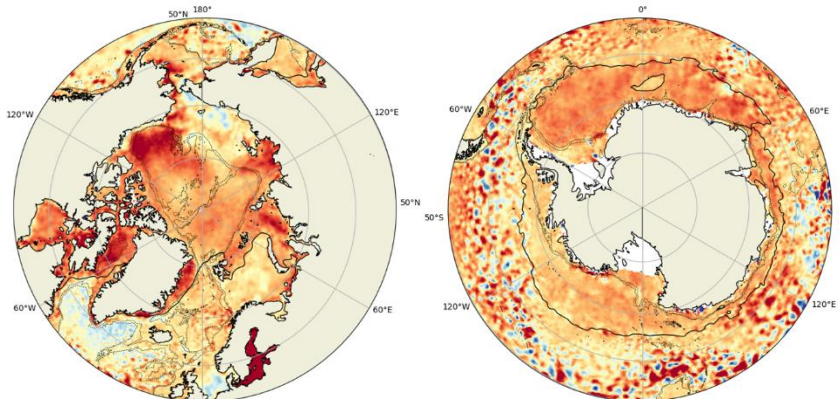
SSALTO/DUACS Experimental Product Handbook:

Gridded and along-track Sea Level Anomalies for the Arctic and Southern Oceans

DOI: 10.24400/527896/a01-2020.001 and 10.24400/527896/a01-2022.010



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Issue:	Date:	Validated by	Reason for change:
1.0	2022/03/18		Creation of the document from existent document
1.1	2023/06/08		Publication of V2.0 and merging Arctic and Southern Oceans

List of Acronyms:

Aviso+	Archiving, Validation and Interpretation of Satellite Oceanographic data
C3S	Copernicus Climage Change Service
CMEMS	Copernicus Marine Environment Monitoring Service
Cnes	Centre National d'Etudes Spatiales
DUACS	Data Unification and Altimeter Combination System
L3	Level-3 products (along-track)
L4	Level 4 products (gridded)
MDT	Mean Dynamic Topography
MSS	Mean Sea Surface
SALP	Service d'Altimétrie et de Localisation Précise
SAR(M)	Synthetic Aperture Radar (Mode)
Ssalto	Segment Sol multimissions d'ALTimétrie, d'Orbitographie et de localisation précise.
SLA	Sea Level Anomaly
SSH	Sea Surface Height

Contents

1 Introduction

This document describes the DUACS Experimental Arctic and Southern Oceans products providing sea level height from 50°N up to 88°N for Arctic Ocean and 50°S to 88°S for Southern Ocean including the ice-covered region thanks to the use of sea level observations within the leads (open water area within a fracture of sea ice). Both along-track (level 3, **Erreur ! Source du renvoi introuvable.** and Figure 4) from 3 satellites (SARAL/AltiKa, Cryosat-2, Sentinel-3A), and gridded (level 4, Figure 3 and Figure 6) products combining the 3 missions are provided. Additional gridded products for each satellite are also available (Figure 2 and Figure 5). Along-track products are available within the leads only and can be combined with DUACS open ocean along-track products (delivered by the Copernicus Marine Service with the name SEALEVEL_GLO_PHY_L3_MY_008_062, doi: 10.48670/moi-00146).

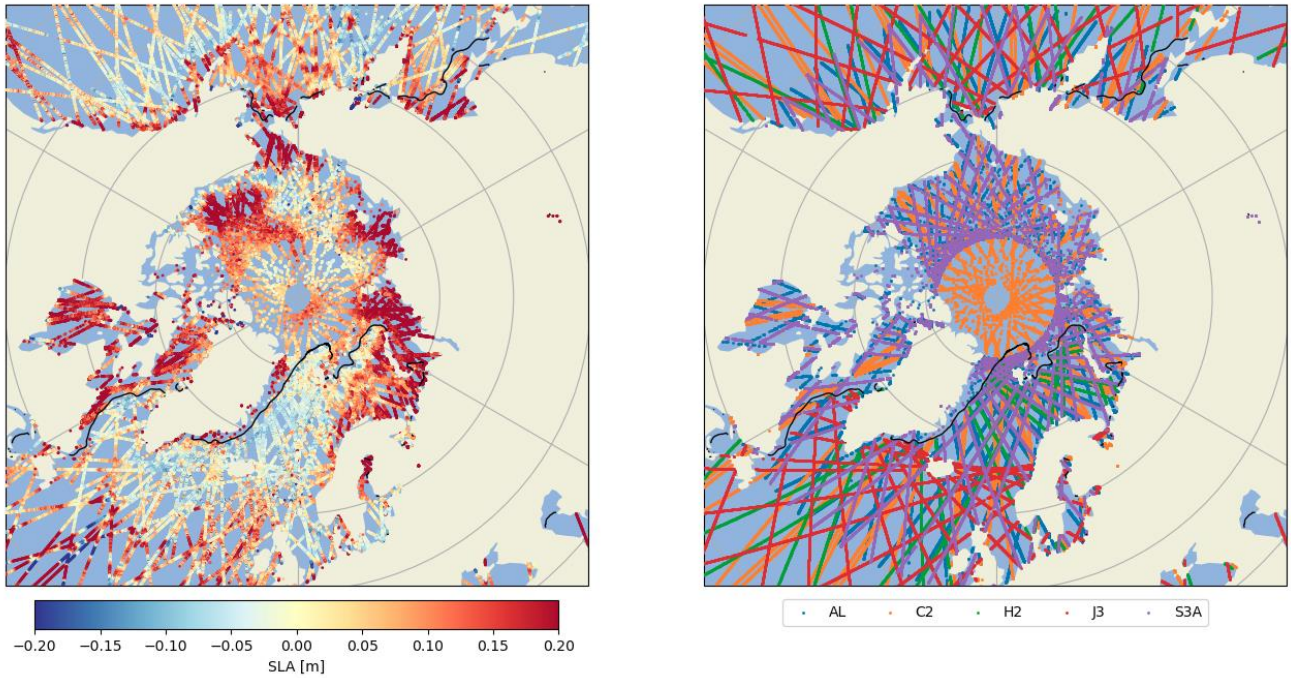

Figure 1 - Along-track sea level observation from satellites for 3 days (2018/01/18 to 2018/01/20) (left) and mission corresponding to the observations (AL : SARAL/AltiKa, C2 : Cryosat-2, H2 : Haiyang-2, J3 : Jason-3, S3A : Sentinel-3A; only AL, S3A and C2 are used for the ice-covered region) (right). The black line denotes the 50% sea ice concentration threshold.

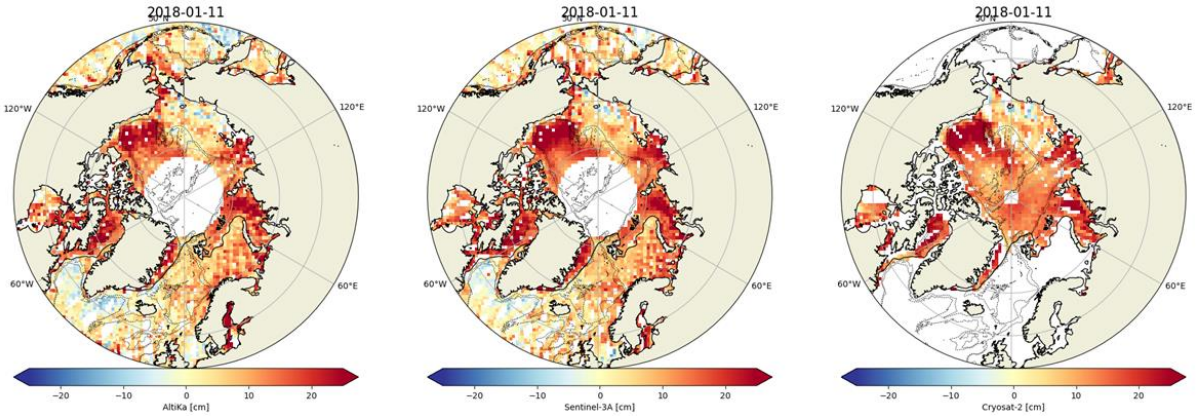

Figure 2 - Mean SLA observations in 75km/10days boxes for 2018/01/11 for SARAL/AltiKa (left), Sentinel-3A (center) and Cryosat-2 (right). The black line denotes the 50% sea ice concentration threshold and satellite observations within the leads in the ice-covered region are used.

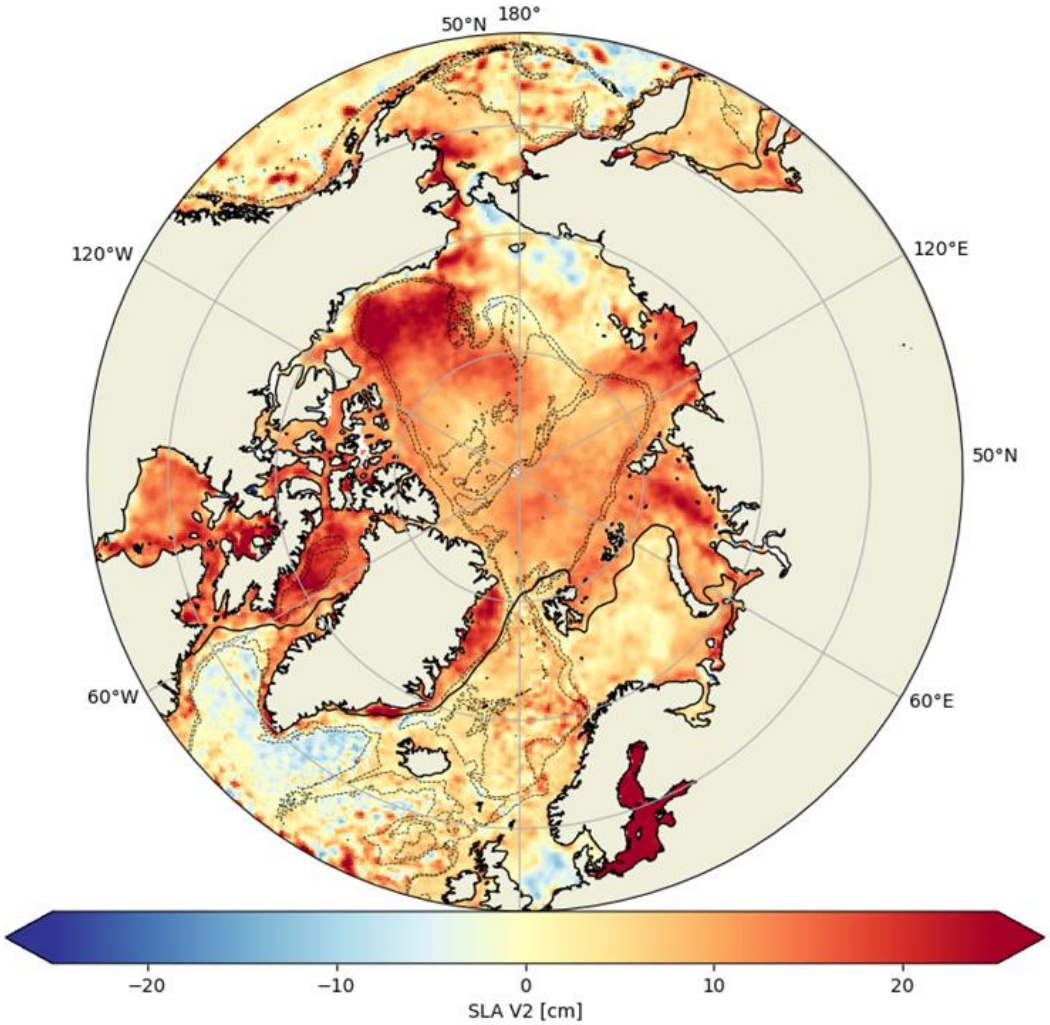

Figure 3 - Multi-mission map of sea level anomaly for 2018/01/08. The black line denotes the 50% sea ice concentration threshold.

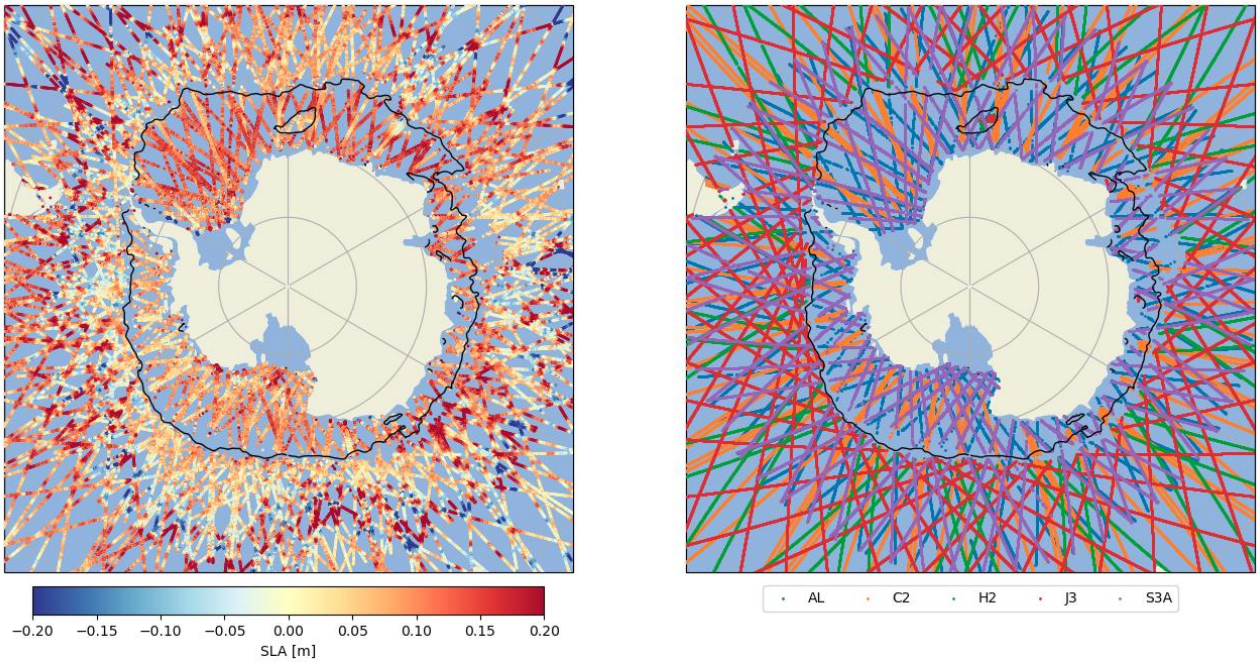

Figure 4 - Along-track sea level observation from satellites for 3 days (2017/11/15 to 2017/11/17) (left) and mission corresponding to the observations (AL : SARAL/AltiKa, C2 : Cryosat-2, H2 : Haiyang-2, J3 : Jason-3, S3A : Sentinel-3A; only AL, S3A and C2 are used for the ice-covered region) (right). The black line denotes the 50% sea ice concentration threshold.

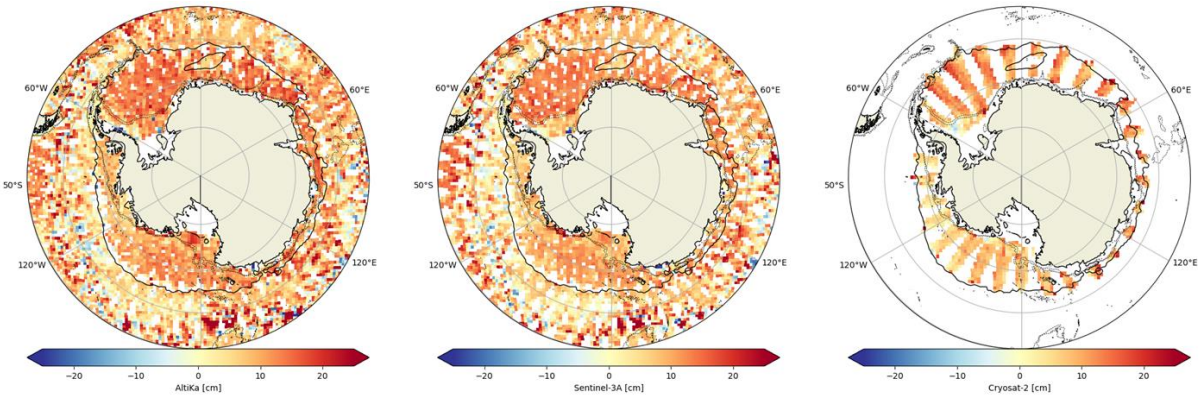

Figure 5 - Mean SLA observations in 75km/10days boxes for 2017/11/22 for SARAL/AltiKa (left), Sentinel-3A (center) and Cryosat-2 (right). The black line denotes the 50% sea ice concentration threshold and satellite observations within the leads in the ice-covered region are used.

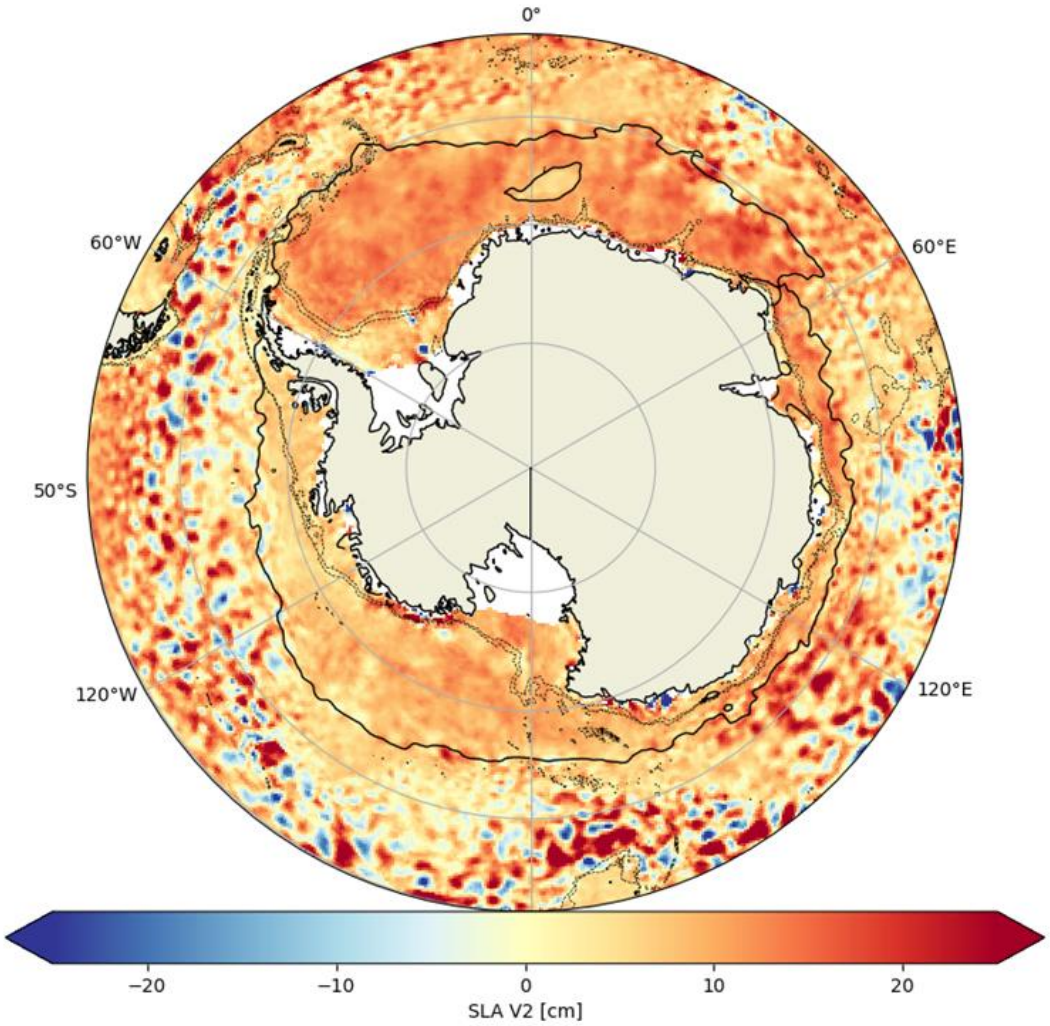

Figure 6 - Multi-mission map of sea level anomaly for 2017/11/16. The black line denotes the 50% sea ice concentration threshold.

1.1 Acknowledgments

When using this experimental SSALTO/DUACS product, please cite:

For Arctic product: "This product was processed by SSALTO/DUACS (DOI: 10.24400/527896/a01-2020.001) and distributed by AVISO+ (https://www.aviso.altimetry.fr) with support from CNES"

For Antarctic product: "This product was processed by SSALTO/DUACS (DOI: 10.24400/527896/a01-2022.010) and distributed by AVISO+ (https://www.aviso.altimetry.fr) with support from CNES"

1.2 User's feedback

The product is an experimental product. Therefore, each and every question, comment, example of use, and suggestion will help us improve the product. You're welcome to ask or send them to aviso@altimetry.fr.

2 Gridded and along-track Sea Level Height dedicated to Polar Oceans products

2.1 Versioning

The original version of the products is the version 01_01 for Arctic Ocean (only gridded products) corresponding to the dataset described in Prandi et al., 2021.

Version 01_02 for Arctic Ocean (gridded and along-track products) is a temporal extension of version 01_01 adding along-track data with some differences in the input data:

- The input data of SARAL/AltiKa mission are in GDR-F version instead of GDR-E for version 01_01
- The input data of Cryosat-2 are in Baseline D from 01/2019 instead of Baseline C for version 01_01

Version 02_00 (Arctic and Southern Oceans) (gridded and along-track products) is a reprocessing and extension of the datasets over the period 2011-2021. Differences with version 01_02 are :

- Use of new geophysical corrections (MSS : CNES/CLS22 hybrid DTU21, ocean tide : FES22B).
- New input parameters for optimal interpolation (variance map, noise error, long-wavelength error).
- Use of DUACS DT21 database on open ocean to complement the 3 satellites processed in the polar region.

It is foreseen to deliver new versions of some products: for any new future version delivered, you will be informed via the AVISO+ user service, by email and on the website. The version number is indicated in the ftp folder and in the file ('product_version' attribute).

2.2 Processing

DUACS Experimental Arctic and Southern Oceans products provide sea level height over 50°N for Arctic Ocean and below 50°S for Southern Ocean including the ice-covered region thanks to sea level observations within the leads (open water area within a fracture of sea ice).

Sea level from 3 satellites (Sentinel-3, Cryosat-2 and SARAL/AltiKa) are processed separately to produce 3 mono-mission gridded products. A cross-calibration between the 3 missions is then performed to get cross-calibrated along-track products. Then, the along-track data are combined through optimal interpolation to produce the multi-mission gridded product. Input data come from 3 satellites within the ice-covered region (Table 1), the period used for all the 3 satellites is summarized in section 2.5.2. The processing is described in this section (following Prandi et al., 2021).

Waveform classification of satellite echoes is performed to differentiate leads and open ocean from floes measurements using neural-network-based classification method (Poisson et al. 2018). Open ocean is identified as class 1 (Brownian echoes) and leads are identified as class 2 (peaky echoes). Furthermore, the Sea Ice Concentration threshold of 30% is added to discard open ocean measurements above this threshold and leads measurements below this threshold. A threshold on the backscatter coefficient is also used to select the brightest measurements corresponding to leads waveforms.

Mission name	Cycle duration (days)	Inclination	Mode	Retracking	Input product	Sampling freq.
SARAL/AltiKa	35	98.538◦	LRM (ocean&leads)	Adaptive (ocean&leads)	GDR-F	40 Hz
CryoSat-2	369 (30 d pseudo-cycle)	92◦	SAR (leads)	TFRMA (leads)	PDGS Ice Baseline C/D	20 Hz
Sentinel-3A	27	98.65◦	SAR (ocean&leads)	TFRMA (leads), CNES retracking (ocean)	CNES S3PP with zero pad. and Hamming	20 Hz

Table 1 - Input-data characteristics

Radar is influenced by small bright targets such as leads in the radar footprint. Radar may thus observe off-nadir targets. On SARAL/AltiKa which operates in LRM mode with a greater footprint compared to SAR (Synthetic Aperture Radar) missions, this is corrected by selecting the maximum backscatter echo within a moving window as leads measurements.

SLA is then calculated as

SLA = orbit – range – corrections

where the corrections account for geophysical and instrumental effects that are summarized in Table 2 - Corrections applied to altimetric along-track data..

Ionospheric correction	GIM (Iijima et al., 1999)
Dry tropospheric correction	ECMWF (European Centre for Medium Range Weather Forecasts) model
Wet tropospheric correction	ECMWF model
DAC (Dynamic Atmospheric Correction)	MOG2D model (Carrère and Lyard, 2003)
Pole tide	Desai et al. (2015)
Ocean tide	FES2022B (Carrère et al., 2016)
Solid earth tide Elastic response to tidal potential	(Cartwright and Edden, 1973)
Sea state bias	Non-parametric (ocean only)
MSS	MSS CNES/CLS22 (Schaeffer et al., 2023) hybrid MSS DTU21
MDT	MDT CNES/CLS22

Table 2 - Corrections applied to altimetric along-track data.

An editing of the SLA measurements is then performed in 3 steps. Firstly, data outside of thresholds are edited (|SLA|>2m) and the instrumental editing is applied to remove outliers. Then an iterative editing is applied on the open ocean data. Finally, large-scale outliers are discarded as the measurements that are dispersed of more than 2.5σ from a 3-month/200km running mean.

Then, we get along-track data for the 3 missions. It can be seen that the inter-mission differences are below 4cm so that the 3 missions are consistent and observe similar signals (Figure 7 and Figure 8). Then the missions are cross calibrated on SARAL/AltiKa which is the reference since it is the only mission using the same retracking on open ocean and leads thus providing a theoretical continuity between the two surfaces. A bias and a seasonal signal are removed from Sentinel-3A and Cryosat-2 by cross-calibration on SARAL/AltiKa.

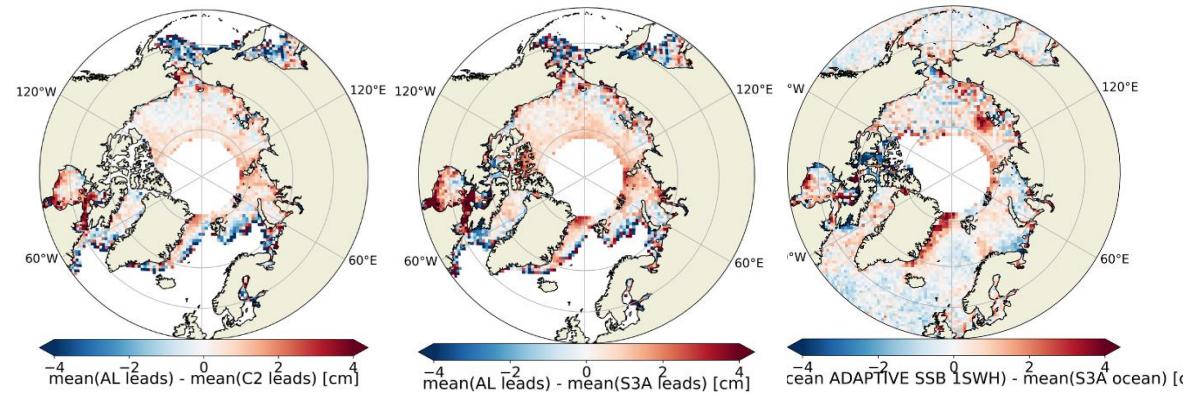

Figure 7 - Inter-mission SLA difference in 75km/10d boxes for SARAL/AltiKa vs Cryosat-2 over leads (left), SARAL/AltiKa vs Sentinel-3A over leads (middle) and SARAL/AltiKa vs Sentinel-3A over open ocean (middle).

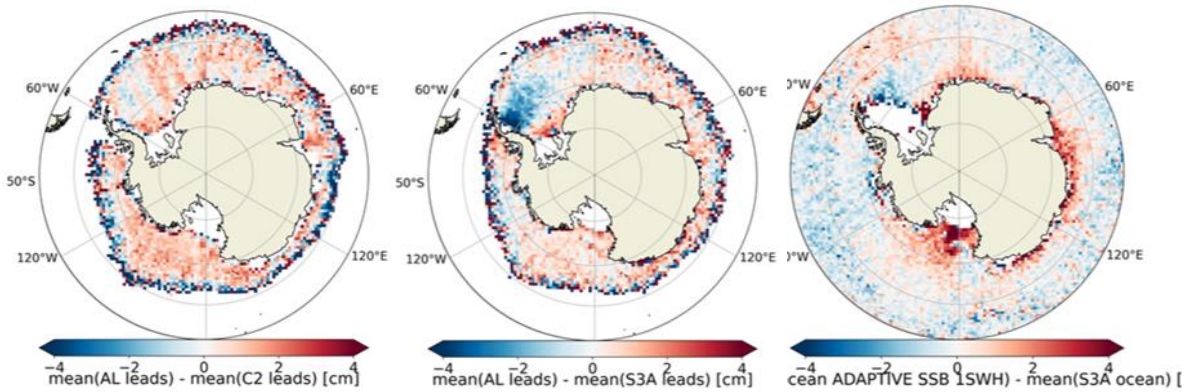

Figure 8 - Inter-mission SLA difference in 75km/10d boxes for SARAL/AltiKa vs Cryosat-2 over leads (left), SARAL/AltiKa vs Sentinel-3A over leads (middle) and SARAL/AltiKa vs Sentinel-3A over open ocean (middle).

After these steps, we get along-track data from 3 altimetry missions from 50°N to 88°N (Arctic) and from 50°S to 88°S (Southern) that are cross-calibrated. To map the along-track data described above, we use optimal interpolation (OI, Bretherton et al. 1976) method derived from the DUACS (Data Unification and Altimeter Combination System) processing (Le Traon and Dibarboure, 1999; Pascual et al., 2006) with adaptations to fit the Polar Oceans. On the open ocean, the polar data is combined with DUACS SLA satellite data that are not processed in the leads (Jason-2, Jason-3, Haiyang-2, ENVISAT, Cryosat-2).

Along-track sea level anomaly products are available within the leads. A cross-calibration is performed to reduce long wavelength error between the 3 missions along-track data. It is based on Optimal Interpolation (Le Traon et al, 2003) and contributes to reducing geographically correlated errors between the missions. The data is finally filtered and subsampled to deliver a 5Hz (~1 km) resolution product. The product is only available in the ice-covered region and can be used in association with DUACS DT21 open ocean dataset (delivered by the Copernicus Marine Service with the name SEALEVEL_GLO_PHY_L3_MY_008_062, doi: 10.48670/moi-00146) to cover all the northern hemisphere.

2.3 Validation

In-situ observations are scarce in the seasonally ice-covered Arctic and Southern Oceans. Here, we selected Gloss/Clivar tide gauge at Prudoe Bay (Beaufort Sea) and Dumont D'Urville (Southern ocean) with data in the seasonally ice-covered region for the comparison with altimetry sea level. The hourly tide gauge data is averaged daily and corrected from ocean tide, Dynamical Atmospheric correction, and glacial isostatic adjustment (accounting for the ongoing movement of land) to be comparable to satellite sea level anomaly. The comparison (Figure 9, Figure 10,Figure 11Figure 12) shows a good correlation between altimetry and tide gauge sea level at monthly time scale. During the ice-covered season (green background), the correlation is still good.

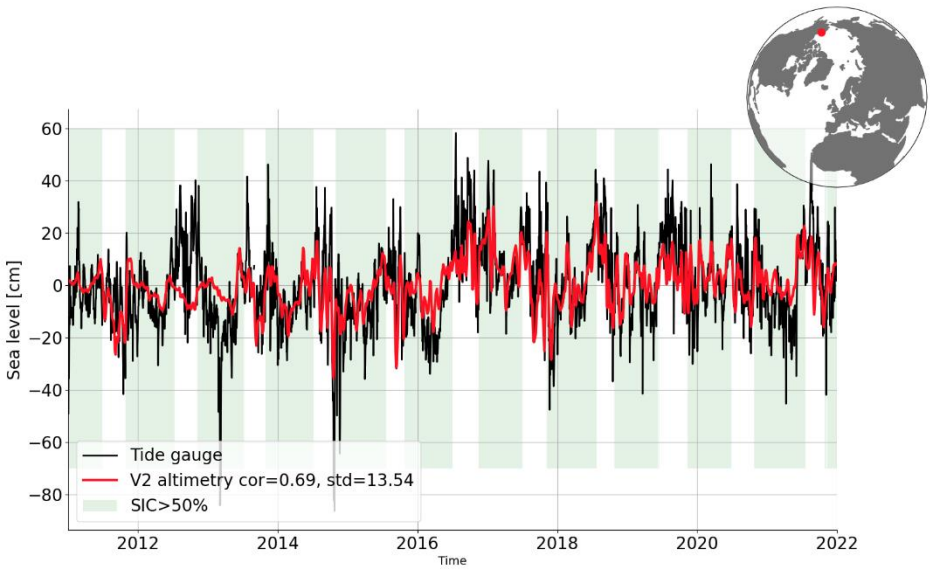

Figure 9 - Tide gauge sea level (black) and altimetry sea level (red) at Prudoe Bay. The green background denotes ice-covered period.

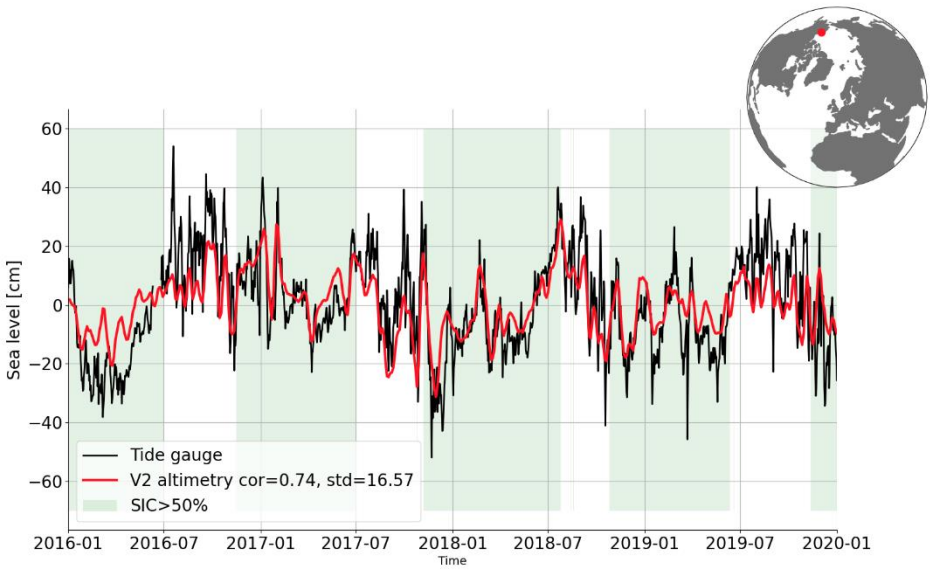

Figure 10 - Tide gauge sea level (black) and altimetry sea level (red) at Prudoe Bay. Zoom on 2016-2019. The green background denotes ice-covered period.

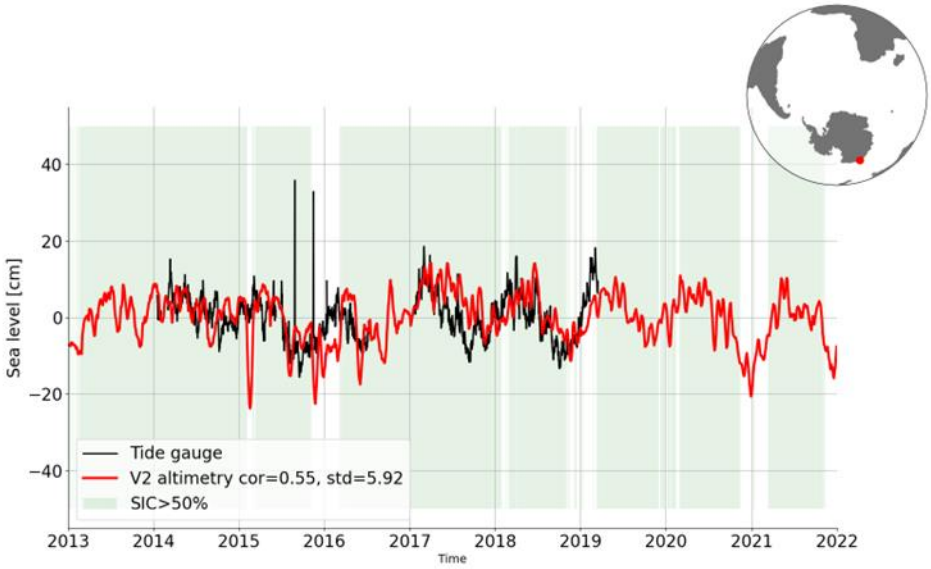

Figure 11 - Tide gauge sea level (black) and altimetry sea level (red) at Dumont D'Urville. The green background denotes ice-covered period.

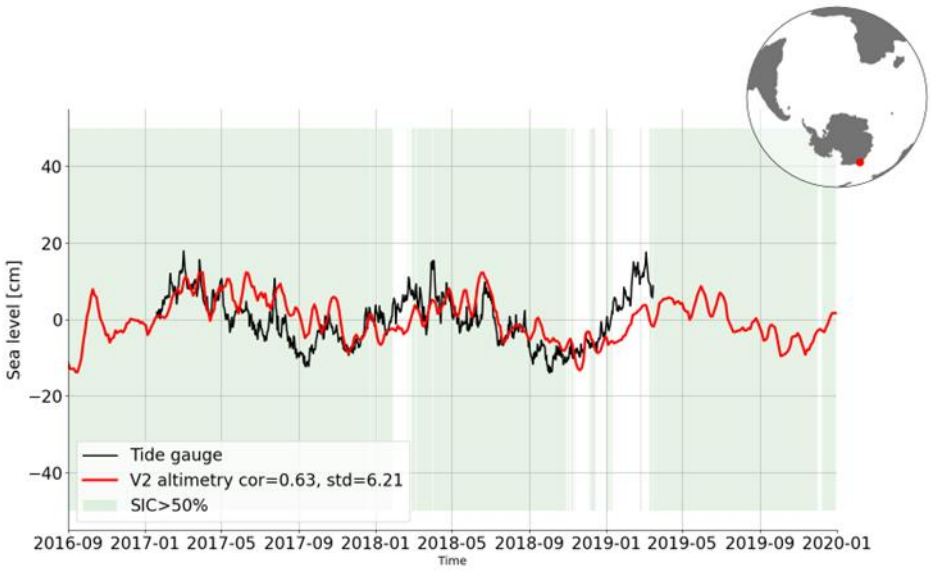

Figure 12 - Tide gauge sea level (black) and altimetry sea level (red) at Dumont D'Urville. Zoom on 2016-2019. The green background denotes ice-covered period.

In the Kara and Laptev Seas, there is a wind-driven accumulation of sea level on the Siberian shelf region through cross-shelf Ekman transport: positive zonal winds induce SLA increase near the coast. Daily NCEP/NCAR reanalysis surface wind (https://www.psl.noaa.gov/data/gridded/data.ncep.reanalysis.html) are used to compare zonal winds to sea level variations. To do so, we average the zonal wind and the altimetry SLA in the Siberian shelf region (longitudes in [60, 180]°W, latitude in [65, 85]°N) and plot the two time series on Figure 13. A good correlation can be found between the two time series. During the ice-covered period (green background), there is still an impact of the wind on the sea level with good correlation.

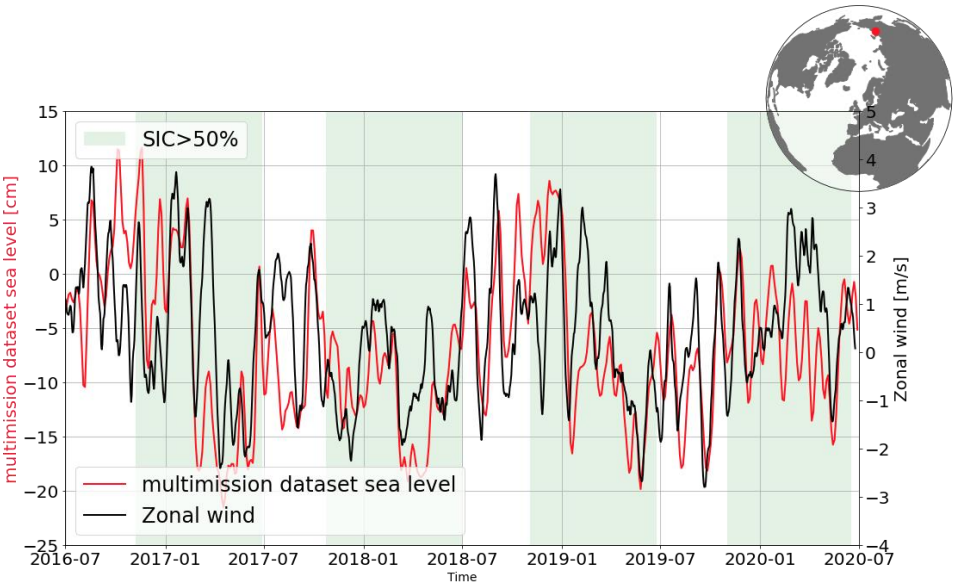

Figure 13 - Average of model zonal wind (red) and altimetry sea level (red) in Siberian shelf region. The green background denotes ice-covered period.

Sea level trends can be computed from the product for the period 2011-2021 for the Arctic ocean (Figure 14, right). On open ocean region, it is comparable to open ocean trends from DUACS product (Figure 14, left) showing trends around 3mm/yr with regional variabilities. In the ice-covered region (Figure 14, right), trends are increased in the Beaufort region and a decrease is observed on the Chukchi plateau. This negative trend corresponds to a decrease of freshwater content observed by Hall et al., 2023 (Figure 10) and by models.

For the Southern ocean, sea level trends are also comparable to DUACS open ocean trends on open ocean (Figure 15) while an increase of the trends can be seen in the ice-covered region in the western part of the Weddell Sea on the polar dataset.

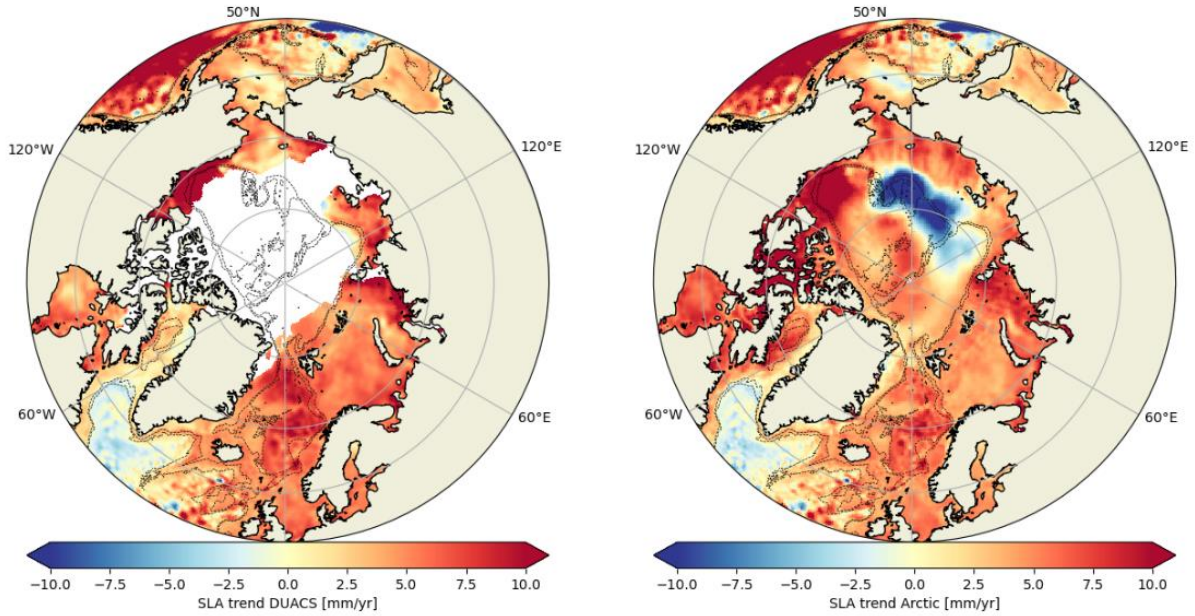

Figure 14 - Altimetry sea level trends from DUACS open ocean product (left) and from V2 Arctic product 01/01/2011 to 01/01/2022 (right)

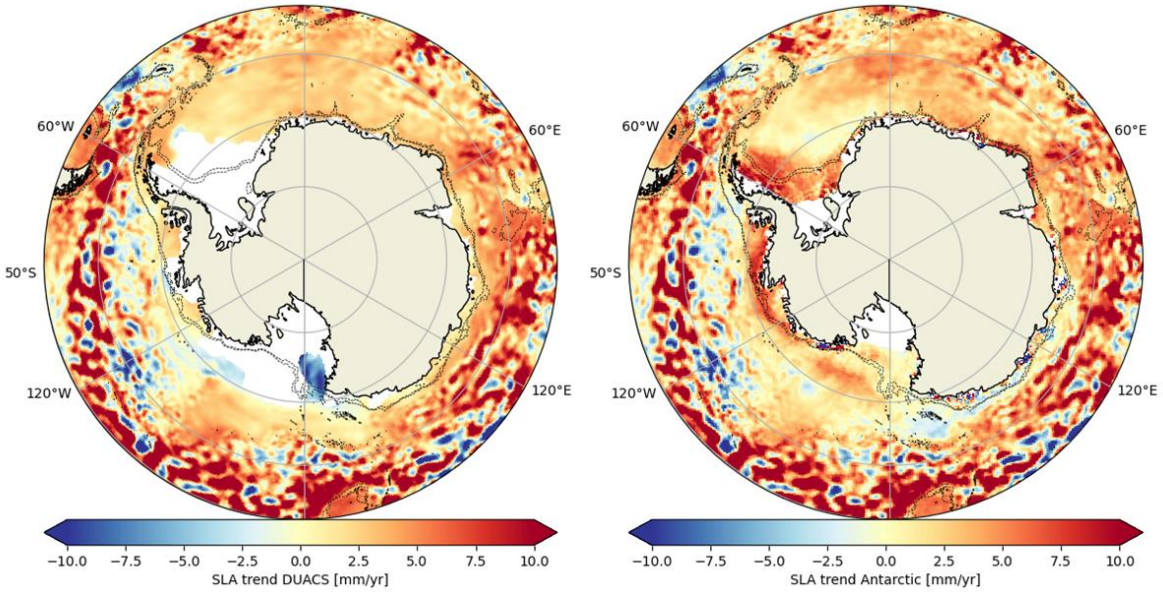

Figure 15 - Altimetry sea level trends from DUACS open ocean product (left) and from V2 Southern product 01/01/2013 to 01/01/2022 (right)

2.4 Perspectives

This product is still experimental now, and we encourage users' feedback on the possible improvements.

Analysis should be dedicated on the products for the summer months for which melt ponds may be observed by satellites (example in June 2016 for the Arctic on Figure 16). It is indeed difficult to differentiate satellite observations from melt ponds surfaces from the ones from leads surfaces as there are both small bright surfaces surrounded by sea ice.

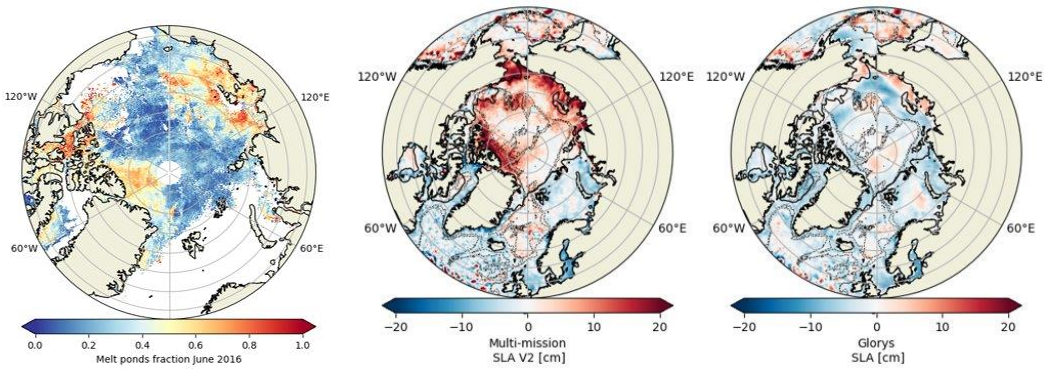

Figure 16 - Melt ponds fraction for June 2016 (left), altimetry SLA (middle) and Glorys12V1 SLA (right)

2.5 Product description

2.5.1 Geographical characteristics

All products cover all latitudes greater than 50°N with differences between the missions:

- SARAL/AltiKa and Sentinel-3A have a polar observation gap north of 82°N,
- CryoSat-2 covers latitudes up to 88°N, but not the open ocean at lower latitudes, due to the use of SAR measurements only,
- The multi-mission product covers the maximum area where data is available.

The along-track product is only available within the leads (open water area within a fracture of sea ice) and only covers the ice-covered region. It can be used in association with DUACS open ocean dataset (delivered by the Copernicus Marine Service with the name SEALEVEL_GLO_PHY_L3_MY_008_062, doi: 10.48670/moi-00146) to cover all the northern hemisphere.

2.5.2 Temporal availability and grid characteristics

One file per mission is delivered for gridded monomission products. One file per day for each mission is delivered for along-track products. For gridded multimission product, 1 file every 3 days is delivered.

Periods of availability differ a bit from along-track, mono-mission and multi-mission products. The maximum period is given for mono-mission products while this period is reduced for along-track and multi-mission products as we want to benefit from multi-mission cross-calibration.

Mission	Type	Start dates	End dates	Time steps for gridded products	Spatial resolution
SARAL/AltiKa	Gridded	2013/03/18	2022/07/09	10 days, but two consecutive dates are not independent as a result of 30 days averages.	Gridded: 75km Along-track: 5Hz≈1km
	Along-track	2013/03/14	2022/01/01		
Sentinel-3A	Gridded	2016/06/30	2021/06/24		
	Along-track	2016/07/01	2021/06/30		
CryoSat-2	Gridded	2010/07/12	2021/12/21		
	Along-track	2010/07/16	2021/12/31		
Mutli-mission	Gridded	2011/01/03	2021/12/30	3 days, but two consecutive dates are not independent	25km

Table 3 - Temporal availability and characteristics of Arctic Ocean SLA for Version 02_00.

Mission	Type	Start dates	End dates	Time steps for gridded products	Spatial resolution
SARAL/AltiKa	Gridded	2013/03/18	2022/07/09	10 days, but two consecutive dates are not independent as a result of 30 days averages.	Gridded: 75km Along-track: 5Hz≈1km
	Along-track	2013/03/14	2022/01/01		
Sentinel-3A	Gridded	2016/06/30	2021/06/24		
	Along-track	2016/07/01	2021/06/30		
CryoSat-2	Gridded	2012/12/18	2021/12/21		
	Along-track	2012/12/21	2021/12/31		
Mutli-mission	Gridded	2013/01/02	2021/12/31	3 days, but two consecutive dates are not independent	25km

Table 4 - Temporal availability and characteristics of Southern Ocean SLA for Version 02_00.

2.5.3 Nomenclature

The generic model of filename are :

For along-track leads files:

dt_arctic_<mission>_leads_phy_l3_<dataset_date>_<production_date>.nc

For gridded monomission files:

dt_arctic_<mission>_<version>_sea_level_<datebegin>_<dateend>.nc

For gridded mutlimission files:

dt_arctic_multimission**_sea_level_<date_meas>.nc**

The products name components are:

- The type of data timeliness dt=delayed-time
- <mission> is either saral, sentinel3a, cryosat2
- <dataset_date> is the date of the measurement
- <production_date> is the date of production
- <datebegin> and <dateend> are the dates of measurement
- <date_meas> is the date of measurement
- <version> is v1.1 or v1.2 or v2.0

2.5.4 Format

All the products are distributed in NetCDF with norm CF.

NetCDF (Network Common Data Form) is an open source, generic and multi-platform format developed by Unidata. An exhaustive presentation of NetCDF and additional conventions is available on the following web site:

http://www.unidata.ucar.edu/packages/netcdf/index.html.

All basic NetCDF conventions are applied to files.

Additionally the files are based on the attribute data tags defined by the Cooperative Ocean/Atmopshere Reasearch Data Service (COARDS) and Climate Forecast (CF) metadata conventions. The CF convention generalises and extends the COARDS convention but relaxes the COARDS constraints on dimension and order and specifies methods for reducing the size of datasets. A wide range of software is available to write or read NetCDf/CF files. API made available by UNIDATA (http://www.unidata.ucar.edu/software/netcdf):

- C/C++/Fortran
- Java
- MATLAB, Objective-C, Perl, Python, R, Ruby, Tcl/Tk.

2.5.4.1 Dimensions

Along-track products:

The defined dimensions are:

- **time:** number of measurements in current file.

Gridded products:

The products use a grid regular in kilometers (EASE2 grid file format), so that latitudes/longitudes do no directly map the grid cells and cannot be used as dimensions.

The defined dimensions are:

- **time:** number of grids in current file.
- **x :** grid cell index in the x direction
- **y :** grid cell index in the y direction

2.5.4.2 Data Handling Variables

You will find hereafter the definitions of the variables defined in the product:

Name of variable	Type	Content	Unit
time	double	Time of measurements	days since 1950-01-01 00:00:00 UTC
latitude	int	Latitude value of measurements	degrees_north
longitude	int	Longitude value of measurements	degrees_east
cycle	short	Cycle the measurement belongs to	-
track	short	Track in cycle the measurement belongs to	-
sla_filtered	short	Filtered Sea Level Anomaly relative to a mean sea surface	meters
sla_unfiltered	short	Unfiltered Sea Level Anomaly relative to a mean sea surface	meters
dac	short	Dynamic Atmospheric Correction	meters
ocean_tide	short	Ocean tide model	meters
lwe	short	Long wavelength error	meters
Mdt	Short	MDT	meters

Table 5: Overview of data handling variables in along-track Arctic Ocean NetCDF file (for leads and ocean files).

Name of variable	Type	Content	Unit
time	float	Time of measurements	days since 1950-01-01 00:00:00 UTC
latitude	float	Latitude value of measurements	degrees_north
longitude	float	Longitude value of measurements	degrees_east
sla	float	Sea Level Anomaly relative to a mean sea surface	meters
std_sla	float	standard deviation of sea level anomaly	meters
number_sla	ushort	number of sea level anomaly observations	counts

Table 6. Overview of data handling variables in gridded Arctic Ocean NetCDF file.

2.5.4.3 Attributes

Additional attributes may be available in files. They are providing information about the type of product or the processing and parameter used.

3 Products accessibility

The products are available via the authenticated **Aviso+ FTP (online products)**:

- You first need to register via the Aviso+ web portal and sign the License Agreement: https://www.aviso.altimetry.fr/en/data/data-access/registration-form.html
- You have to choose the product **"Ssalto/Duacs Experimental products: along-track and gridded Sea Level Heights and velocities"** in the list of products

A login /Password will be provided via email with all the necessary information to access the products.

4 Contacts

For more information, please contact:

Aviso+ User Services
CLS
11 rue Hermès
Parc Technologique du canal
31520 Ramonville Cedex
France
E-mail: aviso@altimetry.fr
On Internet: https://www.aviso.altimetry.fr/

The user service is also interested in user feedbacks; questions, comments, proposals, requests are much welcome.

5 Examples of files

5.1 Along-track products dedicated to Arctic Ocean

```
netcdf dt_arctic_s3a_leads_phy_l3_20210630_20230606 {
dimensions:
    time = 13709 ;
variables:
    double time(time) ;
        time:axis = "T" ;
        time:calendar = "gregorian" ;
        time:long_name = "Time of measurement" ;
        time:standard_name = "time" ;
        time:units = "days since 1950-01-01 00:00:00" ;
    int longitude(time) ;
        longitude:add_offset = 0. ;
        longitude:long_name = "Longitude of measurement" ;
        longitude:scale_factor = 1.e-06 ;
        longitude:standard_name = "longitude" ;
        longitude:units = "degrees_east" ;
    int latitude(time) ;
        latitude:add_offset = 0. ;
        latitude:long_name = "Latitude of measurement" ;
        latitude:scale_factor = 1.e-06 ;
        latitude:standard_name = "latitude" ;
        latitude:units = "degrees_north" ;
    short cycle(time) ;
        cycle:coordinates = "longitude latitude" ;
        cycle:long_name = "Cycle the measurement belongs to" ;
        cycle:units = "1" ;
    short track(time) ;
        track:long_name = "Track in cycle the measurement belongs to" ;
        track:units = "1" ;
    short sla_unfiltered(time) ;
        sla_unfiltered:_FillValue = 32767s ;
        sla_unfiltered:add_offset = 0. ;
        sla_unfiltered:comment = "The sea level anomaly is the sea surface height above mean sea surface height; the
uncorrected sla can be computed as follows: [uncorrected sla]=[sla from
product]+[dac]+[ocean_tide]+[internal_tide]+[lwe]" ;
        sla_unfiltered:coordinates = "longitude latitude" ;
        sla_unfiltered:long_name = "Sea level anomaly not-filtered subsampled with dac, ocean_tide and lwe correction
applied" ;
        sla_unfiltered:scale_factor = 0.001 ;
        sla_unfiltered:standard_name = "sea_surface_height_above_sea_level" ;
        sla_unfiltered:units = "m" ;
    short sla_filtered(time) ;
        sla_filtered:_FillValue = 32767s ;
        sla_filtered:add_offset = 0. ;
        sla_filtered:comment = "The sea level anomaly is the sea surface height above mean sea surface height; the
uncorrected sla can be computed as follows: [uncorrected sla]=[sla from product]+[dac]+[ocean_tide]+[lwe]" ;
        sla_filtered:coordinates = "longitude latitude" ;
        sla_filtered:long_name = "Sea level anomaly filtered subsampled with dac, ocean_tide and lwe correction applied"
;
        sla_filtered:scale_factor = 0.001 ;
        sla_filtered:standard_name = "sea_surface_height_above_sea_level" ;
        sla_filtered:units = "m" ;
    short dac(time) ;
```

dac:_FillValue = 32767s ;
dac:add_offset = 0. ;
dac:comment = "The sla in this file is already corrected for the dac; the uncorrected sla can be computed as follows: [uncorrected sla]=[sla from product]+[dac]" ;
dac:coordinates = "longitude latitude" ;
dac:long_name = "Dynamic Atmospheric Correction" ;
dac:scale_factor = 0.001 ;
dac:units = "m" ;
short ocean_tide(time) ;
ocean_tide:_FillValue = 32767s ;
ocean_tide:add_offset = 0. ;
ocean_tide:comment = "The sla in this file is already corrected for the ocean_tide; the uncorrected sla can be computed as follows: [uncorrected sla]=[sla from product]+[ocean_tide]" ;
ocean_tide:coordinates = "longitude latitude" ;
ocean_tide:long_name = "Ocean tide model" ;
ocean_tide:scale_factor = 0.001 ;
ocean_tide:units = "m" ;
short lwe(time) ;
lwe:_FillValue = 32767s ;
lwe:add_offset = 0. ;
lwe:comment = "The sla in this file is already corrected for the lwe; the uncorrected sla can be computed as follows: [uncorrected sla]=[sla from product]+[lwe]" ;
lwe:coordinates = "longitude latitude" ;
lwe:long_name = "Long wavelength error" ;
lwe:scale_factor = 0.001 ;
lwe:units = "m" ;
short mdt(time) ;
mdt:_FillValue = 32767s ;
mdt:add_offset = 0. ;
mdt:comment = "The mean dynamic topography is the sea surface height above geoid; it is used to compute the absolute dynamic tyopography adt=sla+mdt" ;
mdt:coordinates = "longitude latitude" ;
mdt:long_name = "Mean dynamic topography CNES/CLS 22" ;
mdt:scale_factor = 0.001 ;
mdt:standard_name = "sea_surface_height_above_geoid" ;
mdt:units = "m" ;

// global attributes:
:Conventions = "CF-1.6" ;
:Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
:cdm_data_type = "Swath" ;
:comment = "Sea surface height measured by altimeters; with additional corrections; the proposed sla is already corrected for dac, ocean_tide and lwe; [uncorrected sla]=[sla from product]+[dac]+[ocean_tide]+[lwe]" ;
:contact = "aviso@altimetry.fr" ;
:creator_email = "aviso@altimetry.fr" ;
:creator_name = "ARCTIC_OCEAN_PROTOTYPE" ;
:creator_url = "https://www.aviso.altimetry.fr" ;
:date_created = "2023-06-06 15:10:28Z" ;
:date_issued = "2023-06-06 15:10:28Z" ;
:date_modified = "2023-06-06 15:10:28Z" ;
:geospatial_lat_max = 81.408982 ;
:geospatial_lat_min = 59.784643 ;
:geospatial_lat_resolution = 0.0018310000000028 ;
:geospatial_lat_units = "degrees_north" ;
:geospatial_lon_max = 359.982275 ;
:geospatial_lon_min = 0.017789 ;
:geospatial_lon_resolution = 0.042743999999999 ;
:geospatial_lon_units = "degrees_east" ;
:geospatial_vertical_max = 0. ;
:geospatial_vertical_min = 0. ;
:geospatial_vertical_positive = "down" ;
:geospatial_vertical_resolution = "point" ;

```
        :geospatial_vertical_units = "m" ;
        :history = "2023-06-06 15:10:28Z: Creation" ;
        :institution = "CNES, CLS" ;
        :keywords = "Oceans > Ocean Topography > Sea Surface Height" ;
        :keywords_vocabulary = "NetCDF COARDS Climate and Forecast Standard Names" ;
        :license = "https://www.aviso.altimetry.fr/fileadmin/documents/data/License_Aviso.pdf" ;
        :platform = "Sentinel-3A" ;
        :processing_level = "L3" ;
        :product_version = "V2.0" ;
        :project = "DUACS R&D" ;
        :source = "Sentinel-3A measurements" ;
        :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table
v37" ;
        string :summary = "Delayed-Time Level-3 sea surface height measured in the leads by Sentinel-3A altimetry
observations over Arctic region (lat>50°N)." ;
        :time_coverage_duration = "P06:36:00" ;
        :time_coverage_end = "2021-06-30 22:35:15Z" ;
        :time_coverage_resolution = "P0.2S" ;
        :time_coverage_start = "2021-06-30 00:31:29Z" ;
        :title = "DT Sentinel-3A Arctic Ocean Along track Sea Surface Height L3 product in the leads" ;
}
```

5.2 Gridded monomission products dedicated to Arctic Ocean

```
netcdf s3a_arctic_sea_level_aviso {
        dimensions:
            time = 183 ;
            x = 240 ;
            y = 240 ;
        variables:
            float time(time) ;
                time:axis = "T" ;
                time:calendar = "gregorian" ;
                time:long_name = "Time" ;
                time:standard_name = "time" ;
                time:units = "days since 1950-01-01 00:00:00" ;
            float latitude(x, y) ;
                latitude:axis = "Y" ;
                latitude:long_name = "Latitude" ;
                latitude:standard_name = "latitude" ;
                latitude:units = "degrees_north" ;
                latitude:valid_min = -78.283654 ;
                latitude:valid_max = 89.525192 ;
            float longitude(x, y) ;
                longitude:axis = "X" ;
                longitude:long_name = "Longitude" ;
                longitude:standard_name = "longitude" ;
                longitude:units = "degrees_east" ;
                longitude:valid_min = -179.76027 ;
                longitude:valid_max = 179.76027 ;
            float sla(time, x, y) ;
                sla:_FillValue = 9.96921e+36f ;
                sla:long_name = "Sea Level Anomaly" ;
                sla:coordinates = "time latitude longitude" ;
                sla:standard_name = "sea_surface_height_above_sea_level" ;
                sla:units = "m" ;
            float std_sla(time, x, y) ;
                std_sla:_FillValue = 9.96921e+36f ;
```

```
                std_sla:long_name = "Sea Level Anomaly Standard Deviation" ;
                std_sla:coordinates = "time latitude longitude" ;
                std_sla:units = "m" ;
            ushort number_sla(time, x, y) ;
                number_sla:long_name = "Sea Level Anomaly Number" ;
                number_sla:coordinates = "time latitude longitude" ;
                number_sla:units = "count" ;

        // global attributes:
                :Conventions = "CF-1.7" ;
                :Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
                :cdm_data_type = "Grid" ;
                :comment = "Sea Level Anomaly measured by Altimetry and derived variables" ;
                :contact = "aviso@altimetry.fr" ;
                :creator_email = "aviso@altimetry.fr" ;
                :creator_name = "ARCTIC_OCEAN_PROTOTYPE" ;
                :creator_url = "https://www.aviso.altimetry.fr" ;
                :geospatial_lat_max = 89.525192 ;
                :geospatial_lat_min = -78.283654 ;
                :geospatial_lat_units = "degrees_north" ;
                :geospatial_lon_max = 179.76027 ;
                :geospatial_lon_min = -179.76027 ;
                :geospatial_lon_units = "degrees_east" ;
                :geospatial_vertical_max = 0. ;
                :geospatial_vertical_min = 0. ;
                :geospatial_vertical_positive = "down" ;
                :geospatial_vertical_resolution = "point" ;
                :geospatial_vertical_units = "m" ;
                :history = "Created on 2023-06-08 08:20:45Z by ARCTIC_OCEAN_PROTOTYPE" ;
                :institution = "CLS,CNES" ;
                :keywords = "Oceans>Ocean Topography>Sea Surface Height" ;
                :keywords_vocabulary = "NetCDF COARDS Climate and Forecast Standard Names" ;
                :platform = "Sentinel-3A" ;
                :processing_level = "L2p" ;
                :Grid = "Subset of Northern Hemisphere 75km EASE2 Grid" ;
                :title = "DT mono-satellite sea level gridded product" ;
                :product_version = "v2.0" ;
                :project = "CNES AltiDoppler Glaciologie" ;
                :reference = "http://aviso.altimetry.fr" ;
                :source = "Altimetry measurements in the polar regions (both open ocean and leads surface)" ;
                :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention Standard Name
Table v37" ;
                :time_coverage_duration = "P1820.0D" ;
                :time_coverage_resolution = "P10.0D" ;
                :time_coverage_end = "2021-06-24 12:00:00Z" ;
                :time_coverage_start = "2016-06-30 12:00:00Z" ;
}
```

5.3 Gridded multimission products dedicated to Arctic Ocean

```
netcdf dt_arctic_multimission_sea_level_20211227 {
dimensions:
    time = 1 ;
    x = 350 ;
    y = 350 ;
variables:
    float time(time) ;
        time:axis = "T" ;
        time:calendar = "gregorian" ;
        time:long_name = "Time" ;
```

```
        time:standard_name = "time" ;
        time:units = "days since 1950-01-01 00:00:00" ;
    float latitude(x, y) ;
        latitude:axis = "Y" ;
        latitude:long_name = "Latitude" ;
        latitude:standard_name = "latitude" ;
        latitude:units = "degrees_north" ;
        latitude:valid_min = 32.19727f ;
        latitude:valid_max = 89.84173f ;
    float longitude(x, y) ;
        longitude:axis = "X" ;
        longitude:long_name = "Longitude" ;
        longitude:standard_name = "longitude" ;
        longitude:units = "degrees_east" ;
        longitude:valid_min = -179.8358f ;
        longitude:valid_max = 179.8358f ;
    float sla(time, x, y) ;
        sla:_FillValue = 9.96921e+36f ;
        sla:comment = "The sea level anomaly is the sea surface height above mean sea surface; it is referenced to the
[1993, 2012] period; see the product user manual for details" ;
        sla:coordinates = "longitude latitude" ;
        sla:long_name = "Sea level anomaly" ;
        sla:standard_name = "sea_surface_height_above_sea_level" ;
        sla:units = "m" ;
    float adt(time, x, y) ;
        adt:_FillValue = 9.96921e+36f ;
        adt:comment = "The absolute dynamic topography is the sea surface height above geoid; the adt is obtained as
follows: adt=sla+mdt where mdt is the mean dynamic topography; see the product user manual for details" ;
        adt:coordinates = "longitude latitude" ;
        adt:long_name = "Absolute dynamic topography" ;
        adt:standard_name = "sea_surface_height_above_sea_level" ;
        adt:units = "m" ;
    float ugos(time, x, y) ;
        ugos:_FillValue = 9.96921e+36f ;
        ugos:coordinates = "longitude latitude" ;
        ugos:long_name = "Absolute geostrophic velocity: zonal component" ;
        ugos:standard_name = "surface_geostrophic_eastward_sea_water_velocity" ;
        ugos:units = "m/s" ;
    float vgos(time, x, y) ;
        vgos:_FillValue = 9.96921e+36f ;
        vgos:coordinates = "longitude latitude" ;
        vgos:long_name = "Absolute geostrophic velocity: meridian component" ;
        vgos:standard_name = "surface_geostrophic_northward_sea_water_velocity" ;
        vgos:units = "m/s" ;
    float ugosa(time, x, y) ;
        ugosa:_FillValue = 9.96921e+36f ;
        ugosa:comment = "The geostrophic velocity anomalies are referenced to the [1993, 2012] period" ;
        ugosa:coordinates = "longitude latitude" ;
        ugosa:long_name = "Geostrophic velocity anomalies: zonal component" ;
        ugosa:standard_name = "surface_geostrophic_eastward_sea_water_velocity_assuming_sea_level_for_geoid" ;
        ugosa:units = "m/s" ;
    float vgosa(time, x, y) ;
        vgosa:_FillValue = 9.96921e+36f ;
        vgosa:coordinates = "longitude latitude" ;
        vgosa:long_name = "Geostrophic velocity anomalies: meridian component" ;
        vgosa:standard_name = "surface_geostrophic_northward_sea_water_velocity_assuming_sea_level_for_geoid" ;
        vgosa:units = "m/s" ;

// global attributes:
        :Conventions = "CF-1.7" ;
        :Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
        :cdm_data_type = "Grid" ;
```

:comment = "Sea Surface Height measured by Altimetry and derived variables" ;
:contact = "aviso@altimetry.fr" ;
:creator_email = "aviso@altimetry.fr" ;
:creator_name = "ARCTIC_OCEAN_PROTOTYPE" ;
:creator_url = "https://www.aviso.altimetry.fr" ;
:date_created = "2023-06-07 08:04:14Z" ;
:date_issued = "2023-06-07 08:04:14Z" ;
:date_modified = "2023-06-07 08:04:14Z" ;
:geospatial_lat_max = 89.84173f ;
:geospatial_lat_min = 32.19727f ;
:geospatial_lat_resolution = "25km" ;
:geospatial_lat_units = "degrees_north" ;
:geospatial_lon_max = 179.8358f ;
:geospatial_lon_min = -179.8358f ;
:geospatial_lon_resolution = "25km" ;
:geospatial_lon_units = "degrees_east" ;
:geospatial_vertical_max = 0. ;
:geospatial_vertical_min = 0. ;
:geospatial_vertical_positive = "down" ;
:geospatial_vertical_resolution = "point" ;
:geospatial_vertical_units = "m" ;
:history = "Created on 2023-06-07 08:04:14Z by ARCTIC_OCEAN_PROTOTYPE" ;
:institution = "CLS,CNES" ;
:keywords = "Oceans > Ocean Topography > Sea Surface Height" ;
:keywords_vocabulary = "NetCDF COARDS Climate and Forecast Standard Names" ;
:platform = "SARAL/AltiKa, CryoSat-2, Sentinel-3A" ;
:processing_level = "L4" ;
:product_version = "2.0" ;
:Grid = "Subset of Northern Hemisphere 25km EASE2 Grid" ;
:project = "CNES DUACS R&D" ;
:source = "Altimetry measurements" ;
:ssalto_duacs_comment = "The reference mission used for the altimeter inter-calibration processing is SARAL/AltiKa." ;
:standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table v37" ;
:summary = "SSALTO/DUACS Delayed-Time Level-4 sea surface height and derived variables measured by multi-satellite altimetry observations over Arctic Ocean." ;
:time_coverage_duration = "P1D" ;
:time_coverage_end = "2021-12-27 00:00:00Z" ;
:time_coverage_resolution = "P1D" ;
:time_coverage_start = "2021-12-27 00:00:00Z" ;
:title = "DT merged all satellites Arctic Ocean Gridded SSALTO/DUACS Sea Surface Height L4 product and derived variables" ;
}

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