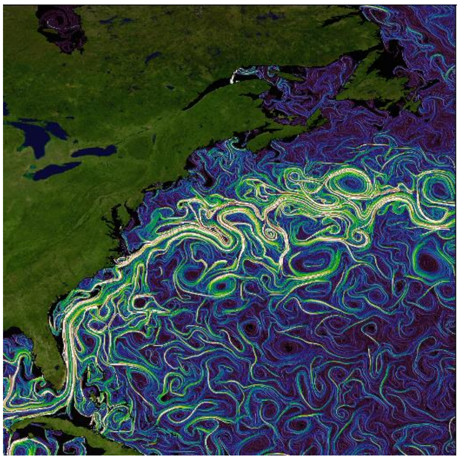
SSALTO/DUACS User Handbook

Finite-Size Lyapunov Exponents (FSLE) and Orientations of the associated eigenvectors Product



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Chronology Issues:			
Issue:	Date:	Validated by	Reason for change:
1.0	2015/04/01		Creation of the document
1.1	2018/06/20		Integration of NRT products
1.2	2018/09/19		DT products full reprocessing
1.3	2022/01/17		DT products full reprocessing vDT2021

List of Acronyms:

ADT	Absolute Dynamic Topography
Aviso+	Archiving, Validation and Interpretation of Satellite Oceanographic data
CLS	Collecte, Localisation, Satellites
CNES	Centre National d'Etudes Spatiales
NRT	Near Real Time
SSALTO	Segment Sol multimissions d'ALTimétrie, d'Orbitographie et de localisation précise.
SLA	Sea Level Anomaly

Contents

1. Introduction

DUACS is part of the CNES multi-mission ground segment (SSALTO). It processes data from all altimeter missions: Jason-3, Sentinel-3A, HY-2A, Saral/AltiKa, Cryosat-2, OSTM/Jason-2, Jason-1, Topex/Poseidon, Envisat, GFO, ERS-1&2.

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.

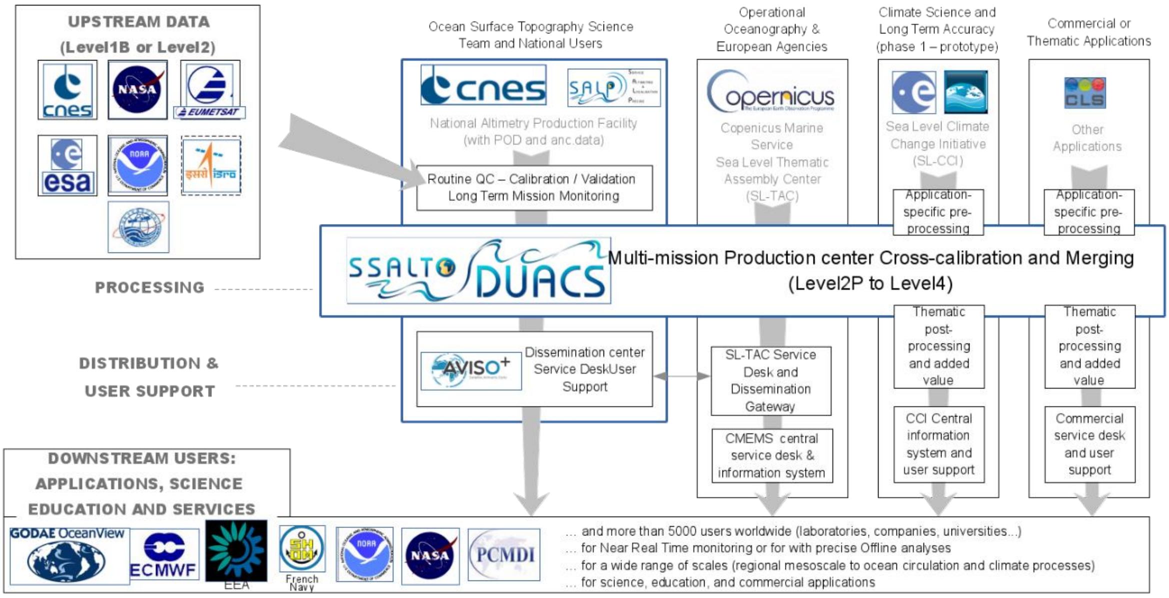

Figure 1: a user-driven altimetry service

DUACS provides a consistent and homogeneous catalogue of products for varied applications, both for near real time applications and offline studies. Some DUACS gridded products are available free of charge.

This document describes the gridded Delayed-Time and Near-Real-Time Backward-in-time Finite Size Lyapunov Exponents (FSLEs) and Orientations of the associated eigenvectors. First, the SSALTO/Duacs System is introduced: after a description of the input data, an overview of the processing steps is given. Then a complete information about the ouptut data is provided (nomenclature, format description,...). The dissemination in Near-Real-Time is effective since June 2018.

Information and examples of applications about the FSLEs and Orientations are given in the Aviso+ website: https://www.aviso.altimetry.fr/en/data/products/value-added-products/fsle-finite-size-lyapunov-exponents.html

1.1. Data policy and data access

The FSLEs and the Orientations of the associated eigenvectors are available on the Aviso+ ftp server and data extraction tool. Note that the routine products are experimental.

SSALTO/DUACS **FSLEs and Orientations of the associated eigenvectors gridded** products (level 4+) are available free of charge for scientific studies or non-profit projects only.

Please, subscribe to get access to SSALTO/DUACS products by filling the registration form on:

http://www.aviso.altimetry.fr/en/data/data-access/registration-form.html

2. Processing

2.1. Input Data

The Delayed-Time FSLE (DT FSLE) are computed from the gridded (or Level-4) SEA LEVEL Absolute Dynamic Topography (ADT) geostrophic velocities products delivered by the Copernicus Marine Service (CMEMS, http://marine.copernicus.eu/). The details of the input L4 products processing is described in the Product User Manual https://catalogue.marine.copernicus.eu/documents/PUM/CMEMS-SL-PUM-008-032-068.pdf and the Quality information Document https://catalogue.marine.copernicus.eu/documents/QUID/CMEMS-SL-QUID-008-032-068.pdf. DOI product : https://doi.org/10.48670/moi-00148

The near-real-time FLSE (NRT FSLE) products are based on internal gridded (or Level-4) SEA LEVEL Absolute Dynamic Topography (ADT) geostrophic velocities products, using the same corrections as in Delayed-Time.

2.2. Computation of FSLEs and Orientations of the associated eigenvectors

The products delivered are backward-in-time Finite Site Lyapunov Exponents computed as detailed in d'Ovidio et al., 2004.

Ridges of FSLEs map approximate the so-called Lagrangian Coherent structures which are the generalization of stable hyperbolic trajectories of time independent flow. FSLEs are computed from the largest eigenvalues of the Cauchy-Green strain tensor of the flow map. The exponents corresponding to the smallest eigenvalues, the orientations of the associated eigenvector are also computed and provided.

The computation of the FSLEs and eigenvector orientations are described in the Aviso+ website at this page:

http://www.aviso.altimetry.fr/en/data/products/value-added-products/fsle-finite-size-lyapunov-exponents.html

2.3. Code delivery

Moreover a code delivery has been set up (https://bitbucket.org/cnes_aviso/lagrangian/wiki/Contents) allowing the users to calculate themselves the variables with the parameters that they want.

3. SSALTO/DUACS FSLEs and Orientations of associated eigenvectors Products

3.1. Grids characteristics

The Exponents and Orientations are distributed on a 1/25° grid on a global coverage 0°E/359.96°E/65°S/85°N.

3.2. Temporal availability

In Delayed-Time, the maps are calculated every day since 1994/04/01. They are updated every year.

In Near-Real-Time, the maps are delivered every day, with 20 days of delay.

3.3. Nomenclature of files

The nomenclature used for these products is:

<DELAY>_<ZONE>_<NBSAT>_<PRODUCT>_<VARIABLE>_<DATEMAP>_<DATEPROD>.nc

DELAY	dt	delayed time products
	nrt	Near-real-time products
ZONE	global	global geographic coverage product
NBSAT	allsat	maximum 6 satellites to compute the map
PRODUCT	madt	maps of absolute dynamic topography
VARIABLE	fsle	finite size Lyapunov Exponents and Orientations
DATEMAP	YYYYMMDD	date of the dataset
DATEPROD	YYYYMMDD	production date of the dataset

4. Data format

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

4.1. NetCdf

The products are stored using the NetCDF-4 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 retrieve 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.

The gridded FSLEs and Orientations of the associated eigenvectors products are stored in **NetCDF 4-Classic** defined by the Cooperative Ocean/Atmosphere Research Data Service (COARDS) and Climate and Forecast (CF) metadata conventions.

The CF convention generalises and extends the COARDS convention but relaxes the COARDS constraints on dimension and order and specifies methods for reducing the size of datasets. A wide range of software is available to write or read NetCDF/CF files. API are made available by UNIDATA http://www.unidata.ucar.edu/software/netcdf :

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

In addition to these conventions, the files are using a common structure and semantic:

- 4 dimensions are defined:
  - **time**: it is used to check NetCDF variables depending on time.
  - **lat**: number of latitudes
  - **lon**: number of longitudes
  - **nv**: used for graphics conventions

- 9 variables are defined:
  - float **time** : contains the time in days since 1950-01-01 00:00:00 UTC for each measurement,
  - int **lat** : contains the latitude for each measurement,
  - int **lon** : contains the longitude for each measurement,
  - float **lat_bnds**: contains the min and max in latitude of each box,
  - float **lon_bnds**: contains the min and max in longitude of each box,
  - int **crs**: used for mapping conventions,

- float **fsle_max**: values of Lyapunov Exponents,
- float **theta_max**: values of Orientations of Vectors.

- global attributes:
  - the global attributes give information about the creation of the file.

Example of a NetCDF file:

```
Netcdf  dt_global_allsat_madt_fsle_20201231_20210921.nc {
dimensions:
	lat = 4500 ;
	lon = 9000 ;
	nv = 2 ;
	time = 1 ;
variables:
	int crs ;
		crs:grid_mapping_name = "latitude_longitude" ;
		crs:inverse_flattening = 298.257 ;
		crs:semi_major_axis = 6378136.3 ;
	int nv(nv) ;
	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 lat(lat) ;
		lat:axis = "Y" ;
		lat:bounds = "lat_bnds" ;
		lat:long_name = "Latitude" ;
		lat:standard_name = "latitude" ;
		lat:units = "degrees_north" ;
		lat:valid_min = -90. ;
		lat:valid_max = 90. ;
	float lat_bnds(lat, nv) ;
	float lon(lon) ;
		lon:axis = "X" ;
		lon:bounds = "lon_bnds" ;
		lon:long_name = "Longitude" ;
		lon:standard_name = "longitude" ;
		lon:units = "degrees_east" ;
		lon:valid_min = 0. ;
		lon:valid_max = 360. ;
	float lon_bnds(lon, nv) ;
	float fsle_max(time, lat, lon) ;
		fsle_max:_FillValue = 9.96921e+36f ;
		fsle_max:grid_mapping = "crs" ;
		fsle_max:long_name = "FSLEs based on the maximum eigenvalue of the Cauchy-Green strain tensor" ;
		fsle_max:units = "days-1" ;
	float theta_max(time, lat, lon) ;
		theta_max:_FillValue = 9.96921e+36f ;
		theta_max:grid_mapping = "crs" ;
		theta_max:long_name = "Orientation of the eigenvector associated to the maximum eigenvalue of the Cauchy-
Green strain tensor" ;
		theta_max:units = "degrees" ;

// global attributes:
		:cdm_data_type = "Grid" ;
		:Conventions = "CF-1.6" ;
```

:standard_name_vocabulary = "http://cf-pcmdi.llnl.gov/documents/cf-standard-names/standard-name-table/12/cf-standard-name-table.html" ;
:title = "Backward-in-time, finite-size Lyapunov exponents (FSLEs)" ;
:summary = "This dataset contains Backward-in-time FSLE product deduced from DT merged Global Ocean Gridded Absolute Geostrophic Velocities DUACS L4 product (version DT2021)." ;
:separation = "Initial separation in degrees: 0.02; Maximal separation (expansion) in degrees: 0.6" ;
:comment = "Surface product; submesoscale filaments" ;
:contact = "aviso@altimetry.fr" ;
:geospatial_lat_min = -89.98 ;
:geospatial_lat_max = 89.98 ;
:geospatial_lon_min = 0.02 ;
:geospatial_lon_max = 359.98 ;
:geospatial_vertical_min = "0.0" ;
:geospatial_vertical_max = "0.0" ;
:geospatial_lat_units = "degrees_north" ;
:geospatial_lon_units = "degrees_east" ;
:geospatial_lat_resolution = 0.04 ;
:geospatial_lon_resolution = 0.04 ;
:institution = "CNES, CLS, LOCEAN, CTOH" ;
:license = "http://www.aviso.altimetry.fr/fileadmin/documents/data/License_Aviso.pdf" ;
:product_version = "1.0" ;
:project = "SSALTO/DUACS" ;
:references = "www.aviso.altimetry.fr" ;
:end_time = "2020-06-14 00:00:00" ;
:start_time = "2020-12-31 00:00:00" ;
:time_coverage_resolution = "P4D" ;

5. Accessibility of the products

5.1. Accessibility

Note that once your request is processed (after filling the online form on http://www.aviso.altimetry.fr/en/data/data-access/registration-form.html), Aviso+ will send you your own access (login/password) and your access validation by e-mail. The accesses (FTP and Extraction tool) will be defined in your dedicated private access to products in your web page: https://www.aviso.altimetry.fr/no_cache/en/my-aviso-plus/products.html

5.2. Gridded Delayed-Time product

The nomenclature used for the file is:

<DELAY>_<ZONE>_<NBSAT>_<PRODUCT>_<VARIABLE>_<DATEMAP>_<DATEPROD>

DELAY	delayed-time	delayed time products
	near-real-time	near-real-time products
NBSAT	allsat	maximum 6 Satellites to compute the map
PRODUCT	madt	maps of absolute dynamic topography
VARIABLE	fsle	Lyapunov Exponents and Orientations
DATEMAP	YYYYMMDD	Day of the map
DATEPROD	YYYYMMDD	Day of production of the map

6. Contacts

For more information, please contact:

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

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

Bibliography

D'Ovidio F., C. Lopez, E. Hernandez-Garcia, V. Fernandez, 2004, "Mixing structures in the Mediterranean sea from Finite-Size Lyapunov Exponents", *Geophys. Res. Lett.*, 31, L17203.

Pujol M.-I., Y. Faugere, O. Titaud, F.Briol, F. d'Ovidio, R. Morrow,E. Bronner, N. Picot, "20 years of reprocessed Lyapunov Exponents from altimetry available on AVISO+", Poster EGU2015-4542, EGU12 17 April 2015, Vienna Australia