

S1-ETAD Project

Product Format Specification Document

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Document Change Control

This document is under configuration control. Latest changes to the document are listed first.

Issue	Date	Chapter	Changes
1.5	16.06.2021	5 NetCDF	Added unit column in Table 1 (AR RID AV-06)
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		Annex A	Changed manifest.safe mimeTypees
1.3	31.01.2021	5 NetCDF 6 XML	Adopt a uniform naming of rangeShift instead of the occasional rangeDelay (AV-04)
		6 XML	Number of polynomials and their application is now included in the comments of dcEstimate and azimuthFmRate nodes (AV-02, AV-03)
		6 XML	Count attribute dropped from list elements and only kept in list header (AV-01)
		6 XML	Added a second horizontal oversampling factor for the tropospheric correction parameters
		7.2 KMZ	Reference to Figure 16 (AV-05)
		Annex A	Removed duplicate dataObjectIDs and only included replIDs for schemas that are referenced within the manifest's metadata section (AV-06, AV-07)
1.2	22.10.2020	All	Document restructured for processor qualification release by moving format details from the Annex into the main chapters. Editorials and clarifications. Additional examples included.
		5 NetCDF	gridStart[Azimuth Range]Time w/o trailing zero and harmonized in XML and NetCDF (NM-12, AV-4). Clarified annotated relative start times with respect to the datatime reference time in the root group (AV-6). Unit attributes for all grids. Inclusion of burst wise averageZeroDopplerVelocity (AV-7).
		6	Added detailed descriptions for all XML elements in tables provided for each main XML node (NM-13), including details on the content and use of the XML elements (NM-16, AV-6).
		6 XML	Non-optional unit attributes for all (physical) parameter elements (not only when given in two representations; NM-3, AV-01). Uniform time format (NM-1), carrierFrequency moved (NM-4), grid layer information moved from burst level to product level to avoid repetition (NM-11). Count attributes for list elements (non-optional and specified to start with 1) & homogenous naming of lists / list elements (NM-8, NM-9, NM-14, AV-5). gridStart[Azimuth Range]Time w/o trailing zero and harmonized in XML and NetCDF (NM-12, AV-3). averageZeroDopplerVelocity in gridInformation of each burst for convenient conversion of azimuth times to ground distances (AV-7) .
		7	KMZ preview file naming, content and description specified. Product structure updated for preview components (Figure 16). Details on CRC-16 checksum added.
		Annex A	Included format description and example of the ETAD manifest.safe file.
		Annex B	XSD schema update to version 1.5. Removed print-out of XSD and embedded XSD file in document.
1.1	16.07.2020	5 Figure 1, 5.1 Table 1	NetCDF rootGroup attributes for temporal coverage t[Min/Max] renamed to azimuthTime[Min/Max] of type string (UTC times) and tau[Min/Max] renamed to rangeTime[Min/Max]. Burst group attributes gridStartT0 renamed to gridStartAzimuthTime0 and gridStartTau0 renamed to gridStartRangeTime0
		7 Figure 12	Content of support directory specified.
		Annex B, 6.1 Fig. 3	XSD schema updated to version 1.4: productCoverage/temporalCoverage and bursts/etadBurst/burstCoverage/temporalCoverage parameters renamed from t[Min/Max] and tau[Min/Max] to azimuthTime[Min/Max] and rangeTime[Min/Max]
		1.2	Scope
1.0	08.07.2020	All	First issue

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1 Introduction

1.1 Purpose

The document at hand defines the format of the Extended Timing Annotation Dataset (ETAD) for the Sentinel-1 level 1 SLC products.

1.2 Scope

This document is an addendum to the ETAD Product Definition Document applicable to the S1-ETAD project. It is released in this version for the SETAP processor verification.

2 Applicable and reference documents

2.1 Applicable document

The following documents are fully applicable for this document.

	Document ID	Document Title	Issue
[A1]	ESA-EOPG-EOPGM-SOW-1	Sentinel-1 Auxiliary product for precise atmospheric and geodetic correction: Statement of Work	1.0 18.06.2018
[A2]	ETAD-DLR-DD-0008	Algorithm Technical Baseline Document	2.1 30.04.2020
[A3]	S1-RS-MDA-52-7441	Sentinel-1 Product Specification	3.5 19.04.2018
[A4]	ETAD-DLR-DD-0004	S1-ETAD Input/Output Description Document	2.2 30.04.2020
[A5]	PGSI-GSEG-EOPG-FS-05-0001	Standard Archive Format for Europe (SAFE) Control Book Volume 1 Core Specifications	1.8 28.06.2008
[A6]	ETAD-DLR-PS-0002	Product Definition Document	2.1 16.06.2021

2.2 Normative references

The following standards have been used for preparing the plan on hand (e.g. ECSS).

	Document ID	Document Title	Issue
[N1]			
[N2]			
[N3]			

2.3 Informative references

The following documents are referenced in the present document.

	Document ID	Document Title	Issue
[I1]	GMES-GSEG-EOPG-FS-10-0075	Sentinels POD Service File Format Specifications	1.22 18.01.2018
[I2]	GEO.2018-1988-2	Copernicus Digital Elevation Model Product Handbook	1.0 28.11.2019
[I3]	EGM2008	https://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/egm08_wgs84.html	
[I4]	ESDS-RFC-022v1	netCDF-4/HDF5 File Format	V0.03 March 2011
[I5]	PDGS MPC-S1	Sentinel-1 Quality Control: https://qc.sentinel1.eo.esa.int/	

3 Terms, definitions and abbreviations

3.1 Terms and Definitions

Term	Definition
Extended Timing Annotation Dataset	Timing corrections to be applied to standard SAR products timings
SAFE format	Format used by the Sentinel-1 data products

3.2 Abbreviations

Abbreviation	Meaning
CDR	Critical Design Review
CF	Climate and Forecast
DEM	Digital Elevation Model
ESA	European Space Agency
EW	Extra Wide-Swath (SAR mode)
FM	Frequency Modulation
GRD	Ground-Range Detected
HDF5	Hierarchical Data Format version 5
IW	Interferometric Wide-Swath (SAR mode)
KML	Keyhole Markup Language
KMZ	Keyhole Markup Language Zip File
L1	Level-1
NWP	Numerical Weather Prediction
PDGS	Payload Data Ground Segment
PDR	Preliminary Design Review
PRF	Pulse Repetition Frequency
RSF	Range Sampling Frequency
S-1	Sentinel-1
S1-ETAD	Extended Time Annotation Dataset for Sentinel-1
SAFE	Standard Archive Format for Europe
SAR	Synthetic Aperture Radar
SET	Solid Earth Tides
SLC	Single Look Complex
SM	Stripmap (SAR mode)
TEC	Total Electron Content
TOPS	Terrain Observation by Progressive Scans (SAR mode)
XML	Extensible Markup Language
XSD	XML Schema Definition

4 Extended Timing Annotation

4.1 Introduction

Precise geolocation for geodetic measurements in the centimeter accuracy range with SAR instruments has been demonstrated in the past years and yielded an emerging field of applications. This precision is not achieved out-of-the-box when using the orbit, the speed of light and the satellite velocity alone to transform the annotated timing parameters of a SAR product into geo-referenced positions.

Rather, the Radar pulses transmitted and received by SAR satellites like Sentinel-1 are subject to signal propagation delay variations when passing through different layers of Earth's atmosphere (troposphere and ionosphere). These delays depend on the actual atmospheric conditions at a certain time and location and the specific geometry of the SAR acquisition.

The object on ground which is to be measured in its position is not stable w.r.t. its absolute geo-coordinates. The dominant effects are caused by the Solid-Earth Tides (SET) which induce temporal variations of the location with respect to a reference coordinate frame.

Additionally, approximations are used in the SAR image formation and product time annotation process which do not fully take into account the movement of the instrument during the signal travel time, the squint angle/Doppler and distance variations to the surface during the TOPS observations.

All the geo-physical effects can be calculated based on the orbits and annotated timing information in the SAR product when evaluating tropospheric numerical weather prediction (NWP) models, ionospheric Total Electron Content (TEC) data and geodynamic models. The errors induced by the SAR processing approximations can be accurately estimated by analyzing the SAR timeline and by the Doppler and FM-rate parameters based on an accurate Digital Elevation Model (DEM).

4.2 The ETAD Product

Creating a data set to correct for the described effects is the task of the S1-ETAD (Extended Time Annotation Dataset for Sentinel-1) processor [A1][A2]. With the output of the processor, i.e. the S1-ETAD product that contains the correction data set, any user may thus achieve precise geo-location from a S-1 standard SAR product.

The ETAD product provides grids to the user, which specify the azimuth and range timing corrections for all the different effects, and which are applicable to each burst of a TOPS data take. Additionally, the sums of the corrections and mapping grids to translate timing information to geographic coordinates are provided. The individual grids are packed in a container file in NetCDF format supplemented with annotation parameters and XML annotation components.

The product content, its rationale as well as the application to the SAR products is detailed in the Product Definition Document [A6]. In this document, only the format, the structure and the naming of the provided data files are specified.

5 NetCDF-4/HDF5 Product Format

Since there are typically 9 bursts for each of the 3 sub-swaths in one slice alone in Sentinel-1 IW mode (21 bursts in 5 sub-swaths in EW mode), in total the 12 correction grids per burst would accumulate to 324 (respectively 1260) grid files for each slice if stored separately. In order to handle this amount of data, a hierarchical product container structure is required for the product format.

The selected format is the NetCDF-4 framework using the Hierarchical Data Format version 5 (HDF5) file format that supports large, complex, heterogeneous data [14]. HDF5 uses a directory like structure to store the different data components. It also supports in-file compression of the data. Note that HDF5 refers to these folder-like hierarchies as “groups” and the files are identified as “datasets”. Groups may contain other groups and/or datasets and associated metadata. The ETAD NetCDF format is structured into individual groups for each swath of the datatake. These swath groups contain burst groups which are numbered increasingly according to their time of acquisition.

The NetCDF format with the Climate and Forecast (CF) metadata conventions is widely used in the Earth observation community. Nevertheless, NetCDF/CF primarily targets the optimal representation of geo-spatial atmospheric and ocean surface data in geo-coordinate systems. The representation of grids in SAR timing is not foreseen by this convention. The organizational structure of the ETAD NetCDF file is depicted in Figure 1. The minimal number of datasets is given by the stripmap mode SLC input and results in 12 datasets for one burst in one sub-swath for one slice.

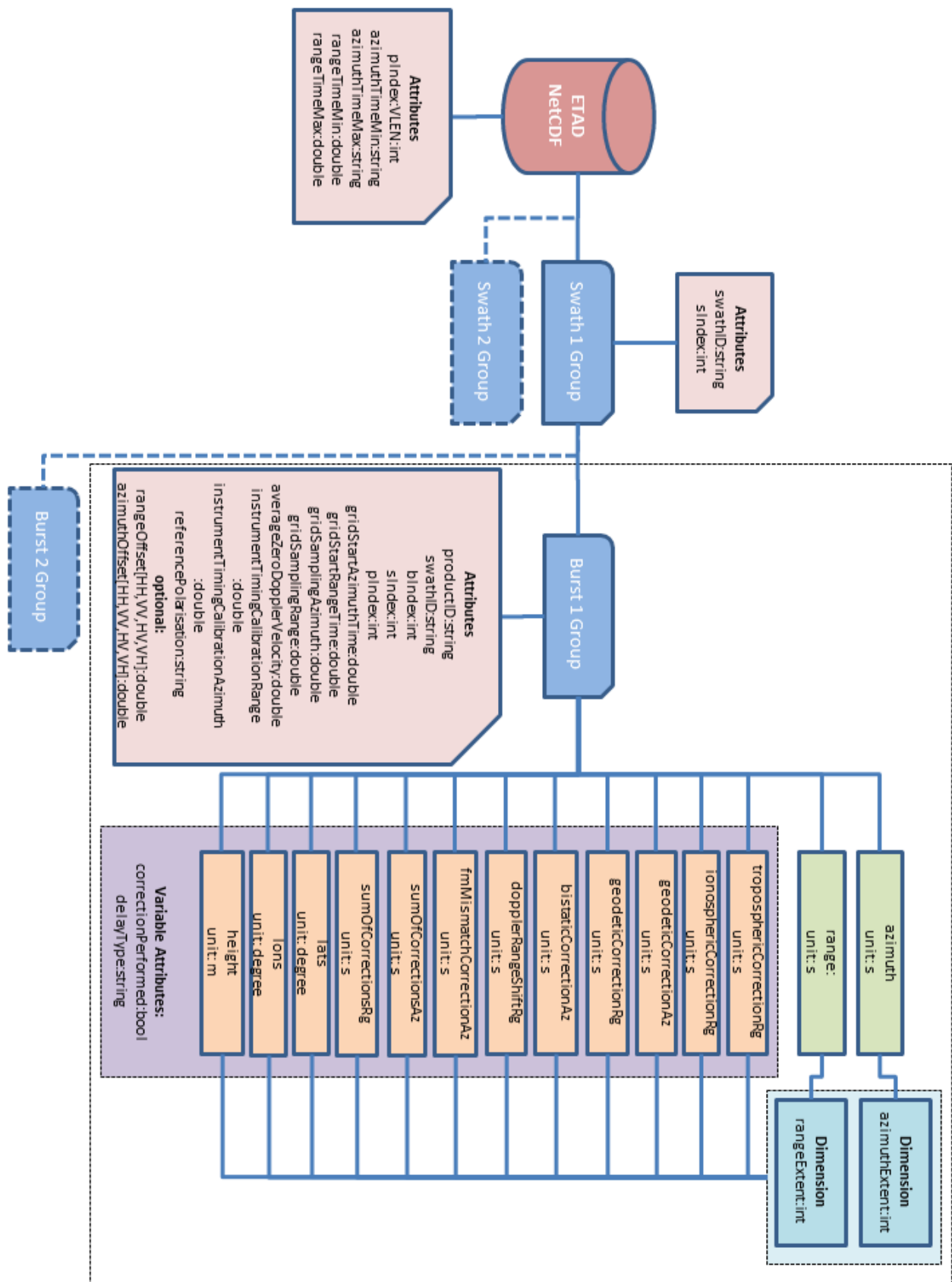


Figure 1: Organizational structure of the ETAD NetCDF4-HDF5 file.

5.1 The NetCDF Parameters

The different groups inside the NetCDF files use the “attributes” data structural element for identifying parameters (e.g. indices and timing parameters). The only “variables” are the correction and mapping grids (lats, lons, height) inside the individual burst groups. These two-dimensional matrices all share the same azimuth and range dimensions. For convenience, the azimuth and range times are also provided as one-dimensional vectors, spanning the X- and Y-axis of the grids. This also facilitates the data representation in NetCDF readers and viewers.

Separate NetCDF groups have been assigned to the product-, swath- and burst-level. Table 1 provides the detailed definition of the NetCDF elements. The correction grids on the burst level are highlighted in orange. Azimuth and range times defining the grid point locations are annotated in two vectors highlighted in green. Each burst has its individual azimuth and range start times which are referenced to the overall azimuth and range minimum times (azimuthTimeMin, rangeTimeMin) given in the root group for the entire data take.

Table 1: The NetCDF parameter list table.

NetCDFProduct:rootGroup					
Attributes:		type	Description	required	unit
	pIndex	VLEN:int	List of product indices	Yes	-
	azimuthTimeMin	string	UTC start time	Yes	-
	azimuthTimeMax	string	UTC stop time	Yes	-
	rangeTimeMin	double	Start time in seconds	Yes	s
	rangeTimeMax	double	Stop time in seconds	Yes	s
Dimensions:		type	Description		
	-	-	-		
Variables:		type	Dimension	unit	description
	-	-	-	-	-
Groups:		type			
	Swath1	Group:swath			
	Swath2	Group:swath			
	...	Group:swath			
Group:swath					
Attributes:		type	Description	required	unit
	swathID	string	For example IW1, IW2,	Yes	-
	sIndex	Int		Yes	-
Dimensions:		type	Description		
	-	-	-		
Variables:		type	Dimension	unit	description
	-	-	-	-	-
Groups:		type			
	Burst1	Group:burst			
	Burst2	Group:burst			
	...	Group:burst			
Group:burst					
Attributes:		type	Description	required	unit
	productID	string	The Sentinel-1 product id	Yes	-
	swathID	string	For example IW1, IW2,	Yes	-
	bIndex	Int	Burst index	Yes	-
	sIndex	Int	Swath index	Yes	-
	pIndex	Int	Product index	Yes	-
	gridStartAzimuthTime	double	Delta azimuth time of first grid point referenced to	Yes	s

			"azimuthTime Min" in seconds		
gridStartRangeTime	double		Delta range time of first grid point referenced to "rangeTimeMin" in seconds	Yes	s
gridSamplingAzimuth	double		Grid sampling in azimuth time domain	Yes	s
gridSamplingRange	double		Grid sampling in range time domain	Yes	s
averageZeroDopplerVelocity	double		Average azimuth beam velocity on ground	Yes	m/s
instrumentTimingCalibrationRange	double		The range timing calibration of the reference polarisation channel (already applied in sum layer)	Yes	s
instrumentTimingCalibrationAzimuth	double		The azimuth timing calibration of the reference polarisation channel (already applied in sum layer)	Yes	s
referencePolarisation	string		The reference polarization for timing offsets. Can take HH, VV, HV, VH.	Yes	-
rangeOffsetHH	double		Range timing offset to reference polarisation	No	s
azimuthOffsetHH	double		Azimuth timing offset to reference polarisation	No	s
rangeOffsetVV	double		Range timing offset to reference polarisation	No	s
azimuthOffsetVV	double		Azimuth timing offset to reference polarisation	No	s
rangeOffsetHV	double		Range timing offset to reference polarisation	No	s
azimuthOffsetHV	double		Azimuth timing offset to reference polarisation	No	s
rangeOffsetVH	double		Range timing offset to	No	s

	azimuthOffsetVH	double	reference polarisation Azimuth timing offset to reference polarisation	No	s	
Dimensions:		type	Description			
	azimuthExtent	Int	Number of grid cells in azimuth direction			
	rangeExtent	Int	Number of grid cells in range direction			
Variables:		type	Dimension	unit	attributes	description
	azimuth	double	azimuthExtent	s	-	The azimuth timing in seconds
	range	double	rangeExtent	s	-	The range timing in seconds
	troposphericCorrectionRg	double	azimuthExtent, rangeExtent	s	correctionPerformed, delayType	Correction Grid
	ionosphericCorrectionRg	double	azimuthExtent, rangeExtent	s	correctionPerformed, delayType	Correction Grid
	geodeticCorrectionAz	double	azimuthExtent, rangeExtent	s	correctionPerformed, delayType	Correction Grid
	geodeticCorrectionRg	double	azimuthExtent, rangeExtent	s	correctionPerformed, delayType	Correction Grid
	bistaticCorrectionAz	double	azimuthExtent, rangeExtent	s	correctionPerformed, delayType	Correction Grid
	dopplerRangeShiftRg	double	azimuthExtent, rangeExtent	s	correctionPerformed, delayType	Correction Grid
	fmMismatchCorrectionAz	double	azimuthExtent, rangeExtent	s	correctionPerformed, delayType	Correction Grid
	sumOfCorrectionsAz	double	azimuthExtent, rangeExtent	s	correctionPerformed, delayType	Correction Grid
	sumOfCorrectionsRg	double	azimuthExtent, rangeExtent	s	correctionPerformed, delayType	Correction Grid
	lats	double	azimuthExtent, rangeExtent	degree	-	Latitude grid
	lons	double	azimuthExtent, rangeExtent	degree	-	Longitude grid
	height	double	azimuthExtent, rangeExtent	m	-	Height grid
Groups:		type				
	-	-				
VariableAttributes		type	Description	required	unit	
	correctionPerformed	bool	Indicates if this correction was performed. Otherwise all grid values are 0	Yes	-	
	delayType	string	Can take the values: [rangeShift, azimuthShift]	Yes	-	

In case one or more of the individual correction grids have not been calculated, because the processor has been configured this way, the corresponding grids are provided nevertheless and filled with zeros. The rationale is to provide a standardized data access and a consistent calculation of the sums and statistics. In such circumstances the Boolean attribute flags of each grid indicate the validity of the specific grid matrix.

The polarisation offsets `rangeOffset[HV][HV]` and `azimuthOffset[HV][HV]` are only annotated for those polarisations which are actually used in the input products. Note that the format permits in principle the annotation of such channel offsets for full polarization data.

For the two grids `sumOfCorrectionsAz` and `sumOfCorrectionsRg`, the sensor calibration offsets have already been applied which has the advantage that product users can apply the corrections without further calculations. If the corrections are desired for a different polarization layer, the respective `rangeOffset[HV][HV]` and `azimuthOffset[HV][HV]` values have to be added. In case the user intends to assemble application specific corrections grids from combinations of the individual correction layers and/or external data, the two `instrumentTimingCalibration[Azimuth][Range]` offsets provided for each burst have to be added in range and azimuth respectively.

The NetCDF file may be opened with standardized software tools like in the example in Figure 2.

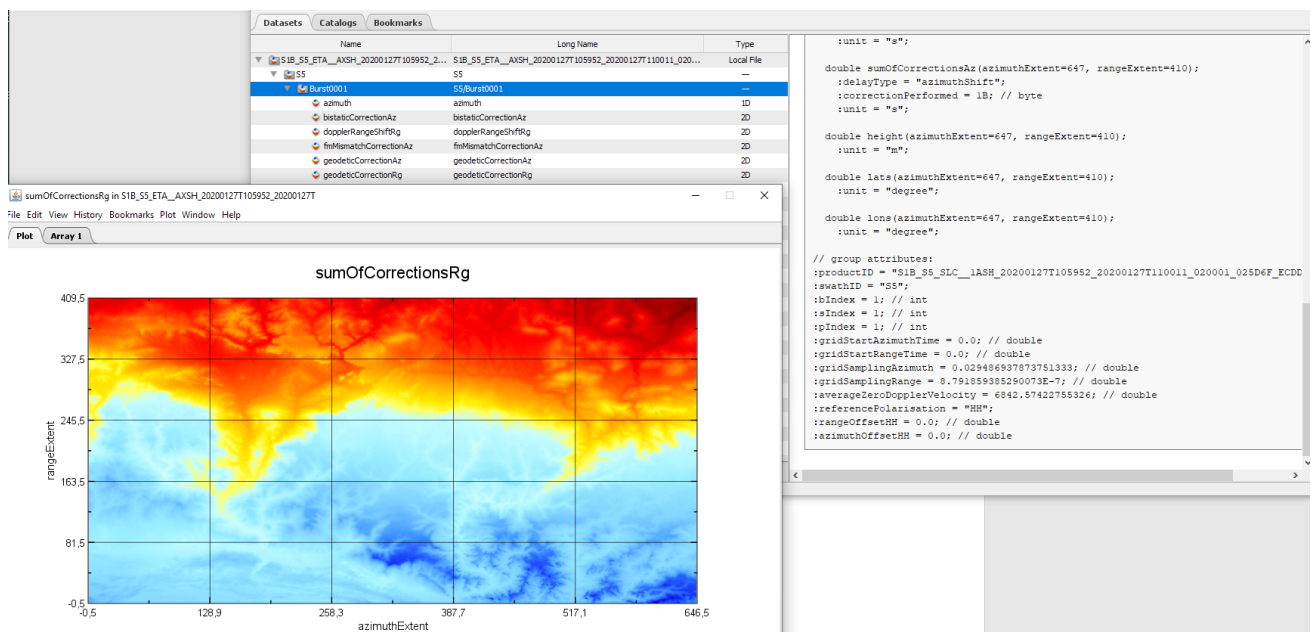


Figure 2: Example of an ETAD NetCDF file opened in the NASA/GISS NetCDF-viewer Panoply¹.

¹ <https://www.giss.nasa.gov/tools/panoply/>

6 The ETAD Main XML Annotation File

This section outlines the main structure and parameter groups of the main XML annotation file. Details on the format definition, types and the full content of this file can be found in Annex B.

The overall structure is given by a group of nodes providing information on the entire product and its generation, and a list of nodes detailing of the individual burst parameters. Note that the corrections may be applied based solely on the basic parameters found in the NetCDF data file. The XML file provides however valuable additional information on the product generation process, the inputs and settings used for the calculations, and statistical information of the results for quick quality assessment. Where applicable (e.g. for SAR parameter description), the Sentinel-1 L1 annotation format is used.

Table 2: Overview of the main XML parameter groups

ETAD main XML product annotation parameter groups	
Component	Description of main information
etadHeader	Identifying parameters of the corresponding S-1 data take
productCoverage	Spatial and temporal coverage of the outer boundaries of the correction grids - i.e. the rectangular coverage of the entire product.
productInformation	Main parameters for the interpretation and application of this specific product; i.e. the reference systems of the spatio-temporal coordinates, the common sampling and polarization channel dependent data. Describing parameters helping in the interpretation and evaluation of the different grid layers.
processingInformation	Information on product generation, the input and auxiliary data and the internal resources and settings of the processor. The processor configuration is summarized and the flags/switches for the different calculations are provided. The calculation methods and higher-level algorithmic parameters are given.
qualityAndStatistics	Quality flags on reliability of processing and the calculated corrections and basic statistics on the common geophysical corrections for the entire data take.
productComponents	The content of the product in terms of SAR input products, swaths and bursts. It lists the identifying parameters of the different input SAR products used and identifies which bursts belong to which input and also indicates the completeness of the inputs.
etadBurstList	The list of the individual etadBurst annotation groups as detailed below.
etadBurst annotation parameter groups	
burstData	Identifying parameters and indices of the individual burst.
burstCoverage	Spatial and temporal coverage of the grids of one burst.
gridInformation	All basic parameters (timing and polarization offsets) required for the application of the grid data to the focused SAR data.
processingInformation	The parameters related to the determination of the SAR specific system corrections of the bursts.

burstDataStatistics	Basic statistical parameters on all calculated corrections for the individual bursts.
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6.1 General ETAD Product Parameter Annotation

The high-level annotation parameter tree of the ETAD product annotation file is depicted in Figure 3.

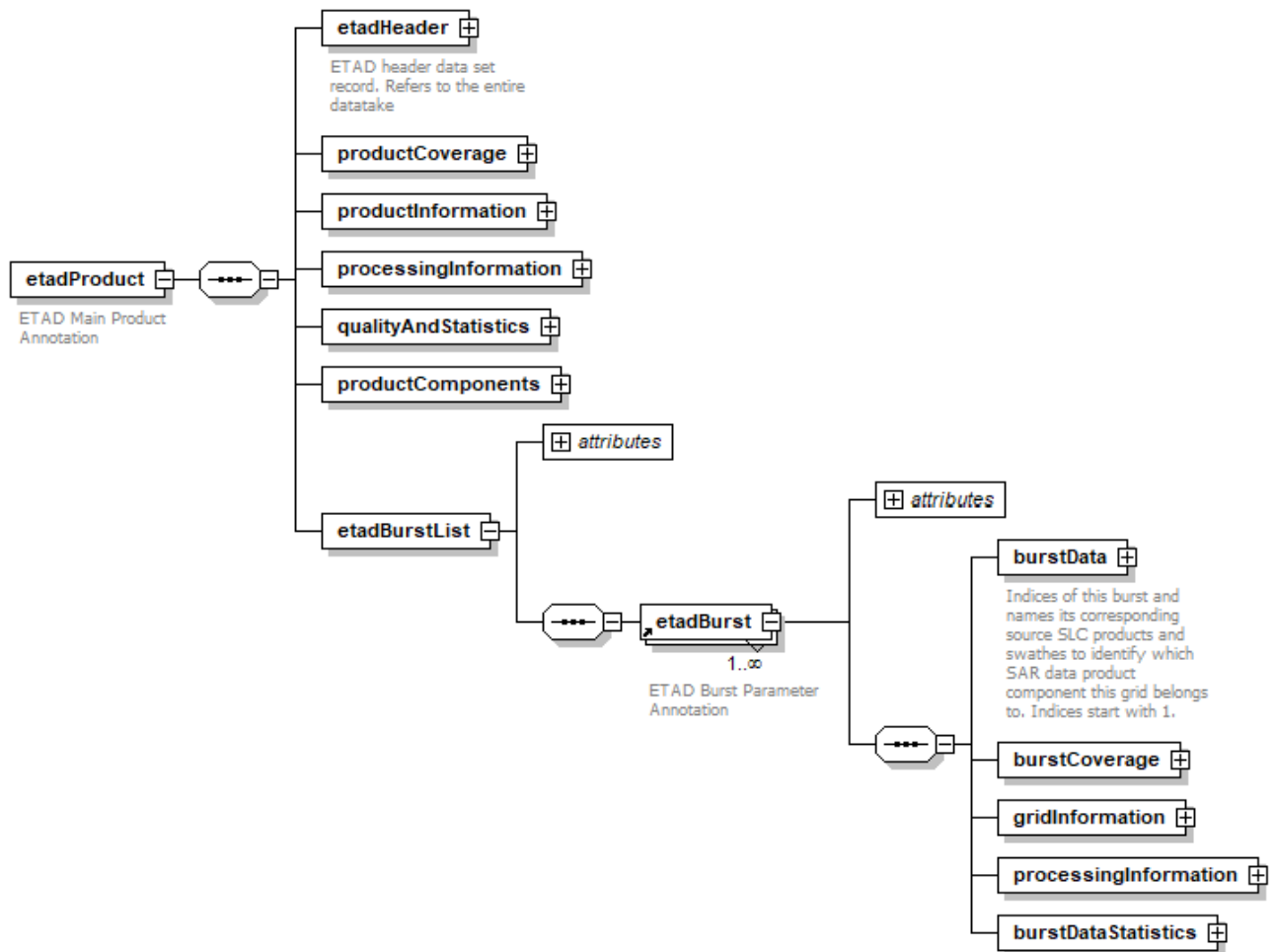


Figure 3: Hierarchical overview of the main XML annotation file components.

The XML file contains header information which associate the ETAD product with the corresponding S-1 acquisition and mission information shown in Figure 4. The coverage provides temporal and spatial coverage parameters and the incidence angle range of the entire product.

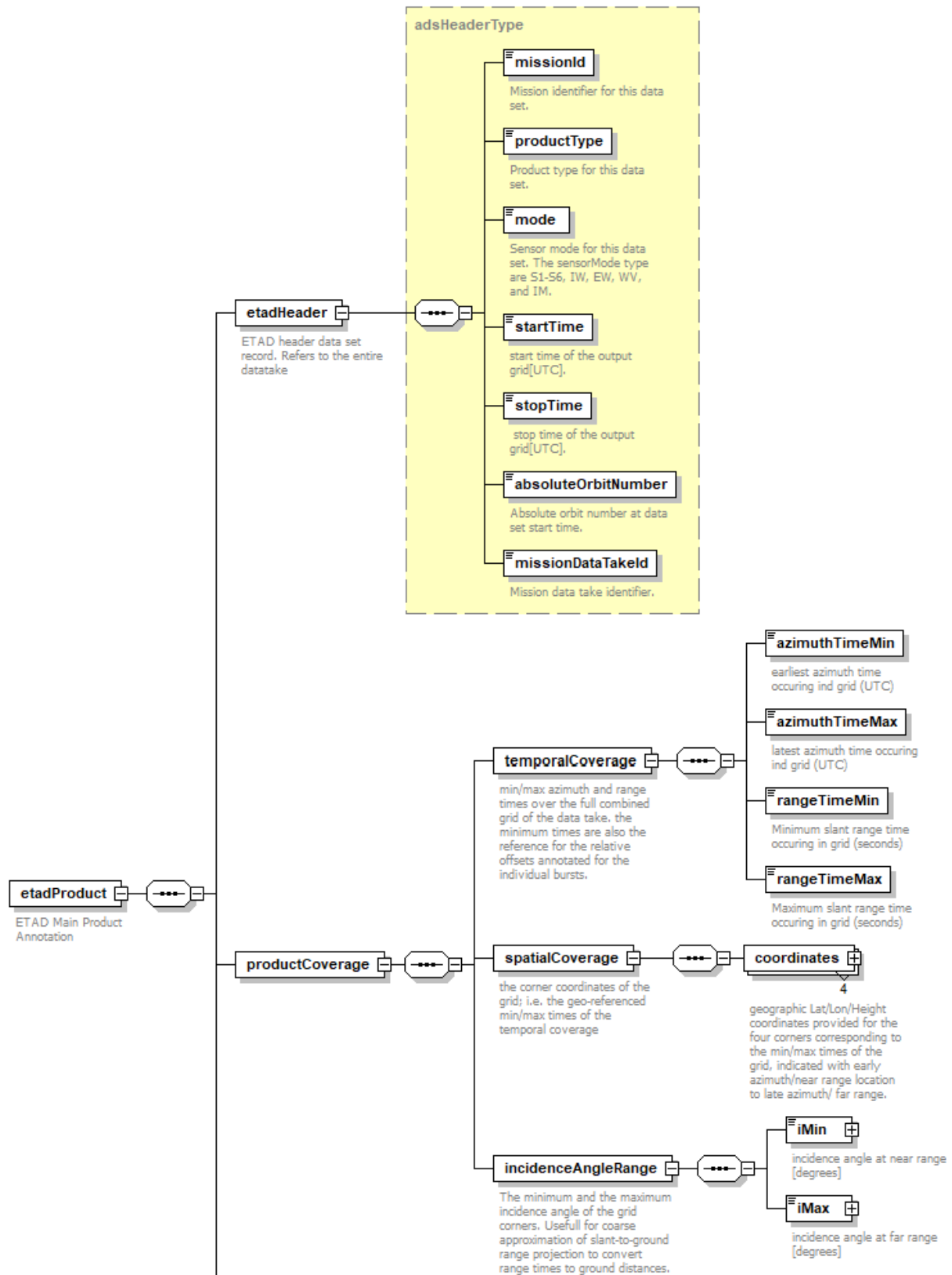


Figure 4: Header and coverage information.



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<i>Element</i>	<i>Description</i>	<i>Attributes</i>
etadHeader	ETAD header data set record. Refers to the entire data take	[]
missionId	Mission identifier for this data set.	[]
productType	Product type for this data set.	[]
mode	Sensor mode for this data set. The sensorMode types supported by the product are S1-S6, IW, EW, WV, and IM.	[]
startTime	start time of the output grid [UTC].	[]
stopTime	stop time of the output grid [UTC].	[]
absoluteOrbitNumber	Absolute orbit number at data set start time.	[]
missionDataTakeId	Mission data take identifier.	[]

<i>Element</i>	<i>Description</i>	<i>Attributes</i>
productCoverage		[]
temporalCoverage	min/max azimuth and range times over the full combined grid of the data take. The minimum times are also the reference for the relative time offsets annotated for the individual bursts.	[]
azimuthTimeMin	earliest azimuth time occurring in grid (UTC)	[]
azimuthTimeMax	latest azimuth time occurring in grid (UTC)	[]
rangeTimeMin	Minimum slant range time occurring in grid (seconds)	['unit']
rangeTimeMax	Maximum slant range time occurring in grid (seconds)	['unit']
spatialCoverage	the corner coordinates of the grid; i.e. the geo-referenced min/max times of the temporal coverage	[]
coordinates	geographic Lat/Lon/Height coordinates provided for the four corners corresponding to the min/max times of the grid, indicated with early azimuth/near range location to late azimuth/ far range.	['corner']
latitude	Latitude of this grid corner [degrees]	['unit']
longitude	Longitude of this grid corner [degrees]	['unit']
height	DEM height of grid corner in reference frame (i.e. WGS84) [meter]	['unit']
incidenceAngleRange	The minimum and the maximum incidence angle of the grid corners. Useful for coarse approximation of slant-to-ground range projection to convert range times to ground distances.	[]
iMin	incidence angle at near range [degrees]	['unit']
iMax	incidence angle at far range [degrees]	['unit']



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The reference systems used as well as the overall grid extent and the sampling in time and its projection on ground is given in the common product information (Figure 5). Also the contained polarizations channels and their corresponding offset values are provided here for informative purposes.

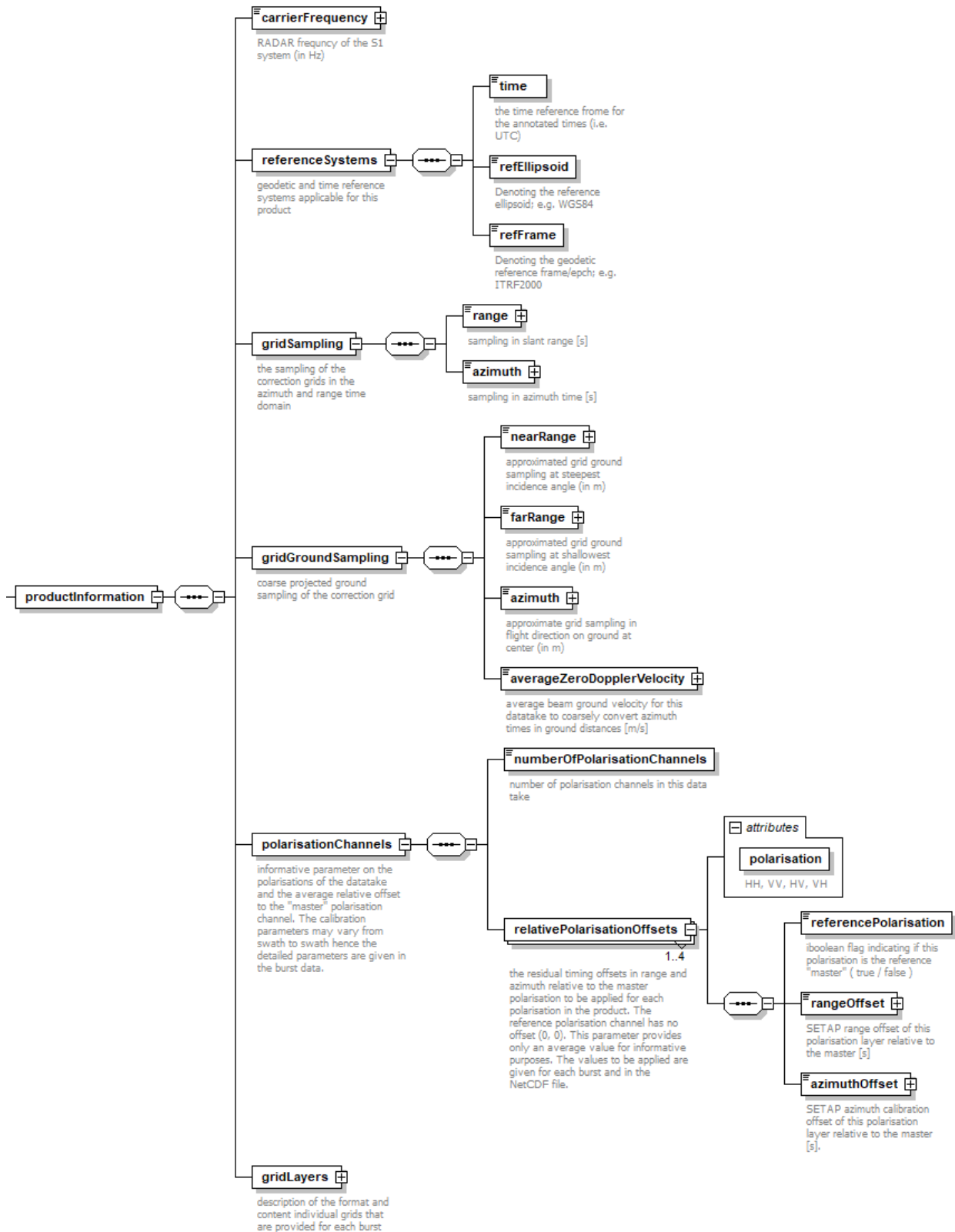


Figure 5: Common product information.

<i>Element</i>	<i>Description</i>	<i>Attributes</i>
productInformation		[]
carrierFrequency	RADAR frequency of the S1 system (in Hz)	['unit']
referenceSystems	geodetic and time reference systems applicable for this product	[]
time	the time reference for the annotated times (i.e. UTC)	[]
refEllipsoid	Denoting the reference ellipsoid; e.g. WGS84	[]
refFrame	Denoting the geodetic reference frame; e.g. ITRF2000	[]
gridSampling	the sampling of the correction grids in the azimuth and range time domain	[]
range	sampling in slant range [s]	['unit']
azimuth	sampling in azimuth time [s]	['unit']
gridGroundSampling	coarse projected ground sampling of the correction grid	[]
nearRange	approximated grid ground sampling at steepest incidence angle (in m)	['unit']
farRange	approximated grid ground sampling at shallowest incidence angle (in m)	['unit']
azimuth	approximate grid sampling in flight direction on ground at center (in m)	['unit']
averageZeroDopplerVelocity	average beam ground velocity for this datatake to coarsely convert azimuth times in ground distances [m/s]	['unit']
polarisationChannels	informative parameter on the polarisations of the datatake and the average relative offset to the "master" polarisation channel. The calibration parameters may vary from swath to swath hence the detailed parameters are given in the burst data.	[]
numberOfPolarisationChannels	number of polarisation channels in this data take	[]
relativePolarisationOffsets	the residual timing offsets in range and azimuth relative to the master polarisation to be applied for each polarisation in the product. The reference polarisation channel has no offset (0, 0). This parameter provides only an average value for informative purposes. The values to be applied are given for each burst and in the NetCDF file.	['polarisation']
referencePolarisation	boolean flag indicating if this polarisation is the reference "master" (true / false)	[]
rangeOffset	SETAP range time calibration offset of this polarisation layer relative to the master [s]	['unit']
azimuthOffset	SETAP azimuth time calibration offset of this polarisation layer relative to the master [s].	['unit']

The grid layer description structure identifies the grids stored for each burst. A basic description for each layer is given, helping in interpretation, evaluation and application of the grids (Figure 6). The units and the format are listed and an indication is given, if it has to be applied to range or azimuth or is simply an annotated coordinate. The validity flag indicates if the calculation of the correction has been performed nominally.

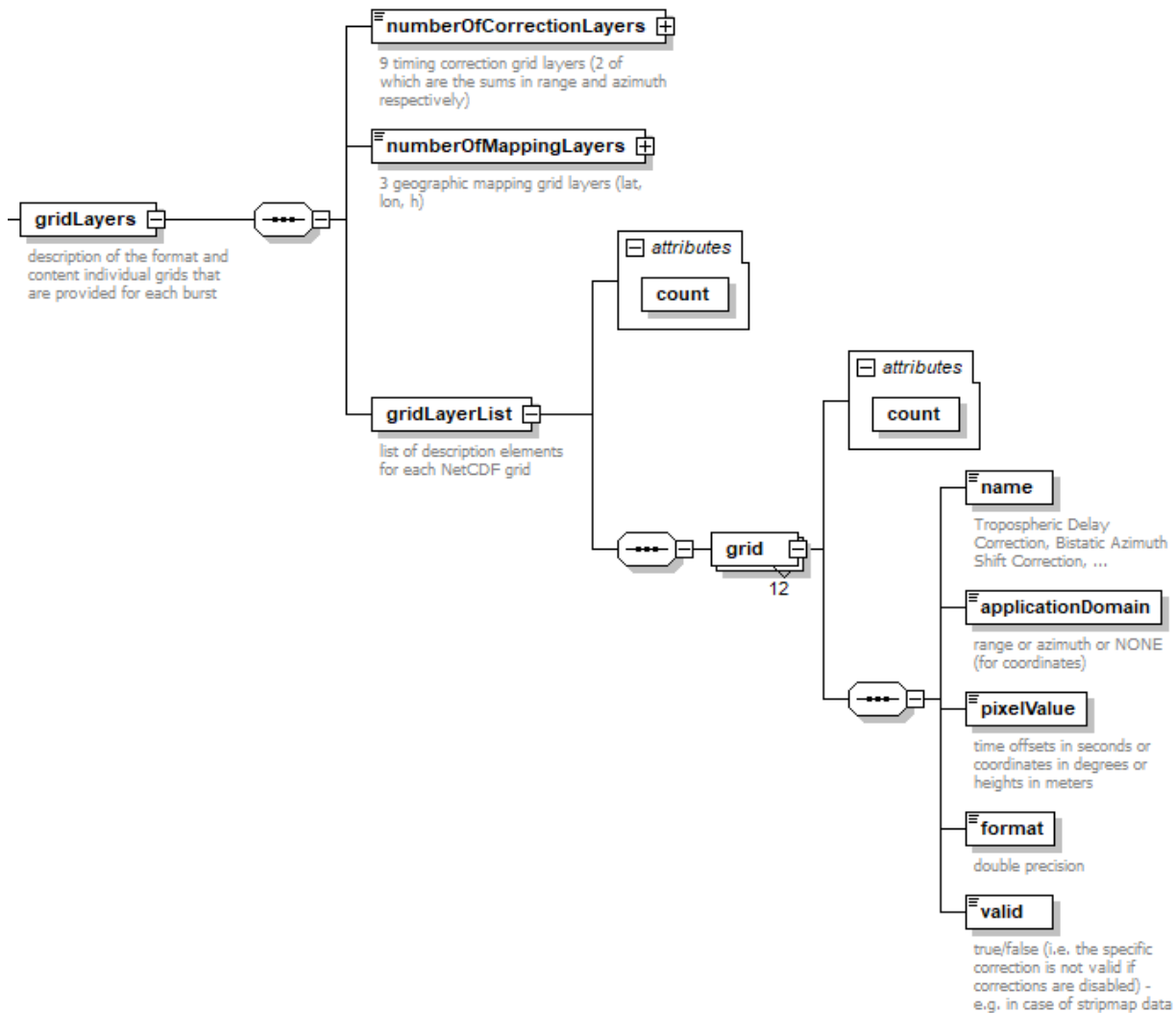


Figure 6: Grid layer information in product information node.

Element	Description	Attributes
gridLayers	description of the format and content of individual grids that are provided for each burst	[]
numberOfCorrectionLayers	9 timing correction grid layers (2 of which are the sums in range and azimuth respectively)	[]
numberOfMappingLayers	3 geographic mapping grid layers (lat, lon, h)	[]

gridLayerList	list of description elements for each NetCDF grid	['count']
grid		[]
name	Tropospheric Delay Correction, Bistatic Azimuth Shift Correction, ...	[]
applicationDomain	range or azimuth or NONE (for coordinates)	[]
pixelValue	time offsets in seconds or coordinates in degrees or heights in meters	[]
format	double precision	[]
valid	true/false (i.e. the specific correction is not valid if corrections are disabled) - e.g. in case of stripmap data	[]

The ETAD processor is configurable with respect to the calculation of the corrections and controlled by flags/switches at runtime. The accuracy, quality and validity of the results strongly depend on the input and auxiliary products used. In order to enable the user to access the results and trace it to the inputs, the following processing Information parameter group (Figure 7) lists the main configuration settings, the input and auxiliary data characteristics and the main algorithmic parameters used for the generation of the specific ETAD product.

The parameter sets of those corrections which may be switched off are optional and only provided if the corresponding inputs were available.

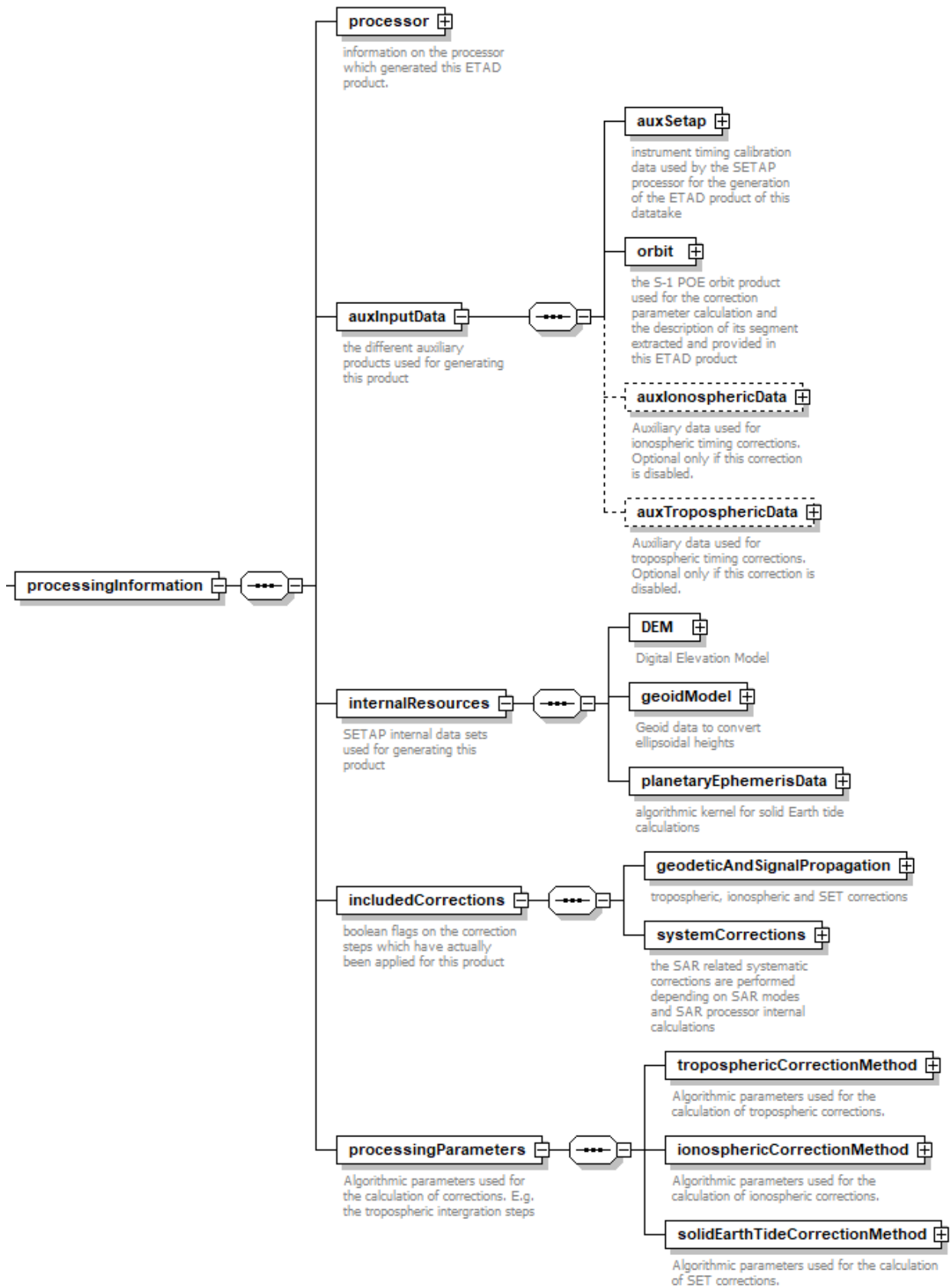


Figure 7: Processing and product generation information.

Element	Description	Attributes
processingInformation		[]
processor	information on the processor which generated this ETAD product.	[]
processorName	SETAP	[]
processorVersion	configured SETAP version in IPF	[]
processorStartTime	time of invocation for this specific processing run	[]
setapConfigurationFile	configuration parameters used for the generation of this product	[]
inputProduct	configuration file ID	[]
generationTime	when this configuration file has been generated	[]
validityStart	from which Sentinel-1 data take start time on this configuration is applicable	[]
processorSettings	configured processor settings on grid spacing and switches for the specific geophysical and SAR related corrections read from the processor configuration for this specific data take type	[]
troposphericDelayCorrection	boolean flag on the calculation of the tropospheric corrections	[]
ionosphericDelayCorrection	boolean flag on the calculation of the ionospheric corrections	[]
solidEarthTideCorrection	boolean flag on the calculation of the SET	[]
correctionGridRangeSampling	configured default grid spacing in range on ground at data take center	['unit']
correctionGridAzimuthSampling	configured default grid spacing in azimuth on ground at data take center	['unit']
bistaticAzimuthCorrection	boolean flag on the calculation of the bistatic corrections	[]
dopplerShiftRangeCorrection	boolean flag on the calculation of the range correction from Doppler shift	[]
FMMismatchAzimuthCorrection	boolean flag on the calculation of the azimuth correction from the FM mismatch	[]
auxInputData	the different auxiliary products used for generating this product	[]
auxSetap	instrument timing calibration data used by the SETAP processor for the generation of the ETAD product of this data take	[]



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inputProduct	SAFE file ID	[]
generationTime	when this auxiliary product has been generated	[]
validityStart	from which Sentinel-1 datatake start time on these calibration data are applicable	[]
instrumentTimingCalibrationList	timing calibration parameters of each swath and polarisation used for this product	['count']
instrumentTimingCalibration	Instrument timing calibration parameters. This record contains swath/polarisation channel dependent parameters related to the instrument. There may be up to one record per swath (23 nominal swaths) per polarisation (4 polarisation combinations for SM, IW, EW) for a maximum total of 56.	[]
orbit	the S-1 POE orbit product used for the correction parameter calculation and the description of its segment extracted and provided in this ETAD product	[]
inputProduct	file ID	[]
type	POE	[]
generationTime	generation time tag of input POE orbit product (UTC)	[]
inputProductValidityStart	validity start time of orbit arc in the input POE product (UTC)	[]
inputProductValidityStop	validity stop time of orbit arc in the input POE product (UTC)	[]
segmentValidityStart	start time of extracted segment annotated as POE in ETAD product (UTC)	[]
segmentValidityStop	stop time of extracted segment annotated as POE in ETAD product (UTC)	[]
quality	nominal or degraded (in segment used for the calculation)	[]
auxlonosphericData	Auxiliary data used for ionospheric timing corrections. Optional only if this correction is disabled.	[]
source	e.g. CODE	[]
type	e.g. FINAL	[]
dataSetList	one or two data sets for the relevant time span	['count']
dataSet	one vTEC product of given day or two vTEC products from consecutive days.	[]
inputProduct	SAFE file ID	[]
generationTime	generation time tag of input product (UTC)	[]
validityStart	validity start time of this input data set (UTC)	[]

auxTroposphericData	Auxiliary data used for tropospheric timing corrections. Optional only if this correction is disabled.	[]
source	e.g. ECMWF	[]
type	e.g. IFS_OPERATIONAL_ANALYSIS	[]
dataSetList	two or three data sets for the relevant time span	['count']
dataSet	Two products that comprise the data take time span. A third product is provided if the data take includes one time tag.	[]
inputProduct	SAFE file ID	[]
generationTime	generation time tag of input product (UTC)	[]
validityStart	validity start time of this input data set (UTC)	[]
internalResources	SETAP internal data sets used for generating this product	[]
DEM	Digital Elevation Model	[]
name	e.g. Copernicus_90m_DEM_DGED	[]
version	of this data set	[]
postingClass	in arcsecs	['unit']
geoidModel	Geoid data to convert ellipsoidal heights	[]
name	e.g. EGM2008_GEOID	[]
version	of this data set	[]
planetaryEphemerisData	algorithmic kernels for solid Earth tide calculations	[]
kernel	algorithmic kernel	[]
name	e.g. earth_assoc_itrf93.tf	[]
version	of this kernel	[]
includedCorrections	boolean flags on the correction steps which have actually been applied for this product	[]
geodeticAndSignalPropagation	tropospheric, ionospheric and SET corrections	[]
troposphericDelayCorrection	boolean flag on the performed calculation of the tropospheric corrections	[]
ionosphericDelayCorrection	boolean flag on the performed calculation of the ionospheric corrections	[]
solidEarthTideCorrection	boolean flag on the performed calculation of the SET corrections	[]
systemCorrections	the SAR related systematic corrections are performed depending on SAR modes and SAR processor internal calculations	[]

bistaticAzimuthCorrection	boolean flag on the performed calculation of the bistatic SAR corrections	[]
dopplerShiftRangeCorrection	boolean flag on the performed calculation of the SAR Doppler shift corrections in range	[]
FMMismatchAzimuthCorrection	boolean flag on the performed calculation of the SAR FM-rate mismatch corrections in azimuth	[]
processingParameters	Algorithmic parameters used for the calculation of corrections, e.g. the tropospheric integration steps	[]
troposphericCorrectionMethod	Algorithmic parameters used for the calculation of tropospheric corrections.	[]
algorithm	e.g. direct integration	[]
modelLayerReductionFactor	reduction factor of height layers (integer value)	[]
horizontalOversamplingFactorLat	oversampling parameter for the NWP data in latitude direction	[]
horizontalOversamplingFactorLon	oversampling parameter for the NWP data in longitude direction	[]
integrationIntervalSlantRange1	steps in meter for heights below tropopause (in m)	['unit']
integrationIntervalSlantRange2	steps in meter for heights above tropopause (in m) but below lower stratosphere	['unit']
integrationIntervalSlantRange3	steps in meter for heights above lower stratosphere (in m)	['unit']
ionosphericCorrectionMethod	Algorithmic parameters used for the calculation of ionospheric corrections.	[]
algorithm	e.g. single-layer approximation	[]
layerHeight	assumed height of ionospheric model layer [meter], from CODE products (450 km)	['unit']
baseRadius	base radius of Earth (in m)	['unit']
scalingVTECORbitHeight	Scaling factor of vTEC due to Sentinel-1 orbit altitude, set to 0.9	[]
solidEarthTideCorrectionMethod	Algorithmic parameters used for the calculation of SET corrections.	[]
algorithm	e.g. IERS Love and Shida based tidal model	[]

The quality and statistics parameter group (Figure 8) has two functions. First, it is providing information if the processing has been performed nominally (i.e. with all required inputs and in default configuration)

and/or if missing data or limit violations were encountered which render specific correction results unreliable.

Secondly, it provides basic statistics over the full data take, specifically the minima, maxima and the mean of the delays and shifts calculated for each common (i.e. geophysical) correction and of their sum. Additional DEM statistics are given to assess the topographic variability of the terrain.

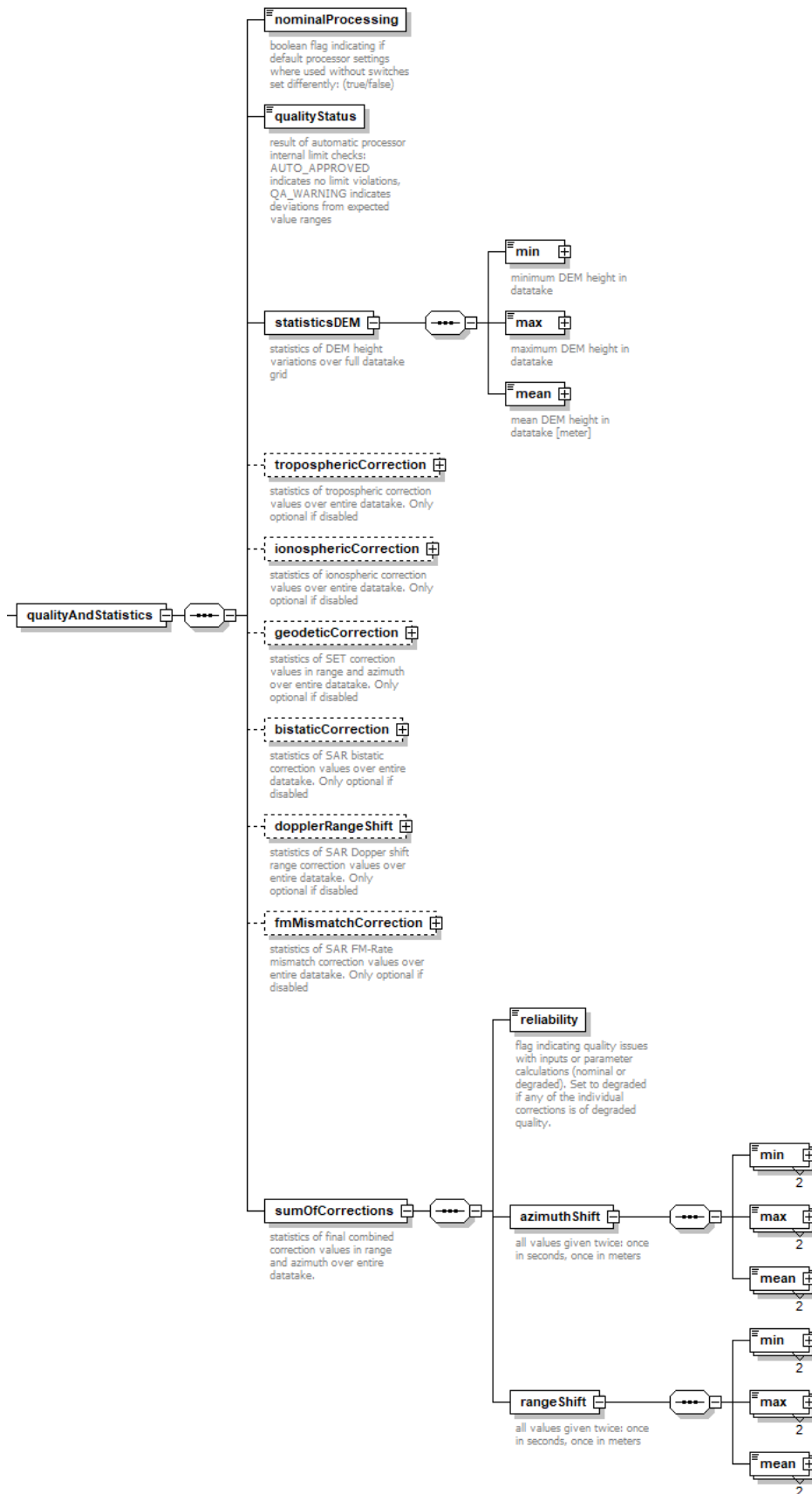


Figure 8: Product quality and correction statistics

Element	Description	Attributes
qualityAndStatistics		[]
nominalProcessing	boolean flag indicating if default processor settings were used without switches set differently: (true/false)	[]
qualityStatus	result of automatic processor internal limit checks: AUTO_APPROVED indicates no limit violations, QA_WARNING indicates deviations from expected value ranges	[]
statisticsDEM	statistics of DEM height variations over full datatake grid	[]
min	minimum DEM height in datatake [meter]	['unit']
max	maximum DEM height in datatake [meter]	['unit']
mean	mean DEM height in datatake [meter]	['unit']
troposphericCorrection	statistics of tropospheric correction values over entire datatake. Only optional if disabled	[]
reliability	flag indicating quality issues with inputs or parameter calculations (nominal or degraded)	[]
rangeShift	all values given twice: once in seconds, once in meters	[]
ionosphericCorrection	statistics of ionospheric correction values over entire datatake. Only optional if disabled	[]
reliability	flag indicating quality issues with inputs or parameter calculations (nominal or degraded)	[]
rangeShift	all values given twice: once in seconds, once in meters	[]
geodeticCorrection	statistics of SET correction values in range and azimuth over entire datatake. Only optional if disabled	[]
reliability	flag indicating quality issues with inputs or parameter calculations (nominal or degraded)	[]
azimuthShift	all values given twice: once in seconds, once in meters	[]
rangeShift	all values given twice: once in seconds, once in meters	[]
bistaticCorrection	statistics of SAR bistatic correction values over entire datatake. Only optional if disabled	[]
reliability	flag indicating quality issues with inputs or parameter calculations (nominal or degraded)	[]
azimuthShift	all values given twice: once in seconds, once in meters	[]
dopplerRangeShift	statistics of SAR Doppler shift range correction values over entire datatake. Only optional if disabled	[]

reliability	flag indicating quality issues with inputs or parameter calculations (nominal or degraded)	[]
rangeShift	all values given twice: once in seconds, once in meters	[]
fmMismatchCorrection	statistics of SAR FM-Rate mismatch correction values over entire datatake. Only optional if disabled	[]
reliability	flag indicating quality issues with inputs or parameter calculations (nominal or degraded)	[]
azimuthShift	all values given twice: once in seconds, once in meters	[]
sumOfCorrections	statistics of final combined correction values in range and azimuth over entire datatake.	[]
reliability	flag indicating quality issues with inputs or parameter calculations (nominal or degraded). Set to degraded if any of the individual corrections is of degraded quality.	[]
azimuthShift	all values given twice: once in seconds, once in meters	[]
rangeShift	all values given twice: once in seconds, once in meters	[]
<i>Minimum, Maximum and Mean elements provided twice for all timing correction statistics</i>		
min	minimum value [seconds] and [meter]	['unit']
max	maximum value [seconds] and [meter]	['unit']
mean	mean value [seconds] and [meter]	['unit']

The product components parameter group (Figure 9, Figure 10) provides the information which swaths and bursts are represented by this ETAD product and from which SAR input products they stem from. It allows identifying the burst grids belonging to a specific SAR SLC slice and its individual swaths. It also indicates if all slices from the slice list of a data take were available at time of product generation.

Since the ETAD processor is nominally fed with the L1A annotation products and not the L1S SLC products with focused data, the product ID which names the respective SLC SAFE product name is not necessarily the one which the user has at hand. In general, the corrections should be applied to SLCs based on the annotated time stamps and the slice numbers.

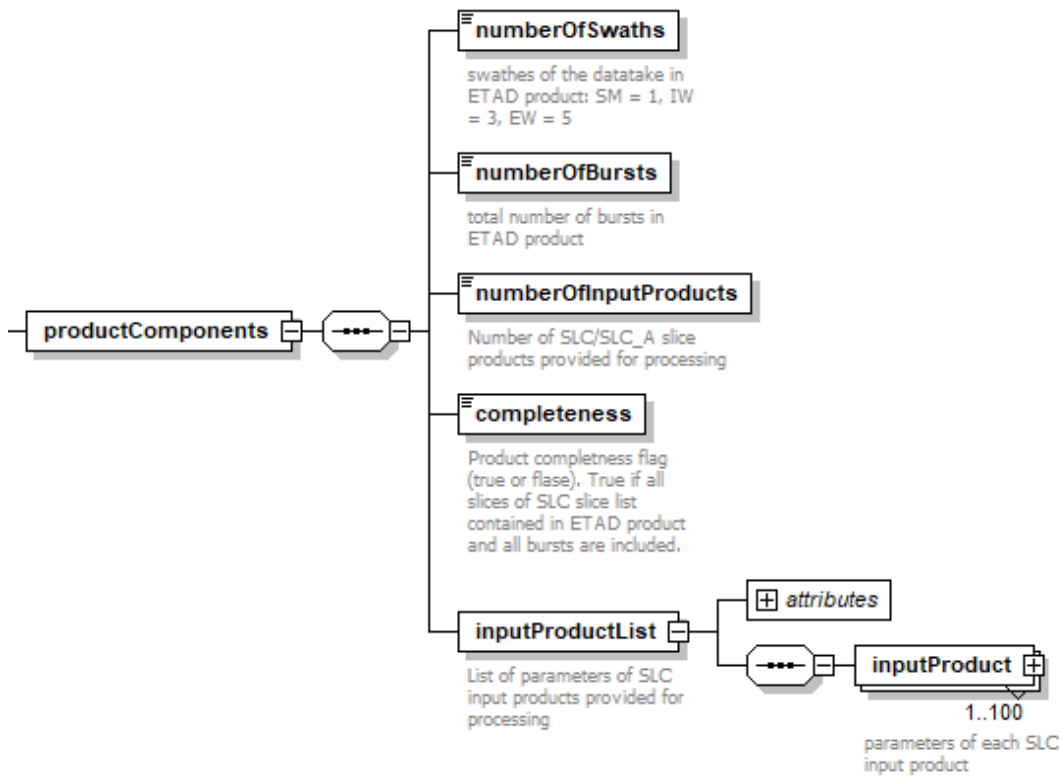


Figure 9: Product components

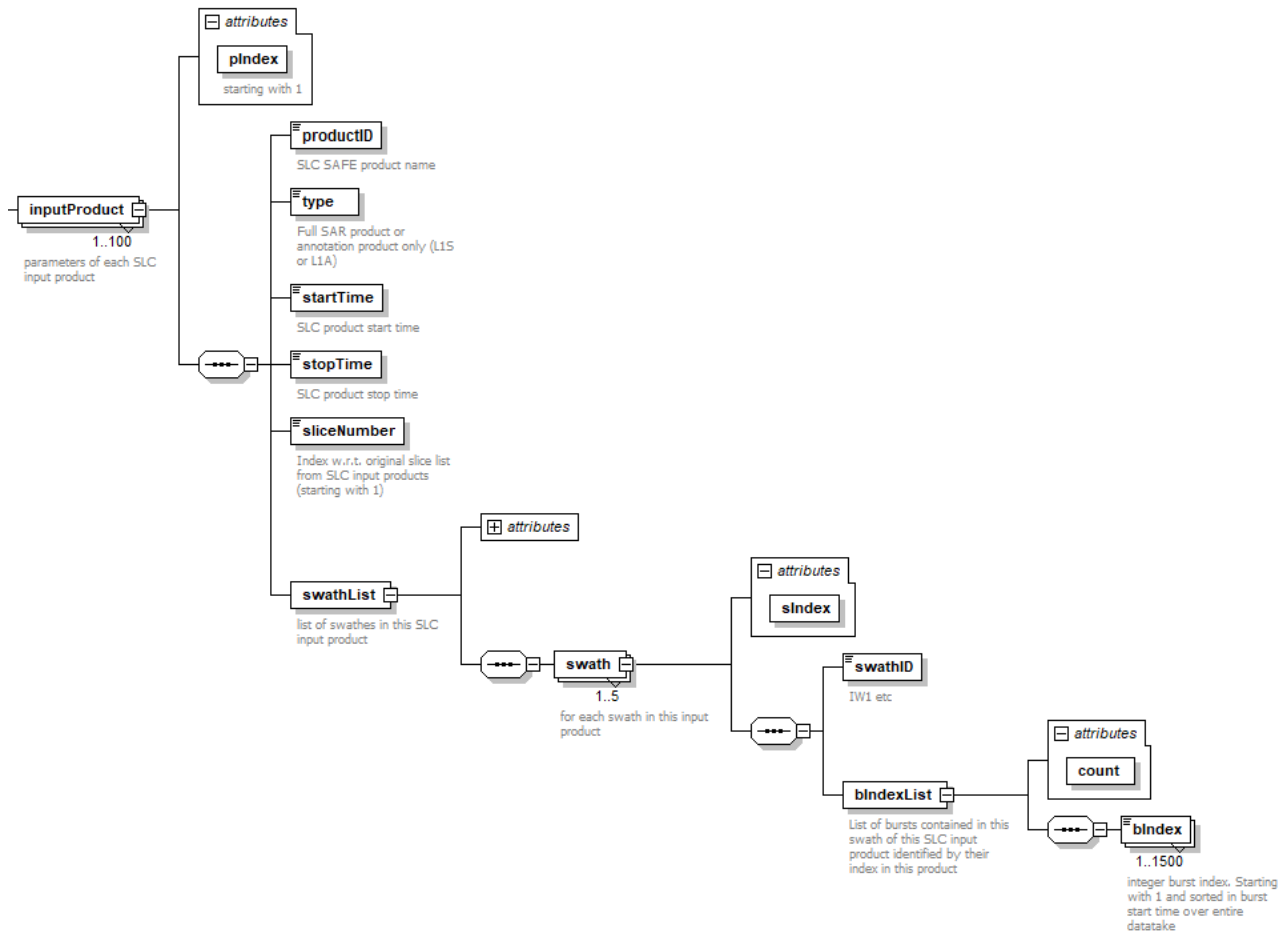


Figure 10: Input product list in product components

Element	Description	Attributes
productComponents		[]
numberOfSwaths	swathes of the datatake in ETAD product: SM = 1, IW = 3, EW = 5	[]
numberOfBursts	total number of bursts in ETAD product	[]
numberOfInputProducts	Number of SLC/SLC_A slice products provided for processing	[]
completeness	Product completeness flag (true or false). True if all slices of SLC slice list contained in ETAD product and all bursts are included.	[]
inputProductList	List of parameters of SLC input products provided for processing	['count']
inputProduct	parameters of each SLC input product	['pIndex']
productID	SLC SAFE product name	[]
type	Full SAR product or annotation product only (L1S or L1A)	[]

startTime	SLC product start time	[]
stopTime	SLC product stop time	[]
sliceNumber	Index w.r.t. original slice list from SLC input products (starting with 1)	[]
swathList	list of swaths in this SLC input product	['count']
swath	for each swath in this input product	['sIndex']
swathID	IW1 etc	[]
bIndexList	List of bursts contained in this swath of this SLC input product identified by their index in this product	['count']
bIndex	integer burst index. Starting with 1 and sorted in burst start time over entire datatake	[]

6.2 Burst Annotation Parameters

The parameters of the individual bursts are given in a list of parameter groups embedded in the etadBurst node (Figure 11). The group burstData provides the indices and the reference to the corresponding input SAR products for the individual burst. The coverage of the specific burst grids is annotated in the same way as for the entire product (Figure 12). The grid information specifies the timing parameters of the grid, specifically the start position in range and azimuth times. The polarization channel offset parameters are for this specific burst can be found here as well.

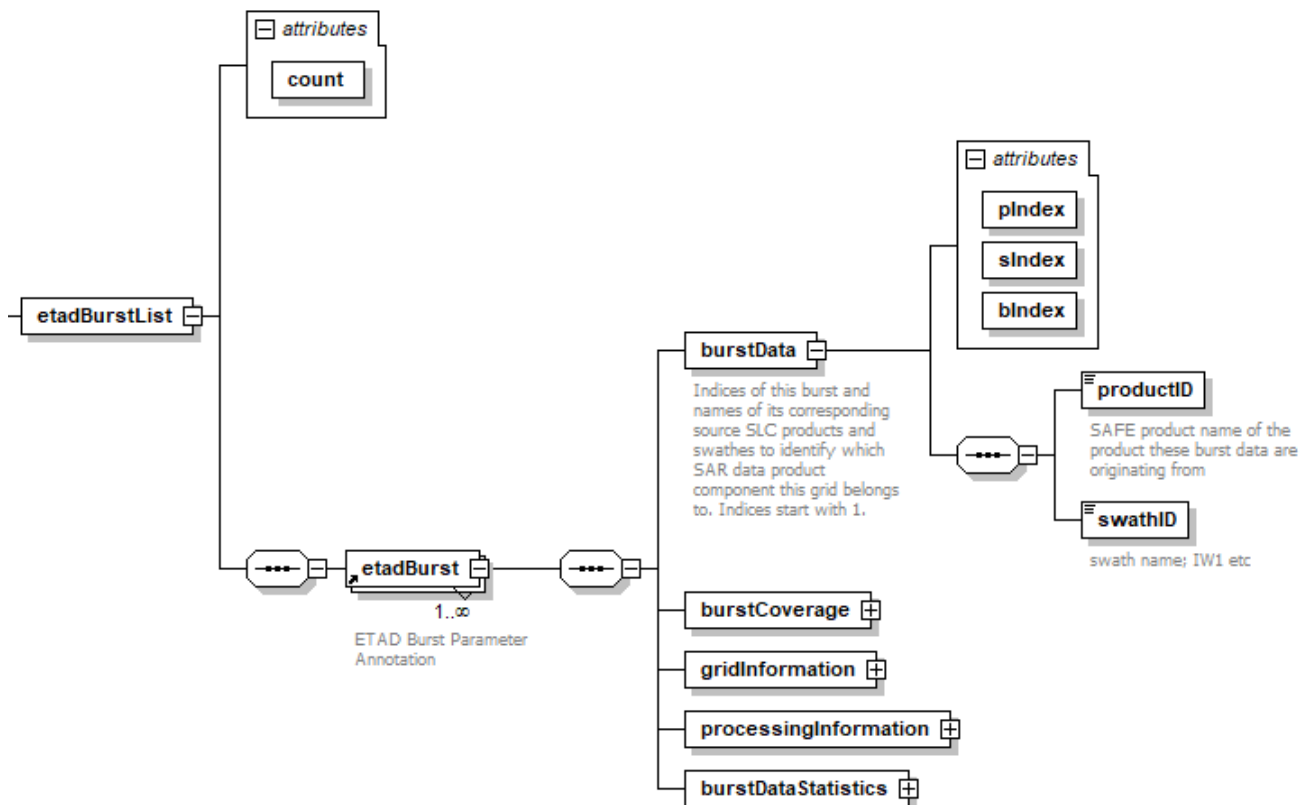


Figure 11: Annotation of the individual bursts for identification and indexing.

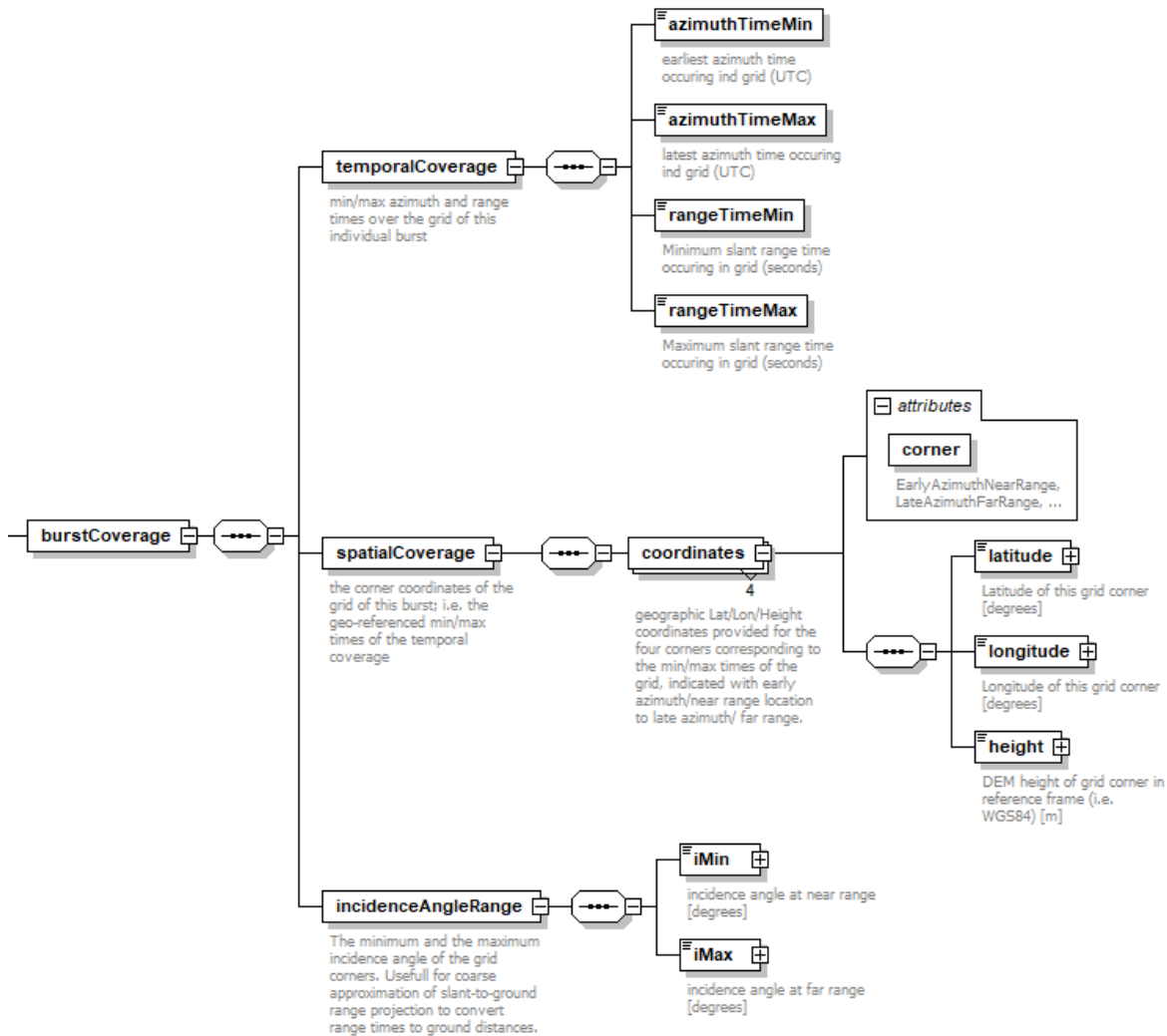


Figure 12: Annotation of the individual burst coverage parameters.

The following parameters are detailing the burst specific correction grids (Figure 13). This comprises specifically the sampling and the polarization dependent offset parameters.

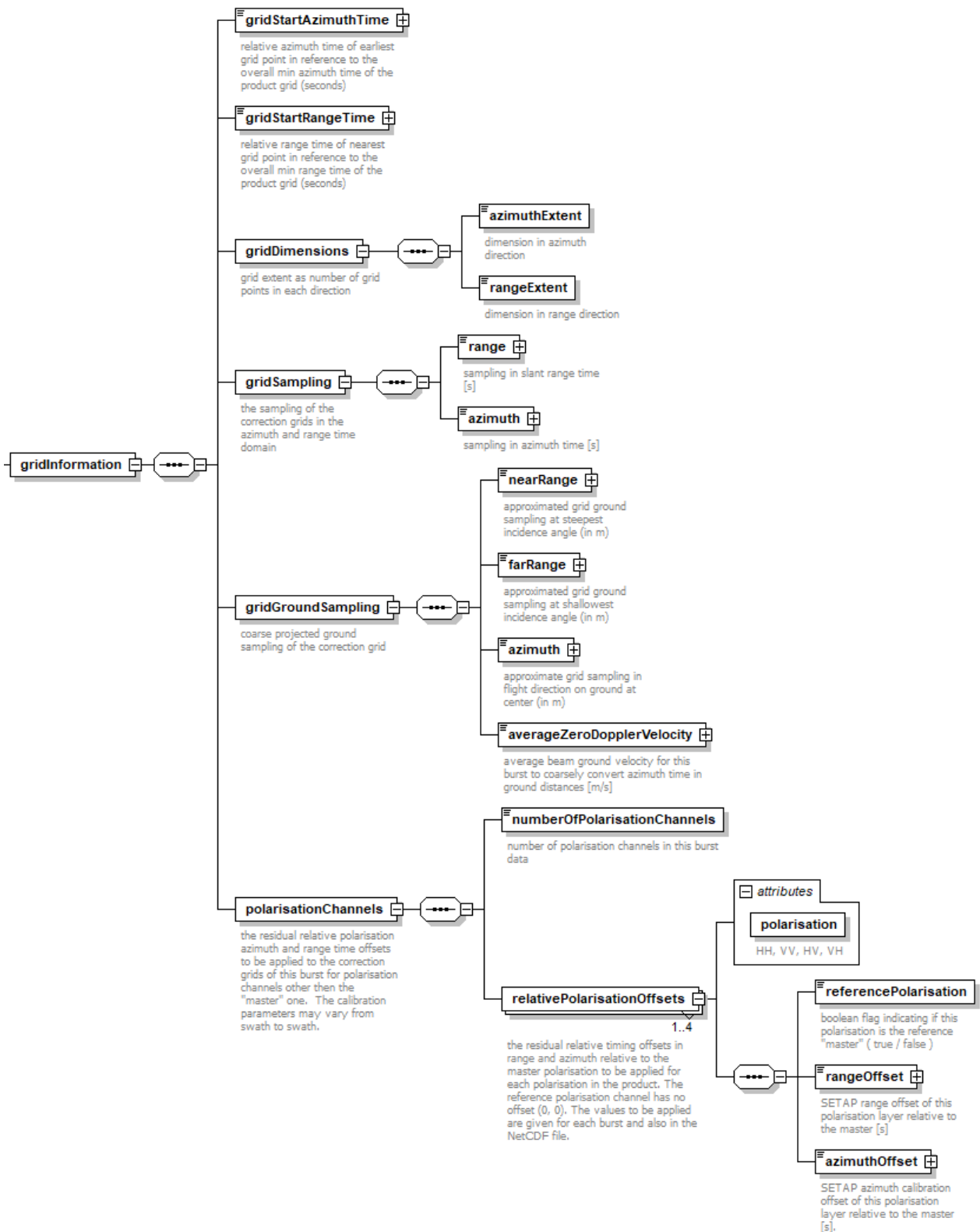


Figure 13: Annotation of the individual burst grid information parameters.

<i>Element</i>	<i>Description</i>	<i>Attributes</i>
etadBurst	ETAD Burst Parameter Annotation	[]
burstData	Indices of this burst and names of its corresponding source SLC products and swathes to identify which SAR data product component this grid belongs to. Indices start with 1.	['pIndex', 'sIndex', 'bIndex']
productID	SAFE product name of the product these burst data are originating from	[]
swathID	swath name; IW1 etc	[]
burstCoverage		[]
temporalCoverage	min/max azimuth and range times over the grid of this individual burst	[]
azimuthTimeMin	earliest azimuth time occurring in grid (UTC)	[]
azimuthTimeMax	latest azimuth time occurring in grid (UTC)	[]
rangeTimeMin	Minimum slant range time occurring in grid (seconds)	['unit']
rangeTimeMax	Maximum slant range time occurring in grid (seconds)	['unit']
spatialCoverage	the corner coordinates of the grid of this burst; i.e. the geo-referenced min/max times of the temporal coverage	[]
coordinates	geographic Lat/Lon/Height coordinates provided for the four corners corresponding to the min/max times of the grid, indicated with early azimuth/near range location to late azimuth/ far range.	['corner']
latitude	Latitude of this grid corner [degrees]	['unit']
longitude	Longitude of this grid corner [degrees]	['unit']
height	DEM height of grid corner in reference frame (i.e. WGS84) [meter]	['unit']
incidenceAngleRange	The minimum and the maximum incidence angle of the grid corners. Useful for coarse approximation of slant-to-ground range projection to convert range times to ground distances.	[]
iMin	incidence angle at near range [degrees]	['unit']
iMax	incidence angle at far range [degrees]	['unit']
gridInformation		[]
gridStartAzimuthTime	relative azimuth time of earliest grid point in reference to the overall min azimuth time of the product grid (seconds)	['unit']
gridStartRangeTime	relative range time of nearest grid point in reference to the overall min range time of the product grid (seconds)	['unit']
gridDimensions	grid extent as number of grid points in each direction	[]

azimuthExtent	dimension in azimuth direction	[]
rangeExtent	dimension in range direction	[]
gridSampling	the sampling of the correction grids in the azimuth and range time domain	[]
range	sampling in slant range time [s]	['unit']
azimuth	sampling in azimuth time [s]	['unit']
gridGroundSampling	coarse projected ground sampling of the correction grid	[]
nearRange	approximated grid ground sampling at steepest incidence angle (in m)	['unit']
farRange	approximated grid ground sampling at shallowest incidence angle (in m)	['unit']
azimuth	approximate grid sampling in flight direction on ground at center (in m)	['unit']
averageZeroDopplerVelocity	average beam ground velocity for this burst to coarsely convert azimuth time to ground distance [m/s]	['unit']
polarisationChannels	the residual relative polarisation azimuth and range time offsets to be applied to the correction grids of this burst for polarisation channels other than the "master" one. The calibration parameters may vary from swath to swath.	[]
numberOfPolarisationChannels	number of polarisation channels in these burst data	[]
relativePolarisationOffsets	the residual relative timing offsets in range and azimuth relative to the master polarisation to be applied for each polarisation in the product. The reference polarisation channel has no offset (0, 0). The values to be applied are given for each burst and also in the NetCDF file.	['polarisation']
referencePolarisation	boolean flag indicating if this polarisation is the reference "master" (true / false)	[]
rangeOffset	SETAP range time calibration offset of this polarisation layer relative to the master [s]	['unit']
azimuthOffset	SETAP azimuth time calibration offset of this polarisation layer relative to the master [s].	['unit']

The processing information parameters are specifically focused on the SAR parameters of the input SLCs and parameters derived thereof relevant for the SAR system corrections of this burst. Figure 14 details this information further. The input SAR parameters used for the correction of SAR systematic effects are taken from the SAR slice product annotation. In TOPS burst modes, this section provides specifically the polynomial representation of the FM rate and the Doppler centroid for the specific burst. The TOPS Doppler centroid estimates are calculated based on the geometric Doppler centroids and the TOPS beam steering. This means, it is the Doppler centroid referring to the *focused* burst image data (not found in the SLC annotation). The polynomials are given in this case for early, mid and late azimuth time tags in

each burst. Note however that the polynomial representation is only an approximation while the SETAP internally uses a more precise grid of the local Doppler centroids. In stripmap mode a list of the original time tagged polynomials is given for the processed slice.

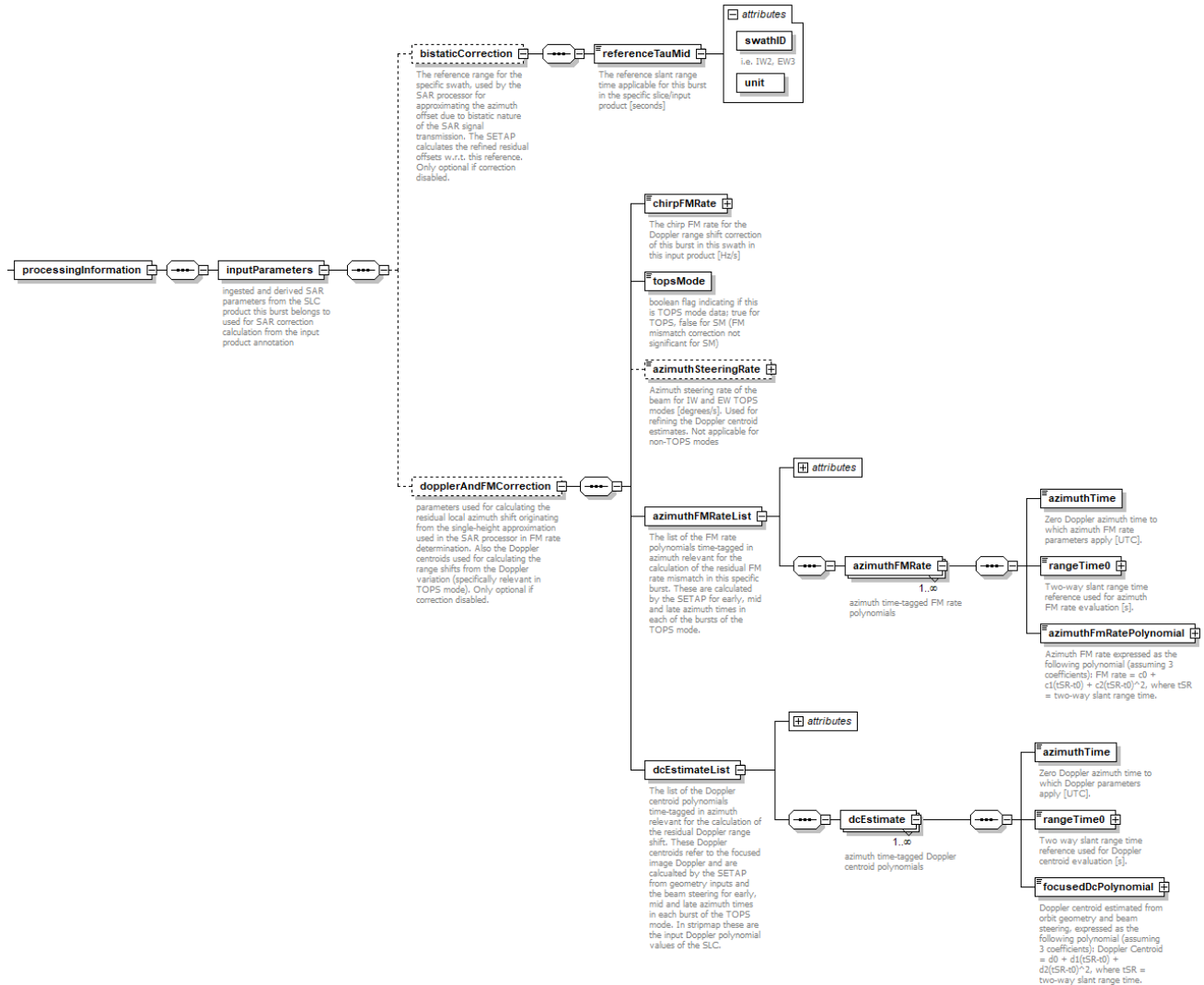


Figure 14: Annotation of the individual burst processing information parameters used for the SAR systematic corrections.

The burst data statistics provide the basic statistics of *all* correction layers of the burst and their sums (Figure 15). All are optional since they may be disabled by configuration.

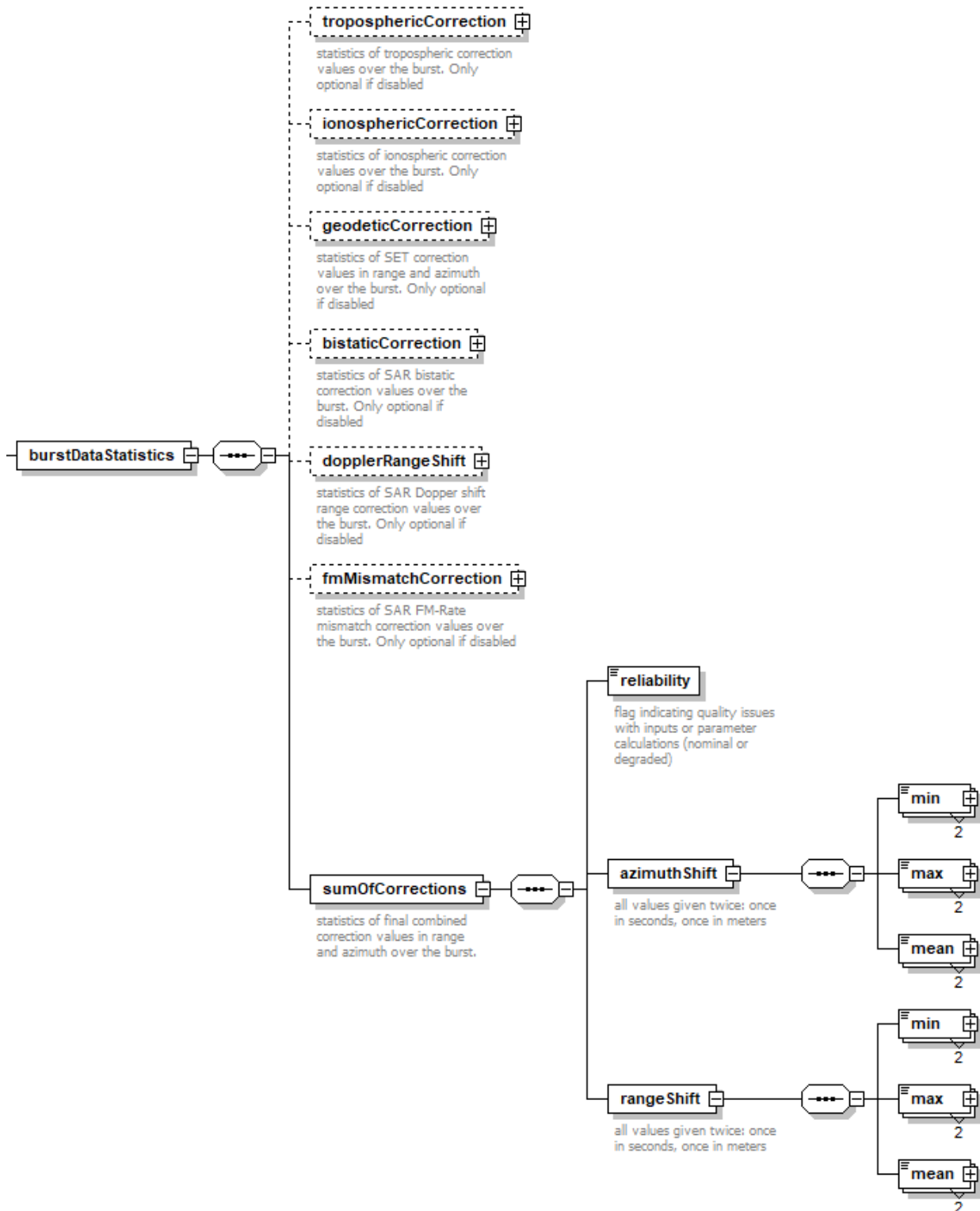


Figure 15: Annotation of the individual burst statistics information parameters.

<i>Element</i>	<i>Description</i>	<i>Attributes</i>
etadBurst	<i>(continued)</i>	
processingInformation		[]
inputParameters	ingested and derived SAR parameters from the SLC product this burst belongs to used for SAR correction calculation from the input product annotation	[]
bistaticCorrection	The reference range for the specific swath, used by the SAR processor for approximating the azimuth offset due to bistatic nature of the SAR signal transmission. The SETAP calculates the refined residual offsets w.r.t. this reference. Only optional if correction disabled.	[]
referenceTauMid	The reference slant range time applicable for this burst in the specific slice/input product [seconds]	[]
dopplerAndFMCorrection	parameters used for calculating the residual local azimuth shift originating from the single-height approximation used in the SAR processor in FM rate determination. Also the Doppler centroids used for calculating the range shifts from the Doppler variation (specifically relevant in TOPS mode). Only optional if correction disabled.	[]
chirpFMRate	The chirp FM rate for the Doppler range shift correction of this burst in this swath in this input product [Hz/s]	['unit']
topsMode	boolean flag indicating if this is TOPS mode data; true for TOPS, false for SM (FM mismatch correction not significant for SM)	[]
azimuthSteeringRate	Azimuth steering rate of the beam for IW and EW TOPS modes [degrees/s]. Used for refining the Doppler centroid estimates. Not applicable for non-TOPS modes	['unit']
azimuthFMRateList	The list of the FM rate polynomials time-tagged in azimuth relevant for the calculation of the residual FM rate mismatch in this specific burst. These are calculated by the SETAP for early, mid and late azimuth times in each of the bursts of the TOPS mode.	['count']
azimuthFMRate	azimuth time-tagged FM rate polynomials	[]
azimuthTime	Zero Doppler azimuth time to which azimuth FM rate parameters apply [UTC].	[]
rangeTime0	Two-way slant range time reference used for azimuth FM rate evaluation [s].	['unit']
azimuthFmRatePolynomial	Azimuth FM rate expressed as the following polynomial (assuming 3 coefficients): $FM\ rate = c_0 + c_1(tSR - t_0) + c_2(tSR - t_0)^2$, where tSR = two-way slant range time.	['count', 'units']
dcEstimateList	The list of the Doppler centroid polynomials time-tagged in azimuth relevant for the calculation of the residual	['count']

	Doppler range shift. These Doppler centroids refer to the focused image Doppler and are calculated by the SETAP from geometry inputs and the beam steering for early, mid and late azimuth times in each burst of the TOPS mode. In stripmap these are the input Doppler polynomial values of the SLC.	
dcEstimate	azimuth time-tagged Doppler centroid polynomials	[]
azimuthTime	Zero Doppler azimuth time to which Doppler parameters apply [UTC].	[]
rangeTime0	Two-way slant range time reference used for Doppler centroid evaluation [s].	['unit']
focusedDcPolynomial	Doppler centroid estimated from orbit geometry and beam steering, expressed as the following polynomial (assuming 3 coefficients): Doppler Centroid = $d_0 + d_1(t_{SR}-t_0) + d_2(t_{SR}-t_0)^2$, where t_{SR} = two-way slant range time.	['count', 'units']
burstDataStatistics		[]
troposphericCorrection	statistics of tropospheric correction values over the burst. Only optional if disabled	[]
reliability	flag indicating quality issues with inputs or parameter calculations (nominal or degraded)	[]
rangeShift	all values given twice: once in seconds, once in meters	[]
ionosphericCorrection	statistics of ionospheric correction values over the burst. Only optional if disabled	[]
reliability	flag indicating quality issues with inputs or parameter calculations (nominal or degraded)	[]
rangeShift	all values given twice: once in seconds, once in meters	[]
geodeticCorrection	statistics of SET correction values in range and azimuth over the burst. Only optional if disabled	[]
reliability	flag indicating quality issues with inputs or parameter calculations (nominal or degraded)	[]
azimuthShift	all values given twice: once in seconds, once in meters	[]
rangeShift	all values given twice: once in seconds, once in meters	[]
bistaticCorrection	statistics of SAR bistatic correction values over the burst. Only optional if disabled	[]
reliability	flag indicating quality issues with inputs or parameter calculations (nominal or degraded)	[]
azimuthShift	all values given twice: once in seconds, once in meters	[]
dopplerRangeShift	statistics of SAR Doppler shift range correction values over the burst. Only optional if disabled	[]

reliability	flag indicating quality issues with inputs or parameter calculations (nominal or degraded)	[]
rangeShift	all values given twice: once in seconds, once in meters	[]
fmMismatchCorrection	statistics of SAR FM-Rate mismatch correction values over the burst. Only optional if disabled	[]
reliability	flag indicating quality issues with inputs or parameter calculations (nominal or degraded)	[]
azimuthShift	all values given twice: once in seconds, once in meters	[]
sumOfCorrections	statistics of final combined correction values in range and azimuth over the burst.	[]
reliability	flag indicating quality issues with inputs or parameter calculations (nominal or degraded)	[]
azimuthShift	all values given twice: once in seconds, once in meters	[]
rangeShift	all values given twice: once in seconds, once in meters	[]
<i>Minimum, Maximum and Mean elements provided twice for all timing correction statistics</i>		
min	minimum value [seconds] and [meter]	['unit']
max	maximum value [seconds] and [meter]	['unit']
mean	mean value [seconds] and [meter]	['unit']

7 The ETAD SAFE Product Structure

The ETAD NetCDF-4 file itself is embedded in the ESA SAFE format [A5]. The precise orbit data used in ETAD product generation are stored in the SAFE product as well and the annotation of the product, which contains the product generation information and main product parameters, is also stored as plain XML in the annotation folder.

The preview files and footprint information of the sum of the corrections are stored separately from the main data in KMZ files for fast access and cataloguing. KMZ allows combining the KML and the preview image information of the individual bursts.

The structure of the ETAD SAFE user product is shown in Figure 16 using naming constituents detailed in Table 3. The manifest file is defined in Annex A.

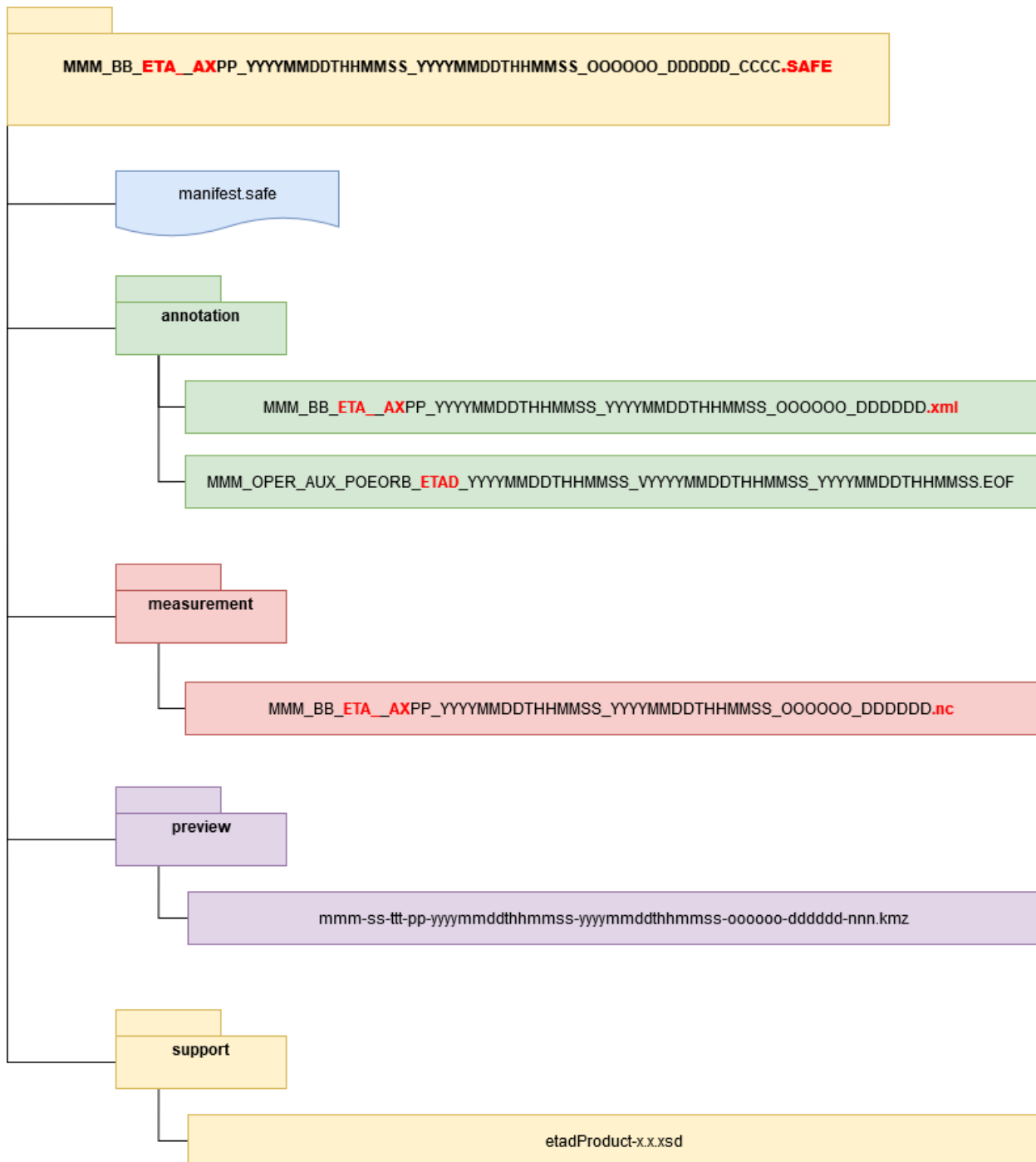


Figure 16: Structure of the ETAD SAFE product using the naming conventions detailed in Table 3

7.1 ETAD Product Naming Conventions

The ETAD product uses the SAFE format and follows structure and naming conventions derived from [A3]. The SAFE product name is thus composed of individual constituents in upper-case alphanumeric characters separated by underscores (and dots for the extension) as outlined in the following Table 3.

Table 3: ETAD product name constituents.

ETAD SAFE output product name:			
MMM_BB_ETA_AXPP_YYYYMMDDTHHMMSS_YYYYMMDDTHHMMSS_OOOOOO_DDDDDD_CCCC.SAFE			
Constituent ID	Constituent Name	Value ranges and/or examples	Remark
MMM	mission	S1A, S1B	
BB	mode / beam	IW, S5, ...	TOPS and non-TOPS supported
ETA	product type	Fixed to ETA	Extended timing annotation
_	resolution class	Fixed to " _ "	No resolution class (as for SLCs)
A	processing level	Fixed to "AX"	Auxiliary product
X	product class		
PP	polarization	SH for single HH, ...	
YYYYMMDDTHHMMSS	UTC start time	20201122T070809	Time of the earliest ETAD grid points in azimuth time. Format: year (YYYY), month (MM), day (DD), "T" , hour (hh), minute (mm), second (ss)
YYYYMMDDTHHMMSS	UTC stop time	20201122T070910	Stop time of "latest" grid points.
OOOOOO	absolute orbit number	000001-999999 (decimal)	
DDDDDD	mission data take ID	000001-FFFFFF (hex)	
CCCC	product unique ID	0000-FFFF (hex)	CRC-16 of the ETAD manifest file
.SAFE	product format extension (fixed)		

There is only one NetCDF file in the ETAD product, which shares the same name as the ETAD SAFE product with the appropriate extension ".nc" but without the product unique ID. The same naming scheme is applied to the XML annotation file with the file extension ".xml".

The CRC-16 checksum of the manifest.safe file is calculated with the CRC-16-CCITT (0xFFFF) implementation also known as CRC-16-IBM-3740. For a test sequence of "123456789" the CRC implementation produces the checksum "0x29B1".

7.2 ETAD Product Preview Files

The preview file contains for the individual overlapping bursts the image files of the sum of corrections in range and azimuth, respectively. Since the grids are already relatively coarse, there is no need for down-sampling. The pixel value color scaling is adapted to 95% of the minimum and maximum range of the entire S-1 datatake and the scaling bar is provided for informative purposes. The geographic information is represented by KML files packed together with the image files in a compressed KMZ container.

The KMZ file content is provided burst-wise since the data representation is based on time domain coordinates which are not well mapped onto geographic projections for larger areas. The corner coordinates are georeferenced but the images are still in slant range and azimuth time domain. Also the identification which burst correction grids are applicable to the area of interest is guaranteed this way. Each KMZ file contains two files for each of the bursts: the sum in range correction and the sum in azimuth correction, each grouped in one hierarchy. The bursts are then further grouped according to their swath structure. Each burst can be displayed individually and/or in the groups.

The S-1 L1 product data set file naming convention is used to identify the KMZ file containing the sets of correction previews for each ETAD product, which includes identification with the corresponding start/stop times. Since the (sub-)swaths are not separated, two characters are used for the swath identifier space ("ss") with iw, ew and s1 to s6 as valid entries and the image number ("nnn") is set to "000". The "ttt" type placeholder is statically set to "eta" as identifier for the ETAD product. The polarization identifier is the same as the one of the ETAD product itself (e.g. "SH", "DH") and not the one of an individual polarization channel (Figure 16). The file formats used are the common KMZ files with embedded KML and PNG files.

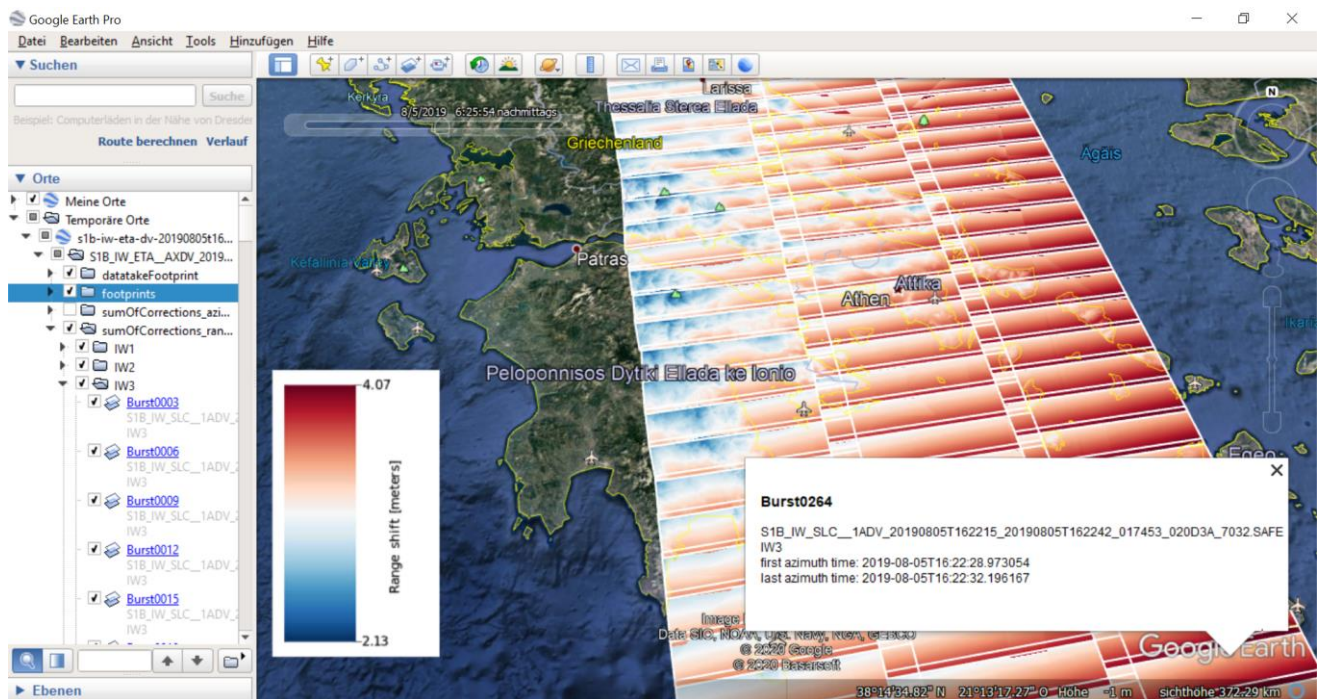


Figure 17: Example of the KMZ preview file opened in GoogleEarth™ showing the ETAD range correction sums for the bursts of an IW S-1 data take over Greece.

7.3 ETAD Product Orbit Component

That part of the precise orbit which is required for the calculation and to be used with the corrections is stored in the annotation for the user's convenience. The user is thus not required to retrieve the precise orbit product from the Sentinel-1 Quality Control Website [I5], which is required to achieve the high geometric accuracy with the help of the ETAD product corrections.

This file uses exactly the structure and format of the precise orbit POE product [I1]. The orbit arc which is extracted covers the data take temporal span plus a margin of about 12 records (equal to 120 s) in both directions. Validity start and stop times in the file name and of the temporal coverage in the annotation are adapted accordingly. The number of records and the file description are also adjusted. The generation time and the creator information are modified in order to distinguish the extracted product from its original source.

As an example, an orbit product named

S1A_OPER_AUX_POEORB_OPOD_20200222T120859_V20200201T225942_20200203T005942.EOF

used for an ETAD product

S1A_IW_ETA__AXSH_20200202T020202_20200202T020304_31088_123456_ABCD.SAFE

would thus be renamed to

S1A_OPER_AUX_POEORB_ETAD_20230411T090107_V20200202T020042_20200202T020512.EOF
and stored in the ETAD product annotation component.

From the XML annotation of the original orbit file, the elements marked in Figure 18 in red are changed in their content and the state vectors (green) are changed in number to the ones relevant for the ETAD product.

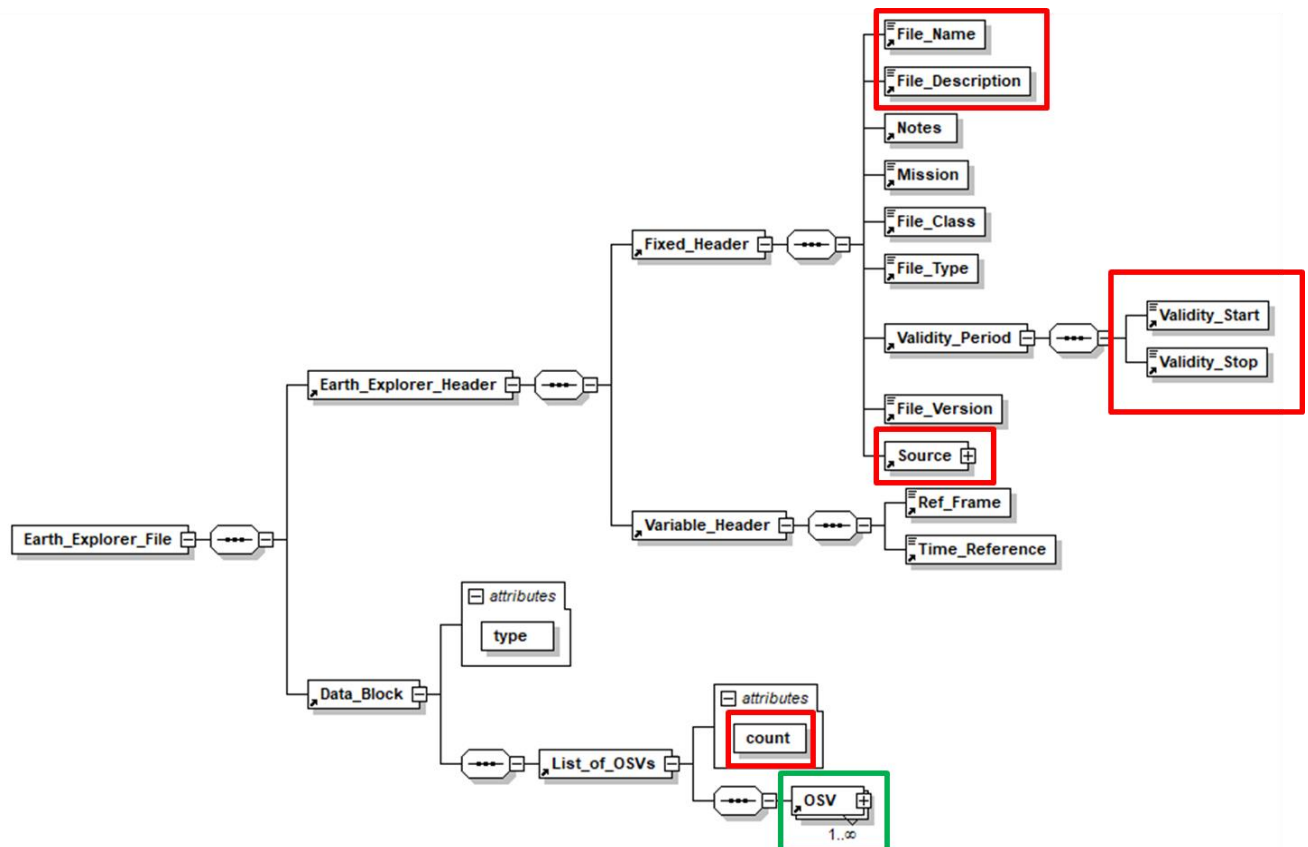


Figure 18: POE orbit file annotation adaption. The elements in red are changed in content, the orbit state vector (OSV) records (in green) are reduced in number.



A. SAFE Manifest File Definition

This section outlines the SAFE format manifest file segments relevant for the ETAD product handling by the users. It is derived from the manifest file of the S-1 L1 product [A3].

The file is an XML file always named **manifest.safe** and found in the root directory of the SAFE product. It inherits information from the associated source and auxiliary products used for the generation of the ETAD product. It also provides an inventory of the ETAD SAFE product components.

From [A3] the role of the file is defined as follows:

The manifest file serves two important purposes within the product:

- 1. It contains information about the collection of data sets that comprise the product, the nature of each data set and how the data sets relate to one another; and*
- 2. It contains general information about the product that is useful for cataloguing and identification purposes.*

The manifest file can be thought of as the map of each product and there is one manifest file present in every product.

The main components of the SAFE product are the Annotation Data Sets (ADS; In the case of ETAD that is the main annotation file and the extracted precise orbit arc) and the Measurement Data Sets (MDS; the ETAD NetCDF file). The preview data are assigned to the ADS as well. The SAFE manifest file thus references its Annotation Data Set Records (ADSR) as indicated in Table 4. An example for the parameters of the manifest.safe file generated by the SETAP for a single-scene stripmap data set is given in the respective sections below.

Table 4: ETAD manifest.safe overview

Data Set Record	Description
Information Package Map	The information package map contains a high-level textual description of the product and references to all of the MDS and ADS contained within the product.
	<code><xfd:XFDU xmlns:xfdu="urn:ccsds:schema:xfdu:1" version="esa/safe/sentinel-1.0/sentinel-1/sar/level-1/slc/annotations/smsp" xmlns:gml="http://www.opengis.net/gml" xmlns:gx="http://www.google.com/kml/ext/2.2" xmlns:s1="http://www.esa.int/safe/sentinel-1.0/sentinel-1" xmlns:s1sar11="http://www.esa.int/safe/sentinel-1.0/sentinel-1/sar/level-1"</code>



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	<pre>xmlns:s1sar12="http://www.esa.int/safe/sentinel-1.0/sentinel-1/sar/level-2" xmlns:safe="http://www.esa.int/safe/sentinel-1.0" xmlns:xsi="http://www.w3.org/2001/XMLSchema- instance" xsi:schemaLocation="..."> <informationPackageMap> <xfdu:contentUnit dmdID="acquisitionPeriod platform generalProductInformation measurementOrbitReference measurementFrameSet" pdiID="processing" textInfo="Sentinel-1 Extended Timing Annotation Dataset Product" unitType="SAFE Archive Information Package"> <xfdu:contentUnit repID="etadProductSchema" unitType="Metadata Unit"> <dataObjectPointer dataObjectID="etadXML"> </dataObjectPointer> </xfdu:contentUnit> <xfdu:contentUnit unitType="Metadata Unit"> <dataObjectPointer dataObjectID="etadOrbit"> </dataObjectPointer> </xfdu:contentUnit> <xfdu:contentUnit unitType="Metadata Unit"> <dataObjectPointer dataObjectID="etadNetCDF"> </dataObjectPointer> </xfdu:contentUnit> <xfdu:contentUnit unitType="Metadata Unit"> <dataObjectPointer dataObjectID="etadProductPreview"> </dataObjectPointer> </xfdu:contentUnit> </xfdu:contentUnit> </informationPackageMap> </xfdu:contentUnit></pre>
Metadata Section	The metadata section contains a minimal set of wrapped product metadata that can be used for product identification and cataloguing and it also contains references to each of the ADS contained within the product.
	<pre><metadataSection> <metadataObject ID="etadXML" category="DMD" classification="DESCRIPTION"> <dataObjectPointer dataObjectID="etadXML"> </dataObjectPointer> </metadataObject> </metadataSection></pre>



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	<pre></metadataObject> <metadataObject ID="etadOrbit" category="DMD" classification="DESCRIPTION"> <dataObjectPointer dataObjectID="etadOrbit"> </dataObjectPointer> </metadataObject></pre>
processing	The processing object informs about the ETAD generation facility and the SETAP software and lists the resources that were used (i.e. the SLC and AUX data input products) as well as the applicable definitions.
	<pre><metadataObject ID="processing" category="PDI" classification="PROVENANCE"> <metadataWrap mimeType="text/xml" textInfo="Processing" vocabularyName="SAFE"> <xmlData> <safe:processing name="ETAD Processing" start="2020-10-19T20:31:09.461140" stop="2020-10-19T20:32:57.000000"> <safe:facility country="Italy" name="S1-PDGS" organisation="ESA-Esrin" site="Frascati"> <safe:software name="SETAP" version="001.00"> </safe:software> </safe:facility> <safe:resource name="S1B_S5_SLC__1ASH_20200127T105952_20200127T110011_020001_025D6F_ECDD.SAFE" role="Level-1 SLC Annotation Product"> <processing name="SLC Post Processing" start="2020-01- 27T13:01:31.000000" stop="2020-01-27T13:02:07.000000" xmlns="http://www.esa.int/safe/sentinel-1.0"> <facility country="Germany" name="Copernicus S1 Core Ground Segment - DPA" organisation="ESA" site="DLR-Oberpfaffenhofen"> <software name="Sentinel-1 IPF" version="003.10"> </software> </facility> </processing> </safe:resource></pre>



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	<pre><resource name="S1B_AUX_ITC_V20190626T100000_G20200420T125307.SAFE" role="AUX_ITC"> </resource> <resource name="S1__AUX_TEC_V20200127T000000_20200127T235959_G20200210T102357.SAFE" role="AUX_TEC"> </resource> <resource name="S1__AUX_TRO_V20200127T060000_20200127T115959_G20200518T085629.SAFE" role="AUX_TRO"> </resource> <resource name="S1__AUX_TRO_V20200127T120000_20200127T175959_G20200518T085641.SAFE" role="AUX_TRO"> </resource> <resource name="S1B_OPER_AUX_POEORB_OPOD_20200216T110532_V20200126T225942_20200128T005942.EOF" role="AUX_POE"> </resource> <resource name="Sentinel-1 ETAD Product Definition (ETAD-DLR-PS-0002)" role="product definition"> </resource> <resource name="Sentinel-1 ETAD Product Format Specification (ETAD-DLR- PS-0014)" role="product specification"> </resource> </safe:processing> </xmlData> </metadataWrap> </metadataObject></pre>
platform	The platform object references the satellite and the instrument.
	<pre><metadataObject ID="platform" category="DMD" classification="DESCRIPTION"> <metadataWrap mimeType="text/xml" textInfo="Platform Description" vocabularyName="SAFE"> <xmlData> <safe:platform></pre>



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	<pre><safe:nssdcIdentifier>2016-025A</safe:nssdcIdentifier> <safe:familyName>SENTINEL-1</safe:familyName> <safe:number>B</safe:number> <safe:instrument> <safe:familyName abbreviation="SAR">Synthetic Aperture Radar</safe:familyName> <safe:extension> <slsar11:instrumentMode> <slsar11:mode>SM</slsar11:mode> <slsar11:swath>S5</slsar11:swath> </slsar11:instrumentMode> </safe:extension> </safe:instrument> </safe:platform> </xmlData> </metadataWrap> </metadataObject></pre>
measurementOrbitReference	The measurementOrbitReference object provides the orbit parameters.
	<pre><metadataObject ID="measurementOrbitReference" category="DMD" classification="DESCRIPTION"> <metadataWrap mimeType="text/xml" textInfo="Orbit Reference" vocabularyName="SAFE"> <xmlData> <safe:orbitReference> <safe:orbitNumber type="start">20001</safe:orbitNumber> <safe:orbitNumber type="stop">20001</safe:orbitNumber> <safe:relativeOrbitNumber type="start">25</safe:relativeOrbitNumber> <safe:relativeOrbitNumber type="stop">25</safe:relativeOrbitNumber> <safe:cycleNumber>121</safe:cycleNumber> <safe:phaseIdentifier>1</safe:phaseIdentifier></pre>



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	<pre><safe:extension> <s1:orbitProperties> <s1:pass>ASCENDING</s1:pass> <s1:ascendingNodeTime>2020-01- 27T09:29:36.405675</s1:ascendingNodeTime> </s1:orbitProperties> </safe:extension> </safe:orbitReference> </xmlData> </metadataWrap> </metadataObject></pre>
generalProductInformation	The generalProductInformation object provides basic product parameters like data take ID, class and type information.
	<pre><metadataObject ID="generalProductInformation" category="DMD" classification="DESCRIPTION"> <metadataWrap mimeType="text/xml" textInfo="General Product Information" vocabularyName="SAFE"> <xmlData> <s1sar11:standAloneProductInformation> <s1sar11:missionDataTakeID>154991</s1sar11:missionDataTakeID> <s1sar11:transmitterReceiverPolarisation>HH</s1sar11:transmitterReceiverPolarisation> <s1sar11:productClass>A</s1sar11:productClass> <s1sar11:productClassDescription>Extended Timing Annotation Dataset Product</s1sar11:productClassDescription> <s1sar11:productType>SLC</s1sar11:productType> <s1sar11:segmentStartTime>2020-01- 27T10:58:12.000000</s1sar11:segmentStartTime> </s1sar11:standAloneProductInformation> </xmlData> </metadataWrap></pre>



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	<code></metadataObject></code>
acquisitionPeriod	The acquisitionPeriod object gives the temporal coverage parameters of the ETAD product.
	<pre><metadataObject ID="acquisitionPeriod" category="DMD" classification="DESCRIPTION"> <metadataWrap mimeType="text/xml" textInfo="Acquisition Period" vocabularyName="SAFE"> <xmlData> <safe:acquisitionPeriod> <safe:startTime>2020-01-27T10:59:52.745583</safe:startTime> <safe:stopTime>2020-01-27T11:00:11.794145</safe:stopTime> <safe:extension> <s1:timeANX> <s1:startTimeANX>1121372612</s1:startTimeANX> <s1:stopTimeANX>1140421174</s1:stopTimeANX> </s1:timeANX> </safe:extension> </safe:acquisitionPeriod> </xmlData> </metadataWrap> </metadataObject></pre>
measurementFrameSet	The measurementFrameSet object gives the spatial coverage footprint parameters of the ETAD product.
	<pre><metadataObject ID="measurementFrameSet" category="DMD" classification="DESCRIPTION"> <metadataWrap mimeType="text/xml" textInfo="Frame Set" vocabularyName="SAFE"> <xmlData> <safe:frameSet> <safe:frame> <safe:footPrint srsName="http://www.opengis.net/gml/srs/epsg.xml#4326"> <gml:coordinates>-29.5919,115.012 -29.3938,115.827 - 28.2603,115.471 -28.4555,114.667</gml:coordinates> </safe:footPrint></pre>



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	<pre></safe:frame> </safe:frameSet> </xmlData> </metadataWrap> </metadataObject></pre>
etadProductSchema	The etadProductSchema object references the XSD schema definition of the ETAD main XML annotation file.
	<pre><metadataObject ID="etadProductSchema" category="REP" classification="SYNTAX"> <metadataReference href="./support/etadProduct-1.5.xsd" locatorType="URL" mimeType="text/xml" vocabularyName="XML Schema"> </metadataReference> </metadataObject> </metadataSection></pre>
Data Object Section	The data object section contains references to the physical location of each MDS and ADS file comprising the product with a description of the file format, file location and checksum of each file.
	<pre><dataObjectSection> <dataObject ID="etadXML" repID="etadProductSchema"> <byteStream mimeType="text/xml" size="26399"> <fileLocation href="./annotation/S1B_S5_ETA_AXSH_20200127T105952_20200127T110011_020001_025D6F.xml" locatorType="URL"> </fileLocation> <checksum checksumName="MD5">f4ce3f5ffe98ddc3216c546f10aef7df</checksum> </byteStream> </dataObject> <dataObject ID="etadOrbit"> <byteStream mimeType="text/xml" size="13112"> <fileLocation href="./annotation/S1B_OPER_AUX_POEORB_ETAD_20200216T110532_V20200127T105812_20200127T110152.EOF" locatorType="URL"> </fileLocation> <checksum checksumName="MD5">9fc8d0c63edc8f8b7e7f7cf7207b4a84</checksum> </byteStream> </dataObject> </dataObjectSection></pre>



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```
</byteStream>
</dataObject>
<dataObject ID="etadNetCDF">
  <byteStream mimeType="application/x-netcdf" size="25494681">
    <fileLocation
href="./measurement/S1B_S5_ETA__AXSH_20200127T105952_20200127T110011_020001_025D6F.nc"
locatorType="URL">
    </fileLocation>
    <checksum checksumName="MD5">1f2a4cf7ae63438c19ce154ac8eb6007</checksum>
  </byteStream>
</dataObject>
<dataObject ID="etadProductPreview">
  <byteStream mimeType="application/vnd.google-earth.kmz" size="201641">
    <fileLocation href="./preview/s1b-s5-eta-sh-20200127t105952-20200127t110011-
020001-025d6f-000.kmz" locatorType="URL">
    </fileLocation>
    <checksum checksumName="MD5">bc0cb8e8a8e4901d14ab32a1dac5ee10</checksum>
  </byteStream>
</dataObject>
</dataObjectSection>
</xfdu:XFDU>
```



B. ETAD XML Annotation Definition

Details of the XML Schema Definition (XSD) of the main annotation file of the ETAD product. The etadBurst element is embedded in the etadProduct scheme and is defined first. Type definitions are derived from S-1 L1 XSD types where appropriate. The XSD is available as link and delivered with each product in its support directory.

Schema **etadProduct-1.6.xsd**



etadProduct-1.6.xsd