## S1-ETAD

## Product Format Specification Document



European Union

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## Document Preparation

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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 |
| :---: | :---: | :---: | :---: |
| 1.8 | 06.03.2023 | $\begin{aligned} & \hline 2.1 \\ & 5,5.1 \\ & 6.1 \\ & \\ & 6.1 \\ & 6.2 \\ & \text { A } \\ & \text { B } \end{aligned}$ | Applicable documents updated for latest versions <br> Burst ID introduced in NetCDF; start time reference of NetCDF annotated grid time vectors emphasized (Table 1) <br> Information on average polarization offsets removed and replaced with flags on the presence of polarization or swath dependent offsets <br> Changes in AUX_ITC structure reflected in processing input information <br> Burst ID added to burst grid XML <br> SAFE file updated for single slice processing <br> ETAD XSD 1.7 updated for burst ID and AUX_ITC changes w.r.t. polarization |
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| 1.5 | 16.06.2021 | 5 NetCDF | Added unit column in Table 1 (AR RID AV-06) |
| 1.4 | 03.05.2021 | 5 NetCDF <br> Annex A | Added instrument timing calibration parameters to NetCDF Changed manifest.safe mimeTypes |
| 1.3 | 31.01.2021 | 5 NetCDF <br> 6 XML <br> 6 XML <br> 6 XML <br> 6 XML <br> 7.2 KMZ <br> Annex A | Adopt a uniform naming of rangeShift instead of the occasional rangeDelay (AV-04) <br> Number of polynomials and their application is now included in the comments of dcEstimate and azimuthFmRate nodes (AV-02, AV-03) <br> Count attribute dropped from list elements and only kept in list header (AV-01) <br> Added a second horizontal oversampling factor for the tropospheric correction parameters <br> Reference to Figure 16 (AV-05) <br> Removed duplicate dataObjectIDs and only included repIDs for schemas that are referenced within the manifest's metadata section (AV-06, AV-07) |
| 1.2 | 22.10.2020 | All <br> 5 NetCDF <br> 6 <br> 6 XML <br> 7 <br> Annex A <br> Annex B | Document restructured for processor qualification release by moving format details from the Annex into the main chapters. <br> Editorials and clarifications. <br> Additional examples included. <br> gridStart[Azimuth\|Range]Time w/o trailing zero and harmonized in XML and NetCDF (NM-12, AV-4). <br> Clarified annotated relative start times with respect to the datatake reference time in the root group (AV-6). <br> Unit attributes for all grids. <br> Inclusion of burst wise averageZeroDopplerVelocity (AV-7). <br> 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). <br> Non-optional unit attributes for all (physical) parameter elements (not only when given in two representations; NM-3, AV-01). <br> Uniform time format (NM-1), carrierFrequency moved (NM-4), grid layer information moved from burst level to product level to avoid repetition (NM-11). <br> 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). <br> gridStart[Azimuth\|Range]Time w/o trailing zero and harmonized in XML and NetCDF (NM-12, AV-3). <br> averageZeroDopplerVelocity in gridlnformation of each burst for convenient conversion of azimuth times to ground distances (AV-7) . <br> KMZ preview file naming, content and description specified. Product structure updated for preview components (Figure 16). Details on CRC-16 checksum added. <br> Included format description and example of the ETAD manifest.safe file. <br> XSD schema update to version 1.5. Removed print-out of XSD and embedded XSD file in document. |

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| 1.1 | 16.07.2020 | 5 Figure 1, <br> 5.1 Table 1 | NetCDF rootGroup attributes for temporal coverage t[Min/Max] renamed to <br> azimuthTime[Min/Max] of type string (UTC times) and tau[Min/Max] renamed <br> to rangTime[Min/Max]. <br> Burst group attributes gridStartT0 renamed to gridStartAzimuthTime0 and <br> gridStartTau0 renamed to gridStartRangeTime0 <br> Content of support directory specified. <br> XSD schema updated to version 1.4: <br> productCoverage/temporalCoverage and <br> bursts/etadBurst/burstCoverage/temporalCoverage <br> parameters renamed from t[Min/Max] and tau[Min/Max] to <br> azimuthTime[Min/Max] and rangeTime[Min/Max] <br> Scope |
| :--- | :--- | :--- | :--- |
| 1.0 | 7 Figure 12 <br> Annex B, <br> 6.1 Fig. 3 |  |  |
|  | 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 was released as version 1.5 for the SETAP processor verification. Since 1.6 the document is updated and maintained by SAR-MPC.

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## 2 Applicable and reference documents

### 2.1 Applicable document

The following documents are fully applicable for this document.

|  | Document ID | Document Title | Issue |
| :---: | :---: | :---: | :---: |
| [A1] | $\begin{aligned} & \text { ESA-EOPG- } \\ & \text { EOPGM-SOW-1 } \end{aligned}$ | Sentinel-1 Auxiliary product for precise atmospheric and geodetic correction: Statement of Work | $\begin{aligned} & 1.0 \\ & 18.06 .2018 \end{aligned}$ |
| [A2] | $\begin{aligned} & \text { ETAD-DLR-DD- } \\ & 0008 \end{aligned}$ | Algorithm Technical Baseline Document | $\begin{aligned} & \text { 2.3 } \\ & 06.03 .2023 \end{aligned}$ |
| [A3] | $\begin{aligned} & \text { S1-RS-MDA-52- } \\ & 7441 \end{aligned}$ | Sentinel-1 Product Specification | $\begin{aligned} & \hline 3.5 \\ & 19.04 .2018 \end{aligned}$ |
| [A4] | $\begin{aligned} & \text { ETAD-DLR-DD- } \\ & 0004 \end{aligned}$ | S1-ETAD Input/Output Description Document | $\begin{aligned} & \hline 2.4 \\ & 08.02 .2023 \end{aligned}$ |
| [A5] | PGSI-GSEG-EOPG-FS-050001 | Standard Archive Format for Europe (SAFE) Control Book Volume 1 Core Specifications | $\begin{aligned} & 1.8 \\ & 28.06 .2008 \end{aligned}$ |
| [A6] | $\begin{aligned} & \text { ETAD-DLR-PS- } \\ & 0002 \end{aligned}$ | Product Definition Document | $\begin{aligned} & 2.4 \\ & 06.03 .2023 \end{aligned}$ |

### 2.2 Normative references

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

|  | Document ID | Document Title | Issue |
| :--- | :--- | :--- | :--- |
| $[\mathrm{N} 1]$ |  |  |  |
| $[\mathrm{N} 2]$ |  |  |  |
| $[\mathrm{N} 3]$ |  |  |  |

### 2.3 Informative references

The following documents are referenced in the present document.

|  | Document ID | Document Title | Issue |
| :---: | :---: | :---: | :---: |
| [11] | $\begin{aligned} & \text { GMES-GSEG- } \\ & \text { EOPG-FS-10- } \\ & 0075 \end{aligned}$ | Sentinels POD Service File Format Specifications | $\begin{aligned} & 1.22 \\ & 18.01 .2018 \end{aligned}$ |
| [12] | $\begin{aligned} & \text { GEO.2018-1988- } \\ & 2 \end{aligned}$ | Copernicus Digital Elevation Model Product Handbook | $\begin{aligned} & 1.0 \\ & 28.11 .2019 \end{aligned}$ |
| [13] | EGM2008 | https://earth- <br> info.nga.mil/GandG/wgs84/gravitymod/egm2008/egm08_wgs84.html |  |
| [14] | ESDS-RFC-022v1 | netCDF-4/HDF5 File Format | $\begin{aligned} & \text { V0.03 } \\ & \text { March } 2011 \end{aligned}$ |
| [15] | 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 <br> 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 |
|  |  |

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## 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 geocoordinates. 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 FMrate 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.

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## 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 geospatial 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.

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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. The azimuth and range times of the two grid vectors are referenced to minimum times (azimuthTimeMin, rangeTimeMin) as well.

Table 1: The NetCDF parameter list table.

|  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| NetCDFProduct:rootGroup Attributes: |  | type | Description | required | unit |
|  | plndex | 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 | - |
|  | slndex | Int |  | Yes | - |
| Dimensions: |  | type | Description |  |  |
|  | - | - | - |  |  |
| Variables: |  | type | Dimension | unit | description |
|  | - | - | - | - | - |
| Groups: |  | type |  |  |  |
|  | Burst1 | Group:burst |  |  |  |
|  | Burst2 | Group:burst |  |  |  |
|  | ... | Group:burst |  |  |  |
| Group:burstAttributes: |  |  |  |  |  |
|  |  | type | Description | required | unit |
|  | productID | string | The Sentinel-1 product id | Yes | - |
|  | swathID | string | For example IW1, IW2, .... | Yes | - |
|  | bIndex | Int | Burst index | Yes | - |
|  | slndex | Int | Swath index | Yes | - |
|  | plndex | Int | Product index | Yes | - |
|  | burstld | Int | Relative burst Id | No | - |
|  | gridStartAzimuthTime | double | Delta azimuth time of first grid | Yes | s |


|  |  | point referenced to "azimuthTimeMi $n$ " 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 |
| averageZeroDopplerVelocit y | double | Average azimuth beam velocity on ground | Yes | $\mathrm{m} / \mathrm{s}$ |
| instrumentTimingCalibratio nRange | double | The range timing calibration of the reference polarisation channel (already applied in sum layer) | Yes | S |
| instrumentTimingCalibratio nAzimuth | 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 reference polarisation | No | S |
| azimuthOffsetVH | double | Azimuth timing offset to | No | S |


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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 Panoply ${ }^{1}$.

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## 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 <br> correction grids - i.e. the rectangular coverage of the entire product. |
| productInformation | Main parameters for the interpretation and application of this specific <br> product; i.e. the reference systems of the spatio-temporal coordinates <br> and the common sampling. Describing parameters helping in the <br> interpretation and evaluation of the different grid layers. |
| processingInformation | Information on product generation, the input and auxiliary data and <br> the internal resources and settings of the processor. The processor <br> configuration is summarized and the flags/switches for the different <br> calculations are provided. The calculation methods and higher-level <br> algorithmic parameters are given. |
| qualityAndStatistics | Quality flags on reliability of processing and the calculated corrections <br> and basic statistics on the common geophysical corrections for the <br> entire data take. |
| productComponents | The content of the product in terms of SAR input products, swaths and <br> bursts. It lists the identifying parameters of the different input SAR <br> products used and identifies which bursts belong to which input and <br> also indicates the completeness of the inputs. |
| etadBurstList | The list of the individual etadBurst annotation groups as detailed <br> 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 <br> application of the grid data to the focused SAR data. |
| processingInformation | The parameters related to the determination of the SAR specific system <br> corrections of the bursts. |

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| burstDataStatistics | Basic statistical parameters on all calculated corrections for the <br> individual bursts. |
| :--- | :--- |

### 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.

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Figure 4: Header and coverage information.

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| Element | Description | Attributes |
| :--- | :--- | :--- |
| etadHeader | ETAD header data set record. Refers to the entire datatake | [] |
| missionld | Mission identifier for this data set. | [] |
| productType | Product type for this data set. | [] |
| mode | Sensor mode for this data set. The sensorMode types <br> 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. | [] |
| missionDataTakeld | Mission data take identifier. | [] |


| Element | Description | Attributes |
| :--- | :--- | :--- |
| productCoverage |  | [] |
| temporalCoverage | min/max azimuth and range times over the full combined grid <br> of the data take. The minimum times are also the reference <br> for the relative time offsets annotated for the individual <br> 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 <br> min/max times of the temporal coverage | [] |
| coordinates | geographic Lat/Lon/Height coordinates provided for the four <br> corners corresponding to the min/max times of the grid, <br> indicated with early azimuth/near range location to late <br> 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) <br> [meter] | ['unit'] |
| incidenceAngleRange | The minimum and the maximum incidence angle of the grid <br> corners. Useful for coarse approximation of slant-to-ground <br> range projection to convert range times to ground distances. | [] |
| incidence angle at near range [degrees] | ['unit'] |  |
| iMin | ['unit'] |  |
| incidence angle at far range [degrees] |  |  |

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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 flags on offsets depending on polarization channels and swathes are provided here for informative purposes. Their corresponding offset values are given in the burst grids.


Figure 5: Common product information.

| Element | Description | Attribute <br> $s$ |
| :---: | :---: | :---: |
| productInformation |  | [] |
| carrierFrequency | RADAR frequency of the S 1 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'] |
| productTimingCalibrationOffsets | Informative section about applied timing offsets in this ETAD product | [] |
| containsSwathDependentTimingInformat ion | Flag indicating if there are any swath dependent timing offsets applied in this ETAD product. Detailed information can be found in the burst data. [bool] | [] |
| containsPolarisationDependentTimingInf ormation | Flag indicating if there are any polarisation dependent timing offsets applied in this ETAD product. Detailed information can be found in the burst data. [bool] | [] |

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

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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 <br> are provided for each burst | [] |
| numberOfCorrectionLayer <br> s | 9 timing correction grid layers (2 of which are the sums in <br> range and azimuth respectively) | [] |
| numberOfMappingLayers | 3 geographic mapping grid layers (lat, lon, h) | [] |
| gridLayerList | list of description elements for each NetCDF grid | $[$ ['count'] |
| grid |  | [] |

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[^2]| name | Tropospheric Delay Correction, Bistatic Azimuth Shift <br> Correction, ... | [] |
| :--- | :--- | :--- |
| applicationDomain | range or azimuth or NONE (for coordinates) | [] |
| pixelValue | time offsets in seconds or coordinates in degrees or heights in <br> meters | [] |
| format | double precision | [] |
| valid | true/false (i.e. the specific correction is not valid if corrections <br> 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 | Attribute $s$ |
| :---: | :---: | :---: |
| 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 datatake 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 datatake 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 datatake center | ['unit'] |
| correctionGridAzimuthSampling | configured default grid spacing in azimuth on ground at datatake 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 datatake | [] |

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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 <br> calibration data are applicable | [] |
| instrumentTimingCalibrationReferenc <br> e | timing calibration parameters reference parameters <br> used for this product | [] |
| rangeCalibration | the instrument timing calibration in range | ['unit'] |
| azimuthCalibration | the instrument timing calibration in azimuth | ['unit'] |
| instrumentTimingCalibrationOffsetLis <br> t | timing calibration offset parameters of each swath <br> and polarisation used for this product | ['count'] |
| instrumentTimingCalibrationOffset | Instrument timing calibration offset parameters to <br> the annotated <br> instrumentTimingCalibrationReference. This record <br> contains swath/polarisation channel dependent <br> parameters related to the instrument. There may be <br> up to one record per swath (23 nominal swaths) per <br> polarisation (4 polarisation combinations for SM, <br> IW, EW) for a maximum total of 56. | [] |
| orbit | the S-1 POE orbit product used for the correction <br> parameter calculation and the description of its <br> segment extracted and provided in this ETAD <br> product | [] |
| source | file ID | e.g. CODE |

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| 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 datatake time span. A third product is provided if the datatake 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 tropospause (in m) | ['unit'] |
| integrationIntervalSlantRange2 | steps in meter for heights above tropospause (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 | [] |

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| solidEarthTideCorrectionMethod | Algorithmic parameters used for the calculation of <br> 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.

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Figure 8: Product quality and correction statistics

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| Element | Description | Attributes |
| :--- | :--- | :--- |
| qualityAndStatistics |  | [] |
| nominalProcessing | boolean flag indicating if default processor settings where <br> used without switches set differently: (true/false) | [] |
| qualityStatus | result of automatic processor internal limit checks: <br> AUTO_APPROVED indicates no limit violations, QA_WARNING <br> 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 <br> datatake. Only optional if disabled | [] |
| reliability | flag indicating quality issues with inputs or parameter <br> calculations (nominal or degraded) | [] |
| rangeShift | all values given twice: once in seconds, once in meters | [] |
| ionosphericCorrection | statistics of ionospheric correction values over entire <br> datatake. Only optional if disabled | [] |
| reliability | flag indicating quality issues with inputs or parameter <br> 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 <br> entire datatake. Only optional if disabled | [] |
| reliability | flag indicating quality issues with inputs or parameter <br> 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 <br> datatake. Only optional if disabled | [] |
| reliability | flag indicating quality issues with inputs or parameter <br> 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 <br> entire datatake. Only optional if disabled | [] |
|  | [] |  |

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| reliability | flag indicating quality issues with inputs or parameter <br> 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 <br> entire datatake. Only optional if disabled | [] |
| reliability | flag indicating quality issues with inputs or parameter <br> 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 <br> azimuth over entire datatake. | [] |
| reliability | flag indicating quality issues with inputs or parameter <br> calculations (nominal or degraded). Set to degraded if any of <br> 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 | [] |
| Minimum, Maximum and | Mean elements provided twice for all timing correction statistics |  |
| 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 <br> $=5$ | [] |
| 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 <br> SLC slice list contained in ETAD product and all bursts are <br> included. | [] |
| inputProductList | List of parameters of SLC input products provided for <br> 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) | [] |

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| startTime | SLC product start time | [] |
| :--- | :--- | :--- |
| stopTime | SLC product stop time | [] |
| sliceNumber | Index w.r.t. original slice list from SLC input products (starting <br> with 1) | [] |
| swathList | list of swathes 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 <br> identified by their index in this product | ['count'] |
| bIndex | integer burst index. Starting with 1 and sorted in burst start <br> 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.

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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.

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

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| Element | Description | Attributes |
| :---: | :---: | :---: |
| 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 | [] |
| burstld | The relative burst ID as found in the SAR-IPF SLC input data (source is set to SAR-IPF). If no relative burst ID is provided in the SLC, a burst ID is calculated with the algorithm outlined in the ATBD [A2] and the source attribute of this node is set to SETAP. The absolute burst ID can be found as an attribute. | ['absolute', 'source'] |
| 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 $\mathrm{min} /$ max times of the temporal coverage | [] |
| coordinates | geographic Lat/Lon/Height coordinates provided for the four corners corresponding to the $\mathrm{min} / \mathrm{max}$ 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-toground 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 |  | [] |

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| gridStartAzimuthTime | relative azimuth time of earliest grid point in reference <br> to the overall min azimuth time of the product grid <br> (seconds) | ['unit'] |
| :--- | :--- | :--- |
| gridStartRangeTime | relative range time of nearest grid point in reference to <br> 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 <br> 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 <br> incidence angle (in m) | ['unit'] |
| farRange | approximated grid ground sampling at shallowest <br> incidence angle (in m) | ['unit'] |
| azimuth | approximate grid sampling in flight direction on ground <br> at center (in m) | ['unit'] |
| averageZeroDopplerVelocity | average beam ground velocity for this burst to coarsely <br> convert azimuth time to ground distance [m/s] | ['unit'] |
| polarisationChannels | the residual relative polarisation azimuth and range time <br> offsets to be applied to the correction grids of this burst <br> for polarisation channels other than the "master" one. <br> The calibration parameters may vary from swath to <br> swath. | [] |
| rangeOffset | SETAP azimuth time calibration offset of this polarisation <br> layer relative to the master [s]. | ['unit'] |
| referencePolarisation | boolean flag indicating if this polarisation is the <br> reference "master" ( true / false ) | [] |
| numberOfPolarisationChannel <br> s | number of polarisation channels in these burst data <br> layer relative to the master [s] | [] |
| relafset | the residual relative timing offsets in range and azimuth <br> relative to the master polarisation to be applied for each <br> polarisation in the product. The reference polarisation <br> channel has no offset (0, 0). The values to be applied are <br> given for each burst and aso in the NetCDF file. | ['arisation' |

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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.


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

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| Element | Description | Attributes |
| :---: | :---: | :---: |
| etadBurst | (continued) |  |
| 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 $[\mathrm{Hz} / \mathrm{s}]$ | ['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 $/ \mathrm{s}$ ]. 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 $=\mathrm{cO}+\mathrm{c} 1(\mathrm{tSR}-\mathrm{tO})+$ $\mathrm{c} 2(\mathrm{tSR}-\mathrm{t} 0)^{\wedge} 2$, where $\mathrm{tSR}=$ two-way slant range time. | $\begin{aligned} & \hline \text { ['count', } \\ & \text { 'units'] } \end{aligned}$ |
| 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 = d0 + $\mathrm{d} 1(\mathrm{tSR}-\mathrm{t} 0)+\mathrm{d} 2(\mathrm{tSR}-\mathrm{t} 0)^{\wedge} 2$, where $\mathrm{tSR}=$ 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 | [] |

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| reliability | flag indicating quality issues with inputs or parameter <br> calculations (nominal or degraded) | [] |
| :--- | :--- | :--- |
| rangeShift | all values given twice: once in seconds, once in meters | [] |
| fmMismatchCorrection | statistics of SAR FM-Rate mismatch correction values <br> over the burst. Only optional if disabled | [] |
| reliability | flag indicating quality issues with inputs or parameter <br> calculations (nominal or degraded) | [] |
| azimuthShift | all values given twice: once in seconds, once in meters | [] |
| sumOfCorrections | statistics of final combined correction values in range <br> and azimuth over the burst. | [] |
| reliability | flag indicating quality issues with inputs or parameter <br> 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 | [] |
| Minimum, Maximum and Mean elements provided twice for all timing correction statistics |  |  |
| min | minimum value [seconds] and [meter] | ['unit'] |
| max | maximum value [seconds] and [meter] | $[$ ['unit'] |
| mean | mean value [seconds] and [meter] | $[' u n i t '] ~$ |

## 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.
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MMM_BB_ETA__AXPP_YYYYMMDDTHHMMSS_YYYYMMDDTHHMMSS_OOOOOO_DDDDDD_CCCC.SAFE


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

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### 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 | 20201122 T070809 | Time of the earliest ETAD grid points in azimuth time. <br> Format: <br> year (YYYY), month (MM), day (DD), "T", hour (hh), minute (mm), second (ss) |
| YYYYMMDDTHHMMSS | UTC stop time | 20201122 T070910 | Stop time of "latest" grid points. |
| 000000 | 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 downsampling. 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.

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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 56 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 ${ }^{\text {TM }}$ 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 [15], 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

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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.

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## 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. |
|  | <xfdu: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:slsarl1="http://www.esa.int/safe/sentinel-1.0/sentinel-1/sar/level-1" |


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xmlns:s1sarl2="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/XMLSchemainstance">
<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="etadAnnotationSchema" unitType="Metadata Unit">
<dataObjectPointer dataObjectID="etadAnnotation" />
</xfdu:contentUnit>
<xfdu:contentUnit repID="etadOrbitSchema" unitType="Metadata Unit">
<dataObjectPointer dataObjectID="etadOrbit" />
</xfdu:contentUnit>
<xfdu:contentUnit repID="etadNetCDFSchema" unitType="Metadata Unit">
<dataObjectPointer dataObjectID="etadNetCDF" />
</xfdu:contentUnit> <xfdu:contentUnit repID="etadProductPreviewSchema"unitType="Metadata Unit"> <dataObjectPointer dataObjectID="etadProductPreview" /> </xfdu:contentUnit>
</xfdu:contentUnit>

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.
<metadataSection>
<metadataObject ID="etadAnnotationAnnotation" category="DMD" classification="DESCRIPTION"> <dataObjectPointer dataObjectID="etadAnnotation" />
</metadataObject>
<metadataObject ID="etadOrbitAnnotation" category="DMD" classification="DESCRIPTION"> <dataObjectPointer dataObjectID="etadOrbit" />
</metadataObject>
<metadataObject ID="etadNetCDFAnnotation" category="DMD" classification="DESCRIPTION"> <dataObjectPointer dataObjectID="etadNetCDF" />

|  | ```</metadataObject> <metadataObject ID="etadProductPreviewAnnotation" category="DMD" classification="DESCRIPTION"> <dataObjectPointer dataObjectID="etadProductPreview" /> </metadataObject>``` |
| :---: | :---: |
| 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. |
|  | ```<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-SM" version="002.10"> </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>``` |

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|  | ```<safe:resource name="S1B_AUX_ITC_V20190626T100000_G20200420T125307.SAFE" role="AUX_ITC"> </safe:resource> <safe:resource name="S1__AUX_TEC_V20200127T000000_G20200210T102357.SAFE" role="AUX_TEC"> </safe:resource> <safe:resource name="S1__AUX_TRO_V20200127T060000_G20200518T085629.SAFE" role="AUX_TRO"> </safe:resource> <safe:resource name="S1__AUX_TRO_V20200127T120000_G20200518T085641.SAFE" role="AUX_TRO"> </safe:resource> <safe:resource name="S1B_OPER_AUX_POEORB_OPOD_20200216T110532_V20200126T225942_20200128T005942.EOF" role="AUX_POE"> </safe:resource> <safe:resource name="Sentinel-1 ETAD Product Definition (ETAD-DLR-PS- 0002)" role="product definition"> </safe:resource> <safe:resource name="Sentinel-1 ETAD Product Format Specification (ETAD-DLR-PS-0014)" role="product specification"> </safe:resource> </safe:processing> </xmlData> </metadataWrap> </metadataObject>``` |
| :---: | :---: |
| platform | The platform object references the satellite and the instrument. |
|  | ```<metadataObject ID="platform" category="DMD" classification="DESCRIPTION"> <metadataWrap mimeType="text/xml" textInfo="Platform Description" vocabularyName="SAFE"> <xmlData> <safe:platform>``` |


|  | ```<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> <s1sarl1:instrumentMode> <s1sarl1:mode>SM</s1sarl1:mode> <s1sarl1:swath>S5</s1sarl1:swath> </s1sarl1:instrumentMode> </safe:extension> </safe:instrument> </safe:platform> </xmlData> </metadataWrap> </metadataObject>``` |
| :---: | :---: |
| measurementOrbitRefe rence | The measurementOrbitReference object provides the orbit parameters. |
|  | ```<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>``` |


|  | ```<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>``` |
| :---: | :---: |
| generalProductInforma tion | The generalProductInformation object provides basic product parameters like data take ID, class and type information. <br> Notes: <br> in case of single slice L1 input, the ETAD product parameters productComposition and sliceProductFlag are set to "Slice" and "true"; the parameters sliceNumber and totalSlices are set in line with the L1 input information <br> in case of multiple slice L1 input, the ETAD product parameters productComposition and sliceProductFlag are set to "Individual" and "false"; the parameters sliceNumber and totalSlices are omitted. |
|  | ```<metadataObject ID="generalProductInformation" category="DMD" classification="DESCRIPTION"> <metadataWrap mimeType="text/xml" textInfo="General Product Information" vocabularyName="SAFE"> <xmlData> <s1sarl1:standAloneProductInformation> <s1sarl1:instrumentConfigurationID>0</s1sarl1:instrumentConfigurationID> <s1sarl1:missionDataTakeID>154991</s1sarl1:missionDataTakeID> <s1sarl1:transmitterReceiverPolarisation>HH</s1sarl1:transmitterReceiverPolarisation> <s1sarl1:productClass>X</s1sarl1:productClass> <slsarl1:productClassDescription>Extended Timing Annotation Dataset Product</s1sarl1:productClassDescription>``` |

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|  | ```<s1sarl1:productComposition>Slice</s1sarl1:productComposition> <s1sarl1:productType>ETA</s1sarl1:productType> <s1sarl1:productTimelinessCategory>Off- line</s1sarl1:productTimelinessCategory> <slsarl1:sliceProductFlag>true</slsarl1:sliceProductFlag> <s1sarl1:segmentStartTime>2020-01- 27T10:58:12.000000</s1sarl1:segmentStartTime> <s1sarl1:sliceNumber>1</s1sarl1:sliceNumber> <slsarl1:totalSlices>1</s1sarl1:totalSlices> </s1sarl1:standAloneProductInformation> </xmlData> </metadataWrap> </metadataObject>``` |
| :---: | :---: |
| acquisitionPeriod | The acquisitionPeriod object gives the temporal coverage parameters of the ETAD product. |
|  | ```<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>``` |

The measurementFrameSet object gives the spatial coverage footprint parameters of the ETAD product.
<metadataObject ID="measurementFrameSet" category="DMD" classification="DESCRIPTION"> <metadataWrap mimeType="text/xml" textInfo="Frame Set" vocabularyName="SAFE"> <xmlData>
[safe:frameSet](safe:frameSet)
[safe:frame](safe:frame)
<safe:footPrint
srsName="http://www.opengis.net/gml/srs/epsg.xml\#4326">
[gml:coordinates](gml:coordinates)-29.5919,115.012 -29.3938,115.827 -
28.2603,115.471-28.4555,114.667</gml:coordinates>
</safe:footPrint>
</safe:frame>
</safe:frameSet>
</xmlData>
</metadataWrap>
</metadataObject>
ETAD Annotation Schema
The ETAD annotation schema object references of the XSD schema definitions of the ETAD product files.
<metadataObject ID="etadAnnotationSchema" category="REP" classification="SYNTAX">
<metadataReference href="./support/etadProduct.xsd" locatorType="URL"
mimeType="text/xml" vocabularyName="XML Schema" />
</metadataObject>
<metadataObject ID="etadOrbitSchema" category="REP" classification="SYNTAX"> <metadataReference href="./support/aux poeorb.xsd" locatorType="URL"
mimeType="text/xml" vocabularyName="XML Schema" />
</metadataObject>
<metadataObject ID="etadNetCDFSchema" category="REP" classification="SYNTAX"> <metadataReference href="./support/etadNetCDF.xsd" locatorType="URL"
mimeType="text/xml" vocabularyName="XML Schema" />
</metadataObject>
<metadataObject ID="etadProductPreviewSchema" category="REP" classification="SYNTAX">

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|  | ```<metadataReference href="./support/etadProductPreview.xsd" locatorType="URL" mimeType="text/xml" vocabularyName="xML Schema" /> </metadataObject> </metadataSection>``` |
| :---: | :---: |
| 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. |
|  | ```<dataObjectSection> <dataObject ID="etadAnnotation" repID="etadAnnotationSchema"> <byteStream mimeType="text/xml" size="26399"> <fileLocation href="./annotation/S1B_S5_ETA__AXSH_20200127T105952_20200127T110011_020001_025D6F.xml" locatorType="URL" /> <checksum checksumName="MD5">f4ce3f5ffe98ddc3216c546f10aef7df</checksum> </byteStream> </dataObject> <dataObject ID="etadOrbit" repID="etadOrbitSchema"> <byteStream mimeType="text/xml" size="13112"> <fileLocation href="./annotation/S1B_OPER_AUX_POEORB_ETAD_20200216T110532_V20200127T105812_20200127T110152.EOF" locatorType="URL" /> <checksum checksumName="MD5">9fc8d0c63edc8f8b7e7f7cf7207b4a84</checksum> </byteStream> </dataObject> <dataObject ID="etadNetCDF" repID="etadNetCDFSchema"> <byteStream mimeType="application/x-netcdf" size="25494681"> <fileLocation href="./measurement/S1B_S5_ETA__AXSH_20200127T105952_20200127T110011_020001_025D6F.nc" locatorType="URL" /> <checksum checksumName="MD5">1f2a4cf7ae63438c19ce154ac8eb6007</checksum> </byteStream> </dataObject> <dataObject ID="etadProductPreview" repID="etadProductPreviewSchema">``` |


|  | ```<byteStream mimeType="application/vnd.google-earth.kmz" size="201641"> <fileLocation href="./preview/s1b-s5-eta-sh-20200127t105952-20200127t110011- 020001-025d6f-000.kmz" locatorType="URL" /> <checksum checksumName="MD5">bc0cb8e8a8e4901d14ab32a1dac5ee10</checksum> </byteStream> </dataObject> </dataObjectSection> </xfdu:XFDU>``` |
| :---: | :---: |

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## 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 attachment to this document and delivered with each product in its support directory.

Attachment: Schema etadProduct.xsd


[^0]:    Versions up to 1.6 The results presented here are outcome of the ESA contract Sentinel-1 Auxiliary Product for Precise Atmospheric and Geodetic Correction 4000126567/19/I-BG. Copernicus Sentinel-1 mission is funded by the EU and ESA.
    Versions after 1.6 The document is maintained under ESA contract Sentinel-1 / SAR Mission Performance Cluster Service 4000135998/21/I BG. Copernicus Sentinel-1 mission is funded by the EU and ESA.

[^1]:    ${ }^{1}$ https://www.giss.nasa.gov/tools/panoply/

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