SSALTO/DUACS Experimental Product Handbook:

Gridded Sea Level Anomalies and geostrophic velocities
combining altimetry and drifters

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List of Acronyms:

ADT	Absolute Dynamic Topography
Aviso+	Archiving, Validation and Interpretation of Satellite Oceanographic data
CMEMS	Copernicus Marine Environment Monitoring Service
Cnes	Centre National d'Etudes Spatiales
DAC	Dynamic Atmospheric Correction
DI	Dynamic Interpolation
DUACS	Data Unification and Altimeter Combination System
ECMWF	European Centre for Medium-range Weather Forecasting
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FES	Finite Element Solution tidal model
GDR	Geophysical Data Record(s)
IB	Inverse Barometer
IGDR	Interim Geophysical Data Record(s)
ISRO	Indian Space Research Organisation
IW	Internal Wave
LASER	Lagrangian Submesoscale ExpeRiment campaign
LRM	Low Resolution Mode
LWE	Large Wavelength Error
L2P	Level-2+ product: global 1 Hz along-track data (sea level anomaly, its components and validity flag) over marine surfaces based on Level-2 products
L3	Level-3 products (along-track)
L4	Level 4 products (gridded)
MIOST	Multiscale Interpolation Ocean Science Topography
MOG2D	Modèle aux Ondes de Gravité 2D
MSS	Mean Sea Surface
MWR	Microwave Radiometer
Nasa	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real Time
NTC	Non Time Critical
OSDR	Operational Sensor Data Records
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.
SSB	Sea State Bias
SST	Sea Surface Temperature
SLA	Sea Level Anomaly
SSB	Sea State Bias
SSH	Sea Surface Height
STC	Short Time Critical

TAI	IAT – International Atomic Time
UTC	Universal Time Coordinated

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 describes the gridded (level4) Sea Level Anomalies and geostrophic velocities combining altimetry and drifters for 1 area: Gulf of Mexico

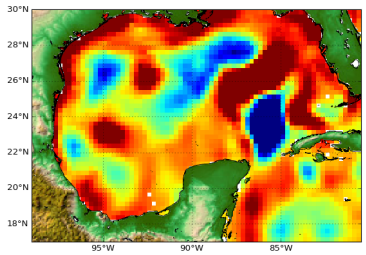

Figure 1: Geographical coverage of Gridded (level4) Sea Level Anomalies and geostrophic velocities combining altimetry and drifters, for Gulf of Mexico with one day of merged Sea Level Anomalies

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"

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 combining altimetry and drifters

Those products are distributed in version 02_00. Compared to version 01_00, some parameter of the Optimal Interpolation have been modified in order to improve the results in the comparison to independent observations. This dataset is described in the paper

S. Mulet, H. Etienne, M. Ballarotta, Y. Faugere, M.H. Rio, G. Dibarboure, N. Picot, Synergy between surface drifters and altimetry to increase the accuracy of sea level anomaly and geostrophic current maps in the Gulf of Mexico, Advances in Space Research, Volume 68, Issue 2, 2021, Pages 420-431, ISSN 0273-1177, https://doi.org/10.1016/j.asr.2019.12.024

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 altimetry input data used to compute the gridded products combining altimetry and drifters are the along-track (or Level-3) SEA LEVEL products delivered by the Copernicus Marine Service (CMEMS, http://marine.copernicus.eu/) for satellites OSTM/Jason-2, SARAL/AltiKa, Cryosat-2, HaiYang-2A as described in Table 1 and from 2015/09/01 to 2016/04/30. The details of the input L3 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

Along-track SLA are corrected, calibrated among the different missions and filtered by the Sea Level Thematic Assembly Centre (SL-TAC) of CMEMS. The along track SLA is processed specifically to be used in the mapping. Specific filtering consistent with the decorrelation scales prescribed in the mapping is applied (Taburet et al., 2019). Data from Jason2, HY2 and Cryosat-2 are used as input to compute maps. Data from SARAL/AltiKA are used firstly as independent data to validate the maps.

Altimeter mission	Name of SEALEVEL CMEMS product	Name of SEALEVEL CMEMS dataset
OSTM/Jason-2	SEALEVEL_GLO_PHY_L3_REP_OBSERVATIONS_008_062	dataset-duacs-rep-global-j2-phy-l3
SARAL/AltiKa		dataset-duacs-rep-global-alg-phy--l3
Cryosat-2		dataset-duacs-rep-global-c2-phy--l3
HaiYang-2A		dataset-duacs-rep-global-h2-phy--l3

Table 1: List of altimetry and input data and their definition in CMEMS for the gridded maps combining altimetry and drifters

2.1.1.2 Drifters

Along-track Sea Level Anomalies (SLA) is combined with geostrophic velocity estimated from surface drifters belonging to Woods Hole Group, a CLS Group company that launches their own drifters in the Gulf of Mexico. The drifters are processed from September 2015 to April 2016 time period to compute geostrophic velocity anomalies

2.1.2 Processing

Strong improvements have been made in our knowledge of the surface ocean geostrophic circulation thanks to satellite observations. However, the synergy of different sources of observation (satellite and in-situ) is mandatory to go toward higher resolution. In this study, we combined altimetric along track Sea Level Anomalies (SLA) with geostrophic velocity estimated from surface drifters to map SLA and associated geostrophic current anomalies in the Gulf of Mexico. The multivariate objective analyses is used to merge drifter and altimetry observations.

First, an important work is done to pre-process drifter data as detail by the following steps:

1- foreward/backward editing process as done by Hansen and Poulain, 96

2- Spike detection

3- Interpolation with regular frequency (6h00)

4- Computation of the velocities

5- Remove ageostrophic signal to have a physical content consistent with altimetry:

5.1- Remove high frequency ageostrophic signal: Filter at 3days

5.2- The Ekman current (Rio et al., 2014), Stokes drift and wind slippage are all estimated and removed if needed depending on the design of the drifters

Second, anomalies of geostrophic current estimated from drifters and along track SLA from Jason2, HY2, Saral and C2 (CMEMS/DUACS DT2018) are combined through multivariate objective analysis to map a time series of SLA and associated geostrophic current anomalies in the Gulf of Mexico. The multivariate objective analysis is based on objective analysis proposed by Bretherton (1976) and adapted to merge height and geostrophic velocities as done by Rio et Hernandez (2004).

The method and assessment results are described in Mulet et al, 2019.

2.2 Product description

2.2.1 Geographical characteristics

Area	Geographical coverage	Spatial resolution
Gulf of Mexico	17°N/31°N-105°W/82°W	1/4°

Table 2. Geographical characteristics of gridded SLA combining altimetry and drifters.

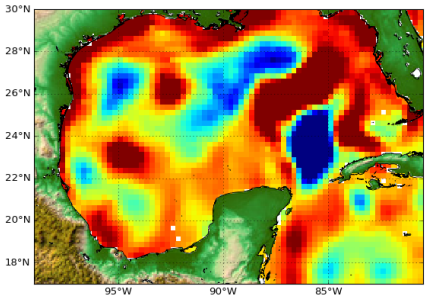

Figure 2: Geographical coverage of Gridded (level4 and level4+) Sea Level Anomalies and geostrophic velocities combining altimetry and drifters, for Gulf of Mexico [17°N/31°N-105°W/82°W] with one day of merged Sea Level Anomalies

2.2.2 Temporal availability

One file per day is delivered.

Area	Start dates	End dates
Gulf of Mexico	2015/09/01	2016/04/30

Table 3 Temporal availability of gridded products combining altimetry and drifters.

2.2.3 Nomenclature

This is the generic model of filename :

dt_gulf_mexico_allsat_drifters_phy_<begin_date>_ <prod_date>.nc

The products name components are:

- The type of data timeliness dt=delayed-time
- <zone>=Gulf of Mexico
- allsat_drifters means that all the available missions are taken into account and drifters are added
- 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
sla	int	Sea Level Anomaly relative to a mean sea surface	meters
err_sla	int	Formal error on sla	meters
ugosa	int	Geostrophic velocity anomalies: zonal component	meters/second
err_ugosa	int	Formal error on ugosa	meters/second
vgosa	int	Geostrophic velocity anomalies: meridian component	meters/second
err_vgosa	int	Formal error on vgosa	meters/second

Table 4. Overview of data handling variables in gridded Alti+drifter 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 Products accessibility

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

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

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

4 Contacts

For more information, please contact:

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

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

5 Examples of files

5.1 Gridded product combining altimetry and drifters

```
netcdf dt_gulf_mexico_allsat_drifters_phy_20160429_20171014 {
dimensions:
        time = 1 ;
        latitude = 56 ;
        longitude = 92 ;
        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" ;
        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 = 17.125 ;
                latitude:valid_max = 30.875 ;
        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 = 260.125 ;
                longitude:valid_max = 282.875 ;
        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 sla(time, latitude, longitude) ;
                sla:_FillValue = -2147483647 ;
                sla:comment = "The sea level anomaly is the sea surface height above mean sea surface; it is referenced to the
[1993, 2012] period; see the product user manual for details" ;
                sla:coordinates = "longitude latitude" ;
                sla:long_name = "Sea level anomaly" ;
                sla:standard_name = "sea_surface_height_above_sea_level" ;
                sla:units = "m" ;
                sla:scale_factor = 0.0001 ;
                sla:grid_mapping = "crs" ;
```

```
    int ugosa(time, latitude, longitude) ;
        ugosa:_FillValue = -2147483647 ;
        ugosa:comment = "The geostrophic velocity anomalies are referenced to the [1993, 2012] period" ;
        ugosa:coordinates = "longitude latitude" ;
        ugosa:long_name = "Geostrophic velocity anomalies: zonal component" ;
        ugosa:standard_name = "surface_geostrophic_eastward_sea_water_velocity_assuming_sea_level_for_geoid" ;
        ugosa:units = "m/s" ;
        ugosa:scale_factor = 0.0001 ;
        ugosa:grid_mapping = "crs" ;
    int vgosa(time, latitude, longitude) ;
        vgosa:_FillValue = -2147483647 ;
        vgosa:comment = "The geostrophic velocity anomalies are referenced to the [1993, 2012] period" ;
        vgosa:coordinates = "longitude latitude" ;
        vgosa:long_name = "Geostrophic velocity anomalies: meridian component" ;
        vgosa:standard_name = "surface_geostrophic_northward_sea_water_velocity_assuming_sea_level_for_geoid" ;
        vgosa:units = "m/s" ;
        vgosa:scale_factor = 0.0001 ;
        vgosa:grid_mapping = "crs" ;
    int err_sla(time, latitude, longitude) ;
        err_sla:_FillValue = -2147483647 ;
        err_sla:long_name = "Formal error on Sea level anomaly" ;
        err_sla:units = "m" ;
        err_sla:scale_factor = 0.0001 ;
        err_sla:grid_mapping = "crs" ;
    int err_ugosa(time, latitude, longitude) ;
        err_ugosa:_FillValue = -2147483647 ;
        err_ugosa:long_name = "Formal error on zonal geostrophic velocity anomaly" ;
        err_ugosa:units = "m/s" ;
        err_ugosa:scale_factor = 0.0001 ;
        err_ugosa:grid_mapping = "crs" ;
    int err_vgosa(time, latitude, longitude) ;
        err_vgosa:_FillValue = -2147483647 ;
        err_vgosa:long_name = "Formal error on meridional geostrophic velocity anomaly" ;
        err_vgosa:units = "m" ;
        err_vgosa:scale_factor = 0.0001 ;
        err_vgosa:grid_mapping = "crs" ;

// global attributes:
        :cdm_data_type = "Grid" ;
        :Conventions = "CF-1.6" ;
        :Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
        :comment = "Sea level anomaly and associated geostrophic current anomaly referenced to the [1993, 2012]
period and estimated from altimetry and drifters from HMI-CLS goup" ;
        :contact = "aviso@altimetry.fr" ;
        :creator_email = "aviso@altimetry.fr" ;
        :creator_url = "http://www.aviso.altimetry.fr" ;
        :date_created = "2017-10-14T10:52:01Z" ;
        :date_issued = "2017-10-12T10:52:01Z" ;
        :date_modified = "2017-10-12T10:52:01Z" ;
        :geospatial_lat_min = 17.125 ;
        :geospatial_lat_max = 30.875 ;
        :geospatial_lon_min = 260.125 ;
        :geospatial_lon_max = 282.875 ;
        :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" ;
        :keywords = "Oceans > Ocean Topography > Sea Surface Height" ;
        :keywords_vocabulary = "NetCDF COARDS Climate and Forecast Standard Names" ;
```

:platform = "Altika, Cryosat-2, Haiyang-2A, OSTM/Jason-2, HMI drifters" ;
:processing_level = "L4" ;
:product_version = "1.0" ;
:project = "SSALTO/DUACS Experimental" ;
:references = "http://www.aviso.altimetry.fr" ;
:source = "Altimetry measurements and geostrophic velocity estimated from drifters from HMI-CLS Group" ;
: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 sea surface height and derived variables measured by multi-satellite altimetry observations and geostrophic velocity estimated from drifters from HMI-CLS Group over Gulf of Mexico." ;
:title = "DT merged all satellites and HMI drifters Gulf of Mexico Area Gridded CLS Sea Surface Height L4 product and derived variables" ;
:standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table v37" ;

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