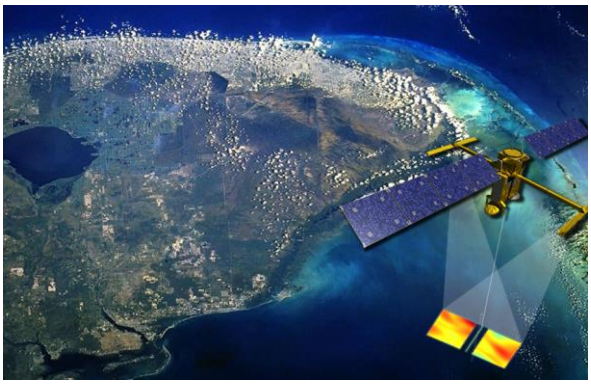
SSALTO/DUACS Experimental Product Handbook:

Gridded optimally merged velocities combining altimetry and SST



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List of Acronyms:

Aviso+	Archiving, Validation and Interpretation of Satellite Oceanographic data
DUACS	Data Unification and Altimeter Combination System
ECMWF	European Centre for Medium-range Weather Forecasting
L3	Level-3 products (along-track)
L4	Level 4 products (gridded)
SALP	Service d'Altimétrie et de Localisation Précise
SAR(M)	Synthetic Aperture Radar (Mode)
Ssalto	Segment Sol multimissions d'ALTimétrie, d'Orbitographie et de localisation précise.
SLA	Sea Level Anomaly
SSH	Sea Surface Height

Contents

1 Introduction

For 20 years, the DUACS system has been producing, as part of the CNES/SALP project, the Copernicus Marine Environment and Monitoring Service (CMEMS) and the Copernicus Climate Change Service (C3S), high quality multimission altimetry Sea Level products for oceanographic applications, climate forecasting centers, geophysic and biology communities... While the operational production of the Sea Level along track and maps is now generated as part as CMEMS and C3S, the development of a new experimental DUACS products started mid 2016 at CNES **aiming at improving the resolution of the current products and designing new products**. Using the global Synthetic Aperture Radar mode (SARM) coverage of Sentinel3A/B and optimizing the LRM altimeter processing (retracking, editing, ...) will notably allow us to fully exploit the fine-scale content of the altimetric missions. Thanks to this increase of real time altimetry observations we will also be able to improve Level-4 products by combining these new Level-3 products and new mapping methodology, such as dynamic interpolation. Finally, these improvements will benefit to downstream products: geostrophic currents, Lagrangian products, eddy atlas…

This document the gridded (level4) optimally merged velocities combining altimetry and SST with global coverage.

1.1 Acknowledgments

When using the experimental SSALTO/DUACS experimental products, please cite: "Those products were processed by SSALTO/DUACS and distributed by AVISO+ (https://www.aviso.altimetry.fr) with support from CNES"

Please note that the gridded optimally merged velocities combining altimetry and SST with global coverage have been calculated in the framework of three different projects:

- a Marie-Curie Fellowship cofunded by the European Union under the FP7-PEOPLE-Cofunding of Regional, National and International Programmes Grant Agreement 600407 and the RITMARE FLAG project (2014-2016),
- the ESA Globcurrent project (2014-2018),
- the DUACS-MR CNES project (2016-2018).

1.2 User's feedback

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

2 Gridded products obtained combining altimetry and Sea Surface Temperature

Those products are distributed in version 01_00.

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

2.1 Processing

2.1.1 Input data

2.1.1.1 Altimetry

The altimeter input data used to compute the gridded products of optimally merged SSH/SST velocities is the gridded (or Level-4) SEA LEVEL 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 http://resources.marine.copernicus.eu/documents/PUM/CMEMS-SL-PUM-008-032-062.pdf and the Quality information Document http://resources.marine.copernicus.eu/documents/QUID/CMEMS-SL-QUID-008-032-062.pdf .

2.1.1.2 Sea Surface Temperature

The Sea Surface Temperature input data used to compute the gridded products of optimally merged SSH/SST velocities are the gridded (or Level-4) Optimally Interpolated (OI) SST produced daily on a 25 km resolution grid by Remote Sensing System using only microwave data (MW) (http://www.remss.com/measurements/sea-surface-temperature/oisst-description/). It contains the SST measurements from all operational radiometers (TMI, AMSR-E, AMSR-2, WindSat, GMI).

2.1.2 Processing

The optimal SSH/SST blended velocities are obtained by inverting the SST conservation equation for the velocity field using the altimeter geostrophic velocities as background velocities. The atmospheric forcing term (heat fluxes) in the SST conservation equation is approximated using the large spatial scales of the daily SST temporal derivatives. Both the errors on the background velocities and the forcing term are taken into account to obtain the optimal blended velocities. The method is fully described in the papers by Piterbarg et al (2009), Rio et al (2016) and Rio and Santoleri (submitted).

2.2 Product description

2.2.1 Geographical characteristics

The geographical coverage of the blended SSH/SST velocities is global (excluding the Mediterranean Sea).

Area	Geographical coverage	Resolution
Global	0.125-359.875; -89.875-89.875	0.25°

Table 1. Geographical characteristics of gridded products combining altimetry and SST.

2.2.2 Temporal availability

One file per day is delivered over year 2015.

Area	Start Date	End Date
Global	01/01/2015	31/12/2015

Table 2 Temporal availability of gridded products combining altimetry and SST.

2.2.3 Nomenclature

This is the generic model of filename:

dt_global_allsat_merged_ssh_sst_phy_<begin_date>_ <prod_date>.nc

The products name components are:

- The type of data timeliness dt=delayed-time
- <zone>=global
- Allsat_ssh_sst means that all the available missions are taken into account with SST
- The begin and production dates of the data: <begin_date>_<prod_date>

2.2.4 Format

All the products are distributed in NetCDF with norm CF.

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

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

All basic NetCDF conventions are applied to files.

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

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

2.2.4.1 Dimensions

The defined dimensions are:

- **time:** number of grids in current file (one grid for one day).
- **Latitude :** number of grid points in latitude
- **Longitude :** number of grid points in longitude
- Nv: for graphical needs

2.2.4.2 Data Handling Variables

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

Name of variable	Type	Content	Unit
time	float	Time of measurements	days since 1950-01-01 00:00:00 UTC
latitude	float	Latitude value of estimate	degrees_north
longitude	float	Longitude value of estimate	degrees_east
lat_bnds	float	latitude values at the north and south bounds of each pixel.	degrees_north
lon_bnds	float	longitude values at the north and south bounds of each pixel.	degrees_east
eastward_eulerian_current_velocity	int	eulerian current velocity : zonal component	meters/second
northward_eulerian_current_velocity	int	eulerian current velocity : meridian component	meters/second

Table 3. Overview of data handling variables in gridded Alti+SST NetCDF file.

2.2.4.3 Attributes

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

3 Gridded confidence flag product

This product is distributed in version 01_00.

3.1 Processing

3.1.1 Input data

3.1.1.1 "allsat" altimeter derived velocities

The altimeter input data used to compute the confidence flag is the gridded (or Level-4) SEA LEVEL 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 http://cmems-resources.cls.fr/documents/PUM/CMEMS-SL-PUM-008-032-051.pdf and the Quality information Document http://cmems-resources.cls.fr/documents/QUID/CMEMS-SL-QUID-008-032-051.pdf.

3.1.1.2 Drifting buoy velocities

The in-situ drifting buoy velocities used to calculate the confidence flag are the velocities from the 15m drogued SVP drifters distributed by the SD-DAC (http://www.aoml.noaa.gov/phod/dac/dacdata.php).

3.1.1.3 Processing

The background (bck) "allsat" altimeter geostrophic velocities and the optimal (opt) SSH/SST blended velocities are interpolated along the drifting buoy trajectories and Root Mean Square (RMS) differences between the different products and the buoy velocities are calculated in 20° by 20° boxes for both components of the velocity (U: zonal, V: meridional). Then in each box a % of improvement (U_{impr},V_{impr}) is obtained using:

$$U_{impr} = 100 * (1 - (RMSU_{opt} / RMSU_{bck})^2)$$

$$V_{impr} = 100 * (1 - (RMSV_{opt} / RMSV_{bck})^2)$$

These % of improvement are used as confidence flag for this demonstration dataset. A positive value means that, on average over the period, the optimally combined SSH/SST velocities are closer to the drifting buoy velocities than the "allsat" altimeter velocities so that the confidence level is good. The higher the % of improvement, the better. On the contrary, negative values indicate that the optimally combined SSH/SST velocities does not compare to drifting buoy velocities as well as the "allsat" altimeter velocities do. The confidence level is thus lower.

The method to derive this confidence flag is fully described in the paper by Rio and Santoleri (submitted).

3.2 Product description

3.2.1 Geographical characteristics

The geographical coverage of the confidence flag is global (excluding the Mediterranean Sea). Effective resolution is 20° (the % of improvement is calculated in 20° by 20° boxes).

Area	Geographical coverage	Resolution
Global	0.125-359.875; -89.875-89.875	0.25°

Table 4. Geographical characteristics of gridded confidence flag product.

3.2.2 Temporal availability

One file is delivered over year 2015 (static file).

3.2.3 nomenclature

Only one file is delivered:

Optimally_merged_SSH_SST_velocity_flag.nc

3.2.4 Format

3.2.4.1 Dimensions

The defined dimensions are:

- **time:** number of grids in current file (one grid for one day).
- **Latitude :** number of grid points in latitude
- **Longitude :** number of grid points in longitude
- Nv: for graphical needs

3.2.4.2 Data Handling Variables

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

Name of variable	Type	Content	Unit
time	float	Time of measurements	days since 1950-01-01 00:00:00 UTC
latitude	float	Latitude value of estimate	degrees_north
longitude	float	Longitude value of estimate	degrees_east
lat_bnds	float	latitude values at the north and south bounds of each pixel.	degrees_north
lon_bnds	float	longitude values at the north and south bounds of each pixel.	degrees_east
eastward_eulerian_current_velocity	int	eulerian current velocity confidence flag: zonal component	-
northward_eulerian_current_velocity	int	eulerian current velocity confidence flag: meridian component	-

Table 5. Overview of data handling variables in gridded Alti+SST NetCDF file.

3.2.4.3 Attributes

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

4 Products accessibility

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

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

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

5 Contacts

For more information, please contact:

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

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

6 Examples of files

6.1 Gridded product combining altimetry and SST

```
netcdf dt_global_allsat_merged_ssh_sst_phy_20151219_20180328 {
dimensions:
    time = 1 ;
    latitude = 720 ;
    longitude = 1440 ;
    nv = 2 ;
variables:
    float time(time) ;
        time:long_name = "Time" ;
        time:standard_name = "time" ;
        time:units = "days since 1950-01-01 00:00:00 UTC" ;
        time:calendar = "gregorian" ;
        time:axis = "T" ;1
    float latitude(latitude) ;
        latitude:long_name = "Latitude" ;
        latitude:standard_name = "latitude" ;
        latitude:units = "degrees_north" ;
        latitude:bounds = "lat_bnds" ;
        latitude:axis = "Y" ;
        latitude:valid_min = -89.875 ;
        latitude:valid_max = 89.875 ;
    float lat_bnds(latitude, nv) ;
        lat_bnds:comment = "latitude values at the north and south bounds of each pixel." ;
        lat_bnds:units = "degrees_north" ;
    float longitude(longitude) ;
        longitude:long_name = "Longitude" ;
        longitude:standard_name = "longitude" ;
        longitude:units = "degrees_east" ;
        longitude:bounds = "lon_bnds" ;
        longitude:axis = "X" ;
        longitude:valid_min = 0.125 ;
        longitude:valid_max = 359.875 ;
    float lon_bnds(longitude, nv) ;
        lon_bnds:comment = "longitude values at the west and east bounds of each pixel." ;
        lon_bnds:units = "degrees_east" ;
    int nv(nv) ;
        nv:comment = "Vertex" ;
        nv:units = "1" ;
    int crs ;
        crs:comment = "This is a container variable that describes the grid_mapping used by the data in this file. This
variable does not contain any data; only information about the geographic coordinate system." ;
        crs:grid_mapping_name = "latitude_longitude" ;
        crs:semi_major_axis = 6378136.3 ;
        crs:inverse_flattening = 298.257 ;
    int eastward_eulerian_current_velocity(time, latitude, longitude) ;
        eastward_eulerian_current_velocity:_FillValue = -2147483647 ;
        eastward_eulerian_current_velocity:limitations = "merged currents are less accurate at high latitudes, where
REMSS SST product error is larger. See the static Optimally_merged_SSH_SST_velocity_flag.nc file for more information" ;
        eastward_eulerian_current_velocity:coordinates = "longitude latitude" ;
        eastward_eulerian_current_velocity:long_name = "eulerian current velocity : zonal component" ;
        eastward_eulerian_current_velocity:standard_name = "eastward_sea_water_velocity" ;
        eastward_eulerian_current_velocity:units = "m/s" ;
```

```
        eastward_eulerian_current_velocity:scale_factor = 0.0001 ;
        eastward_eulerian_current_velocity:grid_mapping = "crs" ;
    int northward_eulerian_current_velocity(time, latitude, longitude) ;
        northward_eulerian_current_velocity:_FillValue = -2147483647 ;
        northward_eulerian_current_velocity:limitations = "merged currents are less accurate at high latitudes, where
REMSS SST product error is larger. See the static Optimally_merged_SSH_SST_velocity_flag.nc file for more information" ;
        northward_eulerian_current_velocity:coordinates = "longitude latitude" ;
        northward_eulerian_current_velocity:long_name = "eulerian current velocity : meridian component" ;
        northward_eulerian_current_velocity:standard_name = "northward_sea_water_velocity" ;
        northward_eulerian_current_velocity:units = "m/s" ;
        northward_eulerian_current_velocity:scale_factor = 0.0001 ;
        northward_eulerian_current_velocity:grid_mapping = "crs" ;

// global attributes:
        :cdm_data_type = "Grid" ;
        :Conventions = "CF-1.6" ;
        :Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
        :comment = "Velocities at 10m estimated from the optimal merging of the ssalto-duacs dt allsat altimeter derived
geostrophic velocities and REMSS microwave Sea Surface Temperature" ;
        :contact = "aviso@altimetry.fr" ;
        :creator_email = "aviso@altimetry.fr" ;
        :creator_url = "http://www.aviso.altimetry.fr" ;
        :date_created = "2018-03-28T10:52:01Z" ;
        :date_issued = "2018-03-28T10:52:01Z" ;
        :date_modified = "2018-03-28T10:52:01Z" ;
        :geospatial_lat_min = -89.875 ;
        :geospatial_lat_max = 89.875 ;
        :geospatial_lon_min = 0.125 ;
        :geospatial_lon_max = 359.875 ;
        :geospatial_vertical_min = "0.0" ;
        :geospatial_vertical_max = "0.0" ;
        :geospatial_lat_units = "degrees_north" ;
        :geospatial_lon_units = "degrees_east" ;
        :geospatial_lat_resolution = 0.25 ;
        :geospatial_lon_resolution = 0.25 ;
        :institution = "CLS, CNES, CNR, ESA" ;
        :keywords = "Oceans > Ocean circulation > Ocean currents " ;
        :keywords_vocabulary = "NetCDF COARDS Climate and Forecast Standard Names" ;
        :platform = "Altika, Cryosat-2, Haiyang-2A, OSTM/Jason-2, TMI, AMSR-E, AMSR2, WindSat, GMI" ;
        :processing_level = "L4" ;
        :product_version = "1.0" ;
        :project = "SSALTO/DUACS Experimental" ;
        :references = "http://www.aviso.altimetry.fr" ;
        :source = "10m depth velocity estimated from the combination of allsat altimeter gridded geostrophic velocities
and REMSS microwave Sea Surface Temperature data" ;
        :ssalto_duacs_comment = "The reference mission used for the altimeter inter-calibration processing is
Topex/Poseidon between 1993-01-01 and 2002-04-23, Jason-1 between 2002-04-24 and 2008-10-18, OSTM/Jason-2
between 2008-10-19 and 2016-06-25, Jason-3 since 2016-06-25." ;
        :summary = "Delayed-Time Level-4 global horizontal velocities at 10m depth calculated from the optimal merging
of ssalto-duacs allsat altimeter velocity products and REMSS MW SST products following a method described in Rio et al
(2016)." ;
        :title = "DT optimally merged SSH/SST velocities for the global ocean" ;
        :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table
v37" ;
```

6.2 Gridded confidence flag product

```
netcdf Optimally_merged_SSH_SST_velocity_flag {
dimensions:
```

time = 1 ;
latitude = 720 ;
longitude = 1440 ;
nv = 2 ;
variables:
float latitude(latitude) ;
latitude:long_name = "Latitude" ;
latitude:standard_name = "latitude" ;
latitude:units = "degrees_north" ;
latitude:bounds = "lat_bnds" ;
latitude:axis = "Y" ;
latitude:valid_min = -89.875 ;
latitude:valid_max = 89.875 ;
float lat_bnds(latitude, nv) ;
lat_bnds:comment = "latitude values at the north and south bounds of each pixel." ;
lat_bnds:units = "degrees_north" ;
float longitude(longitude) ;
longitude:long_name = "Longitude" ;
longitude:standard_name = "longitude" ;
longitude:units = "degrees_east" ;
longitude:bounds = "lon_bnds" ;
longitude:axis = "X" ;
longitude:valid_min = 0.125 ;
longitude:valid_max = 359.875 ;
float lon_bnds(longitude, nv) ;
lon_bnds:comment = "longitude values at the west and east bounds of each pixel." ;
lon_bnds:units = "degrees_east" ;
int nv(nv) ;
nv:comment = "Vertex" ;
nv:units = "1" ;
int crs ;
crs:comment = "This is a container variable that describes the grid_mapping used by the data in this file. This variable does not contain any data; only information about the geographic coordinate system." ;
crs:grid_mapping_name = "latitude_longitude" ;
crs:semi_major_axis = 6378136.3 ;
crs:inverse_flattening = 298.257 ;
int eastward_eulerian_current_velocity_flag(time, latitude, longitude) ;
eastward_eulerian_current_velocity_flag:_FillValue = -2147483647 ;
eastward_eulerian_current_velocity_flag:coordinates = "longitude latitude" ;
eastward_eulerian_current_velocity_flag:long_name = "eulerian current velocity confidence flag : zonal component" ;
eastward_eulerian_current_velocity_flag:standard_name = "eastward_sea_water_velocity confidence flag" ;
eastward_eulerian_current_velocity_flag:units = "-" ;
eastward_eulerian_current_velocity_flag:scale_factor = 0.01 ;
eastward_eulerian_current_velocity_flag:grid_mapping = "crs" ;
int northward_eulerian_current_velocity_flag(time, latitude, longitude) ;
northward_eulerian_current_velocity_flag:_FillValue = -2147483647 ;
northward_eulerian_current_velocity_flag:coordinates = "longitude latitude" ;
northward_eulerian_current_velocity_flag:long_name = "eulerian current velocity confidence flag: meridian component" ;
northward_eulerian_current_velocity_flag:standard_name = "northward_sea_water_velocity confidence flag" ;
northward_eulerian_current_velocity_flag:units = "-" ;
northward_eulerian_current_velocity_flag:scale_factor = 0.01 ;
northward_eulerian_current_velocity_flag:grid_mapping = "crs" ;

// global attributes:
:cdm_data_type = "Grid" ;
:Conventions = "CF-1.6" ;
:Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
:comment = "Confidence flag for the Velocities at 10m estimated from the optimal merging of the ssalto-duacs dt allsat altimeter derived geostrophic velocities and REMSS microwave Sea Surface Temperature. Negative values indicate a poor confidence level, positive values indicate a good confidence level." ;

:contact = "aviso@altimetry.fr" ;
:creator_email = "aviso@altimetry.fr" ;
:creator_url = "http://www.aviso.altimetry.fr" ;
:date_created = "2018-03-28T10:52:01Z" ;
:date_issued = "2018-03-28T10:52:01Z" ;
:date_modified = "2018-03-28T10:52:01Z" ;
:geospatial_lat_min = -89.875 ;
:geospatial_lat_max = 89.875 ;
:geospatial_lon_min = 0.125 ;
:geospatial_lon_max = 359.875 ;
:geospatial_vertical_min = "0.0" ;
:geospatial_vertical_max = "0.0" ;
:geospatial_lat_units = "degrees_north" ;
:geospatial_lon_units = "degrees_east" ;
:geospatial_lat_resolution = 0.25 ;
:geospatial_lon_resolution = 0.25 ;
:institution = "CLS, CNES, CNR, ESA" ;
:keywords = "Oceans > Ocean circulation > Ocean currents " ;
:keywords_vocabulary = "NetCDF COARDS Climate and Forecast Standard Names" ;
:platform = "Altika, Cryosat-2, Haiyang-2A, OSTM/Jason-2, TMI, AMSR-E, AMSR2, WindSat, GMI" ;
:processing_level = "L4" ;
:product_version = "1.0" ;
:project = "SSALTO/DUACS Experimental" ;
:references = "http://www.aviso.altimetry.fr" ;
:source = "confidence flag on the 10m depth velocities estimated from the combination of allsat altimeter gridded geostrophic velocities and REMSS microwave Sea Surface Temperature data" ;
:summary = "This confidence flag is issued from the comparison between the optimally merged SSH/SST velocities and in-situ drifting buoy velocities (Rio and Santoleri, submitted)." ;
:title = "Confidence flags for the DT optimally merged SSH/SST velocities for the global ocean" ;
:standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table v37" ;
}

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Zaron, E. D., 2019: Baroclinic Tidal Sea Level from Exact-Repeat Mission Altimetry. J. Phys. Oceanogr., 49, 193–210, https://doi.org/10.1175/JPO-D-18-0127.1.