Product Information Document (PIDoc)

SeaDataCloud Temperature and Salinity Climatology for the Mediterranean Sea (Version 1)

SDC_MED_CLIM_TS_V1

HORIZON **2020**

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SDC_MED_CLIM_TS_V1

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SeaDataCloud Temperature and Salinity Climatologies for the Mediterranean Sea (Version 1)

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Short description

The SDC_MED_CLIM_TS_V1 product contains Temperature and Salinity climatological fields for the Mediterranean Sea. Monthly and seasonal fields are released for periods 1955-2017, 1955-1984 and 1985-2017, while seasonal fields are provided for 6 decades: 1955-1964, 1965-1974, 1985-1994, 1995-2004, 2005-2017. The climatological fields were obtained from an integrated Mediterranean Sea dataset which combines data extracted from SeaDataNet infrastructure and the Coriolis Ocean Dataset for Reanalysis (CORA5.2). The analysis was performed with the DIVAnd (Data-Interpolating Variational Analysis in n dimensions), version 2.4.0.

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V1	S. Simoncelli	31/07/2019	version 1
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V2	S. Simoncelli	06/03/2020	version 2

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Abstract

The SDC_MED_CLIM_TS_V1 product contains Temperature and Salinity climatological fields for the Mediterranean Sea. Monthly and seasonal fields are released for periods 1955-2017, 1955-1984 and 1985-2017, while seasonal fields are provided for 6 decades: 1955-1964, 1965-1974, 1985-1994, 1995-2004, 2005-2017. The climatological fields were obtained from an integrated Mediterranean Sea dataset which combines data extracted from SeaDataNet infrastructure and the Coriolis Ocean Dataset for Reanalysis (CORA 5.2). The analysis was performed with the DIVAnd (Data-Interpolating Variational Analysis in n dimensions), version 2.4.0.

Whenever SDC_MED_CLIM_TS_V1 product is used, PIDoc should be cited in any publication. The data products providers normally possess insight on the quality and context of the product and tools not always shared with the SeaDataCloud team. Hence, inviting data providers and product leaders to collaborate in scientific investigations that depend on their data products is considered good and fair practice. Importantly, this will promote further sharing of products and will be beneficial to science.

1. Introduction

The SDC_MED_CLIM_TS_V1 product contains Temperature and Salinity climatological fields for the Mediterranean Sea at 1/8 of degree of horizontal resolution on 92 standard levels. Monthly and seasonal fields were produced for the time periods 1955-2017, 1955-1984 and 1985-2017. Seasonal fields were created for 6 decades: 1955-1964, 1965-1974, 1985-1994, 1995-2004, 2005-2017. The table in Annex 1 summarizes the products' components and characteristics.

The climatological fields were obtained from an integrated dataset which combines data extracted from SeaDataNet infrastructure and the Coriolis Ocean Dataset for Reanalysis (CORA), version 5.2. It follows a detailed description of the input data set and how it has been assembled.

1.1. General description of the input data set

Temperature and salinity collocated profiles with Quality Flags (QF) 1 (good) and 2 (probably good) have been extracted from SDC_MED_DATA_TS_V1 unrestricted and restricted data collections to be used for the climatology generation. The SDC_MED_DATA_TS_V1 collections have been obtained harvesting all measurements contained within SeaDataNet infrastructure at the end of October 2017. *Simoncelli et al. (2018b)* describes the data collection and the quality assessment procedures applied. SDC_MED_DATA_TS_V1 contains 739784 stations, among which 665388 collocated temperature and salinity profiles. The collection of restricted data consists of 22503 stations, among which 22294 collocated temperature and salinity profiles.

Unrestricted and restricted data have been merged in ODV obtaining 762287 stations. 685209 stations have both temperature and salinity measurements, whose 99.0% of data has QF equal to 1 or 2. Thermosalinograph (TSG) data have been discarded from the climatology computation, due to their peculiar spatial and temporal distribution (see Fig.11 in *Simoncelli et al., 2018b*) along trajectories at the near surface and their availability only after year 2000. TSG data constitutes about 75% of the stations in SDC_MED_DATA_TS_V1, thus after their removal the climatology dataset contains 143544 collocated temperature and salinity profiles spatially distributed as in Figure 1. Figure 2 presents the temporal data distribution, which is characterized by a data availability increase starting in late eighties and a reduction in the recent years, due to the time lag that occurs among sampling and data submission into the SeaDataNet infrastructure. Data availability is maximum during summertime thanks to the favorable sampling conditions.

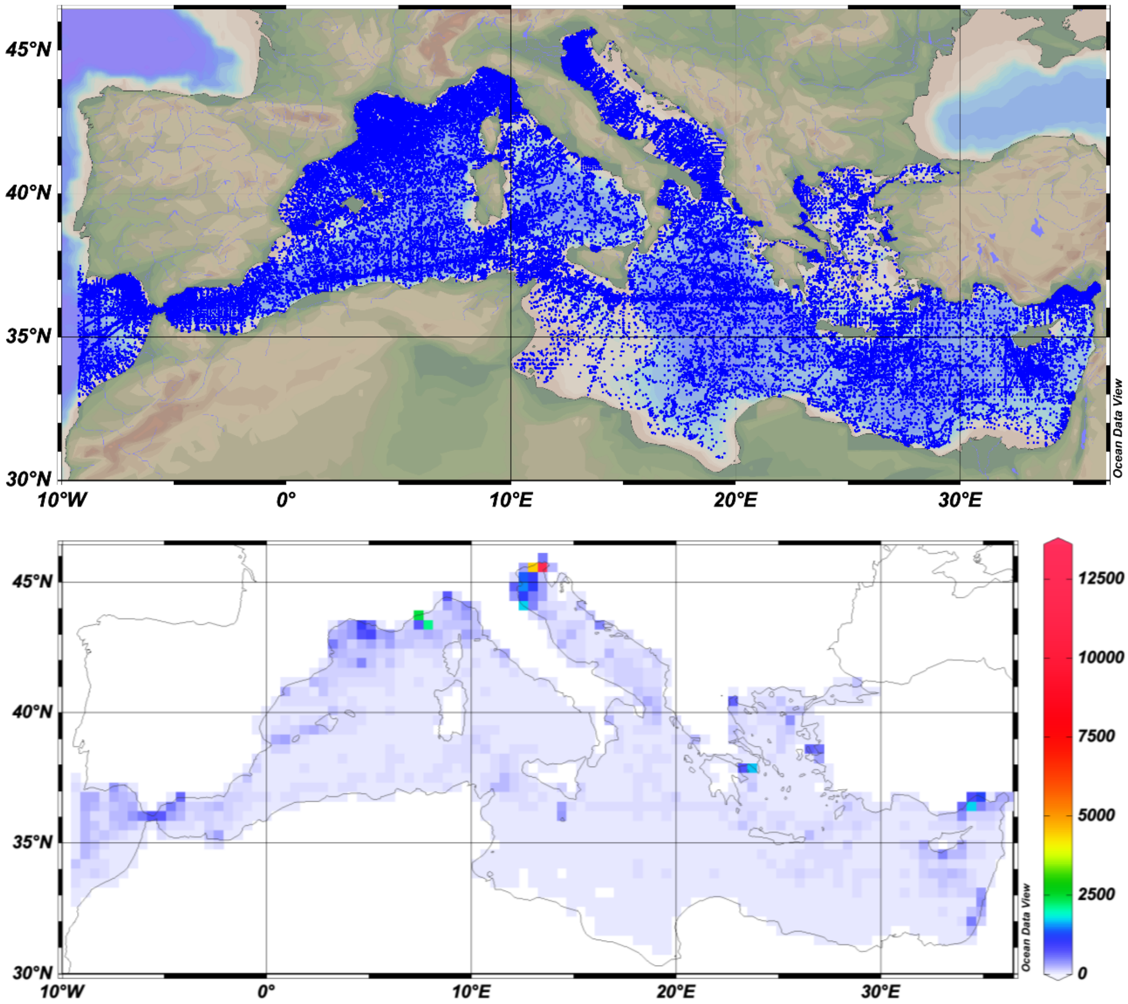


Figure 1 Distribution (top) and data density (bottom) maps of SeaDataCloud unrestricted and restricted stations (143544 collocated temperature and salinity profiles with QF equal to 1 or 2) used to generate the SDC_MED_CLIM_TS_V1 product.

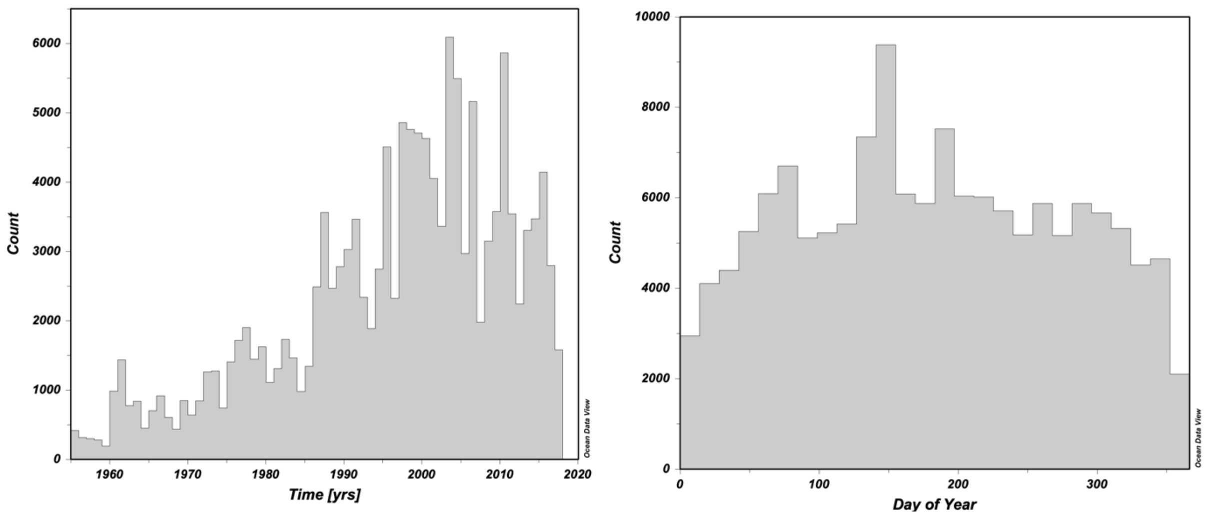


Figure 2 Temporal distribution of SeaDataCloud unrestricted and restricted stations (143544 collocated temperature and salinity profiles with QF equal to 1 or 2) used to generate the SDC_MED_CLIM_TS_V1 product: (left panel) annual distribution, and (right panel) seasonal distribution.

1.2. Coriolis Global CORA5.2 REP data set

CORA5.2 REP data set (*Cabanes et al., 2013*), distributed through the Copernicus Marine Environment Monitoring Service (hereafter CMEMS), contains in-situ observations yearly delivery in delayed mode. The in situ delayed mode product integrates the best available version of in situ data for temperature and salinity measurements. These data are collected from main global networks (Argo, GOSUD, OceanSITES) completed by European data provided by EUROGOOS regional systems and national systems by the regional INS TAC components. The 5.2 version is a merged product between the previous version of CORA and EN4 distributed by the Met Office for the period 1950-1990. The data set covers the global ocean over the time period 1950-2017 (April 2018 update). The sub-set of data covering the Mediterranean Sea domain (Longitude > -5.5 degrees) has been downloaded and used to generate SDC_MED_CLIM_TS_V1 climatology.

The CORA file system is based on 19 daily file types corresponding to the instrument type of the data provider. Only some of the data types within the Mediterranean domain have been considered to be integrated with the SDC data (see Table 1):

- **PR_PF** files: **data from Argo floats** (47716 profiles) directly received from DACS (RT and DM if available). These data have a nominal accuracy of 0.01° and 0.01 PSU and are transmitted with full resolution;
- **PR_CT** files: contains **CTD data from research vessels** (6389 profiles) with accuracy on the order of 0.002° for temperature and 0.003 PSU for salinity after calibration) but also data from sea mammals equipped with CTD (accuracy is on the order of 0.01° for temperature and 0.02 PSU for salinity) and received from MNHN and some sea Gliders.
- **PR_IC** files: **CTD from ICES dataset** (406 profiles) gathered by Danish CIUEM. Those profiles complete the CTDs coverage on the period 1990-2011.
- **PR_SH** files: about 193296 profiles from the SHOM database, most of them cover the 1950-1990 period.
- **PR_ME** files: CTD from SISMER database (11930 profiles), coming from French oceanographic campaigns. First loading in GLOBAL INS TAC in July 2013 (about 60.000 CTDs)
- **PR_OS** files: OceanSites data are mostly CTD (927 profiles).

PR_OC files containing additional **CTD and XCTD data** (87927 stations) coming from the high resolution CTD dataset of the World Ocean Database 2009 (WOD09), has been discarded due to the too many data anomalies encountered (mainly data on land flagged as good) that would have deteriorated the final product's quality.

Table 1 Number of stations per each data type of the CORA5.2 Mediterranean data sub set with QF equal to 1 for positioning and timing.

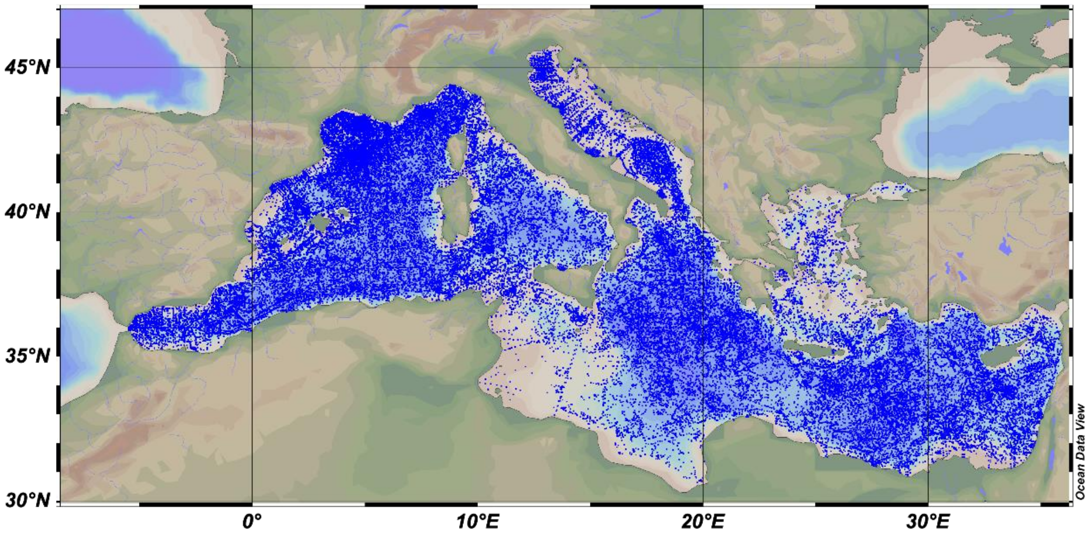
CORA 5.2 data types	Number of Stations
PR_PF	47716

PR_CT	6389
PR_IC	406
PR_ME	11930
PR_SH	193296
PR_OS	927
TOT	259737

The extraction of the CORA5.2 NetCDF files has been done through a common procedure considering the QC on the timing and the location of TS profiles (Quality Flag =1 good) and exported adjusted parameters when they exist. The data were reformatted to ODV spreadsheet (https://odv.awi.de/) and imported to ODV collection for QC and analysis. The additional quality check has been performed through visual inspection following the SDC QC guidelines detailed in *Simoncelli et al. (2018b)*.

CORA5.2 data presented data anomalies, meaning that data flagged as good were visibly wrong. Moreover 266 internal duplicates (8 PR_CT and 258 PR_SH) have been detected and eliminated from further analysis. This fundamental step increases data consistency, since each initiative (SeaDataNet and CMEMS) apply different QC strategies and procedures.

The CORA5.2 sub set consists of 90833 collocated temperature and salinity profiles spatially distributed as in Figure 3. Figure 4 displays the temporal distribution of CORA5.2 sub-set, which shows lower data availability than SDC from the eighties and the 2000s, while data availability rapidly increases in the latest years, when it is maximum. Seasonal data distribution has maximum data availability in June-July and minimum in December-January.



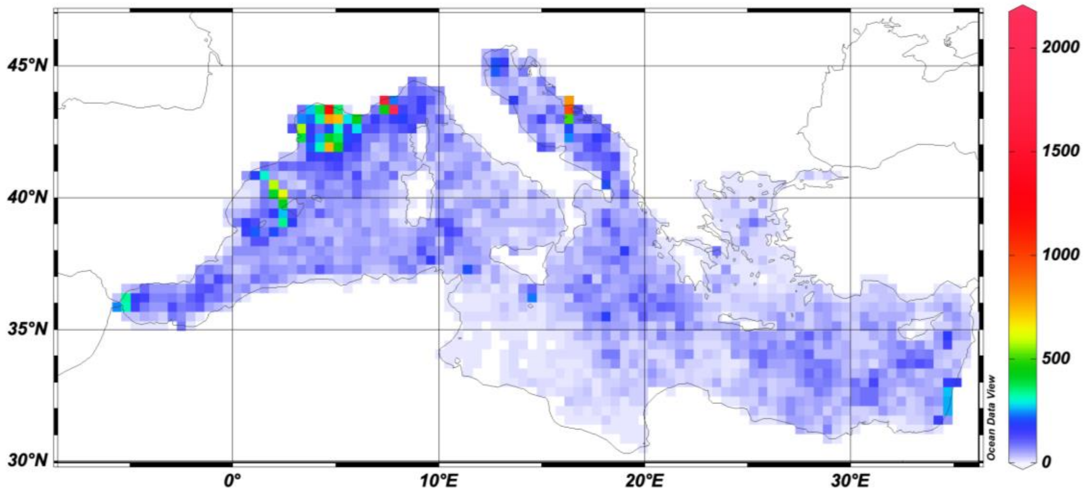
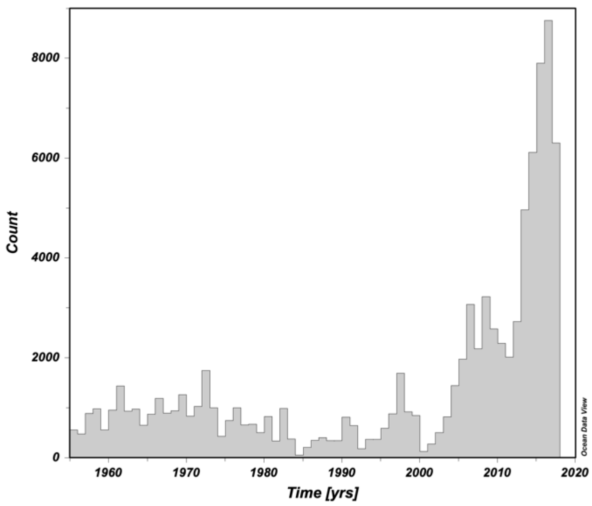


Figure 3 Distribution (top) and data density (bottom) maps of CORA5.2 stations (90883 collocated temperature and salinity profiles with QF equal to 1 or 2) used to generate the SDC_MED_CLIM_TS_V1 product.



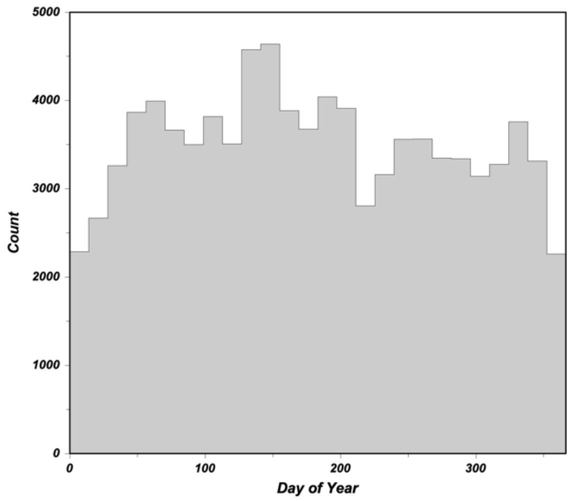


Figure 4 Temporal distribution of CORA5.2 stations (90883 collocated temperature and salinity profiles with QF equal to 1 or 2) used to generate the SDC_MED_CLIM_TS_V1 product: (left panel) annual distribution, and (right panel) seasonal distribution.

1.3. Integration of SDC and CORA5.2data sets

Datasets integration was performed merging SDC and CORA5.2 data in ODV. The duplicate detection and removal was performed using the DIVAnd tool DIVAnd.Quadtrees.checkduplicates (*https://github.com/gher-ulg/SeaDataCloud/blob/master/Julia/Climatologies/duplicate_detection.jl*) with the following values for the parameters:

- latitude and longitude < 0.001°;
- recorded times of measurement < 2 hours;
- depth < 10cm;
- Temperature < 0.001°C;
- Salinity < 0.005PSU.

The check for duplicates is thus done at the data level, not at the station level as could be done with ODV. The criteria on location and time difference are also wider than the standard values used by ODV. The results of duplicate check have been aggregated back in terms of number of stations per month and are summarized in Table 2. The average of detected duplicate stations in the SDC-CORA5.2 sub set is 19.9%.

Table 2 Results of duplicate check in terms of initial number of stations in the climatology data set, the number of detected duplicates and the percentage of duplicates.

	N stations	N duplicates	% of duplicates
Jan	12935	2619	20,2
Feb	16623	3409	20,5
Mar	21805	4186	19,2
Apr	18068	4053	22,4
May	26410	5996	22,7
Jun	20108	4405	21,9
Jul	22811	4631	20,3
Aug	18893	3624	19,2
Sep	18988	3674	19,3
Oct	19021	3298	17,3
Nov	17182	3137	18,3
Dec	14053	2389	17,0

The content of the resulted integrated Mediterranean Sea Temperature and Salinity dataset is provided in Figure 5. In the Mediterranean Sea climatology dataset 70% of stations belong to SDC while the CORA 5.2 is contributing to the remaining 30%.

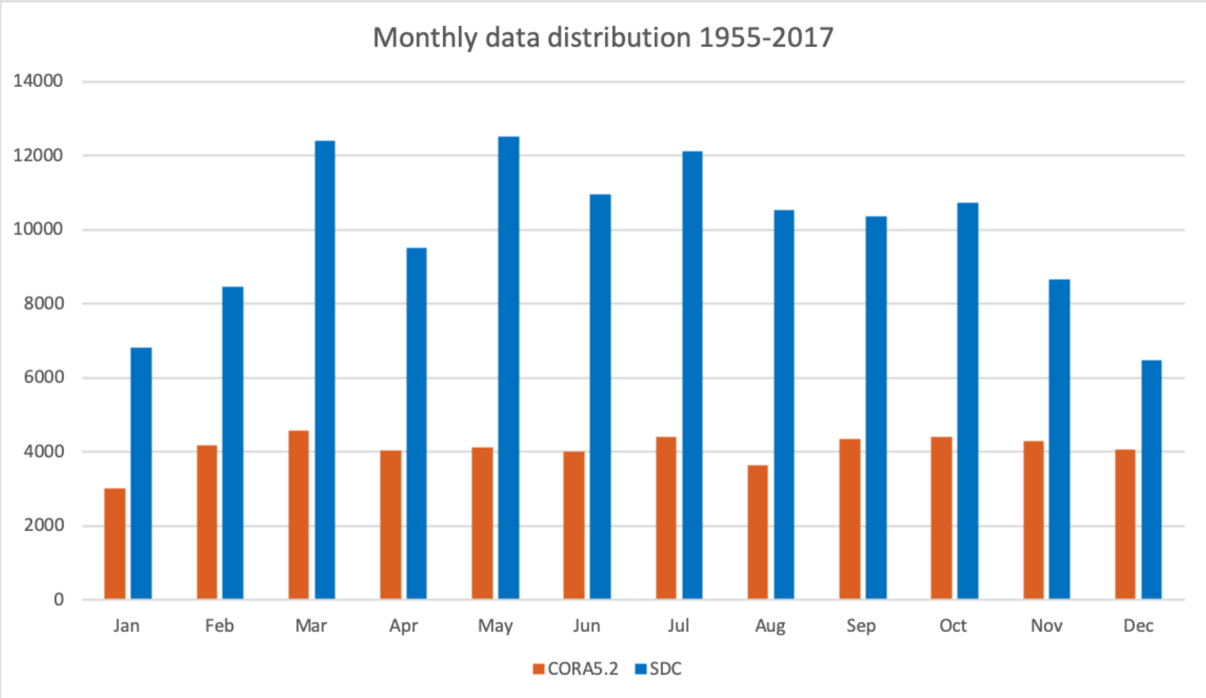


Figure 5 Monthly data distribution over the time period 1955-2017 for the integrated data set in terms of number of stations.

The monthly spatial distribution of stations in the integrated dataset over the time period 1955-2017 is presented in Figure 6. CORA5.2 stations (in red) cover only the Mediterranean, while SDC ones cover a buffer zone in the Atlantic Ocean in order to resolve the temperature and salinity distribution in the Gibraltar Strait. Major data gaps are apparent in the southern-central Mediterranean in all months and in the Aegean Sea in January. Data are sparse in the Tyrrhenian Sea too in several months, i.e. February, May, June, November and December.

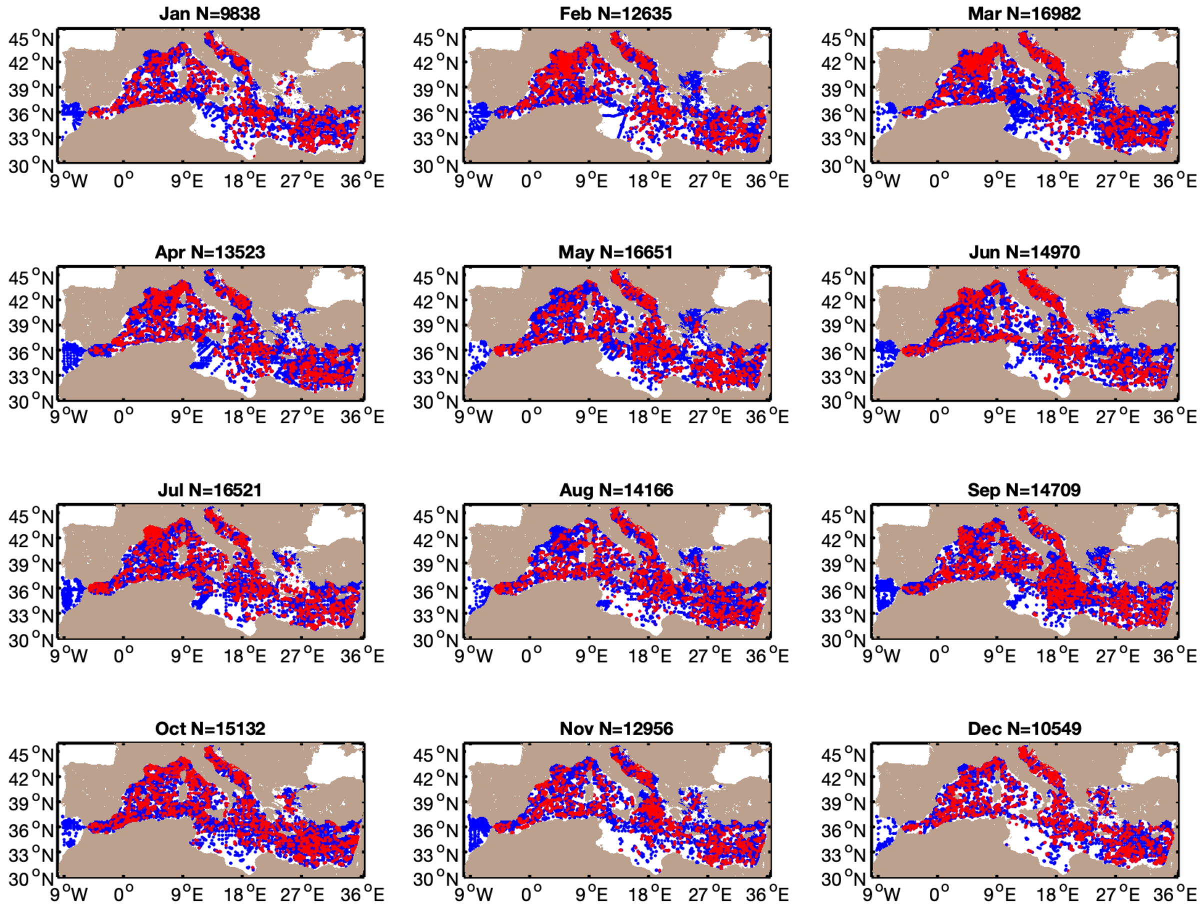


Figure 6 Monthly spatial distribution of collocated temperature and salinity profiles of the climatology data set over the time period 1955-2017. In blue the SDC stations and in red the CORA5.2 ones.

The annual distribution of observations in the integrated dataset (Figure 7) is irregular:

- the number of SDC stations increases from the second half of the eighties with maximum values in early 2000s;
- CORA5.2 stations are scarce in the eighties and nineties, and start to increase in the 2000s. Their maximum contribution is between 2013 and 2017, when the number of SDC data decreases due to a well-known data submission time lag which characterizes the delay mode data infrastructures.

The decadal time distribution of stations in Figure 8 shows how CORA5.2 highly contributes to the climatology generation for the first two and the last decades. In the time periods 1985-1994 and 1995-2004 CORA5.2 contributes with only 4% and 6% of stations respectively.

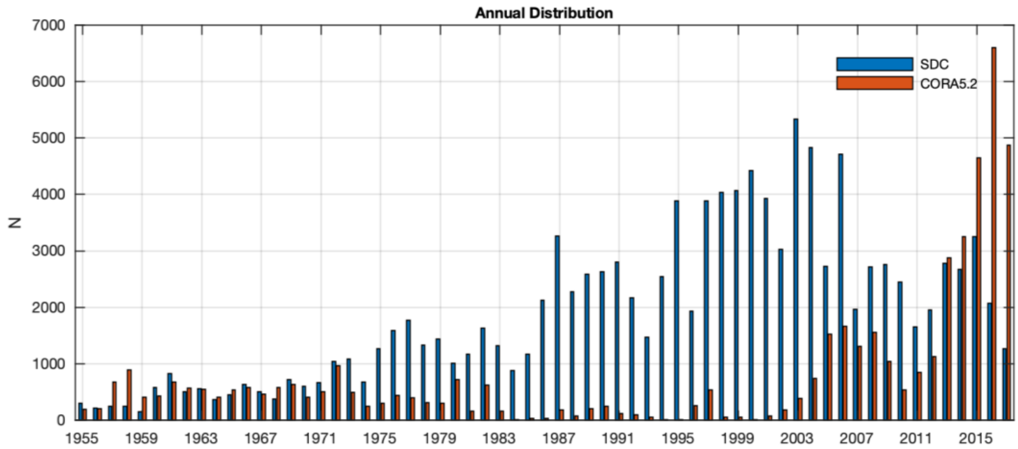


Figure 7 Annual distribution of observed stations in the integrated dataset over the time period 1955-2017.

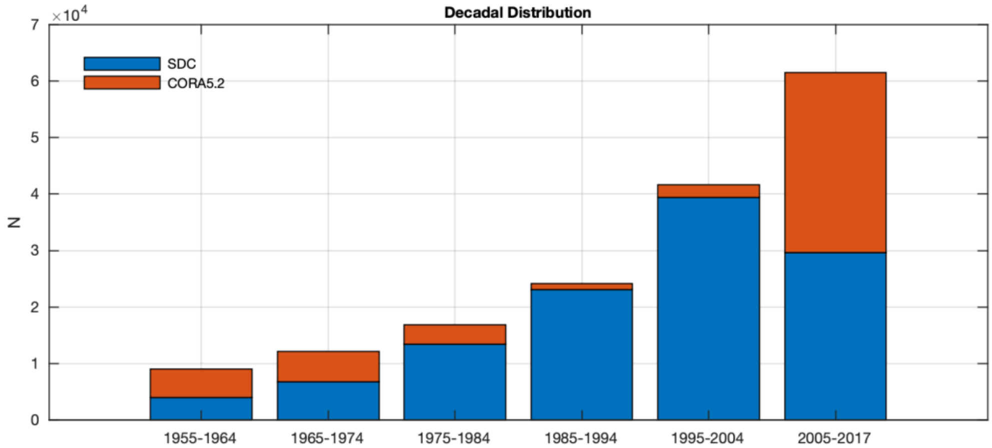


Figure 8 Decadal distribution of observed stations in the integrated dataset over the time period 1955-2017.

Including data from an external data source significantly increased data availability. In certain decades (e.g. 1955-1964 and 2005-2017) the contribution from external data sources is higher than the 50%. However significant data gaps still appear in Figure 9. During the period 1955-1964 SDC data present significant data gaps in the Adriatic, Ionian and Tyrrhenian Seas. In the 1965-1974 CORA5.2 dataset compensates the SDC data gaps in the Adriatic Sea, but gaps are present in the Tyrrhenian, the West Mediterranean and the Southern Ionian. The Southern Levantine basin does not have measurements in the time periods 1975-1984 and 1995-2004. The Tyrrhenian Sea is almost empty of measurements in the decade 1995-2004.

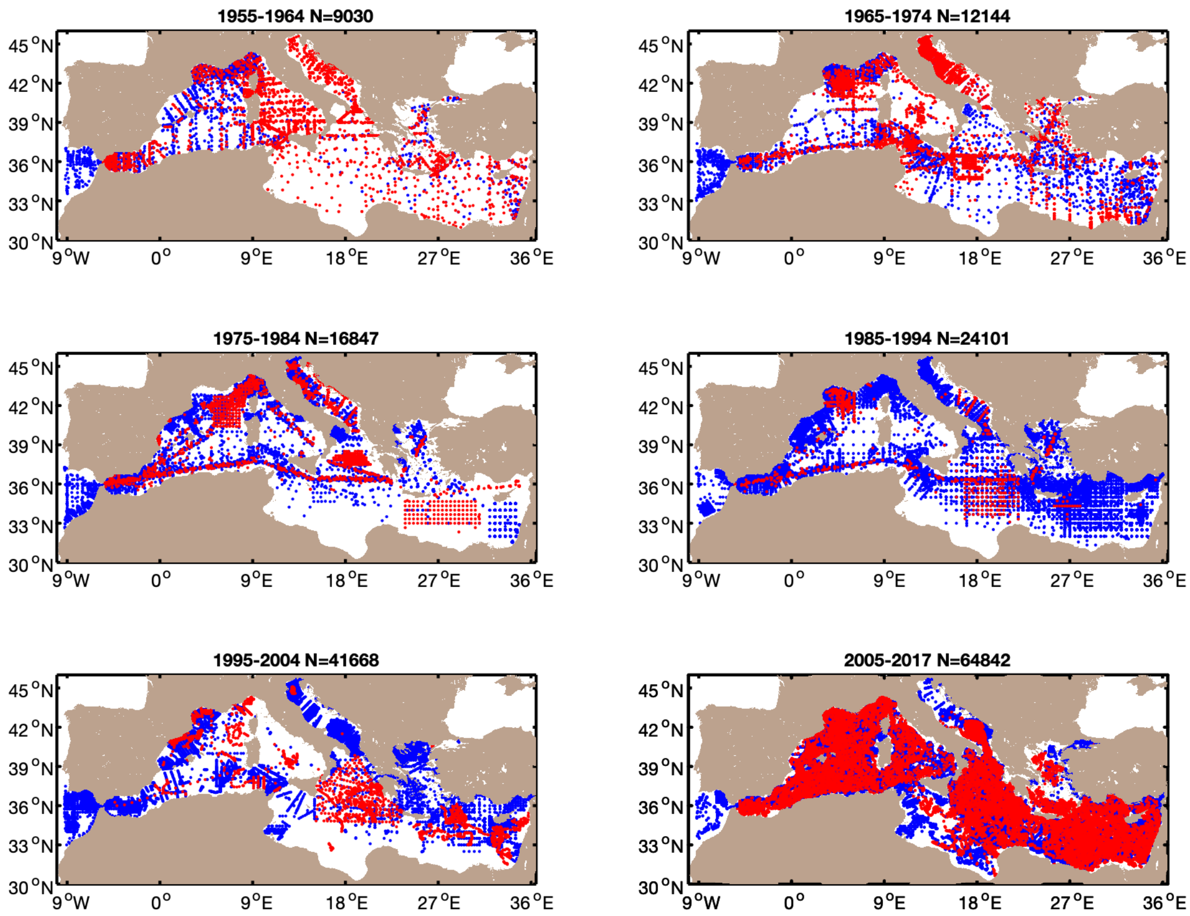


Figure 9 Decadal spatial distribution of profiles observations for 6 decades: 1955-1964, 1965-1974, 1985-1994, 1995-2004, 2005-2017. In blue the SDC stations and in red the CORA5.2 ones.

The vertical data distribution in Figure 10 shows maximum data availability at about 10-15 m that rapidly decreases with depth (2/3 of data at 100m and 1/3 at 1000m). Below 2000m data are very sparse. At the surface (0m) data are sparse too, approximately a half of the measurements at 10m, thus requiring caution when using surface climatological maps.

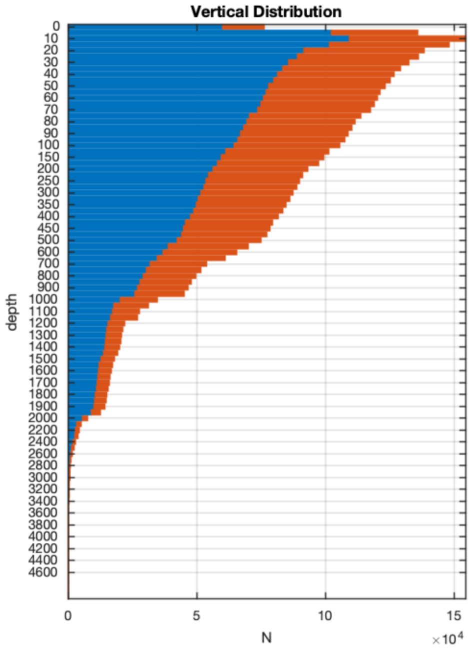


Figure 10 Number of SDC (blue) and CORA5.2 (orange) stations per each standard depth level

2. Methodology

The analysis was performed with the DIVAnd (Data-Interpolating Variational Analysis in n dimensions), version 2.4.0.

2.1. Data QC

SeaDataCloud data have been quality checked according to the guidelines defined in the framework of SeaDataNet2 Project and further refined as described in *Simoncelli et al. (2018b)*. However, an additional QC analysis has been performed on the CORA5.2 data sub-set in order discard data anomalies (outliers, stations on land, wrong spatial or temporal location) from further consideration in the analysis. This QC analysis has been performed also on the merged data set, once removed the duplicates, to guarantee data consistency.

The input dataset has been exported in NetCDF format and read with Matlab software to perform the interpolation of temperature and salinity profiles on the WOA18 standard levels. We input the interpolated profiles to DIVAnd but setting Lc(z) = 0 in order to perform all layers at once, moreover we extrapolated the values at the surface. Surface extrapolation has been applied when the first surface measurement was shallower than 1m of depth to assign the value at 0m.

2.2. DIVA implementation and settings

Computation of the Mediterranean Sea Temperature and Salinity climatological fields has been performed with DIVAnd (Barth et al., 2014) version 2.4.0. DIVAnd has been implemented in the programming language Julia (https://github.com/gher-ulg/DIVAnd.jl) and is used in conjunction with the Jupyter notebooks (https://jupyter.org/), a web-based interactive computational environment for creating and sharing documents that contain live code, equations, visualizations and narrative text. This is particularly convenient for climatology generation, because the input files, analysis parameters, visualisations and outputs can be defined directly in a notebook.

2.2.1. Domain definition

The Mediterranean Sea is a semi-enclosed sea connected to the Atlantic Ocean by the Gibraltar Strait and to the Marmara Sea by the Dardanelles. The Mediterranean Sea domain includes a small Atlantic box (Figure 11) in order to obtain a realistic representation of the Gibraltar Straight-Alboran Sea region. The topography of SDC_MED_CLIM_TS_V1 has been generated using the new GEBCO_2019 Grid - the latest **global bathymetric product** released by the General Bathymetric Chart of the Oceans (GEBCO, Olson et al., 2014). The GEBCO_2019 product provides global coverage on a 15 arc-second grid.

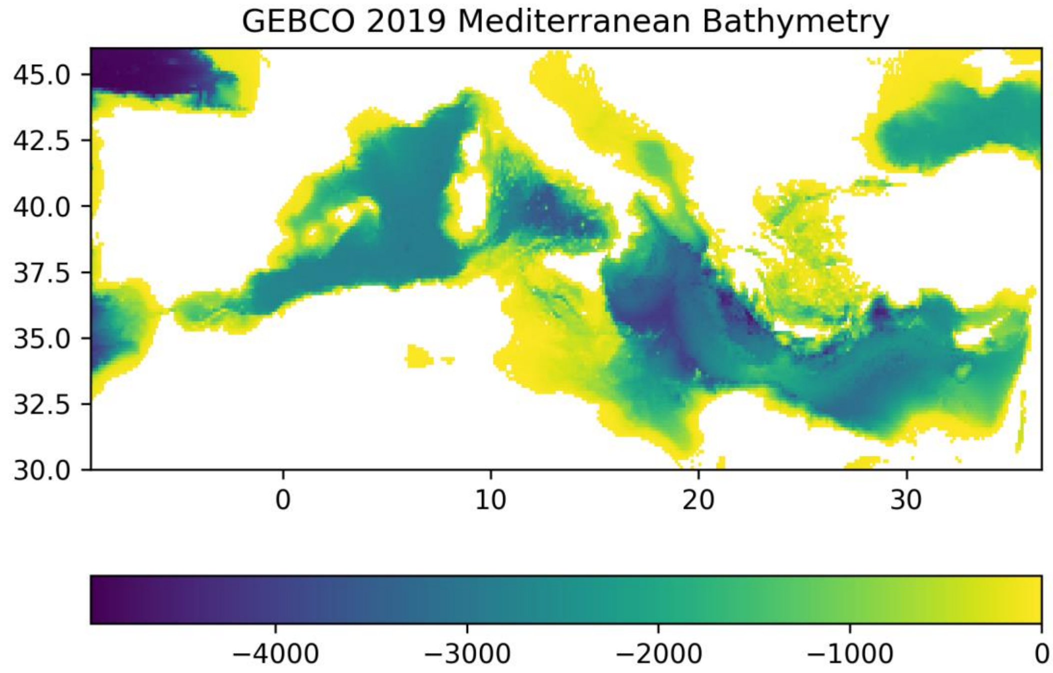


Figure 11 Mediterranean Sea bathymetry from GEBCO_2019 Grid product (Olson et al., 2014).

The **land-sea mask** (Figure 12) has the same dimensions (367x129x92) as the climatology grid and it was produced started from the GEBCO_2019 bathymetry, additionally these regions have been masked:

- Sea of Marmara
- Some isolated grid cells

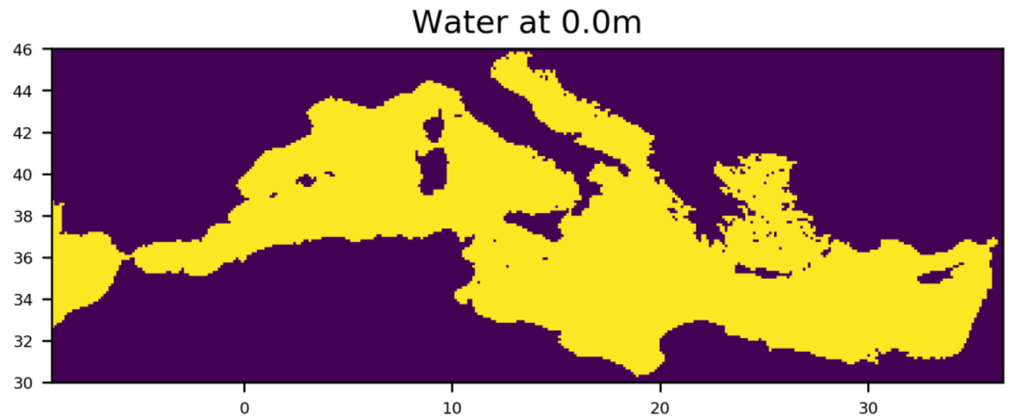


Figure 12 Land-sea mask at the surface.

2.2.2. DIVAnd settings

Spatial coverage:

Longitude: 9.25°W-36.5°E;

Latitude: 30-46°N;

Vertical: 0-4500m.

Horizontal resolution: 1/8°

Horizontal grid: 367x129

Vertical resolution: 92 depth levels (as in WOA18):

- 0:5:100m
- 125:25:500m;
- 500:50:2000m;
- 2100:4500m.

Temporal resolution:

Monthly and seasonal for periods:

- 1955 – 2017;
- 1955 – 1984;
- 1985 – 2017.

Seasonal for periods

- 1955 – 1964;
- 1965 – 1974;
- 1975 – 1984;
- 1985 – 1994;
- 1995 – 2004;
- 2005 – 2017.

Seasons definition: months 1, 2, 3 = winter; 4, 5, 6 = spring; 7, 8, 9 = summer; 10, 11, 12 = autumn.

Background field

The background field has been defined as in *Simoncelli et al. (2015)* to obtain large scale spatial trend fields using a large horizontal correlation length equal to 10 degrees, five times the correlation length used for the analysis. Salinity background is annual, while temperature background is monthly but computed considering a sliding three-month window. Three background fields having different time coverages have been used to run the analyses:

1. 1955-2017 background for the 1955-2017 analysis
2. 1955-1984 background for the 1955-1984 and 1955-1964, 1965-1974 and 1975-1984 analyses;
3. 1985-2017 background for the 1985-2017 and 1985-1994, 1995-2004 and 2005-2017 analyses.

The **surfextend** (false)option has not been activated and **memtofit** parameter, controlling how to cut the domain depending on the memory remaining available for inversion, is equal to

125. **memtofit** depends on computer RAM and it allows to utilize as much memory as possible. This is setting for 32 Gb RAM.

The **correlation length** (Lc) is isotropic and equal to 2 degrees for the analysis and to 10 degrees for the background field estimation (see Table 3). The vertical correlation length is zero.

The **epsilon2** parameter is the error variance of the observations (normalized by the error variance of the background field). If **epsilon2** is a scalar, as in the present analysis (see Table 3), all observations have the same error variance and their errors are decorrelated.

Table 3 SDC_MED_CLIM_TS_V1 correlation length (Lc) and epsilon2 parameters' settings for Temperature and salinity background fields and analyses.

	T_Bkg monthly	T_An	S_Bkg annual	S_An
Lc (x,y)	10°	2°	10°	2°
epsilon2	6.0	0.6	6.0	0.6

2.2.3. A posteriori QC

More data have been discarded from the analysis by visual inspection of climatological fields resulting in anomalous features. In particular some cruises have been flagged as bad data and excluded from the final production analysis.

The computation of residuals between the analysis field and the input observations has been activated aiming at removing automatically anomalous data through an iterative process. The present climatology has been produced through a two-step process which computes the residuals first and then re-run the analysis without the observations with residuals outside the intervals:

- -11PSU < Salinity < 6PSU
- -10°C< Temperature <10°C

This phase of analysis has to be optimized, it needs further tuning of the acceptable residuals and to increase the number of iterations.

3. Climatology

The climatological maps of the produced fields are displayed section 3.1 (Temperature) and 3.2 (Salinity). Please refer to Annex1 for the full list of produced climatological fields.

3.1. Temperature

Figure 13, Figure 14, Figure 15 shows the monthly temperature climatologies at the surface for the whole time period, the pre-EMT (Eastern Mediterranean Transient) and post-EMT periods respectively. Figure 16, Figure 17,Figure 17 Figure 18 show the temperature monthly fields at 300m.

Decadal temperature seasonal fields at the surface are displayed in Figure 19, at 300m depth in Figure 20.

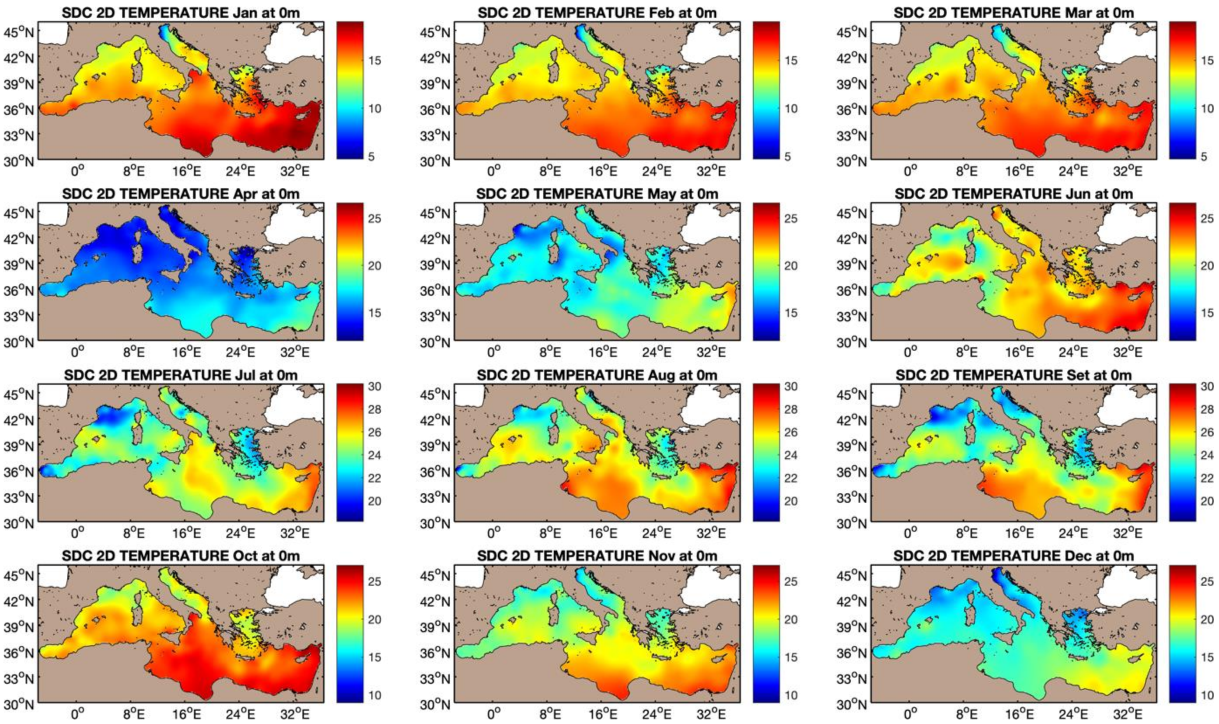


Figure 13 SDC_MED_CLIM_TS_V1_1 monthly temperature at the surface for 1955-2017 time period from January (top left) to December (bottom right). Please notice that the colormap varies per row (season).

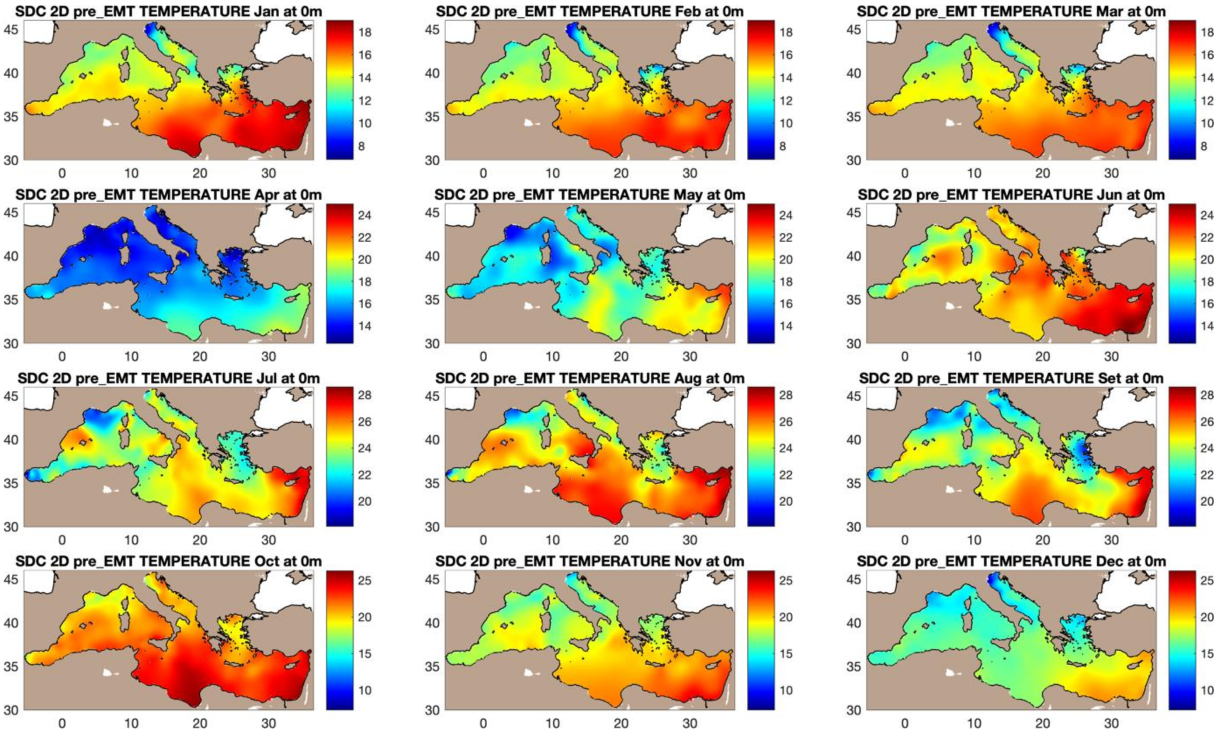


Figure 14 SDC_MED_CLIM_TS_V1_2 monthly temperature at the surface for 1955-1984 time period (pre-Eastern Mediterranean Transient), from January (top left) to December (bottom right). Please notice that the colormap varies per row (season).

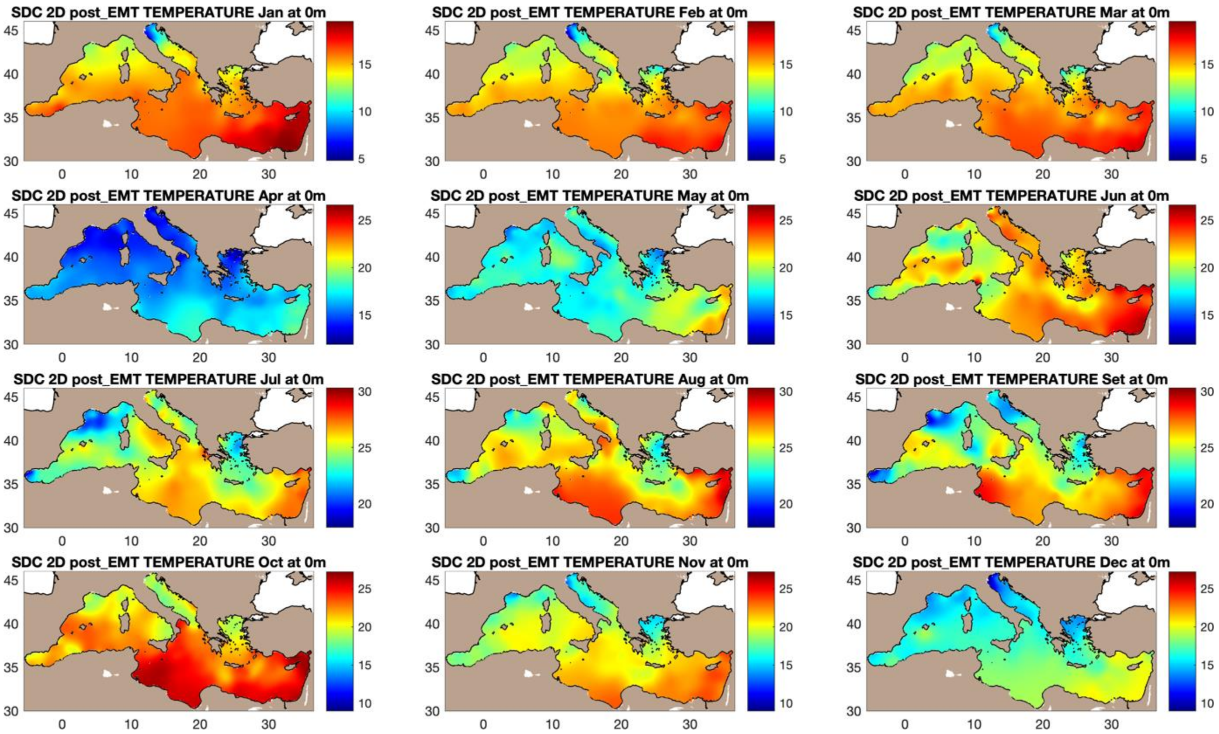


Figure 15 SDC_MED_CLIM_TS_V1_3 monthly temperature at the surface for 1985-2017 time period (post-Eastern Mediterranean Transient), from January (top left) to December (bottom right). Please notice that the colormap varies per row (season).

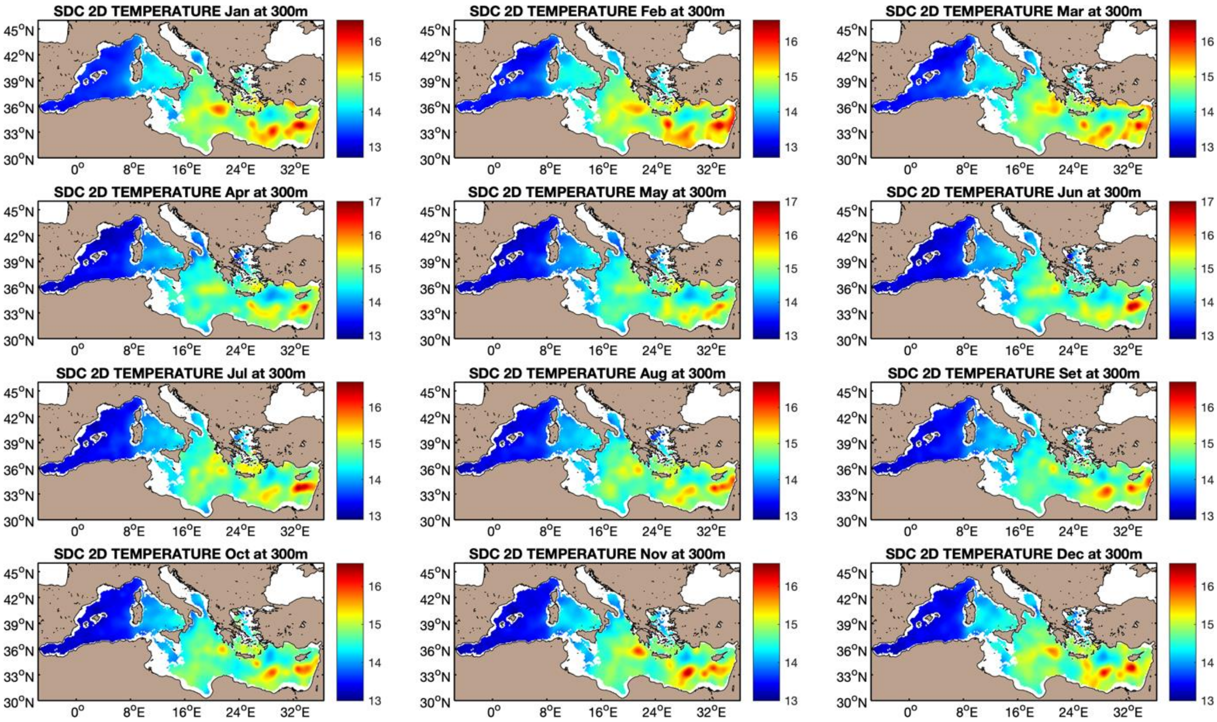


Figure 16 SDC_MED_CLIM_TS_V1_1 monthly temperature at 300m (intermediate water) for 1955-2017 time period from January (top left) to December (bottom right). Please notice that the colormap varies per row (season).

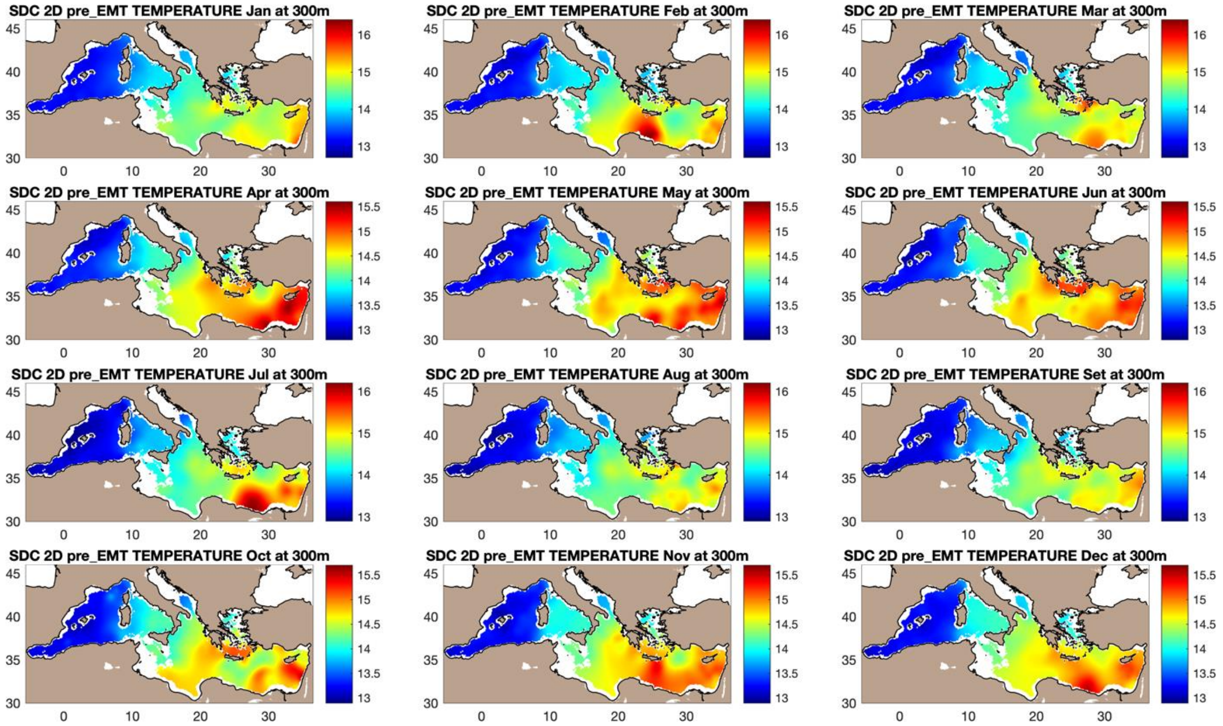


Figure 17 SDC_MED_CLIM_TS_V1_2 monthly temperature at 300m (intermediate water) for 1955-1984 time period (pre-Eastern Mediterranean Transient), from January (top left) to December (bottom right). Please notice that the colormap varies per row (season).

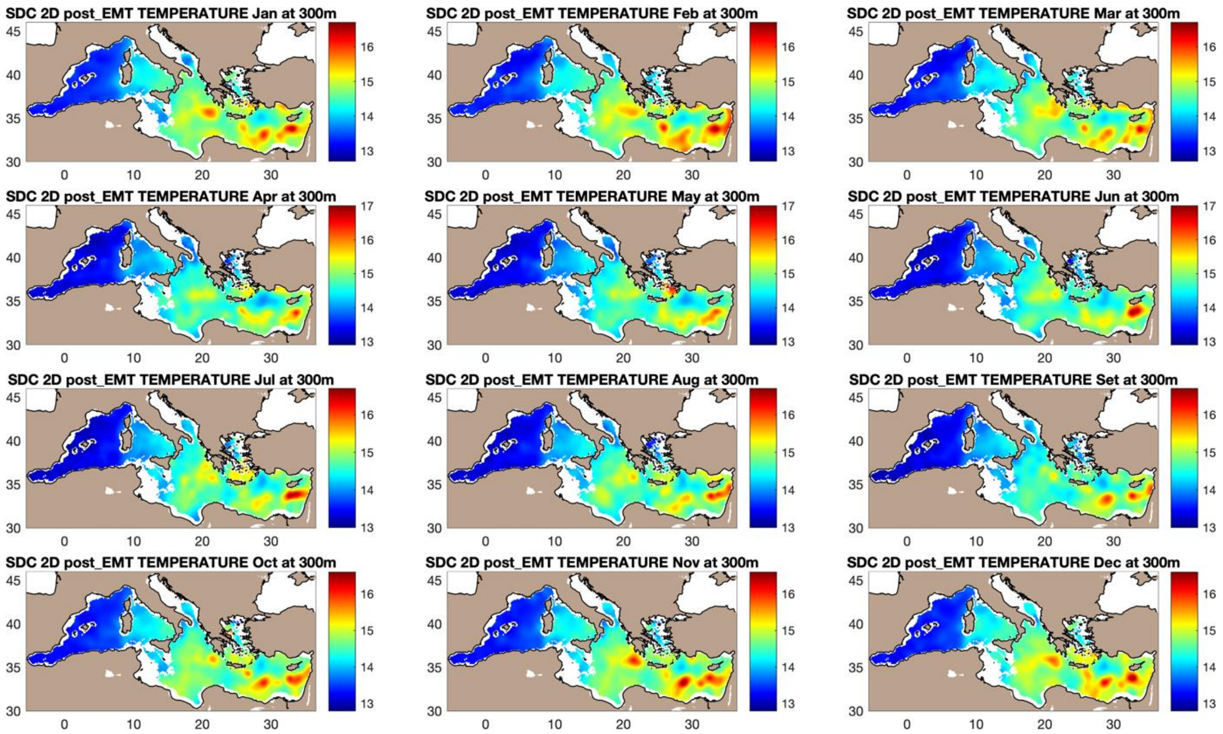


Figure 18 SDC_MED_CLIM_TS_V1_3 monthly temperature at 300m (intermediate water) for 1985-2017 time period (post-Eastern Mediterranean Transient), from January (top left) to December (bottom right).

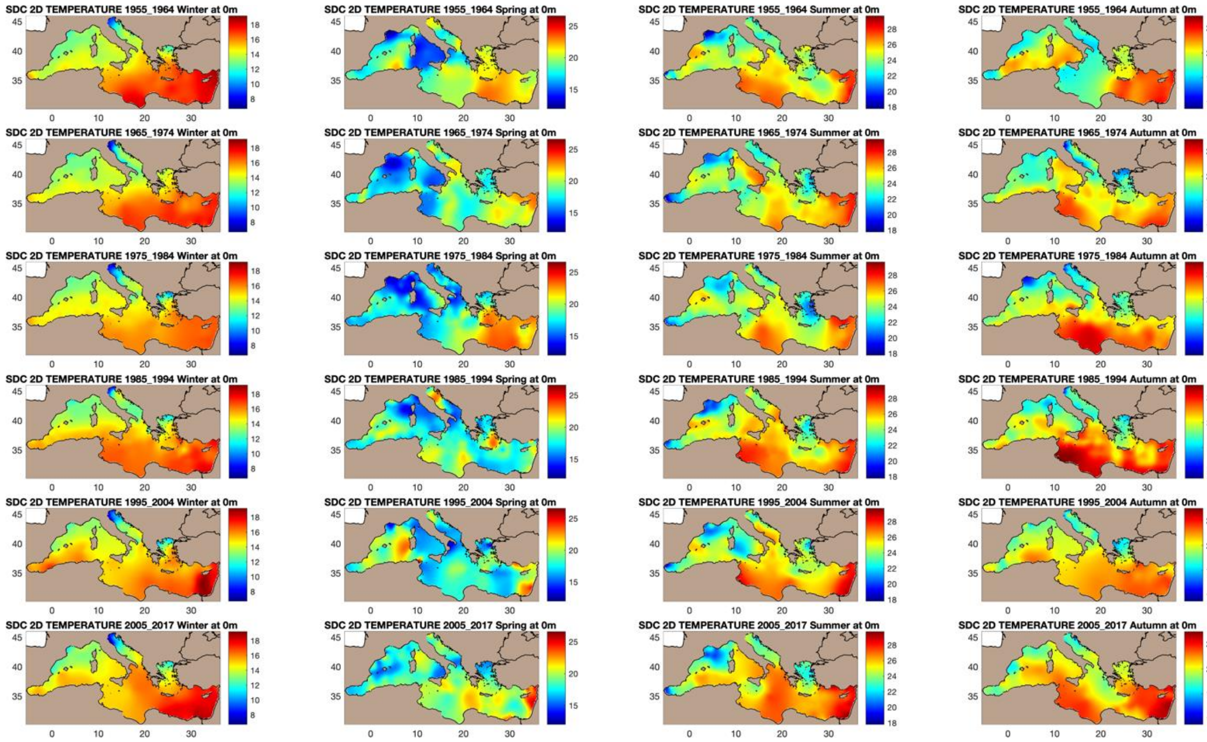


Figure 19 SDC_MED_CLIM_TS_V1_4 seasonal temperature fields (seasons from left to right) at the surface for six decades (from top to bottom): 1955-1964; 1965-1974; 1975-1984; 1985-1994; 1995-2004; 2005-2017. Please notice that the colormap varies per column/season.

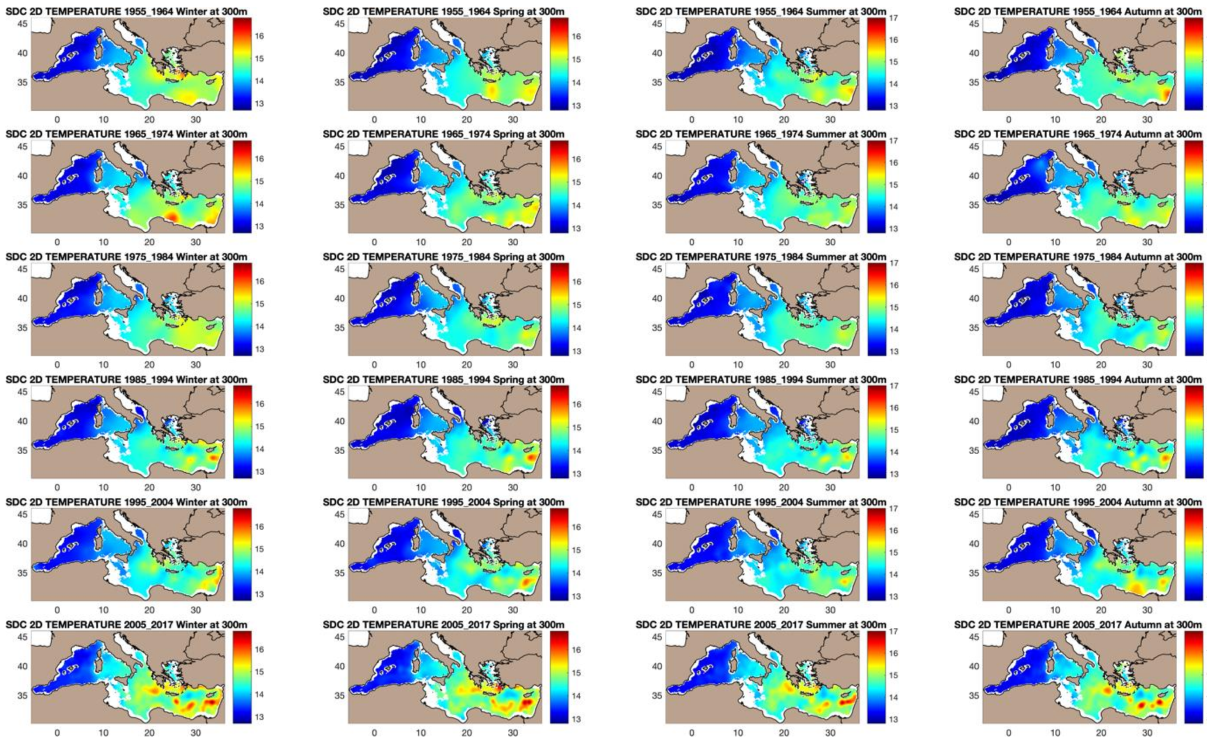


Figure 20 SDC_MED_CLIM_TS_V1_4 seasonal temperature (seasons from left to right) at 300m depth for six decades (from top to bottom): 1955-1964; 1965-1974; 1975-1984; 1985-1994; 1995-2004; 2005-2017. Please notice that the colormap varies per column/season.

3.2. Salinity

Figure 21, Figure 22, Figure 23 show the monthly salinity climatologies at the surface for the whole time period 1955-2017, the pre-EMT (Eastern Mediterranean Transient) and post-EMT periods respectively. Figure 24, Figure 25, Figure 26 show the salinity monthly fields at 300m.

Decadal salinity winter fields at the surface are displayed in Figure 27, at 300m depth in Figure 28.

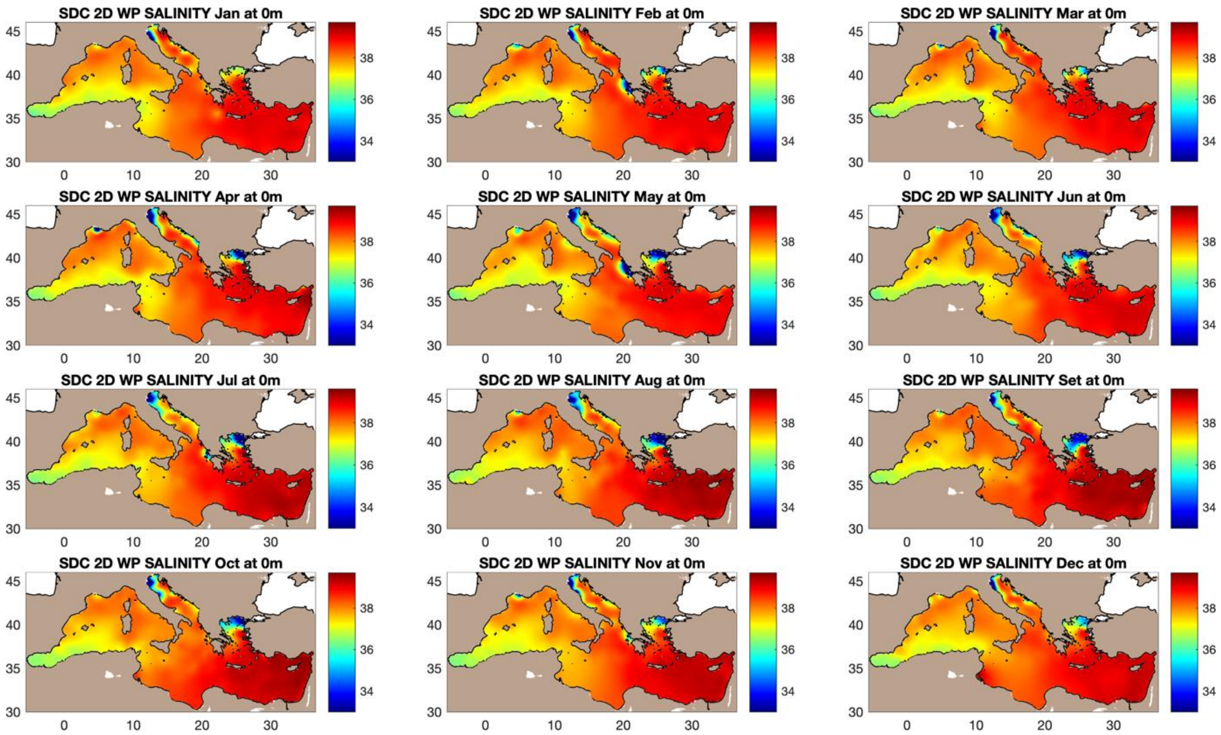


Figure 21 SDC_MED_CLIM_TS_V1_2 monthly salinity at the surface for 1955-2017 time period from January (top left) to December (bottom right).

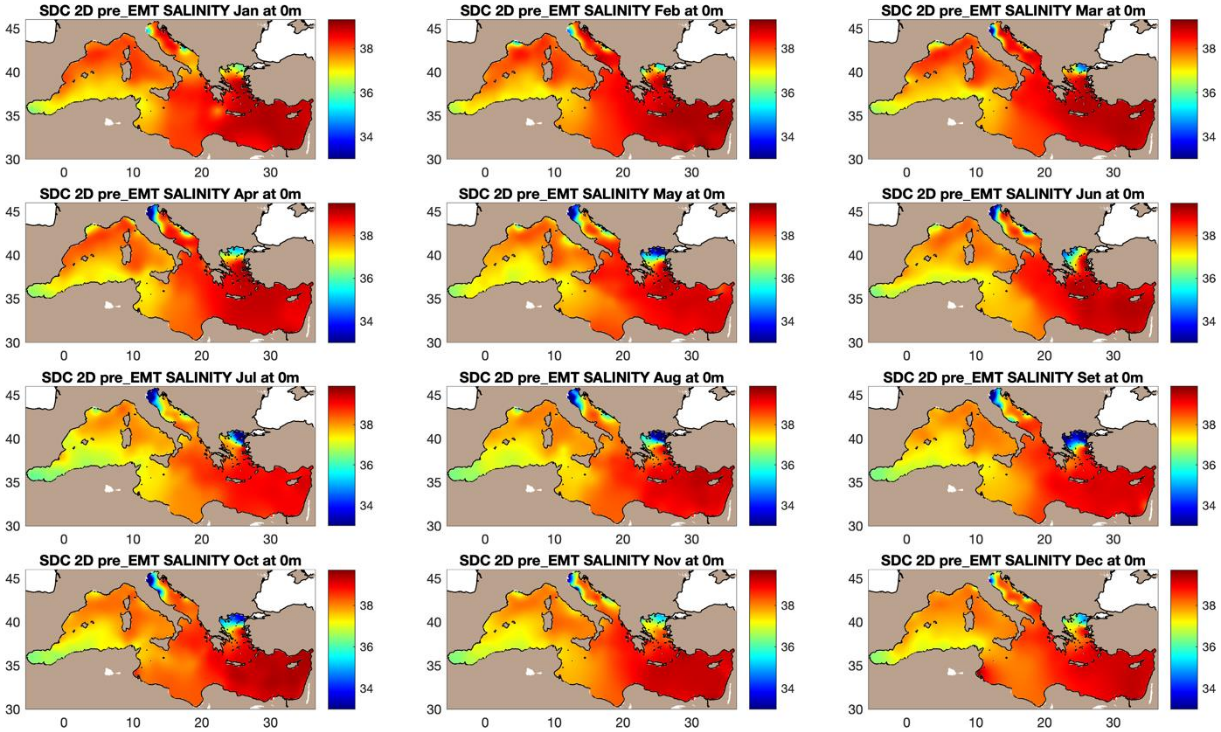


Figure 22 SDC_MED_CLIM_TS_V1_2 monthly salinity at the surface for 1955-1984 time period (pre-Eastern Mediterranean Transient), from January (top left) to December (bottom right).

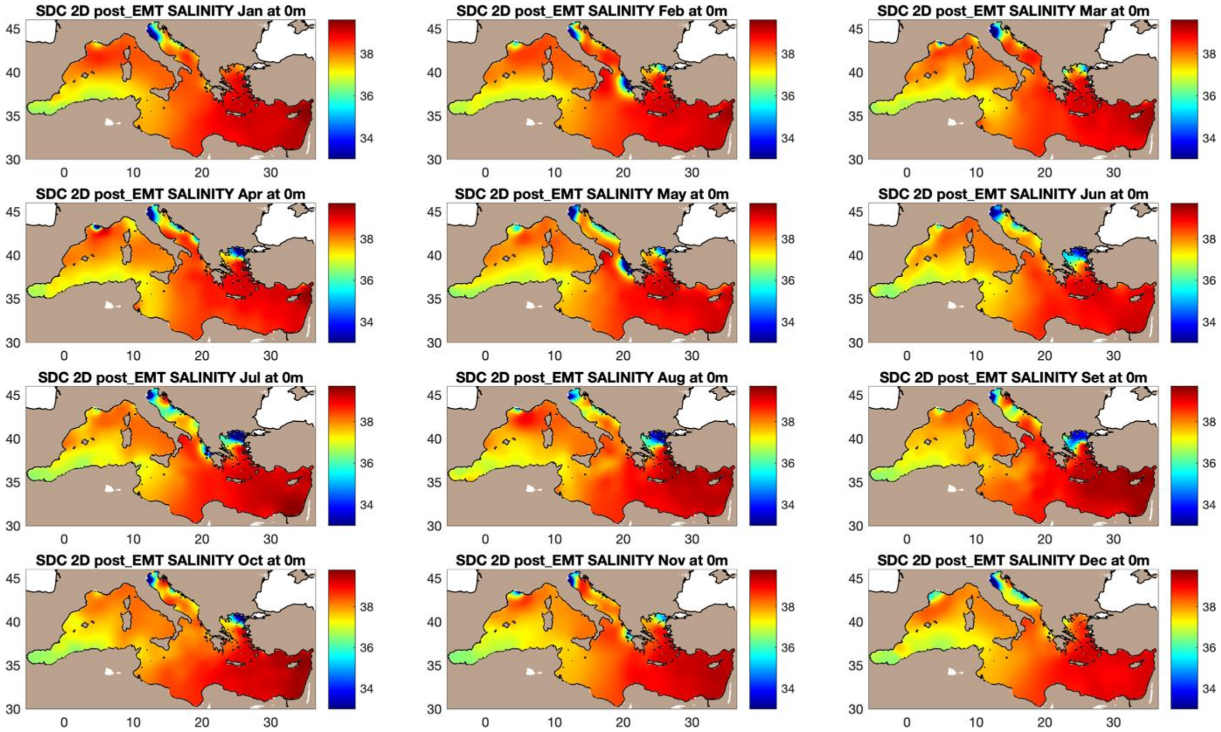


Figure 23 SDC_MED_CLIM_TS_V1_3 monthly salinity at the surface for 1985-2017 time period (post-Eastern Mediterranean Transient), from January (top left) to December (bottom right).

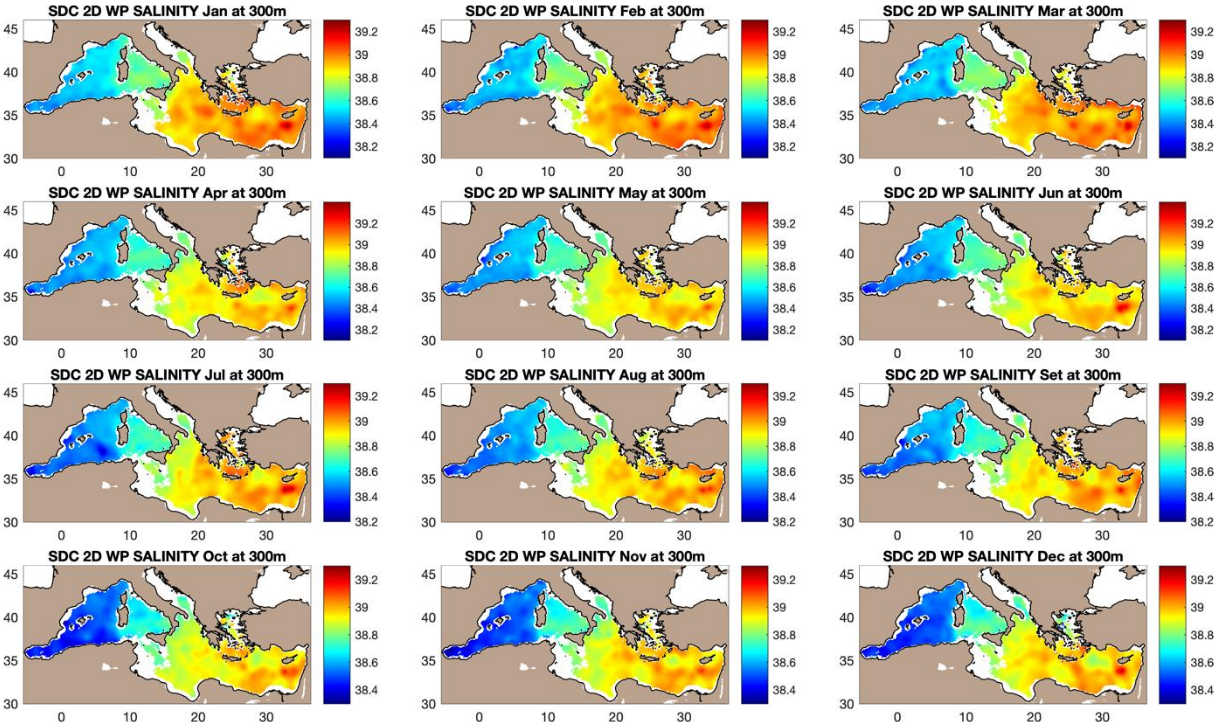


Figure 24 SDC_MED_CLIM_TS_V1_1 monthly salinity at 300m (intermediate water) for 1955-2017 time period from January (top left) to December (bottom right).

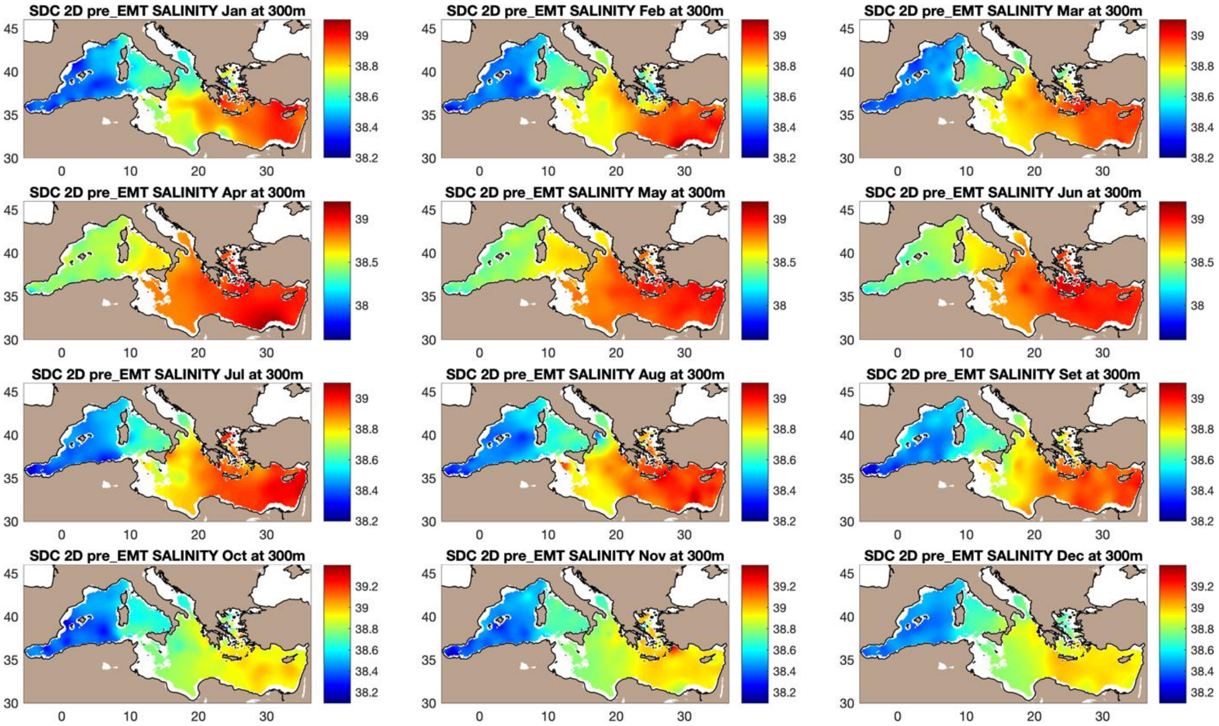


Figure 25 SDC_MED_CLIM_TS_V1_2 monthly salinity at 300m (intermediate water) for 1955-1984 time period (pre-Eastern Mediterranean Transient), from January (top left) to December (bottom right).

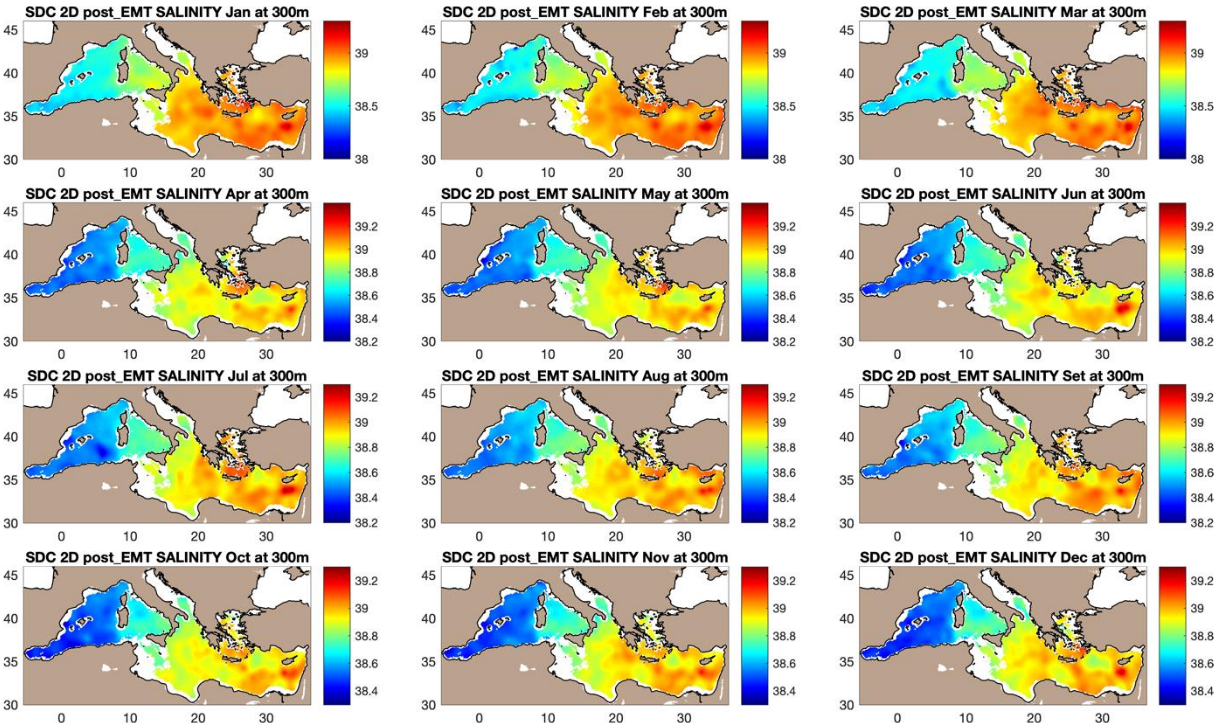


Figure 26 SDC_MED_CLIM_TS_V1_3 monthly salinity at 300m (intermediate water) for 1985-2017 time period (post-Eastern Mediterranean Transient), from January (top left) to December (bottom right).

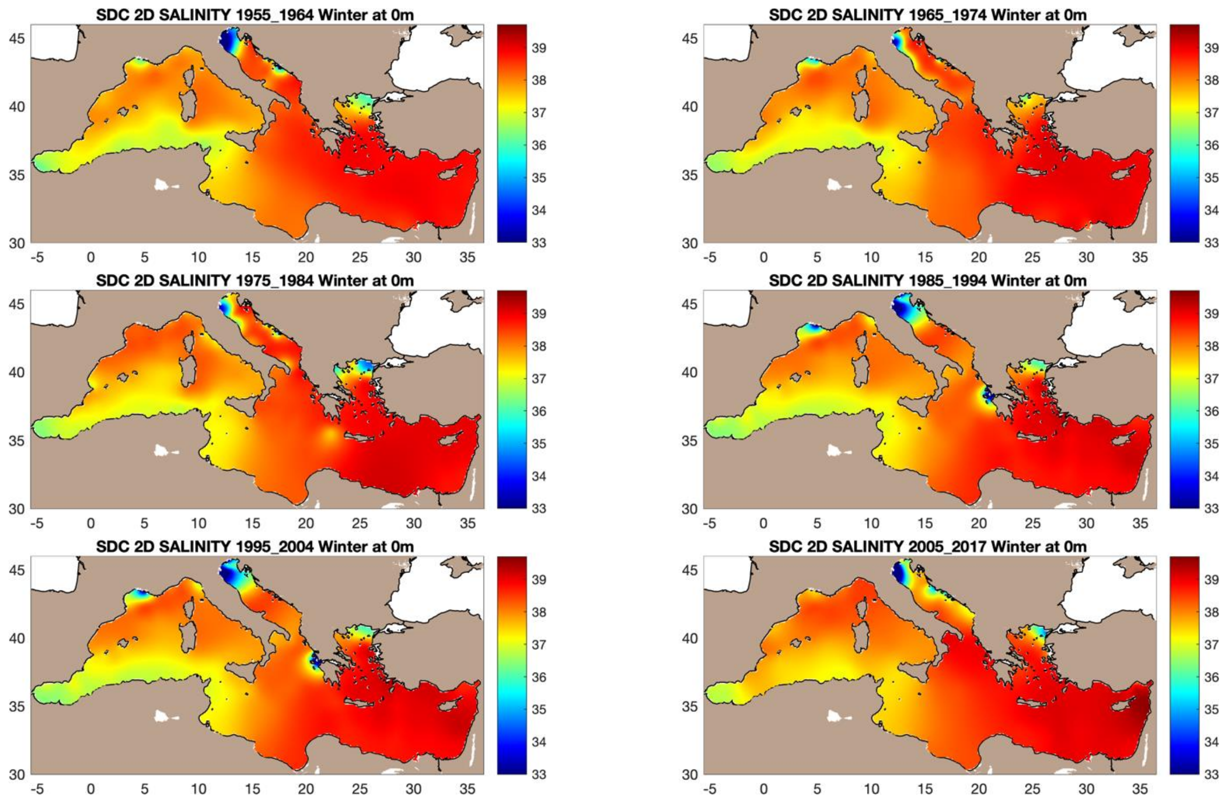


Figure 27 SDC_MED_CLIM_TS_V1_4 winter salinity (seasons from left to right) at the surface for six decades: 1955-1964; 1965-1974; 1975-1984; 1985-1994; 1995-2004; 2005-2017.

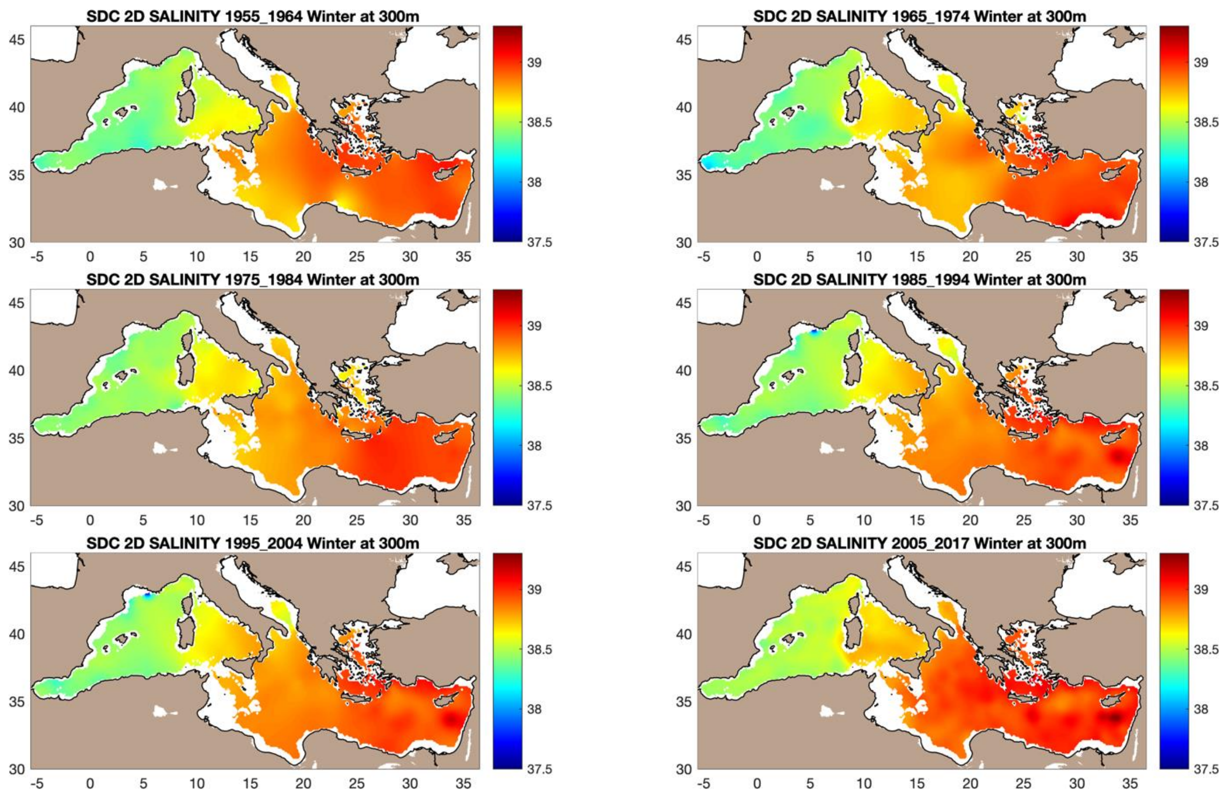


Figure 28 SDC_MED_CLIM_TS_V1_4 winter salinity (seasons from left to right) at 300m (intermediate water) for six decades: 1955-1964; 1965-1974; 1975-1984; 1985-1994; 1995-2004; 2005-2017.

4. Consistency analysis

4.1. Validation with SeaDataNet2 climatology

The first step of consistency analysis aims at comparing SDC_MED_CLIM_TS_V1_1 (monthly over the whole time period 1955-2017, see table in Appendix 1) versus SDN2 V1.1 climatology (*Simoncelli 2015a,b*) produced in the framework of SeaDataNet2 project. The objective is to assess the new SDC_MED_CLIM_TS_V1_1 climatology produced with the new DIVAnd software, keeping a similar set up of previous DIVA product.

SDN2 V1.1 has been computed considering the input data set from *Simoncelli 2014* which spans the time period 1900-2013. SDC_MED_CLIM_TS_V1_1 has been generated with DIVAnd 2.4.0, while SDN V1.1 with DIVA 4.6.9. The two fields have the same horizontal grid (1/8 of degree) but SDC_MED_CLIM_TS_V1_1 has increased vertical resolution (92 WOA18 standard levels instead of 33 IODE standard levels). The intercomparison has been done on the coincident depth levels by mean of bias and RMSE metrics and by visual inspection.

Table 4 summary of SDN2 V1.1 and SDC_MED_CLIM_TS_V1_1 climatologies

	SDN2 V1.1	SDC_MED_CLIM_TS_V1_1
time coverage	1900-2013	1955-2017
horizontal resolution	1/8°	1/8 deg
vertical resolution	33 iode levels	92 WOA levels
Interpolation tool	DIVA 4.6.9	DIVAnd 2.4.0
L	2° analisi 10° background	2° analisi 10° background

4.1.1. Temperature

Figure 29 displays BIAS and RMSE hovmoller plots computed from SDC_MED_CLIM_TS_V1_1 and SDN_V1.1 temperature fields, that suggest quite good consistency of the two fields with a mean bias of 0.1°C (SDC climatology warmer than SDN2) and a mean RMSE of 0.24°C. Negative anomalies appear at the surface level (SDC_MED_CLIM_TS_V1_1 colder than SDN V1.1 and positive anomalies below the surface layer, with maximum values below 2500m where data are very sparse. June and December present the largest surface negative anomalies, while in August there happen the largest positive anomalies between 30 and 50m.

Figure 30 presents some temperature maps to show the different pattern of SDC and SDN2 temperature fields. The different time coverage of the two products should be considered to interpret the main differences of the temperature fields. SDC maps present in general smaller scale features than the SDN2 ones.

The temperature mean monthly profiles over the Mediterranean Sea (without the Atlantic box) of Figure 31 and their relative standard deviation profile suggest that SDC temperature climatology has a smaller variability below 2000m than SDN2 one. SDC values at 4500m are insead not reasonable, due to the small number of grid points at this level.

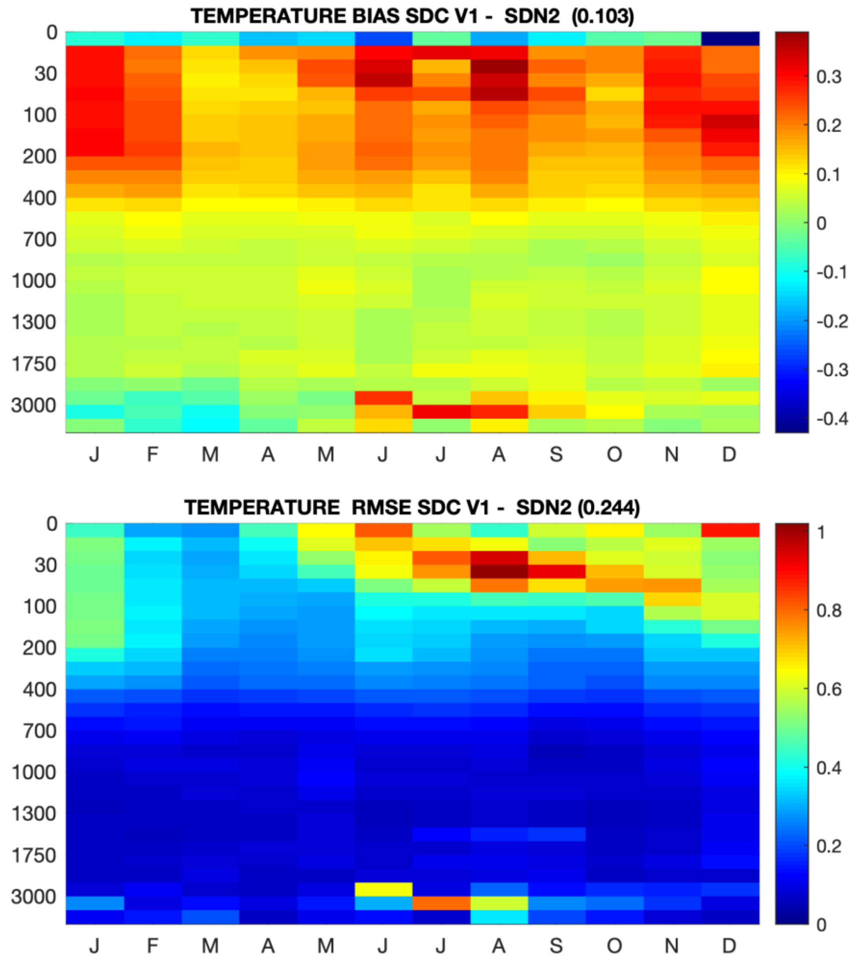
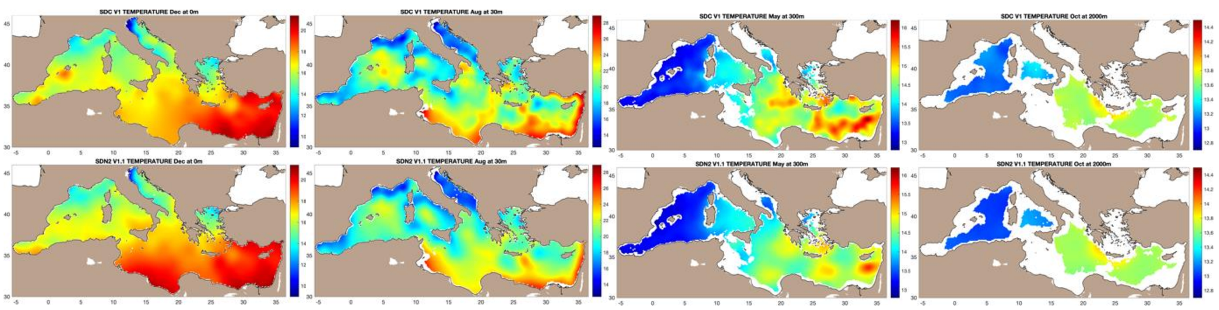


Figure 29 BIAS and RMSE hovmoller plots that summarizes the main differences between SDC_MED_CLIM_TS_V1_1 and SDN2_V1.1 temperature climatologies.



a b c d

Figure 30 Temperature maps from SDC_MED_CLIM_TS_V1_1 (top) computed over the whole time period 1955-2017 and SDN_V1.1: a) in December at the surface; b) in August at 30m depth; c)in May at 300m; in October at 2000m.

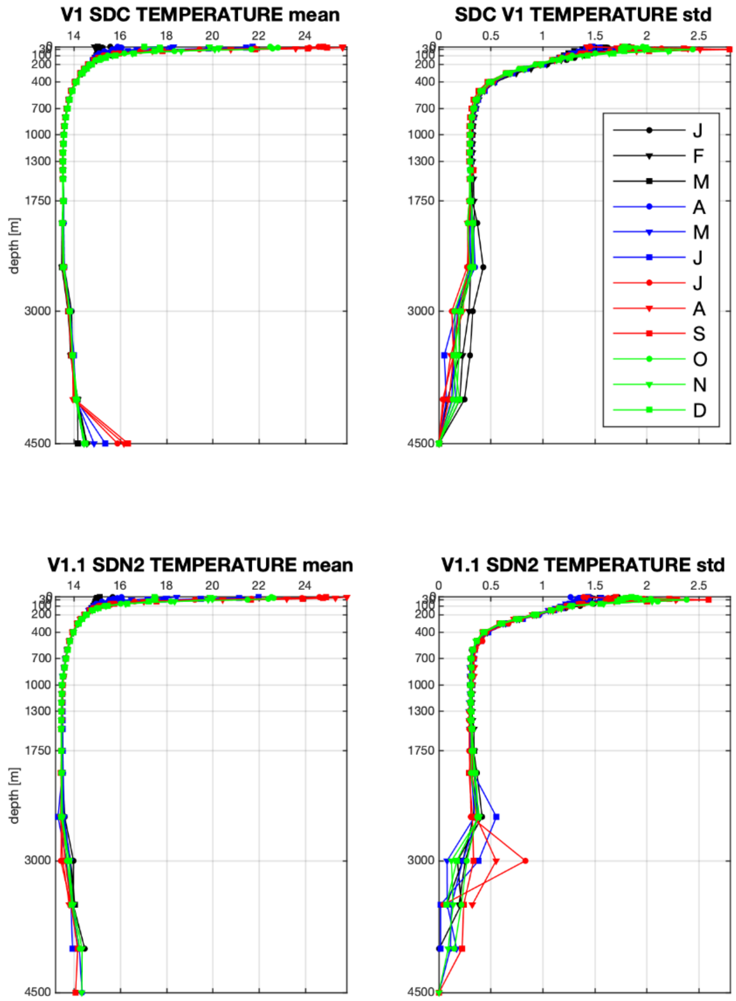


Figure 31 Monthly mean profiles of Temperature fields (left panels) and relative standard deviation profiles (right panels) computed over the Mediterranean Sea: (top) SDC_MED_CLIM_TS_V1, (bottom) SDN2 V1.1.

4.1.2. Salinity

Figure 32 displays salinity bias and RMSE hovmoller plots that suggest a good consistency of the two fields, with 0.03psu of mean bias and 0.08psu of RMSE. SDC surface level appears fresher than SDN2 one, while the largest RMSE value characterizes the May surface fields. Figure 33 explains where the main differences originates, in particular in Figure 33a fresh waters appear in SDC maps along the coast of Greece, along the eastern flank of the Northern Ionian Sea and in the Northern Aegean Sea, where there is the inflow of Black Sea water. The smallest scales of SDC climatology are visible at 300m in Figure 33c.

The seasonal variability of SDC salinity fields seems slightly larger than SDN2 below 2000m, in particular the 0.1 psu difference between June and July mean values is not probable. However, the number of grid points at such levels is small and this could make the average estimate less robust.

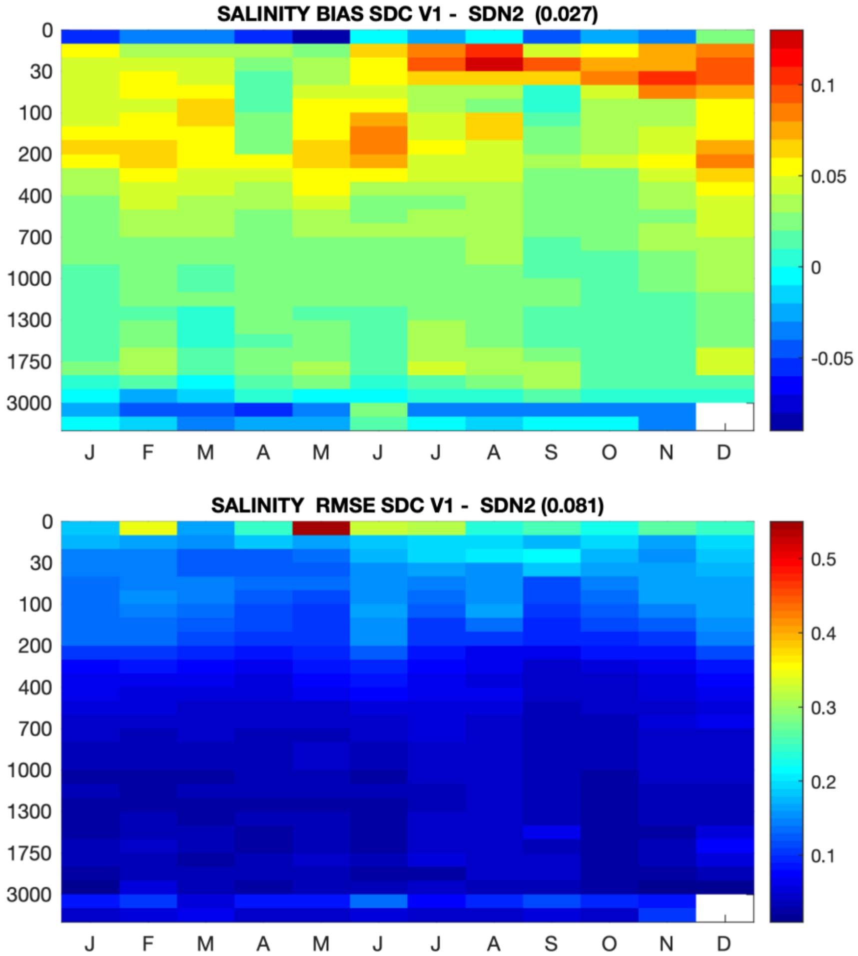


Figure 32 BIAS and RMSE hovmoller plots that summarizes the main differences between SDC_MED_CLIM_TS_V1_1 and SDN2_V1.1 salinity climatologies.

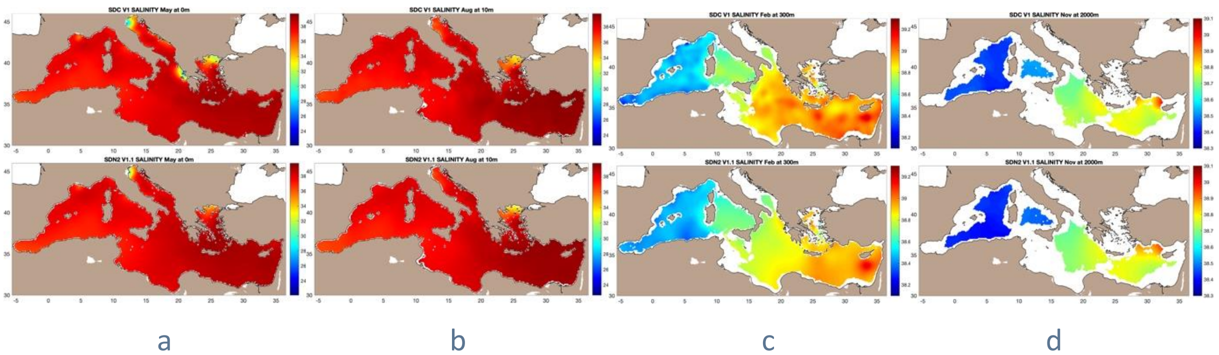


Figure 33 Salinity maps from SDC_MED_CLIM_TS_V1_1 (top) computed over the whole time period 1955-2017 and SDN_V1.1: a) in May at the surface; b) in August at 10m depth; c) in February at 300m; in November at 2000m.

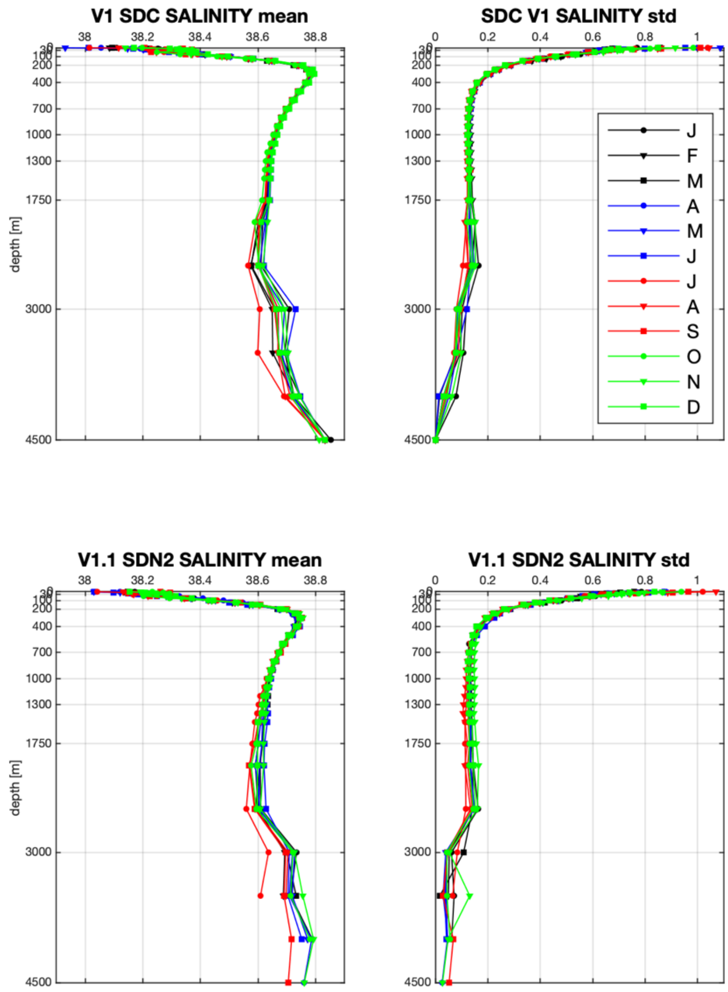


Figure 34 Monthly mean profiles of Salinity fields (left panels) and relative standard deviation profiles (right panels) computed over the Mediterranean Sea: (top) SDC_MED_CLIM_TS_V1, (bottom) SDN2 V1.1.

4.1.3. Error field

Figure 35 presents two example of error fields from SDC_MED_CLIM_TS_V1_1 and SDN2 V1.1 products. SDC_MED_CLIM_TS_V1_1 maps have observation locations overlaid to error fields, this was not feasible for SDN2 product. The error fields are very different, with much lower values in the latest product. This is the result of a different error field computation in DIVAnd but also of a much better data coverage and resolution in the SDC product.

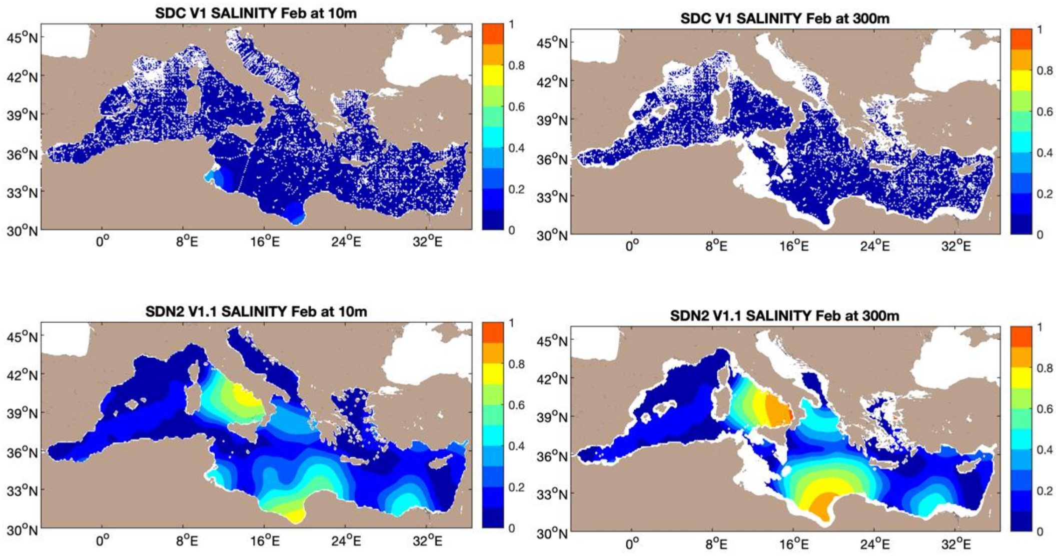


Figure 35 Error fields of SDC_MED_CLIM_TS_V1_1 (top) and SDN2 V1.1 (bottom) in February at 10m (left) and 300m (right).

4.2. Validation with the World Ocean Atlas 2018

A final consistency analysis has been done between SDC_MED_CLIM_TS_V1_1 (monthly fields 1955-2017, see table in Appendix 1) versus the World Ocean Atlas 2018 (WOA18) temperature (*Locarnini et al., 2018*) and salinity climatology (*Zweng et al., 2018*). The objective is to assess the main differences of SDC_MED_CLIM_TS_V1_1 versus WOA and highlights the added value of SDC regional product.

The last WOA18 climatology published in July 2019 has been compared to the SDC climatology, in specific the averaged decades monthly fields at ¼° degree of resolution have been considered to be compared with SDC_MED_CLIM_TS_V1_1 (1955-2017).

4.2.1. Temperature

Temperature monthly mean bias and RMSE are displayed in Figure 36. The bias is always positive indicating that SDC climatology is on average from 0.1 to 0.25 warmer than the WOA one, while the RMSE ranges from 0.23 (February) to 0.4 (November). This large positive bias can be explained from the characteristics of the products. The howmoller plots in Figure 37 show where the largest differences occur within the water column. While at the surface SDC_MED_CLIM_TS_V1_1 is in general colder than WOA18, the warm bias concentrate in the upper 200m layer and in November. The largest RMSEs are in August, September, October and November. The maps in Figure 38 show the temperature fields corresponding to the largest differences between the two considered data products. SDC climatology presents smaller scales features and stronger gradients than WOA18.

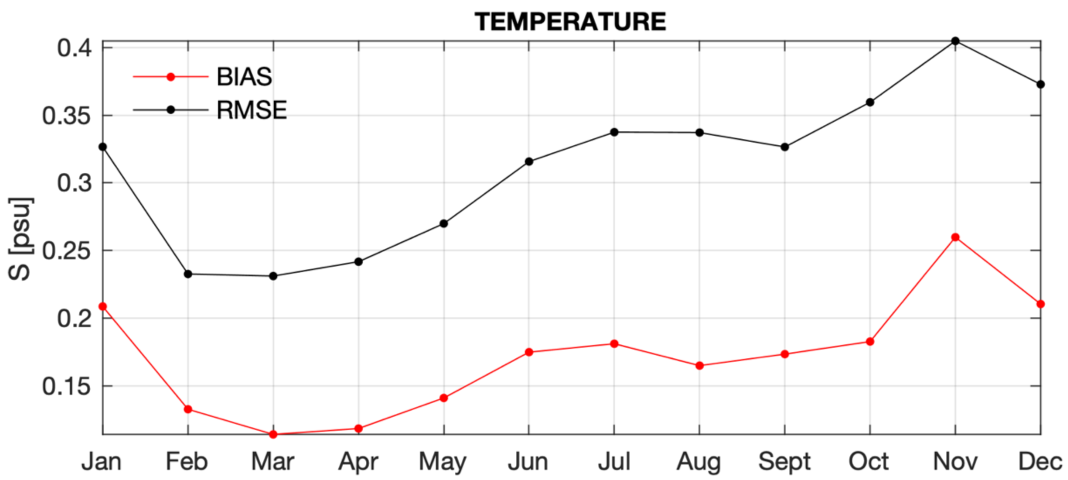
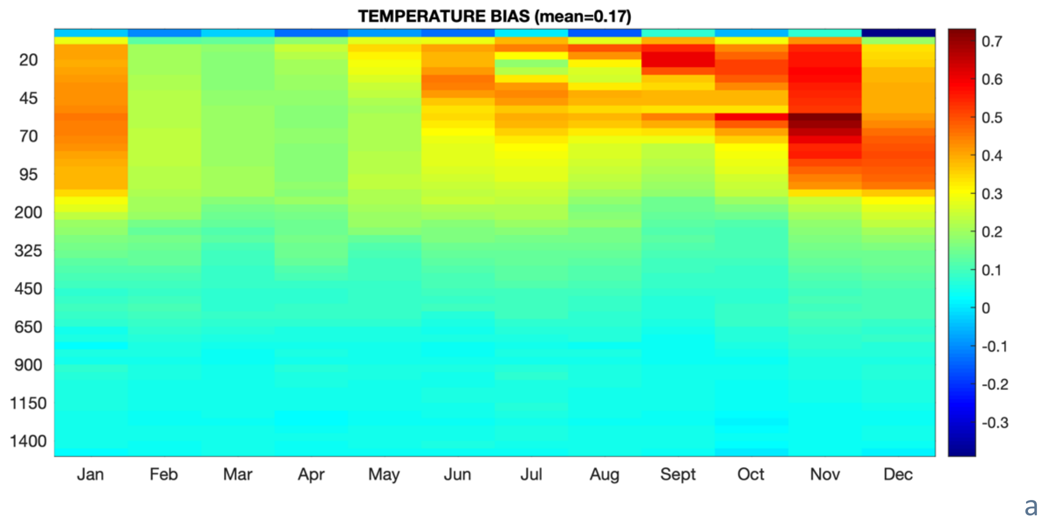


Figure 36 Basin monthly averages of bias and RMSE computed between SDC_MED_CLIM_TS_V1_1 and WOA2018 (averaged decades) temperature fields over the first 57 standard vertical levels (0-1500m).



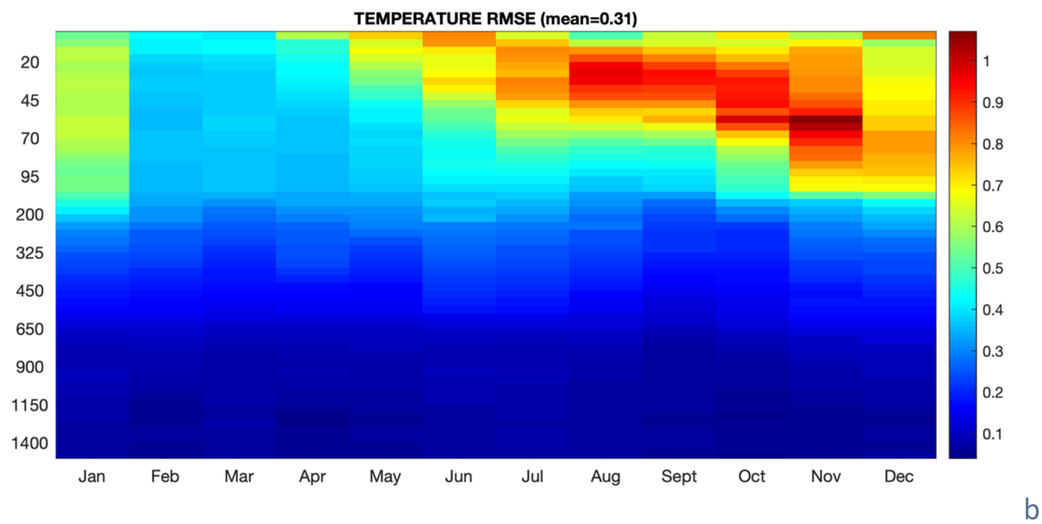
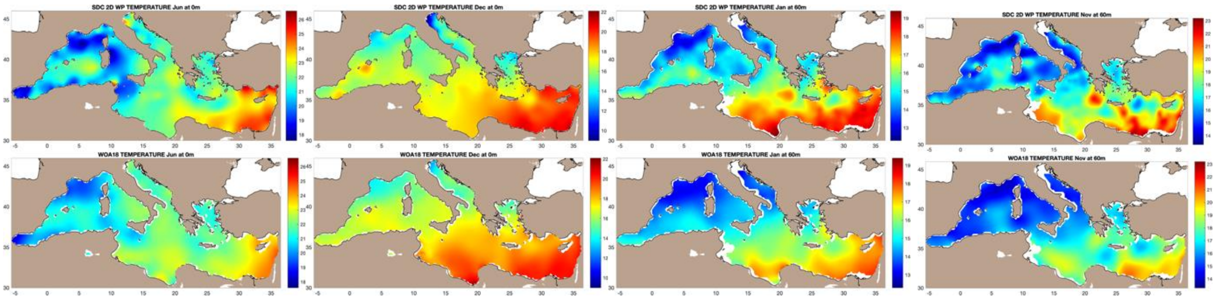


Figure 37 Hovmoller plots of monthly mean profiles of bias (a) and RMSE (b) computed between SDC_MED_CLIM_TS_V1_1 and WOA2018 (averaged decades) temperature fields over the first 57 standard vertical levels (0-1500m).



a b c d

Figure 38 Surface temperature maps from SDC_MED_CLIM_TS_V1_1 (top) and WOA2018 (bottom): a) in June; b) in December. Temperature maps at 60m: c) in January; d) in November.

4.2.2. Salinity

Salinity monthly mean bias and RMSE are displayed in Figure 39. The bias is always positive indicating that SDC climatology is on average from 0.01 to 0.03 saltier than the WOA one, while the RMSE ranges from 0.07 (October) to 0.09 (June, December). The howmoller plots in Figure 40Figure 37 show where the largest differences occur within the water column. While at the surface SDC_MED_CLIM_TS_V1_1 is in general fresher than WOA18, a positive bias characterizes the entire water column The largest RMSEs are ate the surface February, April, May and July. The maps in Figure 38 show some example salinity fields. SDC climatology presents smaller scales features and stronger coastal gradients than WOA18.

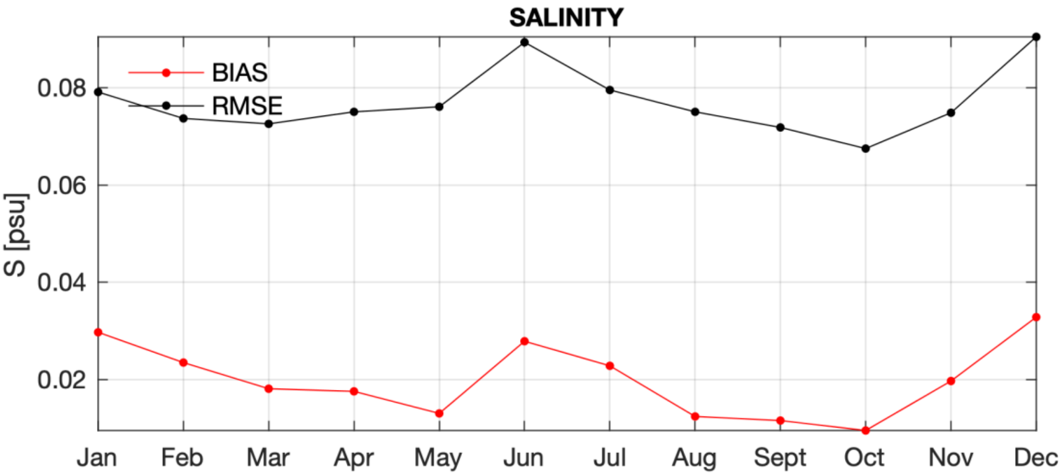


Figure 39 Basin monthly averages of bias and RMSE computed between SDC_MED_CLIM_TS_V1_1 and WOA2018 (averaged decades) salinity fields over the first 57 standard vertical levels (0-1500m).

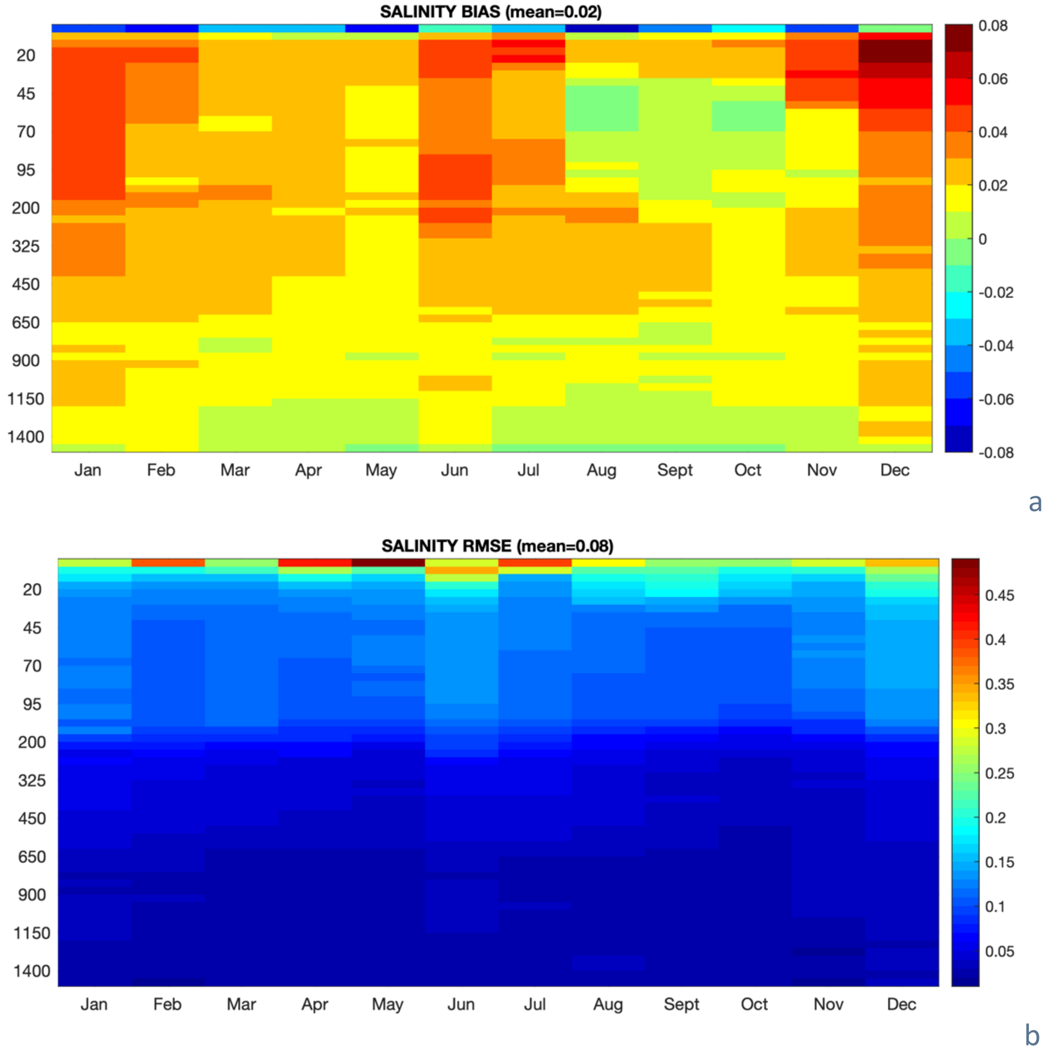


Figure 40 Hovmoller plots of monthly mean profiles of bias (a) and RMSE (b) computed between SDC_MED_CLIM_TS_V1_1 and WOA2018 (averaged decades) salinity fields over the first 57 standard vertical levels (0-1500m).

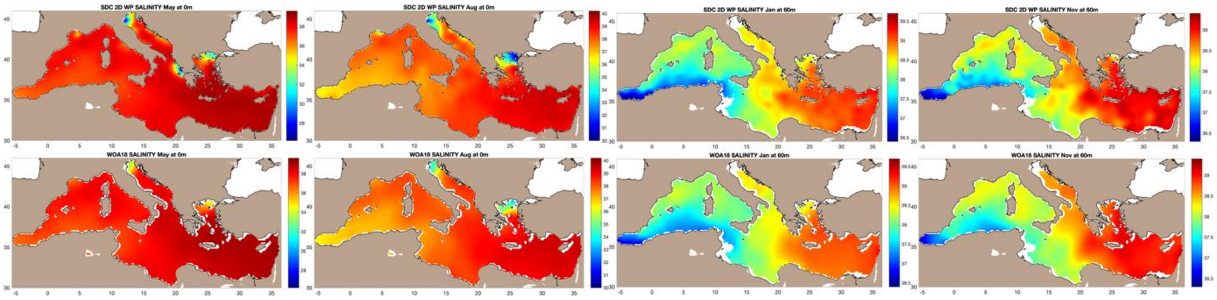


Figure 41 Surface salinity maps from SDC_MED_CLIM_TS_V1_1 (top) and WOA2018: a) in May; b) in August. Salinity maps at 60m: c) in January; d) in November.

5. Technical Specifications

Product Format

SDC_MED_CLIM_TS_V1	time period	Seasonal	Monthly
SDC_MED_CLIM_TS_V1_1955_2017_s_ SDC_MED_CLIM_TS_V1_1955_2017_m_	1955-2017	winter.nc spring.nc summer.nc fall.nc	jan.nc feb.nc mar.nc ... nov.nc dec.nc
SDC_MED_CLIM_TS_V1_1955_1984_s_ SDC_MED_CLIM_TS_V1_1955_1984_m_	1955-1984	X	X
SDC_MED_CLIM_TS_V1_1985_2017_s_ SDC_MED_CLIM_TS_V1_1985_2017_m_	1985-2017	X	X
SDC_MED_CLIM_TS_V1_1955_1964_s_ SDC_MED_CLIM_TS_V1_1965_1974_s_ SDC_MED_CLIM_TS_V1_1975_1984_s_ SDC_MED_CLIM_TS_V1_1985_1994_s_ SDC_MED_CLIM_TS_V1_1995_2004_s_ SDC_MED_CLIM_TS_V1_2005_2017_s_	1955-64 1965-74 1975-84 1985-94 1995-04 2005-17	X	

5.1. Product Usability

While every effort is made to produce an error free grid, some artefacts may still appear in the data set. If you find any anomaly in the climatology then please report them via email (simona.simoncelli@ingv.it), giving the problem specifications, and we will investigate.

Please consider that the first and the last climatology layer might not be reliable and use the presented consistency analysis results to evaluate the adequacy of the SDC_MED_CLIM_TS_V1 product to your scope.

The SDC_MED_CLIM_TS_V1_1 (1955-2017) fields have been produced to first assess the DIVAnd new software results versus the previous DIVA version, but its fields are very similar to the SDC_MED_CLIM_TS_V1_3 ones (1985-2017) due to the largest data availability in the recent decades. Moreover the Atlantic box has been considered as a buffer zone and it has been excluded from the consistency analysis.

5.2. Changes since previous version

In Section 4.1, Table 4, the main differences with the SDN2 temperature and salinity climatology have been summarized. The major upgrade are the uptake of the new DIVAnd software and the increase of the vertical resolution from 33 to 92 levels. While the previous climatology covered the time period 1900-2013, the present SDC climatological products includes also seasonal decades and pre (1955-1984) and post EMT (1985-2017) monthly climatologies.

Annex 1

File naming conventions: [PRO]_[REG]_[PROD]_[V]_[YYYY1]_[YYYY2]_[T], where:

[PRO] - project

[REG] - region

[PROD] - product

[V] - variable

[YYYY1]_[YYYY2] - time coverage

[T] - temporal resolution (m=monthly, s=seasonal, a=annual)

Hereafter some examples:

SDC_MED_CLIM_T_1955_2017_m → monthly temperature climatology for the Mediterranean Sea covering the time period 1955-2017

SDC_MED_CLIM_T_1955_2017_s → seasonal temperature climatology for the Mediterranean Sea covering the time period 1955-2017

SeaDataCloud climatological fields released for the Mediterranean Sea region.

Name	spatial coverage	horizontal resolution	vertical levels	Time coverage	Seasonal	Monthly	External data sets
SDC_MED_CLIM_TS_V1_**1**	9.25W-36.5°E 30-46°N	1/8°	WOA18 standard levels	1955-2017	X	X	CORA5.2
SDC_MED_CLIM_TS_V1_**2**	9.25W-36.5°E; 30-46°N	1/8°	WOA18 standard levels	1955-1984	X	X	CORA5.2
SDC_MED_CLIM_TS_V1_**3**	9.25W-36.5°E; 30-46°N	1/8°	WOA18 standard levels	1985-2017	X	X	CORA5.2
SDC_MED_CLIM_TS_V1_**4**	9.25W-36.5°E; 30-46°N	1/8°	WOA18 standard levels	1955-1964 1965-1974 1975-1984 1985-1994 1995-2004 2005-2017	X		CORA5.2

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List of acronyms

Acronym	Definition
CDI	Common Data Index
CLIM	Climatology
CMEMS	Copernicus Marine Environment Monitoring Service
DATA	Aggregated Dataset
DIVA	Data-Interpolating Variational Analysis (software)
DOI	Digital Object Identifier
EDMO	European Directory of Marine Organisations (SeaDataNet catalogue)
IODE	International Oceanographic Data and Information Exchange (IOC)
MED	Mediterranean Sea
ODV	Ocean Data View Software
QC	Quality Checks
QF	Quality Flags
SDC	SeaDataCloud
SDN	SeaDataNet
TS	Temperature and Salinity
WOA	World Ocean Atlas
WP	Work Package