SPICE

Sentinel-3 Performance improvement for ICE sheets

IODDv2.4

Scientific Exploitation of Operational Missions (SEOM)

Sentinel-3 SAR Altimetry

Study 4: Ice Sheets

Prepared by	:	isardSAT	date:	19/04/2018
Issued by	:	isardSAT	date:	19/04/2018
Checked by	:	Malcolm McMillan	date:	19/04/2018
Approved by	:	Malcolm McMillan	date:	19/04/2018
Accepted by		ESA | Jérôme Benveniste	date:	19/04/2018

Contents

Acronyms and Abbreviations 3

Applicable Documents 4

Reference Documents 4

1 Introduction 5

1.1 Purpose and scope 5

2 Definitions 6

2.1 General products definition 6

2.2 Variable types 6

3 Overview of Processing Scheme 7

4 Input Data Specification 8

4.1 FBR input files 8

4.2 Auxiliary files 9

5 Output Data Specifications 14

5.1 L1B file 14

5.2 L2A file 14

Table of Figures

Figure 1 WP2 and WP3 flow chart.....7

Acronyms and Abbreviations

AD	Applicable Documents
ADC	Analog to Digital Convertor
ASCII	American Standard Code for Information Interchange
ATBD	Algorithm Theoretical Baseline Document
CAL1	CALibration type 1
CAL2	CALibration type 2
CHD	CHaracteriseD parameters file
C-FBR	Calibrated Full Bit Rate
CNF	CoNFigured parameters file
CST	ConSTant parameters file
CS2	CryoSat-2 satellite
DDP	Delay Doppler Processor
DEM	Digital Elevation Map
ESA	European Space Agency
FBR	Full Bit Rate
FFT	Fast Fourier Transform
HR	High Resolution
IODD	Input/Output Description Document
L1A	Level 1 A
L1B	Level 1 B
L1B-S	Level 1 B Stack
L2A	Level 2 A
LPF	Low-Pass Filter
LR	Low Resolution
pLRM	Pseudo-LRM (Low Resolution Mode)
POCCD	Processing Options and Configuration Control Document
PSD	Product Specification Document
RD	Reference Document
RF	Radio Frequency
RFU	Radio Frequency Unit
SAR(in)	Synthetic Aperture Radar (INterferometric mode)
SEOM	Scientific Exploitation of Operational Missions
SPICE	Sentinel-3 Performance improvement for ICE sheets
TCOG	Threshold Center Of Gravity
TPR	Threshold Peak Retracker
USO	Ultra Stable Oscillator
WGS	World Geodetic System
WP	Work Package
ZP	Zero-Padding

Applicable Documents

Reference	Document Name	Source
AD 1	Scientific Exploitation of Operational Missions (SEOM). Sentinel-3 SAR Altimetry Statement of Work (SEOM S3-4SCI SAR Altimetry). Issue 1, 2014/09/27.	ESA
AD 2	SPICE. Algorithm Theoretical Baseline Document (ATBD), issue 2.1, 2018/04/19.	isardSAT
AD 3	SPICE. Processing options Configuration Control Document (POCCD), issue 2.3, 2018/04/16.	isardSAT
AD 4	SPICE. Product Specification Document (PSD), issue 2.0, 2018/02/08.	UL / isardSAT

Table 1. Applicable Documents

Reference	Document Name	Source
UL_ESA_SEOM_S3-4SCI_CL	Cover Letter	UL
UL_ESA_SEOM_S3-4SCI_TP	Technical Proposal (v3, 2015/01/05)	UL
UL_ESA_SEOM_S3-4SCI_MP	Management Proposal (v2, 2015/01/05)	UL
UL_ESA_SEOM_S3-4SCI_IP	Implementation Proposal (v3, 2015/01/05)	UL
UL_ESA_SEOM_S3-4SCI_FP	Financial Proposal (v2, 2015/01/05)	UL
UL_ESA_SEOM_S3-4SCI_CP	Contractual Proposal (v0.1, 2015/01/05)	UL

Table 2. Proposal documents

Reference Documents

Reference	Document Name	Source
RD. 1	ACS/ESA. CryoSat Ground Segment IPF L1B: Product Specification Format, ref. CS-RS-ACS-GS-5106, issue 6.4, 30th Abril 2015.	ESA
RD. 2	ESA. SRAL Input/Output Definition Document for Product Level 1A/1B-S, ref. S3-TN-ESA-SR-0433, issue 1.4, 13th March 2014.	ESA
RD. 3	ESA. Product Data Format Specification- ,SRAL/MWR Level 1 & 2 Instrument Products, ref. S3IPF.PDS.003, issue 1.4, 4th December 2013.	ESA

Table 3. Applicable Documents

1 Introduction

1.1 Purpose and scope

This document is the Input and Output Description Document (IODD) for the Scientific Exploitation of Operational Missions (SEOM), Sentinel-3 Performance improvement for ICE sheets (SPICE) study.

The IODD is prepared to describe the algorithms technical baseline of the processors that will be used within the project.

The scope of this document is to describe the Input and Output Products definition of the WP2 and WP3 within the Scientific Exploitation of Operational Missions (SEOM), Sentinel-3 Performance improvement for ICE sheets (SPICE) study.

2 Definitions

2.1 General products definition

Based on the ESA product definition and more specifically on Sentinel-3 Mission, three levels of data can be found:

- **FBR** products containing unpacked L0 complex echoes that have been sorted and geo-located.
- **Level 1B** products includes the SAR averaged measurements (20 Hz), which have been geo-located, calibrated, azimuth processed and applied geometric corrections.
- **Level 2** products contain geophysical parameters that have been extracted from the L1B waveforms.

2.2 Variable types

Variable type	Description	Range
bool	Boolean	0 or 1
str	String	-
uc	8-bit unsigned integer (ubyte)	0 to 255
sc	8-bit signed integer (byte)	-128 to 127
us	16-bit unsigned integer	0 to 65535
ss	16-bit signed integer	-32768 to 32767
ul	32-bit unsigned integer	0 to 4294967295
sl	32-bit signed integer	-2147483648 to 2147483647
sll	64-bit signed integer	-9223372036854775808 to 9223372036854775807
fl	32-bit single precision floating point	1.17549e-38 (min) 3.4028e+38(max)
do	64-bit double precision floating point	2.22e-308(min) 1.79e+308(max)

Table 4. Variable types

3 Overview of Processing Scheme

In this section we give a brief overview of the different processing stages implemented in the SPICE project. Further details on the description and mathematical formulation of each of the processing stages are defined in the SPICE deliverable D1.3 ATBD (AD 2).

Figure 1 is a block diagram that presents the data flow corresponding to WP2 and WP3 (see Table 2, Implementation Proposal) within the whole SPICE project.

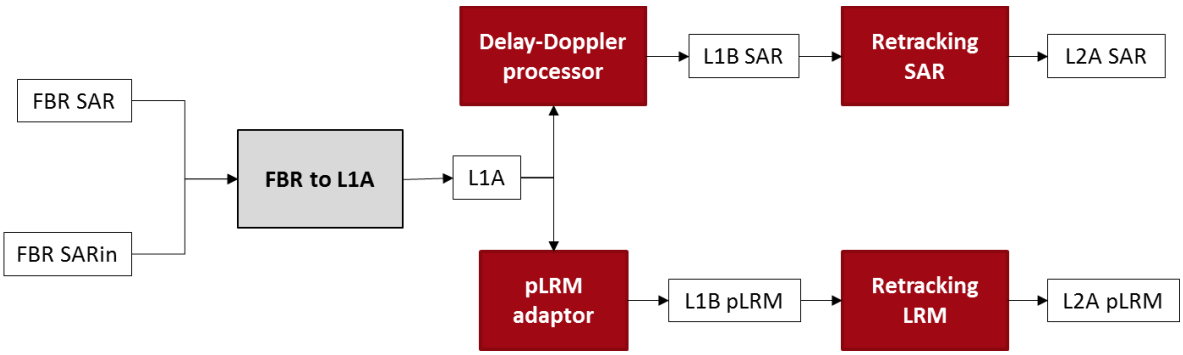

Figure 1 WP2 and WP3 flow chart.

From this, we clearly identify the main input and output products:

Input	Description	Mandatory (M) / Optional(O)
FBR (SAR/SARin)	ASCII binary (Cryosat-2)	M

Table 5. Input file

Output	Description	Mandatory (M) / Optional(O)
L1B (SAR/pLRM)	NetCDF (Sentinel-3 baseline)	M
L2A (SAR/pLRM)	NetCDF (Sentinel-3 baseline)	M

Table 6. Output files

4 Input Data Specification

In the following sections, a list of the input files to the different processors and their description is given.

The different input files can be classified in two different categories:

- FBR
- Auxiliary files:
  - Characterisation file (CHD)
  - Configuration file (CNF)
  - Constants file (CST)
  - Characterisation Arrays:
    - CAL2 correction
    - CAL1 intra-burst corrections

4.1 FBR input files

CryoSat-2 FBR data is a binary product file with specific ASCII header. It contains geolocated bursts of Ku echoes without calibrations applied. However, the starting point of the Delay-Doppler processing chain is the Calibrated FBR (or L1A in Sentinel-3).

Since C-FBR data is not a standard product, the related calibration files are required to apply accordingly the corrections to obtain an equivalent L1A product.

The L1A product consists of a single data file in NetCDF format, containing the measurement data (calibrated complex echoes at burst rate, 80 Hz) and the calibration parameters applied to the echoes. However, in this case where only CryoSat-2 files are input, the L1A product is kept internally and is not generated by the processor.

Further details on the FBR and L1A product dimensions and structures can be found in RD. 1 and RD. 2 respectively.

4.2 Auxiliary files

4.2.1 Characterisation file (CHD)

It contains the system on-ground characterisation (general, time pattern, platform, antenna, calibration…). The characterisation file is a JSON file and contains the parameters listed below.

Field name	Description	Units	Variable type
Main			
freq_ku_chd	Emitted frequency in Ku-band	Hz	fl
bw_ku_chd	Ku-band bandwidth	Hz	fl
mean_sat_alt_chd	Mean satellite altitude	m	fl
Time pattern			
N_bursts_cycle_chd	Number of bursts in a tracking cycle	-	us
N_ku_pulses_burst_chd	Number of Ku-band pulses per burst	-	us
N_c_pulses_burst_chd	Number of C-band pulses per burst	-	us
N_samples_sar_chd	Number of samples of each SAR pulse	-	us
pulse_length_chd	Pulse duration/length	s	fl
prf_chd	Pulse repetition frequency	Hz	fl
brf_chd	Burst repetition interval	Hz	fl
Antenna			
antenna_gain_ku_chd	Antenna gain for Ku-band	dB	fl
antenna_beamwidth_ku_chd	Antenna beamwidth at 3 dB for Ku-band	deg	fl
Gain parameters			
ADC_mult_factor_chd	Factor that is used to compute the combination of on-board fixed digital gains for the SAR digital chain	dB	fl
power_tx_ant_ku_chd	RF Peak Transmitted Power in Ku band	dB	fl
USO clock			
uso_freq_nom_chd	USO nominal frequency	Hz	fl
alt_freq_multiplier_chd	Factor to convert from USO frequency to altimeter frequency	-	fl

Table 7. Characterisation file (CHD) data fields

4.2.2 *Configuration file (CNF)*

The configuration file contains all the processor switches (i.e., processing options), which can be modified without recompiling the software, and the configuration parameters. The configuration file is a JSON file and contains the parameters listed below.

Field name	Description	Values	Variable type
flag_l1b_mode_cnf[1]	Option to set the type of L1B processing	• 'disabled' • 'sar' • 'plrm'	str
flag_l2_mode_cnf[1]	Indicates the type of retracker that is used (see AD 2)	• 'disabled' • 'tcog' • 'tpr'	str
flag_sarin_mode_cnf	Flag that activates the SARin-to-SAR module	0: Off 1: On	bool
pre_retracking_module_cnf	Flag that selects the pre-retracking module that is going to be applied	• 'disabled • 'DEM' • 'batch'	str
flag_uso_correction_cnf	Flag that activates the USO correction	0: Off 1: On	bool
flag_cal1_corrections_cnf	Flag that activates the CAL1 correction	0: Off 1: On	bool
flag_cal1_intraburst_corrections_cnf	Flag that activates the CAL1 intra-burst correction	0: Off 1: On	bool
flag_cal2_correction_cnf	Flag that activates the CAL2 correction	0: Off 1: On	bool
flag_surface_focusing_cnf	Option to move the surface locations	0: Off 1: Only one given surface	bool
surface_focusing_lat_cnf	Latitude where the surface location needs to be moved to	-	fl
surface_focusing_lon_cnf	Longitude where the surface location needs to be moved to	-	fl
surface_focusing_alt_cnf	Altitude where the surface location needs to be moved to	-	fl
flag_azimuth_processing_method_cnf	Value that forces the precision of the Delay-Doppler process	• 'approximate' • 'exact'	str

[1] In order to be able to run L1B and L2 processors separately, a flag to trigger each processor has been created.

Field name	Description	Values	Variable type
flag_azimuth_windowing_method_cnf	Type of window applied to each burst before performing the azimuth FFT	• 'none' • 'boxcar' • 'hamming' • 'hanning'	str
azimuth_window_width_cnf	Value that sets the width of the azimuth window when set	[0,N-1], being N the number of waveform samples	us
flag_doppler_range_correction_cnf	Flag used to decide if the Doppler range correction is applied or not	0: Off 1: On	bool
flag_slant_range_correction_cnf	Flag used to decide if the slant range correction is applied or not	0: Off 1: On	bool
flag_window_delay_alignment_method_cnf	Flag used to decide the window delay alignment method	• 'surface' • 'max_power' • 'least_difference' • 'first_beam' • 'shortest_delay'	str
flag_stack_masking_cnf	Flag to apply a mask to the stack in order to delete undesired phenomena	0: Off 1: On	bool
flag_avoid_zeros_in_multilooking_cnf	Average through all the samples or just consider the non-0 samples	0: All samples 1: Only non-0 samples	bool
zp_fact_range_cnf	Number of zero-padding applied to the waveforms during the range compression process	Powers of two, up to 2048	us
N_looks_stack_cnf	Maximum stack size	-	us
min_lat_cnf	Minimum latitude for ROI filtering	-	fl
max_lat_cnf	Maximum latitude for ROI filtering	-	fl
min_lon_cnf	Minimum longitude for ROI filtering	-	fl
max_lon_cnf	Maximum longitude for ROI filtering	-	fl
leading_edge_percent_cnf	Power threshold used for leading edge estimation	75 for SAR (TPR) / 50 for pLRM (TCoG)	fl
batch_margin_cnf	Maximum sample difference between a new window delay and the previous ones	20	us
flag_dem_option_cnf	Defines the input DEM	'CS2' or 'Russell'	str
range_window_cnf	Window size used to compute range RMSE	5	us
elev_window_cnf	Window size used to compute elevation RMSE	5	us
sigma0_window_cnf	Window size used to compute sigma0 RMSE	5	us
sliding_window_size_cnf	Sliding window size used to average the waveform samples when a DEM is used as a pre-retracking module	16	us
minimum_peak_prominence_cnf	Minimum prominence for a peak to be selected	3	us

Field name	Description	Values	Variable type
waveform_portion_selection_left_samples_cnf	Number of samples to be considered on the left side of a peak when flag_dem_option_cnf is 1	10	us
waveform_portion_selection_right_samples_cnf	Number of samples to be considered on the right side of a peak when flag_dem_option_cnf is 1	5	us

Table 8. DDP configurable processing options

4.2.3 *Constants file (CST)*

The Constants file contains the basic physical constants definition to be used in the DDP. The constants file is a JSON file and its fields are the following.

Field name	Description	Units	Variable type
semi_major_axis_cst	Semi-major axis of WGS84 ellipsoid	m	fl
semi_minor_axis_cst	Semi-minor axis of WGS84 ellipsoid	m	fl
flat_coeff_cst	Flattening coefficient of WGS84	-	fl
earth_radius_cst	Earth radius	m	fl
pi_cst	Pi number		fl
c_cst	Speed of light	m/s	fl
sec_in_dat_cst	Number of a seconds in a day	s	fl

Table 9. Constants file (CST) fields

4.2.4 *Characterisation Arrays file (CHD)*

The Characterisation Arrays file contains the default calibration corrections. It is a NetCDF file containing the following variables:

- **CAL2 mask corrections** correspond to the instrument transfer function correction to be applied to the different waveforms in the frequency-domain before any SAR processing takes place.
- **Intra-burst corrections** correspond to the CAL1-pulse-to-pulse corrections in phase and amplitude to be carried out before any SAR processing stage.

4.2.4.1 NetCDF variables

Variable name	Description	Units	Type	Dimension
CAL2 correction				
cal2_mask_ku	Instrument transfer function		do	N_samples
Units	Unit name	Counts		1
Scale_Factor	The data must be multiplied by this factor	1e-6		1
Comment	CAL2 LPF amplitude correction to be applied to each echo in the bursts acquired in SAR mode. This correction has to be applied to the Fourier transform of each echo in the acquired bursts. The k-th sample of the Fourier Transform of the echo has to be multiplied by the k-th values of the correction. The echo can go then through Inverse Fourier Transform.[2]			1
Intra-burst correction				
cal1_p2p_amplitude_sar_ku	CAL1 SAR pulse-to-pulse amplitude correction (Ku-band)		do	Np
Units	Unit name	count		1
Scale_Factor	The data must be multiplied by this factor	1e-6		1
Comment	CAL1 Amplitude Pulse-to-Pulse correction to be applied to bursts acquired in SAR mode: the k-th echo in the received burst has to be multiplied by the k-th values of the correction.[3]			1
cal1_p2p_phase_sar_ku	CAL1 SAR pulse-to-pulse phase correction (Ku-band)		do	np
Units	Unit name	rad		1
Scale_Factor	The data must be multiplied by this factor	1e-6		1
Comment	CAL1 phase Pulse-to-Pulse correction to be applied to bursts acquired in SAR mode: the k-th echo in the received burst has to be multiplied by complex exponential of the k-th values of the correction.[4]			1

Table 10. CHD Arrays file NetCDF variables

[2] Within this project, only a single transfer function is available, which is the result of temporally averaging all CAL2 SAR LPF corrections read from Baseline C CAL2 L1B products between 01/03/2011 and 08/11/2015.

[3] Within this project, only a single CAL1 pulse-to-pulse file is available, which is the result of temporally averaging all CAL1 SAR pulse-to-pulse amplitude corrections read from Baseline C CAL1 L1B products between 01/03/2011 and 08/11/2015.

[4] Within this project, only a single CAL1 pulse-to-pulse file is available, which is the result of temporally averaging all CAL1 SAR pulse-to-pulse phase corrections read from Baseline C CAL1 L1B products between 01/03/2011 and 08/11/2015.

5 Output Data Specifications

This section provides a list of the science output files with a brief description. However, the full definition of each one of them can be found in the Product Specification Document (PSD), see AD 4.

5.1 L1B file

The L1B is the final output of the high-resolution processor (thus output of WP2; see Table 2, Implementation Proposal). It contains geolocated and fully calibrated multi-looked high-resolution (fully SAR-processed) Ku-band power echoes.

The formatting of this product is in line with the Sentinel-3 L1B product (see RD. 3), using a single data file in NetCDF 4 format.

5.2 L2A file

The L2A is the final output of the retracking process (thus output of WP3; see Table 2, Implementation Proposal). It contains geophysical retrievals information.

It is a much reduced version of the Sentinel-3 L2 product (see RD. 3) and its description can be found in AD 4, using a single data file in NetCDF 4 format.