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ESA Sea Level CCI

D3.4 Product User Guide

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1.1	4/9/2012	New version of the products, updated with new standard altimetric corrections	C.Maheu
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1.4	21/02/2014	globa_msl unit changed to m, plus correction of typos	G.Timms
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List of tables and figures

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Applicable documents

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

Reference documents

[1] Altimetry principle: http://www.aviso.oceanobs.com/en/altimetry/principle/basic-principle/index.html

[2] Altimetry principle: http://www.altimetry.info

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 that we planned to generate two 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)**: The sea level product generated using the algorithms selected and developed in the first phase of the project. This corresponds to the current products delivered.
- **Version 1.1 (V1.1)**: It is an update of V1 including new wet troposphere correction for all altimeter missions and reprocessed level 2 products concerning Jason-2 (GDR-D) and Envisat (V2.1) missions.

The period covered for all these products is from **January 1993 to December 2013**, which is derived from the periods associated with the main altimeter missions: ERS-1, ERS-2, Envisat, TOPEX/Poseidon, Jason-1, Jason-2, Geosat-Follow-On.

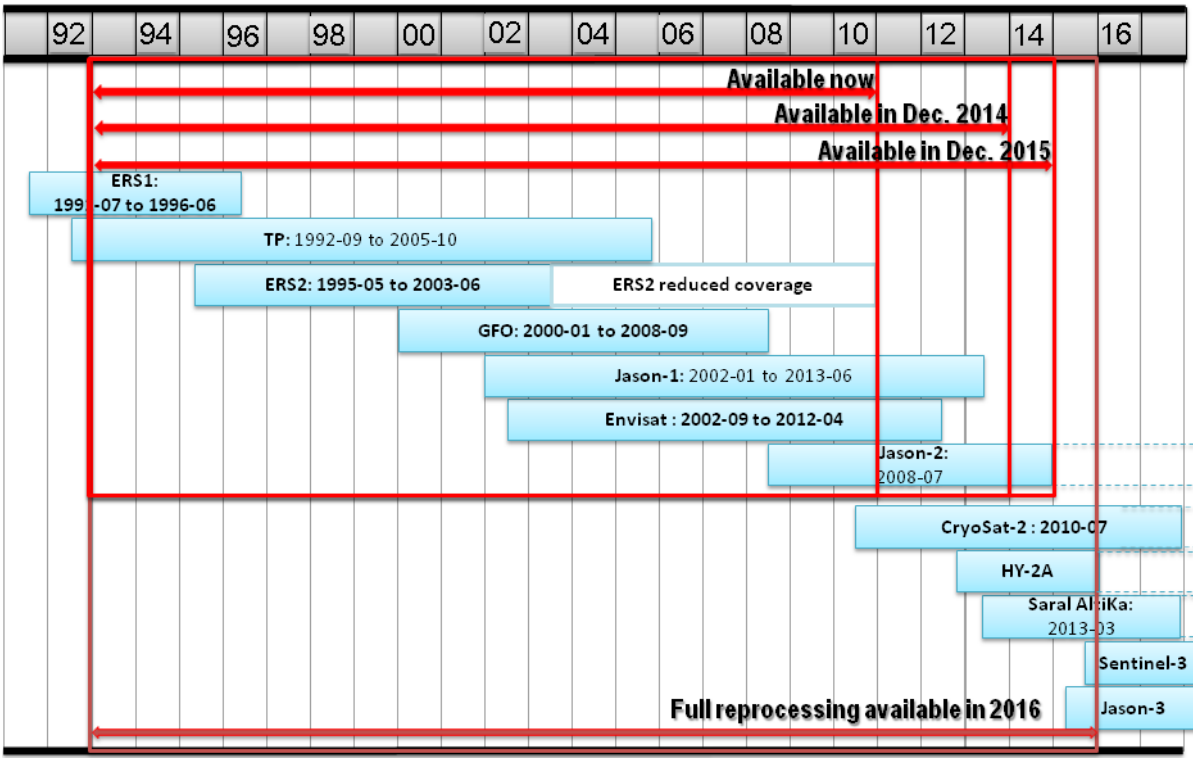

Figure 1: Level 2 GDR altimeter data used as input data of the FCDR and ECV products are included in the red square.

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. Surface height is the difference between a satellites position in orbit with respect to an arbitrary reference surface (the Earth's center or a rough approximation of the Earth's surface: the 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 SSH. See references [1] and [2] for more information.

3. Altimetric standards applied for Version-1.1

The altimetric standards currently applied to calculate the SSH are summarized in the following table. They are described in the following table separating the altimetry missions. They correspond to the version 1.1 of FCDR and ECV products.

Standards and references for version 1.1 of FCDR and ECV products					
Corrections	**Altimeter missions**				
	Jason1 / Jason-2	**TOPEX / Poseidon**	**Envisat**	**ERS-1/ERS-2**	**GFO**
Orbit	CNES POE (GDR-D standards)	GSFC POE (standard 08/2009)	CNES POE (GDR-D)	ESA Reaper POD	- GSFC POE (std 08/2009), - NAVSOC POE (where no GSFC POE)
Dry troposphere	Era Interim based				
Wet troposphere	GPS-based	GPS-based	GPS-based	GPS-based	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
Ionosphere	From dual-frequency altimeter range measurements	From dual-frequency altimeter range measurements (Topex), from Doris (Poseidon)	From dual-frequency altimeter range measurements (cycle 1-64) and GIM model from cycle 65	NIC09 on ERS-1 Bent/GIM on ERS-2	GIM model [Iijima et al., 1999]

Standards and references for version 1.1 of FCDR and ECV products					
Corrections	**Altimeter missions**				
	Jason1 / Jason-2	**TOPEX / Poseidon**	**Envisat**	**ERS-1/ERS-2**	**GFO**
Sea State Bias	Non parametric SSB (from GDR)	Non parametric SSB (Topex) [Tran et al., 2010] BM4 formula (Poseidon) [Gaspar et al., 1996]	Non parametric SSB (GDR product), Labroue (2007)]	Non parametric SSB [Labroue, 2007] Non parametric SSB [Mertz et al.,2005],	Non parametric SSB (updated 2009)
Ocean tide and loading tide	GOT4.8 (Including ocean tides, loading effect, long period equilibrium tide, S1 tides…)				
Solid Earth tide	Elastic response to tidal potential [Cartwright and Tayler, 1971], [Cartwright and Edden, 1973]				
Pole tide	From GDR [Wahr, 1985]			computed from IERS data [Wahr, 1985]	From GDR [Wahr, 1985]
Combined atmospheric correction	Era interim based				
MSS	DTU10				
Major Instrumental correction					USO correction correcting from anomaly periods and aging drift from auxiliary files taken into account

Table 1: Standards and references for version 1.1 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 product (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, etc... In addition, information derived from the cross-calibration of the SSH between all the missions is provided in order to remove the global/regional SSH bias and to homogenize long spatial scale errors (due to orbit calculation for instance).

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
Repetitivity	35 days	35 days	9.9 days	9.9 days	9.9 days	17 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
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 (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	track(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	1e-6 sec	none
int	corssh(time)	Corrected see surface height above the reference	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	comp_wet_tropo_corr(time)	Composite wet tropospheric correction	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	degrees^2	10^{-4}
short	wind_speed_alt(time)	Altimeter wind speed	meters/seconde	10^{-3}
byte	alt_flag_oper(time)	Altimeter state flag	none	1
byte	rad_qual_interp_flag(time)	Radiometer quality interpolation flag	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	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	none	1
short	global_bias	Global relative SSH Bias between all the missions	meters	10^{-4}
short	regional_bias	Regional relative SSH Bias between 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
track(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	Defined
corssh(time)	Corrected see surface height above the reference	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
comp_wet_tropo_corr(time)	Composite wet tropospheric correction	Defined
dyn_atmosph_corr(time)	Combined atmospheric correction[2]	Defined
off_nadir_angle(time)	Square of the off nadir angle computed from Ku waveforms	Empty

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

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	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 Ku band range	Empty
range_rms(time)	RMS of the Ku band range	Empty
sigma0_numval(time)	Number of valid points for 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	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

Finally, the *alt_surf_type* field specifies the altimeter surface type with the value 0 for ocean and 1 for land. However, FCDR products are designed to study Sea Level. Therefore, only measurements over 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		
CreatedBy		
CreatedOn		Date of file creation
Mission		Name (abbreviation) of the altimeter mission the data come from
MeanProfile		Cycle number
Version	string	Version of the product
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 first 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 are to be multiplied by this factor after the data are 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	Smallest and largest theoretical valid value 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 - pole_tide - solid_earth_tide - dry_tropo_corr - comp_wet_tropo_corr - iono_corr

If the user likes, he can therefore easily replace one correction by another (e.g. comp_wet_tropo_corr by a correction of his own).
It is advised to use the validation flag (*validation_flag*), but users may apply their own validation criteria.

4.7. Example

```
netcdf SLCCI_ALTDB_EN_Cycle033_V1 {
dimensions:
        time = UNLIMITED ; // (1651486 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 = "2004-12-13 21:39:39.936071" ;
        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" ;
        short track(time) ;
                track:_FillValue = 32767s ;
                track:long_name = "Track in cycle the measurement belongs to" ;
                track: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" ;
                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 reference" ;
                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 = 700000. ;
                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 = 700000. ;
```

```
                range: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 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), after cycle 64 GIM
ionospheric correction" ;
                iono_corr:units = "m" ;
                iono_corr:scale_factor = 0.0001 ;
                iono_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 = "ECMWF 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" ;
        short comp_wet_tropo_corr(time) ;
                comp_wet_tropo_corr:_FillValue = 32767s ;
                comp_wet_tropo_corr:long_name = "Composite wet tropospheric correction" ;
                comp_wet_tropo_corr:units = "m" ;
                comp_wet_tropo_corr:scale_factor = 0.0001 ;
                comp_wet_tropo_corr: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" ;
        byte alt_flag_oper(time) ;
                alt_flag_oper:_FillValue = 127b ;
                alt_flag_oper:long_name = "altimeter state flag: altimeter operating: 0=SideA  1=SideB" ;
                alt_flag_oper:units = "1" ;
                alt_flag_oper:scale_factor = 1. ;
                alt_flag_oper:coordinates = "longitude latitude" ;
        byte rad_qual_interp_flag(time) ;
                rad_qual_interp_flag:_FillValue = 127b ;
                rad_qual_interp_flag:long_name = "MWR Quality interpolation flag: 0=good 1=interpolation with gap
2=extrapolation 3=fail" ;
                rad_qual_interp_flag:units = "1" ;
                rad_qual_interp_flag:scale_factor = 1. ;
                rad_qual_interp_flag: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" ;
        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" ;
        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 = "Geocentric ocean tide height" ;
                ocean_tide:units = "m" ;
                ocean_tide:scale_factor = 0.0001 ;
                ocean_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 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" ;

// global attributes:
                :title = "SLCCI Altimeter database V1 for  Cycle 033" ;
                :OriginalName = "SLCCI_ALTDB_EN_Cycle033_V1.nc" ;
                :CreatedBy = "slcci" ;
                :CreatedOn = "15-JUN-2012 17:39:00:000000" ;
                :Mission = "EN" ;
                :MeanProfile = "033" ;
                :Version = "0" ;
                :Conventions = "CF-1.4" ;
                :history = "2012/06/15 17:54:11 slcci@px-132.cls.fr ConvertATPInternalToCF: Converted to CF" ;
}
```

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

Users should be aware that in the FCDR V1.0, the validation flag was already applied in the corssh field. This has been modified in the V1.1 release and the *corssh* field includes all valid and invalid measurements. The corssh field includes the same values as the difference "*alt* – *range* – geophysical corrections". Users can now use their own validation flag directly from the *corssh* field.

In the FCDR V1.1 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 V1.0 valid measurements may be invalid in V1.1 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 altimetric 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

5.2.1. ECV Monthly averaged sea level anomalies (SLA)

DATE_PROJECT_LEVEL_ECV_VARIABLE_MISSION_VERSION.nc

Example: 20101215000000-ESACCI-L4_SEALEVEL-MSLA-MERGED-fv01.nc

DATE	*YYYYMMDDHHMMSS*	averaged month date
PROJECT	*ESACCI*	Project name
LEVEL	*L4*	Level of the product
ECV	*SEALEVEL*	Essential Climate Variable name
VARIABLE	*MSLA*	Variable maps of sea level anomalies
MISSION	*MERGED*	Combined data
VERSION	*fvxx*	version number

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

5.2.2. ECV Mean Sea Level changes indicators: Mean Sea Level temporal variations

DATE_PROJECT_INDICATEUR_ECV_VARIABLE_MISSION_VERSION.nc

Example: 20120830000000-ESACCI-IND_SEALEVEL-MSL-MERGED-fv01.nc

DATE	*YYYYMMDDHHMMSS*	production date of the file
PROJECT	*ESACCI*	Project name
INDICATEUR	*IND*	Type of the product
ECV	*SEALEVEL*	Essential Climate Variable name
VARIABLE	*MSL*	Mean Sea Level
MISSION	*MERGED*	Combined data
VERSION	*fvxx*	version number

Table 5: Nomenclature of the ECV Mean Sea Level temporal variations

5.2.3. ECV Mean Sea Level changes indicators: Mean Sea Level changes geographic distribution

DATE_PROJECT_INDICATEUR_ECV_VARIABLE_MISSION_VERSION.nc

Example: 20120830000000-ESACCI-IND_SEALEVEL-MSLTR-MERGED-fv01.nc

DATE	*YYYYMMDDHHMMSS*	production date of the file
PROJECT	*ESACCI*	Project name
INDICATEUR	*IND*	Type of the product
ECV	*SEALEVEL*	Essential Climate Variable name
VARIABLE	*MSLTR*	Mean Sea Level trend
MISSION	*MERGED*	Combined data
VERSION	*fvxx*	version number

Table 6: Nomenclature of the ECV Mean Sea Level changes geographic distribution

5.2.4. ECV Mean Sea Level changes indicators: Mean Sea Level changes amplitude and phases

DATE_PROJECT_INDICATEUR_ECV_VARIABLE_MISSION_VERSION.nc

Example: 20120830000000-ESACCI-IND_SEALEVEL-MSLAMPH-MERGED-fv01.nc

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

Table 7: Nomenclature of the ECV Mean Sea Level changes amplitude and phases

5.3. Format

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

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)

4 dimensions are defined:

- Time
- Latitude : number of latitude boxes between -90° and 90°
- Longitude : number of longitudes boxes between 0° and 360°
- n: bounds associated to 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
- Latitude : number of latitude boxes between -90° and 90°
- Longitude : number of longitudes boxes between 0° and 360°

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

- Time
- Latitude : number of latitude boxes between -90° and 90°
- Longitude : number of longitudes boxes between 0° and 360°
- Period: harmonic period

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.
Method	string	The source of production of the original data.
summary		
keywords		
id		
naming_authority		
keywords_vocabulary		
cdm_data_type		
comment		
date_created		

Attribute	Format	Description
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 format of the file
source	string	The method of production of original data (='Satellite altimetry')
contact	string	Primary contact for information about the data set
product_version	string	

5.6.1.2. Variable attributes

Type	Name	CF standard name attribute	Content	Unit
double	lat(latitude)	latitude	Latitude value of each point of the grid	degree_north
double	lon (longitude)	longitude	Longitude value of each point of the grid	degree_east
float	SLA(latitude, longitude)	sea_surface_height_above_sea_level	Sea level anomalies	m
float	scale_factor	-	If present, the variable are to be multiplied by this factor after the data are read by an application	-
float	date(time)	time	Date of each SLA average	
float	date_bounds(n)		Date bounds	

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.

Attribute	Format	Description
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.
Method	string	The source of production of the original data.
summary		
keywords		
id		
naming_authority		
keywords_vocabulary		
cdm_data_type		
comment		
date_created		
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 format of the file
source	string	The method of production of original data (='Satellite altimetry')
contact	string	Primary contact for information about the data set
product_version	string	

5.6.2.2. Variable attributes

Type	Name	CF standard name attribute	Content	Unit
double	lat(latitude)	latitude	Latitude value of each point of the grid	degree_north
double	lon(longitude)	longitude	Longitude value of each point of the grid	degree_east
float	date(time)	time	Date of each SLA average	
float	global_msl(time)	global_average_sea_level_change	Global mean sea level	m
float	global_msl_trend	tendency_of_global_average_sea_level_change	Global mean sea level estimated trend	mm/yr
float	global_msl_trend_error		Error of global mean sea level trend	mm/yr

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.
Method	string	The source of production of the original data.
summary		
keywords		
id		
naming_authority		
keywords_vocabulary		
cdm_data_type		
comment		
date_created		
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 format of the file
source	string	The method of production of original data (='Satellite altimetry')
contact	string	Primary contact for information about the data set
product_version	string	

5.6.3.2. Variable attributes

Type	Name	CF standard name attribute	Content	Unit
double	lat(latitude)	latitude	Latitude value of each point of the grid	degree_north
double	lon(longitude)	longitude	Longitude value of each point of the grid	degree_east

float	date(time)	time	Date of each SLA average	
float	local_msl_trend (latitude, longitude)	tendency_of_sea_surface_height_above_sea_level	Geographical distribution of mean sea level trends	mm/yr
float	local_msl_trend_error(latitude, longitude)	-	Geographical distribution of mean sea level trends errors	mm/yr

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.
Method	string	The source of production of the original data.
summary		
keywords		
id		
naming_authority		
keywords_vocabulary		
cdm_data_type		
comment		
date_created		
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 format of the file
source	string	The method of production of original data (='Satellite altimetry')
contact	string	Primary contact for information about the data set
product_version	string	

5.6.4.2. Variable attributes

Type	Name	CF standard name attribute	Content	Unit
double	lat(latitude)	latitude	Latitude value of each point of the grid	degree_north
double	lon(longitude)	longitude	Longitude value of each point of the grid	degree_east
float	date(time)	time	Date of each SLA average	
float	ampl (latitude, longitude, period)	amplitude_of_global_average_sea_level_change	Geographical distribution of mean sea level amplitude	m
float	phase(latitude, longitude, period)	phase_of_global_average_sea_level_change	Geographical distribution of mean sea level phase	deg
	period	harmonic_period	'1 year' or '1/2 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:

- ✓ Basic 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
CORSSH	CORrected Sea Surface Height
DT	Delayed-time
ECV	Essential Climate Variable
FCDR	Fundamental Climate Data Record
GDR	Geophysical Data Record
MSLA	Map of Sea Level Anomaly
MSS	Mean Sea Surface
POE	Precise Orbit Ephemeris
RD	Reference Document
SSH	Sea Surface Height
TBC	To be confirmed
TBD	To be defined
T/P	Topex/Poséidon