Coastal Delayed Time Sea Level Anomaly product (CoastalDT-SLA) handbook

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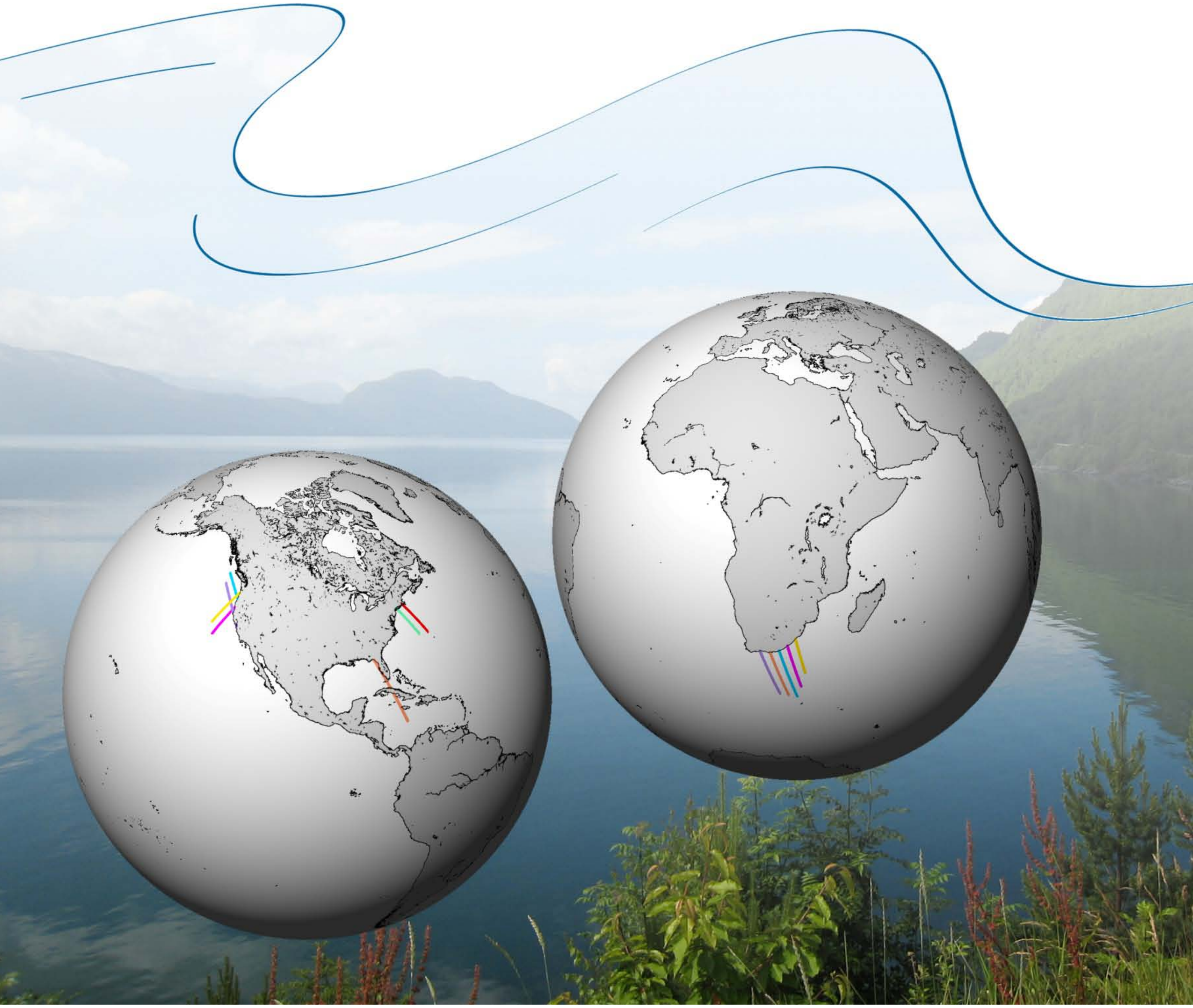

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1. Introduction

1.1. Overview of this document

This document describes the **Coastal along-track Delayed Time Sea Level Anomaly (CoastalDT-SLA) products** distributed by Aviso on dedicated regions (Agulhas current, Florida Strait, Oregon and Mid Atlantic Bight). They are **experimental products**, conceived as an **evolution** of the **"Coastal and Hydrological" products** processed thanks to PISTACH project (Prototype Innovant de Système de Traitement pour les Applications Côtières et l'Hydrologie).

1.2. What are the input "Coastal and Hydrological" PISTACH products?

As described in the dedicated Handbook (http://www.aviso.oceanobs.com/en/data/tools/aviso-user-handbooks/index.html), the **"Coastal and Hydrological" PISTACH** products include new retracking solutions, several state-of-the-art geophysical corrections as well as higher resolution global/local models, in addition to the content of standard Jason2 IGDRs (NetCDF, with the nomenclature of variables and files similar to that for IGDRs). The products are accessible through the Aviso web site with data provided as high-resolution along-track products (20 Hz sampling rate, with fields which are either interpolated or copied), and about 80 extra fields. Two products exist: one dedicated to **coastal applications**, and another one dedicated to **hydrological applications**. The **input product** used for **Coastal along-track Delayed Time Sea Level Anomaly (CoastalDT-SLA) products** is dedicated to **coastal applications**, covering the whole ocean plus a 25-km fringe over land.

The **"Coastal and Hydrological" PISTACH products** in Near Real Time are enriched I-GDR (level 2) dataset in NetCDF with

- Along-track sampling: 20hz (~300 meters) instead of classical 1hz (~ 6 km)
- New estimation of the satellite-sea distance (retracking)
- Atmospheric corrections improved near the coasts (wet tropospheric)
- Up-To-Date global tidal corrections
- Several Mean Sea Surface fields

It has been demonstrated that more altimetry data are recovered in coastal areas thanks to **"Coastal and Hydrological" PISTACH products** compared to standard GDR or AVISO products (subsampled and filtered products: DT-SLA)

BUT, some drawbacks are raised to the use of these products:

- The Level 2 Pistach products address altimetry experts and are quite difficult to use for non expert users
- SSH field is not filled in: it needs to be computed by users as a combination of other fields
- The high-frequency signal is noisy: still need to be proceeded and filtered

This is why Cnes envisionned simpler products for a wider dissemination.

1.3. Contribution of "Coastal along-track Delayed Time Sea Level Anomaly (CoastalDT-SLA)" products

This product supported by Cnes has been developed by CLS with the support of NOVELTIS and LEGOS to fulfill the needs of coastal oceanographers (Dufau et al., 2011, Coastal altimetry book, Springer). It provides a directly usable Level 3 coastal product to address the needs of the scientific community: high resolution sea surface height on reference track. It might be a complementary information to the coastal datasets, as NOAA/Coastwatch or PREVIMER observations. It was demonstrated that products really needed to be updated in order to:

- Ease the use of the coastal dedicated PISTACH product
- Increase/attract new users of altimetry in coastal ocean
- Receive feedback from users and develop collaboration with coastal teams for assessment
- Go through higher resolution SLA (compared to GDRs) to address small-scales signals

1.4. User's feedback

The CoastalDT-SLA products are **experimental** products.

Therefore, we consider that each and every question, comment, example of use, suggestion will help us improve the product and will thus be welcome at aviso@oceanobs.com.

2. Geographical coverage

The products are delivered on 4 areas:

1. Agulhas current
   The delivered passes are the following 198, 20, 96, 172, 248 and are displayed on Figure 1

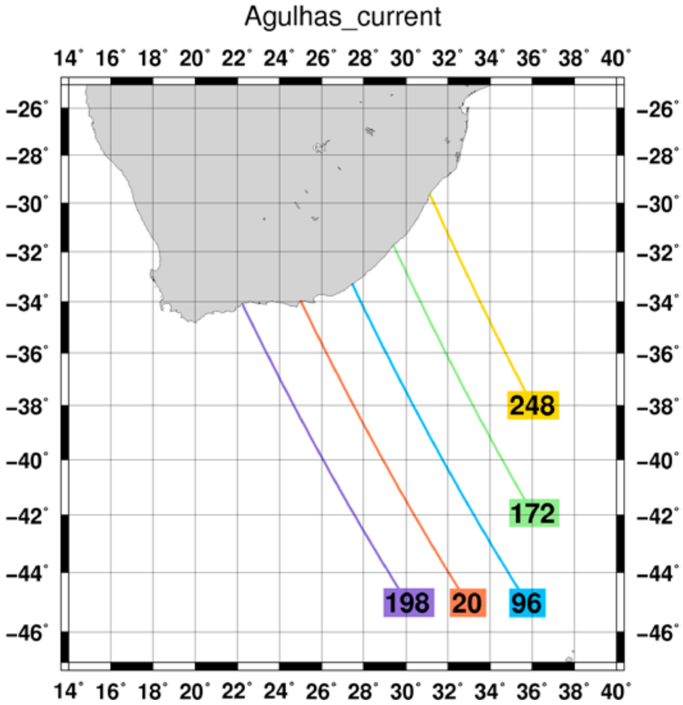

Figure 1: Passes 20, 96, 172, 198, 248 for the region « Agulhas current »

2. Florida Strait

   One pass (number 102) is processed for this area, as shown on Figure 2

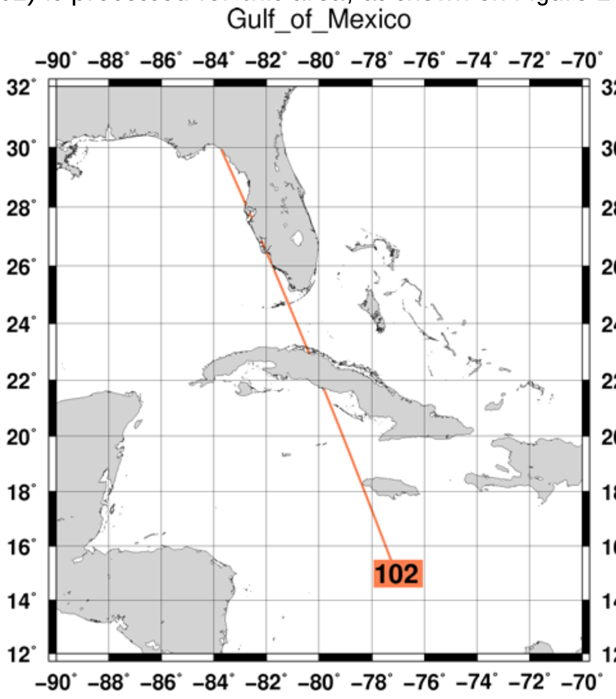

Figure 2: Pass 102 over the "Florida Strait"

3. Mid Atlantic Bight

   Two passes are processed (number 50 and 126) for the Mid Atlantic Bight as displayed in Figure 3

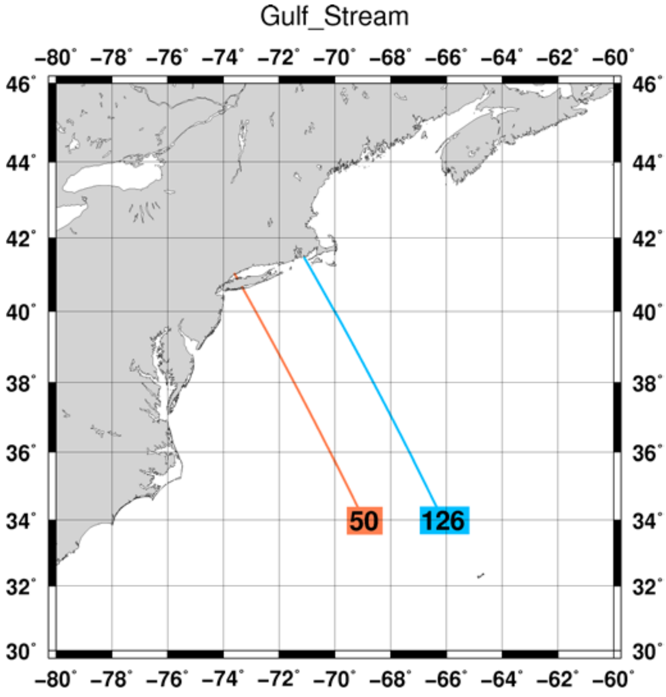

Figure 3: Passes 50 and 126 over the region "Mid Atlantic Bight"

4. Oregon
   Four passes are processed (28, 69,206, 247) for the Oregon area as displayed in Figure 4

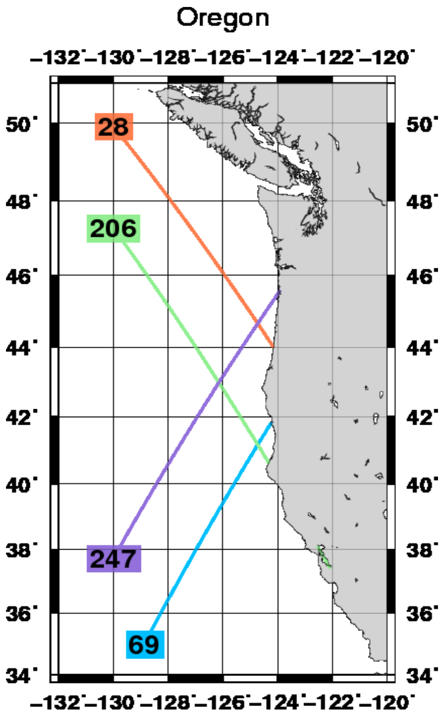

Figure 4: Passes 28, 69,206 and 247 over the region "Oregon"

3. Processing

The processing consists in selecting the most appropriate corrections for the SLA calculation, perform outlier detection and filter the data to remove the 20 Hz noise that prevents from extracting easily the oceanic signal compared to the 1 Hz data.

3.1. Input data

The input products are the **"Coastal and Hydrological"** Level 2 products processed thanks to PISTACH (Prototype Innovant de Système de Traitement pour les Applications Côtières et l'Hydrologie) project. The handbook is available at

http://www.aviso.oceanobs.com/en/data/tools/aviso-user-handbooks/index.html.

They are Near Real Time products available on ftp.

3.2. Models and corrections applied

The retrackings used in the **Jason-2 coastal along-track Delayed Time Sea Level Anomaly (CoastalDT-SLA) products** are the following:

Retracking used	
MLE4	Standard retracking
OCE3	MLE4 retracking applied to filtered waveforms. Should be used for areas where the altimeter is not too much polluted by emerged lands i.e. at least 15 km offshore
RED3	MLE3 retracking applied on a reduced number of gates. Should be used for areas including near shore zones.

Table 1 : List of the retrackings used in the Jason-2 coastal along-track Delayed Time Sea Level Anomaly (CoastalDT-SLA) products

Hereafter, you will find the corrections applied to the raw SSH:

Orbit	CNES preliminary orbit from Jason-2 IGDRs
Dry Troposphere correction	Same as Jason-2 IGDR (from ECMWF model)
Wet Troposphere correction	Composite wet tropospheric model: whereby the model correction (ECMWF) replaces the radiometer near the coasts (<50 km), or the ECMWF correction is shifted to the nearest valid radiometer value in the transition case. Interpolation and detrending are also applied in complex cases.
Ionosphere correction	Filtered Dual Frequency (Labroue Coastalt Workshop San Diego 2011)
Sea State Bias correction	Same as Jason-2 (I)GDR correction for MLE4 and OCE3 retrackings Empirical correction for RED3 retracking
Ocean tide and loading tide correction	GOT4.8 model
Solid Earth tide correction	Same as Jason-2 IGDR (*Cartwright and Tayler* [1971] and *Cartwright and Edden* [1973])
Pole tide correction	Same as Jason-2 IGDR (*Wahr* [1985])
Combined atmospheric correction	DAC from Delayed Time (Carrere and Lyard, 2003)

Table 2 : list of corrections and models used to compute the Sea Surface Height.

3.3. Overview of the processing steps

The analysis of the processing steps is detailed in Labroue et al., 2011 (poster) and Labroue et al, 2012 (to be submitted). We give here just an overview:

3.3.1.1. Ionospheric filtering

Specific editing and low pass filtering has been performed at 20 Hz to filter the dual frequency ionospheric correction. Thanks to this processing, all the 20 Hz valid data are kept and data gaps are filled by interpolation.

3.3.1.2. Data selection

The development of a **20 Hz dynamical editing** has been performed. This allows more available data and removing events impacting the SLA over scales as small as 20 km.

3.3.1.3. SSH filtering

Filtering is needed for most of the users to reduce the noise. Two filtering are proposed:

- A high resolution product with a cut-off of 7 Km
- A lower resolution product for geostrophic velocities calculation with a cut-off of 14km. Geostrophy lies on the first derivative of SLA, which requires to be filtered enough to ensure the hypothesis.

Note that the 14 km filtering results in a product equivalent to 1Hz resolution (i.e. GDRs)

3.3.1.4. SLA computation

The SLA is computed by:

$$SLA = SSH - MeanProfile$$

Indeed, a Mean Profile (MP) has been calculated over three years of data (cycles 1 to 110) for the three retrackings. The use of a MP instead of a Mean Sea Surface (MSS) improves the SLA computation near the coasts: indeed, the MP has been computed with 20 Hz data contrary to the MSS and thus provides a better coverage and a higher quality near the coasts.

Note that the SLA is projected on a theoretical track (with correction of across-track) which is constant from one cycle to another one.

4. Validation of product

Some examples of use and comparisons with standard Aviso products are available at:
http://www.altimetry.info/html/use_cases/data_use_case_Agulhas1_pistachL3_en.html and
http://www.altimetry.info/html/use_cases/data_use_case_Florida1_pistachL3_en.html

Figure 5 and Figure 6 show the improvement of the spatial coverage of **CoastalDT-SLA** products compared to **DT-SLA** distributed by Aviso. **More altimetry data are recovered in coastal areas** compared to standard AVISO products: Both Tide Gauges, SAR comparisons as well as AVISO/PISTACH comparisons evidence it (Labroue 2012, to be submitted).

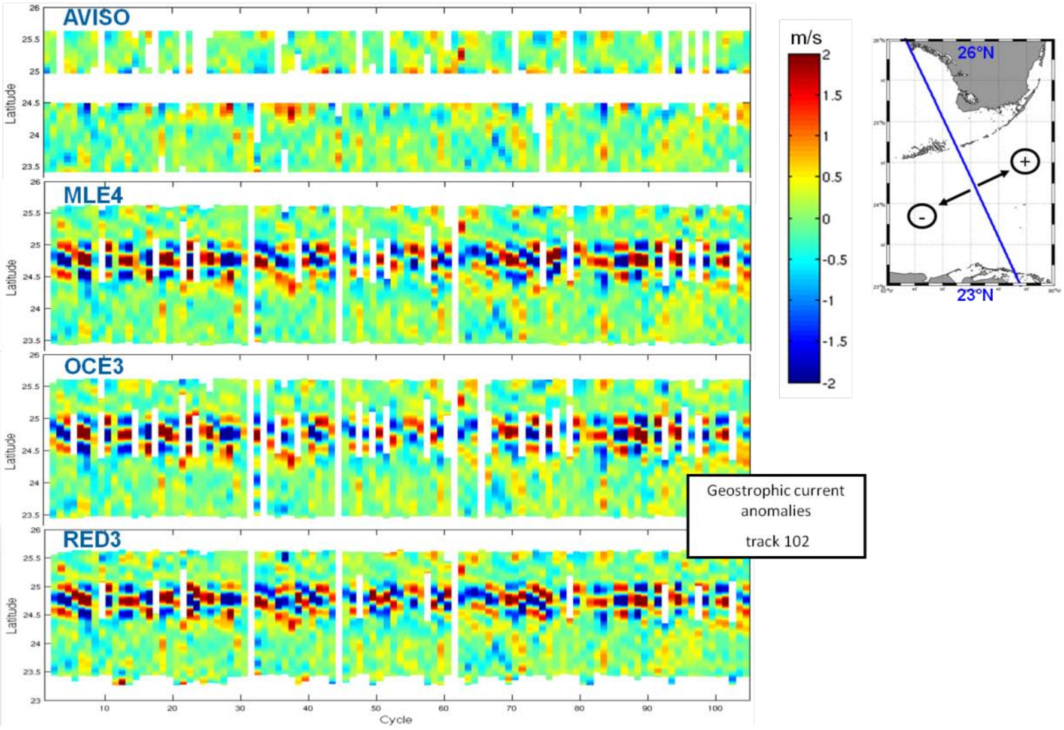

Figure 5 : Comparison of AVISO products (DT-SLA) and CoastalDT-SLA products for pass 102 in Florida Strait

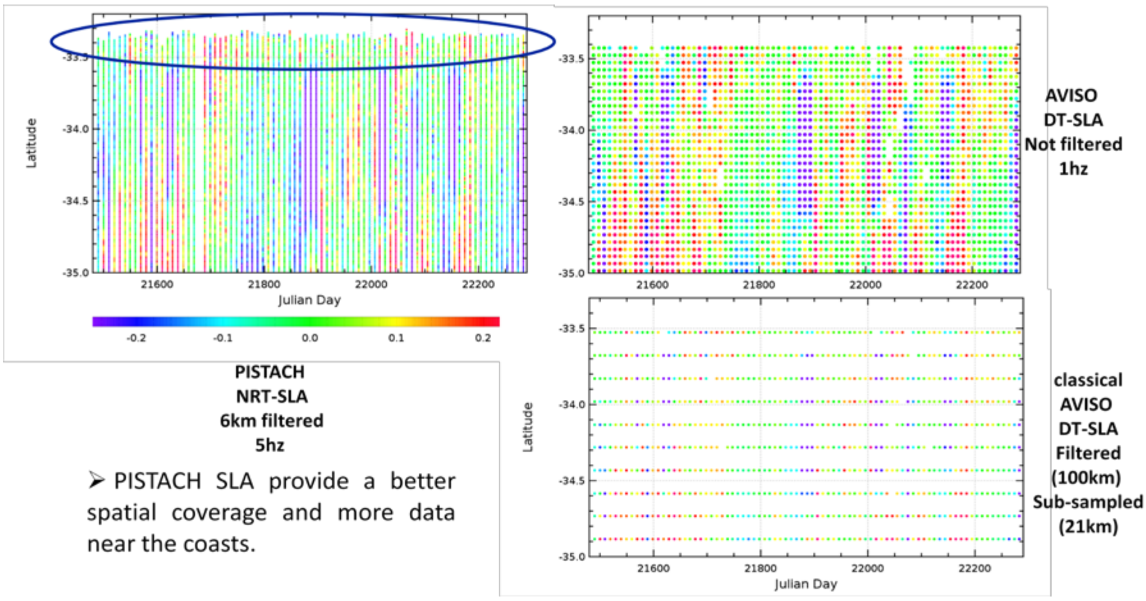

Figure 6 : Comparison of AVISO products (DT-SLA) and CoastalDT-SLA products for pass 96 in Agulhas current

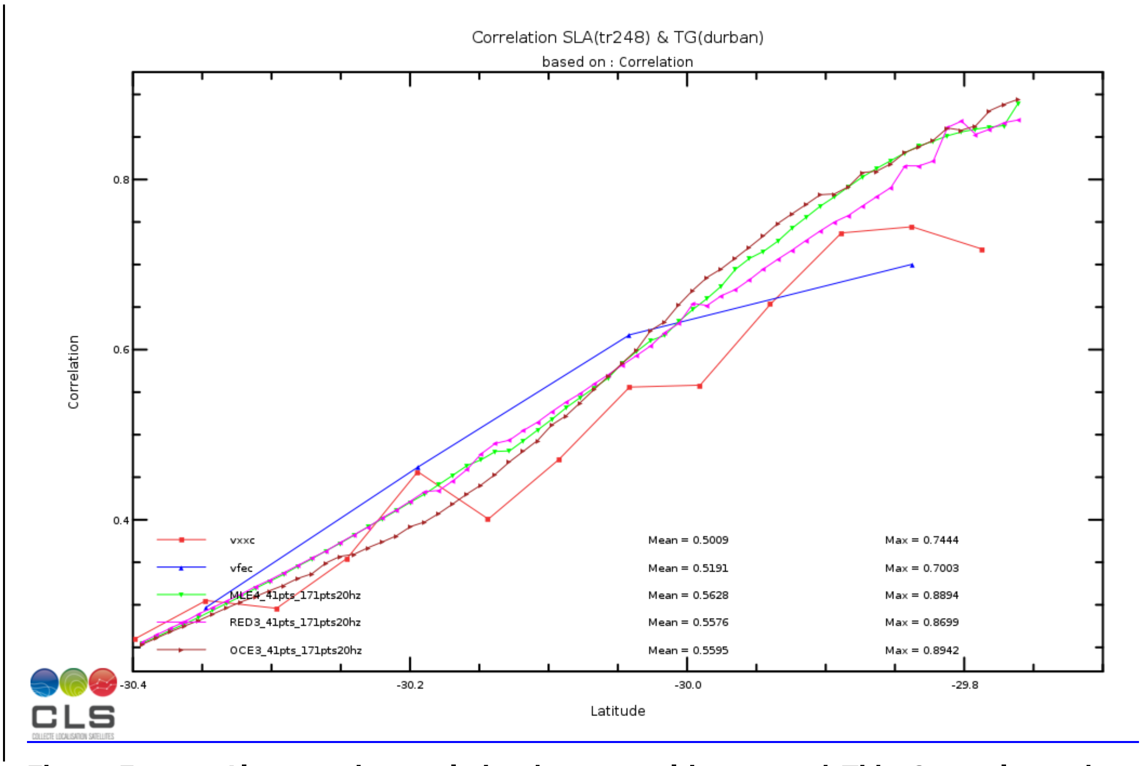

Figure 7: **Along track correlation between altimetry and Tide Gauge located at Durban (Agulhas current). CoastalDT-SLA products (green, pink, dark red) recover more data closer to the coast compared to 1 Hz data (red) and AVISO (blue). The correlation with the tide gauge is improved with the 3 CoastalDT-SLA retrackings and the high resolution data provide a longer data segment where the correlation is significant.**

5. Content of the products

The delivered data contain 6 SLAs computed at 5 Hz sampling: one SLA for each retracking and for each filtering:

SLA = Corrected SSH – Mean Profile

With
Corrected SSH = Orbit – Range
– Dry tropo correction
– Wet tropo correction
– Iono correction
– Sea State bias correction
– Ocean tide and loading tide correction
– Solid Earth tide correction
– Pole tide correction
– Combined atmospheric correction

Moreover, in order to allow modelers to subtract tide and/or atmospheric correction, the tide model and the combined atmospheric corrections are also delivered. Those corrections are issued from the 1 Hz data and interpolated.

6. Data dissemination

6.1. Accessibility of the products

The access to the **CoastalDT-SLA products** needs an authentication. If you already have a login/password on Aviso, the access is automatic. If not, please fill in the form online on: http://www.aviso.oceanobs.com/en/data/registration-form/index.html

Once you have an account, you can log on ftp://ftp.aviso.oceanbs.com, the products are in the following folder:

experimental/coastal_dt_sla_j2

6.2. Nomenclature

The nomenclature of the files is the following:

coastal_dt_sla_j2_**<zone>**_<pass>.nc.gz

where <zone> and <pass> are :

For **Agulhas current**:

coastal_dt_sla_j2_**agulhas**_020.nc.gz
coastal_dt_sla_j2_**agulhas**_096.nc.gz
coastal_dt_sla_j2_**agulhas**_172.nc.gz
coastal_dt_sla_j2_**agulhas**_198.nc.gz
coastal_dt_sla_j2_**agulhas**_248.nc.gz

For **Florida Strait**:

coastal_dt_sla_j2_**florida**_102.nc.gz

For **Mid Atlantic Bight**:

coastal_dt_sla_j2_**mab**_050.nc.gz
coastal_dt_sla_j2_**mab**_126.nc.gz

For **Oregon area**:

coastal_dt_sla_j2_**oregon**_028.nc.gz
coastal_dt_sla_j2_**oregon**_069.nc.gz
coastal_dt_sla_j2_**oregon**_206.nc.gz
coastal_dt_sla_j2_**oregon**_247.nc.gz

6.3. Format

The products are stored using the NetCDF CF 1.4 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 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.

The NetCDF **CoastalDT-SLA** files are based on the attribute data tags defined by the Cooperative Ocean/Atmosphere Research Data Service (COARDS) and Climate and Forecast (CF) metadata conventions. The

CF convention generalizes 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 (see section 6.5)

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

1 dimension is defined:
– time: it is used to check NetCDF variables depending on time.

13 variables are defined:
– double time : contains the time in days since 1950-01-01 00:00:00 UTC for each measurement,
– int latitude : contains the latitude for each measurement,
– int longitude : contains the longitude for each measurement,
– short cycle : contains the cycle number for each measurement.
– short track : contains the track number for each measurement,
– short SLA_Filtered_21pts_MLE4: contains the Sea Level Anomaly values computed with MLE4 retracking and filtered at 7 km for each time given,
– short SLA_Filtered_41pts_MLE4: contains the Sea Level Anomaly values computed with MLE4 retracking and filtered at 14 km for each time given,
– short SLA_Filtered_21pts_RED3: contains the Sea Level Anomaly values computed with RED3 retracking and filtered at 7 km for each time given,
– short SLA_Filtered_41pts_RED3: contains the Sea Level Anomaly values computed with RED3 retracking and filtered at 14 km for each time given,
– short SLA_Filtered_21pts_OCE3: contains the Sea Level Anomaly values computed with OCE3 retracking and filtered at 7 km for each time given,
– short SLA_Filtered_41pts_OCE3: contains the Sea Level Anomaly values computed with OCE3 retracking and filtered at 14 km for each time given,
– short DAC_DT: contains the Dynamic Atmospheric correction for each time given,
– short GOT_4.8: contains the tidal model for each given time.

global attributes: the global attributes gives information about the creation of the file.
Example of a NetCDF sla file:

```
netcdf coastal_dt_sla_j2_agulhas_172.nc
{
dimensions:
        time = UNLIMITED ; // (109294 currently)
variables:
        double time(time) ;
                time:_FillValue = 1.84467440737096e+19 ;
                time:long_name = "Time of measurement" ;
                time:units = "days since 1950-01-01 00:00:00 UTC" ;
                time:standard_name = "time" ;
                time:axis = "T" ;
                time:first_time = "2008-07-18 18:11:50.208277" ;
        int latitude(time) ;
                latitude:_FillValue = 2147483647 ;
                latitude:long_name = "Latitude of measurement" ;
                latitude:units = "degrees_north" ;
                latitude:standard_name = "latitude" ;
                latitude:scale_factor = 1.e-06 ;
                latitude:add_offset = 0. ;
```

```
int longitude(time) ;
        longitude:_FillValue = 2147483647 ;
        longitude:long_name = "Longitude of measurement" ;
        longitude:units = "degrees_east" ;
        longitude:standard_name = "longitude" ;
        longitude:scale_factor = 1.e-06 ;
        longitude:add_offset = 0. ;
short cycle(time) ;
        cycle:_FillValue = 32767s ;
        cycle:long_name = "Cycle the measurement belongs to" ;
        cycle:units = "1" ;
        cycle:coordinates = "longitude latitude" ;
short track(time) ;
        track:_FillValue = 32767s ;
        track:long_name = "Track in cycle the measurement belongs to" ;
        track:units = "1" ;
        track:coordinates = "longitude latitude" ;
short SLA_Filtered_21pts_MLE4(time) ;
        SLA_Filtered_21pts_MLE4:_FillValue = 32767s ;
        SLA_Filtered_21pts_MLE4:long_name = "Sea Level Anomaly" ;
        SLA_Filtered_21pts_MLE4:units = "meters" ;
        SLA_Filtered_21pts_MLE4:scale_factor = 0.001 ;
        SLA_Filtered_21pts_MLE4:coordinates = "longitude latitude" ;
        SLA_Filtered_21pts_MLE4:add_offset = 0. ;
short SLA_Filtered_41pts_MLE4(time) ;
        SLA_Filtered_41pts_MLE4:_FillValue = 32767s ;
        SLA_Filtered_41pts_MLE4:long_name = "Sea Level Anomaly" ;
        SLA_Filtered_41pts_MLE4:units = "meters" ;
        SLA_Filtered_41pts_MLE4:scale_factor = 0.001 ;
        SLA_Filtered_41pts_MLE4:coordinates = "longitude latitude" ;
        SLA_Filtered_41pts_MLE4:add_offset = 0. ;
short SLA_Filtered_21pts_RED3(time) ;
        SLA_Filtered_21pts_RED3:_FillValue = 32767s ;
        SLA_Filtered_21pts_RED3:long_name = "Sea Level Anomaly" ;
        SLA_Filtered_21pts_RED3:units = "meters" ;
        SLA_Filtered_21pts_RED3:scale_factor = 0.001 ;
        SLA_Filtered_21pts_RED3:coordinates = "longitude latitude" ;
        SLA_Filtered_21pts_RED3:add_offset = 0. ;
short SLA_Filtered_41pts_RED3(time) ;
        SLA_Filtered_41pts_RED3:_FillValue = 32767s ;
        SLA_Filtered_41pts_RED3:long_name = "Sea Level Anomaly" ;
        SLA_Filtered_41pts_RED3:units = "meters" ;
        SLA_Filtered_41pts_RED3:scale_factor = 0.001 ;
        SLA_Filtered_41pts_RED3:coordinates = "longitude latitude" ;
        SLA_Filtered_41pts_RED3:add_offset = 0. ;
short SLA_Filtered_21pts_OCE3(time) ;
        SLA_Filtered_21pts_OCE3:_FillValue = 32767s ;
        SLA_Filtered_21pts_OCE3:long_name = "Sea Level Anomaly" ;
        SLA_Filtered_21pts_OCE3:units = "meters" ;
        SLA_Filtered_21pts_OCE3:scale_factor = 0.001 ;
        SLA_Filtered_21pts_OCE3:coordinates = "longitude latitude" ;
        SLA_Filtered_21pts_OCE3:add_offset = 0. ;
short SLA_Filtered_41pts_OCE3(time) ;
        SLA_Filtered_41pts_OCE3:_FillValue = 32767s ;
        SLA_Filtered_41pts_OCE3:long_name = "Sea Level Anomaly" ;
```

```
        SLA_Filtered_41pts_OCE3:units = "meters" ;
        SLA_Filtered_41pts_OCE3:scale_factor = 0.001 ;
        SLA_Filtered_41pts_OCE3:coordinates = "longitude latitude" ;
        SLA_Filtered_41pts_OCE3:add_offset = 0. ;
    short DAC_DT(time) ;
        DAC_DT:_FillValue = 32767s ;
        DAC_DT:long_name = "DAC_DT" ;
        DAC_DT:units = "meters" ;
        DAC_DT:scale_factor = 0.001 ;
        DAC_DT:coordinates = "longitude latitude" ;
        DAC_DT:add_offset = 0. ;
    short GOT_4.8(time) ;
        GOT_4.8:_FillValue = 32767s ;
        GOT_4.8:long_name = "GOT_4.8" ;
        GOT_4.8:units = "meters" ;
        GOT_4.8:scale_factor = 0.001 ;
        GOT_4.8:coordinates = "longitude latitude" ;
        GOT_4.8:add_offset = 0. ;

// global attributes:
        :Conventions = "CF-1.4" ;
        :Comment = "Produced from Jason-2 satellite altimetry data" ;
        :Institution = "CLS/CNES" ;
        :References =
"http://www.aviso.oceanobs.com/fileadmin/documents/data/tools/hdbk_coastal_sla_j2.pdf" ;
        :Source = "Satellite altimetry" ;
        :Title = "PISTACH Level-3 data for track 172, 3 retrackings" ;
```

6.4. Time Availability

The data are available for three years: cycles 1 to 110 (from 12/07/2008 to 07/07/2011)

6.5. Reading software

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

Moreover, BRAT (Basic Radar Altimetry Toolbox: http://www.altimetry.info/html/data/toolbox_en.html), developed for reading altimeter data can be used for the CoastalDT-SLA products make it possible to quickly and efficiently visualize and handle these data. Some examples of use are described in:
http://www.altimetry.info/html/use_cases/data_use_case_Agulhas1_pistachL3_en.html and

http://www.altimetry.info/html/use_cases/data_use_case_Florida1_pistachL3_en.html

Appendix A - List of acronyms

AD	Applicable Document
AGC	Automatic Gain Control
AMR	Advanced Microwave Radiometer
AVISO	Archivage, Validation et Interprétation des données des Satellites Océanographiques
BRAT	Basic Radar Altimetry Toolbox
BUFR	**B**inary **U**niversal **F**orm for the **R**epresentation of Meteorological data
CLIVAR	Climate Variability and Predictability program
CLS	Collecte Localisation Satellites
CNES	Centre National d'Etudes Spatiales
DEM	Digital Elevation Model
DIODE	Détermination Immédiate d'Orbite par Doris Embarque
DORIS	Détermination d'Orbite et Radiopositionnement Intégrés par Satellite
DTM	Digital Terrain Model
ECMWF	European Center for Medium range Weather Forecasting
EGM	Earth Gravity Model
EM	ElectroMagnetic
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FES	Finite Element Solution
FFT	Fast Fourier Transform
GDR	Geophysical Data Records
GIM	Global Ionosphere Maps
GMT	Generic Mapping Tools
GODAE	Global Ocean Data Assimilation Experiment
GPS	Global Positioning System
GTS	Global Telecommunications System
HF	High Frequency
IB	Inverse Barometer
IGDR	Interim Geophysical Data Records
JAXA	Japan Aerospace Exploration Agency
JGM	Joint Gravity Model
JPL	Jet Propulsion Laboratory
LPT	Light Particle Telescope
MDT	Mean Dynamic Topography
MLE	Maximum Likelihood Estimator
MSS	Mean Sea Surface
NASA	National Aeronautics and Space Administration
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real Time
NWP	Numerical Weather Prediction
OGDR	Operational Geophysical Data Records
OSTM	Ocean Surface Topography Mission
OSU	Ohio State University
PO.DAAC	Physical Oceanography Distributed Active Archive Center
POD	Precision Orbit Determination
POE	Precision Orbit Ephemerides
PROTEUS	Plate Forme Reconfigurable pour l'Observation de la TErre, les télécommuncations et les Utilisations Scientifiques
RD	Reference Document
RMS	Root Mean Square
RSS	Root Sum Square
SLA	Sea Level Anomaly
SLR	Satellite Laser Ranging
SSALTO	Segment Sol multimissions d'ALTimétrie, d'Orbitographie et de localisation précise
SSB	Sea State Bias
SSH	Sea Surface Height
SSHA	Sea Surface Height Anomaly
SWH	Significant Wave Height
T/P	Topex/Poseidon
T2L2	Time Transfer by Laser Link
TBC	To be confirmed

TBD	To be defined
TEC	Total Electron Content
TRSR	Turbo Rogue Space Receiver
UTC	Universal Time Coordinated
WMO	World Meteorological Organisation

Appendix B - References

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