# SSALTO/DUACS User Handbook:

**(M)SLA and (M)ADT Near-Real Time and Delayed Time Products**

Reference : CLS-DOS-NT-06-034
Nomenclature : SALP-MU-P-EA-21065-CLS
Issue : 2rev 3
Date : 2011/01/01

| **Chronology Issues :** | | |
|---|---|---|
| Issue : | Date : | Reason for change : |
| 2.2 | 18/11/2010 | |
| 2.3 | 01/01/2011 | Modification of the commentary on the flags and of the part "Product generation" |
| | | |

# List of Tables



# List of Figures



# Applicable documents / reference documents

RD 1: AVISO User Handbook for Merged Topex/Poseidon products (M-GDR)
**Ref: AVI-NT-011-312-CN**

RD 2: AVISO and PO.DAAC User Handbook - IGDR and GDR Jason-1 Products
**Ref: SMM-MU-M5-OP-13184-CN**

RD 3: CERSAT, 1996: Altimeter and Microwave Radiometer ERS Products User manual
**Ref: C2-MUT-A-01-IF**

RD 4: CLS, 1996: Validation of ERS-1/2 OPR cycles
**Ref: CLS.OC/NT/96.010 (ERS-1) and CLS.OC/NT/96.011 (ERS-2) (one report per cycle)**

RD 5: CLS, 2006: Envisat RA2/MWR ocean data validation and crosscalibration - Activities Yearly report - Contract N° 03/CNES/1340/00/DSO310
**Ref: SALP-RP-MA-EA-21316-CLS**

RD 6: CLS, 2006: Jason-1 validation and crosscalibration activities - Contract N° 03/CNES/1340/00/DSO310
**Ref: SALP-RP-MA-EA-21314-CLS**

RD 7: OSTM /Jason-2 Products Handbook
**Ref: SALP-MU-M-OP-15815-CN**

# List of acronyms

| | |
|---|---|
| ATP | Along-Track Product |
| ADT | Absolute Dynamic Topography |
| AVISO | Archiving, Validation and Interpretation of Satellite Oceanographic data |
| BGLO | Biais Grande Longueur d'Onde |
| Cal/Val | Calibration - Validation |
| CERSAT | Centre ERS d'Archivage et de Traitement |
| CMA | Centre Multimission Altimetry center |
| CORSSH | CORrected Sea Surface Height |
| DAC | Dynamic Atmospheric Correction |
| DT | Delayed Time |
| DUACS | Data Unification and Altimeter Combination System |
| E1 | ERS-1 |
| E2 | ERS-2 |
| EN | Envisat |
| ENN | Envisat on its non repetitive orbit (since cycle 94) |
| ECMWF | European Centre for Medium-range Weather Forecasting |
| ENACT | ENhanced ocean data Assimilation and Climate prediction |
| G2 | Geosat Follow On |
| GIM | Global Ionospheric Maps |
| GDR | Geophysical Data Record(s) |
| IERS | International Earth Rotation Service |
| IGDR | Interim Geophysical Data Record(s) |
| J1 | Jason-1 |
| J1N | Jason-1 on its new orbit (since cycle 262) |
| J2 | Jason-2 |
| JPL | Jet Propulsion Laboratory |
| LAS | Live Access Server |
| LWE | Long Wavelength Errors |
| MADT | Map of Absolute Dynamic Topgraphy |
| MDT | Mean Dynamic Topography |
| MOE | Medium Orbit Ephemeris |
| MP | Mean Profile |
| MSLA | Map of Sea Level Anomaly |
| MSS | Mean Sea Surface |
| NRT | Near-Real Time |
| OE | Orbit Error |
| OER | Orbit Error Reduction |
| Opendap | Open-source Project for a Network Data Access Protocol |
| PF | Polynom Fit |
| PO.DAAC | Physical Oceanography Distributed Active Archive Centre |
| POE | Precise Orbit Ephemeris |
| RD | Reference Document |
| SAD | Static Auxiliary Data |

| | |
|---|---|
| SI | Signed Integer |
| SLA | Sea Level Anomaly |
| SSALTO | Ssalto multimission ground segment |
| SSH | Sea Surface Height |
| T/P | Topex/Poseidon |
| TPN | Topex/Poseidon on its new orbit (since cycle 369) |

# References

[1] Carrere, L., F. Lyard, 2003, Modeling the barotropic response of the global ocean to atmospheric wind and pressure forcing- comparisons with observations. *J. Geophys. Res.*, **30(6)**, 1275, doi:10.1029/2002GL016473.

[2] Carrere L., 2003, Etude et modélisation de la réponse HF de l'océan global aux forçages météorologiques. PhD thesis, Université Paul Sabatier (Toulouse III, France), 318 pp.

[3] Cartwright, D. E., R. J. Tayler, 1971, New computations of the tide-generating potential, Geophys. J. R. Astr. Soc., 23, 45-74.

[4] Cartwright, D. E., A. C. Edden, 1973, Corrected tables of tidal harmonics, Geophys. J. R. Astr. Soc., 33, 253-264.

[5] Dibarboure G., P. Schaeffer, P. Escudier, M-I.Pujol, J.F. Legeais, Y. Faugère, R. Morrow, J.K. Willis, J. Lambin, J.P. Berthias, N. Picot, 2010: Finding desirable orbit options for the "Extension of Life" phase of Jason-1. Submitted to *Marine Geodesy*.

[6] Dibarboure G., M-I.Pujol, F.Briol, PY.Le Traon, G.Larnicol, N.Picot, F.Mertz, P. Escudier, M.Ablain, C.Dufau, 2010: Jason-2 in DUACS: first tandem results and impact on processing and products. Submitted in Marine Geodesy.

[7] Dibarboure G., 2009: Using short scale content of OGDR data improve the Near Real Time products of Ssalto/Duacs, oral presentation at Seattle OSTST meeting (pdf).

[8] Dorandeu, J., M. Ablain, Y. Faugère, F. Mertz, B. Soussi, and P. Vincent, 2004: Jason-1 global statistical evaluation and performance assessment. Calibration and cross-calibration results. *Marine Geodesy*, **27**,(3-4), 345-372

[9] Dorandeu, J., M. Ablain, P.-Y. Le Traon, 2003: Reducing Cross-Track Geoid Gradient Errors around TOPEX/Poseidon and Jason-1 Nominal Tracks: Application to Calculation of Sea Level Anomalies. *J. of Atmosph. and Ocean. Techn.*,**20**, 1826-1838.

[10] Dorandeu, J. and P.-Y. Le Traon, 1999: Effects of global mean atmospheric pressure variations on mean sea level changes from TOPEX/Poseidon. *J. Atmos. Oceanic Technol.*, **16**, 1279-1283.

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

[12] Gaspar, P., and F. Ogor, Estimation and analysis of the Sea State Bias of the ERS-1 altimeter. Report of task B1-B2 of IFREMER Contract n° 94/2.426 016/C., 1994.

[13] Gaspar, P., F. Ogor and C. Escoubes, 1996, Nouvelles calibration et analyse du biais d'état de mer des altimètres TOPEX et POSEIDON. Technical note 96/018 of CNES Contract 95/1523, 1996.

[14] 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.

[15] Gaspar, P., S. Labroue and F. Ogor. 2002, Improving nonparametric estimates of the sea state bias in radar altimeter measurements of seal level, *J. Atmos. Oceanic Technology*, **19**, 1690-1707.

[16] Hernandez, F., P.-Y. Le Traon, and R. Morrow, 1995: Mapping mesoscale variability of the Azores Current using TOPEX/POSEIDON and ERS-1 altimetry, together with hydrographic and Lagrangian measurements. *Journal of Geophysical Research*, **100**, 24995-25006.

[17] Hernandez, F. and P. Schaeffer, 2000: Altimetric Mean Sea Surfaces and Gravity Anomaly maps intercomparisons AVI-NT-011-5242-CLS, 48 pp. CLS Ramonville St Agne.

[18] Hernandez, F., M.-H. Calvez, J. Dorandeu, Y. Faugère, F. Mertz, and P. Schaeffer, 2000: Surface Moyenne Océanique: Support scientifique à la mission altimétrique Jason-1, et à une mission micro-satellite altimétrique. Contrat SSALTO 2945 - Lot 2 - A.1. Rapport d'avancement. CLS/DOS/NT/00.313, 40 pp. CLS Ramonville St Agne.

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

[20] Labroue, S., 2007: RA2 ocean and MWR measurement long term monitoring, 2007 report for WP3, Task 2 - SSB estimation for RA2 altimeter. Contract 17293/03/I-OL. CLS-DOS-NT-07-198, 53pp. CLS Ramonville St. Agne

[21] Labroue, S., P. Gaspar, J. Dorandeu, O.Z. Zanifé, F. Mertz, P. Vincent, and D. Choquet, 2004: Non parametric estimates of the sea state bias for Jason-1 radar altimeter. *Marine Geodesy*, **27**, 453-481.

[22] Lagerloef, G.S.E., G.Mitchum, R.Lukas and P.Niiler, 1999: Tropical Pacific near-surface currents estimated from altimeter, wind and drifter data, *J. Geophys. Res.*, **104**, 23,313-23,326

[23] Le Traon, P.-Y. and F. Hernandez, 1992: Mapping the oceanic mesoscale circulation: validation of satellite altimetry using surface drifters. *J. Atmos. Oceanic Technol.*, **9**, 687-698.

[24] Le Traon, P.-Y., P. Gaspar, F. Bouyssel, and H. Makhmara, 1995: Using Topex/Poseidon data to enhance ERS-1 data. *J. Atmos. Oceanic Technol.*, **12**, 161-170.

[25] Le Traon, P.-Y., F. Nadal, and N. Ducet, 1998: An improved mapping method of multisatellite altimeter data. *J. Atmos. Oceanic Technol.*, **15**, 522-534.

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

[27] Le Traon, P.-Y. and G. Dibarboure, 1999: Mesoscale mapping capabilities of multi-satellite altimeter missions. *J. Atmos. Oceanic Technol.*, **16**, 1208-1223.

[28] Le Traon, P.-Y., G. Dibarboure, and N. Ducet, 2001: Use of a High-Resolution Model to Analyze the Mapping Capabilities of Multiple-Altimeter Missions. *J. Atmos. Oceanic Technol.*, **18**, 1277-1288.

[29] Le Traon, P.Y. and G. Dibarboure, 2002 Velocity mapping capabilities of present and future altimeter missions: the role of high frequency signals. *J. Atmos. Oceanic Technol.*, **19**, 2077-2088.

[30] Le Traon, P.Y., Faugère Y., Hernandez F., Dorandeu J., Mertz F. and M. Ablain, 2002: Can we merge GEOSAT Follow-On with TOPEX/POSEIDON and ERS-2 for an improved description of the ocean circulation, *J. Atmos. Oceanic Technol.*, **20**, 889-895.

[31] Le Traon, P.Y. and G. Dibarboure, 2004: An Illustration of the Contribution of the TOPEX/Poseidon-Jason-1 Tandem Mission to Mesoscale Variability Studies. *Marine Geodesy*, **27 (1-2)**.

[32] 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 (pdf)

[33] Pascual, A., Y. Faugère, G. Larnicol, P-Y Le Traon, 2006: Improved description of the ocean mesoscale variability by combining four satellite altimeters. *Geophys. Res. Lett.*, **33**

[34] Pascual A., C. Boone, G. Larnicol and P-Y. Le Traon, 2009. On the quality of Real-Time altimeter gridded fields: comparison with in-situ data. *Journ. of Atm. and Ocean. Techn.* **Vol. 26(3)** pp. 556-569, DOI: 10.1175/2008JTECHO556.1

[35] Pujol M-I. et al., 2009. Three-satellite quality level restored in NRT, poster at OSTST meeting (pdf)

[36] Ray, R., 1999: A Global Ocean Tide model from TOPEX/Poseidon Altimetry, GOT99.2. NASA Tech. Memo. NASA/TM-1999-209478, 58 pp. Goddard Space Flight Center, NASA Greenbelt, MD, USA.

[37] Rio, M.-H. and F. Hernandez, 2003: A Mean Dynamic Topography computed over the world ocean from altimetry, in-situ measurements and a geoid model. *J. Geophys. Res.*, **109**, C12032, doi:10.1029/2003JC002226.

[38] Rio, M.-H. and F. Hernandez, 2003: High frequency response of wind-driven currents measured by drifting buoys and altimetry over the world ocean. *J. Geophys. Res.*, **108**, 39-1.

[39] Rio, M.-H., 2003: Combinaison de données in situ, altimétriques et gravimétriques pour l'estimation d'une topographie dynamique moyenne globale. Ed. CLS. PhD Thesis, University Paul Sabatier (Toulouse III, France), 260pp.

[40] Scharroo, R. and P. Visser, 1998: Precise orbit determination and gravity field improvement for the ERS satellites. *J. Geophys. Res.*, **103**, 8113-8127

[41] Scharroo, R., J. Lillibridge, and W.H.F. Smith, 2004: Cross-calibration and long-term monitoring of the Microwave Radiometers of ERS, Topex, GFO, Jason-1 and Envisat. *Marine Geodesy*, **97**.

[42] Tran N. and E. Obligis, December 2003, "Validation of the use of ENVISAT neural algorithms on ERS-2", **CLS.DOS/NT/03.901**.

[43] Tran, N., S. Labroue, S. Philipps, E. Bronner, and N. Picot, 2010 : Overview and Update of the Sea State Bias Corrections for the Jason-2, Jason-1 and TOPEX Missions. *Marine Geodesy*, accepted.

[44] Vincent, P., Desai S.D.,Dorandeu J., Ablain M., Soussi B., Callahan P.S. and B.J. Haines, 2003: Jason-1 Geophysical Performance Evaluation. *Marine Geodesy*, **26**, 167-186.

[45] Wahr, J. W., 1985, Deformation of the Earth induced by polar motion,*J. of Geophys. Res. (Solid Earth)*, **90**, 9363-9368.

# Contents

# 1. Introduction

DUACS is part of the CNES multi-mission ground segment (SSALTO). It processes data from all altimeter missions: OSTM/Jason-2, Jason-1, Topex/Poseidon, Envisat, GFO, ERS-1&2 and even Geosat. At this time (January 2011) DUACS is using three different altimeters in near real time.
Developed and operated by CLS, it started as an European Commission Project (Developing Use Of Altimetry for Climate Studies), funded under the European Commission and the Midi-Pyrénées regional council. It has been integrated to the CNES multi-mission ground segment SSALTO in 2001, and it is maintained, upgraded and operated with funding from CNES with shared costs from EU projects.
At the beginning of 2004, DUACS was redefined as the Data Unification Altimeter Combination System.

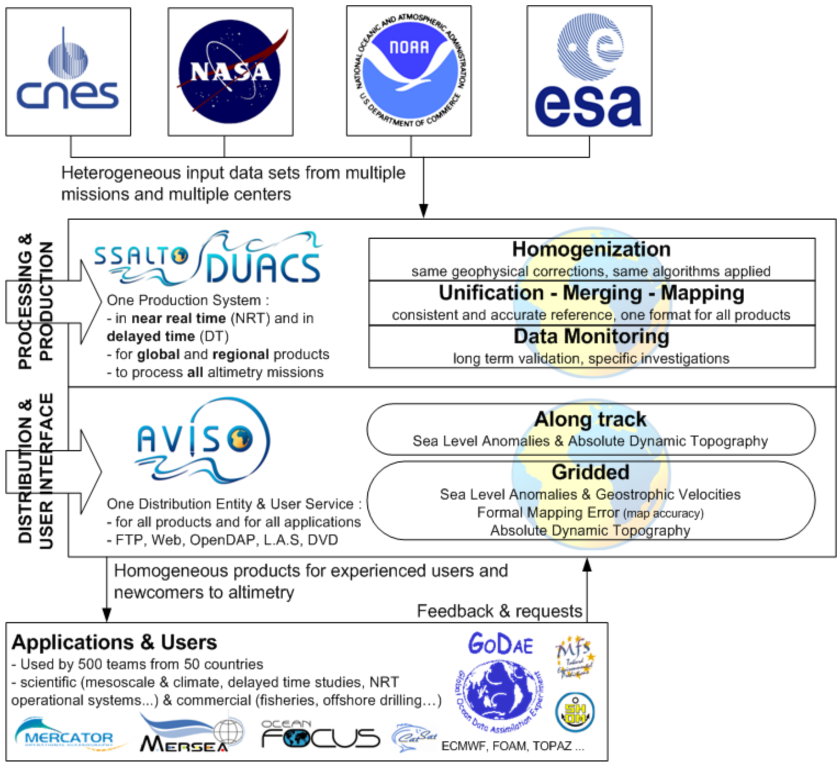


Figure 1: *DUACS and AVISO, a user-driven altimetry service*

DUACS provides a consistent and homogeneous catalogue of products for varied applications, both for near real time applications and offline studies. DUACS gridded products are available free of charge for scientific studies only. Commercial use of gridded products is subject to separate agreement and licence (Contact aviso@oceanobs.com).
For Mediterranean Sea Regional products, a specific component is also operational, following the MF-STEP (Mediterranean Forecasting System Toward Environmental Predictions http://www.bo.ingv.it/mfstep/) project, to provide regional products. Black Sea regional products have been implemented, following the ECOOP project (European COastal sea OPerational observing and forecasting system http://www.ecoop.eu/), to provide Near-real time and Delayed-time Sea Level Anomalies (SLA) products.

This document describes the along-track and gridded products generated by the SSALTO/DUACS real time, near-real time and delayed time altimeter data processing software.
The SSALTO/DUACS system is introduced first: after a description of the input data, an overview of the processing steps is given.
Then complete information about the SSALTO/DUACS output data (i.e user products, in Near-Real Time and in Delayed Time) is provided, giving nomenclature, format description, and software routines.

More information regarding the SSALTO/DUACS project and products may be found on the AVISO web site at the respective addresses:
http://www.aviso.oceanobs.com/duacs/
http://www.aviso.oceanobs.com/en/data/products/

## 1.1. Data policy and data access

All SSALTO/DUACS product users need an account on FTP since june 2010, whether for NRT (as was already the case) or for DT (Delayed-Time, which is new) data, for along-track and gridded products.
The SSALTO/DUACS along-track data (level 3) are now shared with the MyOcean catalogue. MyOcean is a European project dedicated to operational oceanography. MyOcean Service provides the best set of information available on the Ocean for the large and regional scales (European seas), based on the combination of space and in situ observations, and their use into models: temperature, salinity, currents, ice extent, sea level, primary ecosystems... (see www.myocean.eu.org). When users choose these SSALTO/DUACS along-track data, their personal information can be transmitted by Aviso/CNES to the MyOcean European project for their user databases, with the user's agreement.
Duacs **gridded** products are available free of charge for scientific studies or non-profit projects only.
Commercial use of gridded products or applications not in line with the standard license agreement is subject to separate agreement and licence (Contact aviso@oceanobs.com).
Please, subscribe to get access to SSALTO/DUACS products by filling the registration form on:
http://www.aviso.oceanobs.com/en/data/registration-form/index.html.

# 2. SSALTO/DUACS system

## 2.1. Introduction

This chapter presents the input data used by SSALTO/DUACS system and an overview of the different processing steps necessary to produce the output data.
SSALTO/DUACS system is made of two components: a Near Real Time one (NRT) and a Delayed Time (DT) one.
In NRT, the system's primary objective is to provide operational applications with directly usable high quality altimeter data from all missions available.
In DT, it is to maintain a consistent and user-friendly altimeter database using the state-of-the-art recommendations from the altimetry community.
Following figure gives an overview of DUACS system, where processing sequences can be divided into 7 main steps:

- acquisition
- homogenization
- input data quality control
- multi-mission cross-calibration
- product generation
- merging
- final quality control.

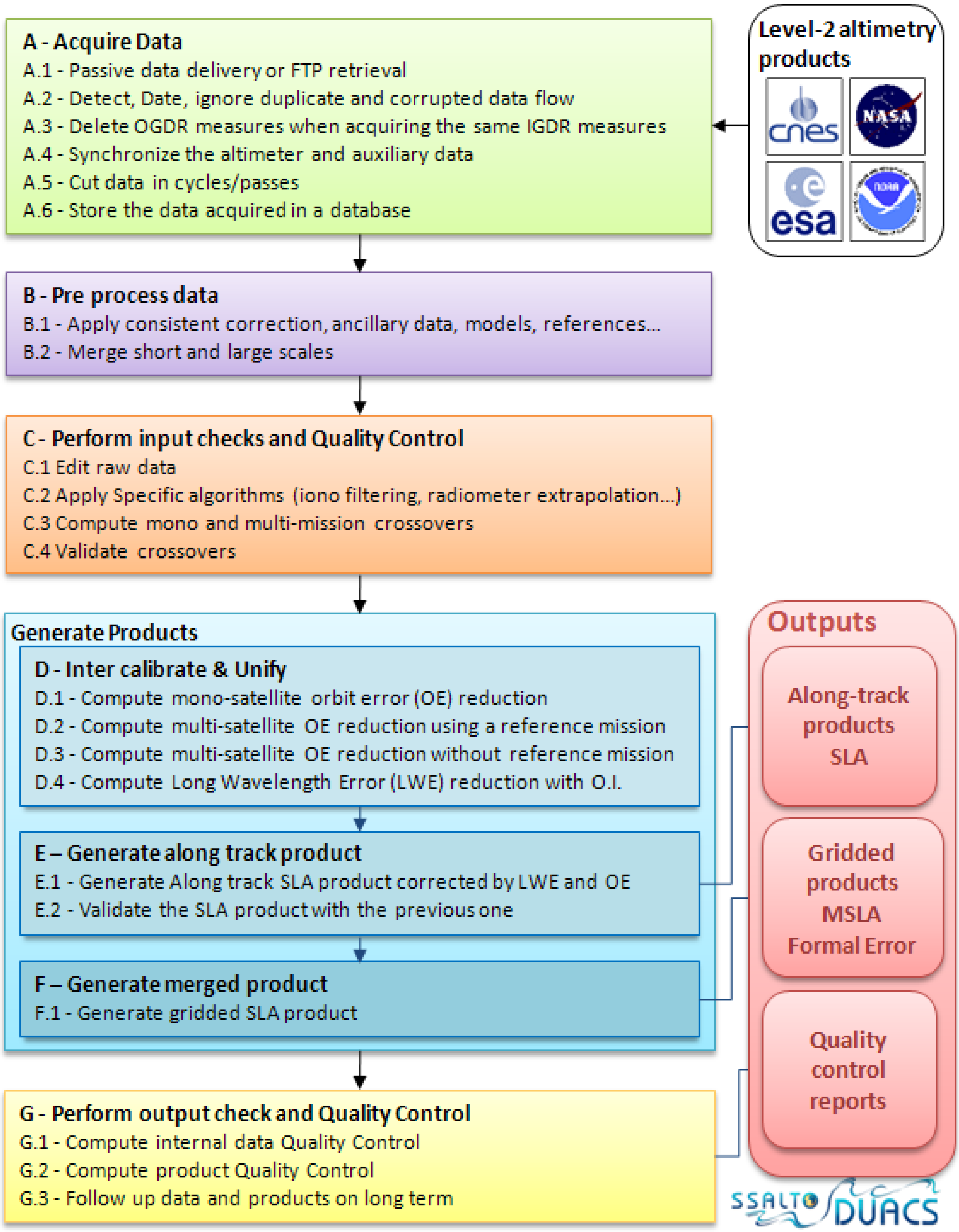


Figure 2: *SSALTO/DUACS processing sequences*

## 2.2. Near Real Time processing steps

### 2.2.1. Input data, models and corrections applied

To produce SLA and MSLA in near-real time, the DUACS system uses two flows, based on the same instrumental measurements but with a different quality:

- The IGDR that are the latest high-quality altimeter data produced in near-real-time.
- The OGDR that includes real time data (OSTM/Jason-2 and Jason-1 OSDR and Envisat FDGDR, hereafter "OGDR") to complete IGDR. These fast delivery products do not always benefit from precise orbit determination, nor from some external model-based corrections (Dynamic Atmospheric Correction (DAC), Global Ionospheric Maps (GIM)).

Integration of OGDR data and the introduction of Jason-2/Jason-1 tandem increased the resilience and precision of the system. A better restitution of ocean variability is observed, especially in high energetic areas.

| Altimetric product | | Source | Availability | Type of orbit |
|---|---|---|---|---|
| Jason-2 | IGDR | CNES | ~24h | CNES MOE |
| | OGDR | NOAA/EUMETSAT | ~3 to 5 h | |
| Jason-1 | IGDR | CNES/NASA | ~48 h | CNES MOE |
| | OGDR | CNES/NASA | ~3 to 12 h | |
| Envisat | IGDR | ESA/CNES | ~48 h | CNES MOE |
| | FDGDR | ESA | ~3 to 12 h | |

Table 1: SSALTO/DUACS Near-Real Time Input data overview

See Figure 3: Overview of the near real time system data flow management.

| | **DUACS 2010 NRT product from IGDR**[1] | | |
|---|---|---|---|
| | j2 | j1n | enn |
| Product standard ref | IGDR-C | | |
| Orbit | CNES MOE | | |
| Ionopheric | From-dual frequency altimeter range measurements | | From GIM model from cycle 65 (Iijima et al, 1998 [19]) |
| Dry troposphere | Model computed from ECMWF Gaussian grids (new S1 and S2 atmospheric tides are applied) | Model computed from ECMWF rectangular grids (new S1 and S2 atmospheric tides are included) | |
| Wet troposphere | From JMR/AMR radiometer | | From MWR radiometer and corrected from side lobes |
| DAC | MOG2D High Resolution forced with ECMWF pressure and wind fields (S1 and S2 were excluded) + inverse barometer computed from rectangular grids. Filtering temporal window is un-centered (no data in the future) | | |
| Ocean tide | GOT4v7 (S1 and S2 are included) | | |
| Pole tide | [Wahr, 1985 [45]] | | |
| Solid earth tide | Elastic response to tidal potential [Cartwright and Tayler, 1971[3]], [Cartwright and Edden, 1973[4]] | | |
| Loading tide | GOT4v7 (S1 and S2 are included) | | |
| Sea state bias | Non parametric SSB [Labroue, 2004[21]] (with cycles J1 1 to 11 using GDR-B standards) | Non parametric SSB [Labroue, 2004[21]] (with cycles 1 to 21 using GDR-B standards) | Non parametric SSB [Labroue, 2004[21]] (with cycles 41 to 60 using GDR-B standards) |
| Orbit error | Global multi-mission crossover minimization (Le Traon and Ogor, 1998[26]) | | |
| Long wavelengh errors | Optimal Interpolation [Le Traon et al., 1998[25]] | | |
| Intercalibration | Reference from cycle 20 | | |
| Mean profile | Computed with cycles 11-353 TP data and with cycles 11-250 J1 data; referenced [1993,1999] | TPN/J1N: computed with cycles 369-479 TPN data; referenced [1993,1999] | Computed with cycles 1-85 E2 data and with cycles 10-72 EN data; referenced [1993,1999] |

(1) A new flag included in the along-track files indicates the source of the production (OGDR or IGDR). If flag=0, the processed data comes from OGDRs; if flag=1, the processed data comes from IGDRs.

Table 2: Corrections and models applied in SSALTO/DUACS NRT products produced from IGDRs.

| | **DUACS 2010 NRT product from OGDR[2]** | | |
|---|---|---|---|
| | j2 | j1n | en |
| Product standard ref | OGDR-C | | |
| Orbit | Navigator | | |
| Ionopheric | From-dual frequency altimeter range measurements | | From GIM model from cycle 65 (Iijima et al, 1998 [19]) |
| Dry troposphere | Model computed from ECMWF Gaussian grids (new S1 and S2 atmospheric tides are applied) | Model computed fromECMWF rectangular grids (new S1 and S2 atmospheric tides are included) | |
| Wet troposphere | From JMR/AMR radiometer | | From MWR radiometer and corrected from side lobes |
| DAC | MOG2D High Resolution forced with ECMWF pressure and wind fields (S1 and S2 were excluded) + inverse barometer computed from rectangular grids. Filtering temporal window is un-centered (no data in the future) | | |
| Ocean tide | GOT4v7 (S1 and S2 are included) | | |
| Pole tide | [Wahr, 1985 [45]] | | |
| Solid earth tide | Elastic response to tidal potential [Cartwright and Tayler, 1971[3]], [Cartwright and Edden, 1973[4]] | | |
| Loading tide | GOT4v7 (S1 and S2 are included) | | |
| Sea state bias | Non parametric SSB [Labroue, 2004[21]] (with cycles J1 1 to 11 using GDR-B standards) | Non parametric SSB [Labroue, 2004[21]] (with cycles 1 to 21 using GDR-B standards) | Non parametric SSB [Labroue, 2004[21]] (with cycles 41 to 60 using GDR-B standards) |
| Orbit error | Specific filtering of long-wavelength signal[3] | | |
| Long wavelengh errors | Optimal Interpolation [Le Traon et al., 1998[25]] | | |
| Intercalibration | Reference from cycle 20 | | |
| Mean profile | Computed with cycles 11-353 TP data and with cycles 11-250 J1 data; referenced [1993,1999] | TPN/J1N: computed with cycles 369-479 TPN data; referenced [1993,1999] | Computed with cycles 1-85 E2 data and with cycles 10-72 EN data; referenced [1993,1999] |

(2) A new flag included in the along-track files indicates the source of the production (OGDR or IGDR). If flag=0, the processed data comes from OGDRs; if flag=1, the processed data comes from IGDRs.
(3) Specific data processing was applied on long wave-length signal (§2.2.3. of the user manual)

Table 3: Corrections and models applied in SSALTO/DUACS NRT products produced from OGDRs.

### 2.2.2. Acquisition

The acquisition process is twofold:

- straightforward retrieval and reformatting of altimeter data and dynamic auxiliary data (pressure and wet troposphere correction grids from ECMWF are provided by Meteo France, TEC grids from JPL, NRT MOG2D corrections,...) from external repositories.
- synchronisation process.

To be homogenized properly, altimeter data sets require various auxiliary data. The acquisition software detects, downloads and processes incoming data as soon as they are available on remote sites (external database, FTP site). Data are split into passes if necessary. If data flows are missing or late, the synchronisation engine put unusable data in waiting queues and automatically unfreezes them upon reception of the missing auxiliary data. This processing step delivers "raw" data, that is to say data that have been divided into cycles and passes, and ordered chronologically.
From SSALTO/DUACS V8.0, the acquisition step uses two different data flows in near-real time: the OGDR flow (within a few hours), and the IGDR flow (within a few days).
For each OGDR input, the system checks that no equivalent IGDR entry is available in the data base before acquisition; for each IGDR input, the system checks and delete the equivalent OGDR entry in the data base. These operations aim to avoid duplicates in SSALTO/DUACS system.

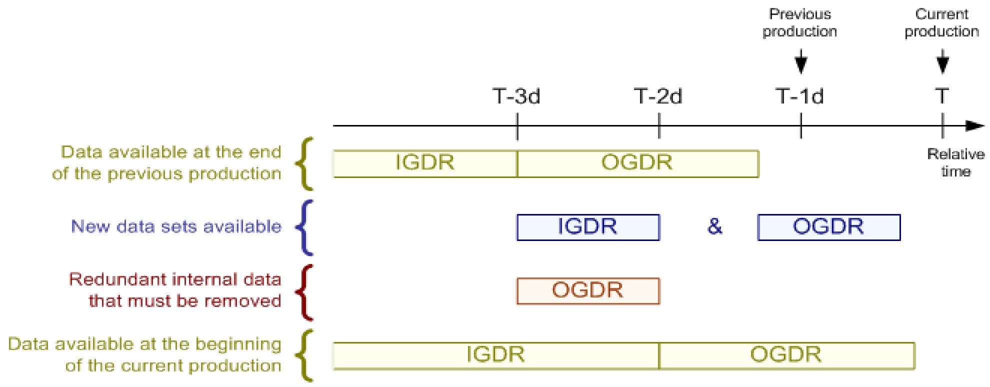


Figure 3: *Overview of the near real time system data flow management*

### 2.2.3. Homogenization

The Homogenization process consists in applying the most recent corrections, models and references recommended for altimeter products. Each mission is processed separately as its needs depend on the base input data. The list of corrections and models currently applied is provided in tables 2 and 3 for NRT data. The system includes SLA filtering to process OGDR data. DUACS extract from these data sets the short scales (space and time) which are useful to better describe the ocean variability in real time, and merge this information with a fair description of large scale signals provided by the multi-satellite observation in near real time (read: IGDR-based DUACS data). Finally an "hybrid" SLA is computed.

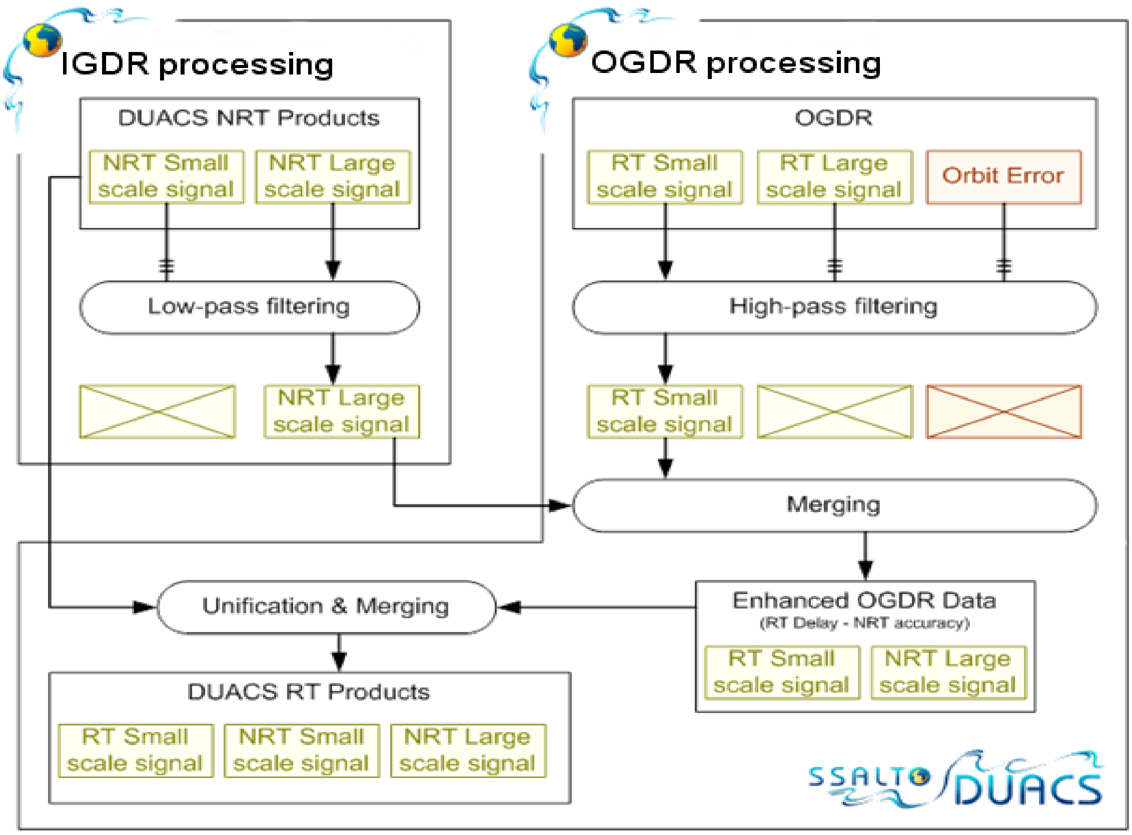


Figure 4: *Merging pertinent information from IGDR and OGDR processing*

### 2.2.4. Input data quality control

The Input Data Quality Control is a critical process applied to guarantee that DUACS uses only the most accurate altimeter data. Thanks to the high quality of current missions, this process rejects a small percentage of altimeter measurements, but these erroneous data could be the cause of a significant quality loss. The quality control relies on standard raw data editing with quality flags or parameter thresholds, but also on complex data editing algorithms based on the detection of erroneous artefacts, mono and multi-mission crossover validation, and macroscopic statistics to edit out large data flows that do not meet the system's requirements.

### 2.2.5. Multi-mission cross-calibration

The Multi-mission Cross-calibration process ensures that all flows from all satellites provide a consistent and accurate information. It removes any residual orbit error (OE, Le Traon and Ogor, 1998[26]), or long wavelength error (LWE, Le Traon et al., 1998[25]), as well as large scale biases and discrepancies between various data flows.

This process is based on two very different algorithms: a global multi-mission crossover minimization for orbit error reduction (OER), and Optimal Interpolation (OI) for LWE.

Multi-satellite crossover determination is performed on a daily basis. All altimeter fields (measurement, corrections and other fields such as bathymetry, MSS,...) are interpolated at crossover locations and dates. Crossovers are then appended to the existing crossover database as more altimeter data become available. This crossover data set is the input of the Orbit Error Reduction (OER) method. Using the precision of the reference mission orbit, a very accurate orbit error can be estimated. This processing step does not concern OGDR data.
LWE is mostly due to residual tidal or inverse barometer errors and high frequency ocean signals. The OI used for LWE reduction uses precise parameters derived from:

- accurate statistical description of sea level variability
- localized correlation scales
- mission-specific noise and precise assumptions on the long wavelength errors to be removed (from a recent analysis of one year of data from each mission).

### 2.2.6. Product generation

The product generation process is composed of four steps: computation of raw SLA, cross-validation, filtering&sub-sampling, and generation of by-products.

#### 2.2.6.1. Computation of raw SLA

Since the geoid is not well known yet, the SSH cannot be used directly, the SSH anomalies are used instead. They are computed from the difference of the instantaneous SSH - a temporal reference. This temporal reference can be a Mean Profile (MP) in the case of repeat track analysis or a gridded MSS when the repeat track analysis cannot be used. The errors affecting the SLAs, MPs and MSS have different magnitudes and wavelengths. The computation of the SLAs and their errors associated are detailed in Dibarboure et al, 2010 [5].

**Utilisation of a Mean Profile**

In the repeat track analysis (when the satellites flies over a repetitive orbit), measurements are re-sampled along a theoretical ground track (or mean track) associated to each mission. Then a Mean Profile (MP) is subtracted from the re-sampled data to obtain SLA. The MP is a time average of similarly re-sampled data over a long period.

- The Mean Profile used for Jason-2 is computed with 10 years of T/P (cycles 11 to 353) and 6 years of Jason-1 (cycles 11 to 250).
- The Mean Profile used from Jason-1 cycle 262 onwards (where satellites are on interleaved ground-tracks) is computed with 3 years of T/P (cycles 369 to 479).
- The Mean Profile used for Envisat (only for the first orbit, before November 2010) is computed with 8 years of ERS-2 (cycles 1 to 85) and 6 years of Envisat (cycles 10 to 72).

**Computation of a Mean Profile**

The computation of a Mean Profile is not a simple average of similarly co-located SSH data from the same ground track on the maximum period of time as possible .

- Indeed, as the satellite ground track is not perfectly controlled and is often kept in a band of about 1km wide, precise cross-track projection and/or interpolation schemes are required to avoid errors.
- The mesoscale variability error (which is <3.5 cm for MP between 3 to 5 years and <1cm for WL of 100-200km for MP between 7 and 15 years) is eliminated with an iterative process using a priori knowledge from Sea Level maps derived from previous iterations or from other missions.
- Moreover, the inter-annual variabilty error (<5cm for WL>5000km and <5-8cm for WL of 200-500km) is accounted for by using the MSS computed over 1993-1999 (e.g. the GFO MP is computed on 2000-2006 but referenced onto 1993-1999 for the sake of coherency with other missions).
- Finally, for these Mean Profiles, the latest standards and a maximum of data were used in order to increase as much as possible the quality of their estimation (see tables 5 and 6: Corrections and models

applied in SSALTO/DUACS Delayed-Time products). Note that a particular care was brought to the processing near coasts.

**Utilisation of a MSS**

When the satellite is not in a repetitive orbit phase as is the case for Envisat since november 2010, the repeat track analysis is impossible. The alternative is to use the MSS instead. The gridded MSS is derived from along track MPs and data from geodetic phases. Thus any error on the MP is also contained in the MSS. There are essentially 4 types of additional errors on gridded MSS which are hard to quantify separately:

- To ensure a global MSS coherency between all data sets, the gridding process averages all sensor-specific errors and especially geographically correlated ones.
- The gridding process has to perform some smoothing to make up for signals which cannot be resolved away from known track, degrading along-track content.
- There are also errors related to the lack of spatial and temporal data (omission errors).
- The error stemming from the geodetic data: the variability not properly removed before the absorption in the MSS and the impossibility to compute mean sea surface height content.

#### 2.2.6.2. Cross validation

After the repeat track analysis, the cross-validation technique is used as the ultimate screening process of isolated and slightly erroneous measurements. Small SLA flows are compared to previous and independent SLA data sets using a- 12 year climatology and a 3 sigma criteria for outlier removal.

#### 2.2.6.3. Filtering and sub-sampling

Residual noise and small scale signals are then removed by filtering the data using a Lanczos filter. As data are filtered from small scales, a sub-sampling is finally applied. Along-track SLA are then produced.

Along-track ADT products are obtained as follows:

$$\text{ADT} = \text{SLA} + \text{MDT}$$

where MDT is the Mean Dynamic Topography. The Mean Dynamic Topography is the part of Mean Sea Surface Height due to permanent currents, so MDT corresponds to the Mean Sea Surface Height minus Geoid. More information about the Mean Dynamic Topography used in SSALTO/DUACS system can be found on AVISO web site at the following address:
http://www.aviso.oceanobs.com/en/data/products/auxiliary-products/mdt/.

The product generation processing step is activated daily in near real time.
The regional ADT product is computed using a specific regional MDT (Mediterranean Sea only):

$$\text{ADT}_{Reg} = \text{SLA}_{Reg} + \text{MDT}_{Reg}$$

### 2.2.7. Merging process

The Merging process is twofold: mapping and generation of by-products.
A mapping procedure using optimal interpolation with realistic correlation functions is applied to produce SLA and ADT maps (respectively MSLA and MADT products) at a given date. The procedure generates one map for each altimeter mission but also a combined map merging measurements from all available altimeter missions (Ducet et al., 2000[11]). From Duacs DT v3.0.0, the mapping process takes into account an updated suboptimal Optimal Interpolation parameterization to minimize transition artefacts.
Combining data from different missions significantly improves the estimation of mesoscale signals (Le Traon and Dibarboure, 1999[27]), (Le Traon et al., 2001[28]), (Pascual et al., 2006[33]). Several improvements were made compared to the version used by (Le Traon et al., 1998[25]). An improved statistical description of sea level variability, noise and long wavelength errors is used. Covariance functions including propagation velocities that depend on geographical position were thus used. For each grid point, the zonal and meridional spatial scales, the time scale and the zonal and meridional propagation velocities were adjusted from five years of TP+ERS combined maps. In addition to instrumental noise, a noise of 10% of the signal variance was used to take into account the small scale variability which cannot be mapped and should be filtered in the analysis. Long wavelengths errors (LWE) due to residual orbit errors but also tidal or inverse barometer errors and high frequency ocean signals were also derived from an analysis of TP and ERS data.
SLA computation from OGDR is based on the same algorithms, only parameters are different to take into account OGDR specificity. LWE and mapping process are based on IGDR and GDR available residuals, also with specific parameters.
The combined map is used to generate by-products such as geostrophic currents or absolute dynamic topography.

#### 2.2.7.1. Computing geostrophic currents

Considering the MSLA grid point i,j (lon, lat), geostrophic velocity anomalies are computed using finite differences. In the equator band (+/-5°) the method recommended by Lagerloef et al (1999)[22] is applied. Absolute geostrophic velocities are computed using the same algorithm, but applied on MADT grid points.

### 2.2.8. Quality control

To ensure a production of homogeneous products in a high quality data with a short delay, are the key features of the DUACS processing system. But some events (failure on payload or on instruments, delay, maintenance on servers), can impact the quality of measurements or the data flows. A strict quality control on each processing step is indispensable to appreciate the overall quality of the system and to provide the best user services.

#### 2.2.8.1. Final quality Control

The Quality Control (QC) is the final process used by DUACS before product delivery. In addition to daily automated controls and warnings to the operators, each production delivers a large QC Report composed of detailed logs, figures and statistics of each processing step. Altimetry experts analyse these reports twice a week. A shorter report is delivered to DUACS users upon each product delivery.
This QC activity is used as a modest Cal/Val activity on NRT products. It provides level2 product centres with a detailed feedback on potential anomalies for a fast reprocessing of erroneous IGDR flows.
Download them from
ftp://ftp.aviso.oceanobs.com/pub/oceano/AVISO/SSH/duacs/quality_report/

#### 2.2.8.2. Performance indicators

To appreciate the quality situation of the DUACS system, new performance indicators are computed daily. They aim at evaluate the status of the main processing steps of the system: the input data availability, the input data coverage, the input data quality and the output product quality. These indicators are computed for each and every currently working satellite, and combined to obtain the overall status.

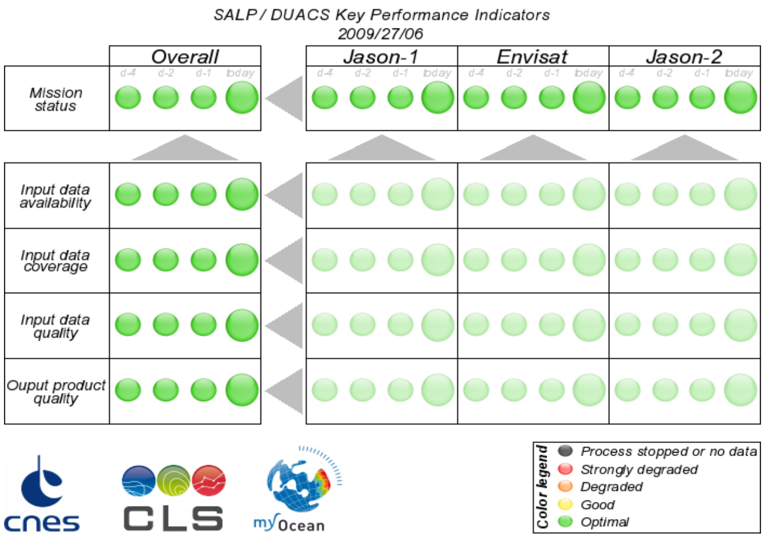


Figure 5: *Example with the key performance indicator on 2009/06/27*

See the description, the latest and previous indicators on Aviso website:
http://www.aviso.oceanobs.com/en/data/product-information/duacs/key-performance-index.html

## 2.3. Delayed Time processing steps

### 2.3.1. Input data, models and corrections applied

Delayed Time SSALTO/DUACS products are generated:

- from Aviso GDR products for T/P, Jason-1, Jason-2 and Envisat (GDR-A: cycles 1 to 22 / GDR-B: cycles 23 to 85 / GDR-C: from cycle 86),

- from NOAA GDR for GFO and from CERSAT (IFREMER) OPR for ERS-1 and ERS-2 (phases C (1st 35-day repeat orbit period), phase E and F (geodetic phases), phase G for ERS-1 (last 35-day repeat orbit period, tandem phase with ERS-2 ; phase A for ERS-2 (1st 35-day repeat orbit period, tandem phase with ERS-1)).

All GDR products are computed with a Precise Orbit Ephemeris (POE) and are delivered within 2 to 3 months depending on the mission. For several missions, an updated orbit is used:

- For ERS-1&-2, the orbit used is DGME-04 provided by Delft Institute (http://www.deos.tudelft.nl/) until June 2003,
- For Topex/Poseidon, the orbit used is GSFC (std0809) for the whole mission,
- For Envisat, CNES POE of GDR-C standard is used for the whole mission,
- For the whole GFO mission, the orbit used is GSFC (std0809) and when not available, NASA POE is used.

| Altimetric product | Source | Availability | Type of orbit |
|---|---|---|---|
| Topex/Poseidon GDR | NASA/CNES | - | GSFC POE |
| Jason-1 GDR (GDR-C) | CNES/NASA | ~40 days | CNES POE |
| Jason-2 GDR (GDR-C) | CNES/NASA | ~60 days | CNES POE |
| GFO GDR | NOAA | - | GSFC/NASA POE |
| ERS-1&2 | IFREMER/ESA | - | DGME-04 |
| Envisat (GDR-A, GDR-B and GDR-C from cycle 86) | ESA | ~2 months | CNES POE |

Table 4: SSALTO/DUACS Delayed Time Input data overview

| | DUACS 2010 DT product (>V3.0.0) | | | | | | |
|---|---|---|---|---|---|---|---|
| | j2 | j1;j1n | tp;tpn | e1 | e2 | en | g2 |
| Product standard ref | GDR-C | | | OPR | | GDR-A (Cycles 1 to 22)/ GDR-B (cycles 23-85) | GDR (NOAA) |
| Orbit | Cnes POE | | GSFC (ITRF 2005,GRACE last standards) | DGME-04 (Scharroo and Visser, 1998[40] | | CNES POE (GDR-1 standards for cycles 9 to 22; GDR-C standards from cycle 23) | GSFC (ITRF 2005, GRACE last standards |
| Ionopheric | Dual frequency altimeter range measurements | | Dual frequency altimeter range measurements (Topex), DORIS (POSEIDON) | Bent model | Bent model (cycles 1-36), GIM modem from cycle 37 ((Iijima et al, 1998 [19]) | Dual-frequency altimeter range measurement (cycle 9-64) and GIM model >cycle 65 (Iijima et al., 1999[19]) corrected from 8 mm bias | From GIM model (Iijima et al, 1998 [19]) |
| Dry tropo-sphere | Model computed from ECMWF Gaussian grids (new S1 and S2 atmospheric tides are applied) | Model computed from ECMWF rectangular grids (new S1 and S2 atmospheric tides are included) | | | | | |
| Wet tropo-sphere | JMR/AMR radiometer further than 50 km from the coasts, From ECMWF model for distances between 10 and 50 km | | TMR radiometer (Scharoo et al. 2004 [41]) | MWR | Correction of the drift on the 23.6 GHz brightness temperature (Scharroo et al., 2004[41]).Neural Network algorithm (Tran and Obligis, 2003[42] | MWR radiometer further than 50 km from the coasts and corrected from side lobes (from cycle 41), ECMWF model for distances between 10 and 50 km | GFO radiometer |
| DAC | MOG2D High Resolution forced with ECMWF pressure and wing fields (S1 and S2 were excluded) + inverse barometer computed from rectangular grids | | | | | | |

Table 5: Corrections and models applied in SSALTO/DUACS DT products (>v3.0.0). (1/2)

| | j2 | j1;j1n | tp;tpn | e1 | e2 | en | g2 |
|---|---|---|---|---|---|---|---|
| Ocean tide | GOT4v7 (S1 and S2 are included) | | | | | | |
| Pole tide | [Wahr, 1985[45]] | | | | | | |
| Solid earth tide | Elastic response to tidal potential [Cartwright and Tayler, 1971[3]], [Cartwright and Edden, 1973[4]] | | | | | | |
| Loading tide | GOT4v7 (S1 parameter is included) | | | | | | |
| Sea state bias | Non parametric SSB [Gaspar et al, 2002[15]] | | Non parametric SSB [N. Tran and al. 2010[43]] | BM3 [Gaspar and Ogor 1994[12]] | Non parametric SSB [Mertz et al., 2005[32]] | Non parametric SSB [Gaspar et al, 2002] with GDR-B standards for cycles 9 to 85 and with GDR-C standards from cycle 86 | Non parametric SSB [N. Tran et al., 2010[43]] |
| Orbit error | Global multi-mission crossover minimization (Le Traon and Ogor, 1998[26]) | | | | | | |
| Long wave-length errors | Optimal Interpolation (Le Traon et al., 1998[25]) | | | | | | |
| Intercalibration | Reference from cycle 11 | | Reference from cycle 1 to 354 | | | | |
| | Correction of regional bias J2/J1 deduced from intercalibration phase ( cycle 11 J2) | Correction of golbal biais J1/TP déduced from intercalibration phase ( cycles 11 J1) | | | | | |
| Mean profile | Computed with cycles 11-353 TP data and with cycles 11-250 J1 data; referenced [1993,1999] | TP/J1: computed with cycles 11-353 TP data and with cycles 11-250 J1 data; referenced [1993,1999]<br>TPN/J1N: computed with cycles 369-479 TPN data; referenced [1993,1999] | | Computed with cycles 1-85 E2 data and with cycles 10-72 EN data; referenced [1993,1999] | | | Computed with cycles 37-187 G2 data ; referenced [1993,1999] |
| Period of use | from cycle 9 | from cycle 9 | cycles 1 to 481 | cycles 15 to 43 Including E-F geodetic phases | cycles 1 to 83 | from cycle 9 | cycles 37 to 222 |

Table 6: Corrections and models applied in SSALTO/DUACS DT products (>v3.0.0). (2/2)

### 2.3.2. Acquisition

The acqusition process in Delayed time is much simpler than in Near Real time: it consists in a synchronisation process of all the auxiliary data required to homogenize propely the altimeter data sets. The acquisition step uses the GDRs or the OPRs provided by the agencies.

### 2.3.3. Homogenization

The Homogenization process consists in applying the most recent corrections, models and references recommended for altimeter products. Each mission is processed separately as its needs depend on the base input data. The list of corrections and models currently applied is provided in tables 5 and 6 for DT data.

### 2.3.4. Input data quality control

The Input Data Quality Control is a critical process applied to guarantee that DUACS uses only the most accurate altimeter data. Thanks to the high quality of current missions, this process rejects a small percentage of altimeter measurements, but these erroneous data could be the cause of a significant quality loss. The quality control relies on standard raw data editing with quality flags or parameter thresholds, but also on complex data editing algorithms based on the detection of erroneous artefacts, mono and multi-mission crossover validation, and macroscopic statistics to edit out large data flows that do not meet the system's requirements.

### 2.3.5. Multi-mission cross-calibration

The Multi-mission Cross-calibration process ensures that all flows from all satellites provide a consistent and accurate information. It removes any residual orbit error (OE, Le Traon and Ogor, 1998[26]), or long wavelength error (LWE, Le Traon et al., 1998[25]), as well as large scale biases and discrepancies between various data flows.

This process is based on two very different algorithms: a global multi-mission crossover minimization for orbit error reduction (OER), and Optimal Interpolation (OI) for LWE.

Multi-satellite crossover determination is performed on a daily basis. All altimeter fields (measurement, corrections and other fields such as bathymetry, MSS,...) are interpolated at crossover locations and dates. Crossovers are then appended to the existing crossover database as more altimeter data become available. This crossover data set is the input of the Orbit Error Reduction (OER) method. Using the precision of the reference mission orbit, a very accurate orbit error can be estimated. LWE is mostly due to residual tidal or inverse barometer errors and high frequency ocean signals. The OI used for LWE reduction uses precise parameters derived from:

- accurate statistical description of sea level variability
- localized correlation scales
- mission-specific noise and precise assumptions on the long wavelength errors to be removed (from a recent analysis of one year of data from each mission).

### 2.3.6. Product generation

The product generation process is composed of four steps: computation of raw SLA, cross-validation, filtering&sub-sampling, and generation of by-products.

#### 2.3.6.1. Computation of raw SLA

Since the geoid is not well known yet, the SSH cannot be used directly, the SSH anomalies are used instead. They are computed from the difference of the instantaneous SSH - a temporal reference. This temporal reference can be a Mean Profile (MP) in the case of repeat track analysis or a gridded MSS when the repeat track analysis cannot be used. The errors affecting the SLAs, MPs and MSS have different magnitudes and wavelengths. The computation of the SLAs and their errors associated are detailed in Dibarboure et al, 2010 [5].

**Utilisation of a Mean Profile**

In the repeat track analysis (when the satellites flies over a repetitive orbit), measurements are re-sampled along a theoretical ground track (or mean track) associated to each mission. Then a Mean Profile (MP) is subtracted from the re-sampled data to obtain SLA. The MP is a time average of similarly re-sampled data over a long period.

- The Mean Profile used for T/P (cycles 1 to 364), Jason-1 (cycles 1 to 259) and Jason-2 is computed with 10 years of T/P (cycles 11 to 353) and 6 years of Jason-1 (cycles 11 to 250).
- The Mean Profile used for T/P (cycles 368 to 481) and from Jason-1 cycle 262 onwards (where satellites are on interleaved ground-tracks) is computed with 3 years of T/P (cycles 369 to 479).
- The Mean Profile used for ERS-1 in its 35 days repetitive orbit mission, ERS-2, and Envisat (only for the first orbit, before November 2010) is computed with 8 years of ERS-2 (cycles 1 to 85) and 6 years of Envisat (cycles 10 to 72).
- The Mean Profile used for GFO is computed with 7 years of GFO cycles 37 to 187.

**Computation of a Mean Profile**

The computation of a Mean Profile is not a simple average of similarly co-located SSH data from the same ground track on the maximum period of time as possible .

- Indeed, as the satellite ground track is not perfectly controlled and is often kept in a band of about 1km wide, precise cross-track projection and/or interpolation schemes are required to avoid errors.
- The mesoscale variability error (which is <3.5 cm for MP between 3 to 5 years and <1cm for WL of 100-200km for MP between 7 and 15 years) is eliminated with an iterative process using a priori knowledge from Sea Level maps derived from previous iterations or from other missions.
- Moreover, the inter-annual variabilty error (<5cm for WL>5000km and <5-8cm for WL of 200-500km) is accounted for by using the MSS computed over 1993-1999 (e.g. the GFO MP is computed on 2000-2006 but referenced onto 1993-1999 for the sake of coherency with other missions).

- Finally, for these Mean Profiles, the latest standards and a maximum of data were used in order to increase as much as possible the quality of their estimation (see tables 5 and 6: Corrections and models applied in SSALTO/DUACS Delayed-Time products). Note that a particular care was brought to the processing near coasts.

**Utilisation of a MSS**

When the satellite is not in a repetitive orbit phase as is the case for ERS-1 for its 168 days geodetic mission (phases E-F from April 1994 to March 1995) or for Envisat since november 2010, the repeat track analysis is impossible. The alternative is to use the MSS instead. The gridded MSS is derived from along track MPs and data from geodetic phases. Thus any error on the MP is also contained in the MSS. There are essentially 4 types of additional errors on gridded MSS which are hard to quantify separately:

- To ensure a global MSS coherency between all data sets, the gridding process averages all sensor-specific errors and especially geographically correlated ones.

- The gridding process has to perform some smoothing to make up for signals which cannot be resolved away from known track, degrading along-track content.

- There are also errors related to the lack of spatial and temporal data (omission errors).

- The error stemming from the geodetic data: the variability not properly removed before the absorption in the MSS and the impossibility to compute mean sea surface height content.

#### 2.3.6.2. Cross validation

After the repeat track analysis, the cross-validation technique is used as the ultimate screening process of isolated and slightly erroneous measurements. Small SLA flows are compared to previous and independent SLA data sets using a- 12 year climatology and a 3 sigma criteria for outlier removal.

#### 2.3.6.3. Filtering and sub-sampling

Residual noise and small scale signals are then removed by filtering the data using a Lanczos filter. As data are filtered from small scales, a sub-sampling is finally applied. Along-track SLA are then produced.

Along-track ADT products are obtained as follows:

$$\text{ADT} = \text{SLA} + \text{MDT}$$

where MDT is the Mean Dynamic Topography. The Mean Dynamic Topography is the part of Mean Sea Surface Height due to permanent currents, so MDT corresponds to the Mean Sea Surface Height minus Geoid. More information about the Mean Dynamic Topography used in SSALTO/DUACS system can be found on AVISO web site at the following address:
http://www.aviso.oceanobs.com/en/data/products/auxiliary-products/mdt/.

The regional ADT product is computed using a specific regional MDT (Mediterranean Sea only):

$$\text{ADT}_{Reg} = \text{SLA}_{Reg} + \text{MDT}_{Reg}$$

### 2.3.7. Merging process

The Merging process is twofold: mapping and generation of by-products.
A mapping procedure using optimal interpolation with realistic correlation functions is applied to produce SLA and ADT maps (respectively MSLA and MADT products) at a given date. The procedure generates one map for each altimeter mission but also a combined map merging measurements from all available altimeter missions (Ducet et al., 2000[11]). From Duacs DT v3.0.0, the mapping process takes into account an updated suboptimal Optimal Interpolation parameterization to minimize transition artefacts.
Combining data from different missions significantly improves the estimation of mesoscale signals (Le Traon and Dibarboure, 1999[27]), (Le Traon et al., 2001[28]), (Pascual et al., 2006[33]). Several improvements were made compared to the version used by (Le Traon et al., 1998[25]). An improved statistical description of sea level variability, noise and long wavelength errors is used. Covariance functions including propagation velocities that depend on geographical position were thus used. For each grid point, the zonal and meridional spatial scales, the time scale and the zonal and meridional propagation velocities were adjusted from five years of TP+ERS combined maps. In addition to instrumental noise, a noise of 10% of the signal variance was used to take into account the small scale variability which cannot be mapped and should be filtered in the analysis. Long wavelengths errors (LWE) due to residual orbit errors but also tidal or inverse barometer errors and high frequency ocean signals were also derived from an analysis of TP and ERS data.
The combined map is used to generate by-products such as geostrophic currents or absolute dynamic topography.

#### 2.3.7.1. Computing geostrophic currents

Considering the MSLA grid point i,j (lon, lat), geostrophic velocity anomalies are computed using finite differences. In the equator band (+/-5°) the method recommended by Lagerloef et al (1999)[22] is applied. Absolute geostrophic velocities are computed using the same algorithm, but applied on MADT grid points.

### 2.3.8. Quality control

To ensure a production of homogeneous products in a high quality data with a short delay, are the key features of the DUACS processing system. But some events (failure on payload or on instruments, delay, maintenance on servers), can impact the quality of measurements or the data flows. A strict quality control on each processing step is indispensable to appreciate the overall quality of the system and to provide the best user services.

#### 2.3.8.1. Final quality Control

The Quality Control (QC) is the final process used by DUACS before product delivery. In addition to daily automated controls and warnings to the operators, each production delivers a large QC Report composed of detailed logs, figures and statistics of each processing step. Altimetry experts analyse these reports twice a week. A shorter report is delivered to DUACS users upon each product delivery.
Download them from
ftp://ftp.aviso.oceanobs.com/pub/oceano/AVISO/SSH/duacs/quality_report/

# 3. SSALTO/DUACS Products

## 3.1. Near Real Time Products

The purpose of the NRT DUACS component is the acquisition of altimeter data from various altimeter missions in near-real time (i.e. within a few days at most), the validation and correction of these altimeter data sets (i.e edition and selection, update of corrections and homogenization, orbit error reduction) in order to produce each day along-track products and gridded products.
Exploitation of real time OGDR/FDGDR data allows the DUACS system to produce multi-mission maps with 0-day and 3-day delay whereas historical NRT (IGDR-based) production have a 6-day delay (induced by historical trade-off in terms of timeliness vs quality).
The quality measurements in the NRT processing is more sensitive to the number of altimeter missions involved in the system. This is mainly due to the orbit error and the non-centered processing time-window (in NRT case, "future" data are not available; the computation time window takes into account only the 6 weeks before the date).
If two altimeters are acknowledged as the bare minimum needed to observe mesoscale signals in DT maps, three or even four missions are needed to obtain equivalent accuracy in NRT (Pascual et al., 2006[33]).

Products are as follows:

Along-track products, global and regional (Mediterranean and Black Seas):

- Sea Level Anomaly (NRT-SLA) for each mission, with NRT-SLA ephemeris
- Absolute Dynamic Topography (NRT-ADT) for each mission. No ADT files for Black Sea regional products.

Gridded products, high resolution, global and regional (Mediterranean and Black Seas):

- High resolution Maps of Sea Level Anomaly (NRT-MSLA) for each mission and a merged map combining all satellites using optimal interpolation and accounting for Long Wavelength errors (Le Traon et al., 1998[25]), (Ducet et al., 2000[11]),
- High resolution Maps of Absolute Dynamic Topography (NRT-MADT) combining all satellites. No MADT files for Black Sea regional products.
- High resolution Maps of geostrophic velocities anomalies derived from maps of Sea Level Anomaly combining all satellites,
- High resolution maps of absolute geostrophic velocities derived from maps of Absolute Dynamic Topography combining all satellites. No such files for Black Sea regional products.

These products are provided on Mercator grids (1/3˚x1/3˚ for global coverage, 1/8˚x1/8˚ on Mediterranean and Black Seas), and on Cartesian grids (1/4˚x1/4˚, basically Mercator grids that were resampled).

**Gridded products, low resolution, global products:**

- Low resolution map of Sea Level Anomaly (NRT-MSLA low resolution) for each mission and a merged map combining all satellites. These maps are notably suitable for large-ocean variation studies.

This product is provided on a 1˚x1˚ Mercator grid.

**Google Earth files:**

- merged MSLA and MADT, with along-track residuals that were used within the mapping process.

- along-track SLA ephemeris

### 3.1.1. Delay of the products

The availability of the products in near real time is three to twelve hours after the measurement for along-track products and with a day-0, day-3 and day-6 days for merged maps . Those products are delivered every day.
Maps in near-real time was originally produced with a 6-day delay. From SSALTO/DUACS v9.1.0, three merged maps are produced daily, each with a different delay and quality:

- A 6-day delay, which represents a final NRT map production (and which corresponds to the delay map production before Ssalto/Duacs V9.1.0),
- A 3-day delay, which represents an intermediate map production,
- and a 0-day delay, which represents a preliminary map production, based on IGDR+OGDR production.

Then, these maps are replaced when a better quality data is available:

- At $d_{0+3}$, the intermediate map replaces the preliminary map which was produced at $d_0$.
- At $d_{0+3}$, the final NRT map replaces the intermediate map which was produced at $d_0$.
- At $d_{0+6}$, the intermediate map replaces the preliminary map which was produced at $d_{0+3}$.
- At $d_{0+6}$, the final NRT map replaces the preliminary map which was produced at $d_0$.

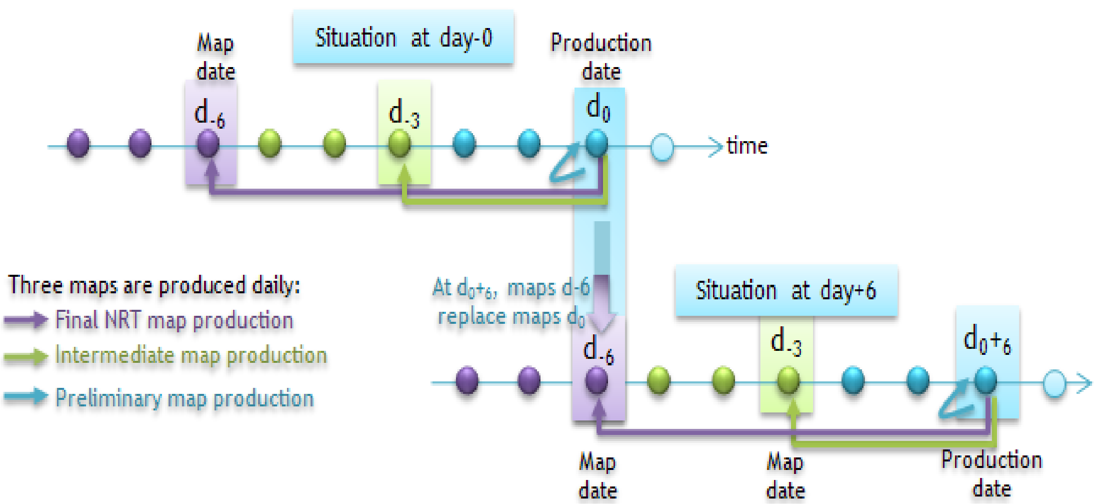


Figure 6: *From SSALTO/DUACS V9.1.0, in near-real time, three merged maps are produced daily: final map (d-6), intermediate map (d-3) and prliminary map (d0)*

### 3.1.2. Temporal availibility

The following table presents the available products by mission and by data period:
Near real time products:

| NRT | Jason-2 | Jason-1 | Envisat new | Merged |
|---|---|---|---|---|
| Temporal Time availability | 2009/11 ongoing | 2009/11 ongoing | 2010/11 ongoing | 2009/11 ongoing |
| NRT-SLA | X | X | X | |
| NRT-MSLA ($\frac{1}{3}^\circ$, low resolution) | X | X | X | X |
| NRT-MSLA ($\frac{1}{3}^\circ$, $\frac{1}{4}^\circ$, low resolution) | | | | X |
| UV anomalies$^{(4)}$ | | | | X |
| NRT-ADT | X | X | X | |
| NRT-MADT | | | | X |
| Absolute UV$^{(5)}$ | | | | X |

[4] UV anomalies are Geostrophic velocities anomalies derived from NRT-MSLA
[5] Absolute UV are absolute Geostrophic velocities derived from NRT-MADT

## 3.2. Delayed Time Products

The Delayed Time component of SSALTO/DUACS system is responsible for the production of processed Jason-1, Jason-2, T/P, Envisat, GFO, ERS1/2 and even Geosat data in order to provide a homogeneous, inter-calibrated and highly accurate long time series of SLA and MSLA altimeter data .
DT products are more precise than NRT products. Two reasons explain this quality difference. The first one is the better intrinsic quality of the POE orbit used in the GDR processing. The second reason is that in the DT DUACS processing, the products can be computed optimally with a centred computation time window for OER, LWE and mapping processes (6 weeks before and after the date) . On the contrary in NRT case, "future" data are not available so the computation time window is not centred and therefore not optimal.
As for NRT products, improved altimeter corrections and processing algorithms are used: ocean tide model to correct altimeter data, improved methods for orbit error reduction and mapping.
But unlike NRT component, DT component is made of two processing series:

- **Upd** (for "Updated"):
  this is an up-to-date series using up to 4 satellites at a given time (taking into consideration T/P on its new orbit and GFO), using all missions available. Thus it has the **best possible sampling**. **Upd series is better in quality** but not homogeneous over the time period, because it is based on the best sampling available in time.
- **Ref** (for "Reference"):
  this set is based on only two missions at most: T/P and ERS followed by Jason-1 and Envisat or OSTM/Jason-2 and Envisat respectively, on the same two orbits. Thus it is **homogeneous all along the available time period**. thanks to a stable sampling, but might not be the best in quality at a given time. The use of the Ref series is mainly for application in need of great stability (but it must be kept in mind that the data might not be of the best possible quality).

The difference between these two processing series is thus the number of missions as key input of Optimal Interpolation (OI) Software for LWE (2.3.5.).
This system finally delivers Delayed Time processed SLA and MSLA combining fully processed data from various altimetric missions (Topex/Poseidon, ERS-1/2, Jason-1, Envisat and OSTM/Jason-2) such as:

Along-Track products, global and regional (Mediterranean and Black Seas):

- Sea Level Anomaly (DT-SLA) for each mission,
- Absolute Dynamic Topography (DT-ADT) for each mission. No ADT nor MDT files for Black Sea regional products.

Gridded products, global (1/3° Mercator grid) and regional (Mediterranean and Black Seas, 1/8° regular grid):

More information about Mercator grid definition can be found in section 4.3.2..

- High resolution Maps of Sea Level Anomaly (DT-MSLA) combining all satellites
- High resolution Maps of Absolute Dynamic Topography (DT-MADT), merging all satellites. No MADT files for Black Sea regional products.
  tem
- High resolution Maps of geostrophic velocities anomalies derived from maps of Sea Level Anomaly combining all satellites,
- High resolution maps of absolute geostrophic velocities derived from maps of Absolute Dynamic Topography combining all satellites. No such files for Black Sea regional products.

### 3.2.1. Delay of the products

The availability of the products in delayed time is at the best two months after the date of the measurement. The product generation needs all the GDR data of all the missions to take into account the best corrections as possible. The time delay can be longer in the case of a missing mission.

### 3.2.2. Temporal availibility

The following table presents the available products by mission and by data period:
Delayed time SSALTO/DUACS **Upd** products:

| Upd | Jason-2 | Jason-1 new[6] | Jason-1 | GFO | Envisat new[7] | Envisat | ERS-1[8] ERS-2 | Topex new[9] | Topex | Merged[10] |
|---|---|---|---|---|---|---|---|---|---|---|
| Temporal Time availability | 2008/10 2010/03 | 2009/02 2010/03 | 2002/04 2008/10 | 2000/01 2008/09 | upcoming | 2002/10 2010/03 | 1992/10 2003/04 | 2002/09 2005/10 | 1992/09 2002/04 | 1992/09 2010/03 |
| DT-SLA | X | X | X | X | | X | X | X | X | |
| DT-MSLA | | | | | | | | | | X |
| UV anomalies[11] | | | | | | | | | | X |
| DT-ADT | X | X | X | X | | X | X | X | X | |
| DT-MADT | | | | | | | | | | X |
| Absolute UV[12] | | | | | | | | | | X |

Delayed time SSALTO/DUACS **Ref** products:

| Ref | Jason-2[13] | Jason-1 | Envisat | ERS-1[8] | ERS-2 | Topex | Merged[10] |
|---|---|---|---|---|---|---|---|
| Temporal Data Coverage | 2008/10 2010/03 | 2002/04 2008/10 | 2002/10 2010/03 | 1992/10 1995/05 | 1995/05 2003/04 | 1992/09 2002/04 | 1992/10 2010/03 |
| DT-SLA | X | X | X | X | X | X | |
| DT-MSLA | X | X | | | | X | X |
| UV anomalies[11] | | | | | | | X |
| DT-ADT | X | X | X | X | X | X | |
| DT-MADT | | | | | | | X |
| Absolute UV[12] | | | | | | | X |

[6] Jason-1 new orbit : starting 2009/02
[7] Envisat new orbit : starting 2010/11
[8] ERS-1: There are no ERS-1 data between December 23, 1993 and April 10, 1994 (ERS-1 phase D - $2^{nd}$ ice phase). Note that, during that time, products are based only on Topex/Poseidon data.
[9] T/P new orbit : starting 2002/09
[10] Merged products were obtained:

- From October 1992 to August 2002: Topex/Poseidon + ERS-1 or ERS-2,
- From August 2002 to June 2003: Jason-1 + ERS-2 (Topex/Poseidon was replaced by Jason-1 in August 2003 after its orbit change (ground track interlaced with Jason-1's),
- From June 2003 to January 2004: Jason-1 + Envisat. ERS-2 is no longer used since the loss of its Low Bit rate recorder (LBR) in June 2003.
- From January 2009: OSTM/Jason-2 + Envisat (Jason-1 was replaced by OSTM/Jason-2 in January 2009 after its orbit change (ground track interlaced with Jason-2?s and with a time lag of approximatively 5 days between both).
- From November 2010: OSTM/Jason-2 + Envisat extended phase (Envisat moved on a new orbit in November 2010).

[11] UV anomalies are Geostrophic velocities anomalies derived from NRT-MSLA.
[12] Absolute UV are Absolute Geostrophic velocities derived from NRT-MADT.
[13] Jason-2 became the reference mission of the system since January 21, 2009.

## 3.3. Nomenclature

### 3.3.1. Gridded Delayed Time products (SLA, ADT, Geostrophic currents and error files)

The nomenclature used for these products is:

DELAY_RANGE_ZONE_MISSION_PRODUCT_VARIABLE_DATEBEGIN_DATEEND_DATEPROD.nc

| | | |
|---|---|---|
| DELAY | dt | delayed time products |
| RANGE | ref | reference product |
| | upd | up-to-date products |
| ZONE | global<br>med<br>black sea | global geographic coverage product<br>Mediterranean products<br>Black Sea products |
| MISSION | tpj1 | reference mission |
| | merged | combined data |
| PRODUCT | msla<br>madt(1) | maps of sea level anomaly<br>maps of absolute dynamic topography |
| VARIABLE | h | sea surface heights |
| | uv | sea surface geostrophic currents |
| | err | formal mapping error |
| | h_qd | resampled on a regular 0.25° grid |
| | h_lr | low resolution products where short wave-length signals have been removed |
| DATEBEGIN | YYYYMMDD | beginning date of the dataset |
| DATEEND | YYYYMMDD | end date of the dataset |
| DATEPROD | YYYYMMDD | production date of the dataset |

(1) No MADT files for Black Sea regional products.

### 3.3.2. Along-track delayed time SLA and ADT files

The nomenclature used for the along-track DT-SLA and DT-ADT products is:

DELAY_RANGE_ZONE_MISSION_PRODUCT_VARIABLE_DATEBEGIN_DATEEND_DATEPROD.nc

| | | |
|---|---|---|
| DELAY | dt | delayed time products |
| RANGE | ref | reference product |
| | upd | up-to-date products |
| ZONE | global<br>med<br>black sea | global geographic coverage product<br>Mediterranean products<br>Black Sea products |
| MISSION | e1 | ERS-1 |
| | e2 | ERS-2 |
| | tp | Topex/Poseidon |
| | tpn | Topex/Poseidon on its new orbit |
| | g2 | GFO |
| | j1 | Jason-1 |
| | j1n | Jason-1 on its new orbit |
| | j2 | Jason-2 |
| | en | Envisat |
| | enn | Envisat on its new orbit (upcoming) |
| PRODUCT | sla<br>adt(1) | sea level anomaly<br>absolute dynamic topography |
| VARIABLE | $X_1X_2X_3X_4$ | $X_1$ is "v" for validated data and "x" for non validated data |
| | | $X_2$ is "f" for filtered data and "x" for non filtered data |
| | | $X_3$ is "e" for sub-sampled and "x" for non sub-sampled data |
| | | $X_4$ is "c" for LWE-corrected data and "x" for non-LWE-corrected data or raw data |
| DATEBEGIN | YYYYMMDD | beginning date of the dataset |
| DATEEND | YYYYMMDD | end date of the dataset |
| DATEPROD | YYYYMMDD | production date of the dataset |

(1) No ADT files for Black Sea regional products.

### 3.3.3. Gridded Near Real Time products (SLA, ADT, Geostrophic currents and error files)

The nomenclature used for these products is:

DELAY_ZONE_MISSION_PRODUCT_VARIABLE_DATEBEGIN_DATEEND_DATEPROD.FORMAT

| | | |
|---|---|---|
| DELAY | nrt | near-real time products |
| ZONE | global | global geographic coverage product |
| | med | Mediterranean products |
| | black sea (1) | Black Sea products |
| MISSION | j2 | Jason-2 |
| | j1 | Jason-1 |
| | enn | Envisat on its new orbit |
| | merged | combined data |
| PRODUCT | msla | maps of sea level anomaly |
| | madt(1) | maps of absolute dynamic topography |
| VARIABLE | h | sea surface heights |
| | uv | sea surface geostrophic currents |
| | err | formal mapping error |
| | h_qd | resampled on a regular $0.25^{\circ}$ grid |
| | h_lr | low resolution products where short wave-length signals have been removed |
| DATEBEGIN | YYYYMMDD | beginning date of the dataset |
| DATEEND | YYYYMMDD | end date of the dataset |
| DATEPROD | YYYYMMDD | production date of the dataset |
| FORMAT | nc | NetCDF |
| | kmz | Google Earth files |

(1) No MADT files for Black Sea regional products.

### 3.3.4. Along-track Near Real Time SLA and ADT files

The nomenclature used for the along-track NRT-SLA and NRT-ADT products is:

DELAY_ZONE_MISSION_PRODUCT_VARIABLE_DATEBEGIN_DATEEND_DATEPROD.nc

| | | |
|---|---|---|
| DELAY | nrt | near-real time products |
| ZONE | global | global geographic coverage product |
| | med | Mediterranean products |
| | black sea | Black Sea products |
| MISSION | j2 | Jason-2 |
| | j1 | Jason-1 |
| | enn | Envisat on its new orbit (upcoming) |
| PRODUCT | sla | sea level anomaly |
| | adt(1) | absolute dynamic topography |
| VARIABLE | $X_1X_2X_3X_4$ | $X_1$ is "v" for validated data and "x" for non validated data<br>$X_2$ is "f" for filtered data and "x" for non filtered data<br>$X_3$ is "e" for sub-sampled and "x" for non sub-sampled data<br>$X_4$ is "c" for LWE-corrected data and "x" for non-LWE-corrected data or raw data |
| DATEBEGIN | YYYYMMDD | beginning date of the dataset |
| DATEEND | YYYYMMDD | end date of the dataset |
| DATEPROD | YYYYMMDD | production date of the dataset |

(1) No ADT files for Black Sea regional products.

# 4. Data format

This chapter presents the data storage format used for SSALTO/DUACS products.

## 4.1. NetCdf

The products are stored using the NetCDF format. NetCDF (network Common Data Form) is an interface for array-oriented data access and a library that provides an implementation of the interface. The netCDF library also defines a machine-independent format for representing scientific data. Together, the interface, library, and format support the creation, access, and sharing of scientific data. The netCDF software was developed at the Unidata Program Center in Boulder, Colorado. The netCDF libraries define a machine-independent format for representing scientific data. Please see Unidata NetCDF pages for more information, and to retreive NetCDF software package on:
http://www.unidata.ucar.edu/packages/netcdf/index.html.

NetCDF data is:

- Self-Describing. A netCDF file includes information about the data it contains.
- Architecture-independent. A netCDF file is represented in a form that can be accessed by computers with different ways of storing integers, characters, and floating-point numbers.
- Direct-access. A small subset of a large dataset may be accessed efficiently, without first reading through all the preceding data.
- Appendable. Data can be appended to a netCDF dataset along one dimension without copying the dataset or redefining its structure. The structure of a netCDF dataset can be changed, though this sometimes causes the dataset to be copied.
- Sharable. One writer and multiple readers may simultaneously access the same netCDF file.

## 4.2. Structure and semantic of NetCDF files

All basic NetCDF conventions are applied to SSALTO/DUACS files. In addition to these conventions, the SSALTO/DUACS files are using a common structure and semantic:

- 3 Dimensions are defined:
  - **Tracks**: maximum number of passes in current file,
  - **Cycles**: maximum number of cycles for each pass,
  - **Data**: (UNLIMITED dimension) number of data per parameter in current file,
- 9 Variables are used:
  - **int DeltaT**: contains the time gap between two measurements (seconds codded on an integer in $\mu$s with 'scale factor' of 1.0E-6 $\mu$s),
  - **int Tracks(Tracks)**: list of passes contained in current file,
  - **int Cycles(Tracks, Cycles)**: list of cycles per pass,
  - **int NbPoints(Tracks)**: number of points per pass,
    N.B.: Data dimension is the total of values included in this variable.
  - **int Longitudes(Data)**: contains the longitude value of each point of each pass. If the longitude value is the default value, data are missing. The array index i of the first point (first longitude) of a given pass i is obtained by following formula:

$$Indice_i = Sum_{j=0..i-1}(NbPoints_j)$$

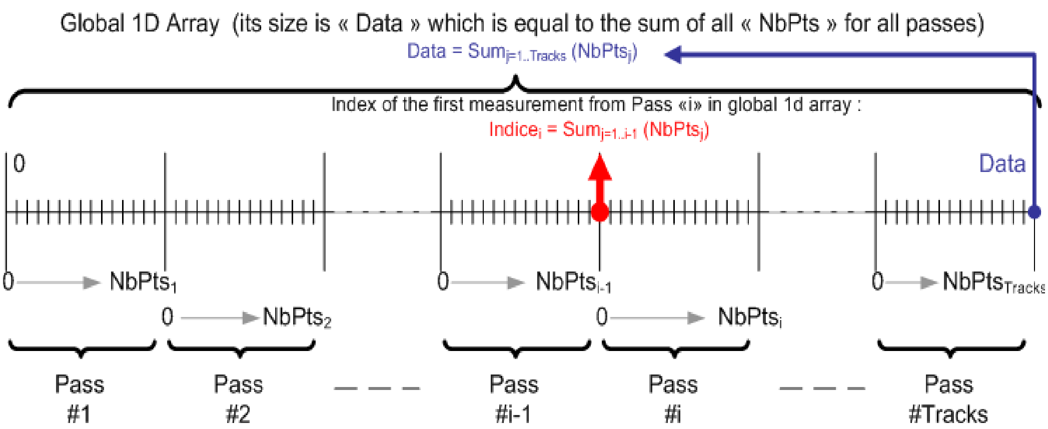


Figure 7: *Illustration of the definition of* $Indice_i$

  - **int Latitudes(Data)**: contains the latitude value of each point of each pass. The index i of the first point (first longitude) of a given pass is obtained by following formula:

$$Indice_i = Sum_{j=0..i-1}(NbPoints_j)$$

  - **int DataIndexes(Data)**: Index of the point in the theoretical profile associated with ATP file. The index formula is the following:

$$Indice_i = Sum_{j=0..i-1}(NbPoints_j)$$

and the datation of each measurement is given by:

$$Date_i = BeginDate + Indice_i * DeltaT$$

As an example (cf. parameter values in NetCDF file below), the datation of the 3rd point of the first cycle(49) of the first pass(1) is:

$$Date_2 = (2 * 1.078)/86400 + 19483.17494212$$
$$= 19485.17496708333 \text{ i.e. } 2003/11/06 \text{ at } 4:11:57.156000.$$

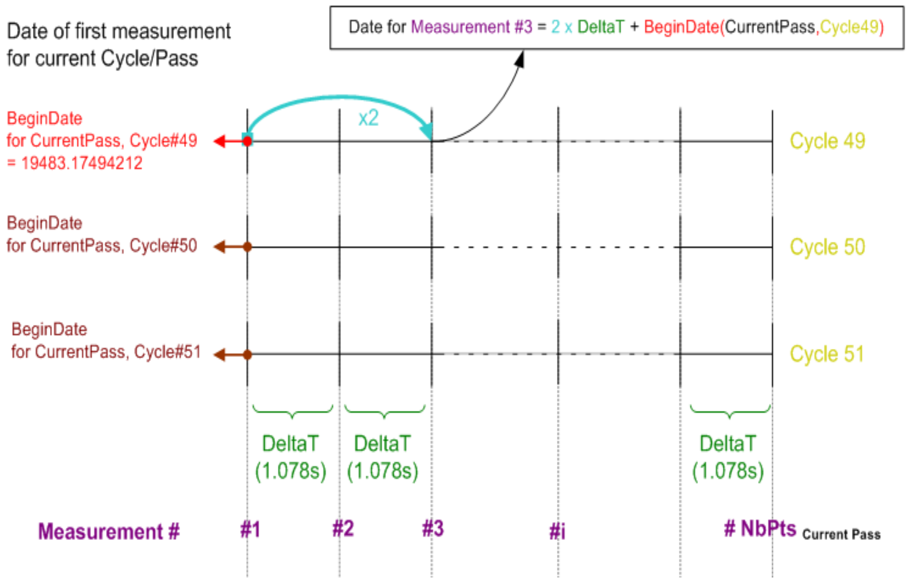


Figure 8: *Data formula illustration*

- **int BeginDates(Tracks, Cycles)**: Date of the point with index 0 for current pass and cycle
- As many variables as needed. They have the same characteristics as "type MyVar(Data, Cycles)" dimension where 'type' is the chosen type of the variable and 'MyVar' the chosen name of the variable (this name cannot be the same as any name used for the variables above). The variables contain Along-Track Product (ATP) for each point and each cycle of each pass. For SSALTO/DUACS products, the name of the variables is SLA (see example below),
- **byte Flag(Data,Cycles)**: indicates the data origin (0 for IGDR data; 1 for OGDR data)

- Global attributes :
  - The global attribute **FileType** contains ALONG_TRACK_PRODUCT,
  - The global attribute **Mission** contains the code (2-3 characters) of the mission associated to the file (E1, E2, TP, J1, EN, J2...) where:
    E1: ERS-1,
    E2: ERS-2,
    TP: Topex/Poseidon,
    J1: Jason-1,
    J2: OSTM/Jason-2,
    EN: Envisat,
    ENN : Envisat new orbit
    G1: GEOSAT,

G2: GFO.

– The global attribute **MeanProfile** contains the name of the Mean Profile file used to generate the along-track profile.

**Examples of NetCDF Along-Track file**:

```
netcdf nrt_global_j2_sla_vfec_20101025_20101114_20101115 {
dimensions:
        Tracks = 254 ;
        Cycles = 3 ;
        Data = UNLIMITED ; // (127035 currently)
variables:
        int DeltaT ;
                DeltaT:_FillValue = 2147483647 ;
                DeltaT:long_name = "Time gap between two measurements in mean profile" ;
                DeltaT:units = "s" ;
                DeltaT:valid_min = 0 ;
                DeltaT:scale_factor = 1.e-06 ;
        int Tracks(Tracks) ;
                Tracks:_FillValue = -1 ;
                Tracks:long_name = "Pass number" ;
                Tracks:units = "count" ;
        int NbPoints(Tracks) ;
                NbPoints:_FillValue = 0 ;
                NbPoints:long_name = "Number of measurements for each pass" ;
                NbPoints:units = "count" ;
        int Cycles(Tracks, Cycles) ;
                Cycles:_FillValue = -1 ;
                Cycles:long_name = "Cycle numbers for each pass" ;
                Cycles:units = "count" ;
        int Longitudes(Data) ;
                Longitudes:_FillValue = 2147483647 ;
                Longitudes:long_name = "Longitude of each measurement" ;
                Longitudes:units = "degrees_east" ;
                Longitudes:scale_factor = 1.e-06 ;
        int Latitudes(Data) ;
                Latitudes:_FillValue = 2147483647 ;
                Latitudes:long_name = "Latitude of each measurement" ;
                Latitudes:units = "degrees_north" ;
                Latitudes:scale_factor = 1.e-06 ;
        double BeginDates(Tracks, Cycles) ;
                BeginDates:_FillValue = 1.84467440737096e+19 ;
                BeginDates:long_name = "Date of first measurement for each cycle/pass" ;
                BeginDates:units = "days since 1950-01-01 00:00:00.000 UTC" ;
                BeginDates:C_format = "%17.11f" ;
        int DataIndexes(Data) ;
                DataIndexes:_FillValue = 2147483647 ;
                DataIndexes:long_name = "Data index in theoretical pass" ;
                DataIndexes:valid_min = 0 ;
        short SLA(Data, Cycles) ;
                SLA:_FillValue = 32767s ;
                SLA:long_name = "Sea Level Anomaly" ;
                SLA:units = "m" ;
                SLA:scale_factor = 0.001 ;
        byte flag(Data, Cycles) ;
```

```
                flag:_FillValue = 127b ;
                flag:long_name = "Data origin (0 for IGDR data; 1 for OGDR data)" ;
                flag:units = "1" ;

// global attributes:
                :FileType = "ALONG_TRACK_PRODUCT" ;
                :OriginalName = "nrt_global_j2_sla_vfec_20101025_20101114_20101115.nc" ;
                :CreatedBy = "SSALTO/DUACS" ;
                :CreatedOn = "15-NOV-2010 10:46:01:000000" ;
                :Mission = "J2" ;
                :MeanProfile = "ProfilMoyen_J2_2010.nc" ;
                :title = "along track Sea Level Anomaly" ;
                :version = "10.0.0" ;
}
data:

DeltaT = 1078580 ;
Tracks = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19,
        20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37,
        38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55,
        ...
        220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233,
        234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247,
        248, 249, 250, 251, 252, 253, 254 ;
NbPoints = 345, 354, 333, 731, 236, 756, 349, 643, 482, 515, 475, 315, 725,
        449, 501, 485, 540, 412, 619, 374, 673, 630, 564, 505, 535, 237, 360
        ...
        538, 616, 342, 682, 317, 622, 492, 508, 477, 598, 416, 662, 598, 545,
        555, 573, 267 ;
Cycles = 85, 86, 87,
        85, 86, 87,
        85, 86, 87,
        85, 86, 87,
        85, 86, 87,
        85, 86, 87,
        85, 86, 87,
        85, 86, 87,
Longitudes = 57191485, 57444541, 57695966, 57945768, 58193956, 58440533,
        58685494, 58928857, 59170640, 59410855, 59649509, 59886612, 60122152,
        ...
        332514593, 332741006, 332968928, 333198350, 333661714, 333895674,
        334131167 ;
Latitudes = -59347611, -59242637, -59137120, -59031066, -58924481,
        -58817368, -58709728, -58601570, -58492902, -58383729, -58274056,
        ...
        -66022798, -66039085, -66054219, -66068186, -66081005, -66092671,
        -66103186, -66112546, -66120750, -66127784, -66133655, -66138367,
        -66141919, -66144312, -66145544 ;
BeginDates =
        22219.88527483341, 22229.80091958847, _,
        22219.92429667456, 22229.83994182052, _
        ...
        22219.80719230744, 22229.72283673062, _,
        22219.84621493783, 22229.76186010445, _ ;
DataIndexes = 346, 349, 352, 355, 358, 361, 364, 367, 370, 373, 376, 379,
```

```
                 382, 385, 388, 391, 394, 397, 400, 403, 406, 409, 412, 415, 418, 421,
                 424, 427, 430, 433, 436, 439, 442, 445, 448, 451, 454, 457, 460, 463,
                 ...
                 2677, 2680, 2683, 2686, 2689, 2692, 2695, 2698, 2701, 2704, 2707, 2710,
                 2713, 2716, 2719, 2722, 2725, 2728, 2731, 2734, 2737, 2743, 2746, 2749 ;
SLA = _, 13, _,
                 _, -12, _,
                 _, 7, _,
                 _, 37, _,
                 _, 58, _,
                 ...
                 -14, 43, _,
                 -12, _, _,
                 24, 89, _,
                 19, 97, _,
                 5, _, _ ;
flag =
                 _, 1, _,
                 _, 1, _,
                 _, 1, _,
                 _, 1, _,
                 _, 1, _,
                 ...
                 1, 1, 0,
                 1, 1, 0,
                 1, 1, 0,
```

Software routines needed to read this product are presented in chapter 4.4..

## 4.3. Structure and semantic of NetCDF maps files

All basic NetCDF conventions are applied to SSALTO/DUACS files. In addition to these conventions, the SSALTO/DUACS files are using a common structure and semantic:

- 4 Dimensions are defined:
  - **LatLon**: is always 2. It is used to check NetCDF variables depending on latitude and longitude,
  - **NbLatitudes**: contains the number of grid points along latitude,
  - **NbLongitudes**: contains the number of grid points along longitude,
  - **GridDepth**: contains the number of values available in each grid point, and for each grid defined (it represents the number of grid "layers"). SSALTO/DUACS files always contain only one layer grids so GridDepth is 1. If this dimension is missing, it is considered to be equal to 1,
- 2 Variables are used for all grids defined below:
  - double **LatLonMin(LatLon)**: contains the minimum values for latitude and longitude (south-west corner),
  - double **LatLonStep(LatLon)**: contains the latitude and longitude resolution ($\Delta$Y and $\Delta$Y for regular grids and $\Delta$Yo and $\Delta$Yo (equator values) for Mercator grids),
    Constraints:
    LatitudeMin+LatStep*NbLatitudes <= 90 (<=89 for Mercator grids)
    LonStep*NbLongitudes <= 360.
  - A grid file may contain as many files as needed although most SSALTO/DUACS contain only one (H, Mapping Error) or two (U/V) grids.
    All grids must have the same Lat/Lon/Depth dimensions defined above, even if each grid can have other specific attributes (default value, unit...). Grids are stored as [Lon, Lat] arrays in C or [Lat, Lon] arrays in Fortran, that is to say by increasing latitude and longitude, with each data set divided into longitude "slices" of consecutive latitude values. Each grid is identified by grid number, that is to say a unique four digit unsigned integer value.

  **Grid_nnnn(NbLongitudes, NbLatitudes)**: grid variable with grid number equal to nnnn and with only one layer.
  **Grid_nnnn(NbLongitudes, NbLatitudes, GridDepth)**: grid variable with grid number equal to nnnn and with GridDepth layers.

- Global attributes:
  The global attribute FileType defines the type of grid. There are currently 4 types of grids: DOTS, BOXES, DOTS_MERCATOR and BOXES_MERCATOR. The SSALTO/DUACS maps are stored on DOTS_MERCATOR grids.
  **ǴRID_DOTS´**: values are defined as POINTS. Each value has been computed exactly on the Lat/Lon values defined by LatLonMin and LatLonStep.
  **ǴRID_BOXES´**: values are defined as BOXES. A single grid box represents the whole area from Latitude and longitude index li,j] to index [i+1,j+1].
  **ǴRID_DOTS_MERCATOR´**: this grid type similar to GRID_DOTS, but the grid definition in latitude is not linear with the latitude index. The Latitude and Longitude values are defined as in 4.3.2..
  **ǴRID_BOXES_MERCATOR´**: this grid type similar to GRID_BOXES, but the grid definition in latitude is not linear with the latitude index. The Latitude and Longitude values are defined as in 4.3.2..

**Examples of NetCDF grid file (NRT-MSLA T/P on a 1/3° Mercator grid)**

```
netcdf msla_tp_h_19015.nc {
Dimensions:
        LatLon = 2 ;
        NbLatitudes = 915 ;
        NbLongitudes = 1080 ;
        GridDepth = 1 ;
Variables:
        double LatLonMin(LatLon) ;
                LatLonMin:_FillValue = 1.84467440737096e+19 ;
                LatLonMin:long_name = "Latitude/Longitude of south/ouest corner" ;
                LatLonMin:units = "degree" ;
        double LatLonStep(LatLon) ;
                LatLonStep:_FillValue = 1.84467440737096e+19 ;
                LatLonStep:long_name = "latitude/longitude steps" ;
                LatLonStep:units = "degree" ;
        float Grid_0001(NbLongitudes, NbLatitudes) ;
                Grid_0001:_FillValue = 1.844674e+19f ;
                Grid_0001:long_name = "SLA" ;
                Grid_0001:units = "cm" ;
// global attributes:
                :FileType = "GRID_DOTS_MERCATOR" ;
                :OriginalName = " msla_ap_tp_h_19015.nc " ;
                :CreatedBy = "SSALTO/DUACS" ;
                :CreatedOn = "04-FEB-2002 23:33:17" ;
                :title = " NRT SLA T/P ? 2002/01/23" ;
data:
LatLonMin = -82, 0 ;
LatLonStep = 0.333333333333333, 0.333333333333333 ;
Grid_0001 =
        _, _, _, _, _, _, _, _, _, -1.119989, -1.191618, -1.24841, -1.244721,
        -0.9649581, -0.592562, 0.04207221, 0.8542445, 1.336711, 1.810621,
        1.906609, 1.767064, 1.736634, 1.394857, 1.033213, 0.6763388, 0.3328404,
        -0.07905415, -0.5154375, -0.9471657, -0.7384071, -0.6251237, -0.6695364,
```

Software routines needed to read this product are presented in chapter 4.4..

### 4.3.1. Grid numbers used by SSALTO/DUACS

All MSLA and NRT-MADT maps (in cm) are stored in grid number 0001 of NetCDF files. Formal mapping error maps (in percentage of variance signal) are stored in grid number 0001. Geostrophic velocity maps (in cm/s) are stored in grid numbers 0001 (U) and grid number 0002 (V).

### 4.3.2. Maps projection

The grid used for global maps is a 1/3° Mercator projection grid, i.e:
$M_{I,J} = (X, Y)$
With:
$X = X_{min} + \Delta X * I$
where $X \in [X_{min}, X_{min} + 360[$ and I $\in [0, I_{count}[$
and
$Y = \frac{180}{\pi} \times \arcsin[\tanh(\Delta Y_{rad}(J + J_{eq}))]$
where $Y \in [Y_{min}, 89]$ and J $\in [0, J_{count}]$

$J_{eq} = \frac{1}{2} \times ln\frac{1+\sin(Y_{rad})}{1-\sin(Y_{rad})} / \Delta Y_{rad}$

$X_{min}$ = min value for X (found in file) = 0
$Y_{min}$ = min value for Y (found in file) = -82, $Y_{min} \in [-89, 89]$

$Y_{rad} = Y_{min}$ in radians = $\frac{Y_{min} \times \Pi}{180}$

$\Delta X$ = X step (found in file) = $\frac{1}{3}$

$\Delta Y$ = Y step (found in file) = $\frac{1}{3}$

$\Delta Y_{rad} = \frac{1}{3} \times \frac{\Pi}{180}$

$I_{count}$ = number of values for X (found in file) = 1080
$J_{count}$ = number of values for Y (found in file) = 915

## 4.4. Software routines

The reading software needed to read products stored in NetCDF (as well as a sample program and a sample NetCDF file with ASCII dump) are available on the AVISO ftp site:
ftp://ftp.aviso.oceanobs.com/pub/oceano/AVISO/software/
For DUACS NetCDF data (both gridded and along-track), two different sets of programmes are available:

- **PublicReadDelivery.tar.gz** contains source programmes, in C and Fortran,
- **PublicReadBinaries.Linux.tar.gz, PublicReadBinaries.MSWindows.zip, and PublicReadBinaries.SunOS.tar.gz** which are precompiled binary files corresponding to the above mentionned sources.
  A Readme file explaining the content of each tar file is included.

# 5. Accessibility of the products

Aviso proposes several ways of accessing data. Some of them need an authentication. If you are not registered and want to access to an authentificated service, we request you to fill in the online form.
According to the type of SSALTO/DUACS data, products are available:

- Via **authenticated FTP** on
  ftp://ftp.aviso.oceanobs.com/
  (/donnees/ftpsedr/DUACS/ is the default FTP directory). Note that once your request is processed (after filling the online form), Aviso will send you your own access (login/password) by e-mail as soon as possible. If you don't enter your login/password, you will only access to the anonymous FTP, where you won't find the data you're interested in.
- Via the **Live Access Server** (LAS) on the AVISO web site
  (http://las.aviso.oceanobs.com/). The LAS is a tool to draw your own map.
  Only gridded products are accessible via the LAS.
- Via **authenticated Opendap**, a framework that simplifies all aspects of scientific data networking (http://opendap.aviso.oceanobs.com). Only gridded products are accessible via Opendap.
- Via the **authentificated** Aviso data extraction (http://atoll-motu.aviso.oceanobs.com/) tool enables you to extract a data sub-set from the Aviso gridded datasets. You can choose either an area (by its geographical coordinates or among pre-defined regions), or a period for variable(s) within a given dataset

| | FTP | Opendap[1] | Aviso extraction Service[1] | LAS[1] |
|---|---|---|---|---|
| Near Real-Time | x | | | |
| « Historical » NRT (for data >1 month) | x | x | x | x |
| Delayed time | x | x | x | x |

(1) Only gridded products

## 5.1. Directory paths on the ftp server

Via the authenticated FTP server, the default directory is **/donnees/ftpsedr/DUACS**. We keep your attention to well enter your login/password to get access, if not, you will access only the anonymous FTP (/donnees/ftpsedr/ftpanonymous/pub/oceano/AVISO/SSH/duacs), where you only find sample data sets.

First, directories are sorted by areas:

- global/ for the whole ocean,
- regional-blacksea/ for the Black Sea,
- regional-gomex/ for the Gulf of Mexico,
- regional-mfstep/ for the Mediterranean Sea.

Then, directories are sorted by timeliness: nrt/ contains near-real time data and dt/ contains delayed-time data. The release is every day for nrt.

Access restrictions are applied on folders. Your account gives you an access to a given list of altimetry data. Thus, the folders you're not subscribed to are empty.

# 6. News and Updates

## 6.1. [Duacs] Operational news

To be kept informed on events occurring on the satellites and on the eventual interruption of the services of the DUACS processing system, see the [Duacs] operational news on the Aviso website:
http://www.aviso.oceanobs.com/en/data/operational-news/index.html.

## 6.2. Updates

To have the information of the DUACS changes, improvements and updates of the system, please refer to:
http://www.aviso.oceanobs.com/en/data/product-information/duacs/presentation/updates/index.html.
Since 2010, a complete reprocessing of all altimetry data (cumulated total of about 55 years of data) is available. The main changes introduced in the Duacs DT v3.0.0 reprocessed data set in "SSALTO/DUACS reprocessed DT data set" are listed here:
http://www.aviso.oceanobs.com/fileadmin/documents/data/duacs/duacs_DT_2010_reprocessing_impact.pdf