NovaSAR Level 1 Products

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1   INTRODUCTION

1.1   SCOPE

This document describes the format of NovaSAR Level 1 data products.

1.2   ACRONYMS AND ABBREVIATIONS

The following abbreviations are used within this document:

GPS	Global Positioning System
IFP	Image Formation Processor
IRF	Impulse Response Function
ISLR	Integrated SideLobe Ratio
PSLR	Peak SideLobe Ratio
SSTL	Surrey Satellite Technology Limited
SWST	Sample Window Start Time

2 LEVEL 1 PRODUCTS

NovaSAR Level 1 products are SAR focused, georeferenced (using WGS84 ellipsoid geometry) and radiometrically calibrated.

2.1 TYPES OF LEVEL 1 PRODUCT

There are four generic types of Level 1 product:

SLC	stripmap, single look, complex, slant range
SRD	stripmap, multi-look, detected, slant range
GRD	stripmap, multi-look, detected, ground range
SCD	scanSAR, multi-look, detected, ground range

2.2 LEVEL 1 PRODUCT FILES

Each Level 1 product consists of the following files:

One or more .tif geoTIFF image files

One .xml metadata

One .xsl metadata style sheet

One low resolution 'Quick-Look' .tif geoTIFF image file

A product will have multiple image files for multi-polar modes. Multiple image files may also be used to divide long images into multiple approximately square image files.

3   LEVEL 1 METADATA FILE

Metadata files are .xml text files with the following contents:

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
Primary Grouping = **Product**					
ProductName	*text_string*		Name of the product		e.g. NovaSAR_01_14008_grd_180125_121508_HH_1
ProductID	*integer_value*				
Primary Grouping = **Source_Attributes**					
Satellite	*text_string*			eg 'NovaSAR1'	
Sensor	*text_string*			eg 'SAR'	
InputDataSetID	*text_string*		File name of processed echo data file		
InputDataSetFacilityID	*text_string*		Name of ground station facility that received echo data.	eg 'SSTL'	
ModeID	*integer_value*		The ID of the instrument mode used.		
OperationalMode	*integer_value*		SAR Operational Mode		
OperationalSwath	*integer_value*		SAR Operational Swath		
AcquisitionID	*integer_value*		Acquisition ID		
ModeMnemonic	*text_string*				A usually 3 char mnemonic for the Image Product
RawDataStartTime	*text_string (YY-MM-DD HH:MM:SS.sssss)*		Start time of acquisition raw data used to generate image.		
Polarisations	*text_array*		List of Polarisation types used	VV, HH, HV, VH	
NumberofSwaths	*integer_value*		Number of range sub swaths used to form image		set to 1 for Strip-map modes

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
PulsesReceivedPerDwell*	*integer_value*		The number of PRI packets of valid raw data used in each subswath burst.		*Output only in ScanSAR & Maritime Modes See Note 1
NumberOfPulseIntervalsPerDwell*	*integer_value*		The number of PRI in each subswath burst.		*Output only in ScanSAR & Maritime Modes See Note 1
Rank	*integer_value*		Rank of received echo ie the number of complete PRI between transmission of pulse and pulse reception		See Note 1
ReceiveGain	*float_value*	dB	Receiver relative gain		See Note 1
RadarCentreFrequency	*float_value*	Hz	Radar Centre Frequency		
PulseRepetitionFrequency	*float_value*	Hz	Pulse Repetition Frequency		See Note 1
PulseLength	*float_value*	sec	Duration of transmit pulse for each sub swath.		See Note 1
ChirpBandwidth	*float_value*	Hz	Bandwidth of transmit pulse for each sub swath.		See Note 1
AntennaPointing	*text_string*		Antenna pointing direction	'LEFT' or 'RIGHT'	
YawSteeringFlag	*text_string*		Defines whether platform is steered to orient antenna in zero Doppler direction	'TRUE' or 'FALSE'	
EchoSamplingRate	*float_value*		Number of raw echo data complex samples per second.		See Note 1
RawBitsPerSample	*float_value*		Equivalent number of bits per I/Q sample	2.5, 3, 3.5, 4, 4.5, 5,12	See Note 1
SamplesPerEchoLine	*integer_value*		Number of raw echo data complex samples per pulse.		See Note 1
InternalRefNoise	*float_value*	counts	RMS of Internal Noise pixels.		See Note 1,3

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
ExternalRefNoise	*float_value*	counts	RMS of External Noise pixels.		See Note 1,3
Bias_I	*float_value*	counts	Mean value of real part of digitised echo data		See Note 3
Bias_Q	*float_value*	counts	Mean value of imaginary part of digitised echo data		See Note 3
StandardDeviation_I	*float_value*	counts	Standard Deviation of real part of digitised echo data samples		See Note 3
StandardDeviation_Q	*float_value*	counts	Standard Deviation of imaginary part of digitised echo data samples		See Note 3
GainImbalance	*float_value*	dB	Ratio of the mean power of the real part of the digitised echo data to the mean power of the imaginary part of the echo data		
PhaseOrthogonality	*float_value*	degrees	Deviation from quadrature of real and imaginary parts of echo data		A positive value indicates that there is less than 90 degrees between real and imaginary parts
FractionOfPacketsWithError	*integer_value*		Fraction of raw data packets used to form image that were detected as containing errors.		Total packet errors is sum of Data Error 1 plus Data Error 2 plus Data Error 3
DataError_MissingPackets	*integer_value*		Number of Missing Packets in processed echo data		
DataError_CRC	*integer_value*		Number of Cyclic Redundancy Check errors in processed echo data		
DataError_PRI_type	*integer_value*		Number of wrong PRI Type errors in processed echo data		

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
Primary Grouping = **OrbitData**					
OrbitDataFile	*text_string*		Name of file containing orbit data.		
PassDirection	*text_string*			'ASCENDING' or 'DESCENDING'	Direction of satellite pass at the start of the image
OrbitDataSource	*text_string*		Origin of the orbit data file used	'GPS DATA' or 'TLE FILE'	
NumberOfStateVectorSets	*integer_value*		Number of state vectors listed.		
For each state vector set....					
Time	*text_string* *(YY-MM-DD HH:MM:SS.sssss)*		GPS Position Timestamp		e.g. 2018-01-25 12:15:09.77851
xPosition	*float_value*	m	GPS Position		
yPosition	*float_value*	m	GPS Position		
zPosition	*float_value*	m	GPS Position		
xVelocity	*float_value*	m/s	GPS Velocity		
yVelocity	*float_value*	m/s	GPS Velocity		
zVelocity	*float_value*	m/s	GPS Velocity		
...end of state vector set details					
AttitudeDataSource	*text_string*		'GPS' or 'MODEL'		Roll/Pitch/Yaw all set to zero if set to 'MODEL' Always 'GPS' for NovaSAR
PlatformRoll	*float_value*	deg	Payload roll angle		Roll Attitude Parameter value at zero Doppler time of mid-image. Relative to Zero Doppler Frame (ZDF)
PlatformPitch	*float_value*	deg	Payload pitch angle		Pitch Attitude Parameter value at zero Doppler time of mid-image. Relative to ZDF
PlatformYaw	*float_value*	deg	Payload yaw angle		Yaw Attitude Parameter value at zero Doppler time of mid-image. Relative to ZDF

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
PlatformRollRate	*float_value*	deg/sec	Payload roll angle rate		Roll rate Parameter value, assumed constant over the acquisition
PlatformPitchRate	*float_value*	deg/sec	Payload pitch angle rate		Pitch rate Parameter value, assumed constant over the acquisition
PlatformYawRate	*float_value*	deg/sec	Payload yaw angle rate		Yaw rate Parameter value, assumed constant over the acquisition
Primary Grouping = **Image_Generation_Parameters**					
ProductType	*text_string*		Product Type	"slc" Stripmap, Single Look Complex, Slant Range "srd" Stripmap, Multilook Detected, Slant Range "grd" Stripmap, Multilook Detected, Ground Range "scd" ScanSAR, Multilook Detected, Ground Range	
ProcessingFacility	*text_string*			e.g. SSTL	
ProcessingTime	*text_string (YYMMDD_HHMM)*		Time of processing to this image product by IFP.		
SoftwareVersion	*text_string*		Version of IFP software used.		
AlgorithmUsed	*text_string*		Selected Processing Algorithm	RM' or 'RD – Interpolator' or 'RD – Fourier Shift' or	RM: Range Migration RD: Range Doppler

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
				'RD – Chirp Scale'	
ExtendedChirpScaling	*text_string*			'TRUE' or 'FALSE'	Set 'TRUE' in ScanSAR or Maritime modes
wK_Flag	*text_string*	N/A	Whether a component of the matched filter in the range/Doppler frequency domain has been applied.	'TRUE' or 'FALSE'	
RadiometricScaling	*text_string*	N/A		'None' Sigma0 Beta0 Gamma0	No radiometric scaling applied rcs per unit area on earth ellipsoid rcs per unit area in the plane of the look direction rcs per unit area in the plane perpendicular to the look direction
RadiometricSmoothingPerformed	*text_string*	N/A	Indicates whether smoothing has been performed to merge neighbouring ScanSAR image blocks (in range and azimuth)	'TRUE' or 'FALSE'	Output in ScanSAR only
DopplerSource	*text_string*	N/A		Always 'ORBIT & ATTITUDE'	
ZeroDopplerTimeFirstLine	*text_string (YY-MM-DD HH:MM:SS.sssss)*		The time at which the radar viewed the location of first image line in direction of closest approach.		
ZeroDopplerTimeLastLine	*text_string (YY-MM-DD*		The time at which the radar viewed the location of last		

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
	HH:MM:SS.sssss)		image line in direction of closest approach.		
SWST	*float_value*	seconds	Time between start of a transmit pulse and start of the receive window in which the ground return from that pulse is received. (for the indicated subswath)		See Note 1, 3
NumberOfRangeLooks	*integer_value*	N/A	Number of Range Looks processed		Looks are defined in frequency and may overlap.
RangeLookBandwidth	*float_value*	Hz	Range Bandwidth per Look		
TotalProcessedRangeBandwidth	*float_value*	Hz	Total Bandwidth spanned by all of the range looks.		Will be less than sum of look bandwidths if looks overlap.
NumberOfAzimuthLooks	*integer_value*	N/A	Number of azimuth Looks processed		In ScanSAR modes looks are defined in time domain.
AzimuthLookBandwidth	*float_value*	Hz	Azimuth Bandwidth per Look		
TotalProcessedAzimuthBandwidth	*float_value*	Hz	Total Bandwidth spanned by all of the azimuth looks.		Will be less than sum of look bandwidths if looks overlap. For ScanSAR is the sum of a look bandwidth plus the range of look centre frequency over imaged ground extent for subswath burst.
IRFWindow	*text_string*	N/A	Type of window function applied to data, in frequency domain, to reduce IRF sidelobe levels.	'None' or 'Taylor' or 'Hanning' or 'Kaiser'	
WindowParam1	*float_value*	N/A	Parameter 1 value for IRF window	Weight parameter.	Taylor: Number of sidelobes of desired peak sidelobe level
WindowParam2*	*float_value*		Parameter 2 value for IRF window	Nominal level first sidelobes.	*Output for Taylor weight only

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
SlantRangeNearEdge	*float_value*	metres	Distance from radar to ground in zero Doppler look direction at near swath edge		
PlatformHeight	*float_value*	metres	Nominal platform height above reference ellipsoid		
DopplerCentroid	*float_array*	Hz	Coefficients of polynomial fit to offset of centre of processed Doppler bandwidth from zero assessed across swath.		Values output in order A_0, A_1, ... A_n for fit Polynomial to be evaluated $A_0 + A_1x ... + A_nx^n$ where x is pixel number across swath. Evaluated polynomial gives Doppler centroid in Hz.
IRF_3dBWidth	*float_value*	m	Replica auto-correlation 3 dB width		
IRF_PSLR	*float_value*	dB	Replica auto-correlation Peak Sidelobe level ratio, PSLR		
IRF_ISLR	*float_value*	dB	Replica auto-correlation Integrated Sidelobe Level Ratio, ISLR		
ChirpAmpCoeffs	*float_array*	N/A	Coefficients of polynomial fit to amplitude component of deramped replica, in amplitude/sample^n.	First sample in line is sample no. 0.	Output only when repFiltmethod = 3 or 4 Array length = repFiltOrd + 1 Values output in order A_0, A_1, ... A_n for fit Polynomial to be evaluated

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
					$A_0 + A_1x \ldots +A_nx^n$ where x is replica sample number. Evaluated polynomial gives linear amplitude.
ChirpPhaseCoeffs	*float_array*	N/A	Coefficients of polynomial fit to phase component of deramped replica, in degrees/sample^n.	First sample in line is sample no. 0.	Output only when repFiltmethod = 3 or 4 Array length = repFiltOrd + 1 Values output in order A_0, A_1, … A_n for fit Polynomial to be evaluated $A_0 + A_1x \ldots +A_nx^n$ where x is replica sample number. Evaluated polynomial gives phase in degrees.
ChirpDirection	*text_string*	N/A	Slope of Transmitted RF Pulse Frequency Modulation	'UPCHIRP', 'DOWNCHIRP' or 'ALTERNATE'	
GroundToSlantRangeCoefficients*	*float_array*	N/A	Coefficients of polynomial fit to the "Ground to Slant Range" transform applied. Fixed along all image slices.	In (slant range in m)/(pixel no.)^n where first pixel in line is pixel no. 0.	*output for ground range products only. Array length = srtgrOrd + 1 Values output in order A_0, A_1, … A_n for fit

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
					Polynomial to be evaluated $A_0 + A_1x \ldots + A_nx^n$ where x is pixel number in the line where the first pixel in the line has x=0. Evaluated polynomial gives Slant Range in metres.
IncAngleCoeffs	*float_array*		Polynomial coefficients for incidence angle at pixel position.	In deg/(pixel no.)^n where first pixel in line is pixel no. 0.	at mid-image Values output in order A_0, A_1, … A_n for fit Polynomial to be evaluated $A_0 + A_1x \ldots + A_nx^n$ where x is pixel number in the line where the first pixel in the line has x=0. Evaluated polynomial gives incidence angle in degrees.
DepAngleCoeffs	*float_array*		Polynomial coefficients for depression angle	In deg/(pixel no.)^n where first pixel in line is pixel no. 0.	at mid-image Values output in order A_0, A_1, … A_n for fit Polynomial to be evaluated $A_0 + A_1x \ldots + A_nx^n$ where x is pixel number in the line where the first pixel in the line has x=0.

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
					Evaluated polynomial gives depression angle in degrees.
Primary Grouping = **Image_Attributes**					
ProductFormat	*text_string*	N/A	Image File Format	'GeoTIFF' or 'Big GeoTIFF'	
OutputMediaInterleaving	*text_string*	N/A	Describes interleaving of real and complex parts of samples for complex products.	'LINE_INTERLEAVED' or 'PIXEL_INTERLEAVED'	
DataType	*text_string*	N/A		'COMPLEX' or 'MAGNITUDE_DETECTED'	
BitsPerSample	*integer_value*	N/A	Number of bits contained in each image pixel component value	8 or 16 or 32	
NumberofSamplesPerLine	*integer_value*	N/A	Number of pixels per line of image.		
NumberOfLinesInImage	*integer_value*		Number of lines in image		
SampledPixelSpacing	*float_value*	metres	Distance between pixels in across-track (range) direction		metres
SampledLineSpacing	*float_value*	metres	Distance between pixels in along-track direction		metres
LineTimeOrdering	*text_string*	N/A	Time ordering of lines in along-track direction	'INCREASING' or 'DECREASING'	
PixelTimeOrdering	*text_string*	N/A	Time ordering of lines in across-track direction	'INCREASING' or 'DECREASING'	
RangeResolution	*float_value*	N/A	Nominal range resolution		metres
AzimuthResolution	*float_value*	N/A	Nominal azimuth resolution		metres
PixelMeanI	*float_value*		Mean value of image pixel I values		Mean of real part of pixel values for complex images
PixelMeanQ	*float_value*		Mean value of image pixel Q values		Mean of complex part of pixel values for complex images

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
PixelStandardDeviationI	*float_value*		Standard Deviation of image pixel I values		Standard Deviation of real part of pixel values for complex images
PixelStandardDeviationQ	*float_value*		Standard Deviation of image pixel Q values		Standard Deviation of complex part of pixel values for complex images
Equiv_Number_of_Looks	*float_value*		Number of independent looks that would give same scattering cross section variance for a uniform distributed scene as the look arrangement used by IFP.		
CalibrationConstant	*float_value*		Radiometric calibration constant		The radiometric scattering cross section, σ_0, β_0 or λ_0, is the (pixel value)^2/ CalibrationConstant
CalibrationStatus	*float_value*	N/A	Status of mission radiometric calibration.	UNCALIBRATED PRELIMINARY RELATIVE CALIBRATED	
ImageNoiseRangePixelPositions	*integer_value*		Across swath pixel positions at which Image Noise values are provided		
ImageNoiseValue	*float_value*	pixel counts^2	Noise contribution to image		Variance of noise contribution to image.
Primary Grouping = **geographicInformation**					
EllipsoidName	*text_string*	N/A	Name of Reference Ellipsoid Model		eg 'WGS84'
SemiMajorAxis	*float_value*	metres	Semi-major axis of reference ellispoid		
SemiMinorAxis	*float_value*	metres	Semi-minor axis of reference ellipsoid		

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
MeanTerrainHeight	_float_value_	metres	Assumed mean scene height used in geolocation calculations		
PixelRMS	_float_value_		Root mean square of image pixel value		
NumberOfRangeTiepoints	_Integer_value_	N/A	Number of across track tie points provided in image		
NumberOfAzimuthTiepoints	_Integer_value_	N/A	Number of along track tie point positions provided in image		
For each tiepoint....					
Line	_float_value_	N/A	Line number of tie point (along-track direction)	First line in image is line no. 0.	
Pixel	_float_value_	N/A	pixel number of tie point (across-track direction)	First pixel in line is pixel no. 0.	
Latitude	_float_value_	degrees	Latitude of tie point		
Longitude	_float_value_	degrees	Longitude of tie point		
Height	_float_value_	metres	Height of tie point above reference ellipsoid		
For each tiepoint....					

Note 1: Subswath, and units, are given as field name attributes eg. `<PulseLength Subswath="S1" units="seconds">`
Note 3: Counts are the equivalent at the receiver 12 bit ADC of the filtered data in the echo packets.

Table 3-1: Metadata Parameters