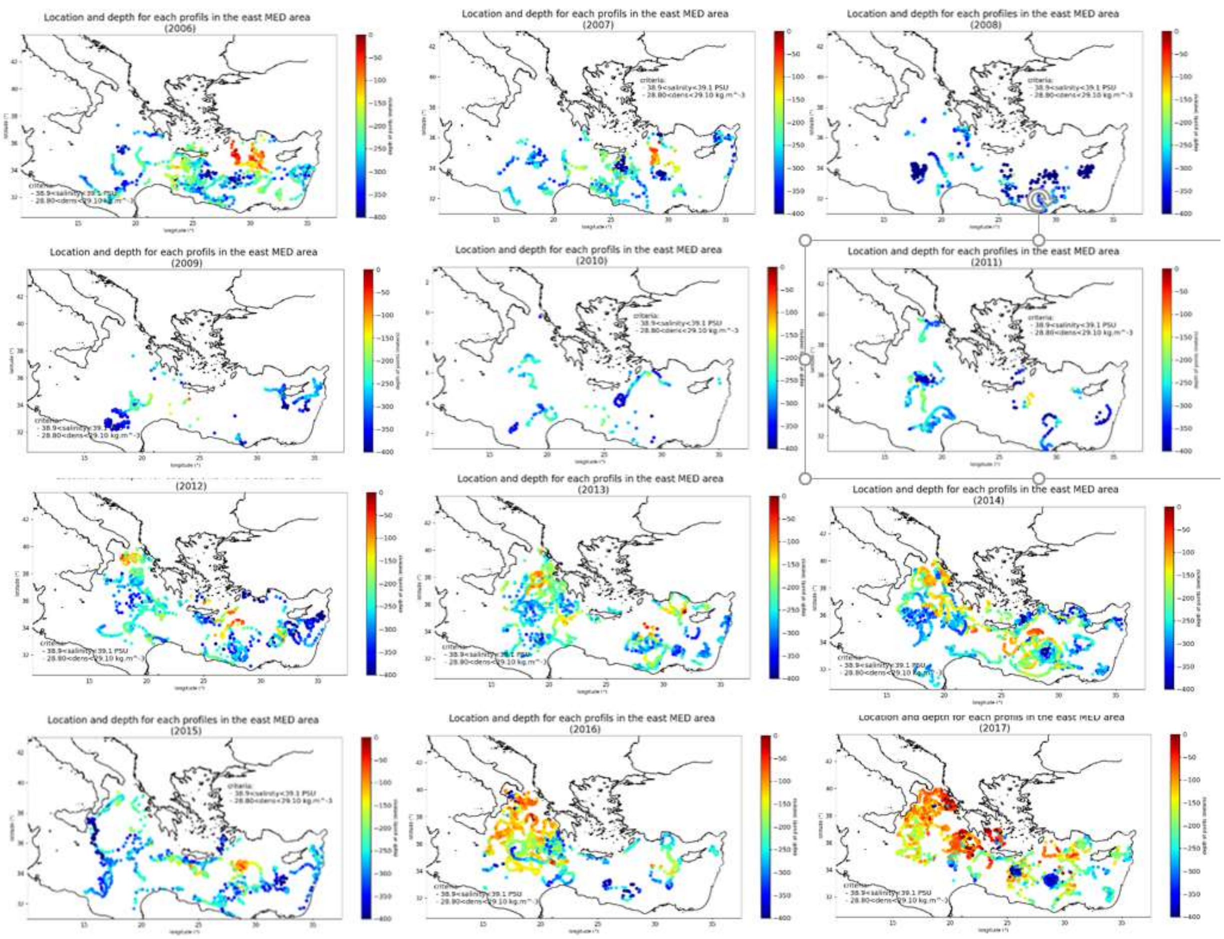

Location and average of potential density in the range for each profiles in the east MED area (2006)
Location and average of potential density in the range for each profiles in the east MED area (2007)
Location and average of potential density in the range for each profiles in the east MED area (2008)
Location and average of potential density in the range for each profiles in the east MED area (2009)
Location and average of potential density in the range for each profiles in the east MED area (2010)
Location and average of potential density in the range for each profiles in the east MED area (2011)
Location and average of potential density in the range for each profiles in the east MED area (2012)
Location and average of potential density in the range for each profiles in the east MED area (2013)
Location and average of potential density in the range for each profiles in the east MED area (2014)
Location and average of potential density in the range for each profiles in the east MED area (2015)
Location and average of potential density in the range for each profiles in the east MED area (2016)
Location and average of potential density in the range for each profiles in the east MED area (2017)

Temperature

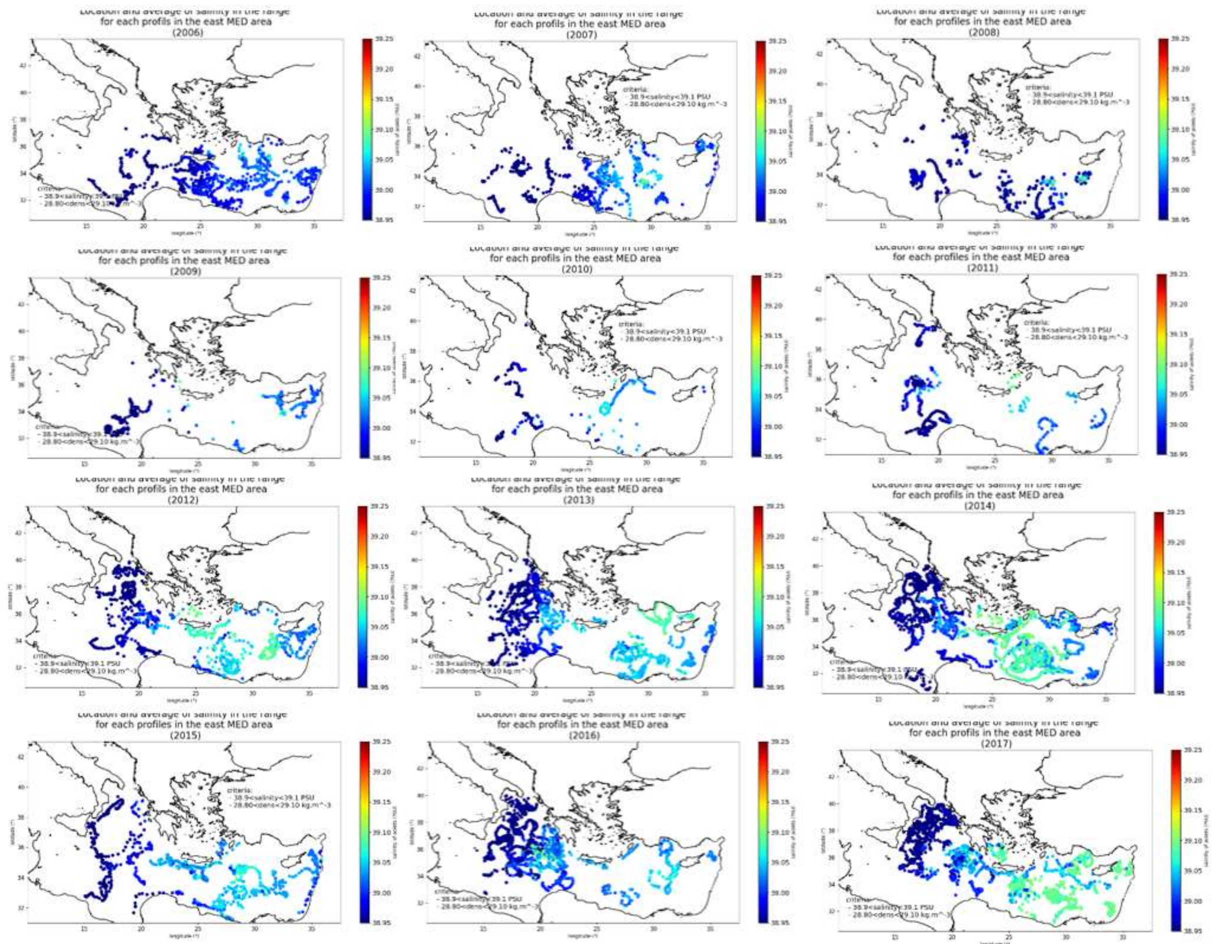


APPENDIX 3

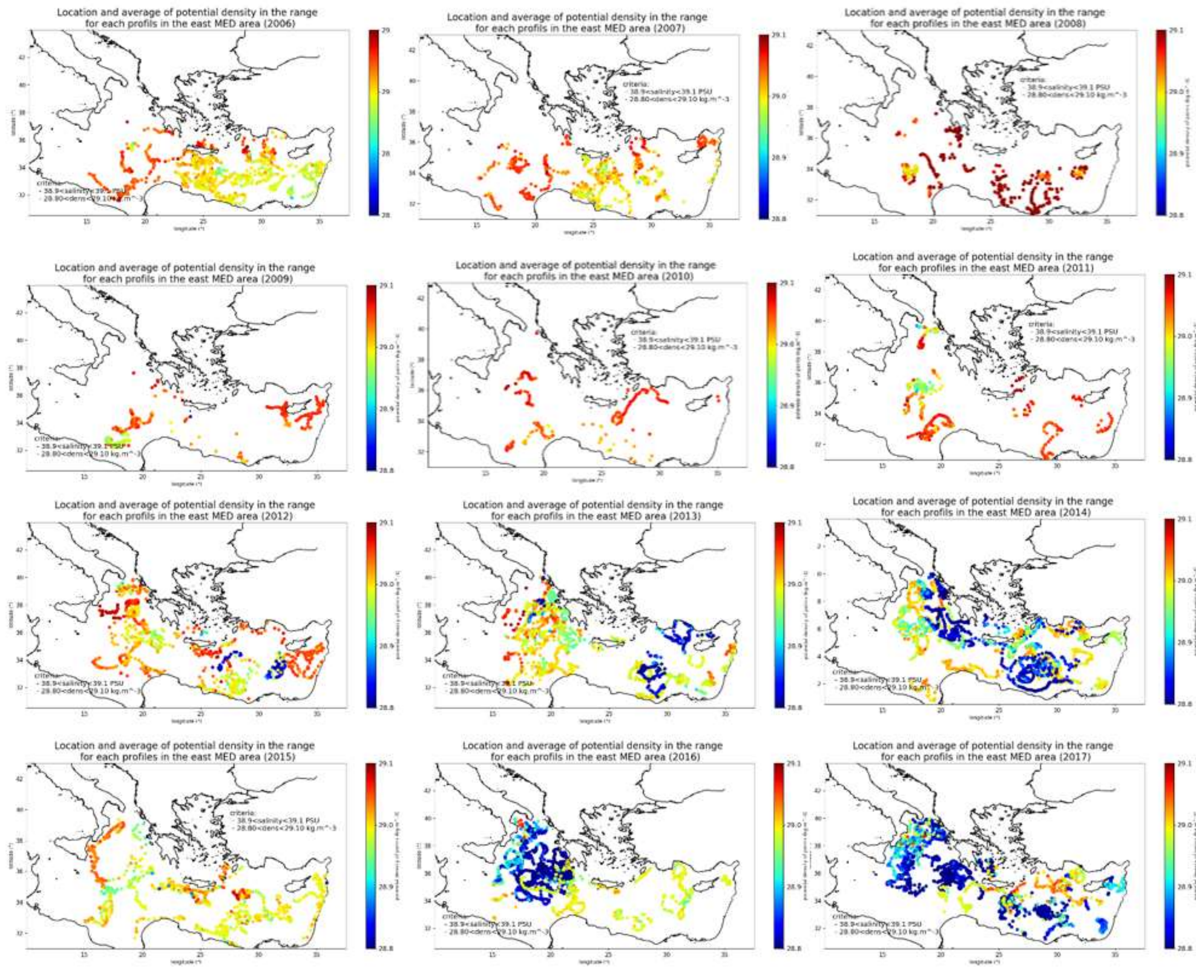
Depth of max salinity



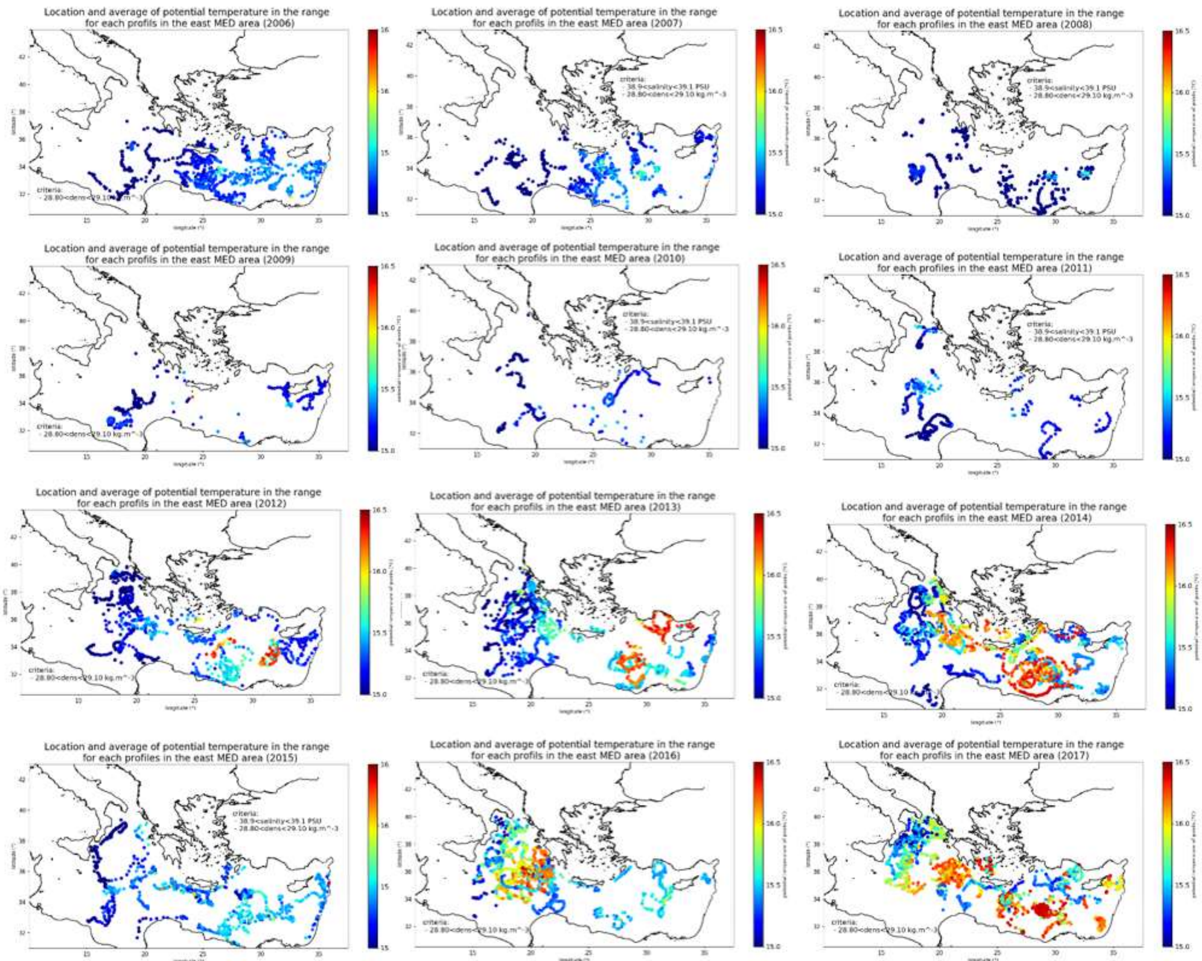
Salinity


for each profils in the east MED area
(2006)
for each profils in the east MED area
(2007)
for each profiles in the east MED area
(2008)
for each profils in the east MED area
(2009)
for each profils in the east MED area
(2010)
for each profiles in the east MED area
(2011)
for each profils in the east MED area
(2012)
for each profils in the east MED area
(2013)
for each profils in the east MED area
(2014)
for each profiles in the east MED area
(2015)
for each profils in the east MED area
(2016)
for each profils in the east MED area
(2017)

Density

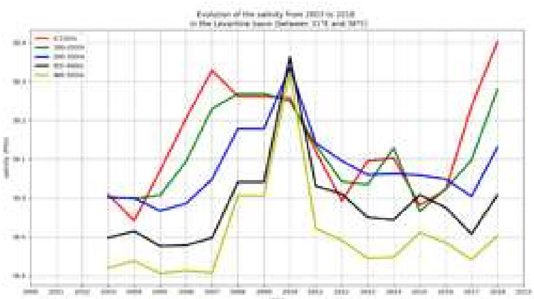

Location and average of potential density in the range for each profils in the east MED area (2006)
Location and average of potential density in the range for each profils in the east MED area (2007)
Location and average of potential density in the range for each profiles in the east MED area (2008)
Location and average of potential density in the range for each profils in the east MED area (2009)
Location and average of potential density in the range for each profils in the east MED area (2010)
Location and average of potential density in the range for each profiles in the east MED area (2011)
Location and average of potential density in the range for each profils in the east MED area (2012)
Location and average of potential density in the range for each profils in the east MED area (2013)
Location and average of potential density in the range for each profils in the east MED area (2014)
Location and average of potential density in the range for each profiles in the east MED area (2015)
Location and average of potential density in the range for each profils in the east MED area (2016)
Location and average of potential density in the range for each profils in the east MED area (2017)

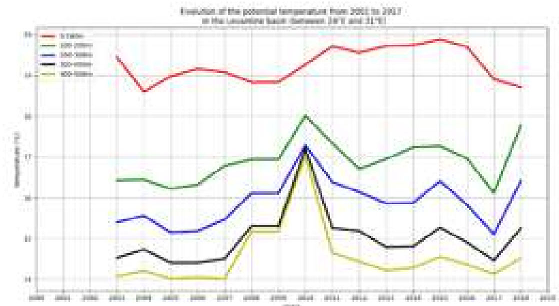
Temperature

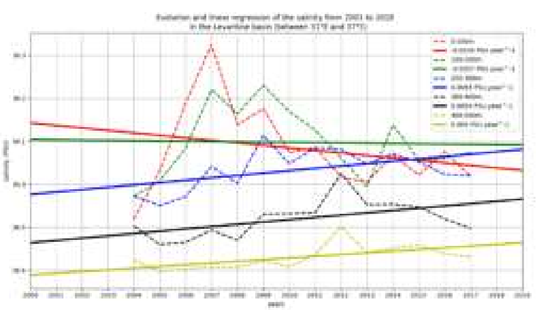


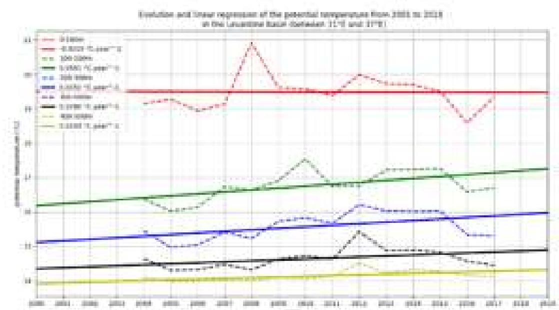
APPENDIX 4

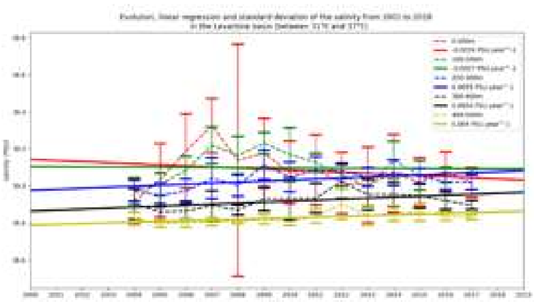
Levantine basin

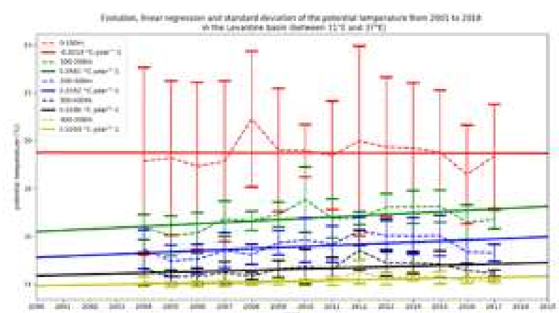


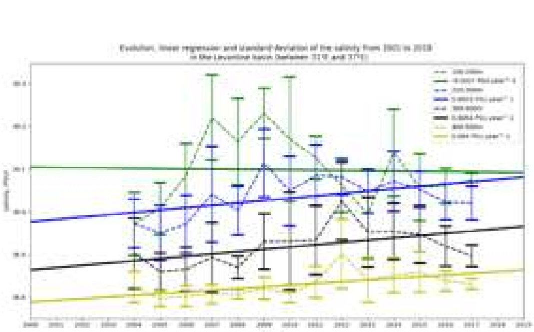


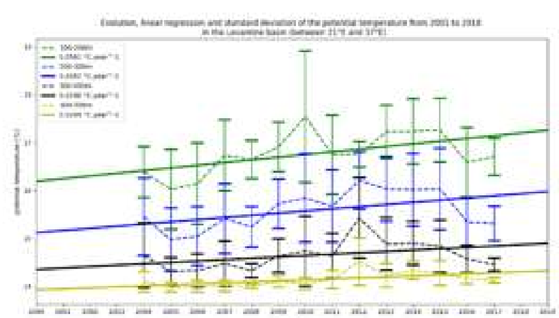




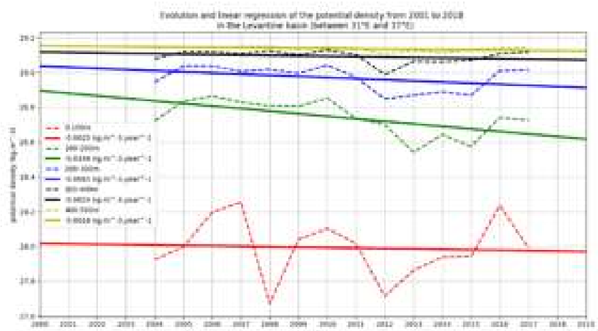


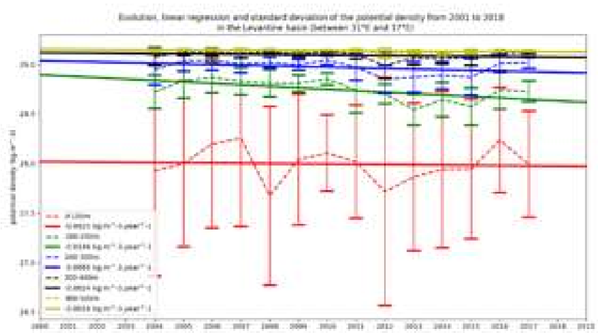


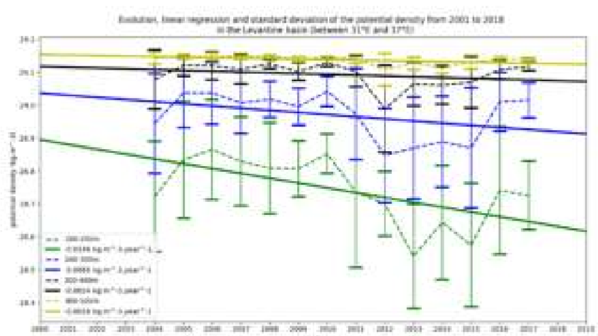




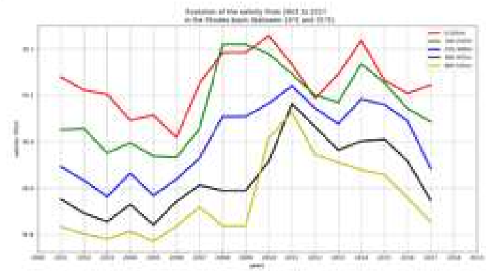
Levantine basin

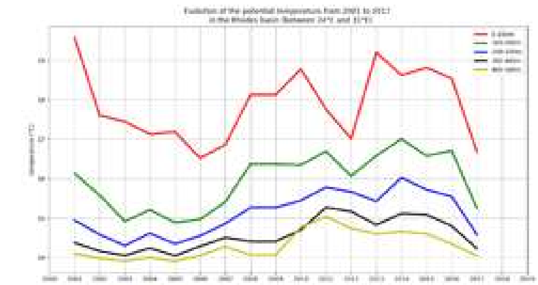


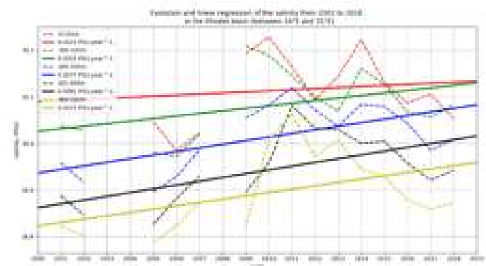


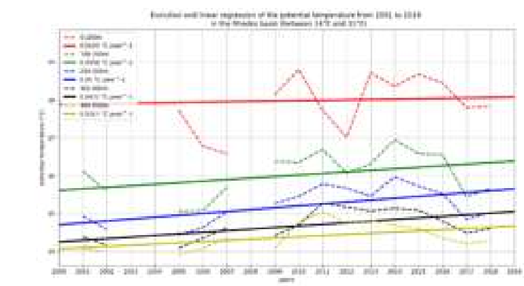


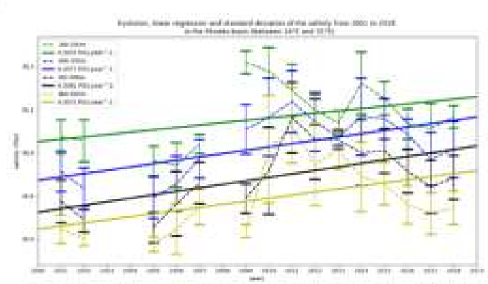
Rhodes Basin

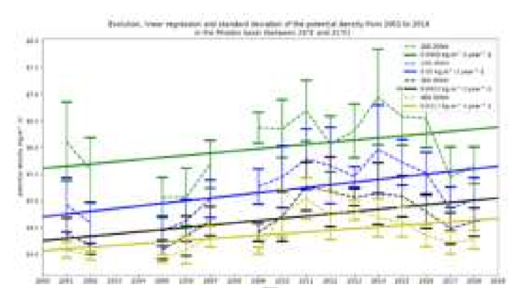




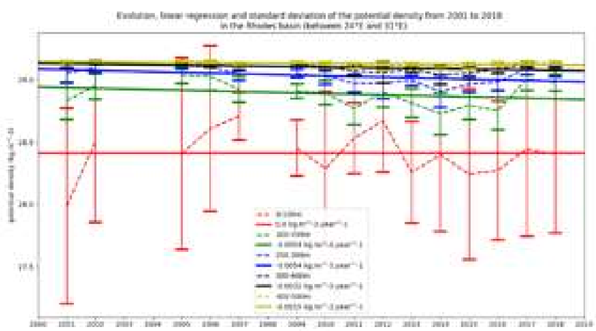


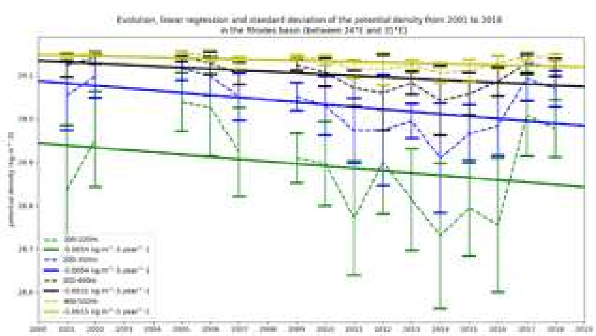




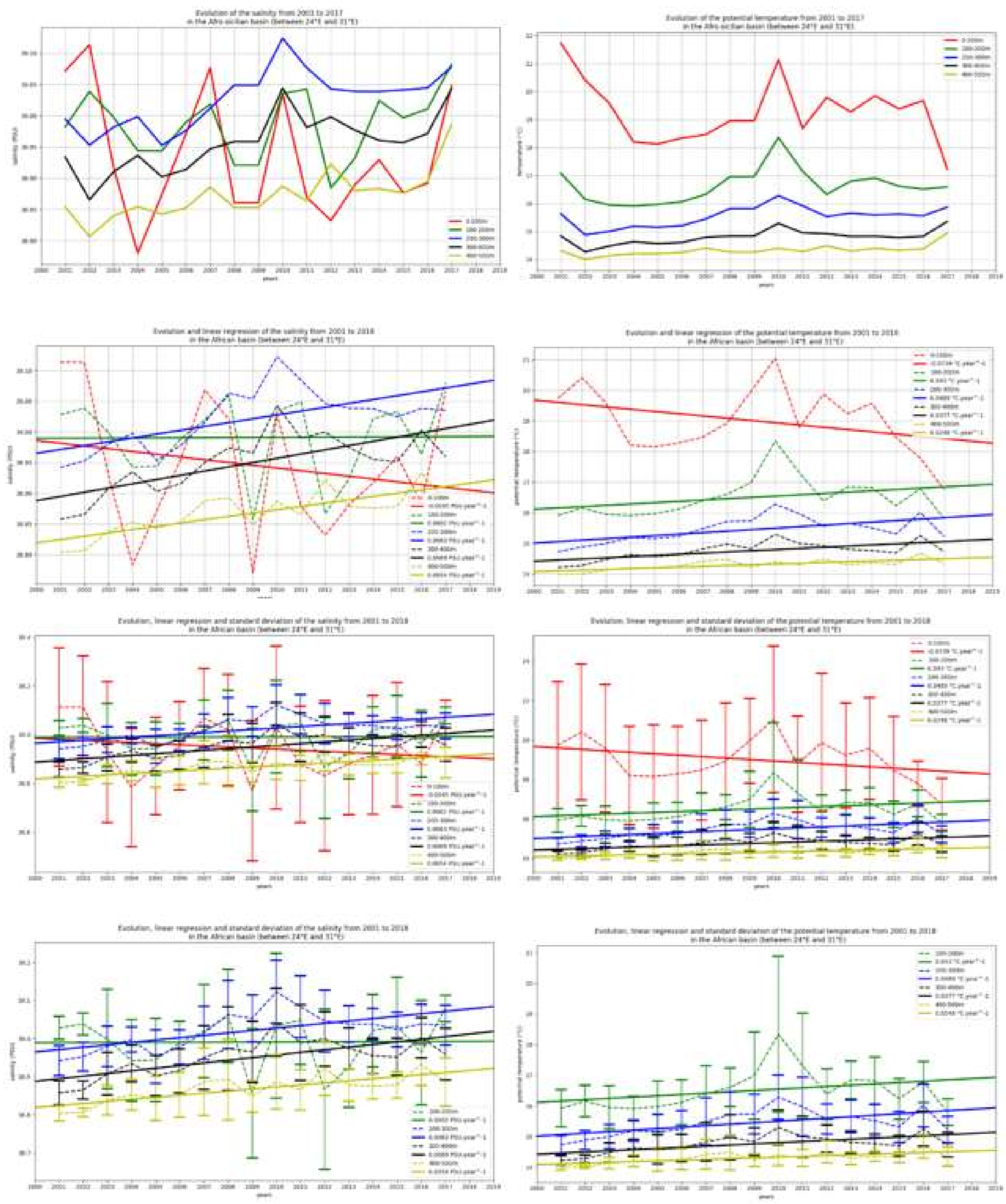


Rhodes Basin

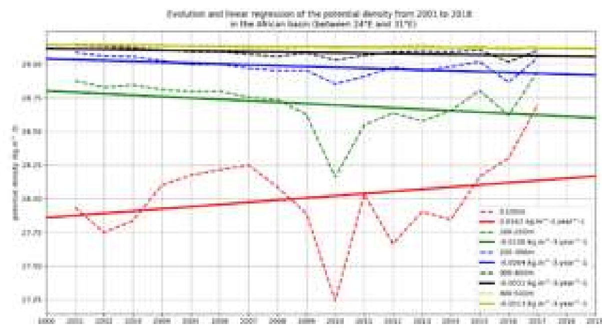


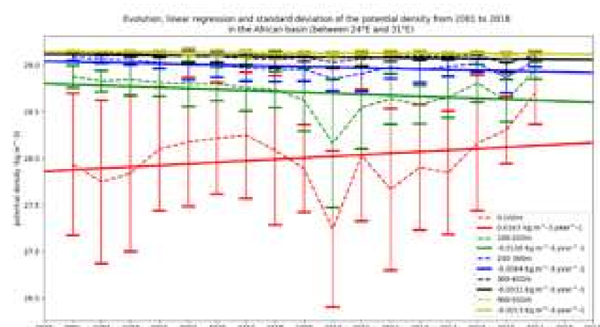


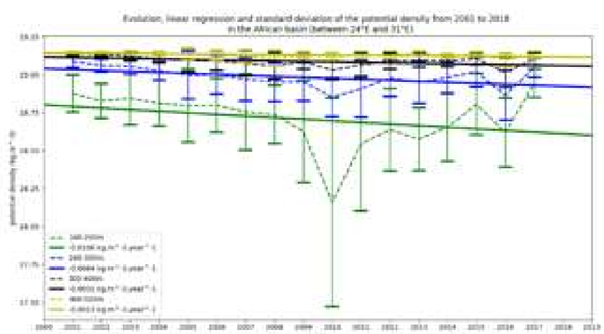
African Basin



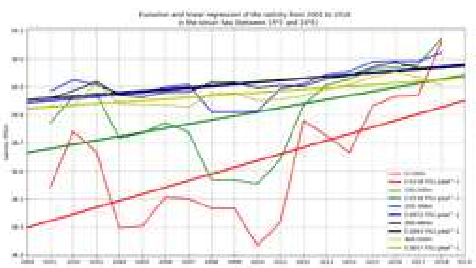
African Basin

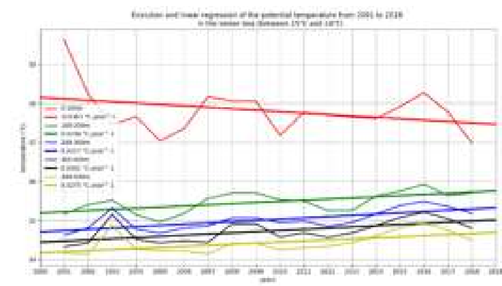


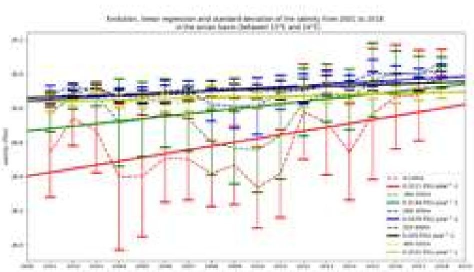


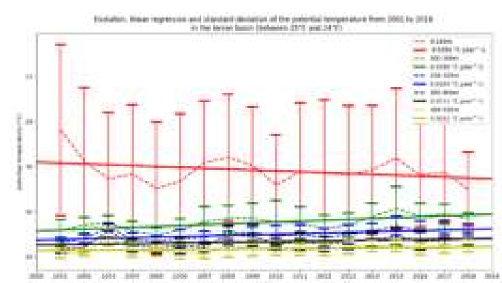


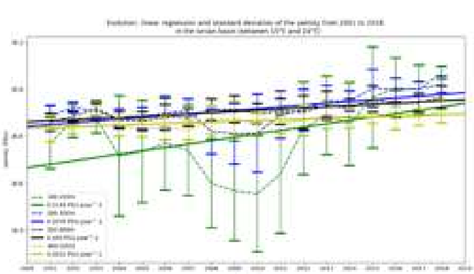
Ionian Basin

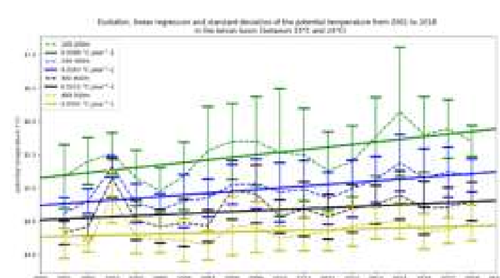












Ionian Basin