ESA/Contract No. 4000126561/19/I-NB

Consortium Members

Product User Guide

Reference:	
Nomenclature:	SLCCI+_PUG_011_ProductUserGuide
Issue:	1.3
Date:	08/06/2020

Chronology Issues:			
Issue:	Date:	Reason for change:	Author
1.0	30/09/19	Initial Version	F. Léger (LEGOS)
1.1	18/11/19	ESA review comments	JF Legeais (CLS)
1.2	5/01/20	Extension with Jason-3	F. Léger (LEGOS)
1.3	25/05/20	SLA and trends product at selected sites (section 4)	Y. Gouzenes (LEGOS)

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Acceptance of this deliverable document:			
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List of Acronyms

ALES	Adaptive Leading Edge Subwaveform
ESA	European Space Agency
CCI	Climate Change Initiative
CTOH	Centre of Topography of the Oceans and Hydrosphere
GDR	Geophysical Data Record
GPD	GNSS Path Delay we troposphere correction
GSHHS	Global Self-consistent, Hierarchical, High-resolution Geography database

Level 2P	Level 2 Plus altimeter data (after editing and validation)
RADS	Radar Altimeter Database System
SLA	Sea Level Anomaly
SSH	Sea Surface Height
X-TRACK	Altimeter production system developed by CTOH

1. Introduction

In the context of the ESA's climate change initiative sea-level project, the Centre of Topography of the Oceans and the Hydrosphere (CTOH, http://ctoh.legos.obs-mip.fr) produces a Level 2P multi-mission altimeter along-track sea level product in some coastal regions. The product benefits from the spatial resolution provided by high-rate data, the Adaptive Leading Edge Subwaveform Retracker (ALES, *Passaro et al.*; 2014, 2015, 2017) and the post-processing strategy of the X-TRACK algorithm (*Birol et al.*, 2017, adapted to 20 Hz data as in *Birol and Delebecque*, 2014) both developed for the processing of coastal altimetry data, as well as the best possible set of geophysical corrections.

The main objective of this product is to provide accurate altimeter Sea Level Anomalies (SLA) time series as close to the coast as possible.

By merging X-TRACK and ALES altimetry processing tools, we compute 20-Hz along-track sea surface height (SSH) time series for Jason-1, Jason-2 and Jason-3 missions. The X-TRACK software reprocesses corrections and parameters from delayed-time geophysical data records provided by space agencies (GDR products) and combines them with the ALES retracker product (range, sigma0 and sea state bias) to compute the SSH, after a robust editing of the measurements and corrections (described in *Birol et al.*, 2017).

This document describes the information required to use the different coastal sea level products. Section 2 describes the altimeter standards used for the SLA computation, section 3 describes the regional along-track coastal sea level product and section 4 presents the thematic product which consists in monthly post-processed and validated SLA and associated trends at selected coastal sites. This thematic product is suitable for studying long-term sea level trends, while the regional coastal along-track product includes all the data and is recommended for studying coastal circulation.

2. Altimeter standards

The Jason-1, Jason-2 and Jason-3 data used by the X-TRACK software are based, respectively, on the GDR-E and GDR-D products. The range, sigma0 and sea state bias are provided by the ALES retracker product. The ocean tide and DAC corrections come from the RADS database. The wet tropospheric correction used is GPD+ (*Fernandes and Lazaro,* 2016), provided by the University of Porto. The list of the parameters used in the computation of the SSH data is provided in the table below. Note that the mean sea surface used to compute the sea level anomalies is an area-averaged mean SSH and is thus not considered as an input dataset.

Parameter	Source	Jason-1	Jason-2	Jason-3
Altitude	GDR	Altitude of satellite		
Range	ALES	20 Hz ku band ALES corrected altimeter range (*Passaro et al.*, 2014)		
sigma0	ALES			

Ionosphere	GDR	From dual-frequency altimeter range measurements, further filtered by X-TRACK
Dry troposphere	GDR	From ECMWF model
Wet troposphere	GPD+	GPD+ radiometer correction (*Fernandes and Lazaro*, 2016)
Sea state bias	ALES	Sea state bias correction in ku band, ALES retracking (*Passaro et al.*, 2015)
Solid tide	RADS	From tide potential model (*Cartwright and Taylor*, 1971, *Cartwright and Eden*, 1973)
Pole tide	GDR	From *Wahr*, 1985
Loading effect	RADS	From FES 2014 (*Carrere et al.*, 2012)
Atmospheric correction	RADS	From MOG2D-G high frequencies (*Carrere and Lyard,* 2003) + inverse barometer
Ocean tide	RADS	From FES 2014 (*Carrere et al.*, 2012) including ocean tide, long period equilibrium tide, S1 tide

3. Regional coastal along-track product

3.1 Definition

Currently, the product is distributed with 6 datasets corresponding to 6 coastal regions (Mediterranean Sea, North East Atlantic Ocean, North Indian Ocean, South Australia, Southeast Asia and West African Coasts). Regions are illustrated on the figure below. They consist in a 20 Hz along-track SLA time series projected onto reference tracks with a spatial interval of circa 320 m between consecutive points. The total time series is derived from the Jason-1, Jason-2 and Jason-3 missions and covers the period from 15 January 2002 to 30 May 2018. The time series have been corrected for the inter mission biases.

3.2 Nomenclature

The nomenclature used for these products is:

ESACCI-SEALEVEL-L3-SLA-<ZONE>-<MISSION>-<ProductionDateYYYYMMDD>-<ORBIT>-<PassNumberXXX>-fv01.nc

Where <MISSION> is:

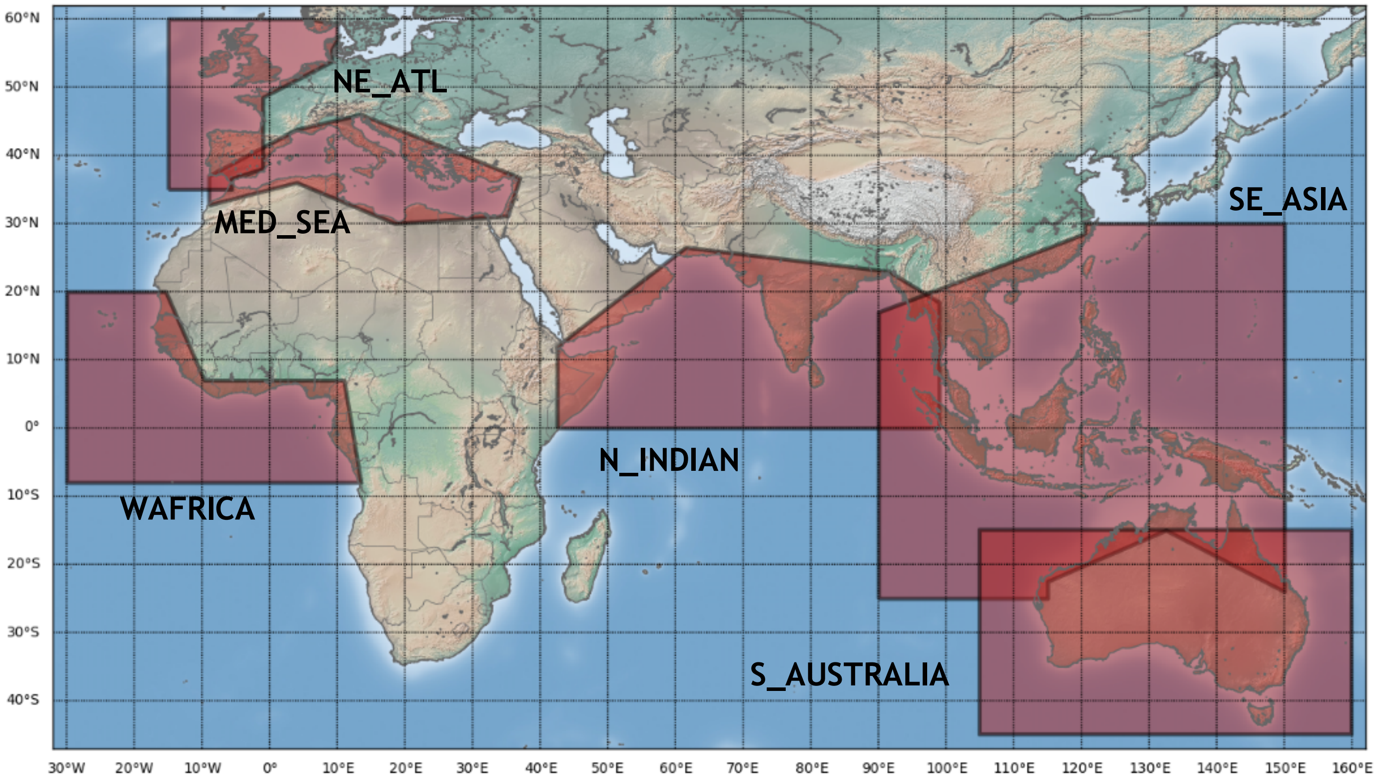
MERGED for multi-mission data

<ORBIT> is:

JA for Jason orbits

and <ZONE> is one of:

MED_SEA, for the Mediterranean Sea, 30°N/46°N, -6°E/37°E
NE_ATL, for the North East Atlantic Ocean, 35°N/60°N, -15°E/10°E
N_INDIAN, North Indian Ocean, 0°N/26,5°N, 42,5°E/99°E
S_AUSTRALIA, South Australia, -45°N/-15°N, 105°E/160°E



SE_ASIA, Southeast Asia, -25°N/30°N, 90°E/150°E
WAFRICA, for the West African Coasts, -8°N/20°N, -30°E/13,5°E.

For example, the time-series data associated with track 222 in the North East Atlantic Ocean, produced on 2020/01/13 is found in a file whose name is:

ESACCI-SEALEVEL-L3-SLA-**NE_ATL**-MERGED-**20200113**-JA-**222**-fv01.1.nc

3.3 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 on: https://www.unidata.ucar.edu/software/netcdf/

3.4 Data handling variables

The variables stored in the NetCDF file are:

Names of variables in files	**Description**
lon	Longitude of the data point at 20 Hz resolution along the mean track
lat	Latitude of the data point at 20 Hz resolution along the mean track
cycle	Mission cycle number
missions_cycles	Original cycle number specific to each mission. It is discontinuous on the date of the change of mission.
sla	Sea Level Anomaly
ocean_tide	Oceanic tide includes the corresponding loading tide and equilibrium long-period ocean tide height from FES2014
dynamic_atmospheric_correction	Dynamic Atmospheric Correction, combining the low and high frequency effect of atmospheric pressure and wind on sea surface height from MOG2D-G
mean_sea_surface	X-TRACK Mean Sea Surface
dist_to_coast_gshhs	Distance to the nearest GSHHS coastline
mdt_cnes_cls18	Mean Dynamic Topography
time	Time of measurement at 20 Hz resolution
qual_flag	Quality flag if distance to the coast is lower than 4 km
biasJ1J2	J1 J2 regional intermission bias
biasJ2J3	J2 J3 regional intermission bias

3.5 NetCDF header

Example for the track 222 in the North East Atlantic Ocean zone

3.5.1 Global attributes

// global attributes:

:title = "SL_cci+ L3 X-TRACK/ALES Altimeter Sea Level Anomalies in the region NE_ATL" ;
:institution = "ESA, CTOH/LEGOS, Toulouse Univ., CNRS, IRD, CNES, UPS, France" ;
:Conventions = "CF-1.6" ;
:history = "2020-01-13 generated by X-TRACK v.1.03" ;
:version = "X-TRACK/ALES 1.1" ;
:pass_number = "222" ;
:source = "Jason-1 GDR-E, Jason-2 GDR-D, Jason-3 GDR-D, RADS 4.0, ALES" ;
:references = "http://www.esa-sealevel-cci.org/products" ;
:tracking_id = "188b974a-ed03-49a5-a369-0106276a8eeb" ;
:product_version = "1.1" ;
:summary = "This dataset contains 20 Hz Level-3 regional sea level anomalies combining ALES retracker and post-processing strategy of X-TRACK" ;
:keywords = "satellite, ocean, coastal altimetry," ;
:id = "DT-SLA-MERGED-20HZ" ;
:naming_authority = "ESA CCI+" ;
:keywords_vocabulary = "NetCDF COARDS Climate and Forecast Standard Names" ;
:cdm_data_type = "Trajectory" ;
:comment = "These data were produced at LEGOS as part of the ESA SL_CCI+ project." ;
:date_created = "2020-01-13" ;
:creator_name = "CTOH/LEGOS, Toulouse Univ., CNRS, IRD, CNES, UPS, France" ;
:creator_url = "http://www.esa-sealevel-cci.org" ;
:creator_email = "info-sealevel@esa-sealevel-cci.org" ;
:project = "Sea Level Climate Change Initiative - European Space Agency" ;
:geospatial_lat_min = "49.826 " ;
:geospatial_lat_max = "59.3069 " ;
:geospatial_lon_min = "-14.9914 " ;
:geospatial_lon_max = "0.512986 " ;
:geospatial_vertical_min = "0" ;
:geospatial_vertical_max = "0" ;
:time_coverage_start = "2002-01-15" ;
:time_coverage_end = "2018-05-30" ;
:time_coverage_duration = "P14Y6M" ;
:time_coverage_resolution = "P9DT21H58M27.84S" ;
:standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table v67" ;
:license = "ESA CCI Data Policy: free and open access" ;
:platform = "Jason-1, Jason-2 and Jason-3" ;
:sensor = "Poseidon-2, Poseidon-3 and Poseidon-3B" ;
:spatial_resolution = "350 m" ;
:geospatial_lat_units = "degrees_north" ;
:geospatial_lon_units = "degrees_east" ;
:key_variables = "sea_surface_height_above_mean_sea_level" ;
}

3.5.2 Variables attributes

Variables:

double biasJ1J2(nbpoints) ;

```
		biasJ1J2:_FillValue = 9.96920996838687e+36 ;
		biasJ1J2:units = "m" ;
		biasJ1J2:long_name = "J1 J2 intermission bias" ;
		biasJ1J2:comment = "J1 J2 regional intermission bias - 1°x1° box average. Mean regional
value is -0.058 m" ;
	double biasJ2J3(nbpoints) ;
		biasJ2J3:_FillValue = 9.96920996838687e+36 ;
		biasJ2J3:units = "m" ;
		biasJ2J3:long_name = "J2 J3 intermission bias" ;
		biasJ2J3:comment = "J2 J3 regional intermission bias - 1°x1° box average. Mean regional
value is -0.026 m" ;
	int cycle(nbcycles) ;
		cycle:long_name = "Cycle number" ;
		cycle:cyc_min = 1 ;
		cycle:cyc_max = 603 ;
		cycle:units = "count" ;
	int dist_to_coast_gshhs(nbpoints) ;
		dist_to_coast_gshhs:_FillValue = -2147483648 ;
		dist_to_coast_gshhs:long_name = "Distance to nearest coastline" ;
		dist_to_coast_gshhs:actual_range = -269448768., 251344672. ;
		dist_to_coast_gshhs:units = "m" ;
		dist_to_coast_gshhs:description = "Geodesic distances on WGS-84" ;
		dist_to_coast_gshhs:GMT_version = "4.5.9_r9889 [64-bit]" ;
		dist_to_coast_gshhs:add_offset = 0.f ;
		dist_to_coast_gshhs:scale_factor = -0.01f ;
		dist_to_coast_gshhs:comment = "Distance to nearest GSHHS 1.3 coastline in m" ;
	float dynamic_atmospheric_correction(nbpoints, nbcycles) ;
		dynamic_atmospheric_correction:_FillValue = 99.9999f ;
		dynamic_atmospheric_correction:units = "m" ;
		dynamic_atmospheric_correction:long_name = "Global Dynamic Atmospheric Corrections" ;
		dynamic_atmospheric_correction:short_name = "DAC" ;
		dynamic_atmospheric_correction:add_offset = 0.f ;
		dynamic_atmospheric_correction:scale_factor = 1.f ;
		dynamic_atmospheric_correction:comment = "Combined low and high frequency effect of
atmospheric pressure and wind on sea surface height from M
OG2D-G" ;
	float lat(nbpoints) ;
		lat:_FillValue = 99.9999f ;
		lat:units = "degrees_north" ;
		lat:long_name = "Latitude" ;
		lat:short_name = "Lat" ;
		lat:lat_min = 49.f ;
		lat:lat_max = 60.f ;
		lat:add_offset = 0.f ;
		lat:scale_factor = 1.f ;
	float lon(nbpoints) ;
		lon:_FillValue = 99.9999f ;
		lon:units = "degrees_east" ;
		lon:long_name = "Longitude" ;
		lon:short_name = "Lon" ;
		lon:lon_min = -15.f ;
		lon:lon_max = 1.f ;
		lon:add_offset = 0.f ;
		lon:scale_factor = 1.f ;
	float mean_sea_surface(nbpoints) ;
		mean_sea_surface:_FillValue = 99.9999f ;
```

```
                mean_sea_surface:units = "m" ;
                mean_sea_surface:short_name = "MSSH" ;
                mean_sea_surface:mssh_period = "Cycles from 1 to 591 are used for the mssh computation"
;
                mean_sea_surface:add_offset = 0.f ;
                mean_sea_surface:scale_factor = 1.f ;
                mean_sea_surface:long_name = "X-TRACK/ALES Mean Sea Surface" ;
        short missions_cycles(nbcycles) ;
                missions_cycles:_FillValue = -99s ;
                missions_cycles:long_name = "Original cycle numbers of the concatenated missions" ;
                missions_cycles:cyc_min = 1 ;
                missions_cycles:cyc_max = 303 ;
                missions_cycles:units = "count" ;
                missions_cycles:comment = "This cycle number is specific to each mission. It is
discontinuous on the date of the change of mission." ;
        float ocean_tide(nbpoints, nbcycles) ;
                ocean_tide:_FillValue = 99.9999f ;
                ocean_tide:units = "m" ;
                ocean_tide:short_name = "Tide" ;
                ocean_tide:add_offset = 0.f ;
                ocean_tide:scale_factor = 1.f ;
                ocean_tide:long_name = "Global FES14 tide correction" ;
                ocean_tide:comment = "Geocentric ocean tide Includes the corresponding loading tide and
equilibrium long-period ocean tide height" ;
                ocean_tide:standard_name =
"sea_surface_height_amplitude_due_to_geocentric_ocean_tide" ;
        byte qual_flag(nbpoints) ;
                qual_flag:comment = "flag if distance to the coast is lower than 4 km" ;
                qual_flag:flag_meanings = "good, bad" ;
                qual_flag:flag_values = 0b, 1b ;
                qual_flag:long_name = "20Hz SLA quality flag" ;
        float sla(nbpoints, nbcycles) ;
                sla:_FillValue = 99.9999f ;
                sla:units = "m" ;
                sla:short_name = "SLA" ;
                sla:add_offset = 0.f ;
                sla:scale_factor = 1.f ;
                sla:comment = "sla = altitude of satellite - 20 Hz Ku band ALES corrected altimeter range
(Passaro et al. 2014) - altimeter ionospheric correction on Ku band (From dual-frequency altimeter range
measurements) - model dry tropospheric correction (From ECMWF model) - GPD+ wet tropospheric
correction (Fernandes et al. 2015)  - sea state bias correction in Ku band (ALES retracking, Passaro et al.
2014) - solid earth tide height (From RADS, tide potential model, Cartwright and Taylor 1971, Cartwright
and Eden 1973) - geocentric ocean tide (FES 2014 from RADS, Carrere et al. 2012) - geocentric pole tide
height (Wahr 1985) - Atmospheric correction (From RADS, Carrere and Lyard 2003) - X-TRACK mean sea
surface (Birol et al. 2017). Each corrective term is edited following
Birol et al. 2017. " ;
                sla:long_name = "X-TRACK/ALES Sea Level Anomalies" ;
                sla:standard_name = "sea_surface_height_above_mean_sea_level" ;
        double time(nbpoints, nbcycles) ;
                time:_FillValue = 99.9999 ;
                time:units = "days since 1950-1-1" ;
                time:calendar = "julian" ;
                time:long_name = "Time of measurement" ;
                time:short_name = "Time" ;
        int mdt_cnes_cls18(nbpoints) ;
                mdt_cnes_cls18:_FillValue = -2147483647 ;
```

```
                mdt_cnes_cls18:coordinates = "longitude latitude" ;
                mdt_cnes_cls18:long_name = "mean dynamic topography" ;
                mdt_cnes_cls18:standard_name = "mean_dynamic_topography" ;
                mdt_cnes_cls18:units = "m" ;
                mdt_cnes_cls18:scale_factor = 0.0001 ;
                mdt_cnes_cls18:grid_mapping = "crs" ;
                mdt_cnes_cls18:creator_url = "https://www.aviso.altimetry.fr" ;
                mdt_cnes_cls18:date_created = "2018-12-03T10:52:01Z" ;
                mdt_cnes_cls18:institution = "CLS, CNES" ;
                mdt_cnes_cls18:product_version = "1.0" ;
                mdt_cnes_cls18:summary = "Mean Dynamic Topography calculated from the combination of
altimetry, gravimetry (including GOCE and GRACE) and in-s
itu data. The reference time-period is 1993-2012." ;
                mdt_cnes_cls18:comment = "MDT_CNES_CLS18" ;
```

3.6 Example

Here you can find a basic example for reading and plotting the product using Python version 3.7. The output is shown in Figure 1 below; the code is shown in the following page. Python (http://www.python.org) is a free, general purpose programming language that is available on multiple operating systems including Linux, Windows and Mac OS (please note that the python 2.x series is deprecated and will not receive any further update after January 1, 2020).

--

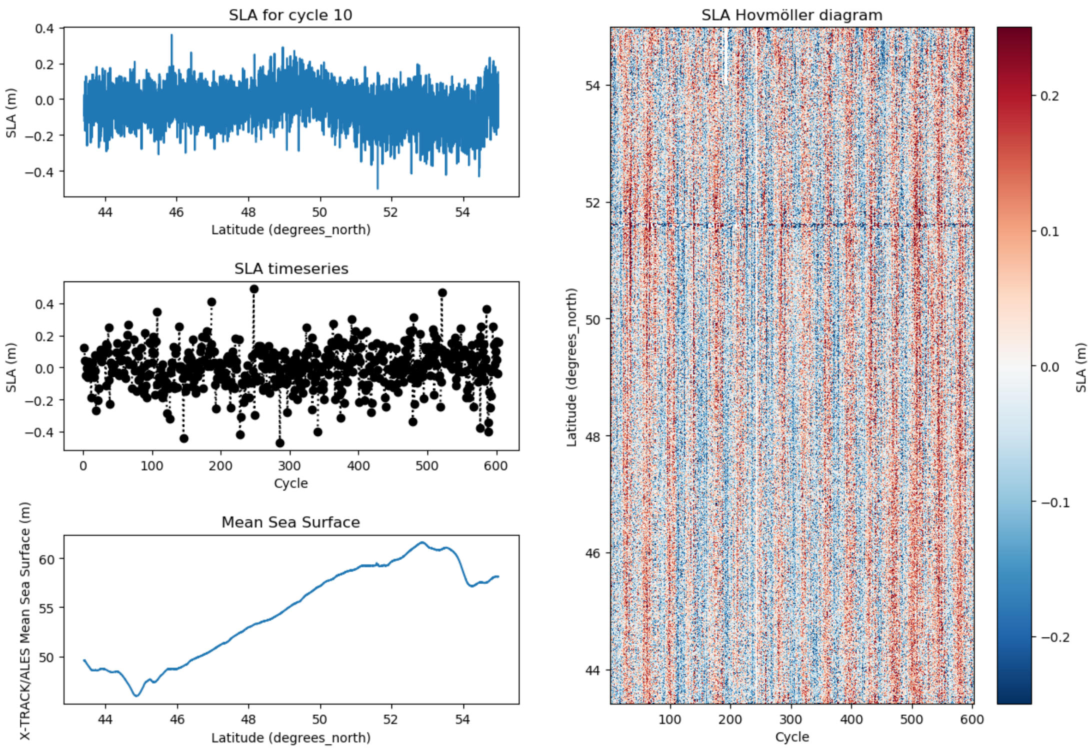


Figure **1** *- Output of the example program of listing 1.*

```
from netCDF4 import Dataset
import matplotlib.pyplot as plt


def read_variable_data(ncid, varname):
    data = ncid.variables[varname][:]
    longname = ncid.variables[varname].long_name
    shortname = ncid.variables[varname].short_name
    units = ncid.variables[varname].units
    return data, shortname, longname, units


# Open the ESA CCI SLA file.
ncid = Dataset("ESACCI-SEALEVEL-L3-SLA-NE_ATL-MERGED-20200113-248-fv01.1.nc")

# get variables and metadata
latData, _, latLongName, latUnits = read_variable_data(ncid, "lat")
slaData, slaShortName, _, slaUnits = read_variable_data(ncid, "sla")
mssData, _, mssLongName, mssUnits = read_variable_data(ncid, "mean_sea_surface")

var = "cycle"
cycleData = ncid.variables[var][:]

# create figure window and plot
plt.figure(figsize=(14, 10))
ax = plt.subplot(3, 2, 1)
ax.plot(latData, slaData[:, 9])  # plot sla along latitude for cycle 10
ax.set_ylabel(slaShortName + " (" + slaUnits + ")")
```

```
ax.set_xlabel(latLongName + " (" + latUnits + ")")
ax.set_title("SLA for cycle 10")

ax = plt.subplot(3, 2, 3)
# plot timeseries of sla for the 10th point at lat[10]
ax.plot(cycleData, slaData[9, :], "ok:")
ax.set_xlabel("Cycle")
ax.set_ylabel(slaShortName + " (" + slaUnits + ")")
ax.set_title("SLA timeseries")

ax = plt.subplot(3, 2, 5)
ax.plot(latData, mssData)
ax.set_xlabel(latLongName + " (" + latUnits + ")")
ax.set_ylabel(mssLongName + " (" + slaUnits + ")")
ax.set_title("Mean Sea Surface")

cmap = "RdBu_r"  # colormap name
ax = plt.subplot(1, 2, 2)
pc = ax.pcolor(cycleData, latData, slaData, vmin=-0.25, vmax=0.25, cmap=cmap)
ax.set_xlabel("Cycle")
ax.set_ylabel(latLongName + " (" + latUnits + ")")
ax.set_title("SLA Hovmöller diagram")
cb = plt.colorbar(pc)
cb.set_label(slaShortName + " (" + slaUnits + ")")

plt.subplots_adjust(hspace=0.5)  # space between subplot

ncid.close()  # Close the NetCDF file.
plt.show()  # Show our completed plot
```

3.7 References

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4. Coastal sea level trends along track product

4.1 Definition

This coastal sea level trend product is derived from the regional coastal along-track product. Thus, this product is a 16-year-long (June 2002 to May 2018), high-resolution (20 Hz), along-track sea level dataset in coastal zones of six regions: Mediterranean Sea, Northeast Atlantic, West Africa, North Indian Ocean, Southeast Asia and Australia. The new coastal sea level data set is based on the standards described in section 2 (i.e., complete reprocessing of raw radar altimetry waveforms from the Jason-1, Jason-2 and Jason-3 missions to derive satellite sea surface ranges as close as possible to the coast and optimization of the geophysical corrections applied to the range measurements). At each point of measurements along the tracks, the 10-day data are further averaged on a monthly basis, annual and semi-annual signals are removed and a new data editing is applied (based on a 2-sigma elimination of Jason cycles), at each 20-Hz sea level anomaly time series up to 20 km offshore. The corresponding monthly coastal sea level time series have been further analysed to compute sea level trends over the 16-year time span at each along-track 20-Hz point, from 20 km offshore to the coast. A severe selection (described in detail in the article “Climate Change Initiative Coastal Sea Level Team, Nature Scientific Data, submitted, June 2020) has been further carried out on all coastal portions of satellite tracks crossing land, leading to retain a set of 429 coastal sites of valid sea level time series and trend values.

This dataset is suitable for studying long-term sea level trends, while the regional coastal along-track product includes all the data and is recommended for studying coastal circulation.

4.2 Nomenclature

The nomenclature used for this product is:
ESACCI-SEALEVEL-IND-MSLTR-<MISSION>-<ZONE>_<ORBIT>_<PassNumber>_<SiteNumber>-<ProductionDateYYYYMMDD>-fv01.1.nc

Where <MISSION> is:
MERGED for multi-mission data

and <ZONE> is one of:
MED_SEA, for the Mediterranean Sea, 30°N/46°N, -6°E/37°E
NE_ATL, for the North East Atlantic Ocean, 35°N/60°N, -15°E/10°E
N_INDIAN, North Indian Ocean, 0°N/26,5°N, 42,5°E/99°E
S_AUSTRALIA, South Australia, -45°N/-15°N, 105°E/160°E
SE_ASIA, Southeast Asia, -25°N/30°N, 90°E/150°E
WAFRICA, for the West African Coasts, -8°N/20°N, -30°E/13,5°E

<ORBIT> is:
JA for Jason orbits

<PassNumber> is the Jason track number

<SiteNumber> is the site number on the track numbered from north to south

For example, the time series data associated with track 222 site number 2 in the North East Atlantic Ocean, produced on 2020/06/02 is found in a file whose name is:
ESACCI-SEALEVEL-IND-MSLTR-MERGED-**NE_ATL**_JA_**222_02**-20200310-fv01.1.nc

4.3 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 on: https://www.unidata.ucar.edu/software/netcdf/

4.4 Data handling variable

Variables	**Description**
lat	Latitude of each 20 Hz point
lon	Longitude of each 20 Hz points
distance_to_coast	Distance to a reference point at the coast of each 20 Hz point
time	Time of measurements
sla	Monthly sea level anomaly (SLA) time series over June 2002 to May 2018 derived from the original 10-day X-TRACK/ALES SLA after post-processing at each 20 Hz point along-track (from 20 km offshore to the coast). Annual and inter-annual signals have been removed.
local_sla_trend	Sea level trends computed from the monthly SLAs time series at each 20 Hz point along track (from 20 km offshore to the coast).
local_sla_trend_error	Sea level trend errors at each 20 Hz point along track

4.5 NetCDF header

4.5.1 Global attributes

// global attributes:

:title = "SL_cci+ L3 X-TRACK/ALES Altimeter Sea Level Trends in the region NE_ATL" ;
:institution = "ESA, CTOH/LEGOS, Toulouse Univ., CNRS, IRD, CNES, UPS, France" ;
:source = "Jason-1 GDR-E, Jason-2 GDR-D, Jason-3 GDR-D, RADS 4.0, ALES" ;
:history = "2020-04-04 generated by X-TRACK v.1.06" ;

:references = "http://www.esa-sealevel-cci.org/products" ;
:tracking_id = "ace2d682-e0da-42e8-ac8f-a366b638edc2" ;
:Conventions = "CF-1.7" ;
:version = "X-TRACK/ALES 1.1" ;
:pass_number = "222" ;
:site_number = "01" ;
:product_version = "1.1" ;
:summary = "This dataset contains 20 Hz regional sea level trends computed from sea level anomalies combining ALES retracker and post-processing strategy of X-TRACK" ;
:keywords = "satellite, ocean, coastal altimetry" ;
:id = "ESACCI-SEALEVEL-IND-MSLTR-MERGED-NE_ATL_JA_222_01-20200404-fv01.1.nc" ;
:doi = " " ;
:naming_authority = "ESA CCI+" ;
:keywords_vocabulary = "NetCDF COARDS Climate and Forecast Standard Names" ;
:cdm_data_type = "Trajectory" ;
:comment = "These data were produced at LEGOS as part of the ESA SL_CCI+ project." ;
:date_created = "2020-02-06" ;
:creator_name = "CTOH/LEGOS, Toulouse Univ., CNRS, IRD, CNES, UPS, France" ;
:creator_url = "http://www.esa-sealevel-cci.org" ;
:creator_email = "info-sealevel@esa-sealevel-cci.org" ;
:project = "Sea Level Climate Change Initiative - European Space Agency" ;
:geospatial_lat_min = "55.2331 " ;
:geospatial_lat_max = "55.3515 " ;
:geospatial_lon_min = "-7.09489 " ;
:geospatial_lon_max = "-6.89854 " ;
:geospatial_vertical_min = "0" ;
:geospatial_vertical_max = "0" ;
:time_coverage_start = "2002-06-01" ;
:time_coverage_end = "2018-05-30" ;
:time_coverage_duration = "P16Y" ;
:time_coverage_resolution = "P9DT21H58M27.84S" ;
:standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table v67" ;
:license = "ESA CCI Data Policy: free and open access" ;
:platform = "Jason-1, Jason-2 and Jason-3" ;
:sensor = "Poseidon-2, Poseidon-3 and Poseidon-3B" ;
:spatial_resolution = "350 m" ;
:geospatial_lat_units = "degrees_north" ;
:geospatial_lon_units = "degrees_east" ;
:key_variables = "local_sla_trend" ;

4.5.2 Variables attributes

variables:

float distance_to_coast(nbpoints) ;

distance_to_coast:_FillValue = 1.844674e+19f ;

distance_to_coast:long_name = "Distance to GSHHS 1.3 coastline" ;

distance_to_coast:units = "m" ;

distance_to_coast:distance_to_coast_min = 1586.44f ;

```
        distance_to_coast:distance_to_coast_max = 19717.8f ;
        distance_to_coast:comment = "Distance along track to a reference point at the coast " ;
float lat(nbpoints) ;
        lat:long_name = "Latitude" ;
        lat:standard_name = "latitude" ;
        lat:units = "degrees_north" ;
        lat:lat_min = 55.2331f ;
        lat:lat_max = 55.3515f ;
float lon(nbpoints) ;
        lon:long_name = "Longitude" ;
        lon:standard_name = "longitude" ;
        lon:units = "degrees_east" ;
        lon:lon_min = -7.09489f ;
        lon:lon_max = -6.89854f ;
double time(nbcycle) ;
        time:_FillValue = 99.9999 ;
        time:units = "days since 1950-1-1" ;
        time:calendar = "julian" ;
        time:long_name = "Time" ;
        time:standard_name = "time" ;
float local_sla_trend(nbpoints) ;
        local_sla_trend:_FillValue = 1.844674e+19f ;
        local_sla_trend:long_name = "Geographical distribution of mean sea level trends" ;
        local_sla_trend:standard_name = "tendency_of_sea_surface_height_above_sea_level" ;
        local_sla_trend:units = "mm/year" ;
        local_sla_trend:comment = "Sea level trends computed from X-TRACK/ALES monthly sea
        level anomalies between 2002-06-01 and 2016-05-30" ;
float local_sla_trend_error(nbpoints) ;
        local_sla_trend_error:_FillValue = 1.844674e+19f ;
        local_sla_trend_error:long_name = "Geographical distribution of mean sea level trends
        errors" ;
        local_sla_trend_error:units = "mm/year" ;
        local_sla_trend_error:add_offset = 0.f ;
        local_sla_trend_error:scale_factor = 1.f ;
float sla(nbpoints, nbcycle) ;
        sla:_FillValue = 1.844674e+19f ;
        sla:units = "m" ;
        sla:standard_name = "sea_surface_height_above_mean_sea_level" ;
```

sla:comment = "sla = altitude of satellite - 20 Hz Ku band ALES corrected altimeter range (Passaro et al. 2014) - altimeter ionospheric correction on Ku band (From dual-frequency altimeter range measurements) - model dry tropospheric correction (From ECMWF model) - GPD+ wet tropospheric correction (Fernandes et al. 2015) - sea state bias correction in Ku band (ALES retracking, Passaro et al. 2014) - solid earth tide height (From RADS, tide potential model, Cartwright and Taylor 1971, Cartwright and Eden 1973) - geocentric ocean tide (FES 2014 from RADS, Carrere et al. 2012) - geocentric pole tide height (Wahr 1985) - Atmospheric correction (From RADS, Carrere and Lyard 2003) - X-TRACK mean sea surface (Birol et al. 2017). Each corrective term is edited following Birol et al. 2017." ;

4.6 Example

This monthly product allows to study long-term coastal trend in numerous sites. Fig.2 shows such an example that contains sea level anomalies and trends at site n°2 on track 20 in the Mediterranean Sea. From top to bottom, it shows a map of the site position on the track, the sea level trends at each 20-Hz point, expressed as a function of distance to the coast, starting from 15 km offshore, and superimposed trend errors, and finally sea level anomaly time series at the first six valid points from the coast. The monthly sea level anomalies also allow to recompute the trend over the desired period, for instance to compare with tide gauges at the coast.

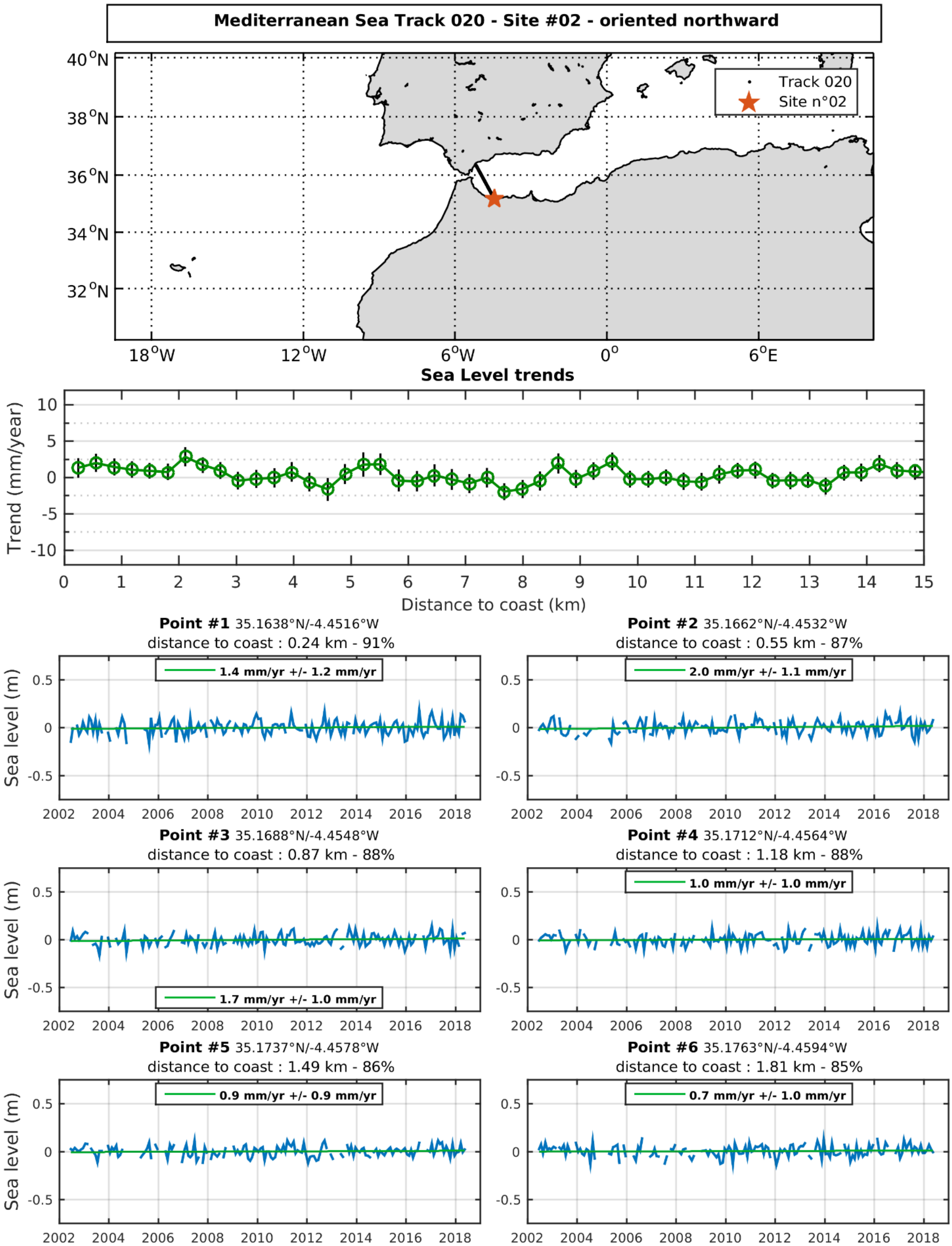

Fig 2. Position (top), trends and trend errors (vertical bars) along-track as a function of distance to the coast (middle) and sea level anomalies time series of the 6 first points (bottom) for the site n°2 on track 20 in Mediterranean Sea; the % of valid data is indicated at the top of each plot.

The product also allows global analyses to be performed (see article "Climate Change Initiative Coastal Sea Level Team, Nature Scientific Data, submitted, June 2020"), as illustrated in figure 3 showing differences between coastal trends (at the closest distance to the coast of the first valid point) and open ocean trends at each site. This map alo provide information on the location of the 429 selected sites.

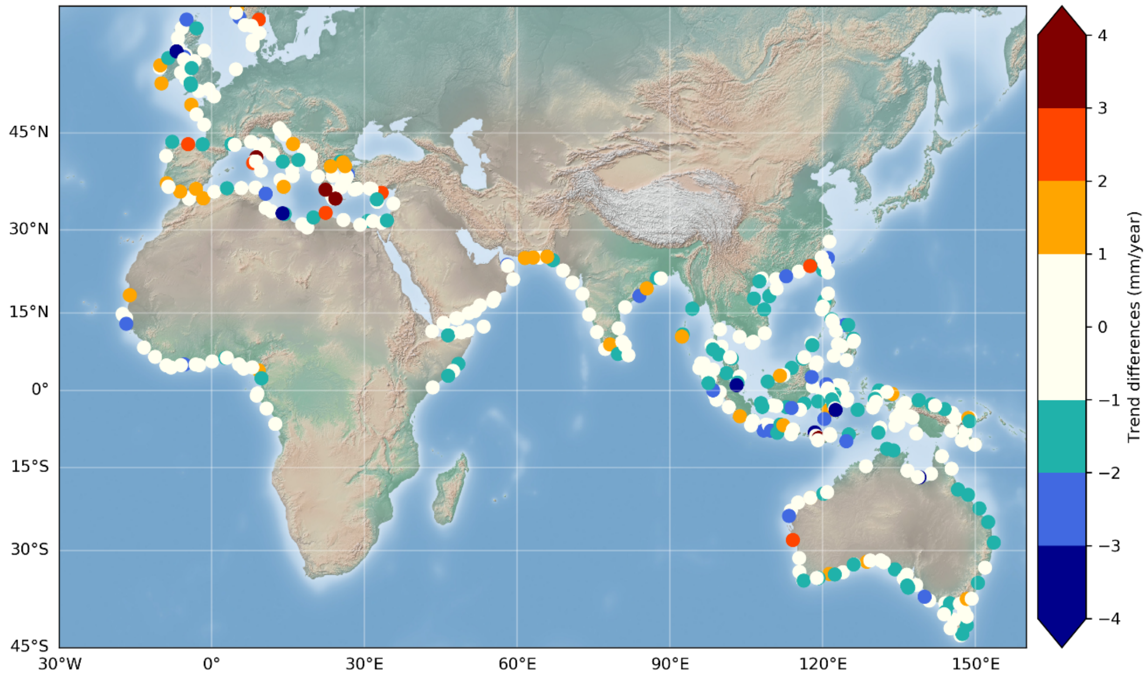

Fig.3. Differences in sea level trends between an along-track band of 2 km from the closest valid point to the coast and the 14-16 km average, offshore. 'Cream' colour corresponds to no significant differences. Orange-red-brown and green-blue dots correspond to coastal trend increase and decrease respectively at the coast.

4.7 Références

Birol F. and C. Delebecque, 2014. Using high sampling rate (10/20 Hz) altimeter data for the observation of coastal surface currents: A case study over the northwestern Mediterranean Sea, *J. Mar. Syst.*, https://doi.org/10.1016/j.jmarsys.2013.07.009.

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