Product Information Document (PIDoc)

SeaDataCloud Temperature and Salinity Climatology for the Arctic Ocean (Version 1)

SDC_ARC_CLIM_TS_V1

HORIZON *2020*

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SeaDataCloud Temperature and Salinity Climatologies for the Arctic Ocean (Version 1)

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Short description

The SeaDataCloud Temperature and Salinity Climatologies have been processed from the historical Data Collection of the Arctic Ocean (from 56°N to 83°N and from 45°W to 70°E) including temperature and salinity in situ data of the water column for the period 1955 – 2014. The analysis was run in six decadal periods (1955-1964/1965-1974/1975-1984/1985-1994/1995-2004/2005-2014). A subset of the World Ocean Database 2018 (WOD18) dataset has been integrated as external data-source to improve data availability for analysis.

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Abstract

The SeaDataCloud Temperature and Salinity Climatologies have been processed from the historical Data Collection of the Arctic Ocean (from 56°N to 83°N and from 45°W to 70°E) including temperature and salinity in situ data of the water column for the period 1955-2014. The analysis was run in six decadal periods (1955-1964/1965-1974/1975-1984/1985-1994/1995-2004/2005-2014). A subset of the World Ocean Database 2018 (WOD18, https://www.nodc.noaa.gov/OC5/WOD/pr_wod.html) dataset has been integrated as external data-source to improve data availability for analysis.

1. Data

1.1. General description of the input data set

The main component of the input data set is the SDC_ARC_SEA_DATA_TS_V1 product containing the Arctic Ocean - Temperature and salinity Historical Data Collection SeaDataCloud V1 and released in April 2018 (https://doi.org/10.12770/5a9df55d-0cb7-4354-acd0-221b3d5f02fe). The Product Information Document (PIDoc, *Sagen et al. 2018* https://doi.org/10.13155/57183) describes in detail the Temperature and Salinity Historical data collection and the quality control performed on the dataset.

The unrestricted dataset 1955-2014 consists of 731286 stations, including ferry box data that are registered as one station per observation in the trajectory. The ferry box data displayed in Figure 2 have not been considered in the climatological analysis to avoid bias towards the coastal areas and have been removed before the merging with restricted SeaDataNet data and World Ocean Database 2018 (WOD18). Their time distribution in Figure 3 also shows their availability from late nineties. The peaks (Figure 3a) in number of observations is due to some glider data characterized by a lot of observations in one depth. The seasonal distribution of data is shown in Figure 4.

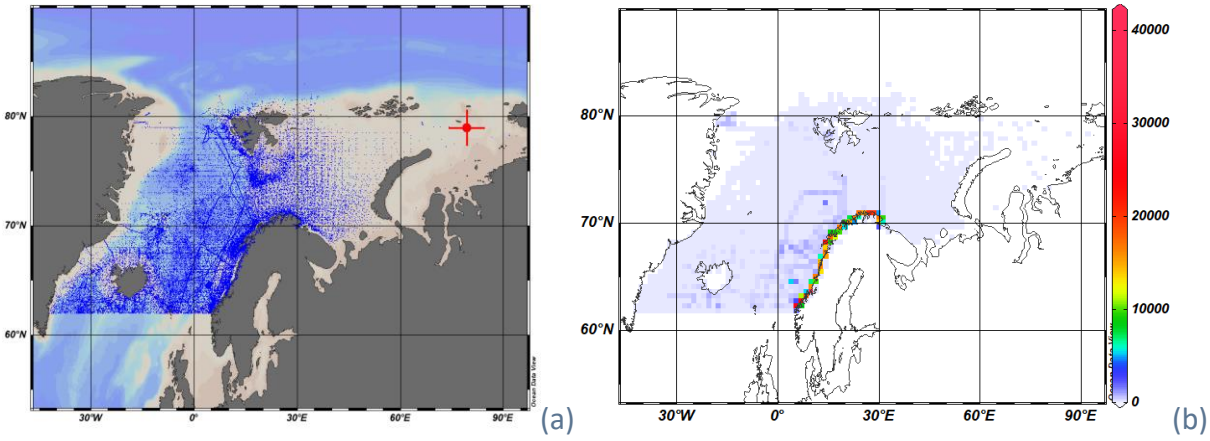


Figure 1: All 731286 stations for the Arctic Ocean SDC_ARCTIC_SEA_DATA-TS_V1: (a) data distribution map; (b) data density plot showing where the largest number of data have been sampled.

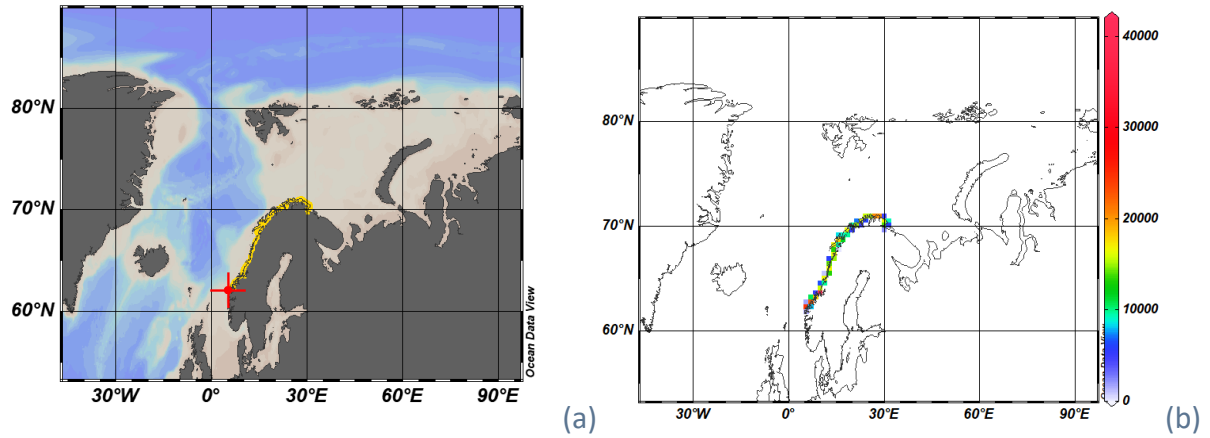


Figure 2: Ferry box stations (568877) along Norwegian coast, (a) data distribution map; (b) data density plot.

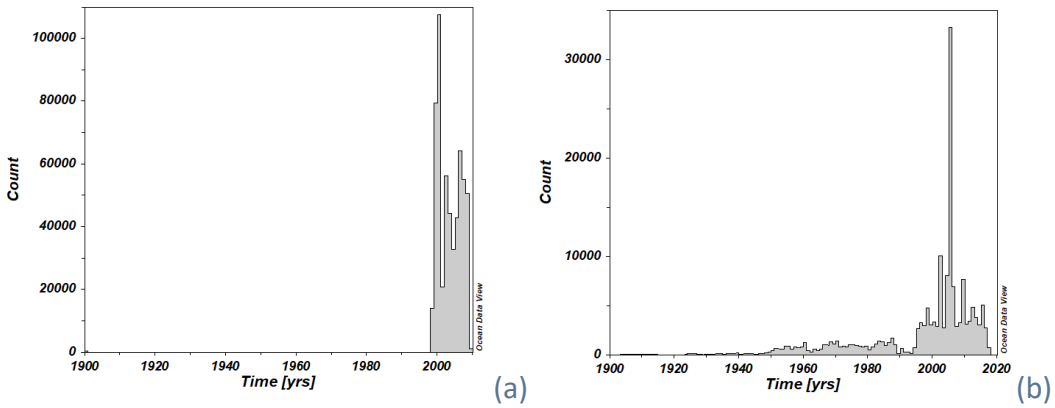


Figure 3: Time distribution for a) 568877 ferry box stations and b) 162409 profile stations

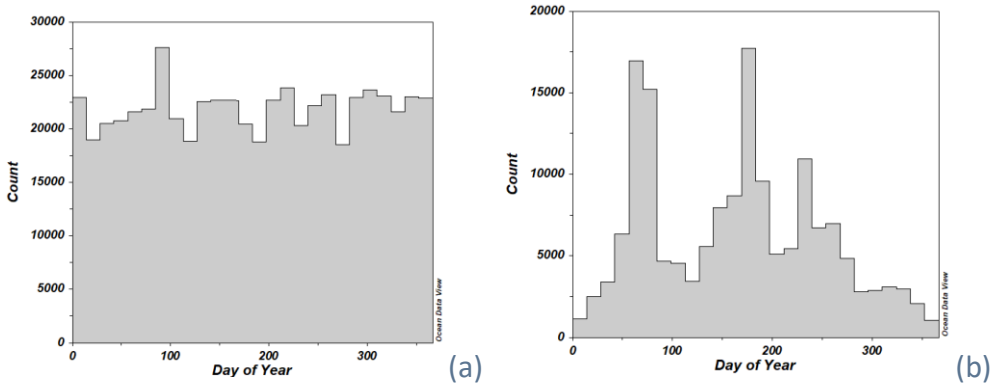


Figure 4: Seasonal distribution for a) 568877 ferry box stations and b) 162409 profile stations.

The temperature and salinity profiles (162409 stations) used to compute the climatology are displayed in Figure 5. The other component of the input dataset is the SDC_ARCTIC_SEA_DATA-TS_V1 restricted data set, made by only 373 stations (Figure 6).

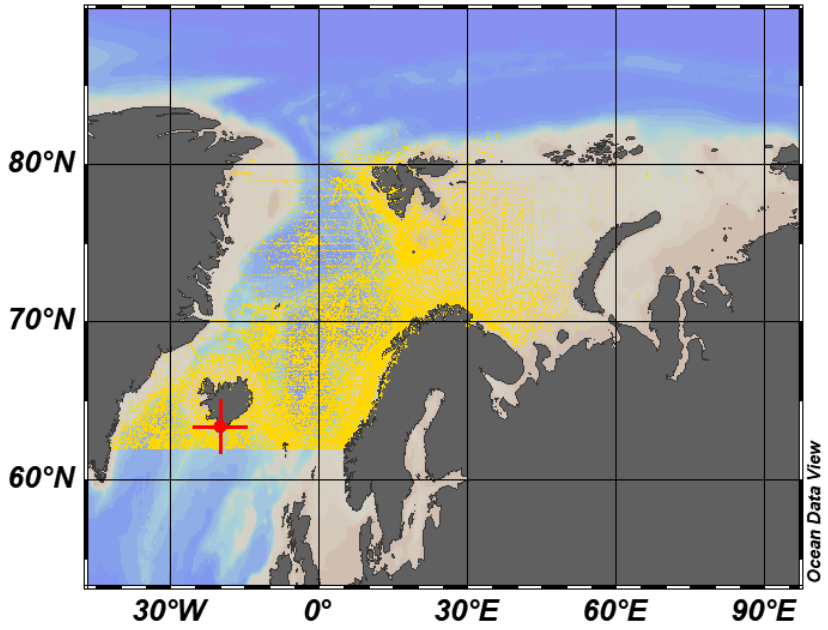


Figure 5: The data distribution without ferry box data, 162409 stations

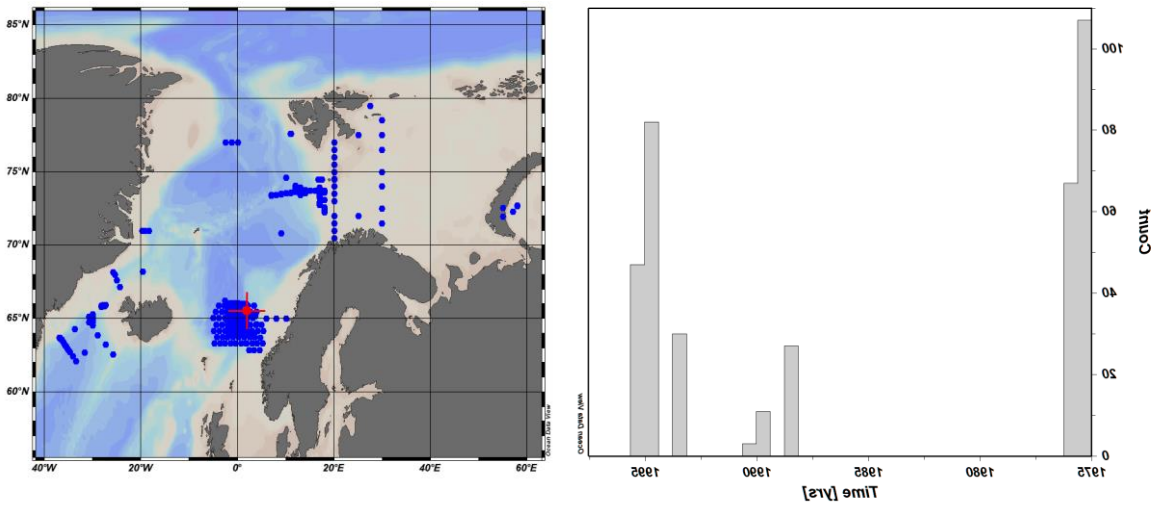
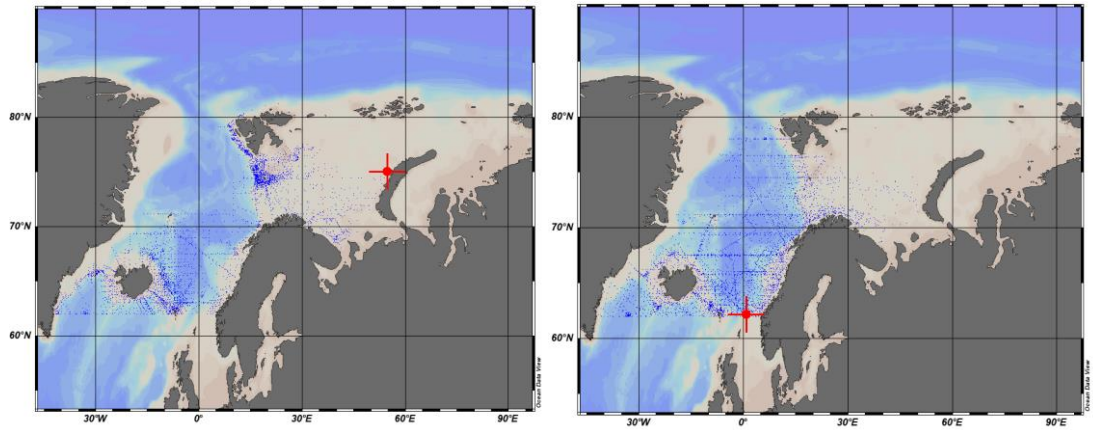


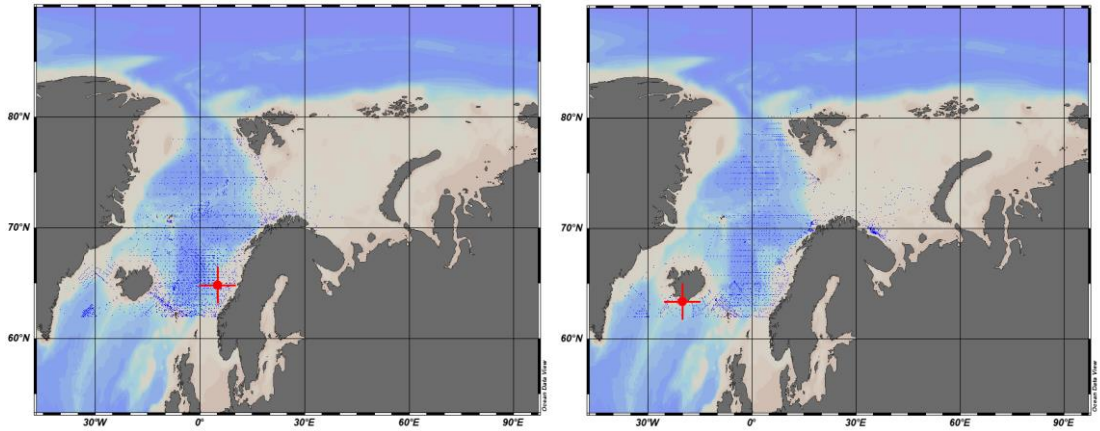
Figure 6: The restricted data, 373 stations; a) data distribution and b) time distribution

The spatial distribution of the SDC dataset split into 6 decades; 1955-1964, 1965-1974, 1975-1984, 1985-1994, 1995-2004, 2005-2014 is shown below in Figure 7.



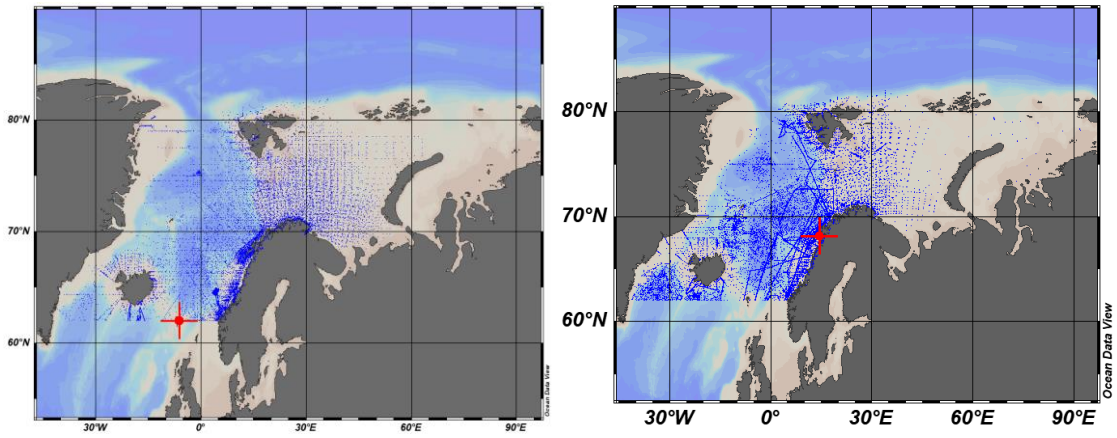
a) 6640 stations 1955-1964

b) 9705 stations 1965-1974



c) 9429 stations 1975-1984

d) 6803 stations 1985-1994



e) 43607 stations 1995-2004 f) 71860 stations 2005-2014

Figure 7: Spatial distribution of the 6 decades

The analysis of monthly and seasonal data distribution in the time period 1955-2014 (Figure 8 and Figure 9) shows a significant increase through the decades, with a denser coverage during the summer months, while the winter months having the smallest number of data. The data availability increases significantly after the 90s.

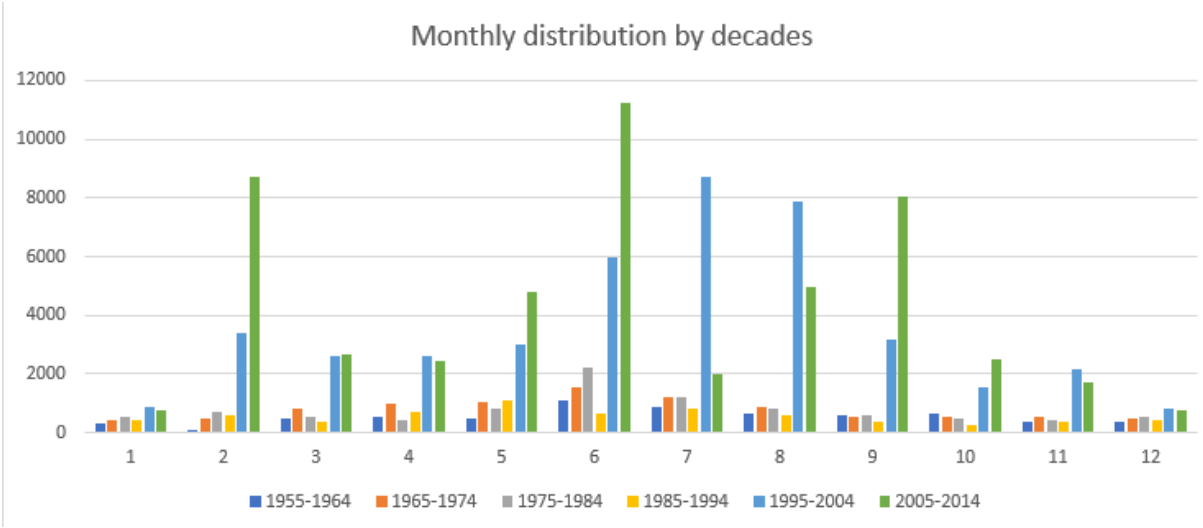


Figure 8: Monthly distribution by decades, removed ferry box (T) data in March 2005-2014

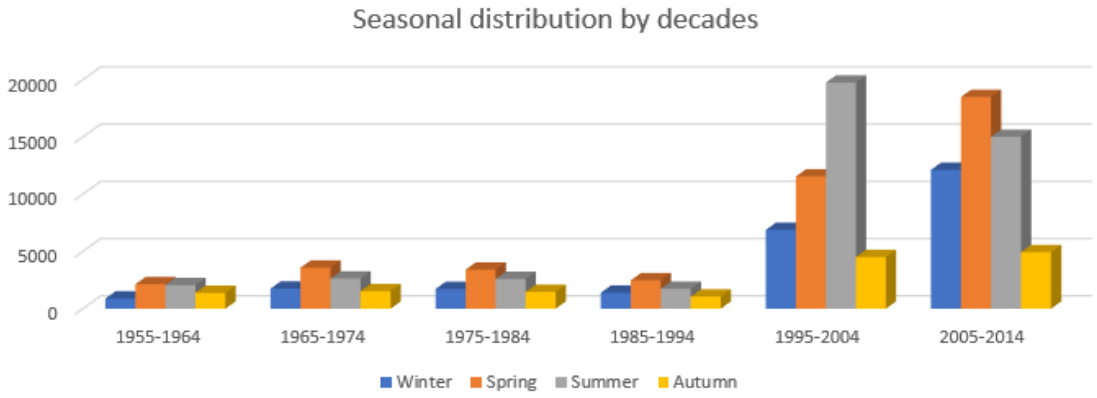


Figure 9: Seasonal distribution by decades

1.2. Integration of external data set

The WOD18 OSD and PFL data types have been extracted using a script for the areas shown in Figure 10 (labels: 1807, 1806, 1805, 1804, 1803, 1802, 1801, 1800, 7800, 7801, 7802, 7803, 7804, 7805, 7806, 7807 and 1707, 1706, 1705, 1704, 1703, 1702, 1701, 1700, 7700, 7701, 7702, 7703, 7704, 7705, 7706, 7707 and 1607, 1606, 1605, 1604, 1603, 1602, 1601, 1600, 7600, 7601, 7602, 7603, 7604, 7605, 7606, 7607 and 1507, 1506, 1505, 1504, 1503, 1502, 1501, 1500, 7500, 7501, 7502, 7503, 7504, 7505, 7506, 7507).

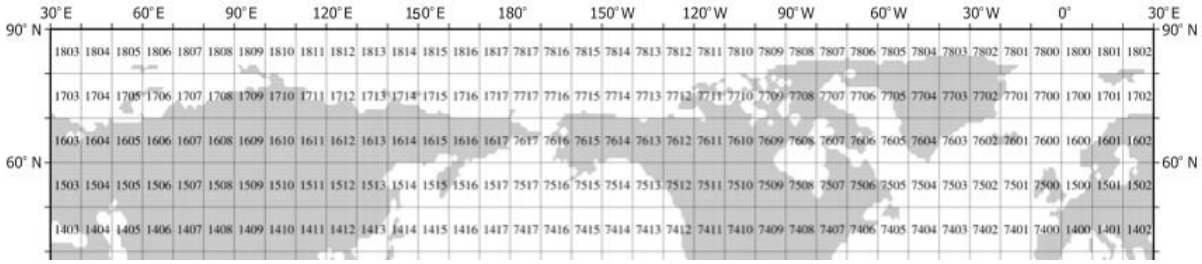
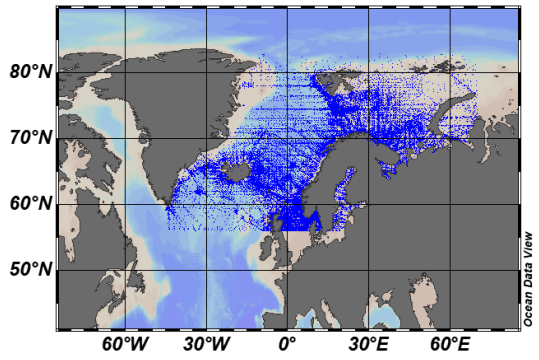
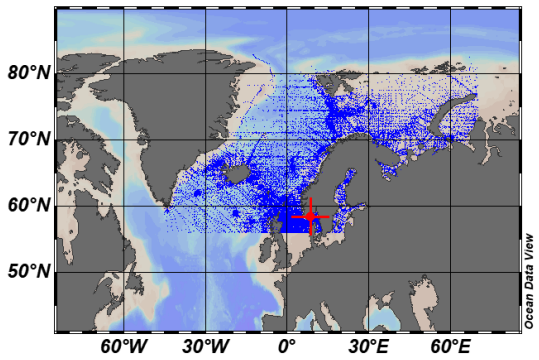


Figure 10: Geographically sorted data in WOD18

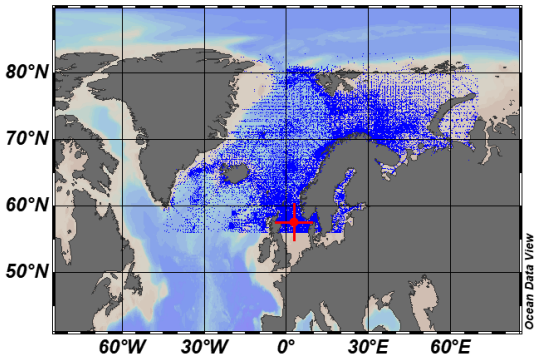
128 files were imported into ODV software version 5.15 (7) and then exported to a spreadsheet file divided into decades, 1955-1964, 1965-1974, 1975-1984, 1985-1994, 1995-2004, 2005-2014. The WOD18 data in 6 decades (Figure 11) were then checked using the IMR developed duplicated removal tool. The tool separates the datasets into three categories: no duplicates, possible duplicates and true duplicates.



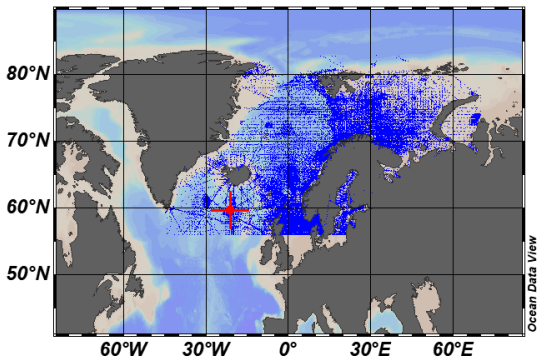
a) 97990 stations 1955 - 1964



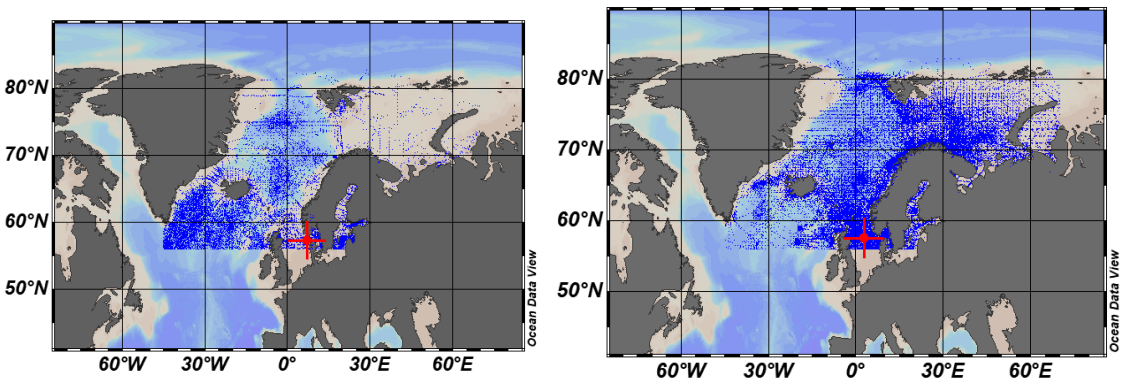
b) 87724 stations 1965 - 1974



c) 108260 stations 1975 - 1984



d) 116307 stations 1985 - 1994



e) 47431 stations 1995 - 2004 f) 54870 stations 2005 – 2014

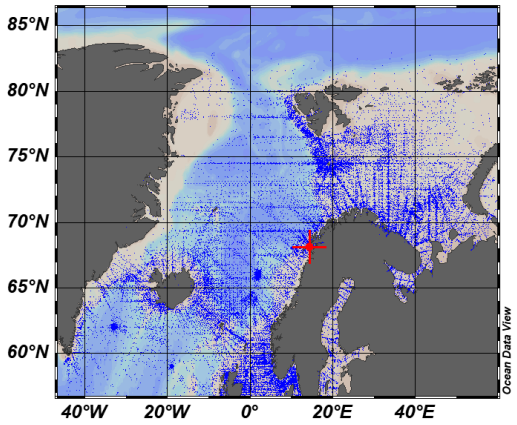
Figure 11: Spatial distribution of WOD18 data before duplicate removal.

The decadal files were first tested for internal duplicates within SDN dataset and within WOD18 dataset. The SDN dataset presents a richer metadata description in the station headers than the WOD18 dataset, thus the SDN data have been considered the starting dataset, in which the WOD18 dataset have been imported using ODV as a merging software. The WOD18 metadata were mapped into the SDN metadata as in Table 1.

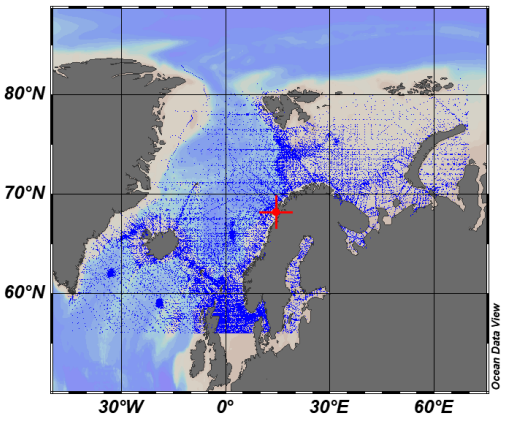
WOD18 metadata fields	ODV metadata fields
OCL cruise name	Alternative cruise name
Originator's cruise	Cruise name
Originator's station	Station name
Investigator	Data distributor
Institution	Originator
Instruments	Instrument/gear type
Depth	Depth
Temperature	ITIS 90 water temperature
Salinity	Water body salinity

Table 1: Metadata mapping between WOD18 and SDN.

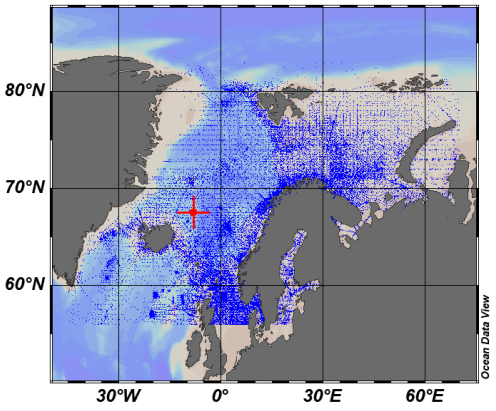
The integration of WOD18 and SDN data improved the data availability significantly (see Figure 12) for most decades, with an approximately 10 times increase, only the sixth decade had a double increase.



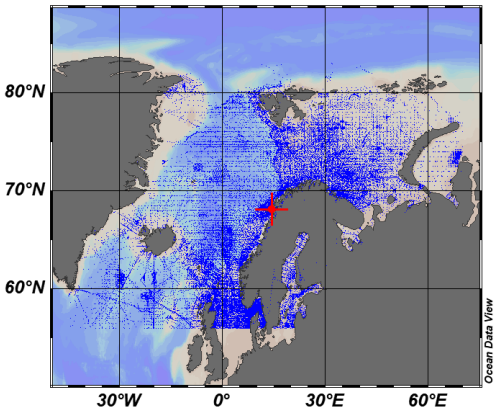
a) 93409(6640+86769) stations 1955 - 1964



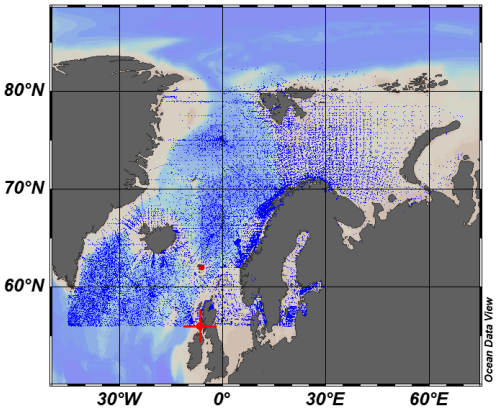
b) 91890(9705+82185) stations 1965 - 1974



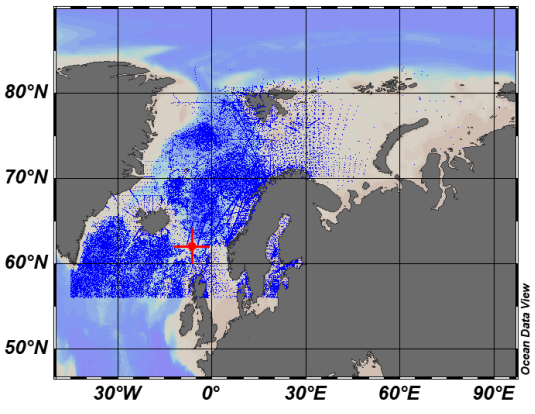
c) 111230(9429+101801) stations 1975 - 1984



d) 120225(6803+113422) stations 1985 - 1994



e) 88754(43607+45147) stations 1995 - 2004



f) 121654(71860+49794) stations 2005 - 2014

Figure 12: Merged dataset SDN and WOD18, duplicates removed.

2. Methodology

2.1. Data Quality Control

All source datasets underwent quality control (QC) according to procedures used by the respective producers. For example, the QC procedures, which were applied to two SDC datasets, are described in detail in (2). Each data value in the source datasets was supplied with the quality flag (5).

2.2. DIVA implementation and settings

Computation of the Arctic Ocean Temperature and Salinity climatic fields was done with DIVA master software (Troupin et al., 2012), version 4.7.2.

The climatology domain (Figure 13) is the Arctic Ocean, starting at 62°N of the North Atlantic Ocean and ending at 83°N. On the western part the longitude limit is 45°W and on the eastern part the longitude limit is 70°E. The GEBCO bathymetry has been used to create the DIVA topography.

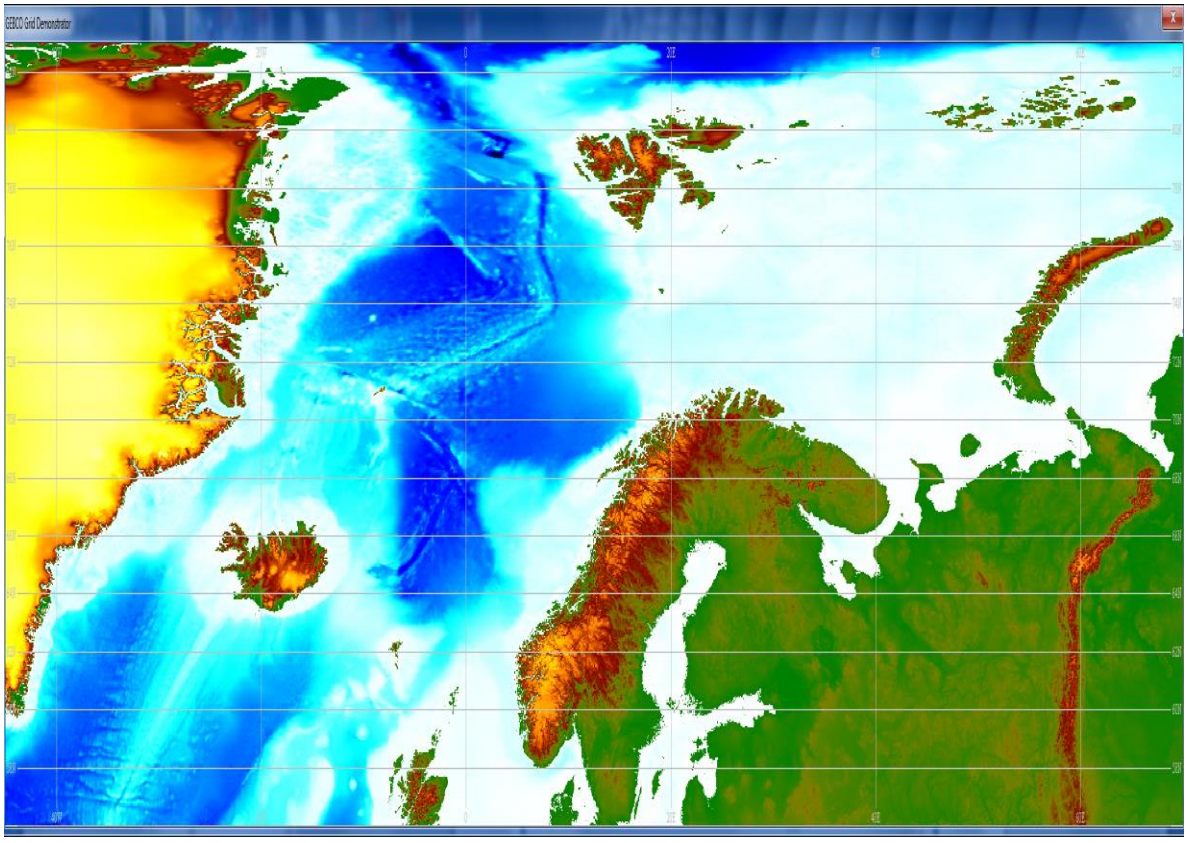


Figure 13: The GEBCO bathymetry for the Arctic Ocean area.

The analysis has been performed for the time period 1955-2014. The seasonal runs are defined for winter months 01-03, spring 04-06, summer 07-09 and autumn 10-12. Additional runs have been performed on a monthly basis. The data has been divided into 6 decades; 1955-1964, 1965-1974, 1975-1984, 1995-2004 and 2005-2014.

The analysis has been performed on a horizontal grid with cell size of 1.0° in longitude and 0.5° in latitude.

The vertical levels have been defined equal to the WOA2018 57 levels (6) down to 1500 m of depth (0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 125, 150, 175, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 550, 600, 650, 700, 750, 800, 850, 900, 950, 1000, 1050, 1100, 1150, 1200, 1250, 1300, 1350, 1400, 1450, 1500 m).

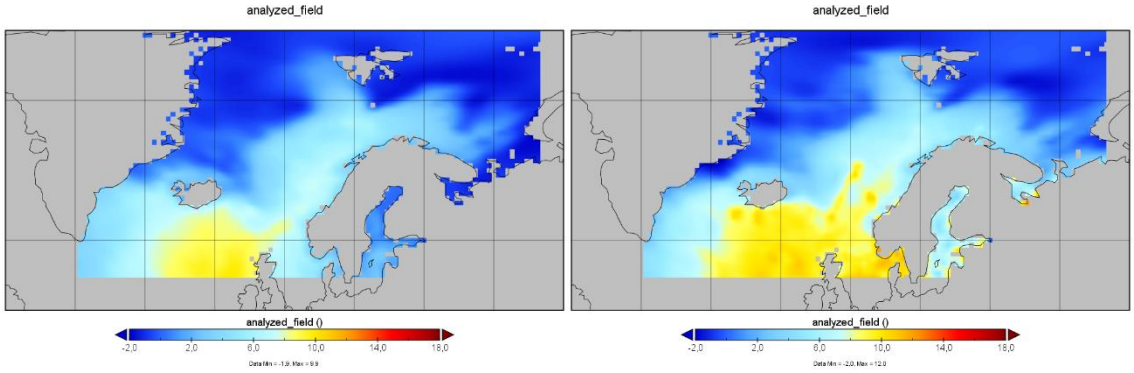
The DIVA settings are described in Table 2. The "Clever poor mans" **error field** has been used.

Resolution 1° x ½°		
Lc: correlation length	1.0	
Snr: signal to noise ratio	0.5	
Varbak	1.0	
Parameters estimation and vertical filtering	-30	
Xori	-45	dx 1.0 – nx 101
Yori	56	dy 0.5 – ny 55
Vertical levels	57 levels	[1500:50:500][475:25:100][95:5:0]

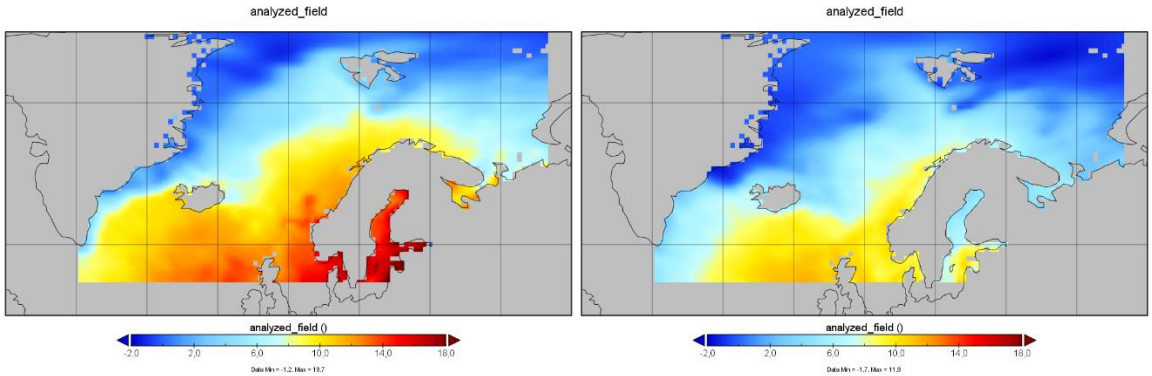
Table 2: Settings for running DIVA software

2.3. Background field

The temperature (Figure 14) and salinity (Figure 15) background fields were computed from all data for the period 1955-2014 split in four seasons. Settings for time period is 1955-2014. Settings for seasons is Winter month 01-03, Spring month 04-06, Summer month 07-09 and Autumn month 10-12. The layers is the same 57 depths as for the analysis.

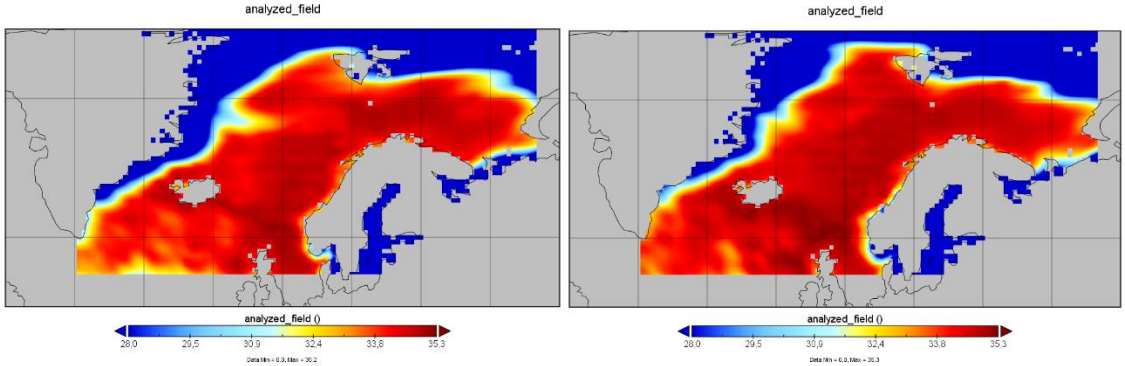


a) Winter b) Spring

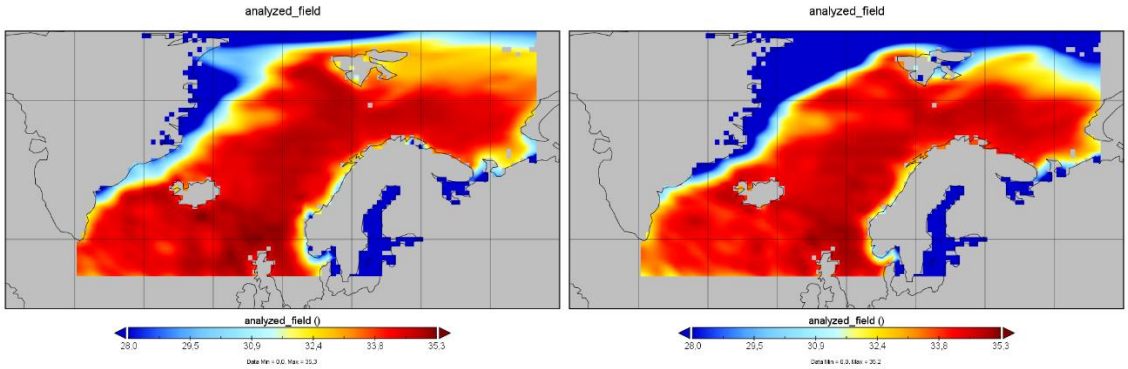


c) Summer d) Autumn

Figure 14: Temperature seasonal reference fields (1955-2014).



a) Winter b) Spring



c) Summer d) Autumn

Figure 15: Salinity seasonal reference fields (1955-2014).

3. Climatology

3.1. Temperature

The temperature fields in Figure 16 (at 50m depth) and Figure 18 (at 200m depth) are consistent with the general understanding of the Arctic area. The 6 decades show warmer water appearing in the northernmost areas.

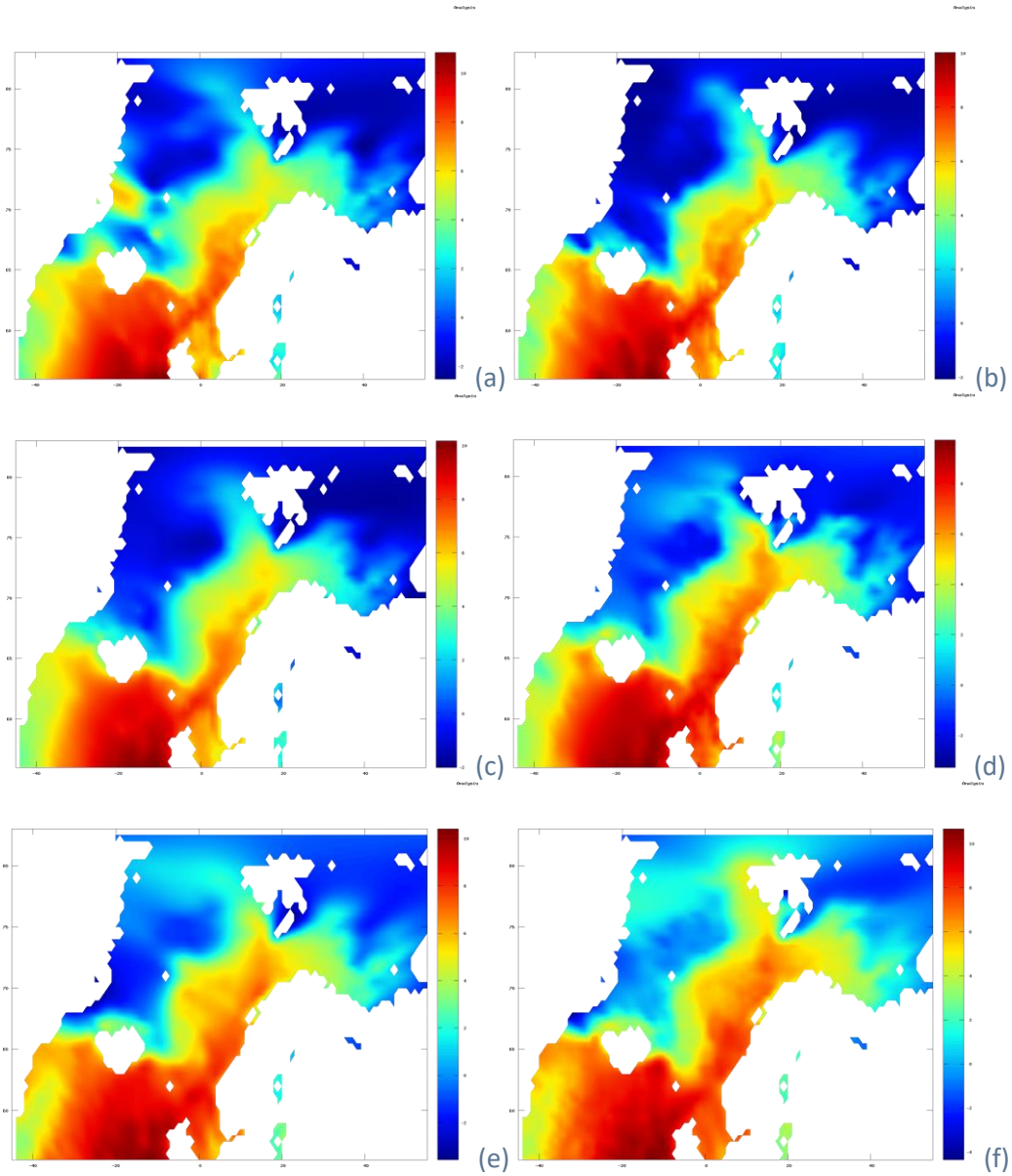


Figure 16: Winter temperature climatology at 50m depth: (a) 1955-1964; (b) 1965-1974; (c) 1975-1984; (d) 1985-1994; (e) 1995-2004; (f) 2005-2014.

The error fields in Figure 17 (at 50m depth) and Figure 18 (200m depth) corresponding to the presented temperature distributions resemble the difference in data availability over the 6 decades analysed. The

decade 1975-1984 presents the smallest geographical coverage compared to the other decades. The recent decades show the best geographic coverage.

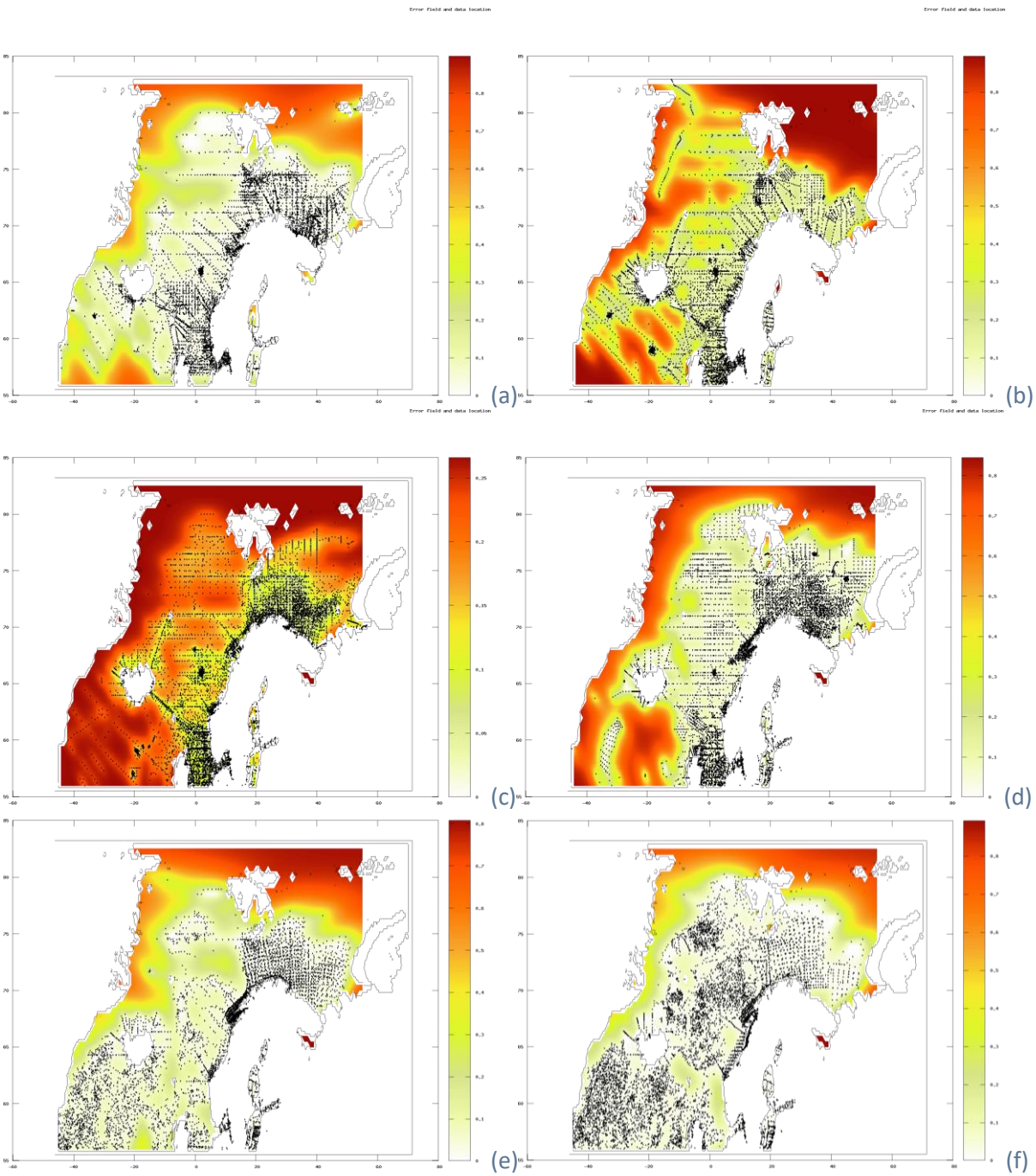


Figure 17: Error field and observation locations (black dots) associated to the winter temperature climatology at 50m depth (Figure 16): (a) 1955-1964; (b) 1965-1974; (c) 1975-1984; (d) 1985-1994; (e) 1995-2004; (f) 2005-2014.

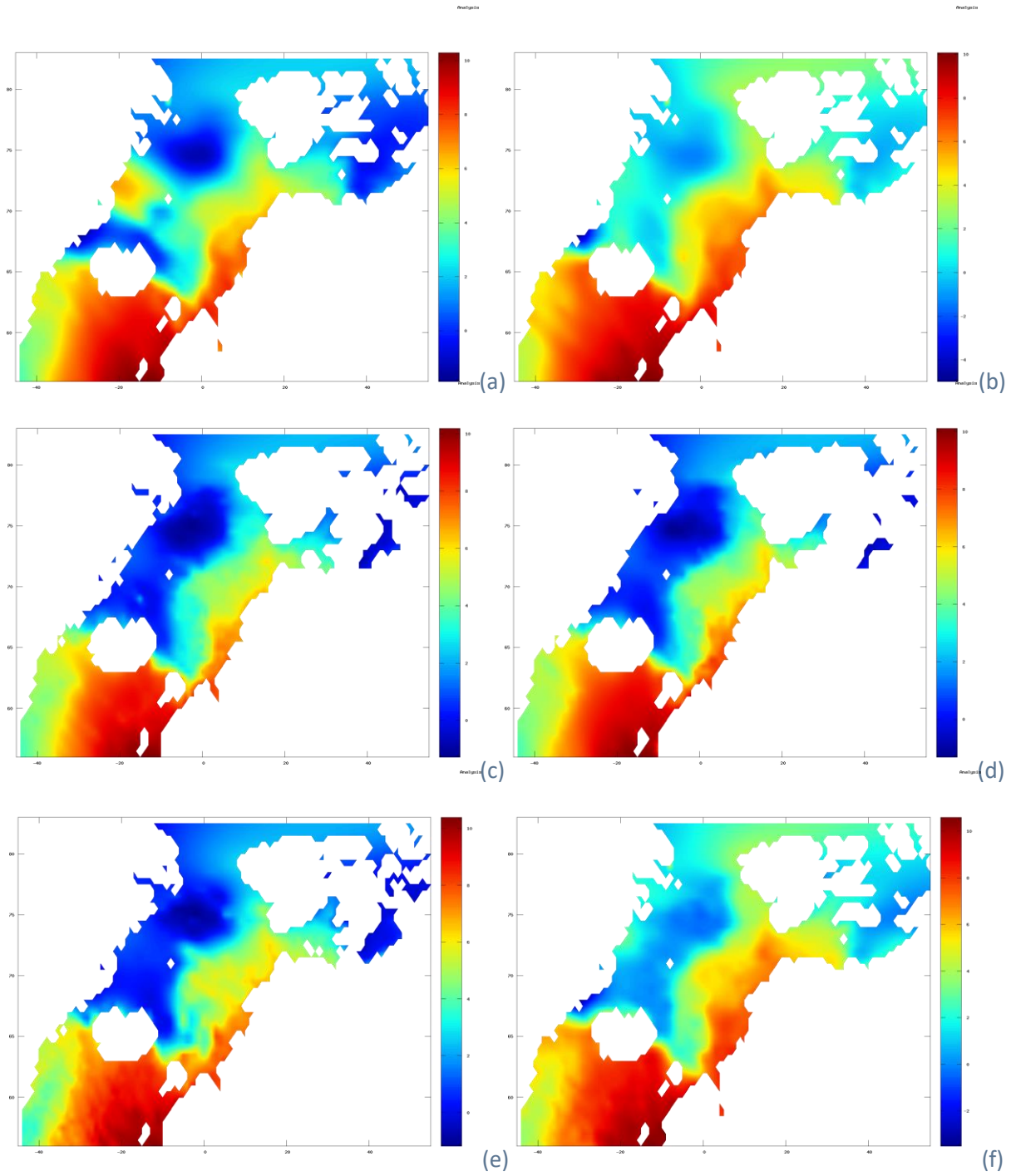


Figure 18: Winter temperature climatology at 200m depth: (a) 1955-1964; (b) 1965-1974; (c) 1975-1984; (d) 1985-1994; (e) 1995-2004; (f) 2005-2014.

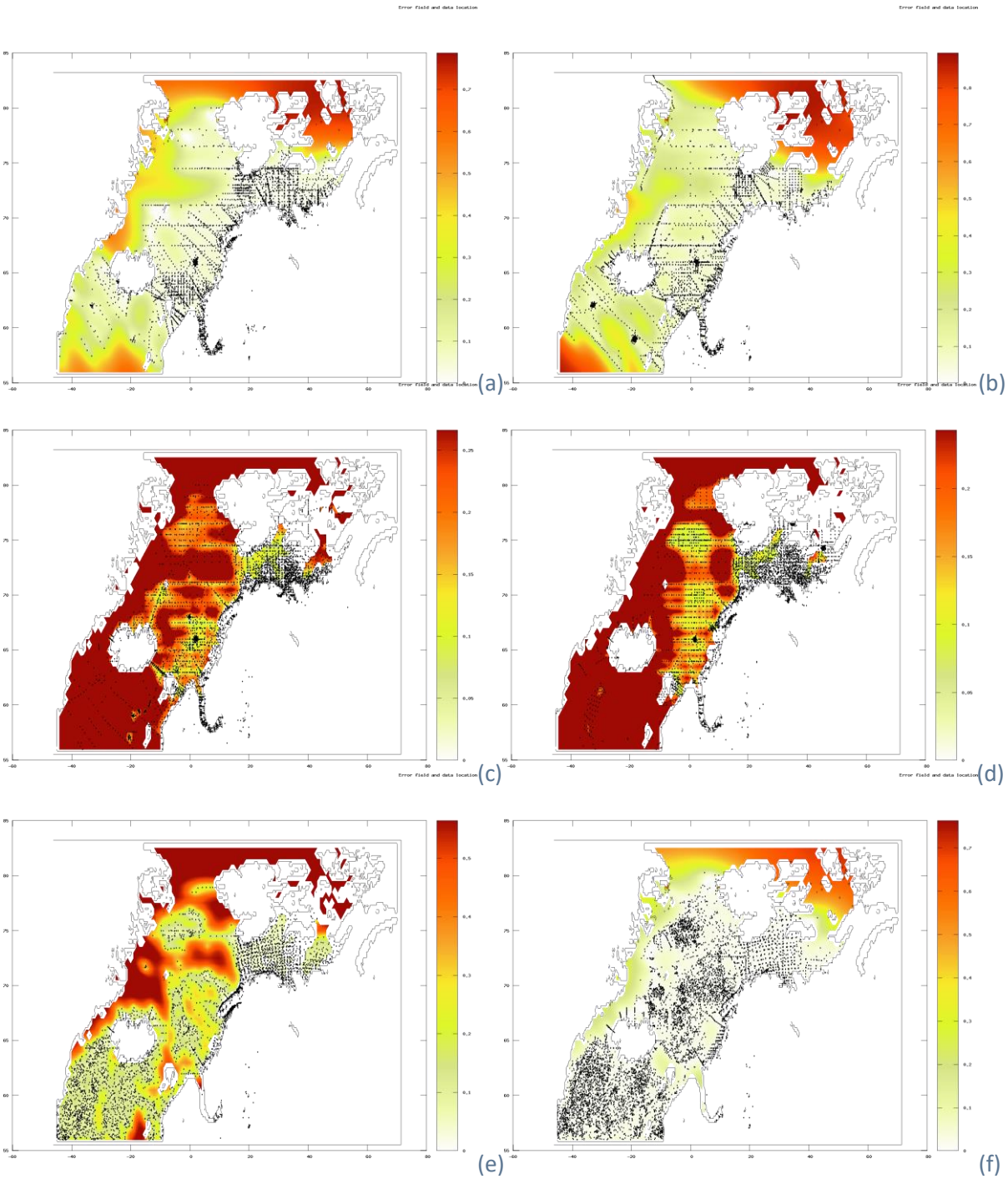


Figure 19: Error field and observation locations (black dots) associated to the winter temperature climatology at 200m depth (Figure 18): (a) 1955-1964; (b) 1965-1974; (c) 1975-1984; (d) 1985-1994; (e) 1995-2004; (f) 2005-2014.

3.2. Salinity

The salinity fields presented in Figure 20 and Figure 22 are scaled from 34.0 to 35.5 meaning that all values below 34.0 are dark blue. The climatological winter salinity over the six decades appear consistent with the general understanding of the Arctic region.

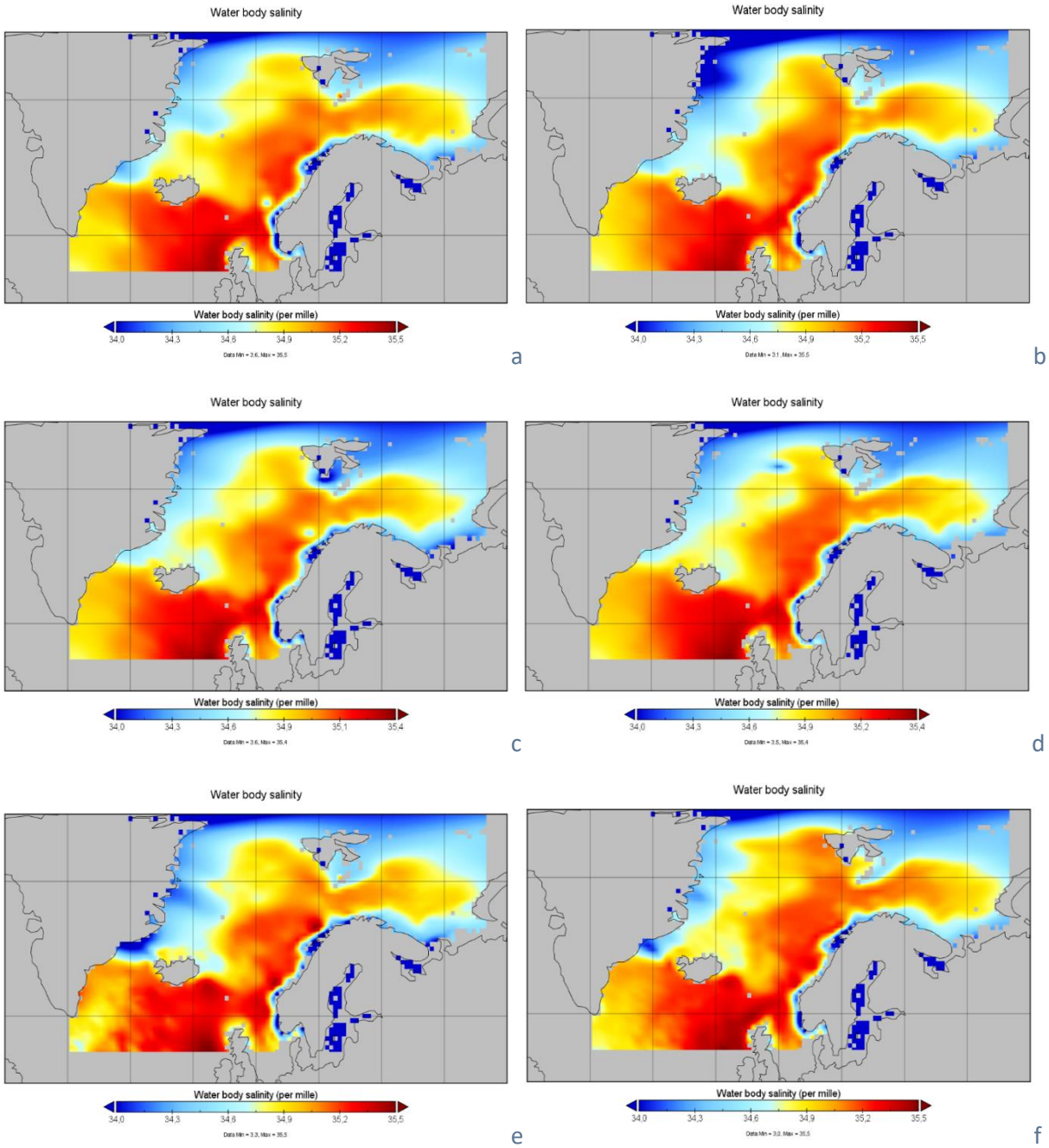


Figure 20: Winter salinity climatology at 50m depth over 6 decades: (a) 1955-1964; (b) 1965-1974; (c) 1975-1984; (d) 1985-1994; (e) 1995-2004; (f) 2005-2014.

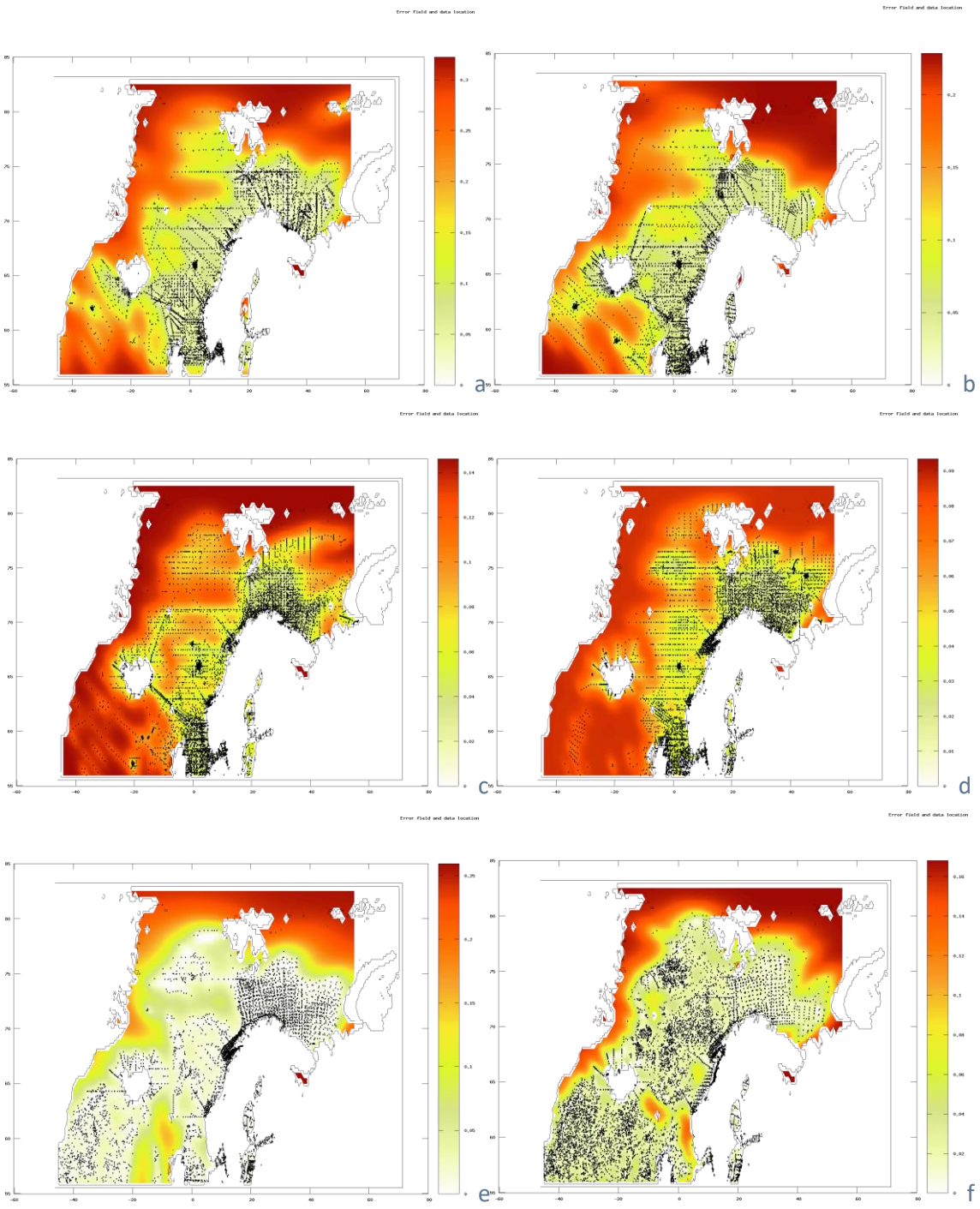


Figure 21: Error field associated to the winter salinity climatology at 50m depth over 6 decades: (a) 1955-1964; (b) 1965-1974; (c) 1975-1984; (d) 1985-1994; (e) 1995-2004; (f) 2005-2014.

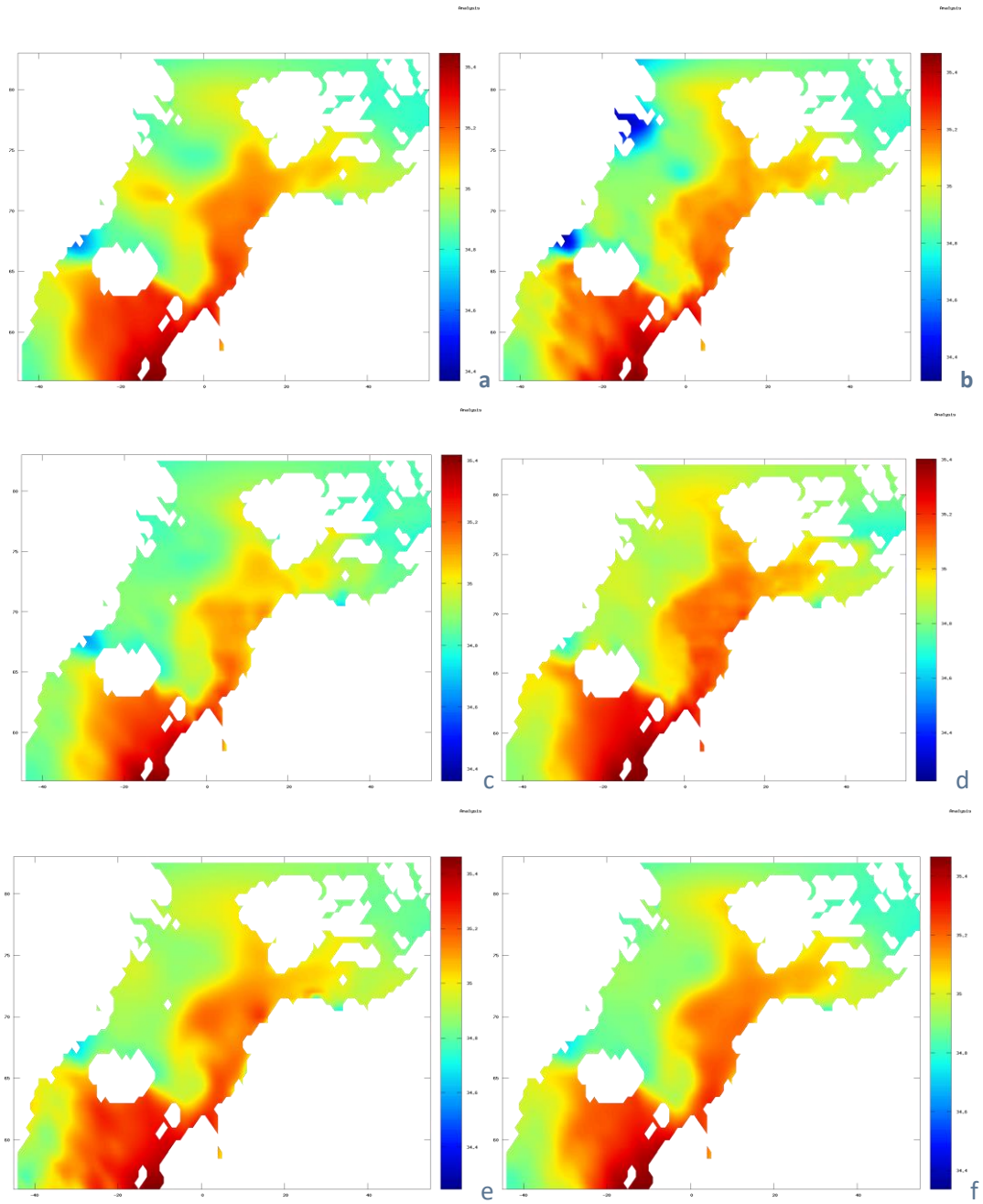


Figure 22: Winter salinity climatology at 200m depth over 6 decades: (a) 1955-1964; (b) 1965-1974; (c) 1975-1984; (d) 1985-1994; (e) 1995-2004; (f) 2005-2014.

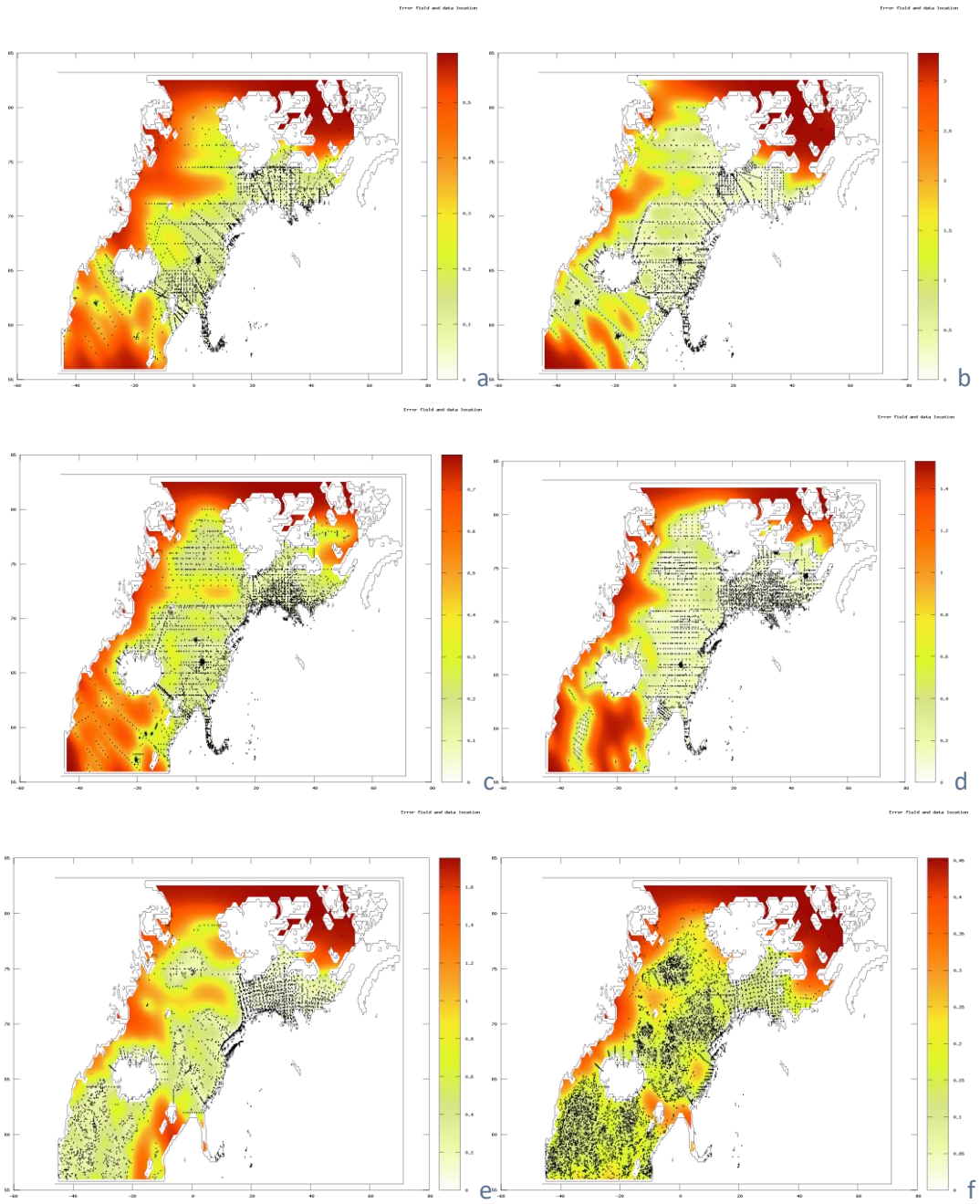


Figure 23: Error field associated to the winter salinity climatology at 200m depth over 6 decades: (a) 1955-1964; (b) 1965-1974; (c) 1975-1984; (d) 1985-1994; (e) 1995-2004; (f) 2005-2014.

4. Consistency analysis

A consistency analysis was performed against the well-known and widely used product of the NOAA NODC Ocean Climate Laboratory – the World Ocean Atlas 2018 (6). The present version of the World Ocean Atlas was released in September 2018 (WOA18). Seasonal and monthly climatological fields of temperature and salinity (objectively analysed mean) are available at several resolutions, and resolution 1° was used for the analysis of the 6 decades: 1955-1964, 1965-1974, 1975-1984, 1985-1994, 1995-2004, and 2005-2017.

The comparison between SDC Climatology V1 and WOA18 has been done between different decades and different seasons:

- Winter temperature (1955-1964) at depth 50m (Figure 24)and 200m (Figure 25);
- Spring temperature (1965-1974) at depth 50m (Figure 26) and 200m(Figure 27);
- Summer temperature (1975-1984) at depth 50m (Figure 28) and 200m (Figure 29);
- Autumn temperature (1985-1994) at depth 50m (Figure 30) and 200m (Figure 31).

Overall, the resemblance between SeaDataCloud and WOA18 is quite good, but some artefacts are visible in the SDC dataset along the Greenland coast that are not present in the WOA18 in the first decade 1955-1964.

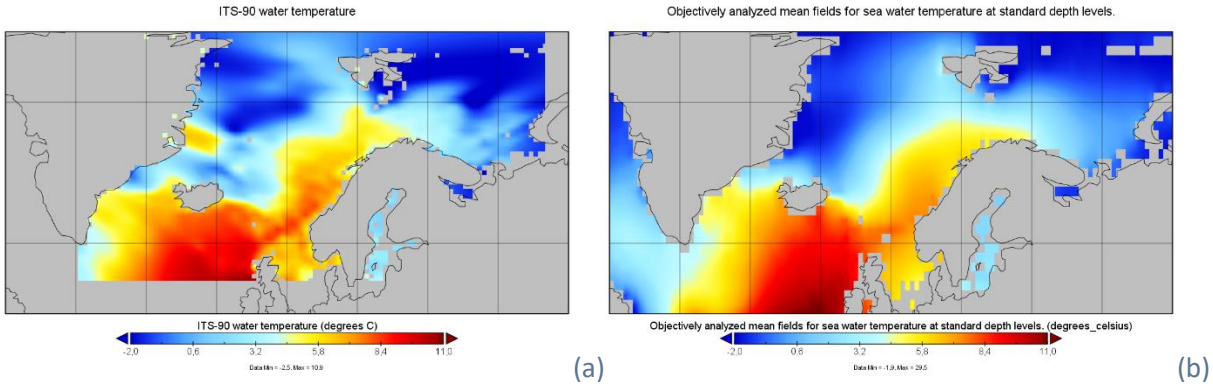


Figure 24: Winter temperature fields at depth 50m for the time period 1955-1964: (a) SDC_ARC_CLIM_TS_V1; (b) WOA18.

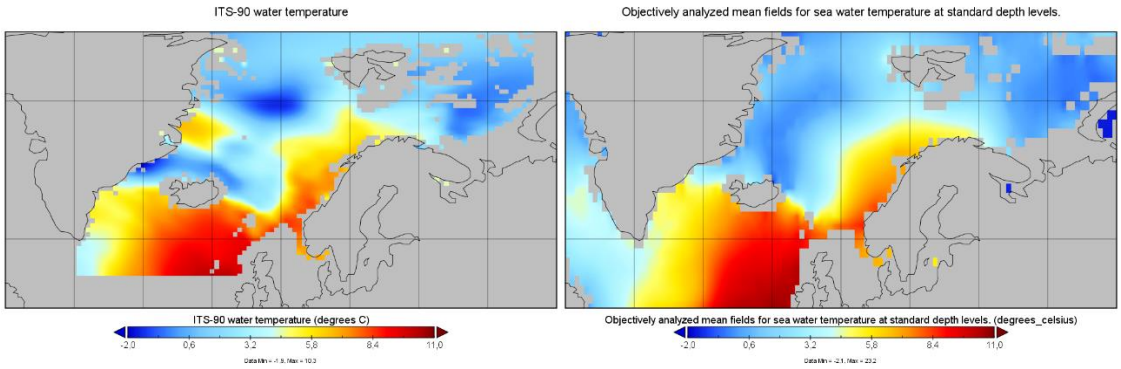
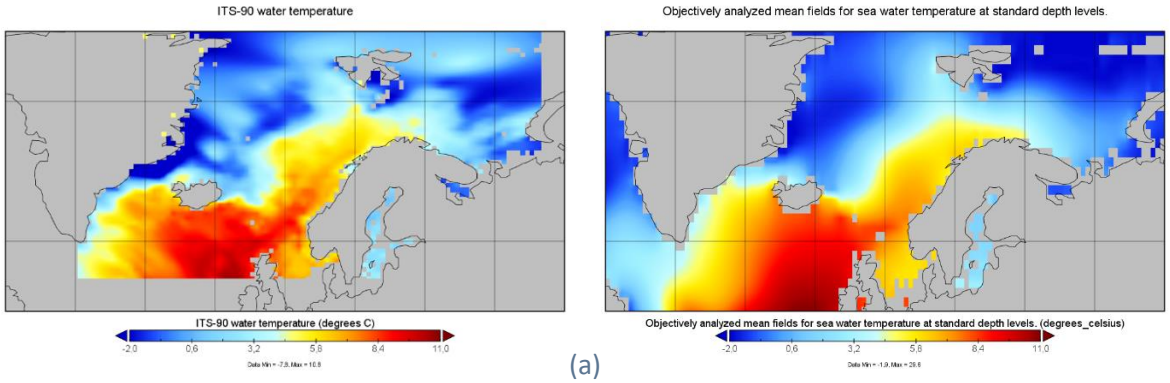
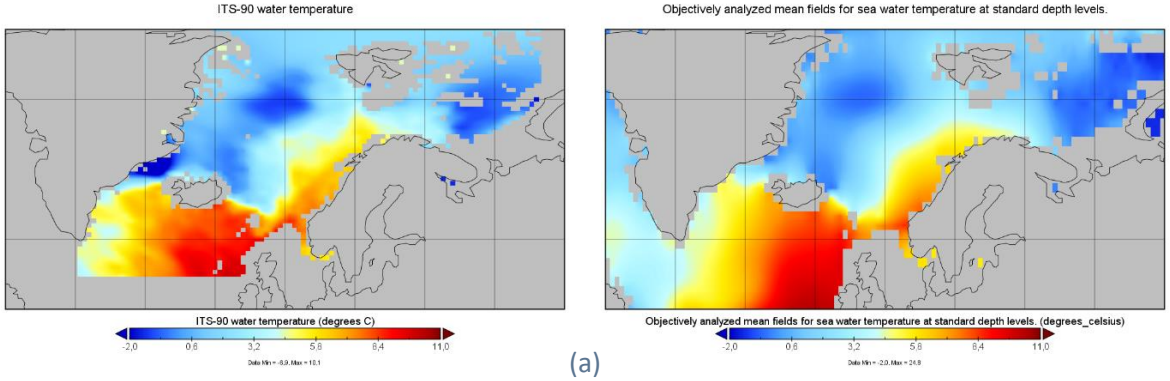


Figure 25: Winter temperature fields at depth 200m for the time period 1955-1964: (a) SDC_ARC_CLIM_TS_V1; (b) WOA18.



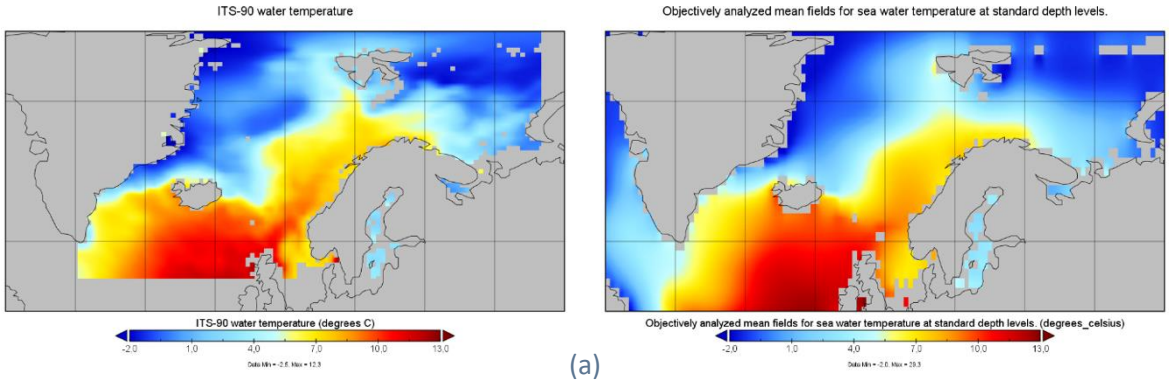
(a) (b)

Figure 26: Spring (0406) temperature fields at depth 50m for the time period 1965-1974: (a) SDC_ARC_CLIM_TS_V1; (b) WOA18.



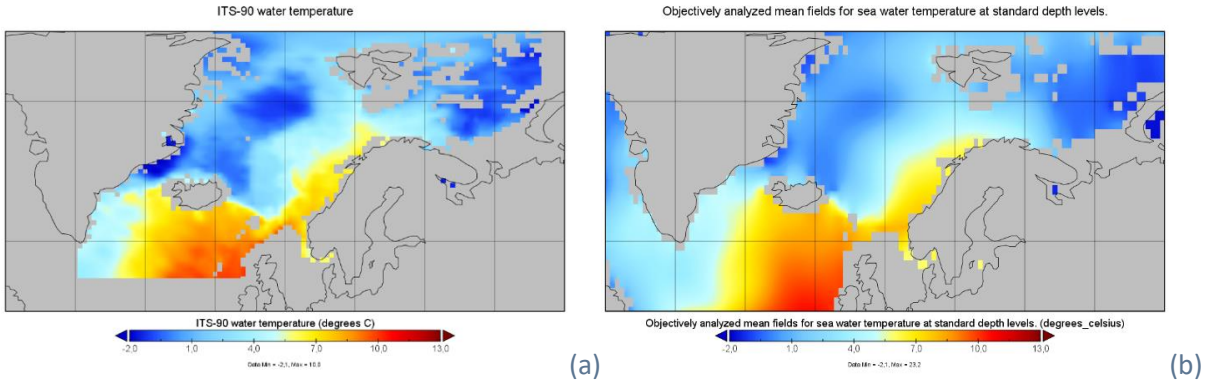
(a) (b)

Figure 27: Spring (0406) temperature fields at depth 200m for the time period 1965-1974: (a) SDC_ARC_CLIM_TS_V1; (b) WOA18.



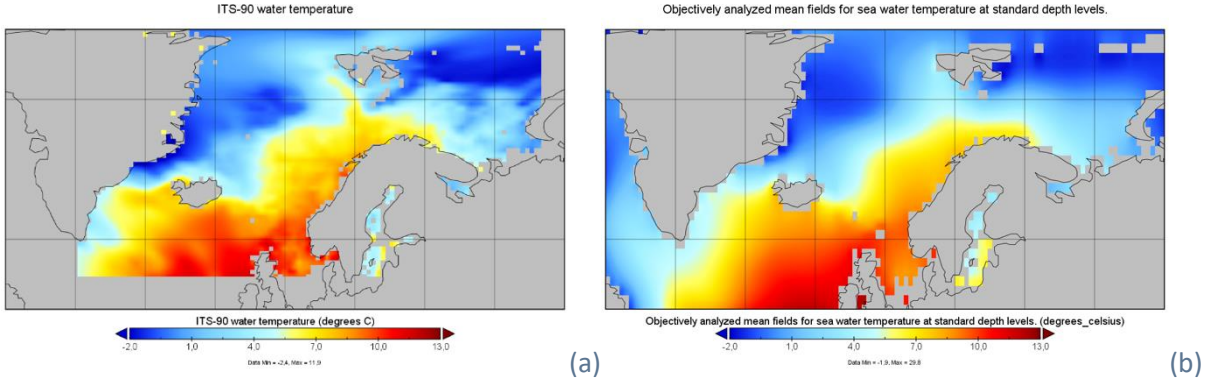
(a) (b)

Figure 28: Summer (0709) temperature fields at depth 50m for the time period 1975-1984: (a) SDC_ARC_CLIM_TS_V1; (b) WOA18.



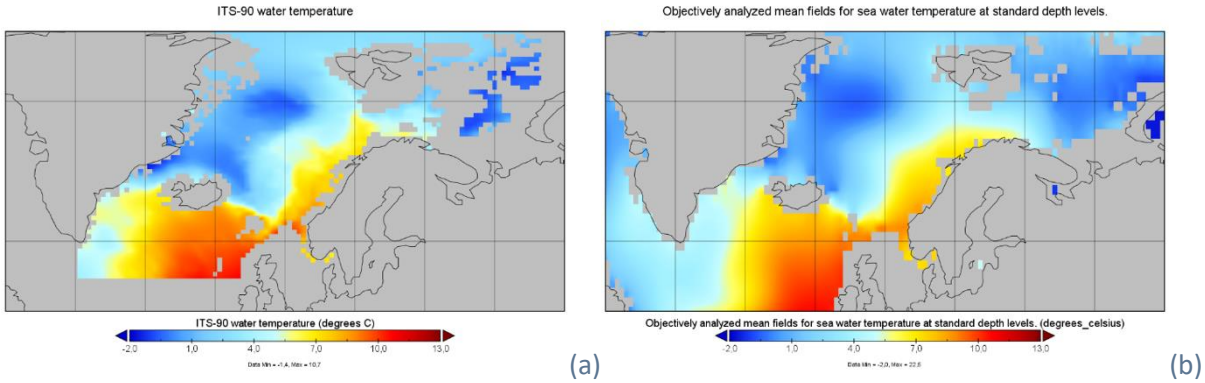
(a) (b)

Figure 29: Summer (0709) temperature fields at depth 200m for the time period 1975-1984: (a) SDC_ARC_CLIM_TS_V1; (b) WOA18.



(a) (b)

Figure 30: Autumn (1012) temperature fields at depth 50m for the time period 1985-1994: (a) SDC_ARC_CLIM_TS_V1; (b) WOA18.



(a) (b)

Figure 31: Autumn (1012) temperature fields at depth 200m for the time period 1985-1994: (a) SDC_ARC_CLIM_TS_V1; (b) WOA18.

Salinity fields have been also validated through a qualitative comparison with the WOA18, in particular:

- Winter salinity (1995-2004) at 50m (Figure 32) and 200m (Figure 33) depth;
- Spring salinity (2005 to 2014) at 50m (Figure 34) and 200m (Figure 35) depth.

Some anomalies can be detected at certain levels. A more detailed check will be performed for the next release.

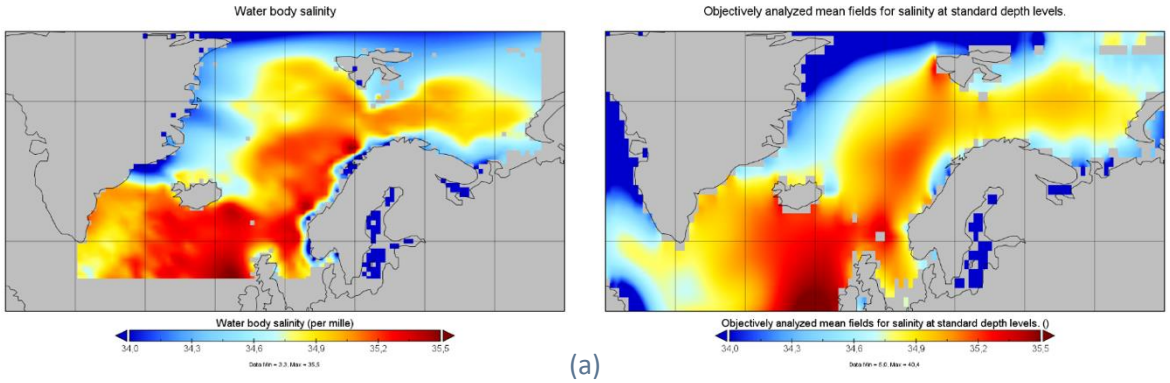


Figure 32: Winter (0103) salinity fields at 50m depth for the time period 1995-2004: (a) SDC_ARC_CLIM_TS_V1; (b) WOA18.

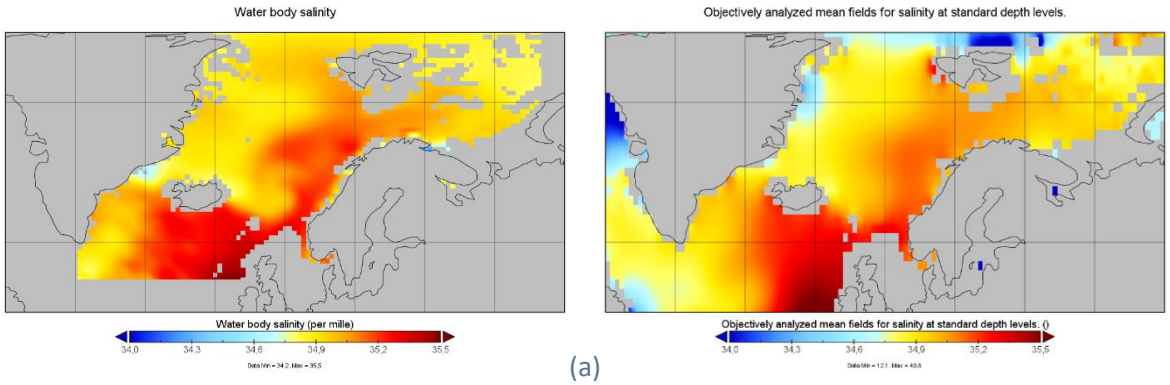


Figure 33: Winter (0103) salinity fields at 200m depth for the time period 1995-2004: (a) SDC_ARC_CLIM_TS_V1; (b) WOA18.

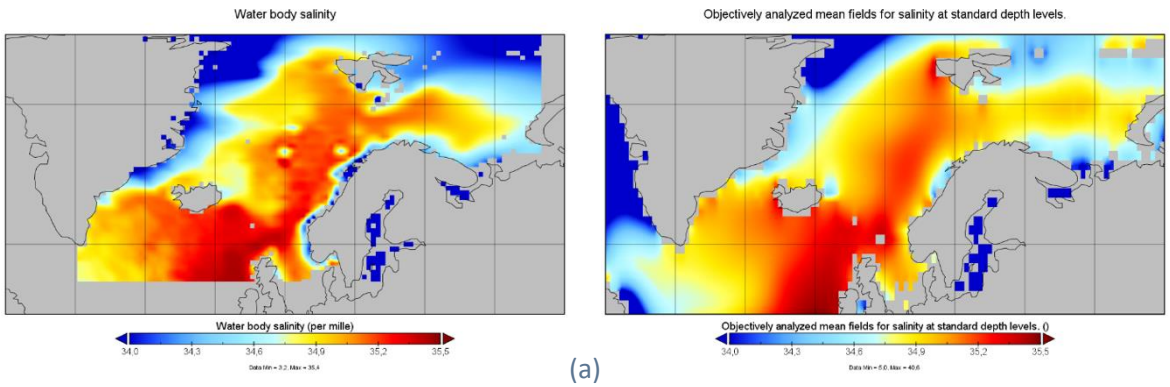


Figure 34: Spring (0406) salinity fields at 50m depth for the time period 1995-2004: (a) SDC_ARC_CLIM_TS_V1; (b) WOA18.

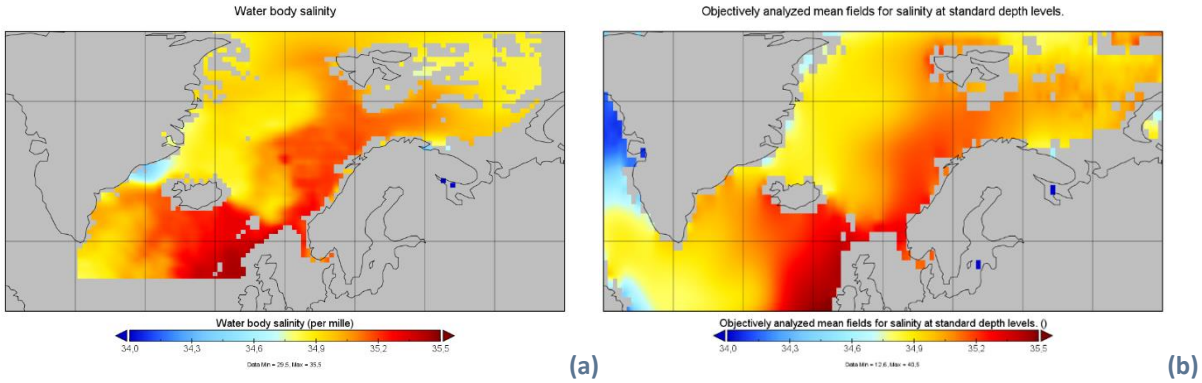


Figure 35: Spring (0406) salinity fields at 200m depth for the time period 1995-2004: (a) SDC_ARC_CLIM_TS_V1; (b) WOA18.

5. Technical Specifications

The product is delivered in 4 files in NetCDF format. Each file contains four 4d arrays (3 space dimensions + 1 time dimension) named according to the following rule:

- *Parameter_Name* – 4d array for a parameter,
- *Parameter_Name_L1* – parameter masked using relative error threshold 0.3,
- *Parameter_Name_L2* – parameter masked using relative error threshold 0.5,
- *Parameter_Name_relerr* – relative error of parameter.

Content of NetCDF files:

1. **SDC_ARC_CLIM_T_1955_2014_1_m.nc** Temperature monthly climatological fields covering the time period 1955-2014 at 1.0x0.5 degrees of resolution
2. **SDC_ARC_CLIM_S_1955_2014_1_m.nc** Salinity monthly climatological fields covering the time period 1955-2014 at 1.0x0.5 degrees of resolution
3. **SDC_ARC_CLIM_T_1955_2014_1_s.nc** Temperature seasonal climatological fields for time periods: 1955-1964, 1965-1974, 1975-1984, 1985-1994, 1995-2004, 2005-2014, 1955-2014.
4. **SDC_ARC_CLIM_S_1955_2014_1_s.nc** salinity seasonal climatological fields for time periods: 1955-1964, 1965-1974, 1975-1984, 1985-1994, 1995-2004, 2005-2014, 1955-2014.

Every NetCDF file written by DIVA 4.7.2, along with the field's attributes, contains a set of attributes describing the product:

- Convention used in the file
- Name of the project
- Name of institution responsible for the product
- Contact email of the group that has produced the product
- Data access and Web visualisation
- Product id
- Author of the product
- Acknowledgement
- Date of the product
- Title of the product
- File name of the product
- Source of observations
- Comments

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 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_ARC_CLIM_TS_V1 product to your scope.

5.2. Changes since previous version

The V1 climatology is an upgrade from the SDN2 temperature and salinity climatology. The major upgrade is the increase of the vertical resolution to 57 levels. While the previous climatology covered the time period 1900-2013, the present SDC climatological products have monthly climatologies for the whole time period 1955-2014 and seasonal climatologies from 6 decades 1955-1964, 1965-1974, 1975-1984, 1985-1994, 1995-2004, 2005-2014, 1955-2014.

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6. Annex 1 - Naming convention for SeaDataCloud climatologies

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

1. [PRO] - project
2. [REG] - region
3. [PROD] - product
4. [V] - variable
5. [YYYY1]_[YYYY2] - time coverage
6. [S] - spatial resolution
7. [T] - temporal resolution (m=monthly, s=seasonal, a=annual)

Project	Region	Product	Var	Time Coverage	Time Res	Full Name
SDC	ARC	CLIM	T	1955-1964 1965-1974 1975-1984 1985-1994 1995-2004 2005-2014 1955-2014	monthly	SDC_ARC_CLIM_T_1955-2014_1_m
SDC	ARC	CLIM	S	1955-1964 1965-1974 1975-1984 1985-1994 1995-2004 2005-2014 1955-2014	monthly	SDC_ARC_CLIM_S_1955-2014_1_m
SDC	ARC	CLIM	T	1955-1964 1965-1974 1975-1984 1985-1994 1995-2004 2005-2014 1955-2014	seasonal	SDC_ARC_CLIM_T_1955-2014_1_s
SDC	ARC	CLIM	S	1955-1964 1965-1974 1975-1984 1985-1994 1995-2004 2005-2014 1955-2014	seasonal	SDC_ARC_CLIM_S_1955-2014_1_s

7. References

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8. List of acronyms

Acronym	Definition
ARC	Arctic Ocean
BAL	Baltic Sea
BLS	Black Sea
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
EC	European Commission
EDMO	European Directory of Marine Organisations (SeaDataNet catalogue)
GLO	GLobal Ocean
IOC	Intergovernmental Oceanographic Commission
IODE	International Oceanographic Data and Information Exchange (IOC)
MED	Mediterranean Sea
NAT	North Atlantic Ocean
NWS	North West Shelf
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