Mixed Layer Depth in the North Atlantic Ocean

SeaDataCloud

SDC_NAT_DP1

HORIZON **2020**

sdn-userdesk@seadatanet.org – www.seadatanet.org

SeaDataCloud - Further developing the pan-European infrastructure for marine and ocean data management

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Product Name

SDC_NAT_DP1

Extended name

SeaDataCloud

Product DOI

Mixed Layer Depth in the North Atlantic Ocean

Short description

The monthly climatology of the mixed layer depth (1/4°) based on the climatology processed on collection of temperature spanning 60 years (1955-2015). The MLD were computed from temperature monthly climatology which was processed with DIVA 4.7.2.

Authors

Christine Coatanoan

Dissemination	Copyright terms
Public	

How to Cite

History

Version	Authors	Date	Comments
1.0	C. Coatanoan	24/09/2020	First version
1.1	C. Coatanoan	08/02/2021	Last corrections

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Abstract

The SDC_NAT_DP1 product contains the North Atlantic Ocean monthly climatology for mixed layer depth (MLD) based on temperature climatology spanning 60 years (1955-2015). The MLD fields have spatial resolution 1/4°. The profiles of temperature combines data from 2 major sources, the SeaDataNet infrastructure and a part of data of the Coriolis Ocean Dataset for Reanalysis (CORA). The used climatology is the SeaDataCloud North Atlantic Ocean Temperature Climatology V1 (https://doi.org/10.13155/61810) done with the DIVA software, version 4.7.2. The product was developed in framework of the SeaDataCloud project. This product must be considered as feasibility study for the next phases, it is a beta-version and that further research needs to be done before its usage from users.

1. Data

1.1. Source data set

The product is created using the SDC North Atlantic Ocean climatology V1 (1/4°) of temperature (https://doi.org/10.13155/61810) which has been processed from the Historical Data Collection SeaDataCloud V1 (https://doi.org/10.13155/57037) and the integration of selected data coming from the external data sets coming from CMEMS In Situ TAC (CORA 5.1, Szekely et al., 2016). The MLD is calculated from that climatology.

1.2. General description of the input data set

The studied area is the North Atlantic Ocean, starting at 10°N up to the boundary of the Artic Sea (62°N). On the western part, the longitude limit is 82°W running to the Mediterranean Sea and the North Sea. Only the output of the Labrador Sea is considered while a mask has been defined to not take into account North Sea, Artic Sea, Mediterranean Sea. 9421968 stations, including some data types (CTD, Thermosalinographs, Thermistor chains, Water temperature sensors, …), covers the studied area. The monthly distribution indicates a more important coverage during the summer months, the winter months having the smallest number of data (Figure 1).

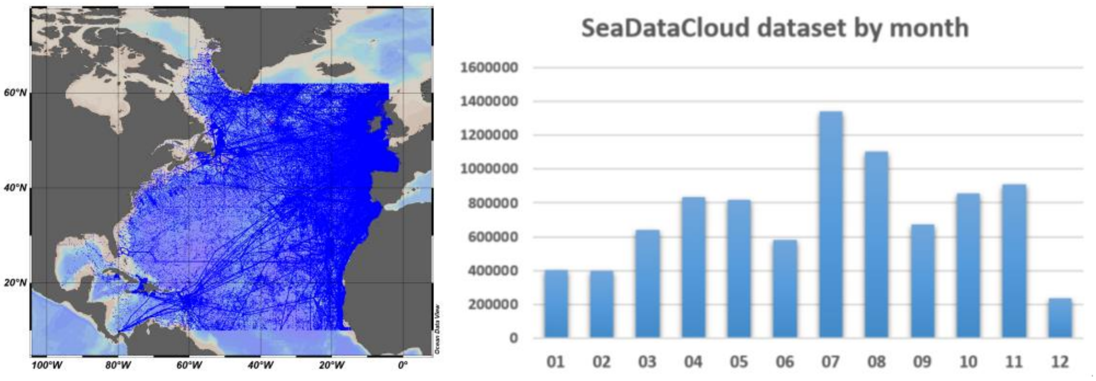


Figure 1. Spatial coverage for Temperature and SeaDataCloud distribution by month.

To produce temperature climatology, only a part of CORA5.1 dataset has been integrated with SDC collection, taking into account some specific types of instrument (BO,CT,MO,PF,TR,TS,XX). The aim to integrate external datasets allows to fill gap in data distribution, especially for oldest years (Figure 2).

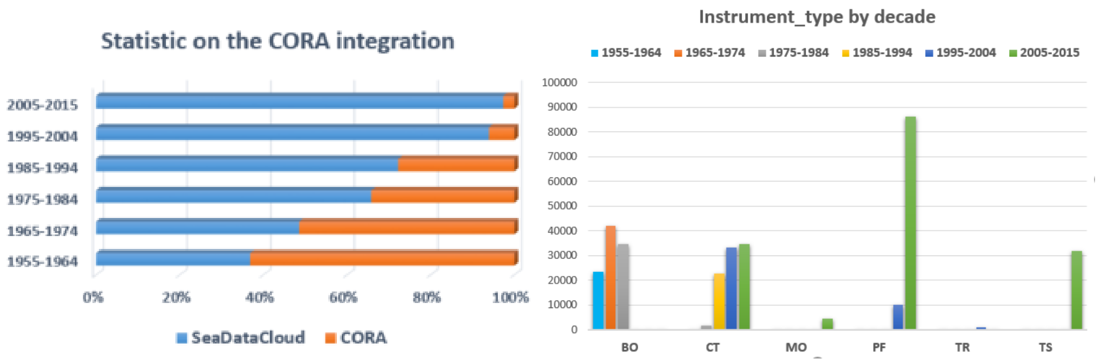


Figure 2. Data distribution of SeaDataCloud and CORA dataset and Instrument_type by decade in the whole dataset.

More information on the data distribution is described in Coatanoan and Simoncelli (2018).

2. Methodology

2.1. Data QC

T profiles comprise between 1955 and 2015 have been QCed and interpolated to standard depths. Data Quality Flags (QF) have been revised using recommended QC procedures defined within SeaDataNet2 project and further refined in the first phase of SeaDataCloud. The QC procedure applied on the SDC aggregated dataset is described in Coatanoan and Simoncelli (2018). All the T measurements have been QCed following the procedure related to the first aggregated dataset V1. The quality control of the data has been performed with the help of ODV software (Schlitzer, 2017).

2.2. Calculation of the MLD

There are many ways to calculate the mixed layer depth based on different physical parameters (temperature, density, salinity). Many computations presented in literature are based on a temperature change criterion, the value of 0.5°C is chosen following Levitus (1982).

Here the simple definition is adopted to compute the mixed layer depth, using the level at which temperature changes by more than 0.5°C with respect to the 10 meter depth. This reference depth was shown to be sufficiently deep to avoid aliasing by the diurnal signal, but shallow enough to give a reasonable approximation of monthly SST (Carton et al., 2008). The algorithm for finding mixed Layer Depths is based on the work done by Holte and Taly (2009). The In situ temperature has been converted to potential temperature for the calculation.

The MLD criteria is applied at every point of the 1/4°x1/4° grid to the vertical profiles of temperature climatology.

2.3. DIVA implementation and settings

The analysis of temperature has been performed for the time period 1955-2015. For this study, the run processed at the resolution ¼° has been used to provide the input for calculation of MLD climatology.
The vertical levels have been defined equal to the WOA2018 ones: [0: 5: 100, 125:25:500, 550:50:2000, 2100:100:6000](meters).

Resolution ¼°		
Lc: correlation length	2	
Snr : signal to noise ratio	1	
Varbak : variance of the background field	1	
Parameters estimation and vertical filtering	-10	correlation length parameters are to be estimated using data mean distance as a minimum and vertically filtered
Xori	-85	dx = 0.25 – nx = 389
Yori	10	dx = 0.25 – ny = 209
Vertical levels	107 levels	[6000:100:2000][1950:50:500][475:25:100][95:5:0]

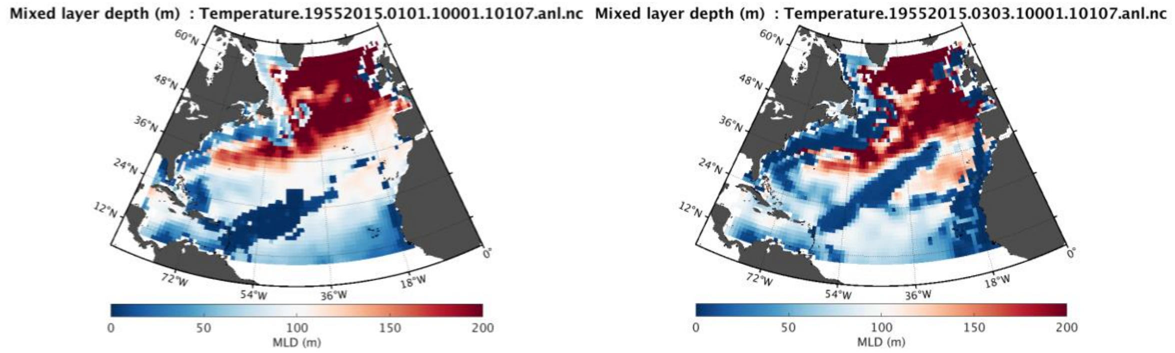
More information on the data distribution is described in Coatanoan et al. (2019).

3. Product Description

The oceanic mixed layer provides a connection between atmosphere and ocean, consequently it plays a central role in climate variability.

A North Atlantic Ocean climatology (1/4° 12 months) of the Mixed Layer Depth based on a comprehensive collection of temperature profiles spanning 60 years (1955–2015) can be used to describe the seasonal cycle of the mixed layer depth on the whole North Atlantic Ocean on a monthly climatological basis. It also permits to identify deep water formation sites, characterized by significant differences in the winter mixing intensity. This product is also useful to the ocean forecasting community for model validation.

a)



b)

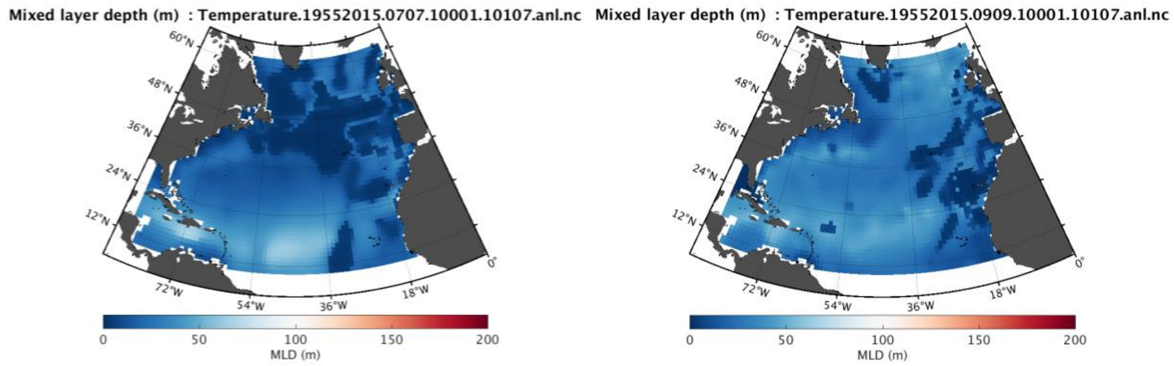


Figure 3. Mixed layer depth during a) the cold months (January, March) and b) during the warm months (July, September).

If the comparison is made between cold months (January, March) and warm months (July, September) (Figure **3**), the main observation is the shallowness MLD during the warm period versus the cold period. Deepest MLD values occur in the Labrador Sea southeast of Greenland, during winter period.

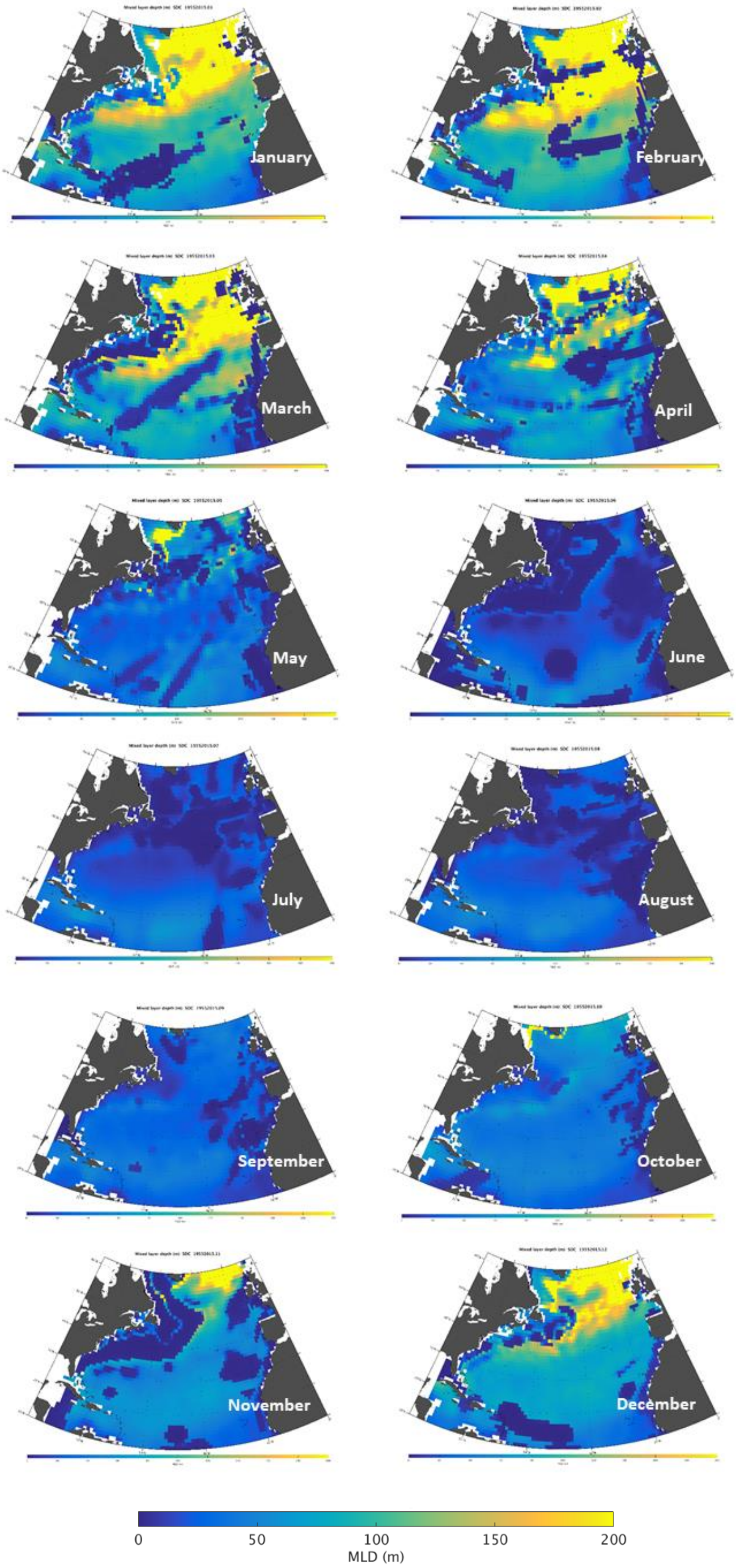


Figure 4. Monthly MLD for the period 1955-2015.

The distribution of the monthly MLD for the period 1955-2015 is shown in Figure **4**. During the summer distributions, the summer heating of the upper ocean is responsible for shallow mixed layers.

The shallow summer MLD is produced by solar heating while air-sea interactions produce the deeper winter MLD. The deep winter layers set the ocean's subsurface properties in regions of deep and intermediate water formation.

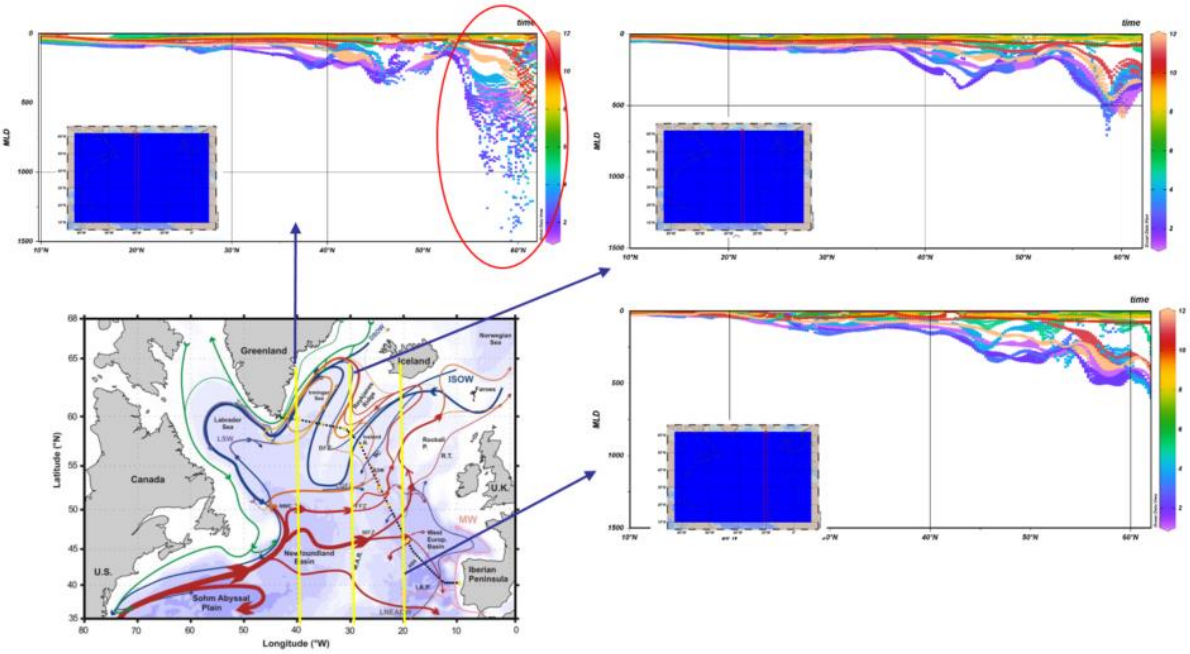


Figure 5. Temporal and spatial evolution of the MLD from three longitude sections.

In the North Atlantic Ocean, and more specifically in the Labrador Sea, the MLD can reach depth deeper than 1000m for winter period, as Figure **5** shows for the section 40°W, very close southeast of Greenland.

4. Consistency analysis

Mixed layer depths are available from NOAA, based on the world ocean atlas 1994, (https://www.nodc.noaa.gov/OC5/WOA94/mix.html). The MLD fields available are computed from climatological monthly mean profiles of potential temperature and potential density based on three different criteria: a temperature change from the ocean surface of 0.5 degree Celsius, a density change from the ocean surface of 0.125 (sigma units), and a variable density change from the ocean surface corresponding to a temperature change of 0.5 degree Celsius. The MLD based on the variable density criterion is designed to account for the large variability of the coefficient of thermal expansion that characterizes seawater. The comparison is made with the criteria of a temperature change from the ocean surface of 0.5 degree Celsius.
In the NOAA calculation, the 1000m depth limit is chosen due to insufficient data coverage at deeper levels. If the corresponding criteria is not met at a certain grid point, the MLD value at the grid point is set to 1000m. For the SDC calculation, since the coverage in time and space is higher, the limit has not been taken into account and can explain deepest MLD comparing to the NOAA values.

The validation methodology is based on a visual comparison between the both datasets on each month (Figure **6**).

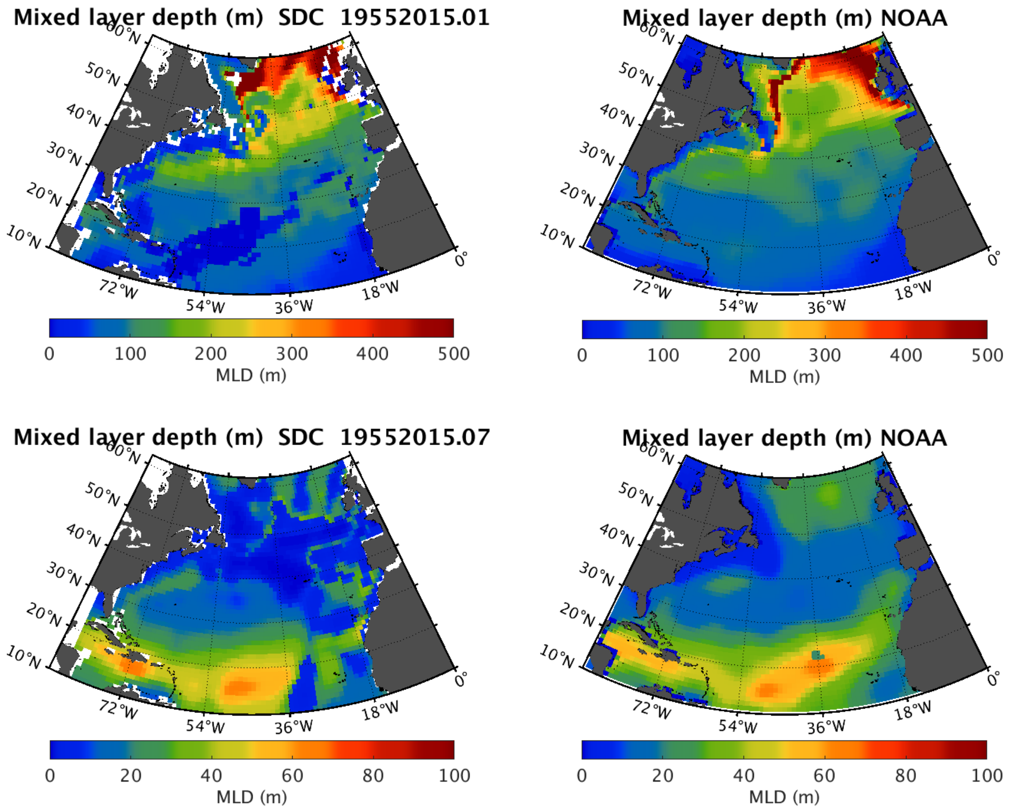
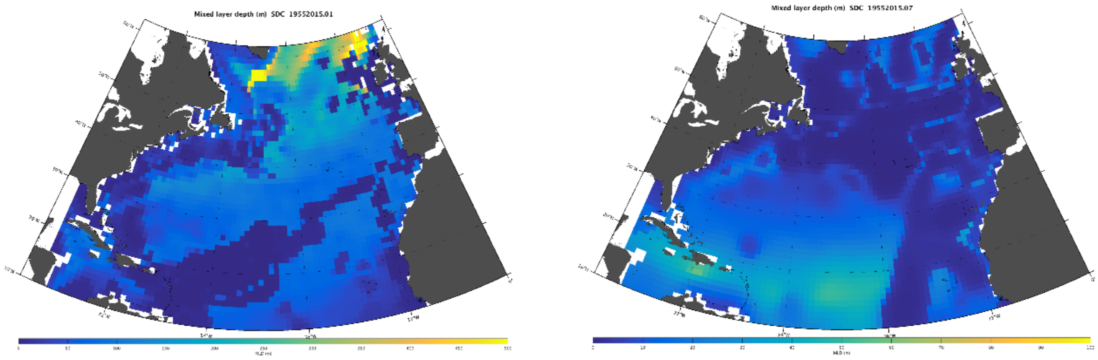


Figure 6. Monthly mean MLD (January on top and July on bottom) based on Potential Temperature criterion 0.5 degree Celsius. Left) SeaDataCloud data, right) NOAA data.

The similarities in the distribution of LDMs between the two datasets are highlighted. The deepest MLDs are found in the north of the region, near Greenland, while the shallowest are observed in the south. Minor differences may arise from the time period covered by the two sources. For the SeaDataCloud set, the period covers the years 1955 to 2015, while for NOAA, the MPL was calculated from the WO94 Atlas, so SeaDataCloud integrates a lot of more recent data.

A test has also been done with a criteria of 0.2°C (Figure **7**) following the work done by Carton et al. (2008), this result needs to be more studied with other parameters as density and salinity.



a) b)

Figure 7. Test with temperature criterion of 0.2°C in a) January and b) July .

The Figure **8** shows annual cycle at different locations in the North Atlantic Ocean. In the area close the Greenland, deepest MLDs are observed (black areas in Figure). The MLD is as its deepest at the end of winter, and then within two months the MLD shoals to its near-minimum value through solar heating.

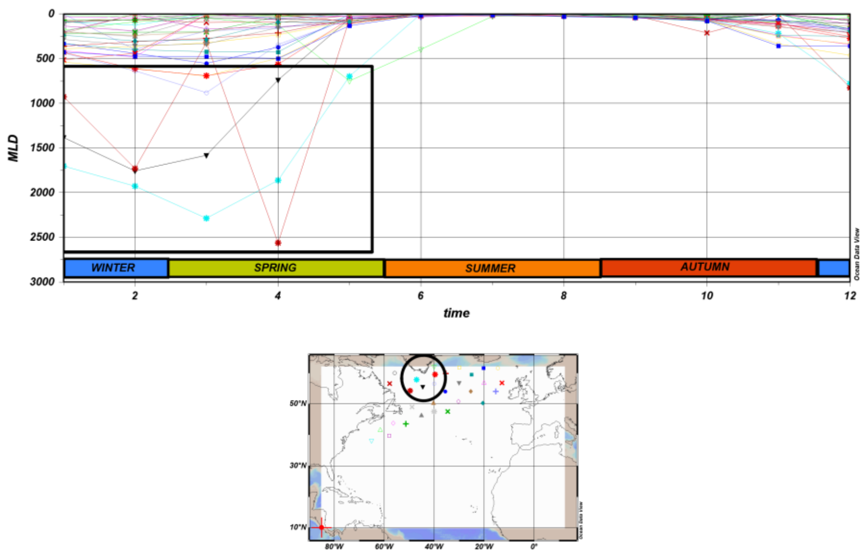
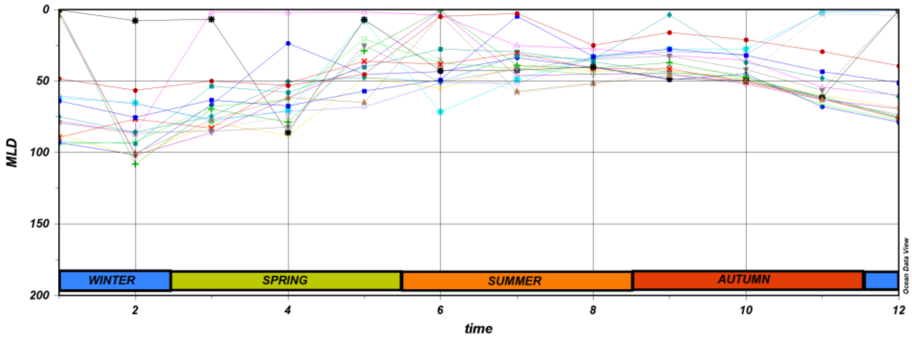


Figure 8. Annual cycle at different locations in the North Atlantic Ocean area close to the Greenland and Labrador Sea.

For the subtropical region, the MLD annual cycle amplitude is relatively small (Figure 9).



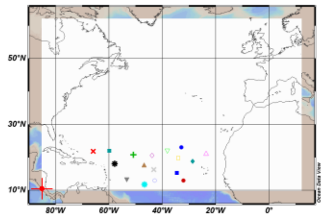


Figure 9. Annual cycle at different locations in the North Atlantic Ocean area close to the Greenland and Labrador Sea.

5. Technical Specifications

5.1. Product Format

The product file is delivered in the NetCDF format. The file contains one variable (2 space dimensions and 1 time dimension). The name of the variable is MLD.

5.2. Product Usability

The MLD computation is only based on the criterion of 0.5°C temperature difference, neglecting any vertical salinity stratification but salinity influences stratification in some oceanic regions, as clearly demonstrated from the MLD differences between the density and temperature criteria. Then a sigma-t criteria should be more correct especially in regions with a small thermocline.

Annex 1 - Naming convention for SeaDataCloud new products

Table A1 - Name convention for SeaDataCloud new Data Products

Project	Region	New Data Product	Product Number
SDC	GLO	NewProduct_DP	1,2,3…
SDC	ARC	NewProduct_DP	1,2,3…
SDC	NWS	NewProduct_DP	1,2,3…
SDC	BAL	NewProduct_DP	1,2,3…
SDC	NAT	NewProduct_DP	1
SDC	MED	NewProduct_DP	1,2,3…
SDC	BLS	NewProduct_DP	1,2,3…

6. References

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7. 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