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ESA Sea Level CCI

D3.4 Product User Guide

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People involved in this issue:		
Written by (*):	C. Maheu (CLS)	Date + Initials:(visa or ref)
Checked by (*):	G Timms (CGI)	Date + Initial:(visa ou ref)
Approved by (*):	JF Legeais (CLS)	Date + Initial:(visa ou ref)
Application authorized by (*):	J. Benveniste (ESA)	Date + Initial:(visa ou ref)

**In the opposite box: Last and First name of the person + company if different from CLS*

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Distribution:		
Company	Means of distribution	Names
ESA	Email	Jérôme Benveniste, Americo Ambrozio, Marco Restano
CLS	Email	Gilles Larnicol, Jean-François Legeais, Michael Ablain
CGI	Email	Gary Timms
SLCCI Project FTP		ftp.esa-sealevel-cci.org
SLCCI Website		http://www.esa-sealevel-cci.org/documents

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Applicable documents

AD 1 Sea level CCI project Management Plan
CLS-DOS-NT-10-013

Reference documents

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List of Contents

1. Introduction

The Product User Guide (PUG) contains the description for the Fundamental Climate Data Record (FCDR) and the Essential Variable Climate (ECV) data products which are produced in the Sea Level CCI project. It provides the end user with practical information regarding the use of these products.

This consists in defining their content, format, the altimetry standards applied for their calculation, the software tools enabled to decode the data and their known limitations.

With regards to the applied altimetry standards, it is important to recall the different versions of these products:

- **Version 0 (v0)**: The sea level product generated using the existing standard algorithms. This product corresponds to the state of the art at the beginning of the project.
- **Version 1 (v1.0)**: The sea level product generated using the algorithms selected and developed in the first phase of the project. It was delivered to users in September 2012.
- **Version 1.1 (v1.1)**: It was an update of v1.0 products including new wet troposphere corrections for all altimeter missions and reprocessed level 2 products concerning Jason-2 (GDR-D) and Envisat (V2.1) missions.
- **Version 2.0 (v2.0)**: It is the last version of the products generated during phase II of the project. The major evolutions compared to v1.1 are associated with the use of new level 2 altimeter standards. New altimeter missions have been included (see Figure 1).

The Version 2.0 of the products will replace the previously existing products. The period covered by the v2.0 sea level record is 1993-2014 and the reprocessing will be extended until December 2015 by the end of 2016.

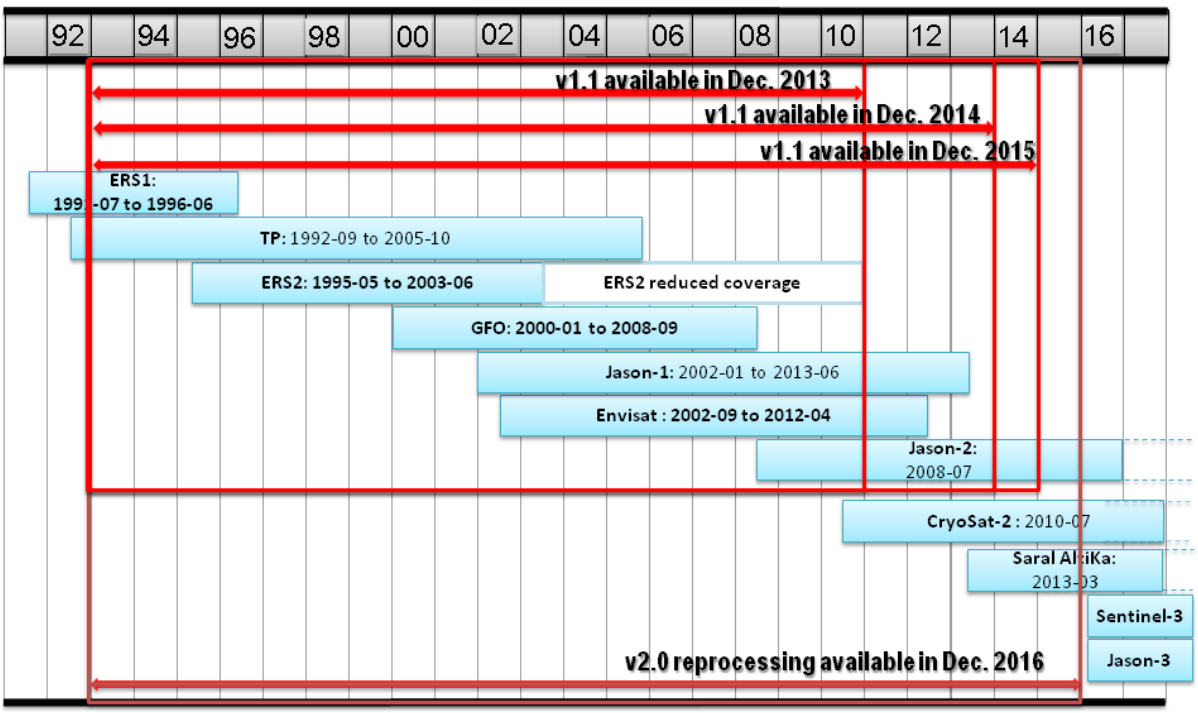

Figure 1: Level 2 GDR altimeter data, used as input data to generate the FCDR and ECV products, are included in the red squares according to the version of the product.

2. Instrument overview

Altimeter satellites measure the height of the sea surface above (or below) some reference level by sending a microwave pulse to the ocean's surface and timing how long it takes to return. The Sea Surface Height (SSH) is the difference between a satellite's position in orbit with respect to an arbitrary reference surface (the Earth's center or a rough approximation of the Earth's surface: the TOPEX/Poseidon reference ellipsoid) and the satellite-to-surface range (calculated by measuring the time taken for the signal to make the round trip).

To obtain measurements accurate to within a few centimeters over a range of several hundred kilometers requires an extremely precise knowledge of the satellite's orbital position. Thus several locating systems are usually aboard altimetry satellites. Any interference with the radar signal also needs to be taken into account. A microwave radiometer corrects any delay that may be caused by water vapor in the atmosphere. Other corrections are also required to account for the influence of electrons in the ionosphere and the dry air mass of the atmosphere. Combining these data with the precise location of the spacecraft makes it possible to determine the SSH. See references [1] and [2] for more information.

3. Altimetric standards applied for Version-2.0

The altimeter standards currently applied to calculate the SSH are summarized in the following table separating the altimetry missions. They correspond to the version 2.0 of FCDR and ECV products.

<table>
<tr><th colspan="8">Standards and references for version 2.0 of FCDR and ECV products</th></tr>
<tr><th rowspan="2">Corrections</th><th colspan="7">Altimeter missions</th></tr>
<tr><th>Jason1 / Jason-2</th><th>TOPEX / Poseidon</th><th>Envisat</th><th>ERS-1/ERS-2</th><th>GFO</th><th>SARAL/AltiKa</th><th>CryoSat-2</th></tr>
<tr><td>Orbit</td><td>CNES POE (GDR-E standards)</td><td>GSFC POE (standard 2015)</td><td>GFZ POE (standard 2015)</td><td>GFZ POE (standard 2015)</td><td>- GSFC POE (std 08/2009),
- NAVSOC POE (where no GSFC POE)</td><td>CNES POE (GDR-E standards)</td><td>CNES POE (GDR-E standards)</td></tr>
<tr><td>Dry troposphere</td><td colspan="7">Era Interim based</td></tr>
<tr><td>Wet troposphere</td><td colspan="4">GPD+ algorithm [Fernandes et al., 2016] [12]</td><td>From GFO radiom. Further than 50 km from the coasts. From ECMWF model for distances between 10 and 50 km. From ECMWF model for cycles 135-137,166,181-189,and >201</td><td colspan="2">GPD+ algorithm [Fernandes et al., 2016] [12]</td></tr>
</table>

Standards and references for version 2.0 of FCDR and ECV products							
Corrections	**Altimeter missions**						
	Jason1 / Jason-2	**TOPEX / Poseidon**	**Envisat**	**ERS-1/ERS-2**	**GFO**	**SARAL/AltiKa**	**CryoSat-2**
Ionosphere	Filtered (iterative method) dual-frequency altimeter range measurements (SLOOP project)	Filtered (iterative method) dual-frequency altimeter range measurements (for TOPEX) and Doris (for *Poseidon*)	- before cy65: Filtered (iterative method) dual-Frequency altimeter range measurements (SLOOP project) - cy65 onwards: GIM+8mm	NIC09 on ERS-1 NIC09/GIM on ERS-2	GIM model [Iijima et al., 1999] [3]	GIM model [Iijima et al., 1999] [3]	GIM model [Iijima et al., 1999] [3]
Sea State Bias	Non parametric SSB (from GDR) Tran et al., 2012 [13]	Non parametric SSB (Topex) [Tran et al., 2010] [4] BM4 formula (Poseidon) [Gaspar et al., 1996] [5]	Non parametric SSB, Tran (2015) [14]	3-parameter SSB [Gaspar, Ogor, 1994] [6] Non parametric SSB [Mertz et al.,2005] [7],	Non parametric SSB, Tran and Labroue, 2009 [15]	Non Parametric SSB (PEACHI project 2014 2D)	Non Parametric SSB (from Jason-1 GDR-C products)
Ocean tide	FES2014 (Including ocean tides, long period equilibrium tide, S1 tides…)						
Loading tide	GOT4V8 AC [Ray, 2013] [10]						
Solid Earth tide	Elastic response to tidal potential [Cartwright and Tayler, 1971] [8], [Cartwright and Edden, 1973] [9]						
Pole tide	[Desai, 2015] [11]						
Combined atmospheric correction	Era interim based						
MSS	DTU15						
Major Instrumental correction					USO correction correcting for anomaly periods and aging drift from auxiliary files		

Table 1: Standards and references for version 2.0 of FCDR and ECV products

4. Fundamental Climate Data Record (FCDR)

4.1. Definition

The FCDR (**SL_FCDR**) is a **mono-mission** product generated from the altimeter level-2 products (as geophysical data records (GDR) product for instance). It contains the **along-track** sea level height (SSH) estimates over ocean with a quality control indicator to remove spurious measurements. It contains also the altimeter standards applied in the SSH calculation as the geophysical corrections, the mean sea surface (MSS), etc... In addition, information derived from the cross-calibration of the SSH among all missions is provided in order to remove the global/regional SSH bias and to homogenize long spatial scale errors (e.g. due to orbit calculation).

Data are produced along the tracks of the different altimeters, with a resolution of 1Hz corresponding to a ground distance close to 6km. There are separated dataset products for each altimeter mission, divided into files by altimetric cycle corresponding to the repetivity of the mission.

Mission	ERS 1 & 2	Envisat	Topex	Jason-1	Jason-2	Geosat Follow-on	SARAL/AltiKa	Cryosat-2
Repetitivity	35 days	35 days	9.9 days	9.9 days	9.9 days	17 days	35 days	369 days

Table 2: Repetitivity of the altimeter missions

4.2. Nomenclature

The nomenclature used for the along-track FCDR is:

***VariableProject_Data_Mission_Cycle_Version*.nc**
Example: SLCCI_ALTDB_J2_Cycle094_V1.nc

VariableProject	**SLCCI**	Sea Level Climate Change Initiative
Data	**ALTDB**	Altimeter Database
Mission	**E1**	ERS-1
	E2	ERS-2
	EN	Envisat
	TP	Topex/Poseidon
	J1	Jason-1
	J2	Jason-2
	G2	Geosat Follow On
	AL	SARAL/AltiKa
	C2	Cryosat-2
Cycle	**xxx**	Cycle number of the given altimeter mission
Version	**Vx**	version number

Table 3: Nomenclature of the FCDR product

4.3. Format

The FCDR products are stored using the NetCDF (Network Common Data Form) using CF v1.4 (Climate and Forecast) Metadata convention (See 6. Software tools on how to read data).

4.4. Data Handling Variables

One dimension is defined:

- time: number of data per parameter in current file

Type	Name	Content	Unit	Scale Factor
double	time(time)	Time of measurement	days since 1950-01-01 00:00:00 UTC	none
int	latitude(time)	Latitude of measurement	degrees_north	10^{-6}
int	longitude(time)	Longitude of measurement	degrees_east	10^{-6}
short	cycle(time)	Cycle the measurement belongs to	1	none
short	pass(time)	Track in cycle the measurement belongs to	1	none
short	TimeDay(time)	Number of days from reference date	days since 1950-01-01 00:00:00 UTC	none
short	TimeSec(time)	Number of seconds within the day	sec	none
short	TimeMicroSec(time)	Microseconds: decimal part of the TimeSec variable	1e-6 sec	none
int	corssh(time)	Corrected sea surface height above the TOPEX/Poseidon reference ellipsoid	meters	10^{-4}
int	alt(time)	1 Hz altitude of satellite	meters	10^{-4}
int	range(time)	1 Hz Ku band corrected altimeter range	meters	10^{-4}
short	dry_tropo_corr(time)	Model dry tropospheric correction	meters	10^{-4}
short	sea_state_bias(time)	Non parametric sea state bias	meters	10^{-4}
short	iono_corr(time)	Ionospheric correction	meters	10^{-4}
short	rad_wet_tropo_corr(time	Radiometer wet tropospheric correction	meters	10^{-4}
short	model_wet_tropo_corr(time)	ECMWF model wet tropospheric correction	meters	10^{-4}
short	gpd_wet_tropo_corr(time)	Wet tropospheric correction based on the GPD+ algorithm	meters	10^{-4}
short	dyn_atmosph_corr(time)	Combined atmospheric correction[1]	meters	10^{-4}

[1] *Combined atmospheric correction : high frequency fluctuations of the sea surface topography and inverted barometer height correction computed from rectangular grids*

short	off_nadir_angle(time)	Square of the off nadir angle computed from Ku waveforms (= (across_track mispointing angle)^2+ (along_track mispointing angle) ^2)	degrees^2	10^{-4}
short	wind_speed_alt(time)	Altimeter wind speed	meters/seconde	10^{-3}
byte	alt_flag_oper(time)	Altimeter state flag, operating: O=SideA, 1=SideB	none	1
byte	rad_qual_interp_flag(time)	Radiometer quality interpolation flag (0=good, 1=interpolation with gap, 2=extrapolation, 3=fail)	none	1
int	bathymetry(time)	Bathymetry	meters	10^{-3}
int	mean_sea_surface(time)	Mean sea surface height	meters	10^{-4}
int	ocean_tide(time)	Ocean tide height, including the corresponding long period equilibrium tide and the S1 tide	meters	10^{-4}
int	loading_tide(time)	Loading tide height corresponding to ocean tide	meters	10^{-4}
short	pole_tide(time)	Pole tide height	meters	10^{-4}
short	sigma0(time)	Backscatter coefficient	dB	10^{-3}
short	solid_earth_tide(time)	Solid earth tide height	meters	10^{-4}
short	swh(time)	Significant wave height	meters	10^{-4}
byte	range_numval(time)	Number of valid points for Ku band range	count	1
short	range_rms(time)	RMS of the Ku band range	meters	10^{-4}
byte	sigma0_numval(time)	Number of valid points for Ku band range	count	1
short	sigma0_rms(time)	RMS of the Ku band backscattering coefficient	dB	10^{-4}
byte	validation_flag(time)	Validity flag (0=valid, 1=non valid)	1	none
byte	rad_surf_type(time)	Radiometer surface type	none	1
byte	alt_surf_type(time)	Altimeter surface type (0=ocean, 1=land)	none	1
byte	ice_flag(time)	Ice flag (0=ocean, 1=ice)	none	1
short	global_bias	Global relative SSH Bias among all the missions	meters	10^{-4}
short	regional_bias	Regional relative SSH Bias among all the missions	meters	10^{-4}

4.4.1. Empty Fields

It should also be noted that only the fields which are useful for the computation of the sea level anomalies are filled with defined values. Other fields are empty. The following table describes if the fields are defined or empty:

Name	Content	Field
time(time)	Time of measurement	Defined
latitude(time)	Latitude of measurement	Defined
longitude(time)	Longitude of measurement	Defined
cycle(time)	Cycle the measurement belongs to	Defined
pass(time)	Track in cycle the measurement belongs to	Defined
TimeDay(time)	Number of days from reference date	Defined
TimeSec(time)	Number of seconds within the day	Defined
TimeMicroSec(time)	Microseconds: decimal part of the TimeSec variable	Defined
corssh(time)	Corrected sea surface height above the TOPEX/Poseidon reference ellipsoid	Defined
alt(time)	1 Hz altitude of satellite	Defined
range(time)	1 Hz Ku band corrected altimeter range	Defined
dry_tropo_corr(time)	Model dry tropospheric correction	Defined
sea_state_bias(time)	Non parametric sea state bias	Defined
iono_corr(time)	Ionospheric correction	Defined
rad_wet_tropo_corr(time	Radiometer wet tropospheric correction	Empty
model_wet_tropo_corr(time)	ECMWF model wet tropospheric correction	Empty
gpd_wet_tropo_corr(time)	Wet tropospheric correction based on the GPD+ algorithm	Defined
dyn_atmosph_corr(time)	Combined atmospheric correction[2]	Defined

[2] *Combined atmospheric correction : high frequency fluctuations of the sea surface topography and inverted barometer height correction computed from rectangular grids*

off_nadir_angle(time)	Square of the off nadir angle computed from Ku waveforms (= (across_track mispointing angle)^2+ (along_track mispointing angle) ^2)	Empty
wind_speed_alt(time)	Altimeter wind speed	Empty
alt_flag_oper(time)	Altimeter state flag	Empty
rad_qual_interp_flag(time)	Radiometer quality interpolation flag	Empty
bathymetry(time)	Bathymetry	Defined
mean_sea_surface(time)	Mean sea surface height	Defined
ocean_tide(time)	Ocean tide height, including the corresponding long period equilibrium tide and the S1 tide	Defined
loading_tide(time)	Loading tide height corresponding to the ocean tide	Defined
pole_tide(time)	Pole tide height	Defined
sigma0(time)	Backscatter coefficient	Empty
solid_earth_tide(time)	Solid earth tide height	Defined
swh(time)	Significant wave height	Empty
range_numval(time)	Number of valid points for the Ku band range	Empty
range_rms(time)	RMS of the Ku band range	Empty
sigma0_numval(time)	Number of valid points for the Ku band range	Empty
sigma0_rms(time)	RMS of the Ku band backscattering coefficient	Empty
validation_flag(time)	Validity flag (0=valid, 1=non valid)	Defined
rad_surf_type(time)	Radiometer surface type	Empty
alt_surf_type(time)	Altimeter surface type (0=ocean, 1=land)	Defined
ice_flag(time)	Ice flag (0=ocean, 1=ice)	Empty
global_bias	Global relative SSH Bias between all the missions	Defined
regional_bias	Regional relative SSH Bias between all the missions	Defined

4.4.2. Surface type flag

The *alt_surf_type* field reported in the previous section specifies the altimeter surface type with the value 0 for ocean and 1 for land. Note that for Jason-2, *alt_surf_type* values may equal to 0, 1, 2 or 3 and all non-zero values are equivalent to *alt_surf_type* = 1 in the other missions' products.

However, as FCDR products are designed to study the Sea Level, only measurements over the ocean are kept. Hence, the alt_surf_type field contains only zeros.

4.5. NetCDF Header

4.5.1. Global attributes

Additional global attributes are available. They are providing information about the type of product or the processing and parameters used.

Attribute	Format	Description
title	string	A succinct description of what is in the dataset.
OriginalName	string	Name of the file
CreatedBy	string	Name of the consortium at the origin of the dataset
CreatedOn	string	Date of file creation
Mission	string	Name (abbreviation) of the altimeter mission the data come from
MeanProfile	string	Cycle number
Version	string	Version number
Conventions	string	Convention used for format of the file
history	string	Provides an audit trail for modifications to the original data

4.5.2. Variable attributes

The different variables can be described with different attributes as listed in the following table:

Attribute	Description
_FillValue	A value used to represent missing or undefined data
add_offset	If present, this number is to be added to the data after it is read by an application. If both *scale_factor* and *add_offset* attributes are present, the data are scaled before the offset is added.
coordinates	Identified auxiliary coordinates variables.
long_name	A descriptive name that indicates a variable's content. This name is not standardized.
scale_factor	If present, the data have to be multiplied by this factor after being read by an application. See also *add_offset* attribute.
units	Unit of a variable's content. The value of this attribute must be a string that can be recognized by the UNIDATA's Udunits package.
Valid_range	If present, smallest and largest theoretical valid values of a variable

4.6. Computation of the Corrected Sea Surface Height

Along with the corrected sea surface height (*corssh*) other altimeter parameters, geophysical corrections, as well as flags, are also provided in altimetric database. The variables used to compute the corssh are detailed below.

For Envisat:

corssh = alt - range - dyn_atmosph_corr - sea_state_bias - ocean_tide - loading_tide - pole_tide - solid_earth_tide - dry_tropo_corr - gpd_wet_tropo_corr - iono_corr

If needed, the user can therefore easily replace one correction by another (e.g. the gpd_wet_tropo_corr by a correction invented by himself).

It is advised to use the validation flag (*validation_flag*), but users may apply their own validation criteria.

4.7. Example

```
netcdf SLCCI_ALTDB_J2_Cycle276_V2 {
dimensions:
        time = UNLIMITED ; // (597458 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 = "2015-12-29 20:34:47.139997" ;
        double latitude(time) ;
                latitude:_FillValue = 1.84467440737096e+19 ;
                latitude:long_name = "Latitude of measurement" ;
                latitude:units = "degrees_north" ;
                latitude:standard_name = "latitude" ;
        double longitude(time) ;
                longitude:_FillValue = 1.84467440737096e+19 ;
                longitude:long_name = "Longitude of measurement" ;
                longitude:units = "degrees_east" ;
                longitude:standard_name = "longitude" ;
        short cycle(time) ;
                cycle:_FillValue = 32767s ;
                cycle:long_name = "Cycle the measurement belongs to" ;
                cycle:units = "1" ;
        short pass(time) ;
                pass:_FillValue = 32767s ;
                pass:long_name = "Track in cycle the measurement belongs to" ;
                pass:units = "1" ;
        short TimeDay(time) ;
                TimeDay:_FillValue = 32767s ;
                TimeDay:long_name = "Number of days from reference date" ;
                TimeDay:units = "days since 1950-01-01 00:00:00.000 UTC" ;
                TimeDay:coordinates = "longitude latitude" ;
        int TimeSec(time) ;
                TimeSec:_FillValue = 2147483647 ;
                TimeSec:long_name = "Number of seconds within the day" ;
                TimeSec:units = "sec" ;
                TimeSec:valid_range = 0, 86400 ;
                TimeSec:coordinates = "longitude latitude" ;
        int TimeMicroSec(time) ;
                TimeMicroSec:_FillValue = 2147483647 ;
                TimeMicroSec:long_name = "Microseconds: decimal part of the TimeSec variable" ;
                TimeMicroSec:units = "1e-6 sec" ;
                TimeMicroSec:valid_range = 0, 999999 ;
                TimeMicroSec:coordinates = "longitude latitude" ;
        int corssh(time) ;
```

```
                corssh:_FillValue = 2147483647 ;
                corssh:long_name = "Corrected sea surface height above the TOPEX/Poseidon reference ellipsoid" ;
                corssh:units = "m" ;
                corssh:scale_factor = 0.0001 ;
                corssh:coordinates = "longitude latitude" ;
        int alt(time) ;
                alt:_FillValue = 2147483647 ;
                alt:long_name = "1 Hz altitude of satellite" ;
                alt:units = "m" ;
                alt:scale_factor = 0.0001 ;
                alt:add_offset = 1300000. ;
                alt:coordinates = "longitude latitude" ;
        int range(time) ;
                range:_FillValue = 2147483647 ;
                range:long_name = "1 Hz Ku band corrected altimeter range" ;
                range:units = "m" ;
                range:scale_factor = 0.0001 ;
                range:add_offset = 1300000. ;
                range:coordinates = "longitude latitude" ;
        short sea_state_bias(time) ;
                sea_state_bias:_FillValue = 32767s ;
                sea_state_bias:long_name = "Non parametric sea state bias correction" ;
                sea_state_bias:units = "m" ;
                sea_state_bias:scale_factor = 0.0001 ;
                sea_state_bias:coordinates = "longitude latitude" ;
        short iono_corr(time) ;
                iono_corr:_FillValue = 32767s ;
                iono_corr:long_name = "altimeter ionospheric correction on Ku band (filtered)" ;
                iono_corr:units = "m" ;
                iono_corr:scale_factor = 0.0001 ;
                iono_corr:coordinates = "longitude latitude" ;
        short gpd_wet_tropo_corr(time) ;
                gpd_wet_tropo_corr:_FillValue = 32767s ;
                gpd_wet_tropo_corr:long_name = "Wet Tropospheric correction based on the GPD+ algorithm, ECMWF
over Caspian Sea" ;
                gpd_wet_tropo_corr:units = "m" ;
                gpd_wet_tropo_corr:scale_factor = 0.0001 ;
                gpd_wet_tropo_corr:coordinates = "longitude latitude" ;
        byte alt_flag_oper(time) ;
                alt_flag_oper:_FillValue = 127b ;
                alt_flag_oper:long_name = "altimeter state flag: altimeter operating" ;
                alt_flag_oper:units = "1" ;
                alt_flag_oper:scale_factor = 1. ;
                alt_flag_oper:coordinates = "longitude latitude" ;
        int bathymetry(time) ;
                bathymetry:_FillValue = 2147483647 ;
                bathymetry:long_name = "Bathymetry" ;
                bathymetry:units = "m" ;
                bathymetry:scale_factor = 0.001 ;
                bathymetry:coordinates = "longitude latitude" ;
        short dyn_atmosph_corr(time) ;
                dyn_atmosph_corr:_FillValue = 32767s ;
                dyn_atmosph_corr:long_name = "Combined atmospheric correction : high frequency fluctuations of the
sea surface topography and inverted barometer height correction computed from rectangular grids" ;
                dyn_atmosph_corr:units = "m" ;
                dyn_atmosph_corr:scale_factor = 0.0001 ;
                dyn_atmosph_corr:coordinates = "longitude latitude" ;
        short dry_tropo_corr(time) ;
                dry_tropo_corr:_FillValue = 32767s ;
                dry_tropo_corr:long_name = "Model dry tropospheric correction" ;
                dry_tropo_corr:units = "m" ;
                dry_tropo_corr:scale_factor = 0.0001 ;
                dry_tropo_corr:coordinates = "longitude latitude" ;
        short rad_wet_tropo_corr(time) ;
                rad_wet_tropo_corr:_FillValue = 32767s ;
                rad_wet_tropo_corr:long_name = "Radiometer wet tropospheric correction" ;
                rad_wet_tropo_corr:units = "m" ;
                rad_wet_tropo_corr:scale_factor = 0.0001 ;
                rad_wet_tropo_corr:coordinates = "longitude latitude" ;
        short model_wet_tropo_corr(time) ;
                model_wet_tropo_corr:_FillValue = 32767s ;
                model_wet_tropo_corr:long_name = "model wet tropospheric correction" ;
                model_wet_tropo_corr:units = "m" ;
```

```
            model_wet_tropo_corr:scale_factor = 0.0001 ;
            model_wet_tropo_corr:coordinates = "longitude latitude" ;
      int mean_sea_surface(time) ;
            mean_sea_surface:_FillValue = 2147483647 ;
            mean_sea_surface:long_name = "Mean sea surface height" ;
            mean_sea_surface:units = "m" ;
            mean_sea_surface:scale_factor = 0.0001 ;
            mean_sea_surface:coordinates = "longitude latitude" ;
      int ocean_tide(time) ;
            ocean_tide:_FillValue = 2147483647 ;
            ocean_tide:long_name = "Ocean tide height (loading tide excluded)" ;
            ocean_tide:units = "m" ;
            ocean_tide:scale_factor = 0.0001 ;
            ocean_tide:coordinates = "longitude latitude" ;
      int loading_tide(time) ;
            loading_tide:_FillValue = 2147483647 ;
            loading_tide:long_name = "Loading tide height" ;
            loading_tide:units = "m" ;
            loading_tide:scale_factor = 0.0001 ;
            loading_tide:coordinates = "longitude latitude" ;
      short pole_tide(time) ;
            pole_tide:_FillValue = 32767s ;
            pole_tide:long_name = "Geocentric pole tide height" ;
            pole_tide:units = "m" ;
            pole_tide:scale_factor = 0.0001 ;
            pole_tide:coordinates = "longitude latitude" ;
      short sigma0(time) ;
            sigma0:_FillValue = 32767s ;
            sigma0:long_name = "Ku-band Backscatter coefficient" ;
            sigma0:units = "dB" ;
            sigma0:scale_factor = 0.001 ;
            sigma0:coordinates = "longitude latitude" ;
      short solid_earth_tide(time) ;
            solid_earth_tide:_FillValue = 32767s ;
            solid_earth_tide:long_name = "Solid earth tide height" ;
            solid_earth_tide:units = "m" ;
            solid_earth_tide:scale_factor = 0.0001 ;
            solid_earth_tide:coordinates = "longitude latitude" ;
      short swh(time) ;
            swh:_FillValue = 32767s ;
            swh:long_name = "Ku-band Significant wave height" ;
            swh:units = "m" ;
            swh:scale_factor = 0.001 ;
            swh:coordinates = "longitude latitude" ;
      byte range_numval(time) ;
            range_numval:_FillValue = 127b ;
            range_numval:long_name = "number of valid points for Ku band range" ;
            range_numval:units = "count" ;
            range_numval:scale_factor = 1. ;
            range_numval:coordinates = "longitude latitude" ;
      short range_rms(time) ;
            range_rms:_FillValue = 32767s ;
            range_rms:long_name = "RMS of the Ku band range" ;
            range_rms:units = "m" ;
            range_rms:scale_factor = 0.0001 ;
            range_rms:coordinates = "longitude latitude" ;
      byte sigma0_numval(time) ;
            sigma0_numval:_FillValue = 127b ;
            sigma0_numval:long_name = "number of valid points for Ku band range" ;
            sigma0_numval:units = "count" ;
            sigma0_numval:scale_factor = 1. ;
            sigma0_numval:coordinates = "longitude latitude" ;
      short sigma0_rms(time) ;
            sigma0_rms:_FillValue = 32767s ;
            sigma0_rms:long_name = "RMS of the Ku band backscattering coefficient" ;
            sigma0_rms:units = "dB" ;
            sigma0_rms:scale_factor = 0.001 ;
            sigma0_rms:coordinates = "longitude latitude" ;
      byte validation_flag(time) ;
            validation_flag:_FillValue = 127b ;
            validation_flag:long_name = "validation flag: 0=valid, 1=non valid" ;
            validation_flag:units = "1" ;
            validation_flag:scale_factor = 1. ;
```

```
                validation_flag:coordinates = "longitude latitude" ;
        byte rad_surf_type(time) ;
                rad_surf_type:_FillValue = 127b ;
                rad_surf_type:long_name = "radiometer surface type: 0=ocean, 1=land" ;
                rad_surf_type:units = "1" ;
                rad_surf_type:scale_factor = 1. ;
                rad_surf_type:coordinates = "longitude latitude" ;
        int regional_bias(time) ;
                regional_bias:_FillValue = 2147483647 ;
                regional_bias:long_name = "regional bias" ;
                regional_bias:units = "m" ;
                regional_bias:scale_factor = 0.0001 ;
                regional_bias:coordinates = "longitude latitude" ;
        int global_bias(time) ;
                global_bias:_FillValue = 2147483647 ;
                global_bias:long_name = "global bias" ;
                global_bias:units = "m" ;
                global_bias:scale_factor = 0.0001 ;
                global_bias:coordinates = "longitude latitude" ;
        byte alt_surf_type(time) ;
                alt_surf_type:_FillValue = 127b ;
                alt_surf_type:long_name = "altimeter surface type: 0=water, 1=land" ;
                alt_surf_type:units = "1" ;
                alt_surf_type:scale_factor = 1. ;
                alt_surf_type:coordinates = "longitude latitude" ;
        byte ice_flag(time) ;
                ice_flag:_FillValue = 127b ;
                ice_flag:long_name = "ice flag: 0=no ice, 1=ice" ;
                ice_flag:units = "1" ;
                ice_flag:scale_factor = 1. ;
                ice_flag:coordinates = "longitude latitude" ;
        byte rad_qual_interp_flag(time) ;
                rad_qual_interp_flag:_FillValue = 127b ;
                rad_qual_interp_flag:long_name = "flag for brightness temperatures: 0=all channels good 1=one or more
channels fair 2=one or more channels poor 3=one or more channels with interpolation failure (bad)" ;
                rad_qual_interp_flag:units = "1" ;
                rad_qual_interp_flag:scale_factor = 1. ;
                rad_qual_interp_flag:coordinates = "longitude latitude" ;
        short off_nadir_angle(time) ;
                off_nadir_angle:_FillValue = 32767s ;
                off_nadir_angle:long_name = "square of the off nadir angle computed from Ku waveforms" ;
                off_nadir_angle:units = "degrees2" ;
                off_nadir_angle:scale_factor = 0.0001 ;
                off_nadir_angle:coordinates = "longitude latitude" ;
        short wind_speed_alt(time) ;
                wind_speed_alt:_FillValue = 32767s ;
                wind_speed_alt:long_name = "altimeter wind speed" ;
                wind_speed_alt:units = "m/s" ;
                wind_speed_alt:scale_factor = 0.001 ;
                wind_speed_alt:coordinates = "longitude latitude" ;

// global attributes:
                :title = "SLCCI Altimeter database V2.0 for Jason-2 Cycle 276" ;
                :OriginalName = "SLCCI_ALTDB_J2_Cycle276_V2.nc" ;
                :CreatedBy = "slcci" ;
                :CreatedOn = "07-NOV-2016 21:12:20:000000" ;
                :Mission = "J2" ;
                :MeanProfile = "Jason-2 276" ;
                :Version = "2.0" ;
                :Conventions = "CF-1.4" ;
                :history = "2016/11/07 21:13:09 slcci@px-2042 ConvertATPInternalToCF: Converted to CF" ;
}
```

4.8. Changes in FCDR v2.0 versus v1.1

Users should be aware that in the FCDR v1.1, the ocean_tide field is a geocentric ocean tide (i.e it contains the loading tide). In FCDR v2.0, the ocean tide (ocean_tide) and the loading tide (loading_tide) have been separated to allow the user to choose to take this effect into account or replace the ocean tide by another model.

The field comp_wet_tropo_corr in FCDR v1.1 has been replaced by gpd_wet_tropo_corr for more clarity.

In the FCDR v2.0 release, standards have been upgraded for a better quality of the products. These standards have been selected in order to provide the best long-term stability for climate applications and not necessarily the best data coverage. The counterpart is the change of the time dimension and of the validation flag. According to the altimeter mission, some v1.1 valid measurements may be invalid in v2.0 or the opposite.

For more details about the change of processing standards for Envisat please check the following link:
http://www.aviso.oceanobs.com/fileadmin/documents/calval/validation_report/EN/EnvisatReprocessingReport.pdf

5. Sea Level ECV products

5.1. Definition

Sea Level ECV products are gridded products, composed of the following categories:

- **Monthly averaged sea level anomalies (SLA):** This corresponds to the SLA grids computed after merging all the altimeter mission measurements together into monthly grids.
- **Mean Sea Level changes indicators:** This corresponds to static files over the whole altimeter period describing the evolution of the SLA grids just previously described. Several indicators are provided such as
  - the temporal evolution of the global mean sea level (MSL) with the global slope,
  - the geographical distribution of MSL trends,
  - the amplitude and phase of the main periodic signals (annual, semi-annual)

5.2. Nomenclature

- **Monthly averaged sea level anomalies (SLA) files** are indicated by:
  PROJECT-ECV-LEVEL-VARIABLE-MISSION-DATE-VERSION.nc

With the following meaning:

PROJECT	ESACCI	Project name
ECV	SEALEVEL	Essential Climate Variable name
LEVEL	L4	Level of the product. L1=instrumental measurements, L2=validated sea level measurements, L3=pre-processed data for mapping, L4=gridded products
VARIABLE	MSLA	Variable maps of sea level anomalies
MISSION	MERGED	Combined data
DATE	YYYYMMDDHHMMSS	Averaged month date
VERSION	fvxx	Version number

Example: ESACCI-SEALEVEL-L4-MSLA-MERGED-19930115000000-fv01.nc

Table 4: Nomenclature of the ECV Monthly averaged sea level anomalies

- **Mean Sea Level temporal variations files** are indicated by:
  PROJECT-ECV-INDICATOR-VARIABLE-MISSION-DATE-VERSION.nc

With the following meaning:

PROJECT	ESACCI	Project name
ECV	SEALEVEL	Essential Climate Variable name
INDICATOR	IND	Type of the product
VARIABLE	MSL	Global Mean Sea Level temporal evolution
MISSION	MERGED	Combined data
DATE	YYYYMMDDHHMMSS	Production date of the file
VERSION	fvxx	Version number

Example: ESACCI-SEALEVEL-IND-MSL-MERGED-20141014000000-fv01.nc

Table 5: Nomenclature of the ECV mean sea level temporal variations

- **Mean Sea Level changes geographic distribution files** are indicated by:
  PROJECT-ECV-INDICATOR-VARIABLE-MISSION-DATE-VERSION.nc

With the following meaning:

PROJECT	ESACCI	Project name
ECV	SEALEVEL	Essential Climate Variable name
INDICATOR	IND	Type of the product
VARIABLE	MSLTR	Map of the Mean Sea Level trends
MISSION	MERGED	Combined data
DATE	YYYYMMDDHHMMSS	Production date of the file
VERSION	fvxx	Version number

Example: ESACCI-SEALEVEL-IND-MSLTR-MERGED-20141014000000-fv01.nc

Table 6: Nomenclature of the ECV mean sea level changes geographic distribution

- **Files of the Amplitude and phase of the periodic signals of the Sea Level** are indicated by:
  PROJECT-ECV-INDICATOR-VARIABLE-MISSION-DATE-VERSION.nc

With the following meaning:

PROJECT	ESACCI	Project name
ECV	SEALEVEL	Essential Climate Variable name
INDICATOR	IND	Type of the product
VARIABLE	MSLAMPH	Map of the amplitude and phase of the Mean Sea Level
MISSION	MERGED	Combined data
DATE	YYYYMMDDHHMMSS	Production date of the file
VERSION	fvxx	Version number

Example: ESACCI-SEALEVEL-IND-MSLAMPH-MERGED-20141014000000-fv01.nc

Table 7: Nomenclature of the ECV mean sea level amplitude and phase

5.3. Format

ECV products are stored using the NetCDF (Network Common Data Form) format and CF v1.6 (Climate and Forecast) metadata conventions. (See 6. Software tools on how to read data).

Note that the sea level grids are defined so that the minimum latitude and longitude are -89.875° and 0.125° and not -90.0° and 0.0° any more as it was defined in the v1.1 previous version.

In addition, the land / sea mask derived from the Land Cover CCI project has been applied on each sea level map.

5.4. Maps projection

All ECV products are provided on Cartesian grids at a spatial resolution of 1/4°.

5.5. Data Handling Variables

5.5.1. ECV Monthly averaged sea level anomalies (SLA)

3 dimensions are defined:

- Latitude (lat) : number of latitude boxes between -89.875° and 89.875°
- Longitude (lon) : number of longitudes boxes between 0.125° and 359.875°
- n: bounds associated with the time period

5.5.2. ECV Mean Sea Level changes indicators

For ECV Mean Sea Level changes indicators (temporal variations, geographic distribution), 3 dimensions are defined:

- time
- lat : number of latitude boxes between -89.875° and 89.875°
- lon : number of longitudes boxes between 0.125° and 359.875°

For ECV Mean Sea Level changes indicators amplitude and phases, 4 dimensions are defined:

- time
- lat : number of latitude boxes between -89.875° and 89.875°
- lon : number of longitudes boxes between 0.125° and 359.875°
- period: harmonic period of the signal (e.g. one year or half a year)

5.6. NetCDF header

5.6.1. ECV Monthly averaged sea level anomalies

5.6.1.1. Global attributes

Attribute	Format	Description
history	string	Provides an audit trail for modifications to the original data. Date and [product_create_time]
tracking_id		
comment	string	Miscellaneous information about the data or methods used to produce it.
institution	string	Specifies where the original data was produced.
references	string	Published or web-based references that describe the data or methods used to produce it.
summary		
keywords		
id		
naming_authority		
keywords_vocabulary		
cdm_data_type		
project	string	Climate Change Initiative --- European Space Agency
geospatial_lat_min		
geospatial_lat_max		
geospatial_lon_min		

Attribute	Format	Description
geospatial_lon_max		
geospatial_vertical_min		
geospatial_vertical_max		
geospatial_lat_units		
geospatial_lon_units		
geospatial_ lat_resolution		
geospatial_lon_resolution		
time_coverage_start		
time_coverage_end		
time_coverage_duration		
time_coverage_resolution		
standard_name_vocabulary		
license		
title	string	A succinct description of what is in the dataset.
Conventions	string	Convention used for the format of the file
source	string	The method of production of original data
contact	string	Primary contact for information about the data set
product_version	string	
platform	string	List of satellites included
sensor	string	List of sensors onboard satellites
date_created	string	Date of creation
creator_name	string	
creator_url	string	
creator_email	string	

5.6.1.2. Variable attributes

Name	Attribute	Value
lon(lon)	long_name	"Longitude"
	standard_name	"longitude"
	units	"degrees_east"
	axis	"X"
	valid_min	0.125
	valid_max	359.875
lat(lat)	long_name	"Latitude"
	standard_name	"latitude"
	units	"degrees_north"
	axis	"Y"
	valid_min	-89.875
	valid_max	89.875
time	long_name	"Time"

	standard_name	"time"
	units	"days since 1950-01-01"
	calendar	"gregorian"
	month	"December 2010"
	axis	"T"
date_bounds(n)	bounds	"date_bounds"
sla(lat,lon)	_FillValue	1.844674e+19f
	long_name	"Monthly sea level anomalies"
	standard_name	"sea_surface_height_above_sea_level"
	units	"m"
	coordinates	"lon lat"

5.6.2. ECV Mean Sea Level temporal variations

5.6.2.1. Global attributes

Attribute	Format	Description
history	string	Provides an audit trail for modifications to the original data. Date and [product_create_time]
tracking_id		
comment	string	Miscellaneous information about the data or methods used to produce it.
institution	string	Specifies where the original data was produced.
references	string	Published or web-based references that describe the data or methods used to produce it.
summary		
keywords		
id		
naming_authority		
keywords_vocabulary		
cdm_data_type		
project	string	Climate Change Initiative --- European Space Agency
geospatial_lat_min		
geospatial_lat_max		
geospatial_lon_min		
geospatial_lon_max		
geospatial_vertical_min		
geospatial_vertical_max		
time_coverage_start		
time_coverage_end		
time_coverage_duration		
time_coverage_resolution		
standard_name_vocabulary		
license		
title	string	A succinct description of what is in the dataset.
Conventions	string	Convention used for the format of the file
source	string	The method of production of original data
contact	string	Primary contact for information

Attribute	Format	Description
		about the data set
product_version	string	
platform	string	List of satellites included
sensor	string	List of sensors onboard satellites
date_created	string	Date of creation
creator_name	string	
creator_url	string	
creator_email	string	

5.6.2.2. Variable attributes

Name	Attribute	Value
lon(lon)	long_name	"Longitude"
	standard_name	"longitude"
	units	"degrees_east"
	axis	"X"
	valid_min	0.125
	valid_max	359.875
lat(lat)	long_name	"Latitude"
	standard_name	"latitude"
	units	"degrees_north"
	axis	"Y"
	valid_min	-89.875
	valid_max	89.875
time(time)	long_name	"Time"
	standard_name	"time"
	units	"days since 1950-01-01"
	calendar	"gregorian"
	month	“December 2010”
	axis	“T”
	bounds	“date_bounds”
global_msl(time)	_FillValue	1.844674e+19f
	long_name	""Global mean sea level variations"
	standard_name	"global_average_sea_level_change"
	units	"m"
global_msl_trend	long_name	"Tendency of global mean sea level variations"

	standard_name	"tendency_of_global_average_sea_level_change"
	units	"mm/year"
global_msl_trend_error	long_name	"Standard error on global mean sea level variations tendency"
	units	"mm/year"

5.6.3. ECV Mean Sea Level changes geographic distribution

5.6.3.1. Global attributes

Attribute	Format	Description
history	string	Provides an audit trail for modifications to the original data. Date and [product_create_time]
tracking_id		
comment	string	Miscellaneous information about the data or methods used to produce it.
institution	string	Specifies where the original data was produced.
references	string	Published or web-based references that describe the data or methods used to produce it.
summary		
keywords		
id		
naming_authority		
keywords_vocabulary		
cdm_data_type		
project	string	Climate Change Initiative --- European Space Agency
geospatial_lat_min		
geospatial_lat_max		
geospatial_lon_min		
geospatial_lon_max		
geospatial_vertical_min		
geospatial_vertical_max		
geospatial_lat_units		
geospatial_lon_units		
geospatial_ lat_resolution		
geospatial_lon_resolution		
time_coverage_start		
time_coverage_end		
time_coverage_duration		
time_coverage_resolution		
standard_name_vocabulary		
license		
title	string	A succinct description of what is in the dataset.
Conventions	string	Convention used for format the of the file
source	string	The method of production of original data
contact	string	Primary contact for information about the data set
product_version	string	
platform	string	List of satellites included

Attribute	Format	Description
sensor	string	List of sensors onboard satellites
date_created	string	Date of creation
creator_name	string	
creator_url	string	
creator_email	string	

5.6.3.2. Variable attributes

Name	Attribute	Value
lon(lon)	long_name	"Longitude"
	standard_name	"longitude"
	units	"degrees_east"
	axis	"X"
	valid_min	0.125
	valid_max	359.875
lat(lat)	long_name	"Latitude"
	standard_name	"latitude"
	units	"degrees_north"
	axis	"Y"
	valid_min	-89.875
	valid_max	89.875
time(time)	long_name	"Time"
	standard_name	"time"
	units	"days since 1950-01-01"
	calendar	"gregorian"
	month	“December 2010”
	axis	“T”
	bounds	“date_bounds”
local_msl_trend(lat,lon)	_FillValue	1.844674e+19f
	long_name	"Geographical distribution of mean sea level trends"
	standard_name	"tendency_of_sea_surface_height_above_sea_level"
	units	"mm/year"
local_msl_trend_error(lat,lon)	_FillValue	1.844674e+19f
	long_name	"Geographical distribution of mean sea level trends errors"
	units	"mm/year"

5.6.4. Mean Sea Level changes amplitude and phases

5.6.4.1. Global attributes

Attribute	Format	Description
history	string	Provides an audit trail for modifications to the original data. Date and [product_create_time]
tracking_id		
comment	string	Miscellaneous information about the data or methods used to produce it.
institution	string	Specifies where the original data was produced.
references	string	Published or web-based references that describe the data or methods used to produce it.
summary		
keywords		
id		
naming_authority		
keywords_vocabulary		
cdm_data_type		
project	string	Climate Change Initiative --- European Space Agency
geospatial_lat_min		
geospatial_lat_max		
geospatial_lon_min		
geospatial_lon_max		
geospatial_vertical_min		
geospatial_vertical_max		
geospatial_lat_units		
geospatial_lon_units		
geospatial_ lat_resolution		
geospatial_lon_resolution		
time_coverage_start		
time_coverage_end		
time_coverage_duration		
time_coverage_resolution		
standard_name_vocabulary		
license		
title	string	A succinct description of what is in the dataset.
Conventions	string	Convention used for the format of the file
source	string	The method of production of original data
contact	string	Primary contact for information about the data set
product_version	string	
platform	string	List of satellites included
sensor	string	List of sensors onboard satellites
date_created	string	Date of creation
creator_name	string	
creator_url	string	
creator_email	string	

5.6.4.2. Variable attributes

Name	Attribute	Value

lon(lon)	long_name	"Longitude"
	standard_name	"longitude"
	units	"degrees_east"
	axis	"X"
	valid_min	0.125
	valid_max	359.875
lat(lat)	long_name	"Latitude"
	standard_name	"latitude"
	units	"degrees_north"
	axis	"Y"
	valid_min	-89.875
	valid_max	89.875
time(time)	long_name	"Time"
	standard_name	"time"
	units	"days since 1950-01-01"
	calendar	“gregorian”
	month	“December 2010”
	axis	“T”
	bounds	“date_bounds”
ampl(lat,lon,period)	_FillValue	1.844674e+19f
	long_name	"Geographical distribution of mean sea level amplitude"
	standard_name	"amplitude_of_global_average_sea_level_change"
	units	"m"
phase(lat,lon,period)	_FillValue	1.844674e+19f
	long_name	"Geographical distribution of mean sea level phase" (referenced to the 15th January 1993)
	standard_name	"phase_of_global_average_sea_level_change"
	units	"degrees"
period(period)	long_name	"Period of signal" (annual, semi-annual)
	standard_name	"harmonic_period"
	units	"year"

6. Software tools

The products are stored using the NetCDF-CF format. Note that these data can be browsed and used through several softwares, like:

- ✓ Broadview Radar Altimetry Toolbox: http://www.altimetry.info
- ✓ ncBrowse: http://www.epic.noaa.gov/java/ncBrowse/

- ✓ NetCDF Operator (NCO): http://nco.sourceforge.net/
- ✓ http://www.unidata.ucar.edu/software/netcdf/

Appendix A - **List of acronyms**

AD	Applicable Document
AL	SARAL/AltiKa
C2	CryoSat-2
CCI	Climate Change Initiative
CF	Climate and Forcast
CNES	Centre National des Etudes Spatiales
CORSSH	CORrected Sea Surface Height
DORIS	Doppler Orbitography by Radiopositioning Intergrated System
DT	Delayed-time
ECV	Essential Climate Variable
EN	Envisat
E1, E2	ERS-1, ERS-2 (European Remote Sensing)
ECMWF	European Center for Medium-range Weather Forcast
ERA Interim	ECMWF atmospheric ReAnalysis
FCDR	Fundamental Climate Data Record
FES	Finite Element System
GDR	Geophysical Data Record
GFO	Geosat Follow-On
GFZ	Geodetische Forschung Zentrum
GIM	Global Ionosphere Maps
GOT	Goddard Ocean Tide
GPD	GNSS-derived Path Delay
GSFC	Goddard Space Flight Center
J1, J2, J3	Jason-1, Jason-2, Jason-3
MSLA	Map of Sea Level Anomaly
MSS	Mean Sea Surface
NAVSOC	Naval Satellite Operations Center
NIC09	NOAA Ionosphere Climatology 2009

POE	Precise Orbit Ephemeris
RD	Reference Document
S1 tide	First semi diurnal ocean tide wavelength
S3	Sentinel-3
SLA	Sea Level Anomaly
SL_cci	Sea Level Climate Change Initiative
SLOOP	A Step forward aLtimetry Open Ocean Project
SSH	Sea Surface Height
TBC	To be confirmed
TBD	To be defined
T/P, TP	TOPEX/Poseidon
USO	Ultra Stable Oscillator