ECMWF COPERNICUS REPORT

Copernicus Climate Change Service

# Product User Guide and Specification

## Sea Level v1.2

Issued by: CLS / F. Mertz and J.-F. Legeais

Date: 20/04/2020

Ref: D3.SL.1-v1.2_PUGS_of_v1DT2018_SeaLevel_products_v2.4

Official reference number service contract: 2018/C3S_312b_Lot3_CLS/SC2

European Commission

Copernicus Europe's eyes on Earth

IMPLEMENTED BY ECMWF

# Contributors

**CLS**
F. Mertz
J.-F. Legeais

## History of modifications

| Version | Date | Description of modification | Chapters / Sections |
|---|---|---|---|
| 1.0 | 30/03/2017 | creation | |
| 1.1 | 15/05/2017 | Review from ECMWF | |
| 1.2 | 04/07/2017 | Addition of S3A mission | |
| 2.0 | 19/03/2018 | Mean and references<br>Adaptation to CDR v1-c3s | |
| 2.1 | 05/03/2019 | Update of temporal period of the missions processed by DUACS for C3S production. | 1.2.1 |
| 2.2 | 16/04/2019 | Review from ECMWF | |
| 2.3 | 30/03/2020 | TOPEX-A warning message | Executive summary & 1.1.2.1 |
| 2.4 | 20/04/2020 | Review from ECMWF and Assimila | |

## Related documents

| Reference ID | Document |
|---|---|
| C3S_ATBD | C3S_312a_Lot2 Algorithm Theoretical Basis Document, D312a_Lot2.2.1.2-v2_ATBD_201803 |
| C3S_TRD | C3S_312b_Lot3 Target Requirement and Gap Analysis Document, D1.1.1-2019_312b_Lot3_SeaLevel_TRD_GAD_v2 |
| C3S_SQAD | C3S_312a_Lot2 System Quality Assurance Document, D312a_Lot2.2.2.2-v2_201803 |
| C3S_PQAD | C3S_312b_Lot3 Product Quality Assurance Document, C3S_312b_Lot3_D2.SL.1-v1.2_202003_Product_Quality_Assurance_Document |
| C3S_PQAR | C3S_312b_Lot3 Product Quality Assessment Report, C3S_312b_Lot3_D2.SL.2-v1.1_201906_Product_Quality_Assessment_Report |

## Acronyms

| Acronym | Definition |
|---|---|
| AL | AltiKa |
| ADT | Absolute Dynamic Topography |
| C2 | Cryosat-2 |
| CCI | ESA Climate Change Initiative Project |
| CDR | Climate Data Record |
| DAC | Dynamic Atmospheric Correction |
| DUACS | Data Unification and Altimeter Combination System |
| E1 | ERS-1 |
| E2 | ERS-2 |
| ECMWF | European Centre for Medium-Range Weather Forecasting |
| EN | ENVISAT |
| ESA | European Space Agency |
| GCOS | Global Climate Observing System |
| GIM | Global Ionosphere Maps |
| GDR | Geophysical Data Record |
| ICDR | Intermediate Climate Data Record |
| IGDR | Interim Geophysical Data Record(s) |
| J1 | Jason-1 |
| J2 | OSTM/Jason-2 |
| J3 | Jason-3 |
| L2P | Level-2 Plus |

| | |
|---|---|
| LWE | Long Wavelength Errors |
| MDT | Mean Dynamic Topography |
| MSL | Mean Sea Level |
| MSS | Mean Sea Surface |
| NTC | Non Time Critical |
| SLA | Sea Level Anomaly |
| SSH | Sea Surface Height |
| T/P | Topex/Poseidon |

## General definitions

**SSH** is the Sea Surface Height above the reference ellipsoid measured by altimeters.
**MSS** is the Mean Sea Surface above the reference ellipsoid and is calculated thanks to the SSH.
**MDT** is the Mean Dynamic Topography, i.e. the Mean SSH above the geoid. It is estimated from a combination of MSS and a geoid model.
**SLA** is the Sea Level Anomaly. It is given by the difference between SSH and MSS
**ADT** is the Absolute Dynamic Topography above the geoid. It is given by the sum of SLA and MDT.
These variables are fully described in section 1.1.1.

**L4** (Level 4) gridded products are spatially complete global maps combining cross-calibrated altimeter measurements from several missions using an optimal interpolation.

# Table of Contents

## Scope of the document

This document is the Product User Guide and Specification (PUGS) of the Sea level products disseminated by the Copernicus Climate Change Service (C3S) in the frame of the 2018/C3S_312b_Lot3_CLS/SC1 contract. It provides the end user with practical information regarding the use of these products.

## Executive summary

The Product User Guide and Specification explains the basic altimetry principles that allow the computation of the altimeter sea level products and provides a brief description of the associated production system. The details of the input data are provided, including their origin. The technical characteristics of each altimeter mission used in the production system are described as well as the level 2 altimeter algorithms (geophysical standards and orbit solutions). The characteristics of the satellite constellation are described, and the principle of the sea level mapping procedure is provided. Finally, the product characteristics are described (format, nomenclature and data handling variables) and a description of the file content is provided in Annex.

Warning message: The altimeter mean sea level record has been known to be affected by an instrumental drift in the TOPEX-A measurements (1993-1998). The C3S sea level datasets have not been corrected for this instrumental drift (see section 1.1.2.1).

# 1. Sea Level product

This section provides the specifications of the Sea Level products.

## 1.1 Product description

The Sea Level product is a time series of gridded Sea Surface Height and derived variables obtained by merging two satellite altimetry measurements. It is generated by the DUACS processing system including data from several altimetry missions. Three areas are delivered: the global Ocean, the Mediterranean Sea and the Black Sea.

The C3S products mainly focus on the retrieval of the long-term variability of the ocean, which is only obtained using a stable altimeter constellation and homogeneous corrections and standards in time. One way to address the later constraints is to use **a two-satellite constellation** during all the altimeter period (see 1.1.2.2).

The present document applies to the C3S altimeter sea level Climate Data Record (CDR) and the following temporal extensions (Interim CDR). The current version corresponds to the reprocessed DUACS Delayed-Time DT-2018 products.

### 1.1.1 Usual variables in Altimetry

The Altimetry gives access to the Sea Surface Height (SSH) above the reference ellipsoid (see Figure 1)

$$SSH = Orbit - Altimetric\ Range$$

The Mean Sea Surface ($MSS_N$) is the temporal mean of the SSH over a period N. It is a mean surface above the reference ellipsoid and it includes the Geoid.

$$MSS_N = \langle SSH \rangle_N$$

The Sea Level Anomaly ($SLA_N$) is the anomaly of the signal around the mean component. It is deduced from the SSH and $MSS_N$ :

$$SLA_N = SSH - MSS_N$$

The Mean Dynamic Topography ($MDT_N$) is the temporal mean of the SSH above the Geoid over a period N.

$$MDT_N = MSS_N - Geoid$$

The Absolute Dynamic Topography (ADT) is the instantaneous height above the Geoid. The geoid is a gravity equipotential surface that would correspond to the ocean surface if the ocean was at rest (i.e. without any currents and only under the gravity field). When the ocean is influenced by wind, differential heating and precipitation and other sources of energy, the ocean surface moves from the geoid. Thus, the departure from the geoid provides information on ocean dynamics.

The ADT is the sum of the $SLA_N$ and $MDT_N$:

$$ADT = SLA_N + MDT_N = SSH - MSS_N + MDT_N$$

The reference period N considered can be changed as described in Pujol et al (2016).

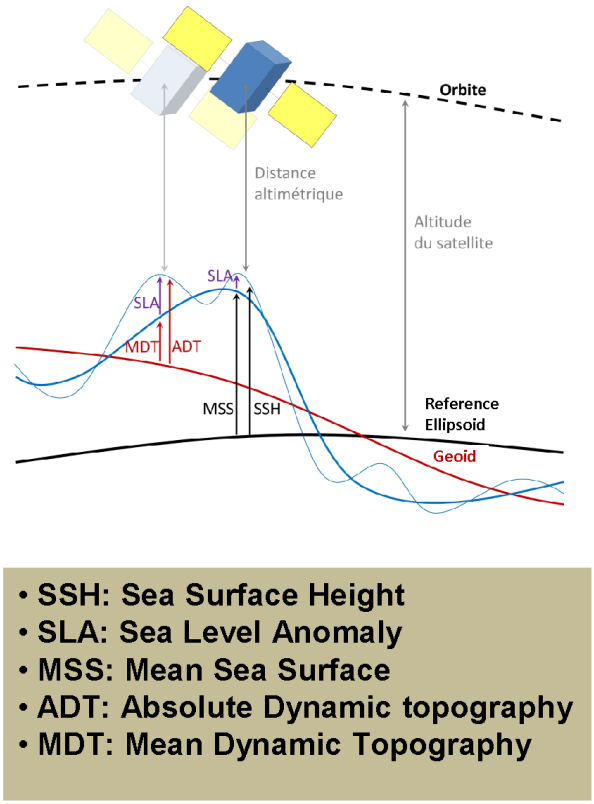


Figure 1: Different concepts of sea surface height used in altimetry

The geostrophic current products disseminated to users are issued from the SLAs and the ADTs. They are computed using a nine-point stencil width methodology (Arbic et al., 2012) for latitudes outside the 5°S/5°N band. In the equatorial band, the Lagerloef methodology (Lagerloef et al., 1999) is used.

The variables disseminated to users are the Sea Level Anomalies (sla), Absolute Dynamic Topography (adt, except for Black Sea), formal mapping error (err), the geostrophic velocities anomalies (ugosa and vgosa) and the absolute geostrophic velocities (ugos and vgos, except for Black Sea).

### 1.1.2 Processing

The Delayed Time DUACS component maintains a consistent and user-friendly altimeter database using state-of-the-art recommendations from the altimetry community.

The processing sequences can be divided into the following main steps (fully described in [C3S_ATBD]):

- Acquisition
- Pre-processing homogenization
- Input data quality control
- Multi-mission cross-calibration
- Along-track products generation
- Gridded merged products generation
- Final quality control

#### 1.1.2.1 Input data and corrections

The altimeter measurements used to compute the C3S Sea Level products consist of Level-2 products from different missions called Delayed Time Geophysical Data Records (GDR) or Non Time Critical (NTC) products. Details of the different L2 altimeter products sources and delay of availability are given in Table 1.

Table 1: Source and delay of availability of the different altimeter data used in input of DUACS system

| Altimeter mission | Type of product | Source | Availability delay |
|---|---|---|---|
| Sentinel-3A | NTC | EUMETSAT | ~1 month |
| Jason-3 | GDR | CNES/EUMETSAT | ~3 months |
| OSTM/Jason-2 | GDR | CNES | Reprocessing only |
| Cryosat-2 | GDR | ESA | Best effort |
| SARAL/AltiKa | GDR | CNES | ~2 months |
| Topex/POSEIDON | GDR | CNES | Reprocessing only |
| Jason-1 | GDR | CNES | Reprocessing only |
| Envisat | GDR | ESA | Reprocessing only |
| ERS-1 | GDR | ESA | Reprocessing only |
| ERS-2 | GDR | ESA | Reprocessing only |

The auxiliary products (altimeter standards, geophysical corrections) used in the production are described in Table 2. They are the most up-to-date standards (whose timeliness is compatible with the C3S production planning) and most of them follow the recommendations of the ESA Sea Level CCI project (Quartly et al. 2017; Legeais et al., 2018). More details on the description of these standards can be found in Taburet et al., 2019.

Table 2: Altimeter standards used in the C3S Sea Level v1 products.

| | ERS-1 | ERS-2 | Topex/ Poseidon | ENVISAT | Jason-1 | OSTM/ Jason-2 | Cryosat-2 | AltiKa | Jason-3 | Sentinel-3A |
|---|---|---|---|---|---|---|---|---|---|---|
| **Orbit** | Reaper [Rudenko et al., 2012] | | GFSC STD15 until c365, STD12 afterwards | GDR-D | GDR-E | GDR-E | GDR-E | GDR-E | GDR-E | GDR-E |
| **retracking** | MLE3 | | Topex: Tracker Topex Poseidon: MLE3 | MLE3 (OCE-1) | MLE4 [Amarouche et al, 2004] | MLE4 [Amarouche et al, 2004] | Before Jan 2016 MLE4 on LRM mode area [Amarouche et al, 2004]; | MLE4 [Amarouche et al, 2004] | MLE4 [Amarouche et al, 2004] | SAMOSA 2.3 [ESRIN, 2015] up to December 2017; SAMOSA2.5 after. |
| **Ionospheric** | Reaper [NIC09 model, Scharroo and Smith, 2010] | NIC09 [Scharroo and Smith, 2010] (c≤36), GIM [Ijima et al., 1999] (c≥37) | Dual-frequency altimeter range measurements (Topex) [Guibbaud et al., 2015] Doris (Poseidon) | Dual-frequency altimeter range measurement [Guibbaud et al.,2015] (6≤c≤64)/GIM [Ijima et al. 1999] Corrected for 8mm bias (c≥65) | Dual-frequency altimeter range measurement [Guibbaud et al., 2015] | Dual-frequency altimeter range measurement [Guibbaud et al., 2015] Recomputed after SSB C-band update | GIM [Ijima et al., 1999] | | Filtered dual-frequency altimeter range measurements [Guibbaud et al., 2015] | |
| **Dry troposphere** | Model based on ERA-INTERIM | | | Model based on ECMWF Gaussian grids | Model based on ECMWF rectangular grids | Model based on ECMWF Gaussian grids | Model based on ECMWF Gaussian grids | | | |
| **Wet troposphere** | GNSS derived Path Delay [Fernandes et al., 2015] | | | Obligis et al., 2009 | JMR issued from GDR-E | Neural Network correction (3 entries), Fréry et al. In preparation | From ECMWF model | Neural Network correction (5 entries), Picard et al., In preparation | From J3-AMR radiometer | From S3A-AMR radiometer |
| **DAC** | MOG2D High frequencies forced with analysed ERA-INTERIM pressure and wind field [Carrère et al., 2016] + inverse barometer Low frequencies | | | MOG2D High frequencies forced with analysed ECMWF pressure and wind field [Carrere and Lyard, 2003; operational version used, current version is 3.2.0] + inverse barometer low frequencies | | | | | | |
| **Ocean tide** | FES2014 [Carrère et al., 2015] | | | | | | | | | |
| **Pole tide** | [Desai, 2015] | | | | | | | | | |
| **Solid earth tide** | Elastic response to tidal potential [Cartwright and Tayler, 1971], [Cartwright and Edden, 1973] | | | | | | | | | |
| **Sea state bias** | BM3 (Gaspar, Ogor, 1996) | Non parametric [Mertz et al., 2005] using c 70 to 80 with DELFT orbit and equivalent of GDR-B standards) | Non parametric SSB [N. Tran and al. 2010] (using c 1 to 111 with GDR-C standards and GDR-D orbit) | Non parametric SSB , [Tran, 2015] | SSB issued from GDR-E | Non Parametric SSB [Tran 2012] | Non parametric SSB from J1 with unbiased sig0 | Non parametric SSB [Tran et al., 2014] | Non Parametric SSB [Tran 2012] | |

| | |
|---|---|
| **Mean Sea Surface** | CNES_CLS_2015 referenced to the 1993-2012 period (Schaeffer et al, 2016; Pujol et al, 2018) |
| **Mean Dynamic Topography** | Global and Europe area: MDT_CNES_CLS13 (Mulet et al, 2013) corrected to be consistent with the 20-year reference period used for the SLA. Mediterranean Sea: SMDT_MED_2014 (Rio et al, 2014) |

Warning message:

Between 1993 and 1998, the retrievals of global mean sea level (MSL) have been known to be affected by an instrumental drift in the TOPEX-A measurements, which has been quantified by several studies as discussed in the C3S Product Quality Assessment Report (PQAR, section 3.3) and in Legeais et al. (2020). The altimeter sea level community agrees that it is necessary to correct the TOPEX-A record for the instrumental drift to improve the accuracy and the uncertainty of the total sea level record. However, there is not yet consensus on the best approach to estimate the drift correction on global and regional scales. The recommendation of the Ocean Surface Topography Science Team (OSTST) is to wait for the future release of a reprocessed TOPEX dataset.

Therefore, the C3S sea level datasets are not corrected for the TOPEX-A drift but users can apply their own correction.

#### 1.1.2.2 Altimetry constellation

The complete altimetry satellite constellation used in the C3S Sea Level products is illustrated in Figure 2.

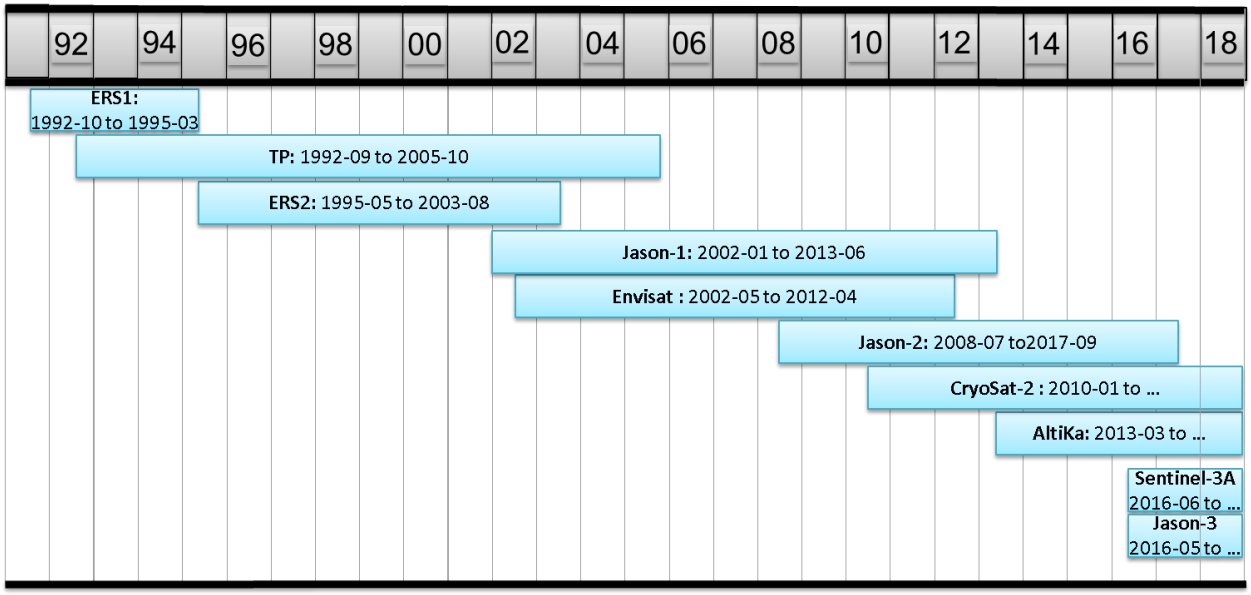


Figure 2: Overview of the L2P products (input for DUACS system) availability period for each altimetric mission.

The C3S sea level altimeter products are based on a satellite constellation with a stable number of altimeters in order to ensure the long-term stability of the ocean observation system. The different altimeter satellites included in the products are the reference missions and the complementary missions as well as the missions of opportunity, as illustrated in Figure 3 and described below:

- the reference missions are the TOPEX/Poseidon, Jason-1, Jason-2 and Jason-3, which are successively introduced into the production system. These missions are essential for the computation of the long-term trend of the MSL since they are used to wedge complementary missions in terms of sea level drift. Jason-3 is the current reference mission used in the system and it should be followed by Sentinel-6 (also called Jason - Continuity of Service) around 2021.
- the complementary missions provide additional information for the estimation of mesoscale signal variabilities (>200-300 km) and also increase the observing capacity at high latitudes, which is of great interest for climate. The missions that are successively included in the C3S products are ERS-1, ERS-2, Envisat, SARAL/Altika and presently Sentinel-3A. Note that the ERS-1 mission was operated in an ice phase (phase D) from 23/12/1993 to 10/04/1994; no ERS-1 altimeter measurements are used as input to the sea level production system during this period. As no other altimeter data are available, this means that the C3S product is based on TOPEX/Poseidon data only during this 3.5-month period. During the following two successive geodetic phases (phase E, 10/04/1994 – 28/09/1994 and phase F, 28/09/1994 – 21/03/1995), the changes to the ERS-1 mission operations has been taken into account in sea level production.
- In addition, after the loss of the Envisat mission in April 2012, only the opportunity CryoSat-2 mission has been available. Thus, this opportunity mission was included in the C3S product until SARAL/AltiKa delayed-time measurements become available in March 2013.

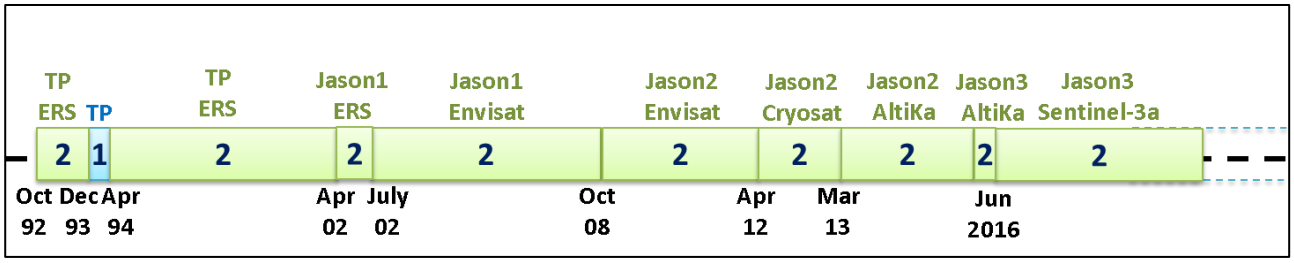

Figure 3: Satellite constellation in the C3S time series.

Note that the information about the satellites used to compute each map is given in the global attribute “platform” of each file.
The use of such a constant number in the satellite constellation contributes to ensure the long-term Mean Sea Level (MSL) stability, which is not the case when using all satellites available throughout the altimeter period (see section 3.2 of [C3S_PQAR]).

### 1.1.2.3 Gridded merged product generation

The gridded merged products are based on the along-track altimeter measurements, which benefit from several processing as already mentioned. First of all, global and regional inter-mission biases are removed. Then, the along-track measurements are cross-calibrated following Le Traon and Ogor (1998), which allows for the reduction of the long wavelength errors (LWE), also considered as geographically-correlated errors. Along-track high frequency aliased signals are also removed. In addition, the data are filtered (Dufau et al., 2016) with a 65km cut-off length low-pass filtering. The along-track measurements are also subsampled for the mapping procedure, keeping one along-track

point out of two. All the details are described in Taburet et al. (2019) and Pujol et al (2016). These procedures ensure the long-term stability of the sea level record.
An optimal interpolation method is used for the mapping procedure following Ducet et al. (2000) and Le Traon et al. (2003). This ensures mesoscale signal reconstruction. The parameters used for the mapping procedure are a compromise between the characteristics of the physical field we focus on and the sampling capabilities associated with the altimeter constellation.

#### 1.1.2.4 Mean and reference period

The along-track and gridded sea surface heights (sea level anomalies and absolute dynamic topography) are computed with respect to a 20-year reference period (1993-2012). In addition to the reference period, a mean reference convention has been adopted in the DUACS products: the sea level time series has been arbitrarily referenced so that the mean sea level averaged during the year 1993 is set to zero (see Figure 4). This convention explains why the DUACS global mean SLA during the reference period (1993-2012) is different from zero. The obtained value (about 2.5cm without a GIA correction) is directly related to the global sea level rise (see Figure 4 ,right).

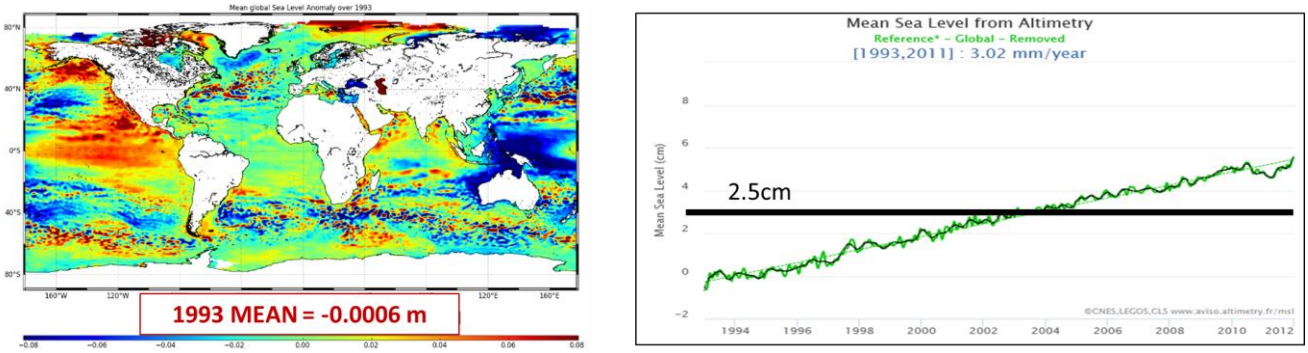


Figure 4: Left: Averaged map of sea level anomalies during the year 1993. The global mean for the year 1993 is -0.0006m and can be fairly considered as a zero mean. Right: Global mean sea level evolution during 1993-2012 (without GIA correction) deduced from DUACS L4 gridded products. The horizontal line indicates the DUACS global mean SLA during the reference period (1993-2012)

## 1.2 Specifications and target requirements

### 1.2.1 Spatial and temporal coverage

The daily time series begins on 01/01/1993. The times series benefit from regular temporal extensions approximately 3 times per year (ICDR production) and the timeliness of the products is of 5 months at the minimum. Such a delay depends on:

- The input data availability (see section 1.1.2.1)
- The production algorithms (centred temporal windows, [C3S_SQAD])
- The time required for the computation and validation processes.

The time delay can be longer in case of missing altimeter measurements of a mission or longer than usual validation process for instance.

The characteristics of the different missions used in the C3S sea level products are described in Table 3.

Table 3: Characteristics and time availability of the different altimeter data used in input of DUACS system

| Altimeter mission | Cycle duration (days) | Latitude range (°N) | Number of tracks in the cycle | Inter-track distance at equator (km) | Sun-synchronous | Dual-frequency Altimeter | Radiometer on board | Temporal period processed by DUACS system for C3S products | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Begin date | End date |
| **Topex/Poseidon** | 10 | ±66 | 254 | ~315 | No | Yes | Yes | 1992/11/20 | 2002/04/24 |
| **Jason-1** | 10 | ±66 | 254 | ~315 | No | Yes | Yes | 2002/04/24 | 2008/10/19 |
| **OSTM/Jason-2** | 10 | ±66 | 254 | ~315 | No | Yes | Yes | 2008/10/19 | 2016/05/26 |
| **Jason-3** | 10 | ±66 | 254 | ~315 | No | Yes | Yes | 2016/05/26 | On-going |
| **ERS-1** | 35 | ±81.5 | 1002 | ~80 | Yes | Yes | Yes | 1992/11/20[1] | 1995/05/15 |
| **ERS-2** | 35 | ±81.5 | 1002 | ~80 | Yes | Yes | Yes | 1995/05/15 | 2002/07/10 |
| **Envisat** | 35 | ±81.5 | 1002 | ~80 | Yes | Yes (S-band lost after cycle 65) | Yes | 2002/07/10 | 2010/10/19 |
| **Envisat-New Orbit** | 30 | ±81.5 | 862 | - | | | | 2010/10/26 | 2012/04/08 |
| **Cryosat-2** | 29 (sub cycle) | ±88 | 840 | ~98 | No | No | No | 2012/04/08 | 2013/03/14 |
| **SARAL/AltiKa** | 35 | ±81.5 | 1002 | ~80 | Yes | No | Yes | 2013/03/14 | 2016/06/14 |
| **Sentinel-3A** | 27 | ±81.5 | 770 | ~100 | Yes | Yes | Yes | 2016/06/15 | Ongoing |

The user and service requirements related to the sea level ECV products are described in detail in [C3S_TRD]. The characteristics (spatial and temporal coverage) listed in the above table are in agreement with these target requirements. The [C3S_TRD] document also includes the gap analysis, describing what could be achieved to better answer the user's needs so that the sea level products remain up-to-date.

[1] ERS-1: Geodetic phases (E-F) are included. No ERS-1 data between December 23,1993 and April 10, 1994 (ERS-1 phase D - 2nd ice phase)

### 1.2.2 Validation and uncertainty estimates

Validation activities are carried out to assess the quality of the products. The validation method is described in the Product Quality Assurance Document [C3S_PQAD] and details of the validation results are provided in the Product Quality Assessment Report [C3S_PQAR].
The description of the altimeter errors and characterization of the uncertainties are available in [C3S_PQAR].

## 1.3 Data usage information

### 1.3.1 Grid characteristics

The products are delivered in a Cartesian grid with the coverage definition detailed in the table below:

| **Area** | **Latitude coverage** | **Longitude coverage** |
|---|---|---|
| Global Ocean | 90°S/90°N | 0°/360° |
| Mediterranean Sea | 30°N/46°N | 6°W/37°E |
| Black Sea | 40°N/47°N | 27°E/42°E |

Note that the latitudinal coverage of the maps depends on the ice coverage and nominally reaches 82° of latitude (except for CryoSat-2) because of the orbital inclination of the satellites. When no measurement is available (at higher latitudes or over the continents), the grid is filled with the default '_FillValue'.

Note that the values taken into account to generate a map are ocean values and the mapping process (see 1.1.2.3) computes some slight extrapolation into the coasts: this allows avoiding gaps that can occur near the coast and also to compute the velocities more precisely.

### 1.3.2 Format

The products are stored using the NetCDF (Network Common Data Form) using CF (Climate and Forecast) Metadata convention.

### 1.3.3 File nomenclature

The nomenclature of the file is the following:
dt_<area>_twosat_phy_l4_<DateMap>_vDT2018.nc.gz

where:
<area>=global or blacksea or med
<DateMap>=the date of the map in the form YYYYMMDD

### 1.3.4 Data Handling Variables

4 dimensions are defined:

- time
- latitude
- longitude
- nv

The variables are listed below

| Type | Name | Content | Unit | Scale Factor |
|---|---|---|---|---|
| float | time(time) | Time of measurement | days since 1950-01-01 00:00:00 UTC | none |
| float | latitude(latitude) | Latitude of measurement | degrees_north | none |
| float | longitude(longitude) | Longitude of measurement | degrees_east | none |
| float | lat_bnds (latitude,nv) | latitude values at the north and south bounds of each pixel. | degrees_north | none |
| float | lon_bnds(longitude,nv) | longitude values at the west and east bounds of each pixel. | degrees_east | none |
| int | nv(nv) | Useful for grid definition | none | none |
| int | crs | Describes the grid_mapping used by the data in this file. This variable does not contain any data; only information about the geographic coordinates system. | none | none |
| int | sla(time,latitude,longitude) | Sea level anomaly | meters | $10^{-4}$ |
| int | err(time,latitude,longitude) | Formal mapping error | meters | $10^{-4}$ |
| int | ugosa(time,latitude,longitude) | Geostrophic velocity anomalies: eastward zonal component | m/s | $10^{-4}$ |
| int | vgosa(time,latitude,longitude) | Geostrophic velocity anomalies: northward meridian component | m/s | $10^{-4}$ |
| int | adt(time,latitude,longitude) (*) | Absolute dynamic topography | meters | $10^{-4}$ |
| int | ugos(time,latitude,longitude) (*) | Absolute geostrophic velocity: eastward zonal component | m/s | $10^{-4}$ |
| int | vgos(time,latitude,longitude) (*) | Absolute geostrophic velocity: northward meridian component | m/s | $10^{-4}$ |

(*) not delivered for Black Sea products

# Appendix A - Specifications of the Sea Level product

The description of the content specification of the product is presented in this section for the global ocean, Mediterranean Sea and Black Sea areas.

### The global Ocean:

```
netcdf dt_global_twosat_phy_l4_20170515_vDT2018 {
dimensions:
	time = 1 ;
	latitude = 720 ;
	longitude = 1440 ;
	nv = 2 ;
variables:
	int crs ;
		crs:comment = "This is a container variable that describes the grid_mapping used by the data in this file. This variable does not contain any data; only information about the geographic coordinate system." ;
		crs:grid_mapping_name = "latitude_longitude" ;
		crs:inverse_flattening = 298.257 ;
		crs:semi_major_axis = 6378136.3 ;
	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(latitude) ;
		latitude:axis = "Y" ;
		latitude:bounds = "lat_bnds" ;
		latitude:long_name = "Latitude" ;
		latitude:standard_name = "latitude" ;
		latitude:units = "degrees_north" ;
		latitude:valid_max = 89.875 ;
		latitude:valid_min = -89.875 ;
	float lat_bnds(latitude, nv) ;
		lat_bnds:comment = "latitude values at the north and south bounds of each pixel." ;
		lat_bnds:units = "degrees_north" ;
	float longitude(longitude) ;
		longitude:axis = "X" ;
		longitude:bounds = "lon_bnds" ;
		longitude:long_name = "Longitude" ;
		longitude:standard_name = "longitude" ;
		longitude:units = "degrees_east" ;
		longitude:valid_max = 359.875 ;
		longitude:valid_min = 0.125 ;
	float lon_bnds(longitude, nv) ;
		lon_bnds:comment = "longitude values at the west and east bounds of each pixel." ;
		lon_bnds:units = "degrees_east" ;
	int nv(nv) ;
		nv:comment = "Vertex" ;
		nv:units = "1" ;
	int err(time, latitude, longitude) ;
		err:_FillValue = -2147483647 ;
		err:comment = "The formal mapping error represents a purely theoretical mapping error. It mainly traduces errors induced by the constellation sampling capability and consistency with the spatial/temporal scales considered, as described in Le Traon et al (1998) or Ducet et al (2000)" ;
		err:coordinates = "longitude latitude" ;
```

err:grid_mapping = "crs" ;
err:long_name = "Formal mapping error" ;
err:scale_factor = 0.0001 ;
err:units = "m" ;
int adt(time, latitude, longitude) ;
adt:_FillValue = -2147483647 ;
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:grid_mapping = "crs" ;
adt:long_name = "Absolute dynamic topography" ;
adt:scale_factor = 0.0001 ;
adt:standard_name = "sea_surface_height_above_geoid" ;
adt:units = "m" ;
int ugos(time, latitude, longitude) ;
ugos:_FillValue = -2147483647 ;
ugos:coordinates = "longitude latitude" ;
ugos:grid_mapping = "crs" ;
ugos:long_name = "Absolute geostrophic velocity: zonal component" ;
ugos:scale_factor = 0.0001 ;
ugos:standard_name = "surface_geostrophic_eastward_sea_water_velocity" ;
ugos:units = "m/s" ;
int vgos(time, latitude, longitude) ;
vgos:_FillValue = -2147483647 ;
vgos:coordinates = "longitude latitude" ;
vgos:grid_mapping = "crs" ;
vgos:long_name = "Absolute geostrophic velocity: meridian component" ;
vgos:scale_factor = 0.0001 ;
vgos:standard_name = "surface_geostrophic_northward_sea_water_velocity" ;
vgos:units = "m/s" ;
int sla(time, latitude, longitude) ;
sla:_FillValue = -2147483647 ;
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:grid_mapping = "crs" ;
sla:long_name = "Sea level anomaly" ;
sla:scale_factor = 0.0001 ;
sla:standard_name = "sea_surface_height_above_sea_level" ;
sla:units = "m" ;
int ugosa(time, latitude, longitude) ;
ugosa:_FillValue = -2147483647 ;
ugosa:comment = "The geostrophic velocity anomalies are referenced to the [1993, 2012] period" ;
ugosa:coordinates = "longitude latitude" ;
ugosa:grid_mapping = "crs" ;
ugosa:long_name = "Geostrophic velocity anomalies: zonal component" ;
ugosa:scale_factor = 0.0001 ;
ugosa:standard_name = "surface_geostrophic_eastward_sea_water_velocity_assuming_sea_level_for_geoid" ;
ugosa:units = "m/s" ;
int vgosa(time, latitude, longitude) ;
vgosa:_FillValue = -2147483647 ;
vgosa:comment = "The geostrophic velocity anomalies are referenced to the [1993, 2012] period" ;
vgosa:coordinates = "longitude latitude" ;
vgosa:grid_mapping = "crs" ;
vgosa:long_name = "Geostrophic velocity anomalies: meridian component" ;
vgosa:scale_factor = 0.0001 ;
vgosa:standard_name = "surface_geostrophic_northward_sea_water_velocity_assuming_sea_level_for_geoid" ;
vgosa:units = "m/s" ;

// global attributes:

:Conventions = "CF-1.6" ;
:Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
:cdm_data_type = "Grid" ;
:comment = "Sea Surface Height measured by Altimetry and derived variables" ;
:contact = "http://climate.copernicus.eu/c3s-user-service-desk" ;
:creator_email = "http://climate.copernicus.eu/c3s-user-service-desk" ;
:creator_name = "Copernicus Climate Change Service (C3S)" ;
:creator_url = "http://climate.copernicus.eu" ;
:date_created = "2019-01-25T06:41:35Z" ;
:date_issued = "2019-01-25T06:41:35Z" ;
:date_modified = "2019-01-25T06:41:35Z" ;
:geospatial_lat_max = 89.875 ;
:geospatial_lat_min = -89.875 ;
:geospatial_lat_resolution = 0.25 ;
:geospatial_lat_units = "degrees_north" ;
:geospatial_lon_max = 359.875 ;
:geospatial_lon_min = 0.125 ;
:geospatial_lon_resolution = 0.25 ;
: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 = "2019-01-25 06:41:39Z: Creation" ;
:institution = "CLS, CNES" ;
:keywords = "Oceans > Ocean Topography > Sea Surface Height" ;
:keywords_vocabulary = "NetCDF COARDS Climate and Forecast Standard Names" ;
:license = "http://climate.copernicus.eu/c3s-user-service-desk" ;
:platform = "Jason-3, Sentinel-3A," ;
:processing_level = "L4" ;
:product_version = "2019" ;
:project = "Copernicus Climate Change Service (C3S)" ;
:references = "http://climate.copernicus.eu" ;
:software_version = "6.2_DUACS_DT2018_baseline" ;
:source = "Altimetry measurements" ;
:ssalto_duacs_comment = "The reference mission used for the altimeter inter-calibration processing is Topex/Poseidon between 1993-01-01 and 2002-04-23, Jason-1 between 2002-04-24 and 2008-10-18, OSTM/Jason-2 between 2008-10-19 and 2016-06-25, Jason-3 since 2016-06-25." ;
: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 Global Ocean." ;
:time_coverage_duration = "P1D" ;
:time_coverage_end = "2017-05-15T00:00:00Z" ;
:time_coverage_resolution = "P1D" ;
:time_coverage_start = "2017-05-15T00:00:00Z" ;
:title = "DT merged two satellites Global Ocean Gridded SSALTO/DUACS Sea Surface Height L4 product and derived variables" ;
}

## The Mediterranean Sea:

```
netcdf dt_med_twosat_phy_l4_20170515_vDT2018 {
dimensions:
	time = 1 ;
	latitude = 128 ;
	longitude = 344 ;
	nv = 2 ;
variables:
	int crs ;
		crs:comment = "This is a container variable that describes the grid_mapping used by the data in this file. This variable does not contain any data; only information about the geographic coordinate system." ;
		crs:grid_mapping_name = "latitude_longitude" ;
		crs:inverse_flattening = 298.257 ;
		crs:semi_major_axis = 6378136.3 ;
	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(latitude) ;
		latitude:axis = "Y" ;
		latitude:bounds = "lat_bnds" ;
		latitude:long_name = "Latitude" ;
		latitude:standard_name = "latitude" ;
		latitude:units = "degrees_north" ;
		latitude:valid_max = 45.9375 ;
		latitude:valid_min = 30.0625 ;
	float lat_bnds(latitude, nv) ;
		lat_bnds:comment = "latitude values at the north and south bounds of each pixel." ;
		lat_bnds:units = "degrees_north" ;
	float longitude(longitude) ;
		longitude:axis = "X" ;
		longitude:bounds = "lon_bnds" ;
		longitude:long_name = "Longitude" ;
		longitude:standard_name = "longitude" ;
		longitude:units = "degrees_east" ;
		longitude:valid_max = 36.9375 ;
		longitude:valid_min = -5.9375 ;
	float lon_bnds(longitude, nv) ;
		lon_bnds:comment = "longitude values at the west and east bounds of each pixel." ;
		lon_bnds:units = "degrees_east" ;
	int nv(nv) ;
		nv:comment = "Vertex" ;
		nv:units = "1" ;
	int err(time, latitude, longitude) ;
		err:_FillValue = -2147483647 ;
		err:comment = "The formal mapping error represents a purely theoretical mapping error. It mainly traduces errors induced by the constellation sampling capability and consistency with the spatial/temporal scales considered, as described in Le Traon et al (1998) or Ducet et al (2000)" ;
		err:coordinates = "longitude latitude" ;
		err:grid_mapping = "crs" ;
		err:long_name = "Formal mapping error" ;
		err:scale_factor = 0.0001 ;
		err:units = "m" ;
	int adt(time, latitude, longitude) ;
		adt:_FillValue = -2147483647 ;
		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:grid_mapping = "crs" ;
            adt:long_name = "Absolute dynamic topography" ;
            adt:scale_factor = 0.0001 ;
            adt:standard_name = "sea_surface_height_above_geoid" ;
            adt:units = "m" ;
      int ugos(time, latitude, longitude) ;
            ugos:_FillValue = -2147483647 ;
            ugos:coordinates = "longitude latitude" ;
            ugos:grid_mapping = "crs" ;
            ugos:long_name = "Absolute geostrophic velocity: zonal component" ;
            ugos:scale_factor = 0.0001 ;
            ugos:standard_name = "surface_geostrophic_eastward_sea_water_velocity" ;
            ugos:units = "m/s" ;
      int vgos(time, latitude, longitude) ;
            vgos:_FillValue = -2147483647 ;
            vgos:coordinates = "longitude latitude" ;
            vgos:grid_mapping = "crs" ;
            vgos:long_name = "Absolute geostrophic velocity: meridian component" ;
            vgos:scale_factor = 0.0001 ;
            vgos:standard_name = "surface_geostrophic_northward_sea_water_velocity" ;
            vgos:units = "m/s" ;
      int sla(time, latitude, longitude) ;
            sla:_FillValue = -2147483647 ;
            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:grid_mapping = "crs" ;
            sla:long_name = "Sea level anomaly" ;
            sla:scale_factor = 0.0001 ;
            sla:standard_name = "sea_surface_height_above_sea_level" ;
            sla:units = "m" ;
      int ugosa(time, latitude, longitude) ;
            ugosa:_FillValue = -2147483647 ;
            ugosa:comment = "The geostrophic velocity anomalies are referenced to the [1993, 2012] period" ;
            ugosa:coordinates = "longitude latitude" ;
            ugosa:grid_mapping = "crs" ;
            ugosa:long_name = "Geostrophic velocity anomalies: zonal component" ;
            ugosa:scale_factor = 0.0001 ;
            ugosa:standard_name = "surface_geostrophic_eastward_sea_water_velocity_assuming_sea_level_for_geoid" ;
            ugosa:units = "m/s" ;
      int vgosa(time, latitude, longitude) ;
            vgosa:_FillValue = -2147483647 ;
            vgosa:comment = "The geostrophic velocity anomalies are referenced to the [1993, 2012] period" ;
            vgosa:coordinates = "longitude latitude" ;
            vgosa:grid_mapping = "crs" ;
            vgosa:long_name = "Geostrophic velocity anomalies: meridian component" ;
            vgosa:scale_factor = 0.0001 ;
            vgosa:standard_name = "surface_geostrophic_northward_sea_water_velocity_assuming_sea_level_for_geoid" ;
            vgosa:units = "m/s" ;

// global attributes:
            :Conventions = "CF-1.6" ;
            :Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
            :cdm_data_type = "Grid" ;
            :comment = "Sea Surface Height measured by Altimetry and derived variables" ;
            :contact = "http://climate.copernicus.eu/c3s-user-service-desk" ;
            :creator_email = "http://climate.copernicus.eu/c3s-user-service-desk" ;
            :creator_name = "Copernicus Climate Change Service (C3S)" ;
            :creator_url = "http://climate.copernicus.eu" ;
```

:date_created = "2019-01-25T13:47:39Z" ;
:date_issued = "2019-01-25T13:47:39Z" ;
:date_modified = "2019-01-25T13:47:39Z" ;
:geospatial_lat_max = 45.9375 ;
:geospatial_lat_min = 30.0625 ;
:geospatial_lat_resolution = 0.125 ;
:geospatial_lat_units = "degrees_north" ;
:geospatial_lon_max = 36.9375 ;
:geospatial_lon_min = -5.9375 ;
:geospatial_lon_resolution = 0.125 ;
: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 = "2019-01-25 13:47:39Z: Creation" ;
:institution = "CLS, CNES" ;
:keywords = "Oceans > Ocean Topography > Sea Surface Height" ;
:keywords_vocabulary = "NetCDF COARDS Climate and Forecast Standard Names" ;
:license = "http://climate.copernicus.eu/c3s-user-service-desk" ;
:platform = "Jason-3, Sentinel-3A," ;
:processing_level = "L4" ;
:product_version = "2019" ;
:project = "Copernicus Climate Change Service (C3S)" ;
:references = "http://climate.copernicus.eu" ;
:software_version = "6.2_DUACS_DT2018_baseline" ;
:source = "Altimetry measurements" ;
:ssalto_duacs_comment = "The reference mission used for the altimeter inter-calibration processing is Topex/Poseidon between 1993-01-01 and 2002-04-23, Jason-1 between 2002-04-24 and 2008-10-18, OSTM/Jason-2 between 2008-10-19 and 2016-06-25, Jason-3 since 2016-06-25." ;
: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 Mediterranean Sea." ;
:time_coverage_duration = "P1D" ;
:time_coverage_end = "2017-05-15T00:00:00Z" ;
:time_coverage_resolution = "P1D" ;
:time_coverage_start = "2017-05-15T00:00:00Z" ;
:title = "DT merged two satellites Mediterranean Sea Gridded SSALTO/DUACS Sea Surface Height L4 product and derived variables" ;
}

## The Black Sea:

```
netcdf dt_blacksea_twosat_phy_l4_20170515_vDT2018 {
dimensions:
	time = 1 ;
	latitude = 56 ;
	longitude = 120 ;
	nv = 2 ;
variables:
	int crs ;
		crs:comment = "This is a container variable that describes the grid_mapping used by the data in this file. This variable does not contain any data; only information about the geographic coordinate system." ;
		crs:grid_mapping_name = "latitude_longitude" ;
		crs:inverse_flattening = 298.257 ;
		crs:semi_major_axis = 6378136.3 ;
	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(latitude) ;
		latitude:axis = "Y" ;
		latitude:bounds = "lat_bnds" ;
		latitude:long_name = "Latitude" ;
		latitude:standard_name = "latitude" ;
		latitude:units = "degrees_north" ;
		latitude:valid_max = 46.9375 ;
		latitude:valid_min = 40.0625 ;
	float lat_bnds(latitude, nv) ;
		lat_bnds:comment = "latitude values at the north and south bounds of each pixel." ;
		lat_bnds:units = "degrees_north" ;
	float longitude(longitude) ;
		longitude:axis = "X" ;
		longitude:bounds = "lon_bnds" ;
		longitude:long_name = "Longitude" ;
		longitude:standard_name = "longitude" ;
		longitude:units = "degrees_east" ;
		longitude:valid_max = 41.9375 ;
		longitude:valid_min = 27.0625 ;
	float lon_bnds(longitude, nv) ;
		lon_bnds:comment = "longitude values at the west and east bounds of each pixel." ;
		lon_bnds:units = "degrees_east" ;
	int nv(nv) ;
		nv:comment = "Vertex" ;
		nv:units = "1" ;
	int err(time, latitude, longitude) ;
		err:_FillValue = -2147483647 ;
		err:comment = "The formal mapping error represents a purely theoretical mapping error. It mainly traduces errors induced by the constellation sampling capability and consistency with the spatial/temporal scales considered, as described in Le Traon et al (1998) or Ducet et al (2000)" ;
		err:coordinates = "longitude latitude" ;
		err:grid_mapping = "crs" ;
		err:long_name = "Formal mapping error" ;
		err:scale_factor = 0.0001 ;
		err:units = "m" ;
	int sla(time, latitude, longitude) ;
		sla:_FillValue = -2147483647 ;
		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:grid_mapping = "crs" ;
        sla:long_name = "Sea level anomaly" ;
        sla:scale_factor = 0.0001 ;
        sla:standard_name = "sea_surface_height_above_sea_level" ;
        sla:units = "m" ;
    int ugosa(time, latitude, longitude) ;
        ugosa:_FillValue = -2147483647 ;
        ugosa:comment = "The geostrophic velocity anomalies are referenced to the [1993, 2012] period" ;
        ugosa:coordinates = "longitude latitude" ;
        ugosa:grid_mapping = "crs" ;
        ugosa:long_name = "Geostrophic velocity anomalies: zonal component" ;
        ugosa:scale_factor = 0.0001 ;
        ugosa:standard_name = "surface_geostrophic_eastward_sea_water_velocity_assuming_sea_level_for_geoid" ;
        ugosa:units = "m/s" ;
    int vgosa(time, latitude, longitude) ;
        vgosa:_FillValue = -2147483647 ;
        vgosa:comment = "The geostrophic velocity anomalies are referenced to the [1993, 2012] period" ;
        vgosa:coordinates = "longitude latitude" ;
        vgosa:grid_mapping = "crs" ;
        vgosa:long_name = "Geostrophic velocity anomalies: meridian component" ;
        vgosa:scale_factor = 0.0001 ;
        vgosa:standard_name = "surface_geostrophic_northward_sea_water_velocity_assuming_sea_level_for_geoid" ;
        vgosa:units = "m/s" ;

// global attributes:
        :Conventions = "CF-1.6" ;
        :Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
        :cdm_data_type = "Grid" ;
        :comment = "Sea Surface Height measured by Altimetry and derived variables" ;
        :contact = "http://climate.copernicus.eu/c3s-user-service-desk" ;
        :creator_email = "http://climate.copernicus.eu/c3s-user-service-desk" ;
        :creator_name = "Copernicus Climate Change Service (C3S)" ;
        :creator_url = "http://climate.copernicus.eu" ;
        :date_created = "2019-01-25T19:51:35Z" ;
        :date_issued = "2019-01-25T19:51:35Z" ;
        :date_modified = "2019-01-25T19:51:35Z" ;
        :geospatial_lat_max = 46.9375 ;
        :geospatial_lat_min = 40.0625 ;
        :geospatial_lat_resolution = 0.125 ;
        :geospatial_lat_units = "degrees_north" ;
        :geospatial_lon_max = 41.9375 ;
        :geospatial_lon_min = 27.0625 ;
        :geospatial_lon_resolution = 0.125 ;
        :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 = "2019-01-25 19:51:35Z: Creation" ;
        :institution = "CLS, CNES" ;
        :keywords = "Oceans > Ocean Topography > Sea Surface Height" ;
        :keywords_vocabulary = "NetCDF COARDS Climate and Forecast Standard Names" ;
        :license = "http://climate.copernicus.eu/c3s-user-service-desk" ;
        :platform = "Jason-3, Sentinel-3A," ;
        :processing_level = "L4" ;
        :product_version = "2019" ;
        :project = "Copernicus Climate Change Service (C3S)" ;
        :references = "http://climate.copernicus.eu" ;
        :software_version = "6.2_DUACS_DT2018_baseline" ;
```

:source = "Altimetry measurements" ;
:ssalto_duacs_comment = "The reference mission used for the altimeter inter-calibration processing is Topex/Poseidon between 1993-01-01 and 2002-04-23, Jason-1 between 2002-04-24 and 2008-10-18, OSTM/Jason-2 between 2008-10-19 and 2016-06-25, Jason-3 since 2016-06-25." ;
: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 Black Sea." ;
:time_coverage_duration = "P1D" ;
:time_coverage_end = "2017-05-15T00:00:00Z" ;
:time_coverage_resolution = "P1D" ;
:time_coverage_start = "2017-05-15T00:00:00Z" ;
:title = "DT merged two satellites Black Sea Gridded SSALTO/DUACS Sea Surface Height L4 product and derived variables" ;
}

# References

Amarouche L., P.Thibaut, O.Z.Zanife, J.P.Dumont, P.Vincet, N.Steunou, “Improving the Jason-1 Ground Retracking to Better Account for Attitude Effects.” Marine Geodesy. Vol. 27,Iss 1-2,2004

Arbic, B. K., Scott, R. B., Chelton, D. B., Richman, J.G., and Shriver, J. F.: Effects on stencil width on surface ocean geostrophic velocity and vorticity estimation from gridded satellite altimeter data, J. Geophys. Res., 117, C03029, doi:10.1029/2011JC007367, 2012.

Carrère, L., andF. Lyard,Modeling the barotropic response of the global ocean to atmospheric wind and pressure forcing - comparisons with observations, Geophys. Res. Lett.,30, 1275, doi: 10.1029/2002GL016473, 2003.

Carrère, L, F. Lyard, M. Cancet, A. Guillot, N. Picot, 2015: FES2014: a new tidal model on the global ocean with enhanced accuracy in shallow seas and in the Arctic region, OSTST2015: http://meetings.aviso.altimetry.fr/fileadmin/user_upload/tx_ausyclsseminar/files/29Red1100-2_ppt_OSTST2014_FES2014_LC.pdf

Carrere, L., Faugère, Y., and Ablain, M.: Major improvement of altimetry sea level estimations using pressure-derived corrections based on ERA-Interim atmospheric reanalysis, Ocean Sci., 12, 825–842, doi:10.5194/os-12-825-2016, 2016.

Cartwright, D. E. and Tayler, R. J.: New computations of the tide generating potential, Geophys. J. R. Astr. Soc., 23, 45–74, 1971.

Cartwright, D. E. and Edden, A. C.: Corrected tables of tidal harmonics, Geophys. J. R. Astr. Soc., 33, 253–264, 1973.

Desai S., J. Wahr, B. Beckley, Revisiting the pole tide for and from satellite altimetry, J. of Geodesy, Vol 89, issue 12, pp 1233-1243, 2015, DOI: 10.1007/s00190-015-0848-7

Ducet, N., Le Traon, P.-Y., and Reverdun, G.: Global high resolution mapping of ocean circulation from TOPEX/Poseidon and ERS-1 and -2, J. Geophys. Res., 105, 19477–19498, 2000.

Dufau, C., Orstynowicz, M., Dibarboure, G., Morrow, R., and Le Traon, P.-Y.: Mesoscale Resolution Capability of altimetry: present & future, J. Geophys. Res, 121, 4910–4927, doi:10.1002/2015JC010904, 2016

ESRIN, “Detailed Processing Model of the Sentinel-3 SRAL SAR altimeter ocean waveform retracker, Development of SAR Altimetry Mode Studies and Applications of Ocean, Coastal Zones and Inland

Water (SAMOSA project)", ESRIN Contract No. 20698/07/I-LG, SAMOSA3 WP2300, 10 September 2015, version 2.5.0.

Fernandes J., C. Lázaro, M. Ablain, N. Pires, Improved wet path delays for all ESA and reference altimetric missions, Remote Sensing of Environment, Vol 169, p 50-74, 2015, https://doi.org/10.1016/j.rse.2015.07.023

Gaspar, P., and F. Ogor, Estimation and analysis of the Sea State Bias of the new ERS-1 and ERS-2 altimetric data (OPR version 6). Report of task 2 of IFREMER Contract n° 96/2.246 002/C, 1996.

Guibbaud, M., A. Ollivier and M. Ablain, A new approach for dual-frequency ionospheric correction filtering, ENVISAT Altimetry Quality Working Group (QWG), 2015 available in the Section 8.5 of the 2012 Envisat annual activity report: http://www.aviso.altimetry.fr/fileadmin/documents/calval/validation_report/EN/annual_report_en_2012.pdf

Iijima, B. A., Harris, I. L., Ho, C. M., Lindqwiste, U. J., Mannucci, A. J., Pi, X., Reyes, M. J., Sparks, L. C., and Wilson, B. D.: Automated daily process for global ionospheric total electron content maps and satellite ocean altimeter ionospheric calibration based on Global Positioning System data, J. Atmos. Sol.-Terr. Phy., 61, 16, 1205–1218, 1999.

Lagerloef, G. S. E., Mitchum, G., Lukas, R., and Niiler, P.: Tropical Pacific near-surface currents estimated from altimeter, wind and drifter data, J. Geophys. Res., 104, 23313–2332, 1999.

Legeais J.-F., W. Llovel, A. Melet, and B. Meyssignac: Evidence of the TOPEX-A Altimeter Instrumental Anomaly and Acceleration of the Global Mean Sea Level. In: Copernicus Marine Environment Monitoring Service Ocean State Report, Issue 4, J Oper Oceanogr, under review.

Legeais, J.-F., Ablain, M., Zawadzki, L., Zuo, H., Johannessen, J. A., Scharffenberg, M. G., Fenoglio-Marc, L., Fernandes, M. J., Andersen, O. B., Rudenko, S., Cipollini, P., Quartly, G. D., Passaro, M., Cazenave, A., and Benveniste, J.: An improved and homogeneous altimeter sea level record from the ESA Climate Change Initiative, Earth Syst. Sci. Data, 10, 281-301, https://doi.org/10.5194/essd-10-281-2018, 2018.

Le Traon, P.-Y. and F. Ogor: ERS-1/2 orbit improvement using TOPEX/POSEIDON: the 2 cm challenge. J. Geophys. Res., 103, 8045-8057, 1998.

Le Traon, P.-Y, Faugere, Y., Hernamdez, F., Dorandeu, J., Mertz, F., and Ablain, M.: Can We Merge GEOSAT Follow-On with TOPEX/Poseidon and ERS-2 for an Improved Description of the Ocean Circulation?, J. Atmos. Ocean. Technol., 20, 889–895,2003.

Mertz F., F. Mercier, S. Labroue, N. Tran, J. Dorandeu, 2005: ERS-2 OPR data quality assessment; Long-term monitoring – particular investigation. CLS.DOS.NT-06.001

Mulet, S., Rio, M. H., Greiner, E., Picot, N., and Pascual, A.: New global Mean Dynamic Topography from a GOCE geoid model, altimeter measurements and oceanographic in-situ data, OSTST Boulder USA 2013, available at: http://www.aviso.altimetry.fr/fileadmin/documents/OSTST/2013/oral/mulet_MDT_CNES_CLS13.pdf (last access: 31 August 2016), 2013.

Obligis, E., Rahmani, A., Eymard, L., Labroue, S., & Bronner, E. (2009). An improved retrieval algorithm for water vapor retrieval: Application to the envisat microwave radiometer. IEEE Transactions on Geoscience and Remote Sensing, 47(9), 3057–3064.

Pujol, M.-I., Faugère, Y., Taburet, G., Dupuy, S., Pelloquin, C., Ablain, M., and Picot, N.: DUACS DT2014: the new multi-mission altimeter data set reprocessed over 20 years, Ocean Sci., 12, 1067-1090, doi:10.5194/os-12-1067-2016, 2016 http://www.ocean-sci.net/12/1067/2016/os-12-1067-2016.pdf

Pujol, M. ‐ I., Schaeffer, P., Faugère, Y., Raynal, M., Dibarboure, G., & Picot, N. ( 2018). Gauging the improvement of recent mean sea surface models: A new approach for identifying and quantifying their errors. Journal of Geophysical Research: Oceans, 123, 5889– 5911. https://doi.org/10.1029/2017JC013503

Quartly, G. D., Legeais, J.-F., Ablain, M., Zawadzki, L., Fernandes, M. J., Rudenko, S., Carrère, L., García, P. N., Cipollini, P., Andersen, O. B., Poisson, J.-C., Mbajon Njiche, S., Cazenave, A., and Benveniste, J.: A new phase in the production of quality-controlled sea level data, Earth Syst. Sci. Data, 9, 557–572, https://doi.org/10.5194/essd-9-557-2017, 2017.

Rio, M.-H., Pascual, A., Poulain, P.-M., Menna, M., Barceló, B., and Tintoré, J. (2014b). Computation of a new mean dynamic topography for the Mediterranean Sea from model outputs, altimeter measurements and oceanographic in situ data. Ocean Sci., 10, 731-744, doi:10.5194/os-10-731-2014.

Rudenko, S., Otten, M., Visser, P., Scharroo, R., Schöne, T., and Esselborn, S.: New improved orbit solutions for the ERS-1 and ERS-2 satellites, Adv. Space Res., 49, 1229–1244, 2012.

Scharroo, R. and Lillibridge, J. L.: Non-parametric sea-state bias models and their relevance to sea level change studies, Proc. Of the 2004 Envisat & ERS Symposium, Salzburg, Austria, 6–10 September 2004 (ESA SP-572, edited by: Lacoste, H. and Ouwehand, L., 2005.

Scharroo R., W H. F. Smith, A global positioning system–based climatology for the total electron content in the ionosphere, *J. Geoph. Res.*, Vol. 115, Issue A10, 2010, https://doi.org/10.1029/2009JA014719

Schaeffer P., I. Pujol, Y. Faugere, A. Guillot, N. Picot, The CNES CLS 2015 Global Mean Sea surface. Presentation OSTST 2016, http://meetings.aviso.altimetry.fr/fileadmin/user_upload/tx_ausyclsseminar/files/GEO_03_Pres_OSTST2016_MSS_CNES_CLS2015_V1_16h55.pdf (last access 2017/01/10)

Taburet, G., Sanchez-Roman, A., Ballarotta, M., Pujol, M.-I., Legeais, J.-F., Fournier, F., Faugere, Y., and Dibarboure, G.: DUACS DT-2018: 25 years of reprocessed sea level altimeter products, Ocean Sci., 15, 1207–1224, 2019, https://doi.org/10.5194/os-15-1207-2019

Tran, N., Labroue, S., Philipps, S., Bronner, E., and Picot, N.: Overview and Update of the Sea State Bias Corrections for the Jason-2, Jason-1 and TOPEX Missions, Mar. Geod., 33, 348–362, 2010.

Tran N, D. Vandemark, H. Feng, A Guillot and N Picot: "Updated wind speed and sea state bias models for Ka-band altimetry", poster in 2014 SARAL/Altika workshop, 2014. https://meetings.aviso.altimetry.fr/fileadmin/user_upload/tx_ausyclsseminar/files/Poster_PEACHI_ssb_tran2014.pdf

Tran N.: "Envisat ESL Phase-F: Sea State Bias", Technical report CLS-DOS-NT-15-031, 1rev0-07/05/2015.

Tran N., Philipps, S., Poisson, J.-C., Urien, S., Bronner, E., and Picot, N.: Impact of GDR_D standards on SSB corrections, Presentation OSTST2012 in Venice, http://www.aviso.altimetry.fr/fileadmin/documents/OSTST/2012/oral/02_friday_28/01_instr_processing_I/01_IP1_Tran.pdf (last access: 31 August 2016), 2012.

Copernicus Climate Change Service

ECMWF - Shinfield Park, Reading RG2 9AX, UK

Contact: info@copernicus-climate.eu

climate.copernicus.eu copernicus.eu ecmwf.int