QUality Information Document
for
Med Physics reanalysis product:
MEDSEA_REANALYSIS_PHY_006_009

Issue: 1.2

Contributors: C.Fratianni, E.Clementi, S.Simoncelli

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CHANGE RECORD

When the quality of the products changes, the QuID is updated and a row is added to this table. The third column specifies which sections or sub-sections have been updated. The fourth column should mention the version of the product to which the change applies.

Issue	Date	§	Description of Change	Author	Validated By
1.0	26 January 2016	All	First version of the document at CMEMS V1	Claudia Fratianni	
1.1	04 April 2016	All	Second version of the document after V2 Acceptance Review	Claudia Fratianni	
1.2	11 January 2017	All	Third version of the document	Claudia Fratianni	

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I EXECUTIVE SUMMARY

I.1 Products covered by this document

This document describes the quality of the product MEDSEA_REANALYSIS_PHY_006_009, one of the two products for the reanalysis of the physical state of the Mediterranean Sea which includes 2D monthly fields of sea surface height and 3D monthly fields of temperature, salinity, meridional and zonal currents at 1/16° horizontal resolution and 72 vertical levels.

The aim of the MEDSEA_REANALYSIS_PHY_006_009 is to provide an integrated set of information coherent and consistent across space-time dimension, through an optimal melding of observations and appropriate space and time numerical model, covering the period 1955-2015.

I.2 Summary of the results

The quality of the MEDSEA_REANALYSIS_PHY_006_009 has been assessed for the entire 1955 to 2015 period by comparing results with available observations, consolidated climatological products and current knowledge of the ocean circulation.

The quality of the product change proportionally to the data availability, as showed in the assessment of ocean state variables (salinity, temperature and sea level anomaly), and the performance of the reanalysis increases with time, as the number of ocean observations increases. The assessment of the results suggests that the overall performance of the reanalysis is satisfactory: the ocean state is well constrained by data assimilation and the ocean physics appear well represented in many aspects.

The results are grouped by ocean state variables and summarized below:

- **Sea Surface Temperature (SST):** SST RMS and BIAS with respect to monthly satellite Hadley SST maps are presented as time series and as horizontal maps. RMS and BIAS present a seasonal signal and remain quite stable all over the years, oscillating respectively around 0.59°C and 0.22°C.
- **Temperature (T):** The temperature RMS and BIAS with respect to in-situ data assimilated by the system are presented as profiles averaged over the whole domain (up to 1000m) over the entire reanalysis period. RMS errors along the water column is on average 0.4°C with a peak at about 30m of depth (>0.9°C). Temperature BIAS exhibits a maximum positive value (~0.2°C) in the surface layer, while below 200 m the values are negative.
- **Salinity (S):** The salinity RMS and BIAS with respect of in-situ data assimilated by the system are presented as profiles averaged over the whole domain (up to 1000m) and over the entire time period. RMS errors along the water column is on average ~0.11 psu, with the maximum at

the surface (0.3psu), where the atmospheric and land forcing are crucial, and less than 0.1 psu below. Salinity BIAS is negative in the first 400 m of the water column and positive below 200m of depth.

- **Sea Level Anomaly (SLA):** the SLA RMS with respect to along track data assimilated oscillates from about 3 to 4.5 cm with a mean of ~3.7 cm, which is comparable with the RMS of observations.

I.3 Estimated Accuracy Numbers

The results for each variable assessed are presented in Table 1

Parameter	Metrics	Units	Decimal places
Sea Surface Temperature	MEAN BIAS	°C	0.22 ± 0.3
Sea Surface Temperature	MEAN RMS	°C	0.56 9± 0.16
Temperature	MEAN BIAS	°C	-0.02 ± 0.004
Temperature	MEAN RMS	°C	0.4 ± 0.02
Salinity	MEAN BIAS	PSU	0.01 ± 0.004
Salinity	MEAN RMS	PSU	0.11 ± 0.01
Sea Level Anomaly	MEAN BIAS	cm	-0.09 ± 0.02
Sea Level Anomaly	MEAN RMS	cm	3.76 ± 0.65

Table 1 Summary of MEDSEA_REANALYSIS_PHY_006_004 performance for different parameters over the entire time period (1987 - 2015).

II PRODUCTION SYSTEM DESCRIPTION

- Production Centre Name: Med-MFC
- Production subsystem Name: Med-MFC Currents Reanalysis
- Production unit: INGV

The MEDSEA_REANALYSIS_PHY_006_009 has been produced by Physics PU at INGV by combining, every day, the output of the ocean model, forced by atmospheric surface fluxes and relaxed to SST, and quality controlled ocean observations, through the data assimilation scheme.

II.1 Brief overview of V2 Mediterranean Sea Physical Reanalysis System (MED REA)

The Mediterranean Physical Reanalysis system relies on three main components:

1. **ocean model**: is a hydrodynamic model, supplied by Nucleous for European Modelling of the Ocean (NEMO);
2. **data assimilation scheme**: is a variational data assimilation scheme (OceanVar) for temperature and salinity profiles and satellite Sea Level Anomaly along track data;
3. **assimilated data**: are in-situ temperature and salinity profiles and Sea Level Anomaly along track.

II.1.1 Description of the circulation model system:

The OGCM used to produce the MEDSEA_REANALYSIS_PHY_006_009 are NEMO version 3.2 for the period 1955-2012 and NEMO version 3.4 for the update of the last three years (2013-2015). The two codes were used with the same settings. Some tests were done in order to align the two codes during a common period showing no evident differences. Moreover the validation task performed on the entire time series didn't show any change in the quality of the products due to the updating.

The model solves the primitive equations in spherical coordinated and has been implemented in the Mediterranean at 1/16°x1/16° horizontal resolution and 72 unevenly spaced vertical layers (*Oddo et al., 2009*). The model covers the Mediterranean Basin and also extends into the Atlantic in order to better resolve the exchanges with the Atlantic Ocean at the Strait of Gibraltar.

The NEMO model is nested in the Atlantic within the monthly mean climatological fields computed from ten years of daily output of the 1/4° x 1/4° degrees PSY3 global model provided by MERCATOR (*Drevillon et al., 2008*). Details on the nesting technique and major impacts on the model results are in *Oddo et al., 2009*. The model uses vertical partial cells to fit the bottom depth shape.

The model is forced by momentum, water and heat fluxes interactively computed by bulk formulae adapted to the Mediterranean case, using AMIP data (*Cherchi and Navarra, 2007*). AMIP data are available from 1900 and were created through a set of experiments performed with the ECHAM4 atmospheric AGCM on a T126 grid (1.125° of horizontal resolution) forced by HadISST and have a 12 hours temporal resolution. Heat flux is corrected proportionally to the difference between the model and observed SST (*Pinardi et al., 2003*), with a relaxation coefficient equal to -60 Wm-2 k-1, corresponding to about 2.5 day scale over a depth of 3m. The observed SST dataset consist of monthly SST provided by Met Office Hadley Centre (HadISST) on regular grid of 1° x 1° starting from 1870 (*Rayner et al., 2003*) and this choice is consistent with using AMIP atmospheric forcing which is also forced by HadISST.

Water balance is computed as Evaporation minus Precipitation and Runoff. The evaporation is derived from the latent heat flux while the precipitation and the runoff are provided by monthly mean dataset. Precipitation is taken from Climate Prediction Centre Merged Analysis of Precipitation (CMAP) data (*Xie and Arkin, 1997*). Runoff is provided by monthly mean datasets: the Global Runoff Data Centre dataset (*Fekete et al., 1999*) for the Ebro, Nile and Rhone and the dataset from Raicich (*Raicich, 1996*) for the Adriatic rivers (Po, Vjosë, Seman and Bojana). The Dardanelles inflow is parameterized as a river and the climatological net inflow rates are taken from *Kourafalou and Barbopoulos* (2003).

II.1.2 Description of data assimilation scheme:

The data assimilation system is the three-dimensional variation scheme called OceanVar, set up by *Dobricic and Pinardi* (2008), that allows to correct model fields for the dynamic variables. The vertical covariance matrixs are represented by 20 seasonally and regionally vertical EOFs of surface elevation and vertical profiles of temperature and salinity, estimated from the temporal variability of parameters in a historical model simulation (*Dobricic et al., 2005*). The MDT used for SLA data assimilation has been computed by *Dobricic et al., 2005*. In order to handle historical observations, which are normally given with regularly and finely sampling, a localization technique was implemented in OceanVar in order to decrease the correlation length scales in the background error covariance matrix.

The assimilation cycle is daily and both in-situ and satellite data are jointly assimilated to estimate the initial condition for numerical model.

II.1.3 Description of assimilated data:

The assimilated data consist of satellite SLA data and in-situ temperature and salinity profiles.

The SLA dataset used to produce MEDSEA_REANALYSIS_PHY_006_009 is a concatenation of:

- **SEALEVEL_MED_SLA_L3_REP_OBSERVATION_008_020** updated on October 2013 completing the time series till the end of 2012;
- **SEALEVEL_MED_SLA_L3_REP_OBSERVATION_008_020** updated at the latest version released on June 2016 completing the time series till the end of 2015;

The two dataset differ in terms of the temporal mean used to compute the sea surface heights, respectively seven-year mean and twenty-year mean. All the missions are homogenized with respect to a reference mission, which is currently Jason2. This product is computed with an optimal and centred computation time window (6 week before and after the date). The time coverage depends on the duration of the missions and starts from 1992.

The in situ temperature and salinity profiles considered for the MED REA production belong from different instrumental data type: CTDs, XBTs, MBTs, bottles, ARGO floats. In situ data sets have been collected from European Marine databases and have been archived in a specific format to be assimilated. They were downloaded from different sources: 1) SeaDataNet European infrastructure (DG-Research-FP6); 2) MEDAR-MEDATLAS dataset covering the period 1985-1999 (*Maillard et al. 2005*); 3) MFS (Mediterranean Forecasting System) operational observation infrastructure based on Enea and Coriolis data centers and 4) MyOcean In situ TAC. Potential duplicates were thus identified and excluded from successive usage and analysis. The decrease of the number of observations for the recent years due to a time lag between the sampling and the insertion of the data inside the SDN infrastructure is a common characteristic of historical databases. This required the use of MFS and MyOcean in situ TAC operational observations to integrate the SDN data set in the recent period. We intend for MFS operational observations, near real time (NRT) observations collected in the Mediterranean Sea within different precursor projects spanning a time period from 1999 to April 2009 when MyOcean Project started:

- MFSPP (Mediterranean ocean Forecasting System Pilot Project) 1998-2001 EU-MAST project MA 53-CT98-0171
- MFSTEP (Mediterranean ocean Forecasting System Towards Environmental Prediction) 2003-2005 DG-Research – FP5 EU Contract Number EVK3-CT-2002-00075.

The SST dataset are not assimilated but they are used to correct the surface heat flux by a relaxation of the numerical model surface layer temperature towards the observed SST. The observed SST dataset consist of monthly SST provided by Met Office Hadley Centre (HadISST) on regular grid of 1° x 1° starting from 1870 (*Rayner et al., 2003*).

Table 2 summarizes the atmospheric forcing and data assimilated in the reanalysis system.

DATA TYPE	EXTERNAL PRODUCTS
ATMOSPHERIC FORCING	AMIP
SLA	SEALEVEL_MED_SLA_L3_REP_OBSERVATIONS_008_020 SEALEVEL_MED_SLA_L3_NRT_OBSERVATIONS_008_019
ARGO	Coriolis and INSITU TAC dataset INSITU_MED_NRT_OBSERVATIONS_013_035 INSITU_GLO_NRT_OBSERVATIONS_013_030
XBT	MEDATLAS, MFS (Enea), INSITU-TAC dataset
CTD	SeaDataNet, MEDATLAS,MFS (Enea), INSITU-TAC dataset in-situ SeaDataNet product (FREE access temperature Salinity Observations) in-situ SeaDataNet product (RESTRICTED access temperature Salinity Observations) MEDAR MEDATLAS (Historical data)
SST	Met Office Hadley Centre SST dataset (HadSST1)

Table 2 Atmospheric forcing and data assimilated details.

The Mediterranean Sea Physical reanalysis has been initialized by a temperature and salinity monthly climatology (named SDN_V2aa) produced within the framework of SeaDataNet FP6 Project. It has been calculated utilizing the extensive historical in situ data set from 1900 to 1987. We considered only observations before 1987 to compute the initial condition because we did not want the climatology to be affected by the Eastern Mediterranean Transient (EMT). The EMT (*Roether et al. 1996*) is a large climatic event evolved between the late eighties and early nineties that showed for the first time the contribution of the Aegean Sea to the Eastern Mediterranean deep waters formation, in particular the Cretan Deep Water (CWD), which started to be formed in 1987, it reached its maximum rate (1Sv) in 1992-1993 and in 1996 decayed permanently. EMT changed consistently the water mass characteristics of the Mediterranean Basin thanks to the subsequent spread of saltier and warmer waters towards the Adriatc Sea and the Western basin (*Pinardi et al. 2015*). Mediterranean observations have been blended to the World Ocean Atlas climatology (WOA) in the Atlantic Box. The climatology has been computed with DIVA software tool (Data-Interpolating Variational Analysis, which allows to spatially interpolate observations onto a regular grid in an optimal way (modb.oce.ulg.ac.be/mediawiki/index.php/DIVA).

The Mediterranean Sea Physical reanalysis has been initialized on the 1st of January 1953 and run till the 31st of December 2015. The first to years are considered the period of model spin up.

III VALIDATION FRAMEWORK

The performance of the MEDSEA_REANALYSIS_PHY_006_009 has been evaluated for the period 1 January 1955 - 31 December 2015 considering a set of standardized metrics grouped by ocean state variables and applied in order to assess different aspect that can affect the quality of the products.

All confrontations were undertaken from an "in-situ point of view", where the observational dataset were kept on their original position and the corresponding model estimates are interpolated to the sensor position.

The EANs have been computed using the misfits (*Adani et al., 2011; Tonani et al., 2008*). The observation operator h is used to interpolate the model fields x^f to the location in time and space of the observations, y. This enables calculation of innovation or misfits:

$$m = [y - h(x^f)]$$

Misfits have been calculated before the data are inserted via data assimilation and the data can be considered as independent since the data are mostly sparse in space and time. The deviations between the datasets are quantified in terms of RMSE and BIAS, where RMSE provides estimates of the model precision while the BIAS indicates possible systematically errors in the model reanalysis, assuming that the observational dataset is correct. The RMSE and BIAS from temperature and salinity misfits are presented as monthly mean time series over 5 layers: L1) 0-30m; L2) 30-150m; L3) 150-300m; L4) 300-600m; L5) 600-1000m and as mean profile computed over the entire domain and the entire time period. A deeper layer 1000-3000m has not been considered because scares data availability in time and space below 1000m that does not provide enough statistical significance.

IV VALIDATION RESULTS

IV.1 SST

Table 3 summarizes the metrics and the observations used in the assessment of Sea Surface Temperature.

Name	**Reference dataset**	**Quantity**
SST-CLASS1-MEAN	Monthly satellite estimates from Met Office Hadley Centre SST dataset (HadSST1)	Maps of long-term annual mean from reanalysis product and reference dataset and differences between reference dataset and reanalysis product
SST-CLASS4-RMS-MONTHLY	Monthly satellite estimates from Met Office Hadley Centre SST dataset (HadSST1)	Time series of RMS of reference dataset minus reanalysis product on daily basis
SST-CLASS4-BIAS-MONTHLY	Monthly satellite estimates from Met Office Hadley Centre SST dataset (HadSST1)	Time series of BIAS of reference dataset minus reanalysis product on daily basis
SST-CLASS1-RMS	Monthly satellite estimates from Met Office Hadley Centre SST dataset (HadSST1)	Maps of annual mean RMS of reference dataset minus reanalysis product on monthly basis
SST-CLASS1-BIAS	Monthly satellite estimates from Met Office Hadley Centre SST dataset (HadSST1)	Maps of annual mean BIAS of reference dataset minus reanalysis product on monthly basis
SST-CLASS3-2DMEAN	Monthly satellite estimates from Met Office Hadley Centre SST dataset (HadSST1)	Time series of domain averaged monthly SST computed from reanalysis product and reference dataset
QNET-CLASS3-2DMEAN	QNET as computed from *Pettenuzzo et al., 2010*	Time series of domain averaged monthly surface heat flux computed from reanalysis product

Table 3 Metrics and observations used to assess the SST

Figure 1 (**SST-CLASS1-MEAN**) shows the SST comparison between annual mean computed from reanalysis product and from satellite observations and their differences. The spatial pattern of satellite observation is well reproduced by the reanalysis product and the major differences are located in the areas where the atmospheric forcing, topography and upwelling processes play a crucial role, such as in the Northern Adriatic Sea, Aegean Sea and along the southern coast of Sicily.

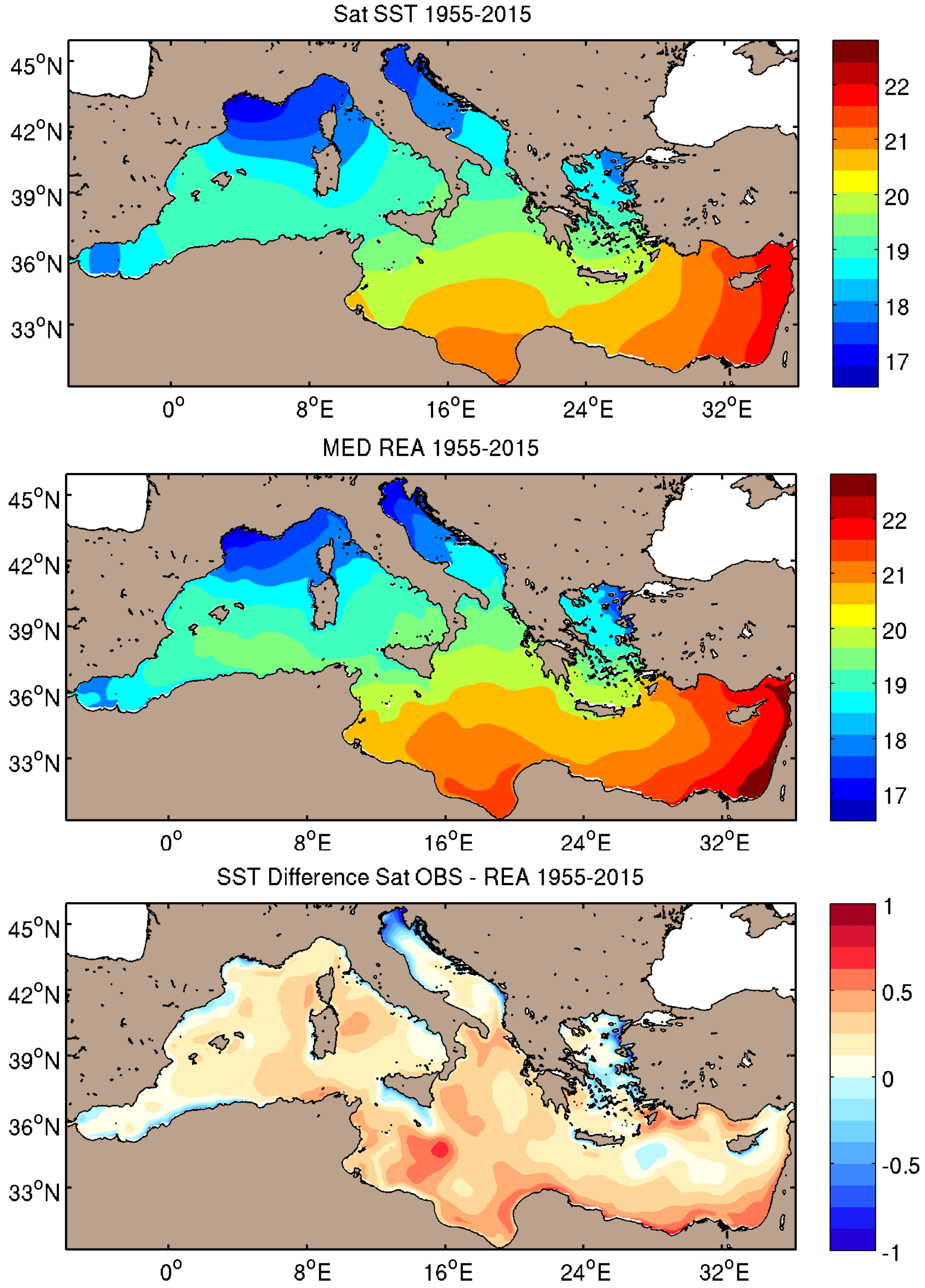


Figure 1 SST-CLASS1-MEAN Maps of long term annual mean from Satellite SST (upper panel), reanalysis product (middle panel) and differences (bottom panel).

Figure 2 (**SST-CLASS4-RMS-MONTHLY** and **SST-CLASS4-BIAS-MONTHLY**) shows SST RMSE and BIAS of the differences between reanalysis product and satellite observations computed from monthly estimates over the period 1955-2015. Both the statistics present a seasonal signal, with error increase during summer period, in which the system shows a warm bias, and are quite well stable all over the years. RMSE oscillates between ~0.3°C and 1.3°C around its average of 0.59°C. BIAS is positive during summertime and negative during wintertime and oscillates between -0.5°C and 1°C around its average of 0.22°C.

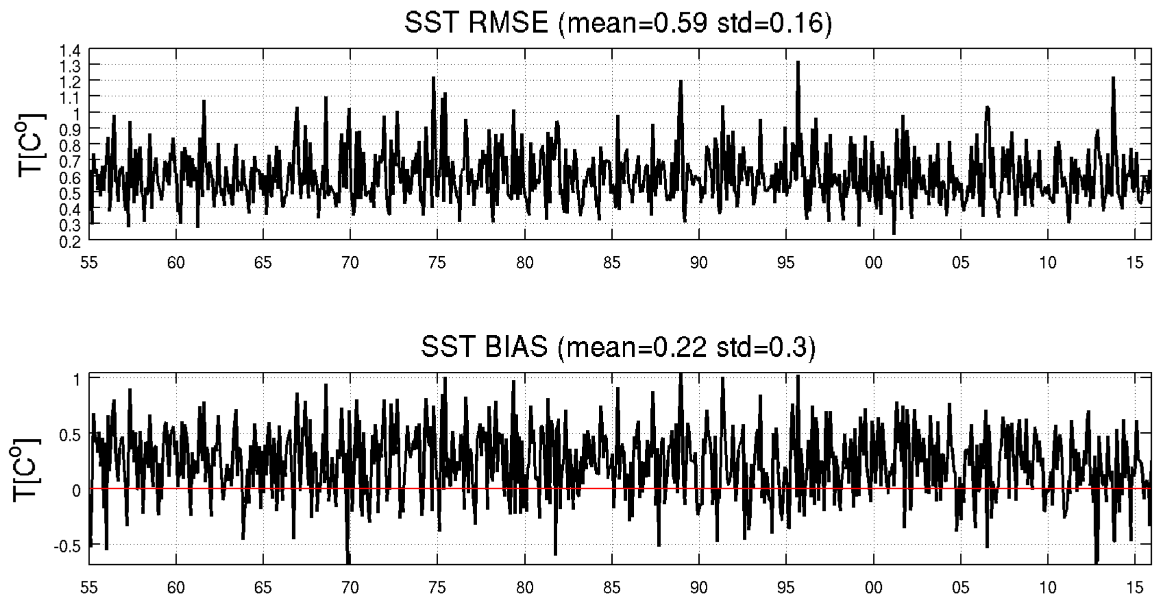


Figure 2 SST-CLASS4-RMS-MONTHLY (upper panel) and SST-CLASS4-BIAS-MONTHLY (bottom panel) computed from reanalysis product and satellite observations on monthly basis.

Figure 3 (**SST-CLASS1-RMS and SST-CLASS1-BIAS**) shows SST RMS and BIAS maps computed over the whole time period 195-2015. The horizontal maps highlight the areas where the major model deficiencies are located, the shallow water areas. Negative BIAS and large positive RMS values appear in the upwelling areas of the Mediterranean Sea, such as Eastern Adriatic Sea and Southern Sicily, and in the Northern Adriatic Sea and Aegean Sea.

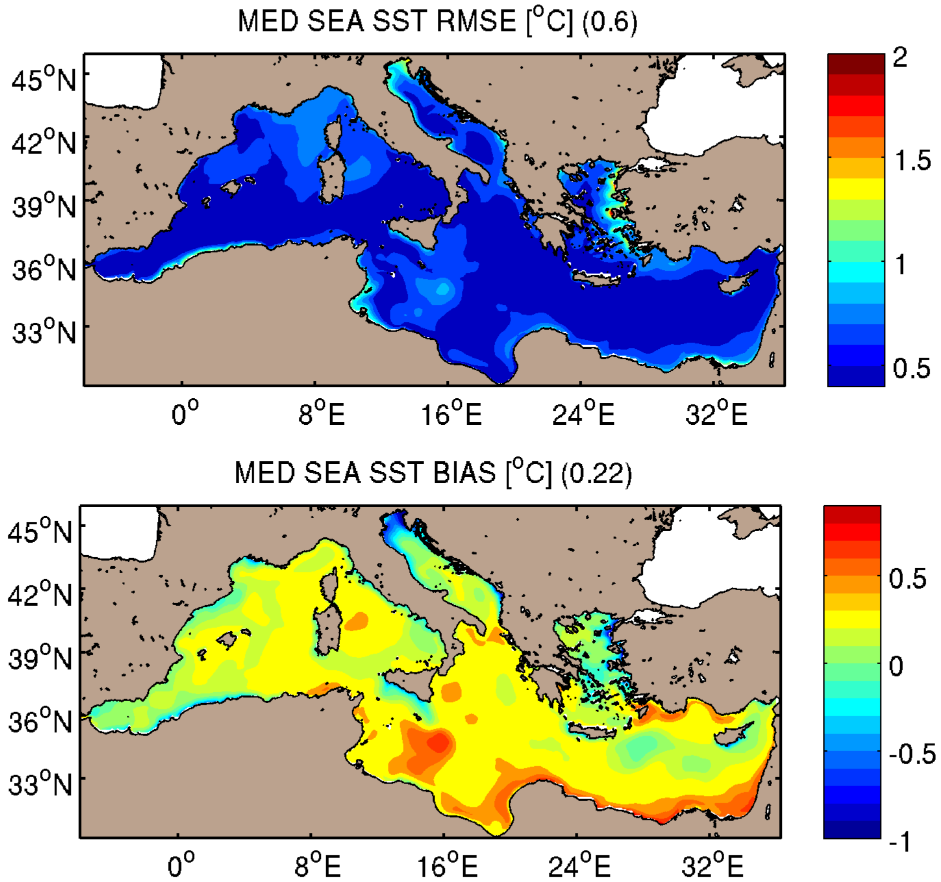


Figure 3 SST-CLASS1-RMS (upper panel) and SST-CLASS1-BIAS (bottom panel) maps computed from reanalysis product and satellite observations on monthly basis over the entire 1955-2015.

SST-CLASS3-2DMEAN) shows the time series of domain averaged monthly SST computed from reanalysis product and from satellite observations over the whole period. The multiyear mean for the reanalysis product is 20.1°C, while for the observations is 20°C.

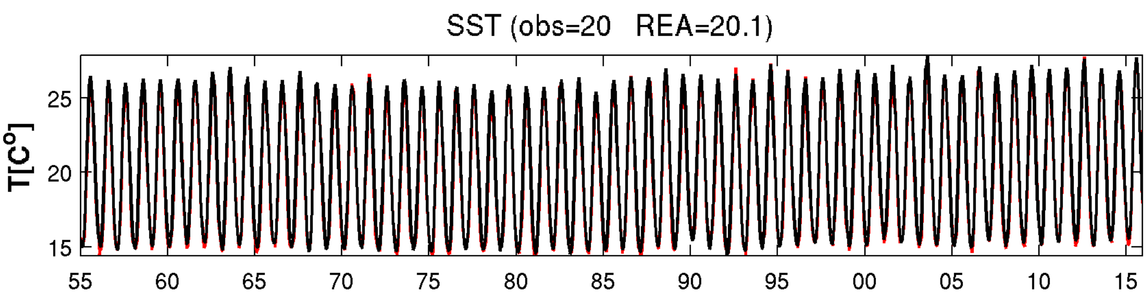


Figure 4 SST-CLASS3-2DMEAN Domain averaged monthly SST computed from reanalysis product (black line) and from satellite observations (redline).

Figure 5 (**QNET-CLASS3-2DMEAN**) shows the multiyear monthly mean net heat flux. The net heat budget is equal to 0 W/m^2 slightly higher than the negative literature values -6±3 W/m^2 (*Pettenuzzo et al., 2010*).

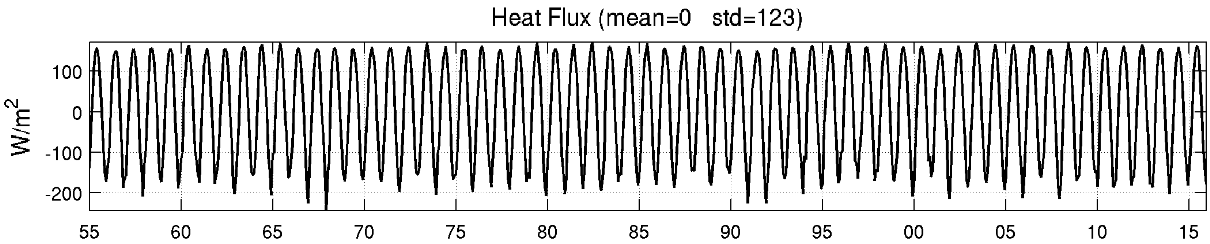


Figure 5 QNET-CLASS3-2DMEAN Domain averaged surface net heat flux computed from reanalysis product.

IV.2 Temperature

summarizes the metrics and the observations used in the assessment of Temperature.

Name	Reference dataset	Quantity
T-CLASS1-MEAN-DEPTHS	Targeted monthly mean gridded climatology from SDN	Maps of long-term annual mean from reanalysis product and reference dataset and differences at different depths
T-CLASS3-BIAS	Targeted monthly mean gridded climatology from SDN	Monthly climatology and monthly basin averaged profiles comparison against reference dataset
T-CLASS3-LAYERS	None	Time series of temperature computed from reanalysis product at different layers
T-CLASS3-IC-CHANGE	Targeted monthly mean gridded climatology from SDN	Water column differences between monthly basin averaged reanalysis temperature profiles and the IC
T-CLASS4-RMS-LAYERS	Coriolis and INSITU TAC dataset INSITU_MED_NRT_OBSERVATIONS_013_035 INSITU_GLO_NRT_OBSERVATIONS_013_030 MEDAR-MEDATLAS MFS and Insitu SDN products	Time series of RMS computed from misfits in different layers
T-CLASS4-BIAS-LAYERS	Coriolis and INSITU TAC dataset INSITU_MED_NRT_OBSERVATIONS_013_035 INSITU_GLO_NRT_OBSERVATIONS_013_030 MEDAR-MEDATLAS MFS and Insitu SDN products	Time series of BIAS computed from misfits in different layers
T-CLASS4-RMS-DEPTH	Coriolis and INSITU TAC dataset INSITU_MED_NRT_OBSERVATIONS_013_035 INSITU_GLO_NRT_OBSERVATIONS_013_030 MEDAR-MEDATLAS MFS and Insitu SDN products	Mean RMS profiles
T-CLASS4-BIAS-DEPTH	Coriolis and INSITU TAC dataset INSITU_MED_NRT_OBSERVATIONS_013_035 INSITU_GLO_NRT_OBSERVATIONS_013_030 MEDAR-MEDATLAS MFS and Insitu SDN products	Mean BIAS profiles

Table 4 Metrics and observations used to assess the Temperature.

Figure 6 - Figure 9 (**T-CLASS1-MEAN-DEPTHS)** show the temperature annual mean computed for different depths (15-100-350-1000m) from the SDN climatology, reanalysis products and their differences. SDN climatology was computed considering observations from 1900 to 2009 and applying a 2°C of correlation length in the mapping procedure.

At 15 m of depth (Figure 6), the major positive differences (~3°C) are located in the proximity to the Po river plume in the Northern Adriatic Basin where the reanalysis appears warmer than the climatology. This is due to the absence of the signal of the Po river in the climatology dataset.

The major negative differences are located instead in the areas where upwelling events occur, such as South West of Sicily and West of Sardinia, and along the coasts of Algeria.

At 100m of depth (Figure 7), the largest negative differences are related to some circulation features (see Iera-Petra gyre) and positive differences appear in correspondence of the areas where the main currents form (*Pinardi et al., 2015*): along coast of Algeria (Algerian Current), Tunisia (Sicily Strait Tunisian Current) and Turkey (Asia Minor Current).

At 350m of depth (Figure 8), negative differences are located in the central part of the Levantine basin, while the largest positive differences are located in particular along the northern coasts of the same basin.

At 1000m of depth (Figure 9), maximum negative differences are located in the Southern Tyrrhenian basin and along the Ionian coast of Greece, while positive differences are concentrated in the Southern Adriatic sea.

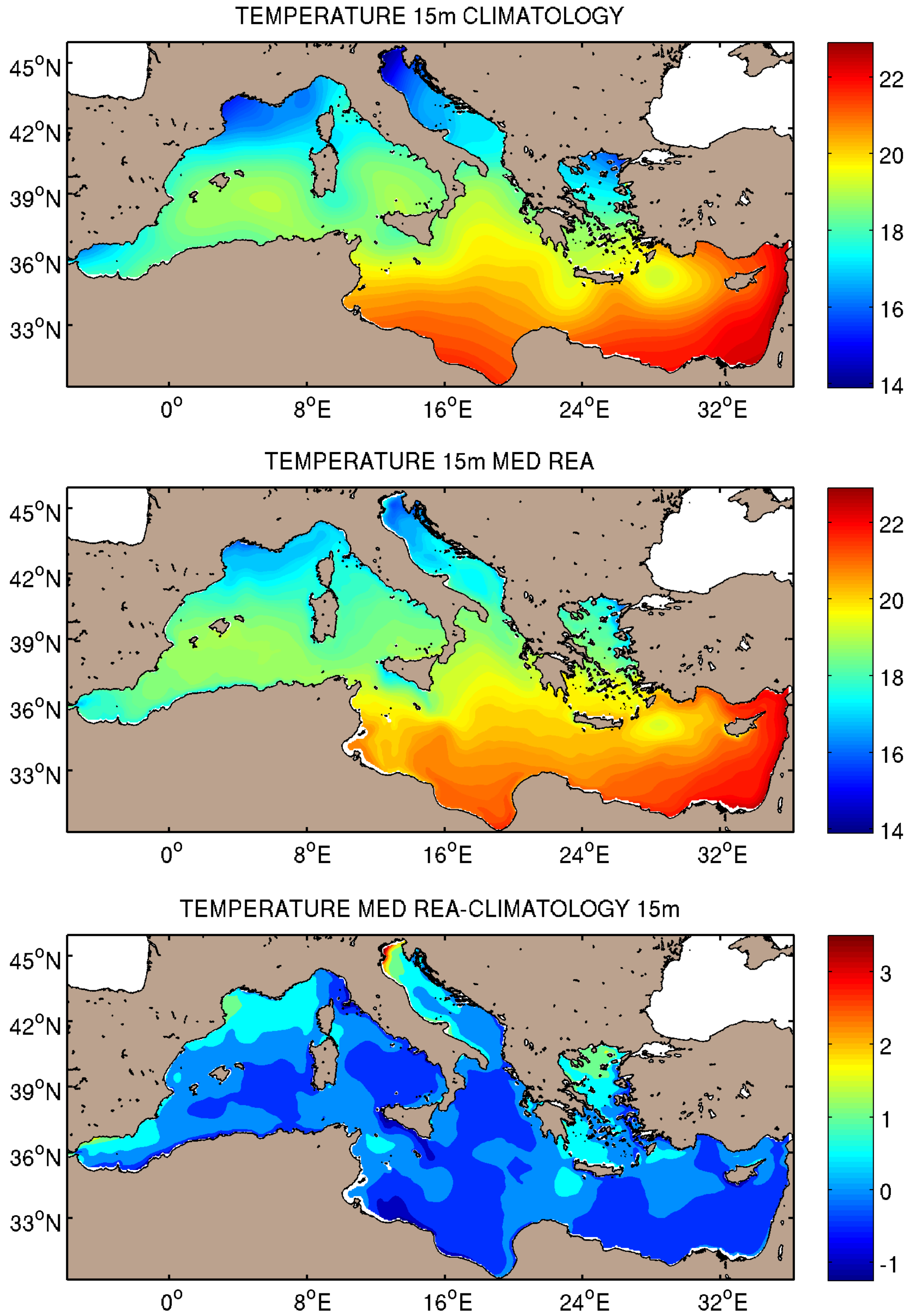


Figure 6 T-CLASS1-MEAN-DEPTHS Annual mean maps of temperature at 15m of depth computed from SDN climatology (upper panel), reanalysis product (middle panel) and differences (bottom panel).

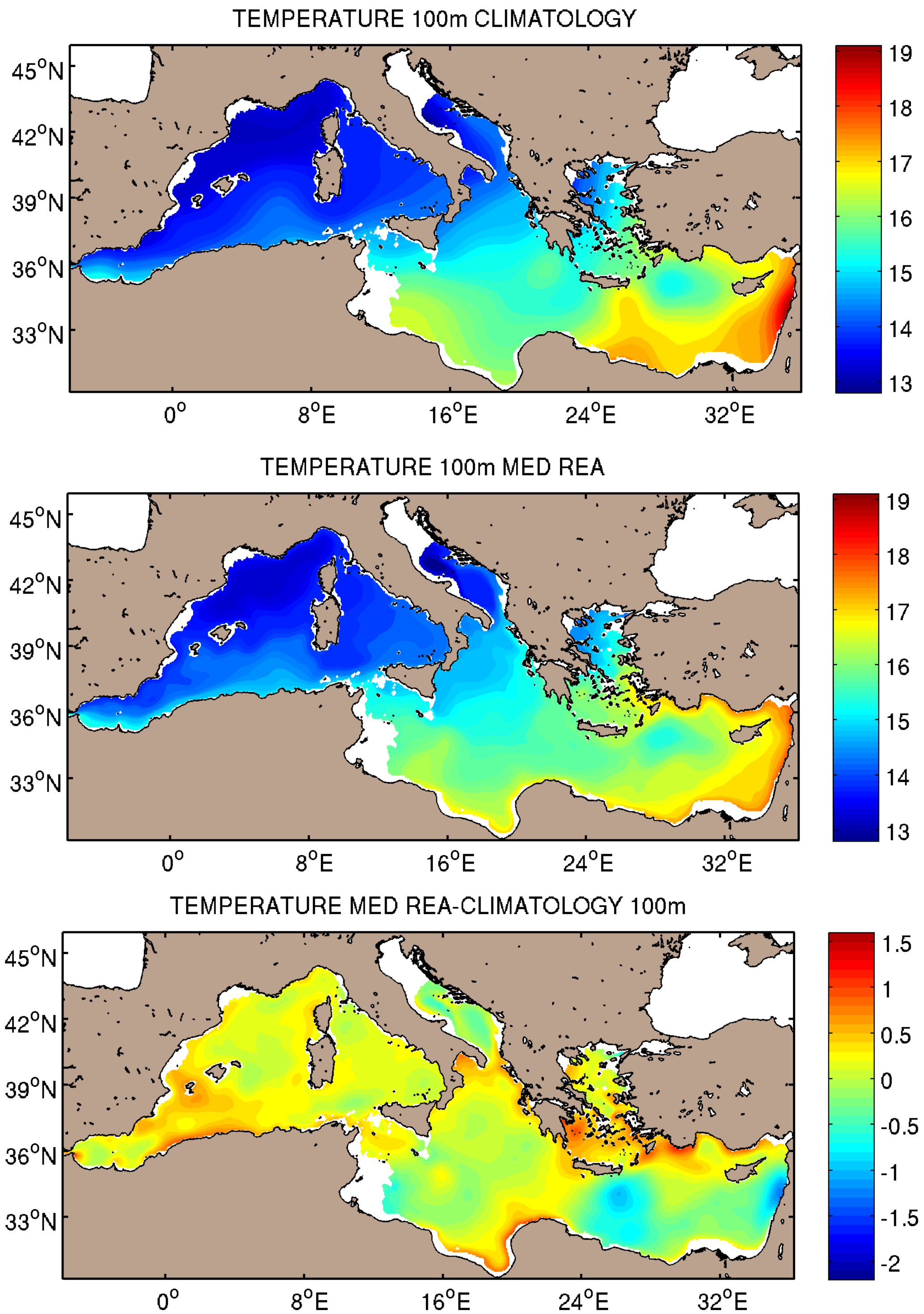


Figure 7 T-CLASS1-MEAN-DEPTHS Annual mean maps of temperature at 100m of depth computed from SDN climatology (upper panel), reanalysis product (middle panel) and differences (bottom panel).

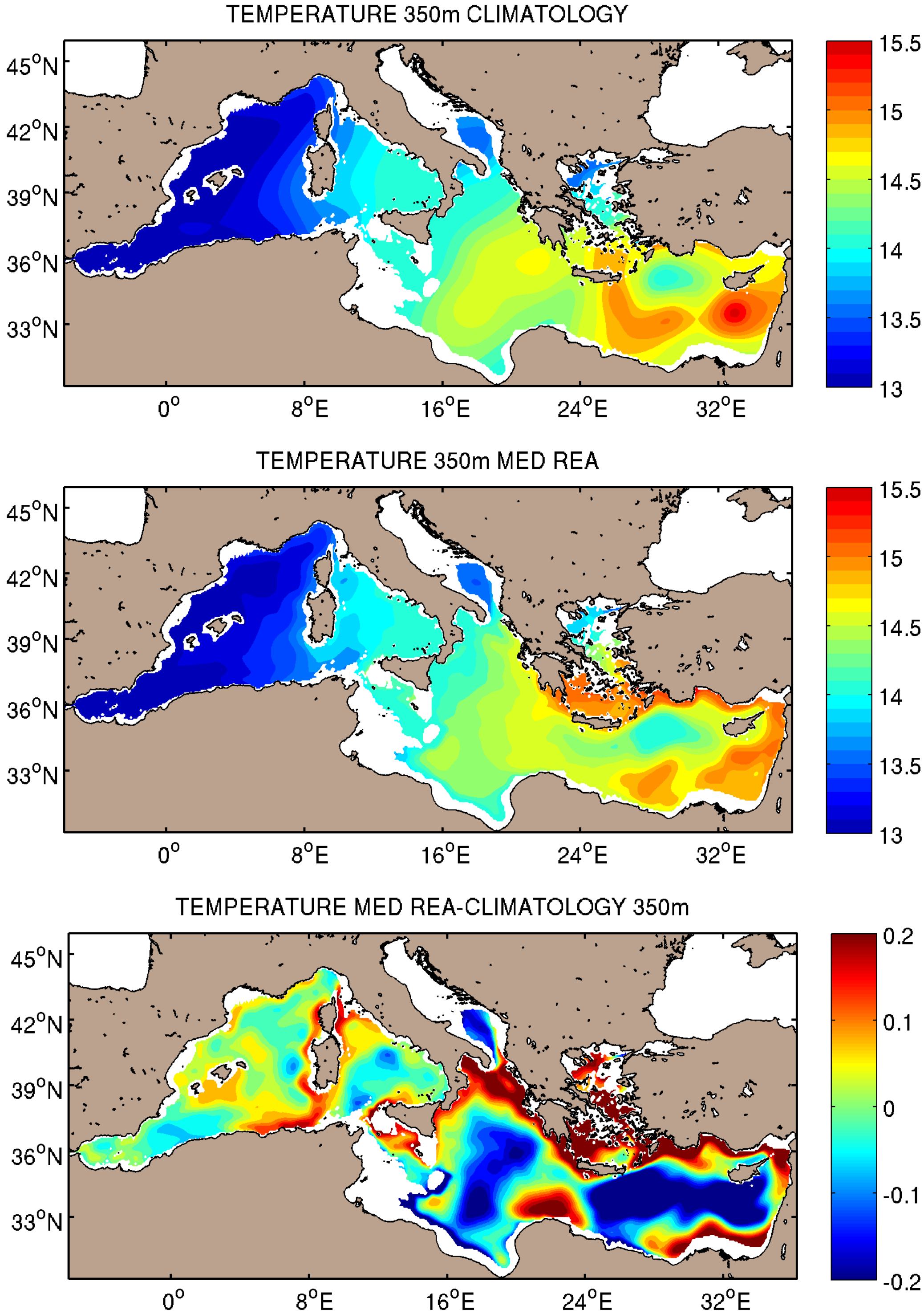


Figure 8 T-CLASS1-MEAN-DEPTHS Annual mean maps of temperature at 350m of depth computed from SDN climatology (upper panel), reanalysis product (middle panel) and differences (bottom panel).

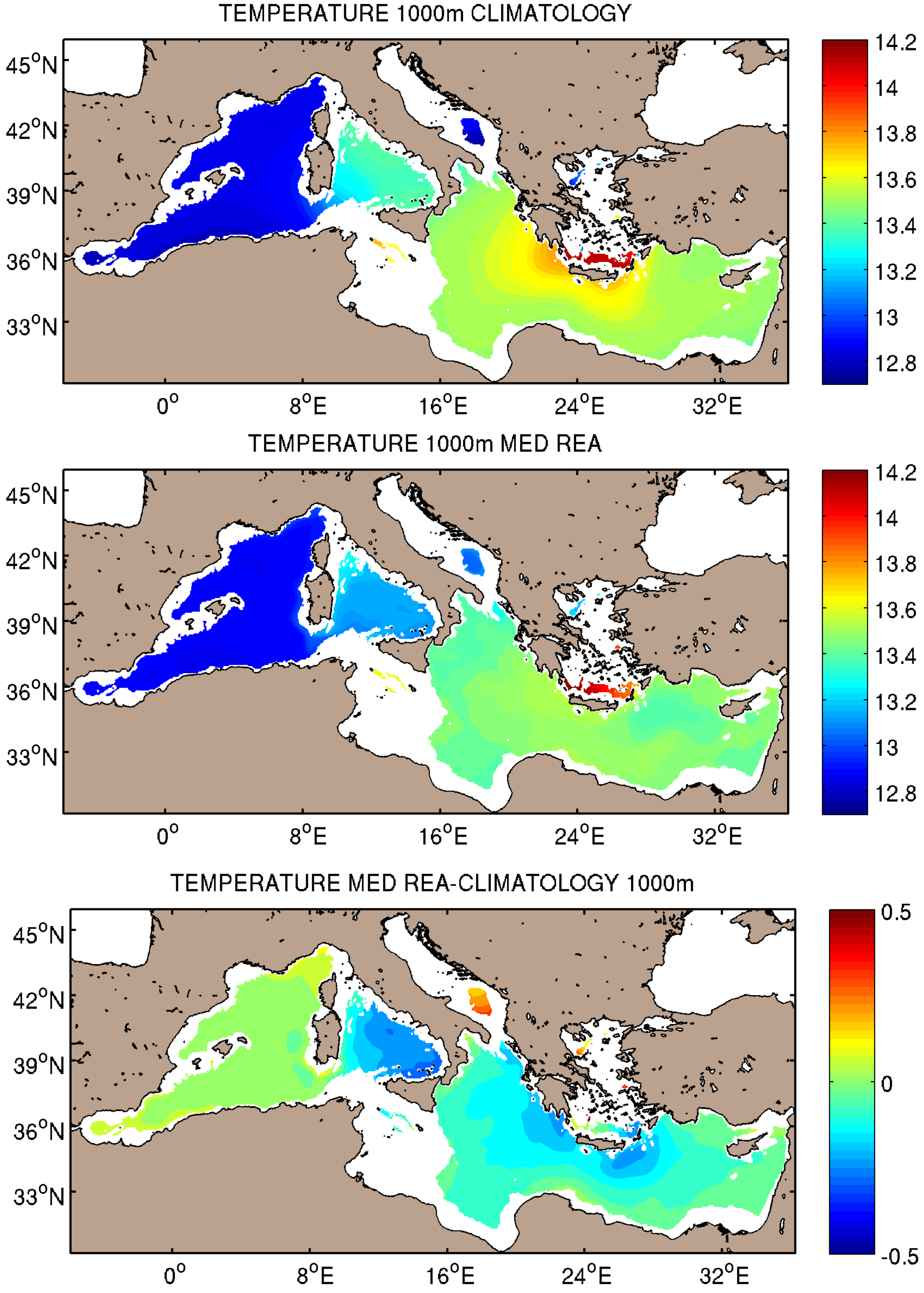


Figure 9 T-CLASS1-MEAN-DEPTHS Annual mean maps of temperature at 1000m of depth computed from SDN climatology (upper panel), reanalysis product (middle panel) and differences (bottom panel).

Figure 10 shows the temperature monthly climatology and monthly basin averaged profiles comparison against the SDN climatology as a function of depth, up to 1000m. Starting from the surface, and considering the differences as monthly climatology (upper panel), from May to September, reanalysis product is warmer (~0.3 °- 0.8°C) than the SDN climatology within the first 15 m of depth, while is colder (~0.1°-0.2°C) between 15-50m of depth. From September to December, the major positive differences, indicating that the reanalysis is warmer than the SDN climatology, are located between 20-50m of depth. Positive differences (~0.2°C) are present also during January to March months around 120m.

The differences between reanalysis and SDN climatology as monthly basin averaged profiles highlight the interannual variability (Figure 10 bottom panel): starting from the mid nineties years, it is evident a positive anomalies extension in the temperature reanalysis product from surface up to 200m of depth with some peaks within the first 20m during summer of years 2003 (~2°C) and 2012 (1.5°C), while below 200m of depth a negative anomaly (~0.5°C) is present between 1995 and 2005.

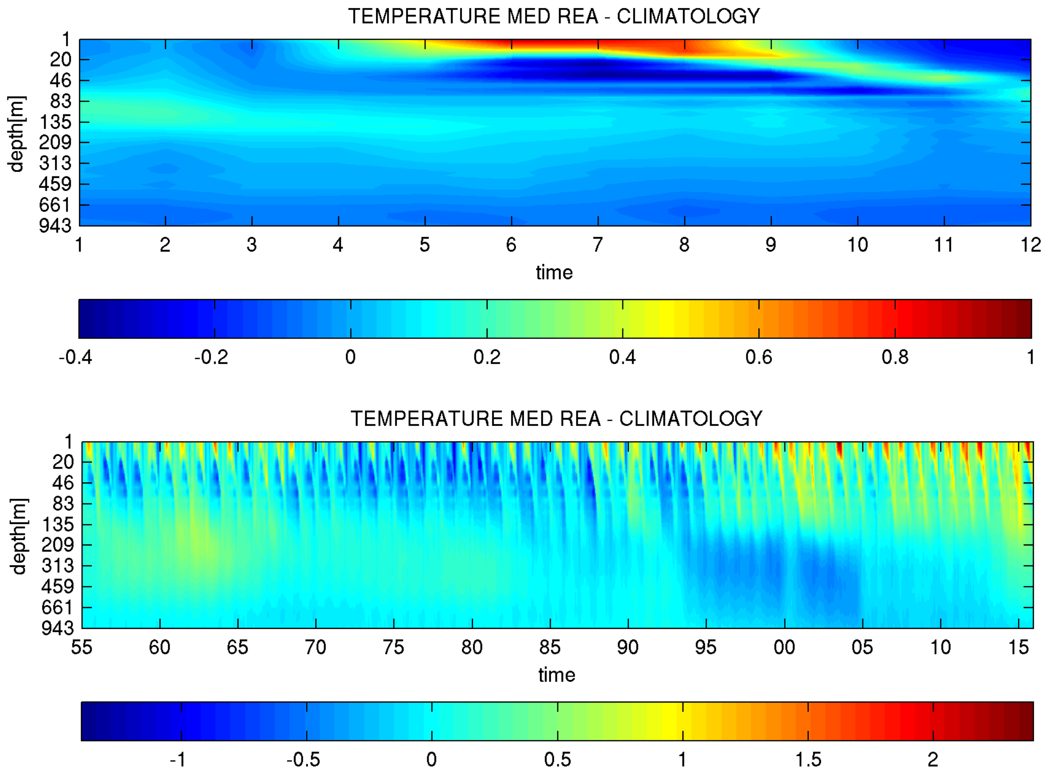


Figure 10 T-CLASS3-BIAS Monthly climatology (upper panel) and monthly basin averaged profiles (bottom panel) comparison between reanalysis product and SDN climatology.

Figure 11 (**T-CLASS3-LAYER**) shows the time series of temperature in different layers over the Mediterranean Sea. The first layer (0-30m) presents a clear seasonal signal with the highest values during summertime (~26°C) and lowest values during wintertime (~15°C). This layer is highly influenced by the atmospheric forcing and is where the seasonal thermocline evolves.

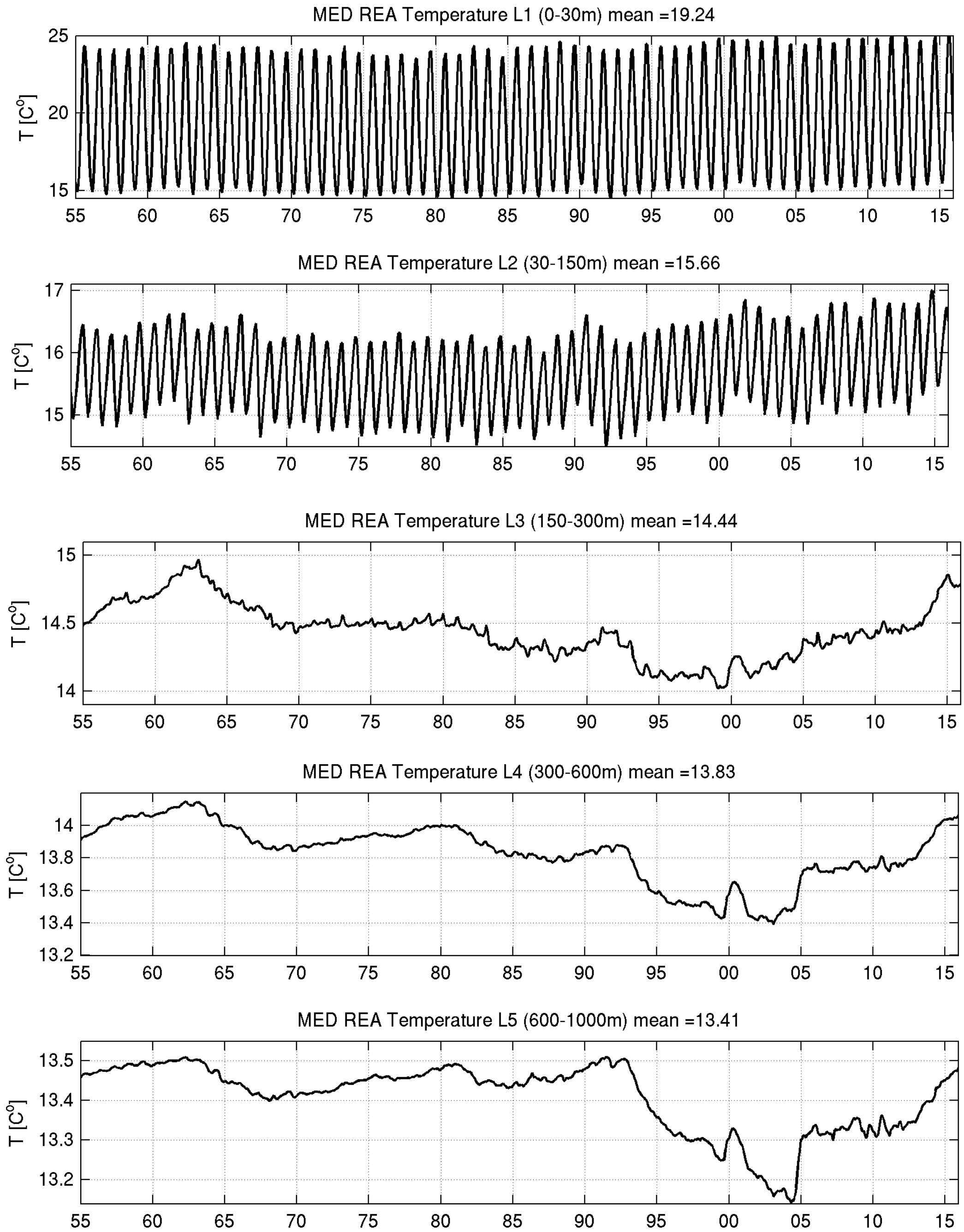


Figure 11 T-CLASS3-LAYERS Domain average temperature monthly mean computed from reanalysis product.

The seasonal signal is also evident in the change of temperature with respect to initial condition (**T-CLASS3-IC-CHANGE**), as shown in Figure 12.

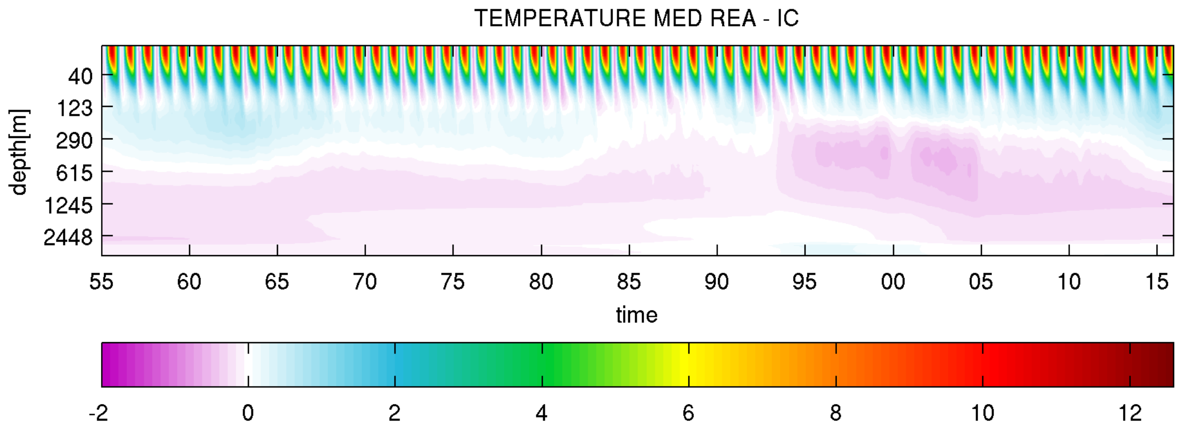


Figure 12 TCLASS3-IC-CHANGE Domain average temperature change with respect to initial condition.

Figure 13 - Figure 14 (**T-CLASS4-RMS-LAYERS and T-CLASS4-BIAS-LAYERS**) present the RMS and BIAS computed in different layers at observation space-time location.

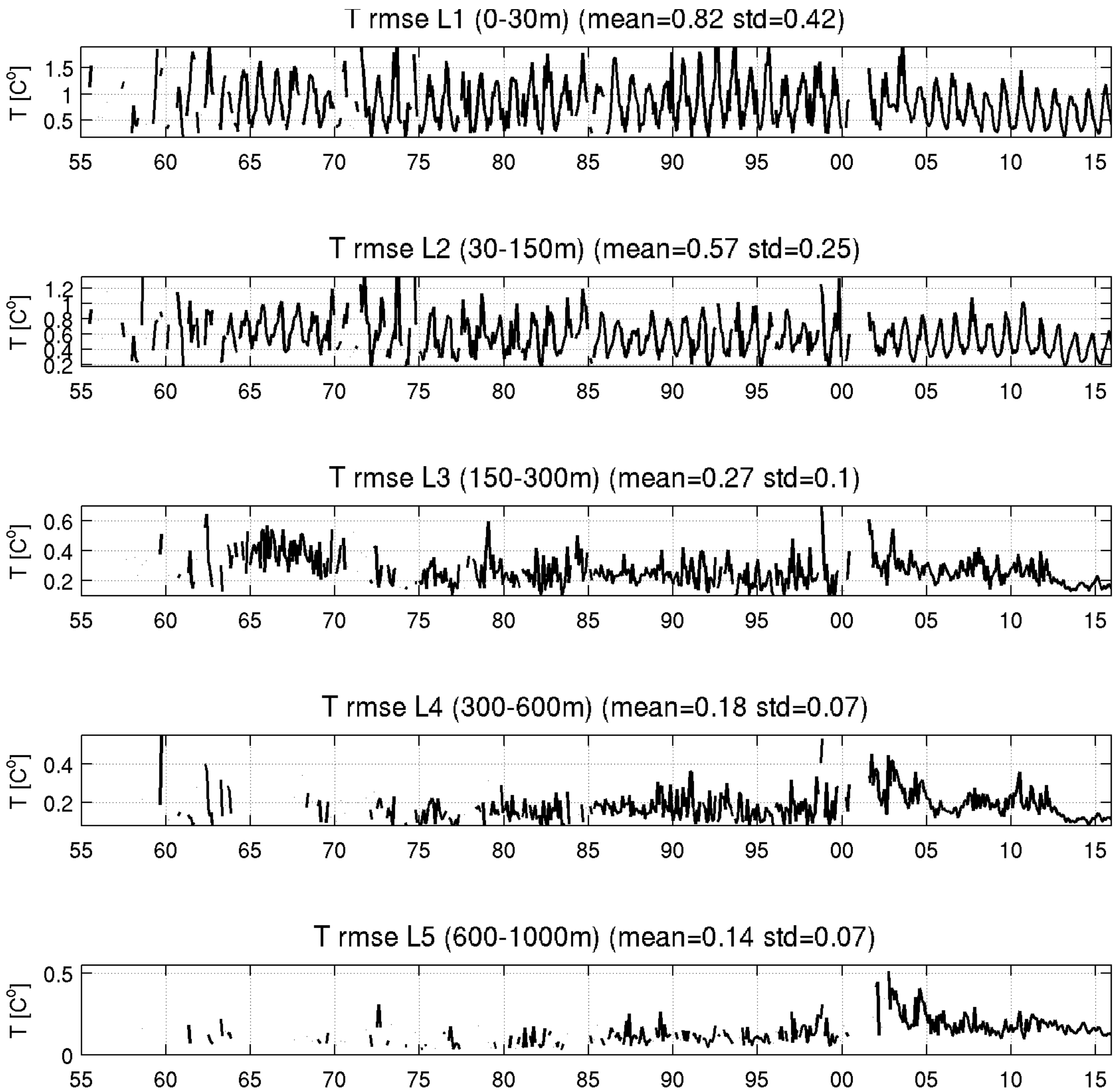


Figure 13 T-CLASS4-RMS-LAYERS RMSE computed from misfits of reanalysis product in different layers.

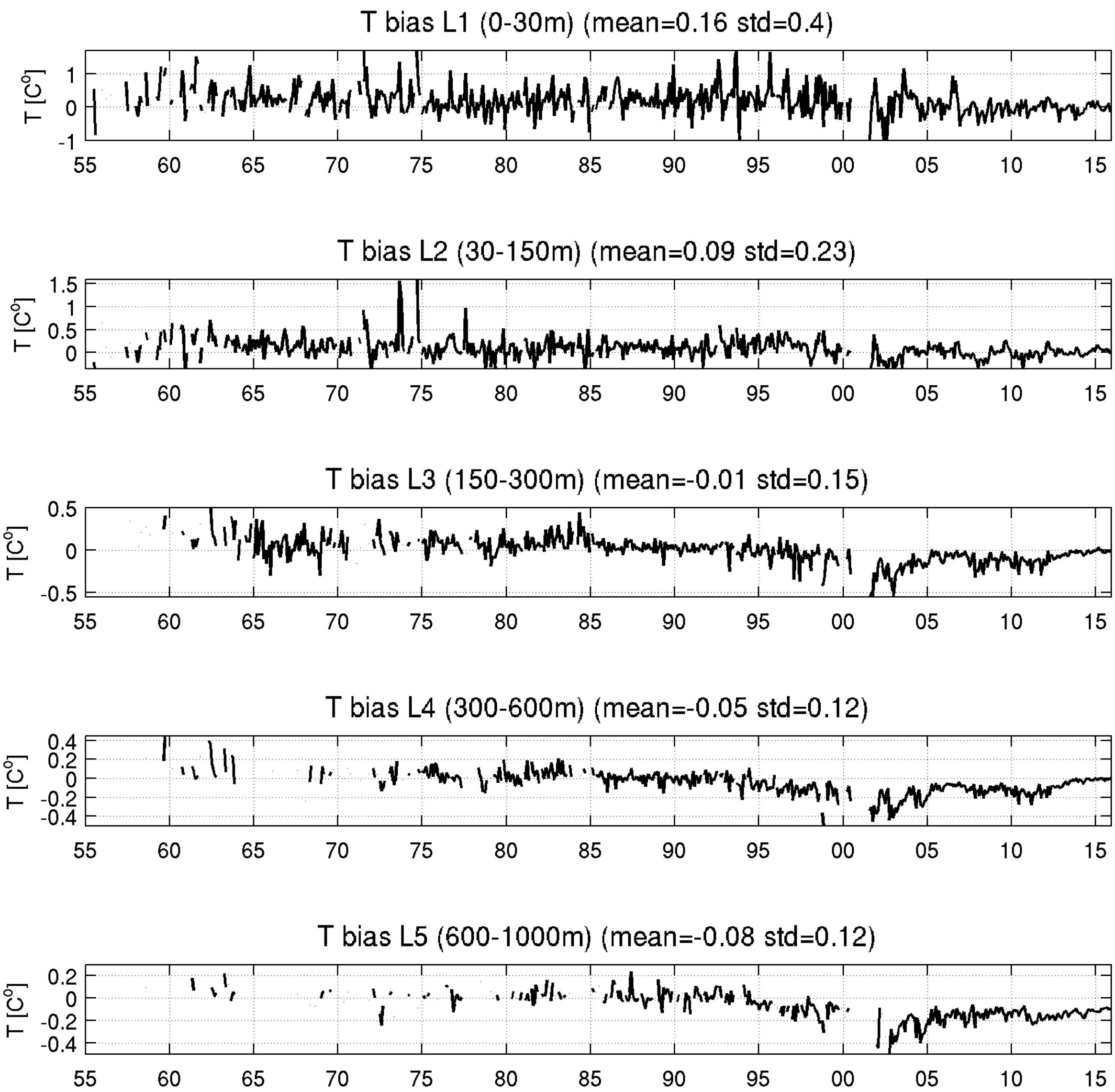


Figure 14 T-CLASS4-BIAS-LAYERS BIAS computed from misfits of reanalysis product in different layers.

Figure 15 (**T-CLASS4-RMS-DEPTH**) displays temperature BIAS (left) and RMSE (middle) profiles averaged up to 1000m over the entire reanalysis period. Skill scores below 1000m are not shown due to data sparseness. BIAS exhibits maximum positive values (~0.2°C) at the surface, while below 200m of depth the BIAS is negative. RMSE peaks at about 30m of depth (>0.8°C). The water column averaged BIAS is equal to 0.02 and RMSE is equal to 0.4°C.

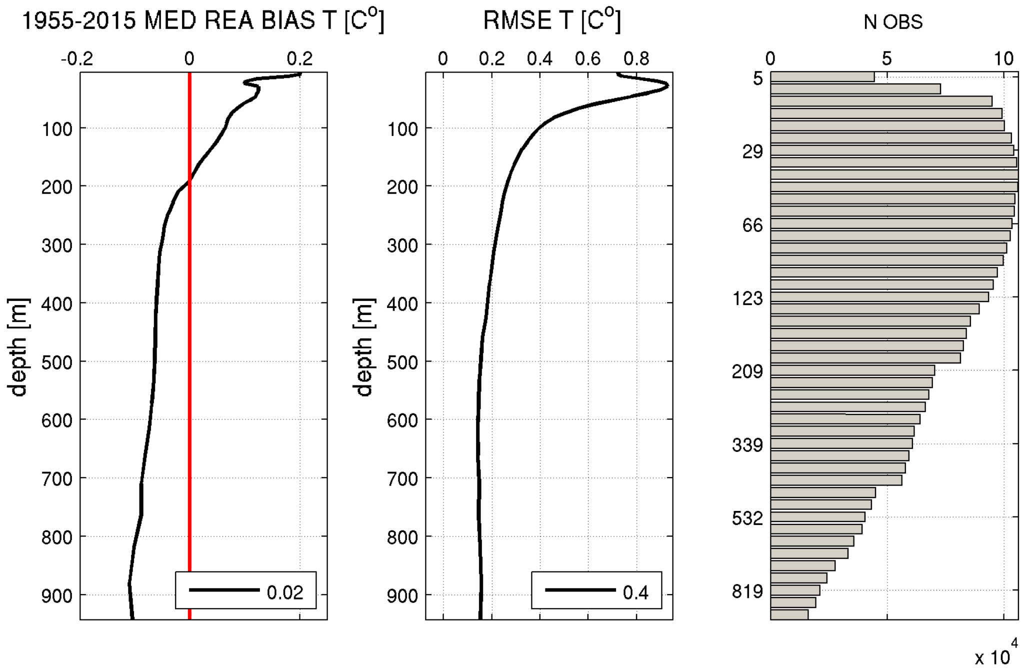


Figure 15 T-CLASS4-RMS-DEPTH and T-CLASS4-BIAS-DEPTH computed from reanalysis misfits.

The total EANs, BIAS and RMS for temperature are included in Table 1

TEMPERATURE [°C]	BIAS	RMS
0 -30 m	0.16 ± 0.4	0.82 ± 0.42
30 -150 m	0.09 ± 0.23	0.57 ± 0.25
150 - 300 m	-0.01 ± 0.15	0.27 ± 0.1
300 - 600m	0.05 ± 0.12	0.18 ± 0.07
600 -1000m	-0.08 ± 0.2	0.14 ± 0.07
Total	-0.02 ± 0.004	0.4 ± 0.02

Table 5 EANs for temperature at different layers depths.

IV.3 Sea Surface Salinity

Table 6 summarizes the metrics and the observations used in the assessment of Sea Surface Salinity.

Name	**Reference dataset**	**Quantity**
SSS-CLASS3-2DMEAN	None	Averaged monthly mean over the Mediterranean Sea
SFW-CLASS3-2DMEAN	SFW from from Pettenuzzo, D., Large, W.G., & Pinardi, N. (2010); Mariotti et al., 2010.	Mediterranean Sea averaged monthly fresh water flux

Table 6 Metrics and observations used to assess the Sea Surface Salinity.

Figure 16 SSS-CLASS3-2DMEAN Averaged monthly mean of SSS.(**SSS-CLASS3-2DMEAN**) shows the domain averaged monthly sea surface salinity temporal evolution. The SSS has a multiyear average of 38.13psu and oscillates around 38.1psu up to 2005 when it increases. The net water flux (**SFW-CLASS3-2DMEAN**) Figure 17 for the same period does not evidence any abrupt change and its average is equal to 484 mm/yr. Climatological river runoff is 185mm/yr, thus E-P is 669 mm/yr, in agreement with the literature (*Mariotti et al.,2010; Pettenuzzo et al., 2010*). The reason for the increase of surface salinity cannot be due to the water budget change and could be addressed to the ARGO advent, which started to provide systematic measurements in the Mediterranean Sea since 2005.

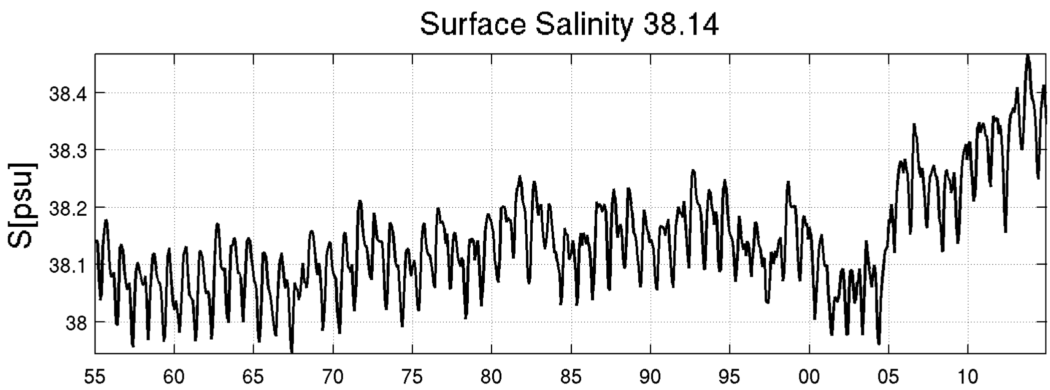


Figure 16 SSS-CLASS3-2DMEAN Averaged monthly mean of SSS.

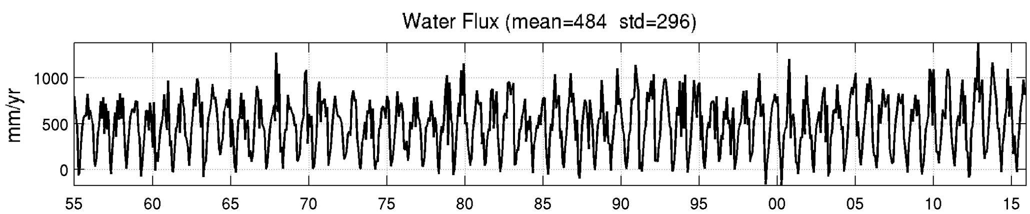


Figure 17 SFW-CLASS3-2DMEAN Averaged monthly fresh water flux.

IV.4 Salinity

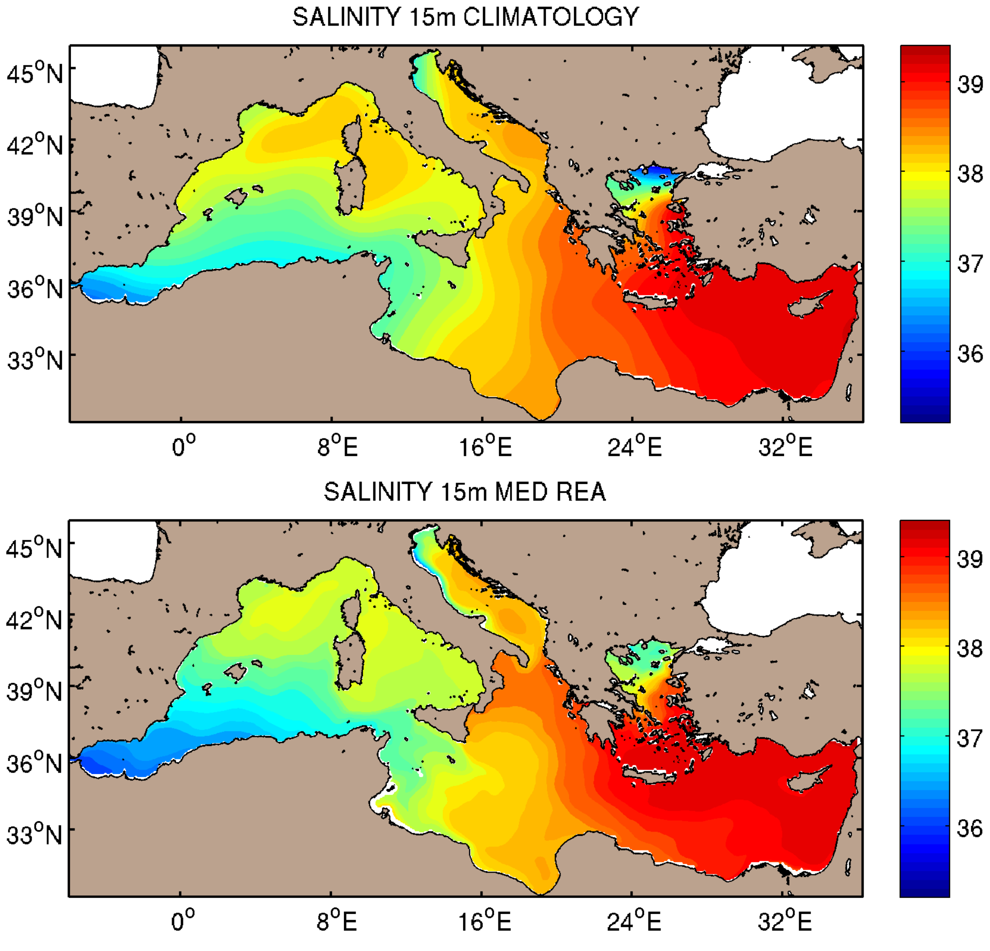
Table 7 summarizes the metrics and the observations used in the assessment of Salinity.

Name	Reference dataset	Quantity
S-CLASS1-MEAN-DEPTHS	Targeted monthly mean gridded climatology from SDN	Maps of long-term annual mean from reanalysis product and reference dataset and differences at different depths
S-CLASS3-BIAS	Targeted monthly mean gridded climatology from SDN	Monthly climatology and monthly basin averaged profiles comparison against reference dataset
S-CLASS3-LAYERS	None	Time series of salinity computed from reanalysis product at different layers
S-CLASS3-IC-CHANGE	Targeted monthly mean gridded climatology from SDN	Water column differences between monthly basin averaged reanalysis salinity profiles and the IC
S-CLASS4-RMS-LAYERS	Coriolis and INSITU TAC dataset INSITU_MED_NRT_OBSERVATIONS_013_035 INSITU_GLO_NRT_OBSERVATIONS_013_030 MEDAR-MEDATLAS MFS and Insitu SDN products	Time series of RMS computed from misfits in different layers
S-CLASS4-BIAS-LAYERS	Coriolis and INSITU TAC dataset INSITU_MED_NRT_OBSERVATIONS_013_035 INSITU_GLO_NRT_OBSERVATIONS_013_030 MEDAR-MEDATLAS MFS and Insitu SDN products	Time series of BIAS computed from misfits in different layers
S-CLASS4-RMS-DEPTH	Coriolis and INSITU TAC dataset INSITU_MED_NRT_OBSERVATIONS_013_035 INSITU_GLO_NRT_OBSERVATIONS_013_030 MEDAR-MEDATLAS MFS and Insitu SDN products	Mean RMS profiles
S-CLASS4-BIAS-DEPTH	Coriolis and INSITU TAC dataset INSITU_MED_NRT_OBSERVATIONS_013_035 INSITU_GLO_NRT_OBSERVATIONS_013_030 MEDAR-MEDATLAS MFS and Insitu SDN products	Mean BIAS profiles

Table 7 Metrics and observations used to assess the Salinity.

Figure 18 - Figure 21 (**S-CLASS1-MEAN-DEPTHS**) show the salinity annual mean computed for different depths (15-100-350-1000m) from SDN climatology, reanalysis and their differences.

At 15m of depth **Figure 18**, major positive differences (~1.5psu) are located in the Northern Aegean Sea at the Dardanelles inflow, where the reanalysis results too salty. Negative differences values are instead located in the Western basin along the Catalan coast, in the Central basin along the continental slope and along the Western coast of the Adriatic Sea, where the signal of Po river, as for the temperature, is absent in the SDN climatology.



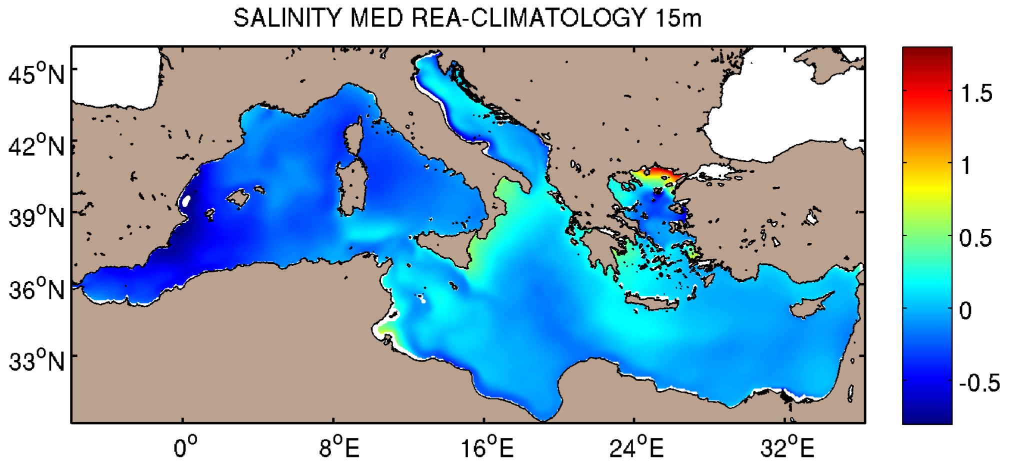
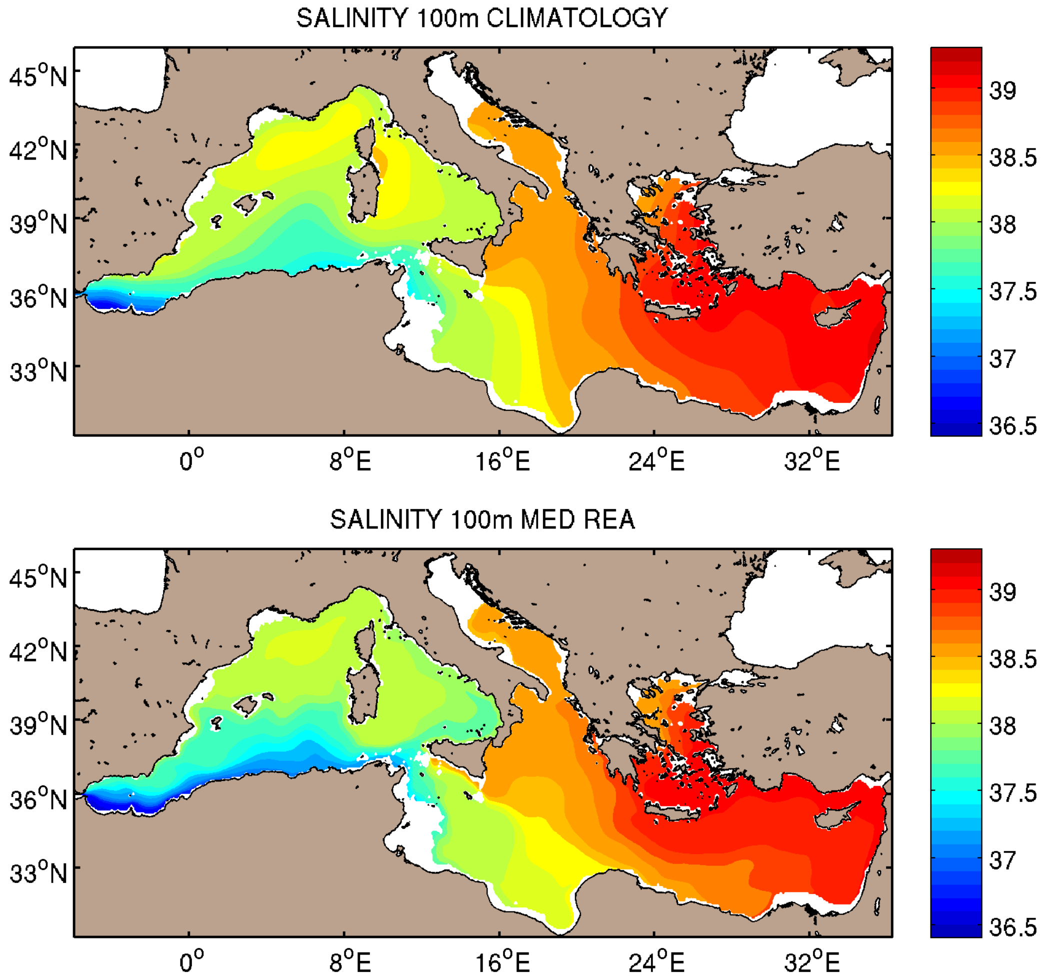


Figure 18 S-CLASS1-MEAN-DEPTHS Annual mean maps of salinity at 15m of depth computed from SDN climatology (upper panel), reanalysis product (middle panel) and differences (bottom).

At 100m of depth (Figure 19), the northern part of the Ionian Sea and of the Levantine basin are saltier than the SDN climatology. Major positive values are located along the southern part of the Sicily.



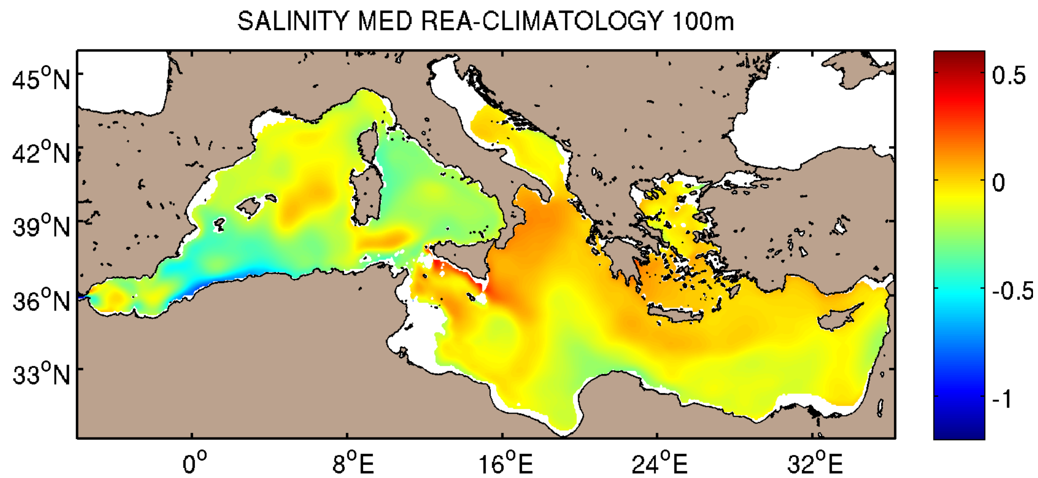
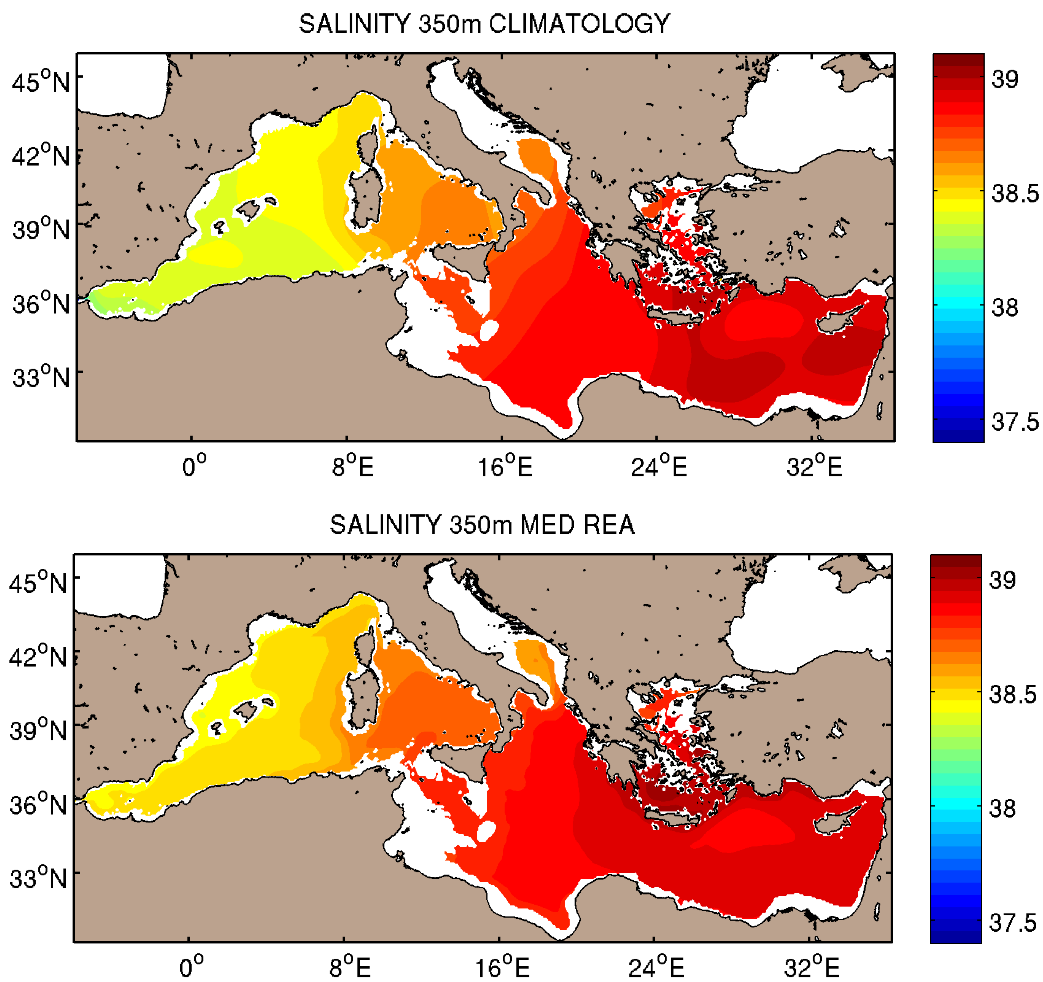


Figure 19 S-CLASS1-MEAN-DEPTHS Annual mean maps of salinity at 100m of depth computed from SDN climatology (upper panel), reanalysis product (middle panel) and differences (bottom).

At 350m of depth instead (Figure 20), the major positive differences are located in the Sardinia Channel, in the Ionian Sea, in the Cretan Sea and in the Western basin, indicating that the reanalysis waters are saltier than SDN climatology.



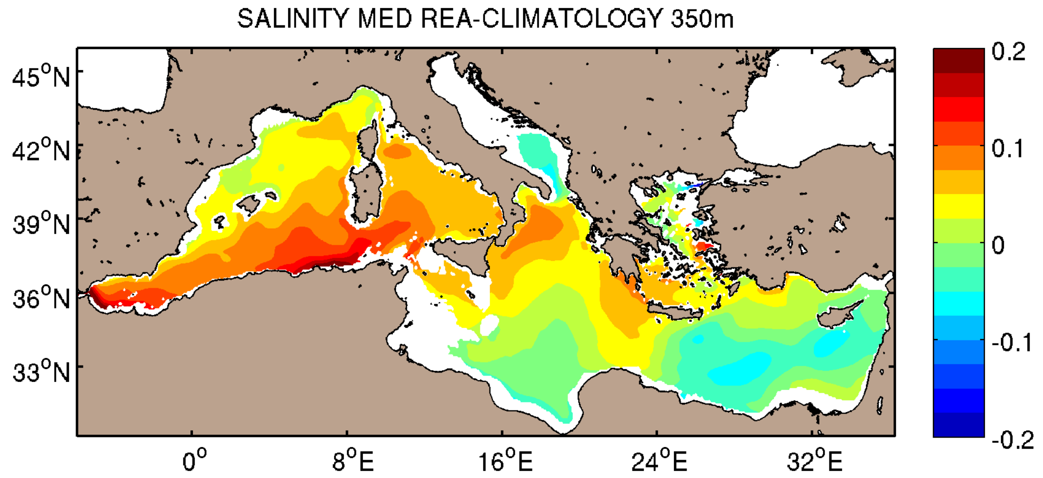
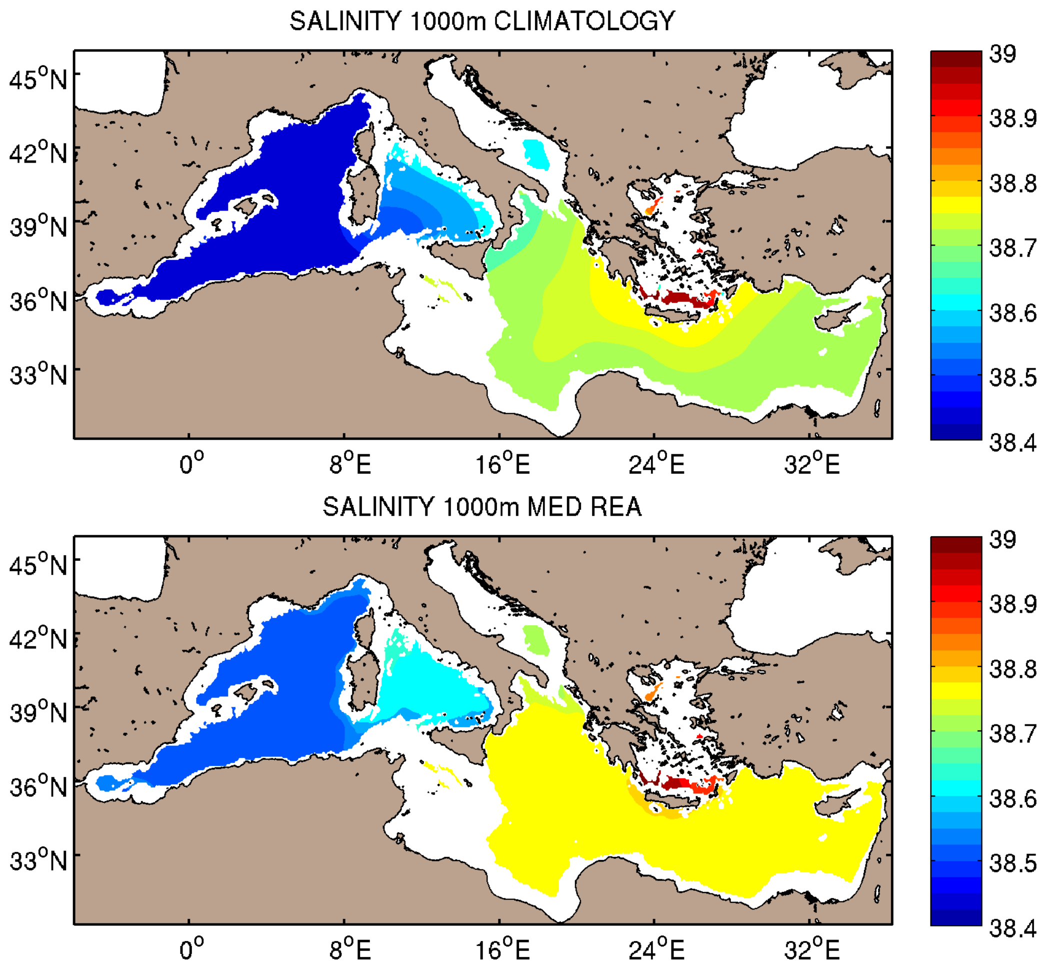


Figure 20 S-CLASS1-MEAN-DEPTHS Annual mean maps of salinity at 350m of depth computed from SDN climatology (upper panel), reanalysis product (middle panel) and differences (bottom).

At 1000m of depth (Figure 21), the major positive differences are located in the western basin and in the Southern Adriatic Sea, while Southern Tyrrhenian Sea and eastern basin appear slightly fresher than SDN climatology.



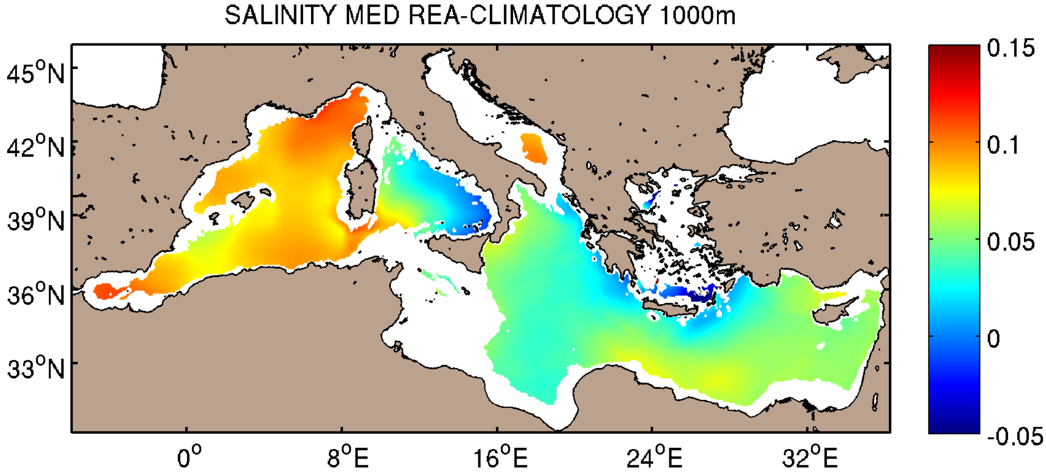
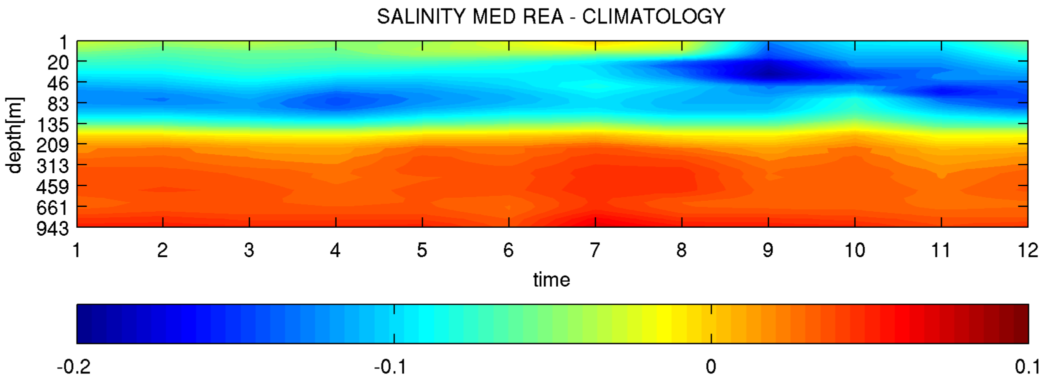


Figure 21 S-CLASS1-MEAN-DEPTHS Annual mean maps of salinity at 1000m of depth computed from SDN climatology (upper panel), reanalysis product (middle panel) and differences (bottom panel).

Figure 22 (**S-CLASS3-BIAS**) shows the salinity monthly climatology and monthly basin averaged profiles comparison against the SDN climatology as a function of depth up to 1000m.

Within the first 150m of depth, the reanalysis is fresher than the SDN climatology, while below it is saltier.

The differences between the reanalysis and the SDN climatology as monthly basin averaged profiles (Figure 22 – bottom panel) show that the reanalysis is fresher than the SDN climatology within the first 200m of depth from 1955 to 2005 when a positive trend starts.



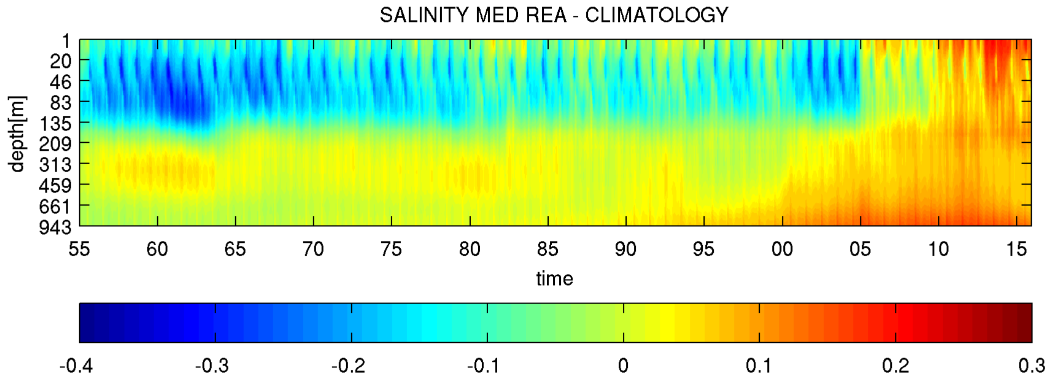
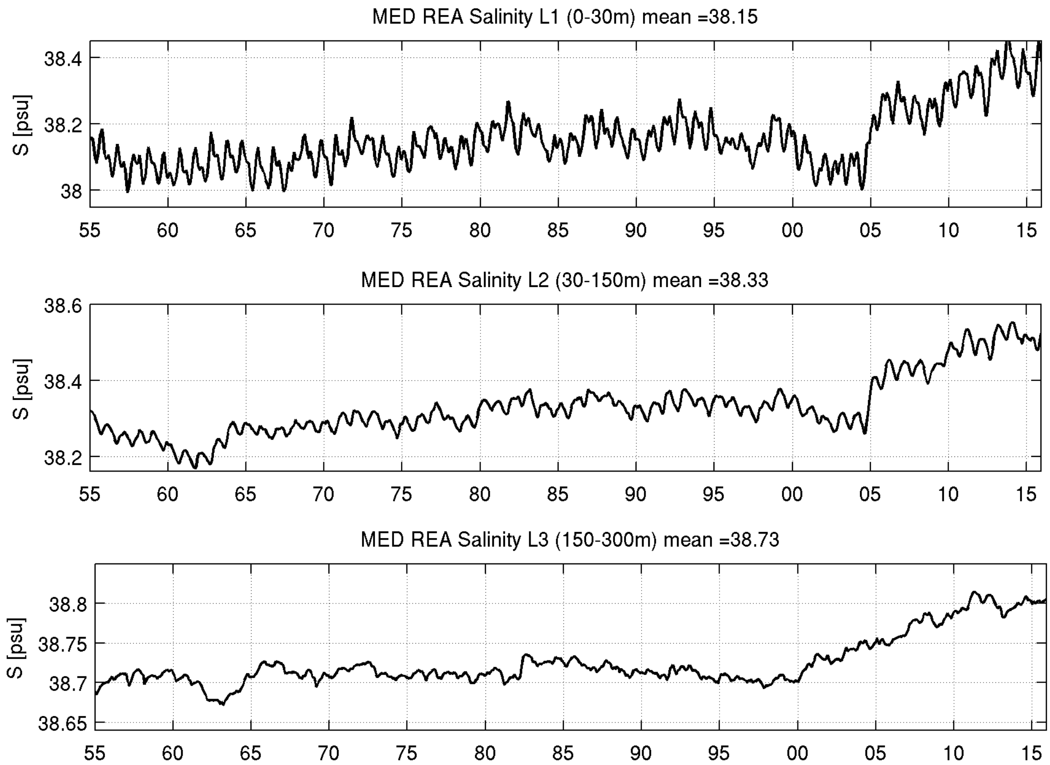


Figure 22 S-CLASS3-BIAS Monthly climatology (upper panel) and monthly basin averaged profiles (bottom panel) comparison between reanalysis product and SDN climatology

(S-CLASS3-LAYERS) shows the evolution of the domain-averaged salinity computed as function of time in different layers. As for the temperature, the first layer (0-30m) shows a clear seasonal signal with minimum values at the end of summertime and an average of 38.15 psu. Starting from 2005, it is evident a jump in the salinity behaviour above 150m and starting from 2000 below 150m. The salinity increase could be explained by ARGO advent (from 2000 onwards and more systematically since 2005), that provides a better representativity of water column characteristics. The advantages of the assimilation of ARGO data is evident also in the time series of salinity RMS where, after 2001, model is much more constrained by observation from ARGO and RMS errors tend to decrease.



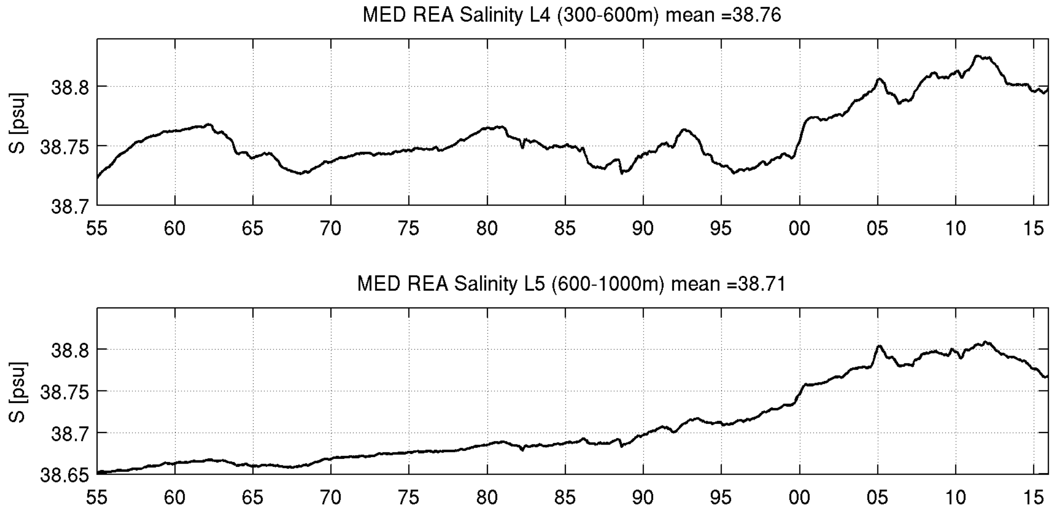


Figure 23 S-CLASS3-LAYERS Domain average salinity monthly mean computed from reanalysis product.

Evidence of the seasonal signal is also present in the water column differences between monthly basin averaged salinity profiles and the initial condition (**S-CLASS3-IC-CHANGE**) (Figure 24), where salinity increases within the first 50m during summertime, while decreases up to 100m of depth during springtime. Also in this comparison, it is evident an increase of salinity starting from 2005 in the first 150m of depth.

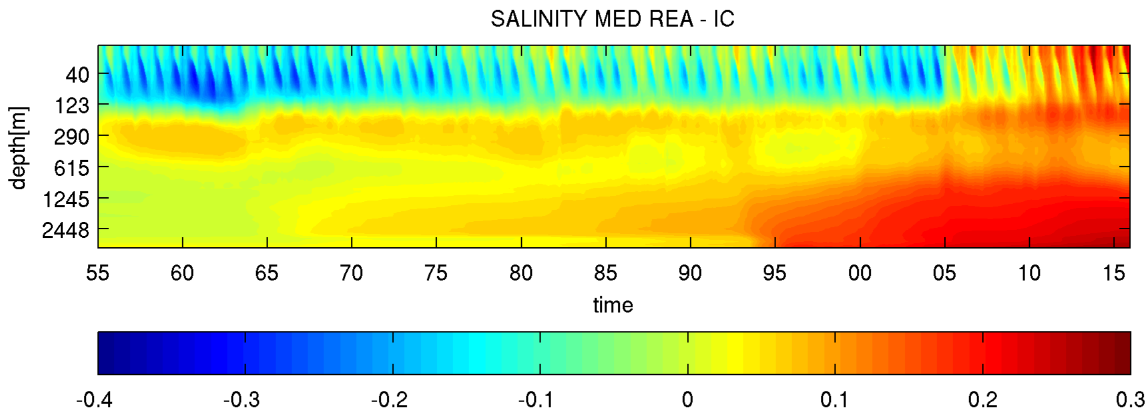


Figure 24 S-CLASS3-IC-CHANGE Domain average salinity change with respect to initial condition.

Figure 25 - Figure 26 (**S-CLASS4-RMS-LAYERS and S-CLASS4-BIAS-LAYERS**) present the RMS and BIAS computed in different layers at observation space-time location.

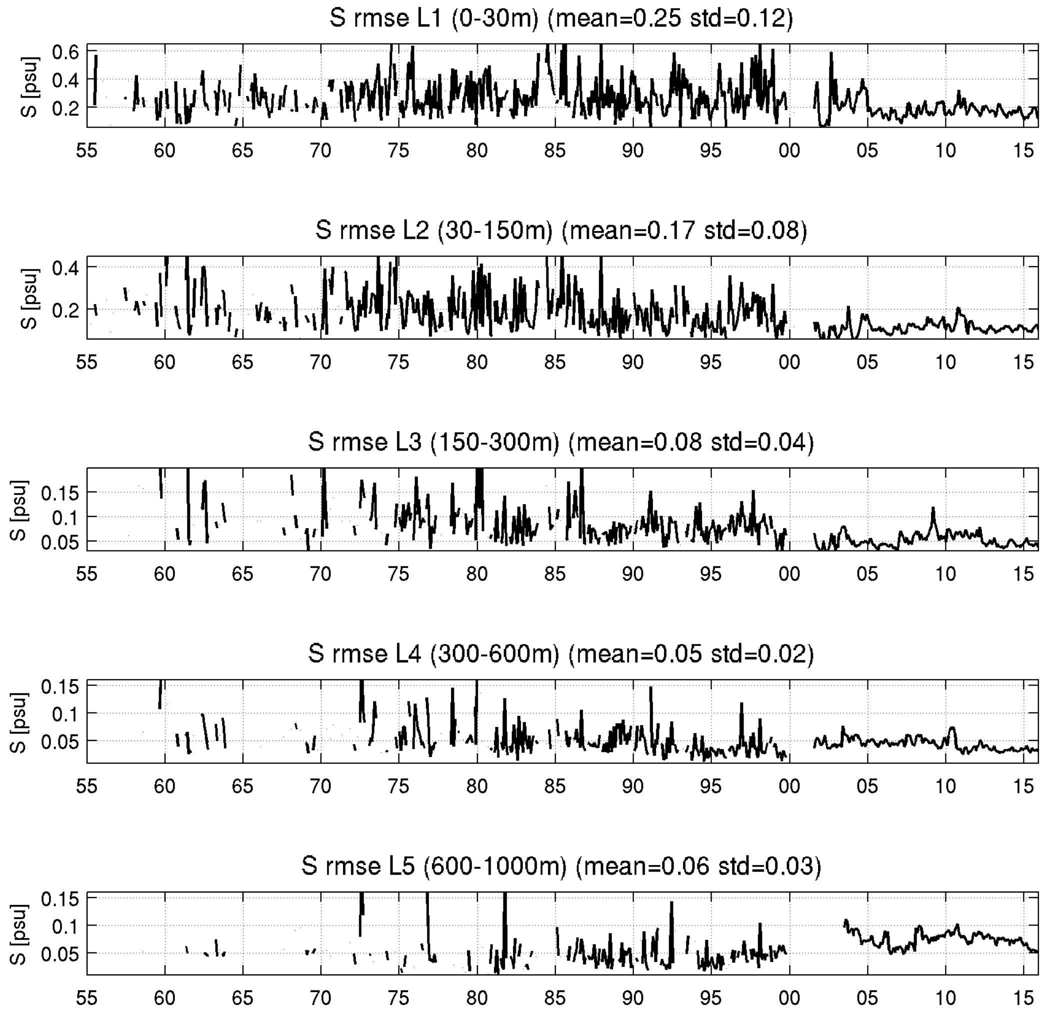


Figure 25 S-CLASS4-RMS-LAYERS computed from misfits of reanalysis product in different layers.

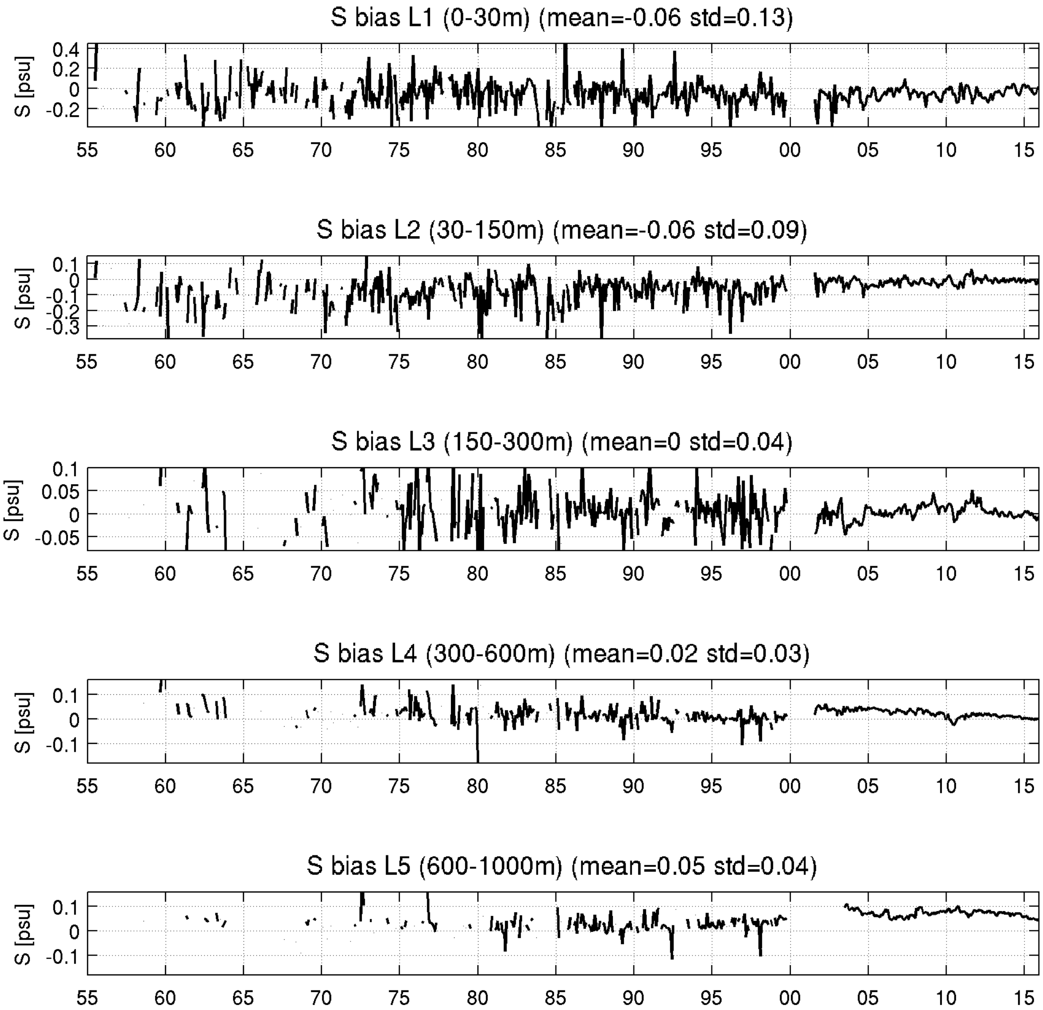


Figure 26 S-CLASS4-BIAS-LAYERS computed from misfits of reanalysis product in different layers.

Figure 27 (**S-CLASS4-RMS-DEPTH** and **S-CLASS4-BIAS-DEPTH**) displays salinity BIAS (left) and RMS (middle) mean profiles computed on the misfits. Salinity BIAS is negative within the first 200m and positive below. The RMSE reaches maximum value of 0.3psu at the surface where the atmospheric and land forcing play a fundamental role and decreases below 0.1psu below 150m of depth.

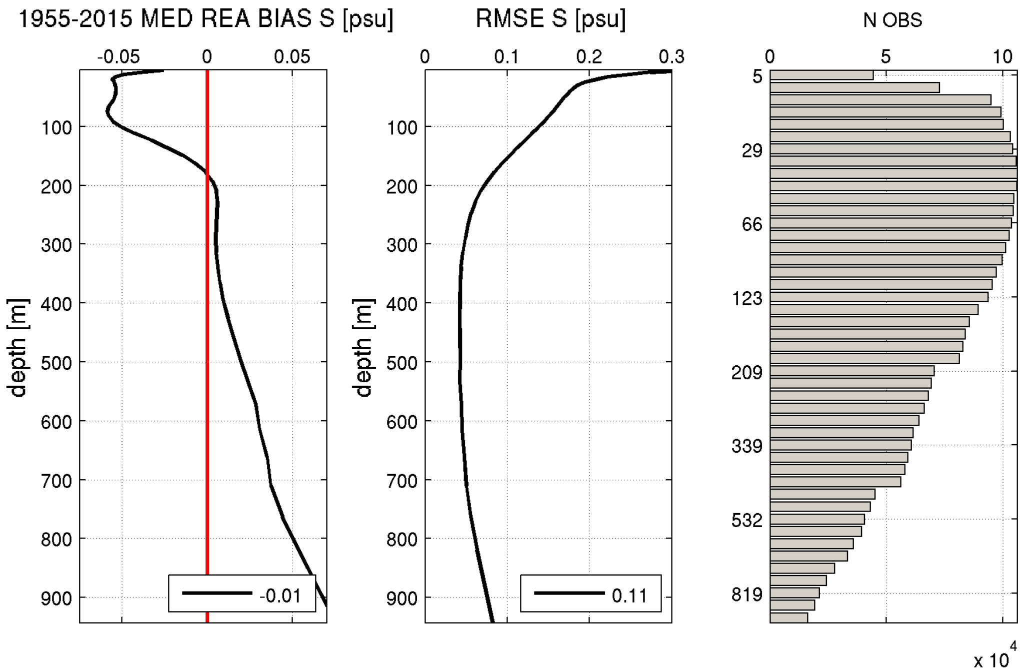


Figure 27 S-CLASS4-RMS-DEPTH and S-CLASS4-BIAS-DEPTH computed from reanalysis misfits

The total EANs, BIAS and RMS for salinity are included in

Salinity [psu]	BIAS	RMS
0 -30 m	-0.06 ± 0.13	0.25 ± 0.12
30 -150 m	-0.06 ± 0.09	0.17 ± 0.08
150 - 300 m	0 ± 0.04	0.08 ± 0.04
300 - 600m	0.02 ± 0.03	0.05 ± 0.02
600 -1000m	0.05 ± 0.04	0.06 ± 0.03
Total	0.01 ± 0.004	0.12 ± 0.01

Table 8 EANs for salinity.

IV.5 Currents

Table 9 summarizes the metrics and the observations used in the assessment of currents.

Name	**Reference dataset**	**Quantity**
UV-CLASS1-15M-MEAN	*Pinardi et al., 2015*	Maps of Mediterranean Sea surface mean currents at 15m

Table 9 Metrics and observations used to assess the currents.

Figure 28 displays maps of surface mean currents at 15m of depth computed from reanalysis product over two different time period, following *Pinardi et al., 2015*. The climatological circulation was computed over the period 1987-2996 and 1997-2006 in order to compare the decadal variability of the Mediterranean Sea circulation as in *Pinardi et al., 2015*. The changes between the two periods in the Western Mediterranean take place in the Alboran Sea and the Tyrrhenian Sea, while in the Eastern Mediterranean Sea the circulation becomes stronger. The major changes happened in the Easterm Mediterranean circulation where a current reversal took place in the Northern Ionain Sea related to the reversal from anti-cyclonic to cyclonic circulation.

The mean surface circulation is in agreement with the literature and presents the well-know Mediterranean surface circulation features.

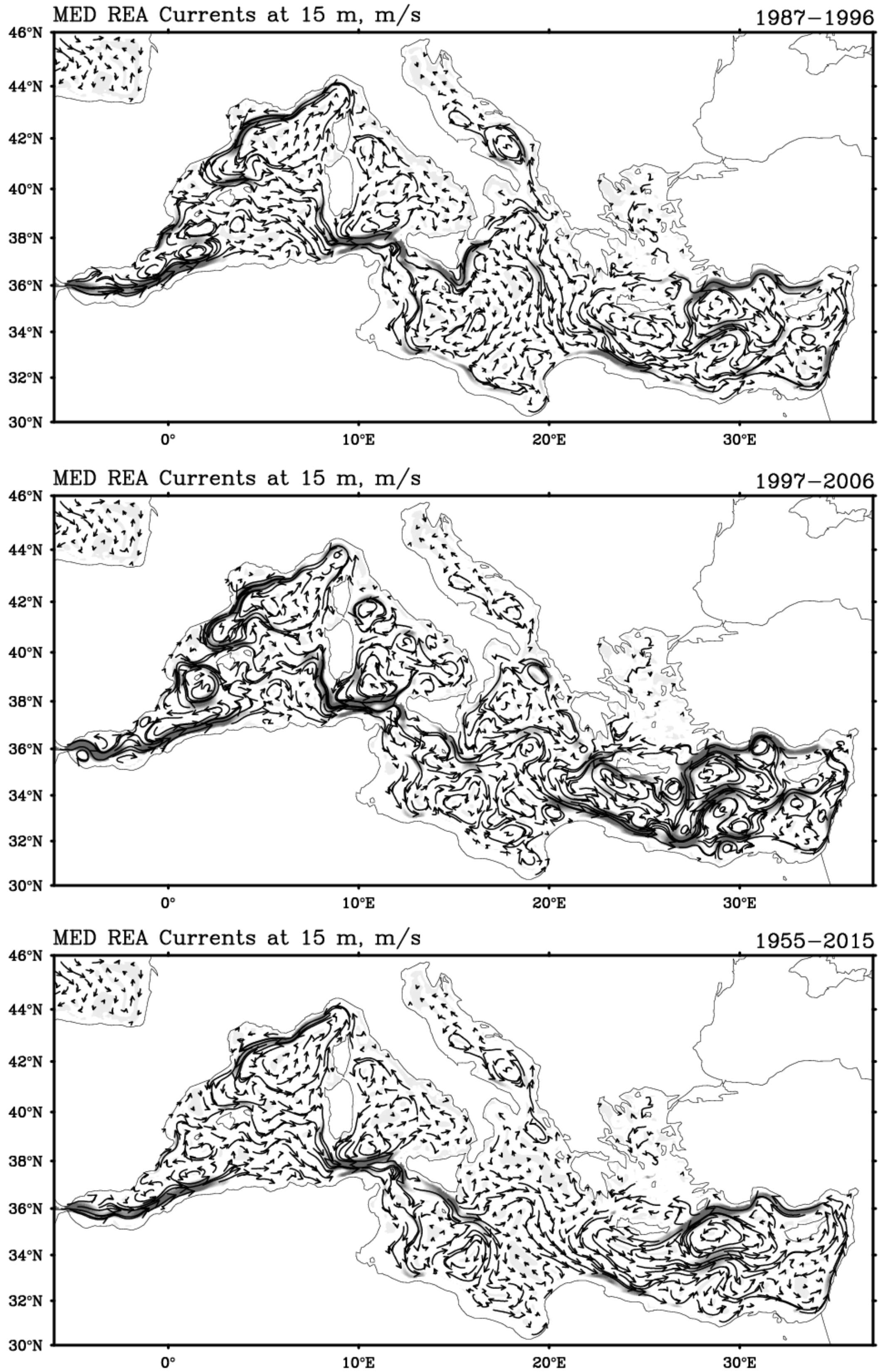


Figure 28 UV-CLASS1-15M-MEAN for different periods.

IV.6 Sea Level

Table 10 summarizes the metrics and the observations used in the assessment of Sea Level.

Name	Reference dataset	Quantity
SL-CLASS4-RMS	SELEVEL_MED_SLA_L3_REP_OBSERVATIONS_008_020	SL RMSE averaged over the whole domain
SL-CLASS3-2DMEAN	SEALEVEL_MED_SLA_MAP_L4_REP_OBSERVATIONS_008_029	Domain averaged SL monthly mean time series.

Table 10 Metrics and observations used to assess the sea level.

(**SL-CLASS4-RMS**) presents SLA RMS computed along track over the reanalysis period on a daily and monthly basin. The RMSE oscillates around a 3.7cm on monthly basis, with a peak at the beginning of 2015. When the number of observations increases, RMSE decreases, as it is evident between 2002 and 2006.

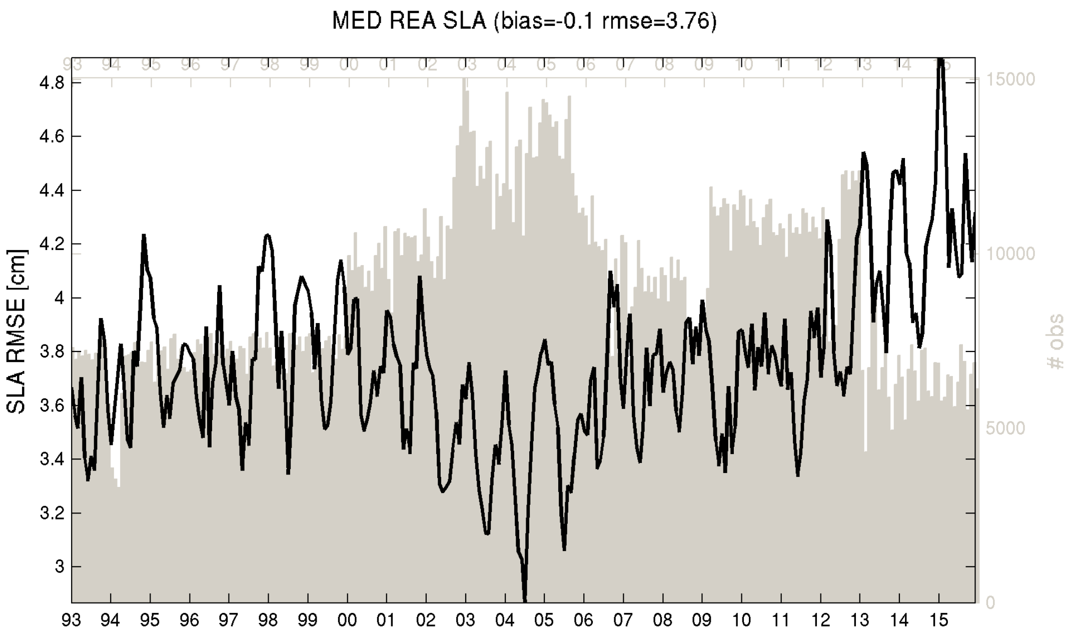


Figure 29 SL-CLASS4-MEAN.

Figure 30 (**SL-CLASS3-2DMEAN**) presents basin average SL monthly mean time series computed respectively from MED REA (blue line) and reference altimetry gridded dataset (green line). The full signal is wider in the case of MED REA product than in the altimetry data, instead when the monthly climatological signal is removed, the signals become comparable, in particular before 2010.

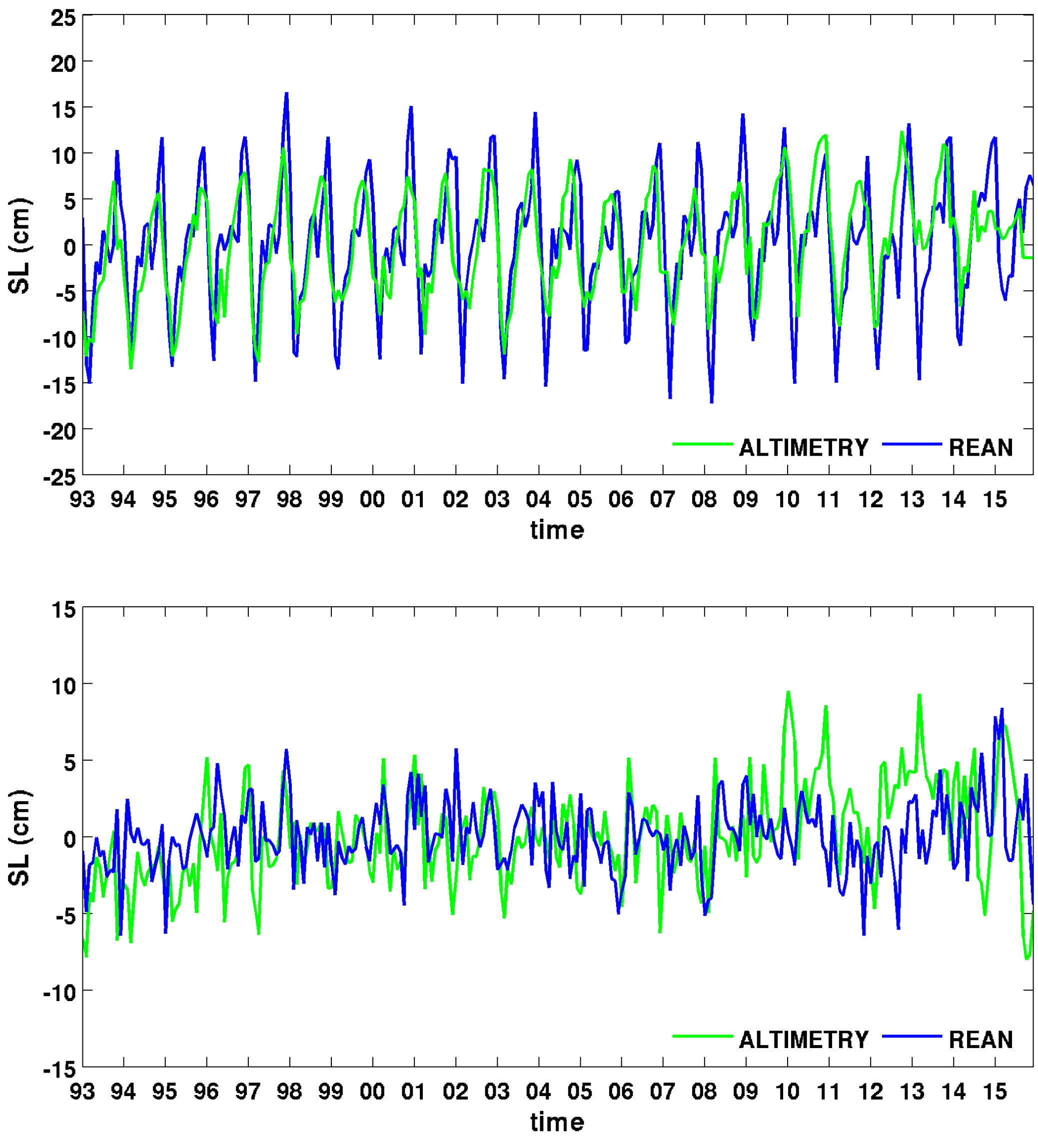


Figure 30 SL-CLASS3-2DMEAN Domain averaged sea level monthly mean time series computed from MED REA (blue line) and altimetry gridded reference product (green line): full signal (upper panel) and monthly climatological signal removed (bottom panel).

IV.7 Transport

Monthly time series of net volume transport through the Gibraltar Straight is displayed in **Error! Reference source not found.** (**UV-CLASS3-VOL_TRANSP**), while shows its westward and the eastward components. The eastward inflow component is slightly higher than the westward outflow component determining a long-term net value of 0.04Sv with a standard deviation of 0.06Sv. These values are coherent with the literature (*Menemellis et al., 2007*).

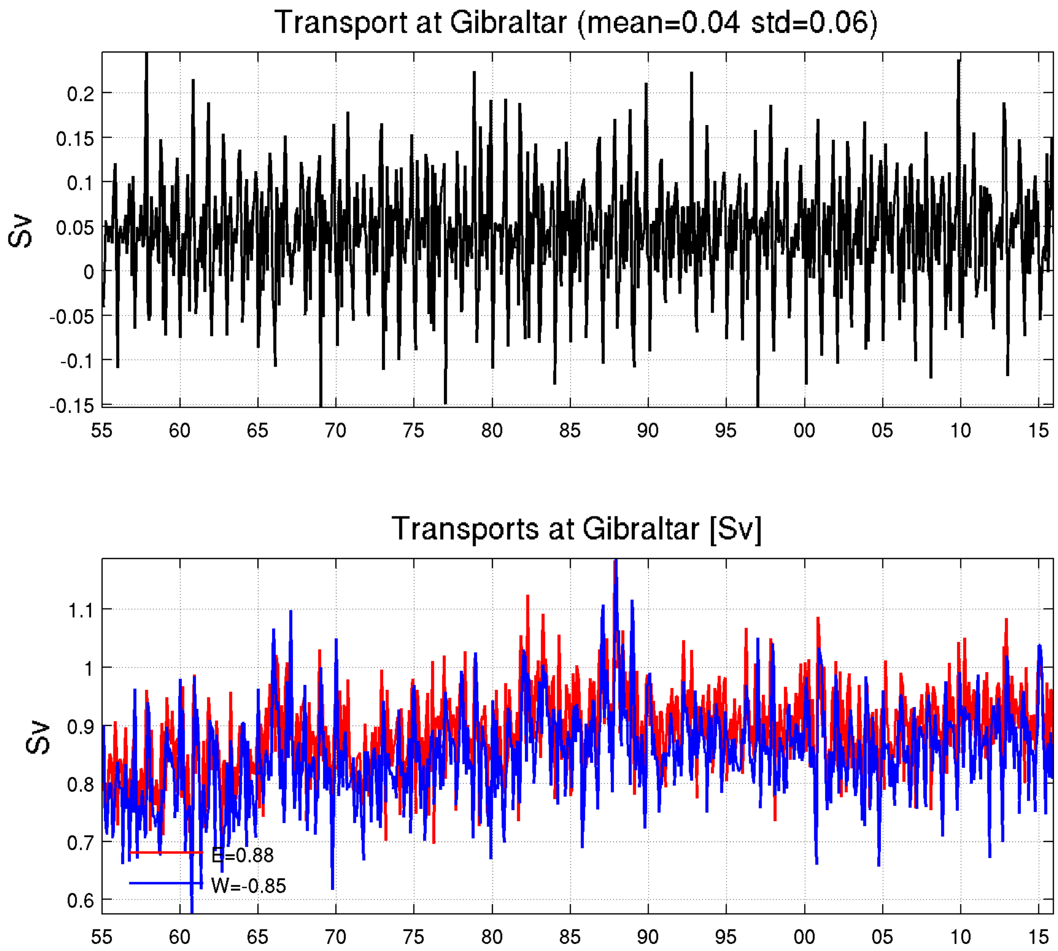


Figure 31 UV-CLASS3-VOL_TRANSP.

V SYSTEM'S NOTICEABLE EVENTS, OUTAGES OR CHANGES

Date	Change/Event description	System version	other
13/04/2016	Numerical ocean model was changed from Nemo version 3.2 to Nemo version 3.4	MFSe2r1	

VI QUALITY CHANGES SINCE PREVIOUS VERSION

Year 2015 has been added to the previous reanalysis time series, that covered the time period between 1955 and 2014. A consistency check was performed on the 2015 results in order to assure the continuity in the quality of the reanalysis product that remains substantially unchanged.

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