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Metadata specification for the TROPOMI L1b products



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1 Introduction

1.1 Identification

This document, identified by S5P-KNMI-L01B-0014-SD contains the metadata specification of the TROPOMI Level-1b (L1b) data products. The metadata specification is based on *ISO 19115 International Geographic Metadata Standard* together with the *ISO 19115-2 extension for imagery and gridded data* and the *Earth Observation Metadata profile of Observations and Measurements*. In addition, metadata related to the *ESA Earth Observation File Format Standard* and the CF/netCDF conventions are described.

This document is identified in [AD1] as CI-6530-MDS.

1.2 Purpose and objective

The TROPOMI L01b processor developed by KNMI produces L1b data products from L0 input data and auxiliary data products. The TROPOMI L1b data products distinguish radiance, irradiance, calibration and engineering data. A common data format for all TROPOMI L1b products has been defined based on netCDF. The data specification of these products is defined in document [RD4].

This document addresses the specific tailoring of the metadata specification [RD5] and [RD6] for the L1b data products.

1.3 Document overview

This document describes the metadata related to the official products that are the result from the Level 0 to Level 1b processing of the data collected by TROPOMI onboard the Sentinel-5 Precursor satellite.

2 Applicable and reference documents

2.1 Applicable documents

- [AD1] Software development plan for TROPOMI L01b data processor.
source: KNMI; **ref:** S5P-KNMI-L01B-0002-PL; **issue:** 2.0.0; **date:** 2012-11-14.
- [AD2] Earth Observation Ground Segment File Format Standard.
source: ESA; **ref:** PE-TN-ESA-GS-0001; **issue:** 2.0; **date:** 2012-05-03.
- [AD3] Tailoring of the Earth Observation File Format Standard for the Sentinel 5-Precursor Ground Segment.
source: ESA; **ref:** S5P-TN-ESA-GS-106; **issue:** 2.2; **date:** 2015-02-20.

2.2 Standard documents

There are no standard documents.

2.3 Reference documents

- [RD4] Input/output data specification for the TROPOMI L01b data processor.
source: KNMI; **ref:** S5P-KNMI-L01B-0012-SD; **issue:** 11.0.0; **date:** 2022-03-31.
- [RD5] Earth Observation Metadata profile of Observations Measurements.
source: OGC; **ref:** OGC 10-157r4; **issue:** 1.0.3-DRAFT; **date:** 2014-01-10.
- [RD6] Geographic Information – Metadata.
source: ISO; **ref:** ISO 19115:2003(E); **issue:** First Edition; **date:** 2003-05-01.
- [RD7] Terms, definitions and abbreviations for TROPOMI L01b data processor.
source: KNMI; **ref:** S5P-KNMI-L01B-0004-LI; **issue:** 3.0.0; **date:** 2013-11-08.
- [RD8] NetCDF Climate and Forecast (CF) Metadata Conventions.
source: CFConventions; **ref:** n/a; **issue:** 1.6; **date:** 2011-12-05.
- [RD9] Geographic Information - Metadata - Part 2: Extensions for imagery and gridded data.
source: ISO; **ref:** ISO 19115-2:2009(E); **issue:** First Edition; **date:** 2009-02-15.
- [RD10] Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE).
source: EC; **ref:** Directive 2007/2/EC; **date:** 2007-03-14.
- [RD11] INSPIRE Metadata Regulation, Commission Regulation (EC), No1205/2008.
source: EC; **ref:** Commission Regulation (EC) No 1205/2008; **date:** 2008-12-03.
- [RD12] INSPIRE Metadata Implementing Rules: Technical Guidelines based on EN ISO 19115 and EN ISO 19119.
source: EC JRC; **ref:** MD_IR_and_ISO_v1_2_20100616; **issue:** 1.2; **date:** 2010-06-16.
- [RD13] Geographic Information – Metadata - XML schema implementation.
source: ISO; **ref:** ISO/TS 19139:2007(E); **date:** 2007-04-15.
- [RD14] Geographic Information – Metadata - XML schema implementation - Part 2: Extensions for imagery and gridded data.
source: ISO; **ref:** ISO/TS 19139-2:2012(E); **date:** 2012-12-15.
- [RD15] EO Product Collection, Service and Sensor Discovery using the CS-W ebRIM Catalogue.
source: OGC; **ref:** OGC 11-035r1; **issue:** 1.0; **date:** 2013-03-26.
- [RD16] Observations and Measurements - XML Implementation.
source: OGC; **ref:** OGC 10-025r1; **issue:** 2.0; **date:** 2011-03-22.
- [RD17] OGC Catalogue Services Standard 2.0 Extension Package for ebRIM Application Profile: Earth Observation Products.
source: OGC; **ref:** OGC 06-131r6; **issue:** 1.0.0; **date:** 2010-02-10.

- [RD18] Definition identifier URNs in OGC namespace.
source: OGC; **ref:** OGC 07-092r3; **issue:** 1.2.1; **date:** 2009-01-15.
- [RD19] Algorithm theoretical basis document for the TROPOMI L01b data processor.
source: KNMI; **ref:** S5P-KNMI-L01B-0009-SD; **issue:** 10.0.0; **date:** 2022-03-31.
- [RD20] OpenGIS Implementation Specification for Geographic information - Simple feature access - Part 1: Common architecture.
source: OGC; **ref:** OGC 06-103r4; **issue:** 1.2.1; **date:** 2011-05-28.

2.4 Electronic references

- [ER21] http://wiki.esipfed.org/index.php/Category:Attribute_Conventions_Dataset_Discovery.
- [ER22] http://wiki.esipfed.org/index.php/NetCDF,_HDF,_and_ISO_Metadata.

3 Terms, definitions and abbreviated terms

Terms, definitions and abbreviated terms that are used in the development program for the TROPOMI L01b data processor are described in [RD7]. Terms, definitions and abbreviated terms that are specific for this document can be found below.

3.1 Terms and definitions

There are no terms and definitions specific to this document.

3.2 Acronyms and Abbreviations

ACDD	Attribute Convention for Dataset Discovery
EC	European Commission
EO-FFS	Earth Observation Ground Station File Format Standard
EOP	Earth Observation Product
ESA	European Space Agency
EU	European Union
FGDC	Federal Geographic Data Committee
GEMET	GEneral Multilingual Environmental Thesaurus
GMES	Global Monitoring for Environment and Security
HDF	Hierarchical Data Format
HMA	Heterogeneous Mission Accessibility
INSPIRE	Infrastructure for Spatial Information in the European Community
IODS	Input/Output Data Specification
JRC	Joint Research Centre
NcML	NetCDF Markup Language
NetCDF	Network Common Data Form
OGC	Open Geospatial Consortium
THREDDS	Thematic Realtime Environmental Distributed Data Services
UCAR	University Corporation for Atmospheric Research
UTC	Coordinated Universal Time
WGS	World Geodetic System
XML	Extensible Markup Language

4 Metadata models

4.1 Introduction

The purpose of this section is to present a description of the conventions and the standards and to present the rationale for the selected implementation of metadata information into the L1b product. The baseline for providing metadata for the L1b product is formed by the ISO 19115 International Geographic Metadata Standard together with the ISO 19115-2 extension for imagery and gridded data and Earth Observation Metadata profile of Observations & Measurements (OGC 10-157). These standards are leading as prescribed by INSPIRE and ESA.

In specifying the metadata for the TROPOMI L1b products several metadata conventions and standards are taken into account. Two relevant conventions are related to the use of netCDF as file format for the L1b products: the NetCDF Climate and Forecast (CF) Metadata Conventions [RD8] and the Attribute Convention for Data Discovery (ACDD) [ER21] (governed by the Federation of Earth Science Information Partners (ESIP), which is an open networked community).

In addition, two ISO standards are important that are related to the description of collections of Earth Observation (EO) products (ISO 19115-2) and to the description of individual EO products (ISO 19156), respectively. The ISO 19115-2 and ISO 19156 are conceptual models that do not provide any encoding. Encoding standards for these models are documented in ISO 19139, OGC 10-025 and OGC 10-157, providing XML implementation schemas for describing, validating and exchanging metadata about geographic datasets and for observations and measurements.

Finally, the ESA Earth Observation File Format Standard also introduces some elements related to the description of the data products. In particular, metadata have to be included in the header file of the product according to the specifications of [AD2] and [AD3].

As shown in the input/output data specification document [RD4], metadata are included into the netCDF L1b product as global attributes and as attributes organized into groups-of-groups, based on their intended use. It will facilitate the easy extraction of metadata and creation of XML documents according to the relevant schemas. However, it is important to note that only those attributes are included in the netCDF L1b product for which the information is known at production time; missing metadata relating to, for instance, archiving are to be added when the actual metadata files (in XML) are generated. It is the responsibility of the facility that generates the metadata files to provide the missing metadata items and to ensure that the metadata files are valid and conform to the standard.

4.2 ISO 19115-2 metadata model

The core ISO standard for documenting geospatial data is the ISO 19115 International Geographic Metadata Standard [RD6]. The objective of this International Standard is to provide a structure for describing digital geographic data. The standard defines the schema required for describing geographic information and services. It provides information about the identification, the extent, the quality, the spatial and temporal schema, spatial reference, and distribution of digital geographic data.

Imagery and gridded data are important information sources and products used within a geospatial environment. The ISO 19115-2 standard [RD9] provides an extension to ISO 19115 by defining the schema required for describing imagery and gridded data. It provides information about the properties of the measuring equipment used to acquire the data, the geometry of the measuring process employed by the equipment, and the production process used to digitize the raw data.

The ISO metadata model consists of both optional and mandatory metadata elements; the major metadata objects are shown in the UML diagram of the root class MI_Metadata presented in Figure 1. Figure 2 shows the UML diagram of the MD_DataIdentification class and the relationship with other classes. A short description of the meaning of the different major ISO metadata objects is provided in Table 1.

ISO Object	Description
MI_Metadata	Root element that contains information about the metadata itself.
MI_AcquisitionInformation	Information about instruments, platforms, operations and other element of data acquisition.
MD_ContentInformation	Information about the physical parameters and other attributes contained in a resource.
MD_Distribution	Information about who makes a resource available and how to get it.

ISO Object	Description
DQ_DataQuality	Information about the quality and lineage of a resource.
MD_SpatialRepresentation	Information about the geospatial representation of a resource.
MD_ReferenceSystem	Information about the spatial and temporal reference systems used in the resource.
MD_MetadataExtensionInformation	Information about user specified extensions to the metadata standard used to describe the resource.
MD_ApplicationSchemaInformation	Information about the application schema used to build a dataset.
MD_PortrayalCatalogueReference	Information identifying portrayal catalogues used for the resource.
MD_MaintenanceInformation	Information about maintenance of the metadata and the resource it describes.
MD_Constraints	Information about constraints on the use of the metadata and the resource it describes.
MD_Identification	Information about constraints on the use of the metadata and the resource it describes.
MD_AggregateInformation	Information about groups that the resource belongs to.
MD_Keywords	Information about discipline, themes, locations, and times included in the resource.
MD_Format	Information about formats that the resource is available in.
MD_Usage	Information about how the resource has been used and identified limitations.
MD_BrowseGraphic	Information about graphical representations of the resource.

Table 1: Description of ISO objects

The metadata objects and the information elements contained therein form an extensive set of which most of the time only a subset will be used. Because it is essential that a basic minimum of elements is used, the ISO standard provides a list (see Figure 3) of the core metadata elements (mandatory and recommended optional) required for describing and identifying a dataset, typically for catalogue purposes. An “M” indicates that the element is mandatory. An “O” indicates that the element is optional. A “C” indicates that the element is mandatory under certain conditions. Many of the elements are shown in the UML diagrams presented in Figures 1 and 2.

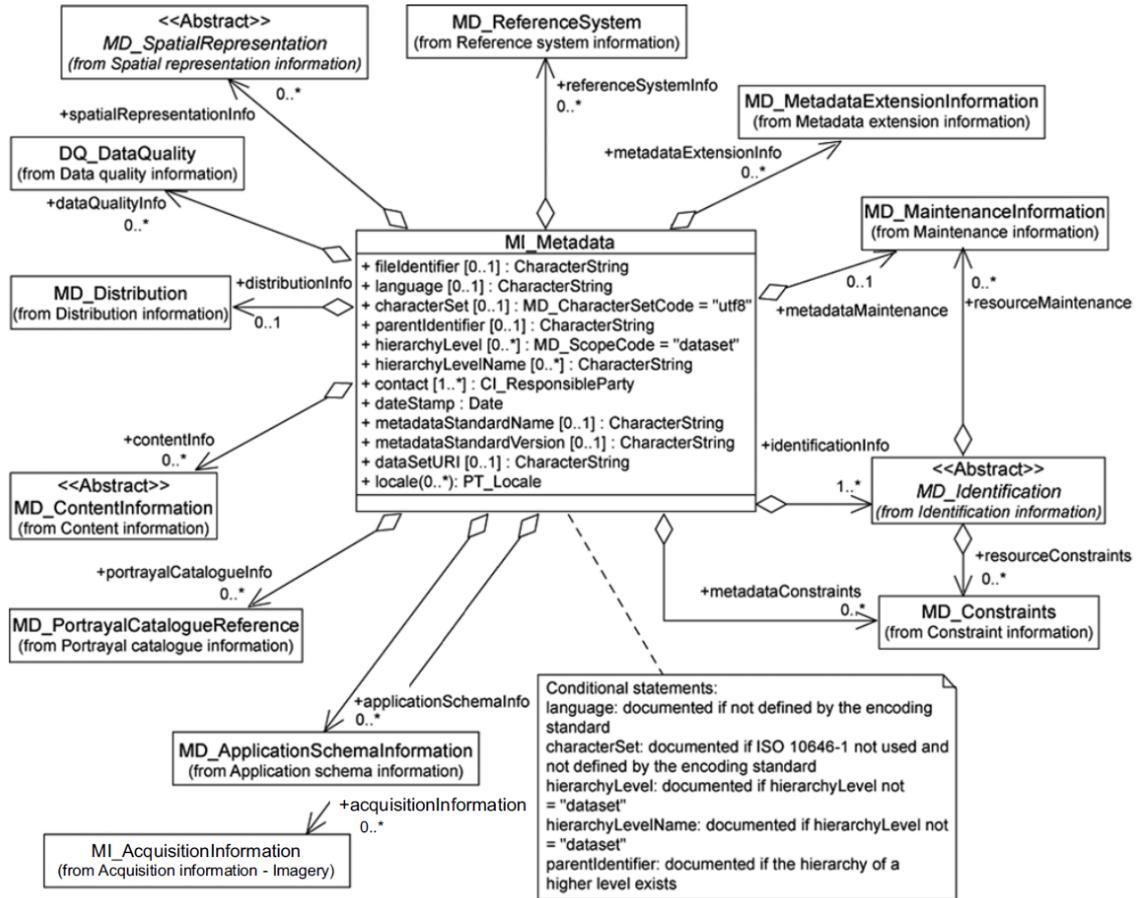


Figure 1: UML diagram of the root class MI_Metadata showing the major metadata classes (see: [RD6], [RD9])

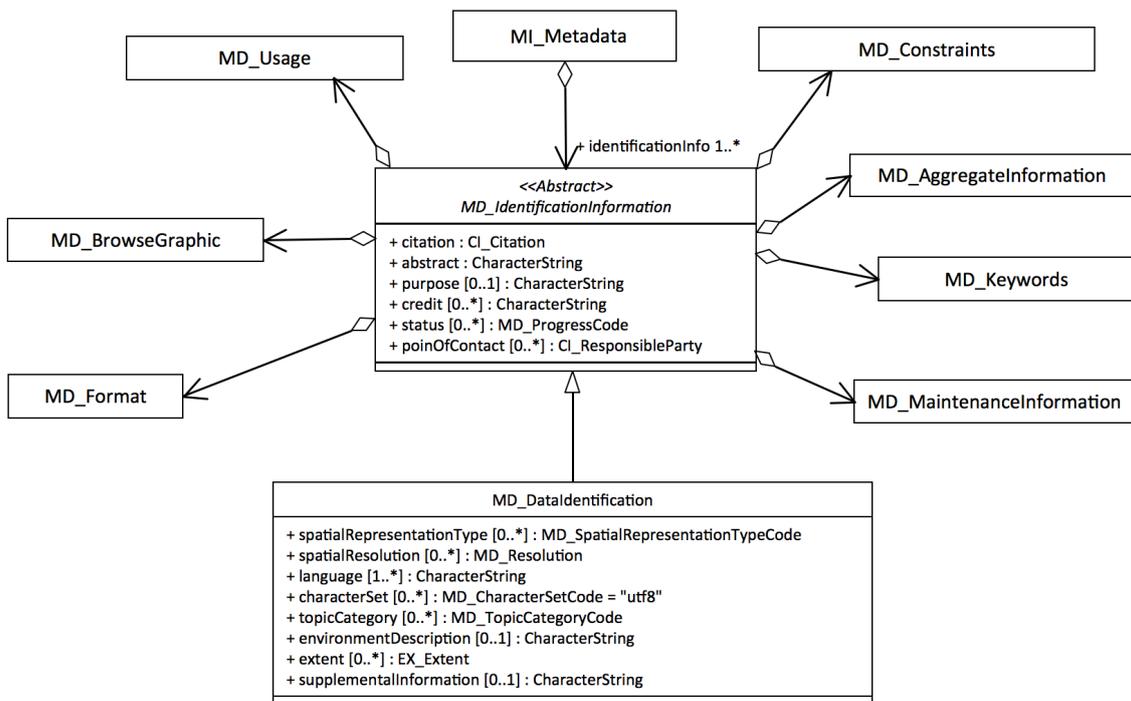


Figure 2: UML diagram of the MD_DataIdentification class (see: [RD6], [RD9])

Dataset title (M) (MD_Metadata > MD_DataIdentification.citation > CI_Citation.title)	Spatial representation type (O) (MD_Metadata > MD_DataIdentification.spatialRepresentationType)
Dataset reference date (M) (MD_Metadata > MD_DataIdentification.citation > CI_Citation.date)	Reference system (O) (MD_Metadata > MD_ReferenceSystem)
Dataset responsible party (O) (MD_Metadata > MD_DataIdentification.pointOfContact > CI_ResponsibleParty)	Lineage (O) (MD_Metadata > DQ_DataQuality.lineage > LI_Lineage)
Geographic location of the dataset (by four coordinates or by geographic identifier) (C) (MD_Metadata > MD_DataIdentification.extent > EX_Extent > EX_GeographicExtent > EX_GeographicBoundingBox or EX_GeographicDescription)	On-line resource (O) (MD_Metadata > MD_Distribution > MD_DigitalTransferOption.onLine > CI_OnlineResource)
Dataset language (M) (MD_Metadata > MD_DataIdentification.language)	Metadata file identifier (O) (MD_Metadata.fileIdentifier)
Dataset character set (C) (MD_Metadata > MD_DataIdentification.characterSet)	Metadata standard name (O) (MD_Metadata.metadataStandardName)
Dataset topic category (M) (MD_Metadata > MD_DataIdentification.topicCategory)	Metadata standard version (O) (MD_Metadata.metadataStandardVersion)
Spatial resolution of the dataset (O) (MD_Metadata > MD_DataIdentification.spatialResolution > MD_Resolution.equivalentScale or MD_Resolution.distance)	Metadata language (C) (MD_Metadata.language)
Abstract describing the dataset (M) (MD_Metadata > MD_DataIdentification.abstract)	Metadata character set (C) (MD_Metadata.characterSet)
Distribution format (O) (MD_Metadata > MD_Distribution > MD_Format.name and MD_Format.version)	Metadata point of contact (M) (MD_Metadata.contact > CI_ResponsibleParty)
Additional extent information for the dataset (vertical and temporal) (O) (MD_Metadata > MD_DataIdentification.extent > EX_Extent > EX_TemporalExtent or EX_VerticalExtent)	Metadata date stamp (M) (MD_Metadata.dateStamp)

Figure 3: Core set of ISO 19115 elements (from [RD6])

4.3 INSPIRE metadata implementation rules

The Infrastructure for Spatial Information in the European Community (INSPIRE) directive [RD10] came into force on 15 May 2007 and will be implemented in various stages, with full implementation required by 2019. The INSPIRE directive aims to create a European Union (EU) spatial data infrastructure. This will enable the sharing of environmental spatial information among public sector organisations and better facilitate public access to spatial information across Europe.

To ensure that the spatial data infrastructures of the Member States are compatible and usable in a Community and transboundary context, the Directive requires that common Implementing Rules (IR) are adopted in a number of specific areas (Metadata, Data Specifications, Network Services, Data and Service Sharing and Monitoring and Reporting).

With respect to metadata the EC issued the INSPIRE Metadata Regulation No 1205/2008 [RD11]. This Regulation sets out the requirements for the creation and maintenance of metadata for spatial data sets, spatial data set series and spatial data services corresponding to the themes listed in the annexes of the regulation.

The INSPIRE Metadata Implementing Rules [RD12] aim to define how the Regulation can be implemented using ISO 19115 (and ISO 19119, which is out of scope in the context of this document), describing for each element of the Regulation its relation with the mentioned European standards. The document presents a comparison of the core requirements of ISO 19115 (see Figure 3) and the requirements of INSPIRE for spatial dataset and spatial dataset series as defined in the implementing rules for metadata. The conclusions of this comparison are:

- “The conformance of an ISO 19115 metadata set to the ISO 19115 Core does not guarantee the conformance to INSPIRE;”
- “The use of these guidelines to create INSPIRE metadata ensures that the metadata is not in conflict with ISO 19115. However, full conformance to ISO 19115 implies the provision of additional metadata elements which are not required by INSPIRE.”

An initial list is presented of INSPIRE constraints applicable to an ISO 19115 metadata set (i.e. an instance of MD_Metadata¹) describing a resource:

1. MD_Metadata.language is mandatory;
2. MD_Metadata.hierarchyLevel is mandatory;
3. INSPIRE only considers the first instance of MD_Metadata.hierarchyLevel (i.e. MD_Metadata.hierarchyLevel[1]) when there are many;
4. If the value of MD_Metadata.hierarchyLevel[1] is not service, dataset or series, the metadata set is out of scope of the directive;
5. When there are many instances of MD_Metadata.identificationInfo, only the first one (i.e. MD_Metadata.identificationInfo[1]) concerns the current INSPIRE Resource;
6. INSPIRE only considers the instance of MD_Metadata.dataQualityInfo applicable to the whole resource;
7. There shall not be more than one instance of MD_Metadata.identificationInfo[1].MD_Identification.citation.CI_Citation.date declared as a creation date (i.e. CI_Date.dateType having the creation value);
8. MD_Metadata.identificationInfo[1].MD_DataIdentification.citation.CI_Citation.identifier is mandatory for metadata sets related to spatial dataset and spatial dataset series;
9. The data type of MD_Metadata.identificationInfo.MD_DataIdentification.language is the codelist LanguageCode from ISO/TS 19139;
10. There is at least one instance of MD_Metadata.identificationInfo[1].MD_DataIdentification.extent defining the geographic location of the resource as a geographic bounding box (i.e. an instance of EX_GeographicBoundingBox or one of its subclasses).
11. There shall be at least one instance of MD_Metadata.identificationInfo[1].MD_Identification.resourceConstraints

¹ MD_Metadata is the root class of ISO 19115 objects. In the case of ISO 19115-2 the root element is MI_Metadata.

12. The coordinates of the bounding boxes (instance of EX_GeographicBoundingBox) shall be expressed in any geodetic coordinate reference system with the Greenwich Prime Meridian
13. MD_Metadata.identificationInfo[1].MD_DataIdentification.pointOfContact[1].CI_ResponsibleParty.organisationName and MD_Metadata.identificationInfo[1].MD_DataIdentification.pointOfContact[1].CI_ResponsibleParty.contactInfo.CI_Contact.address.CI_Address.electronicMailAddress are mandatory.
14. MD_Metadata.contact[1].CI_ResponsibleParty.organisationName and MD_Metadata.contact[1].CI_ResponsibleParty.contactInfo.CI_Contact.address.CI_Address.electronicMailAddress are mandatory.
15. The value of MD_Metadata.contact[1].CI_ResponsibleParty.role.CI_RoleCode shall be pointOfContact.
16. At least one keyword of GEMET thesaurus² shall be documented using MD_Metadata.identificationInfo[1].MD_DataIdentification.descriptiveKeywords.

4.4 ISO 19139 XML Schema implementation for metadata

The ISO 19115(-2) model described in one of the previous sections is a conceptual model that does not provide any encoding for implementing the geographic information. The ISO 19139(-2) Technical Specification [RD13], [RD14] however, provides the XML implementation schema for ISO 19115 specifying the metadata record format. This de facto standard may be used to describe, validate, and exchange geospatial metadata prepared in XML.

In the ISO 19139 XML Schema, much attention is paid to the types of the XML elements described in the schema. All elements in the schema are of a known type and together they form the XML objects that build up the metadata record. These objects directly relate to the ISO 19115 metadata objects.

Annex B provides an example of a metadata record formatted according to ISO 19139.

4.5 Earth observation collection discovery

The document OGC 11-035r1 [RD15] presents an analysis of the minimal set of metadata required for a meaningful and concise description of EO product collections. It also describes the relations between several metadata conceptual models. Although the document is an OGC Best Practice document rather than a standard, it provides a very useful recommendation on applying the ISO and INSPIRE standards to collections of Earth observation products. An EO product collection is equivalent to a dataset series as defined within ISO 19115. It is a collection of datasets sharing the same product specification. An EO product collection typically corresponds to datasets (i.e. products) derived from data acquired by a single or set of sensors onboard a satellite and having the same operation mode.

OGC 11-035r1 lists the minimal set of ISO 19115-2 metadata elements comprising instances of the root class and the following major classes (see also Figure 1):

- MI_Metadata
- MD_DataIdentification
- DQ_DataQuality
- MD_ContentInformation (optional)
- MI_AcquisitionInformation

The document provides a detailed overview of the mandatory (from the EO product collection perspective) metadata elements and relates these elements to the INSPIRE metadata elements.

² see: http://www.eionet.europa.eu/gemet/inspire_themes?langcode=en

4.6 Earth observation metadata profile of observations & measurements

As has been described in the previous section, ISO distinguishes dataset series and individual datasets, which in the context of Earth observation is translated to collections and products. Whereas the EO collections can be described with metadata based on the ISO 19115-2/ISO 19139-2 model, the product specific metadata need another model. To this end the EO metadata profile of observations and measurements [RD5] was developed in the context of the Heterogeneous Mission Accessibility (HMA) project initiated by European Space Agency (ESA) and submitted to the OGC.

Based on the OGC 10-025 standard for Observations & Measurements [RD16], an Earth Observation Product (EOP) schema was developed which refines an observation³ into the feature type *earth observation*. This schema was then extended with sensor-specific thematic schemas as illustrated in Table 2.

Schema name	Describes characteristics of
opt.xsd	High-resolution optical products
sar.xsd	Products created with SAR sensors
atm.xsd	Products created with atmospheric sensors
alt.xsd	Products created with altimetry sensors
lmb.xsd	Products created with limb-looking sensors
ssp.xsd	Synthesis and systematic products

Table 2: XML schemas for EO products. The associated XML namespaces for these thematic products are: *opt*, *sar*, *atm*, *alt*, *lmb* and *ssp*, respectively.

The root class of the EOP schema (with XML namespace *eop*) is: *eop:EarthObservation*, which contains the following classes:

- *eop:EarthObservationEquipment*
- *eop:Footprint*
- *eop:EarthObservationResult*
- *eop:EarthObservationMetadata*.

The complete description of the *eop:EarthObservation* element and child elements, including the S5p profiling, is given in section 5.3.

Annex C provides an example of a metadata record formatted according to OGC 10-157. Note that in the example the namespace prefix *atm* = <http://www.opengis.net/atm/2.1> is used for the root class *EarthObservation* and the class *EarthObservationResult* to allow for the sensor-specific thematic schema for atmospheric sensor products.

4.7 CF-metadata conventions

The CF-Metadata Conventions [RD8] recommend to include global attributes in the netCDF file, providing information about the contents of the data file and the origin of the data. Although the attributes are recommended, none of them are actually mandatory.

The CF-Metadata Conventions suggest the following attributes (either global or as variable attribute)(see Table 3):

Attribute	Description
Conventions*	Specifies the names of the conventions followed by the dataset
title*	A succinct description of what is in the dataset
history*	A list of programs that have modified the data (preferably providing: date, time of day, user name, program name and command arguments).
institution	Specifies where the original data was produced

³ An observation is an event that estimates an observed property of some feature of interest using a specified procedure and generates a result.

Attribute	Description
source	The method of production of the original data. If it was model-generated, source should name the model and its version, as specifically as could be useful. If it is observational, source should characterize it (e.g., "surface observation" or "radiosonde").
references	Published or web-based references that describe the data or methods used to produce it
comment	Miscellaneous information about the data or methods used to produce it.

Table 3: Main metadata attributes suggested by CF-Metadata conventions. Indicated with a “*”: global attributes recommended by the NetCDF User Guide (NUG).

4.8 NetCDF attribute convention for dataset discovery

The wiki pages [ER22] of the Federation of Earth Science Information Partners (ESIP) provide information on Attribute Conventions for Dataset Discovery. These conventions identify and define a list of netCDF global attributes recommended for describing a netCDF dataset to discovery systems such as Digital Libraries.

Although some of the attributes are recommended or highly recommended, none of them are actually mandatory. Only the highly recommended attributes are presented here, because more detailed information is provided by the ISO metadata information. Although also these highly recommended attributes overlap with ISO metadata, they are useful because they provide easy to extract human readable information, using many available software tools.

In the current version (Version 2.0 beta) of NetCDF Attribute Convention for Dataset Discovery the following global attributes are highly recommended (see Table 4):

Attribute	Description
title	The "title" attribute gives a brief description of the dataset. The "title" attribute is recommended by the NetCDF Users Guide (NUG) and the CF-Metadata convention
summary	The "summary" attribute gives a longer description of the dataset. In many discovery systems, the title and the summary will be displayed in the results list from a search. It should therefore capture the essence of the dataset it describes
keywords	The "keywords" attribute lists key words and phrases that are relevant to the dataset. The values in the list may be taken from a controlled list of keywords
Metadata_Link*	The value of this attribute is a URL that gives the location of the more complete metadata

Table 4: Highly recommended attributes by ACDD. Indicated with a “*”: recommended attributes but not part of the current version.

5 TROPOMI L1b product metadata profile

5.1 Rationale

The previous sections provide a comprehensive overview of the various standards related to geo-information and Earth observation metadata models and their implementation. The use of these standards not only facilitates the discovery of data products but also enables information sharing about, amongst others, the content, the processing history and the proper use of the product. Many metadata elements are available for producing extensive and detailed descriptions of data products. However, in practice only a limited set of metadata elements will be sufficient to fulfill a minimal set of requirements with respect to the product description.

In the following sections the profiling of the metadata standards (i.e. ISO Metadata profile, EO metadata profile, ESA FFS metadata profile and the CF/Netcdf metadata profile) for Sentinel-5p will be presented.

The approach for the TROPOMI L1b products is to include all the required metadata information into the product allowing the automated extraction of XML formatted metadata records that are fully conformant to the INSPIRE standard [RD12], the OGC standard [RD5], which is adopted by ESA and the ESA standard [AD2]. This means that the metadata are integrated into the product independent of a metadata implementation and that tools are required to produce the standardized metadata representations.

5.2 ISO Metadata profile for Sentinel-5p

The tables in the following sections list the metadata information that will be provided in the L1b product. The definitions are taken from references [RD6] and [RD9]. Where relevant, also fixed values and/or example values are provided.

Only the metadata classes and the members within these classes are listed that are minimally required to create metadata conforming the INSPIRE and ESA standards. Sometimes, the description of classes (typically, *CI_Date*, *CI_Citation*) is only repeated when some information on the used values is present.

For the XML elements representing these classes tables are provided which describe the various fields (child elements); for each field the table provides the description (including S5p specific comments in blue), the cardinality (as defined by ISO) and the S5p tailoring (in blue). The fields that are printed in italics (shaded rows) are child elements representing subclasses of the model; when relevant these subclasses are described in subsequent sections, in which case it is indicated in the table. The XML elements are provided including the namespace prefix, where *gmi*= <http://www.isotc211.org/2005/gmi> , *gmd*= <http://www.isotc211.org/2005/gmd> , *gco*= <http://www.isotc211.org/2005/gco> and *gml*= <http://www.opengis.net/gml/3.2> . Typically, the “*gmd:*” prefix is used for the standard ISO fields and the “*gmi:*” prefix is used for fields of the ISO extensions.

5.2.1 XML Type: *gmi:MI_Metadata*

The (mandatory) root class *MI_Metadata* contains information about the metadata itself and also acts as a container for the other metadata classes. There are two required elements: a contact and a date. The contact is the organization or person responsible for the metadata. The date is the date that the metadata were created. Note that the *MD_Metadata* object was extended in Part 2 of the ISO Metadata Standard (19115-2) to include the *MI_AcquisitionInformation* class for describing platforms, instruments, and other aspects of data acquisition. This extension requires changing the name *MD_Metadata* to *MI_Metadata*. For the L1b products the full standard (including Part 2) is used.

gmi:MI_Metadata			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:fileIdentifier	unique identifier for metadata file In case the metadata describes a collection of products (i.e. series), the fileIdentifier is equal to the identifier of the EO Product Collection (i.e. eop:parentIdentifier in Table 44. This allows for relating individual products (described by EOP metadata) to EO Collections (described by ISO metadata). For a discussion on the format of the fileIdentifier see the text below this table).	0..1	Yes Used with cardinality 1 example (dataset): "S5P_OFFL_ L1B_RA_BD1_ 20151114T112005_ 20151114T125934_ 00140_02_010203_ 20151204T093045.xml"
gmd:language	language used for metadata	0..1	Yes fixed: "eng"
gmd:characterSet	character coding of metadata	0..1	Yes fixed: "utf8"
gmd:hierarchyLevel	scope to which metadata applies	0..n	Yes "dataset" or "series"
gmd:hierarchyLevelName	name of the hierarchy levels for which the metadata is provided	0..n	Yes (if "series") fixed: "EO Product Collection"
<i>gmd:contact/ gmd:CI_ResponsibleParty</i>	<i>party responsible for the metadata information</i>	<i>1..n</i>	Yes See below
<i>gmd:dateStamp/ gco:Date*</i>	<i>date that the metadata was created</i>	<i>1</i>	
gmd:metadataStandardName	name of the metadata standard fixed: "ISO 19115-2 Geographic Information - Metadata Part 2 Extensions for imagery and gridded data"	0..1	Yes Used with cardinality 1
gmd:metadataStandardVersion	version (profile) of the metadata standard used fixed: "ISO 19115-2:2009(E), S5P profile"	0..1	Yes Used with cardinality 1
<i>gmd:identificationInfo/ gmd:MD_DataIdentification</i>	<i>basic information about the resource(s) to which the metadata applies</i>	<i>1..n</i>	Yes Used with cardinality 1 See section below on gmd:MD_DataIdentification
<i>gmd:dataQualityInfo/ gmd:DQ_DataQuality</i>	<i>provides overall assessment of quality of a resource(s)</i>	<i>0..n</i>	Yes Used with cardinality 1 See section below on gmd:DQ_DataQuality
<i>gmi:acquisitionInformation/ gmi:MI_AcquisitionInformation</i>	<i>provides information about the acquisition of the data</i>	<i>0..n</i>	Yes Used with cardinality 1 See section below on gmi:MI_AcquisitionInformation

Table 5: MI_Metadata class. *) Date: gives values for year, month and day. Character encoding of a date is a string which shall follow the format for date specified by ISO 8601. This class is documented in full in ISO/TS 19103 (see: [RD6] section B.4).

On the use of gmd:fileIdentifier

As mentioned in Table 5 the use of the same identifier for the gmd:fileIdentifier (ISO metadata) and eop:parentIdentifier (EOP metadata) allows linking of individual products to a collection of EO products. In [RD17] the following approach with respect to the naming convention is described for the eop:parentIdentifier. This approach is suggested here for the eop:parentIdentifier and gmd:fileIdentifier in case the metadata describe a collection. From [RD17]:

“Often EO collections are organized per satellite, instrument or even submode of the instrument. The convention for the parentIdentifier is as defined in “*Definition identifier URNs in OGC namespace*” [RD18] i.e. urn:ogc:def:objectType:authority:version:code. where the registered namespace authority is ogc, the objectType is EOP (it cannot be thematic or mission specific acronyms like OPT, ATM, PHR, etc), the authority representing the Ground Segment i.e ESA, SPOT, EUM etc. The version is optional. The code is a unique identifier specified by the authority which corresponds here to the collection name. The ":" will delimit the start of the collection name. The collection name can be defined as required by the Ground Segment but to ensure unique names the following representation is proposed: programme.satellite_instrument_processing.”

An example of the fileIdentifier for the case of TROPOMI:
 urn:ogc:def:EOP:ESA:SENTINEL.S5P_TROP_L1B_RAD_BD1.

gmd:CI_ResponsibleParty			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:individualName	name of the responsible person Not used for Sentinel-5p L1b products	0..1	
gmd:organisationName	name of the responsible organization	0..1	Yes fixed: “Copernicus Space Component Data Access System, ESA, Services Coordinated Interface”
gmd:positionName	role or position of the responsible person Not used for Sentinel-5p L1b products	0..1	
<i>gmd:contactInfo/ gmd:CI_Contact</i>	<i>address of the responsible party</i>	<i>0..1</i>	Yes See below
gmd:role	function performed by the responsible party	1	Yes fixed: “pointOfContact”

Table 6: MI_Metadata.contact. Multiple occurrences of *contact* are allowed.

gmd:CI_Contact			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmd:address/ gmd:CI_Address</i>	<i>physical and email address at which the organization or individual may be contacted</i>	0..1	Yes See below

Table 7: MI_Metadata.contact.contactInfo

gmd:CI_Address			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmd:electronicMailAddress</i>	<i>address of the electronic mailbox of the responsible organization or individual</i>	0..1	Yes fixed: "EOSupport@copernicus.esa.int"

Table 8: MI_Metadata.contact.contactInfo.address

5.2.2 XML Type: gmd:MD_DataIdentification

Identification information contains information to uniquely identify the data. Identification information includes information about the citation for the resource, an abstract, the purpose, credit, the status and points of contact. The MD_Identification entity is mandatory. The MD_Identification entity is specified (subclassed) as MD_DataIdentification because in this case it used to identify data.

gmd:MD_DataIdentification			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmd:citation/ gmd:CI_Citation</i>	<i>citation data for the resource(s)</i>	1	Yes See below
<i>gmd:status</i>	<i>status of the resource(s)</i> Not used for Sentinel-5p L1b products	0..n	
<i>gmd:pointOfContact/ gmd:CI_ResponsibleParty</i>	<i>identification of, and means of communication with, person(s) and organization(s) associated with the resource(s)</i>	0..n	Yes Used with cardinality 1 See below
<i>gmd:descriptiveKeywords/ gmd:MD_Keywords</i>	<i>provides category keywords, their type, and reference source</i>	0..n	Yes Used with cardinality 1 See below
<i>gmd:resourceConstraints/ gmd:MD_Constraints</i>	<i>provides information about constraints which apply to the resource(s)</i>	0..n	Yes Used with cardinality 1 See below
<i>gmd:spatialRepresentationType gmd:MD_SpatialRepresentationCode</i>	<i>method used to spatially represent geographic information.</i>	0..n	Yes fixed: "grid"
<i>gmd:spatialResolution/ gmd:MD_Resolution</i>	<i>factor which provides a general understanding of the density of spatial data in the dataset</i> Not used for Sentinel-5p L1b products	0..n	
<i>gmd:language</i>	<i>language(s) used within the dataset</i>	1..n	Yes fixed: "eng"
<i>gmd:characterSet</i>	<i>full name of the character coding standard used for the dataset</i>	0..n	Yes fixed: "utf8"

gmd:MD_DataIdentification (cont'd)			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:topicCategory	main theme(s) of the dataset	0..n	Yes fixed: "climatologyMeteorologyAtmosphere"
<i>gmd:extent/ gmd:EX_Extent</i>	<i>extent information including the bounding box, bounding polygon, vertical, and temporal extent of the dataset</i>	<i>0..n</i>	Yes See below
gmd:abstract	brief narrative summary of the content of the resource(s)	1	fixed: "The S5p mission is a single-payload satellite in a low Earth orbit that provides daily global information on concentrations of trace gases and aerosols important for air quality, climate forcing, and the ozone layer. The payload of the mission is the TROPOspheric Monitoring Instrument (TROPOMI), which is jointly developed by The Netherlands and ESA. The instrument consists of a spectrometer with spectral bands in the ultraviolet, the visible, the near-infrared and the shortwave infrared. The selected wavelength range for TROPOMI allows observation of key atmospheric constituents, including ozone (O3), nitrogen dioxide (NO2), carbon monoxide (CO), sulfur dioxide (SO2), methane (CH4), formaldehyde (CH2O), aerosols and clouds."

Table 9: MI_Metadata.identificationInfo

gmd:CI_Citation			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:title	name by which the cited resource is known	1	Yes example: "S5p TROPOMI Radiance L1b product"

gmd:CI_Citation (cont'd)			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmi:date/ gmd:CI_Date</i>	<i>reference date for the cited resource</i>	<i>1..n</i>	Yes See below
<i>gmd:identifier/ gmd:MD_Identifier</i>	<i>value uniquely identifying an object within a namespace</i>	<i>0..n</i>	Yes See below

Table 10: MI_Metadata.identificationInfo.citation

gmd:CI_Date			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:date	reference date for the cited resource	1	
gmd:dateType	event used for reference date	1	Yes "creation" for files, "publication" for standards or documents

Table 11: MI_Metadata.identificationInfo.citation.date

gmd:MD_Identifier			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmd:authority/ gmd:CI_Citation</i>	<i>person or party responsible for maintenance of the namespace</i> Not used for Sentinel-5p L1b products	<i>0..1</i>	
gmd:code	alphanumeric value identifying an instance in the namespace	1	Yes example (dataset): "S5P_OFFL_ L1B_RA_BD1_ 20151114T112005_ 20151114T125934_ 00140_02_010203_ 20151204T093045"

Table 12: MI_Metadata.identificationInfo.citation.identifier

gmd:CI_ResponsibleParty			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:individualName	name of the responsible person Not used for Sentinel-5p L1b products	0..1	

gmd:CI_ResponsibleParty (cont'd)			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:organisationName	name of the responsible organization	0..1	Yes fixed: "Copernicus Space Component Data Access System, ESA, Services Coordinated Interface"
gmd:positionName	role or position of the responsible person Not used for Sentinel-5p L1b products	0..1	Yes
<i>gmd:contactInfo/ gmd:CI_Contact</i>	<i>address of the responsible party</i>	<i>0..1</i>	Yes See below
gmd:role	function performed by the responsible party	1	Yes fixed: "distributor"

Table 13: MI_Metadata.identificationInfo.pointOfContact

gmd:CI_Contact			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmd:address/ gmd:CI_Address</i>	<i>physical and email address at which the organization or individual may be contacted</i>	<i>0..1</i>	Yes Used with cardinality 1 See below

Table 14: MI_Metadata.identificationInfo.pointOfContact.contactInfo

gmd:CI_Address			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:electronicMailAddress	address of the electronic mailbox of the responsible organization or individual	0..1	Yes fixed: "eohelp@esa.int"

Table 15: MI_Metadata.identificationInfo.pointOfContact.contactInfo.address

gmd:MD_Keywords			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:keyword	commonly used word(s) or formalised word(s) or phrase(s) used to describe the subject	1..n	Yes fixed: "Atmospheric conditions"
gmd:type	subject matter used to group similar keywords	0..1	Yes fixed: "theme"

gmd:MD_Keywords (cont'd)			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmd:thesaurusName/ gmd:CI_Citation</i>	<i>name of the formally registered thesaurus or a similar authoritative source of keywords</i>	0..1	Yes See below

Table 16: MI_Metadata.identificationInfo.descriptiveKeywords. Presented here is the descriptive keyword expressing the INSPIRE Data Theme which is required by INSPIRE. Multiple occurrences of this element specifying other keywords are allowed.

gmd:CI_Citation			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:title	name by which the cited resource is known	1	Yes fixed: "GEMET - INSPIRE themes version 1.0"
<i>gmd:date/ gmd:CI_Date</i>	<i>reference date for the cited resource</i>	1..n	Yes fixed: date="2008-06-01"; date-Type="publication"

Table 17: MI_Metadata.identificationInfo.descriptiveKeywords.thesaurusName. Presented here is the thesaurusName to be used in combination with the keyword specifying the INSPIRE Data Theme.

gmd:MD_LegalConstraints			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:useLimitation	limitation affecting the fitness for use of the resource or metadata	0..n	Yes Used with cardinality 1 fixed: "no conditions apply"
gmd:accessConstraints/ gmd:MD_RestrictionCode	access constraints applied to assure the protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the resource or metadata.	0..n	Yes fixed: "copyright"
gmd:otherConstraints/ gco:CharacterString	other restrictions and legal prerequisites for accessing and using the resource or metadata	0..n	Yes fixed: "no limitations"
gmd:classification	name of the handling restrictions on the resource or metadata	0..n	Yes fixed: "unclassified"

Table 18: MI_Metadata.identificationInfo.resourceConstraints. The presented example is in line with the INSPIRE guidelines [RD12]: "There shall be at least one instance of MD_Constraints or one of its subclasses (here: MD_LegalConstraints) even if there is no limitation on public access or no specific condition applies to access and use of the resource. When a single instance is provided in a given metadata set, it shall handle metadata elements representing both at least one condition applying to access and use (here: accessConstraints) and at least one limitation on public access (here: useLimitation)."

gmd:EX_Extent			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmd:geographicElement/ gmd:EX_GeographicBoundingBox</i>	<i>geographic position of the dataset. Note: this is only an approximate reference so specifying the coordinate reference system is unnecessary</i>	<i>0..n</i>	Yes Used with cardinality 1 (series) See below
<i>gmd:geographicElement/ gmd:EX_BoundingPolygon</i>	boundary enclosing the dataset, expressed as the closed set of (x,y) coordinates of the polygon (last point replicates first point) Not used for Sentinel-5p L1b products		
<i>gmd:temporalElement/ gmd:EX_TemporalExtent</i>	<i>time period covered by the content of the dataset</i>	<i>0..n</i>	Yes Used with cardinality 1 See below

Table 19: MI_Metadata.identificationInfo.extent. In addition to the commonly used geographic bounding box, also a polygon is provided. This polygon provides a better representation of the coverage of the TROPOMI L1b product.

gmd:EX_GeographicBoundingBox			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmd:extentTypeCode</i>	indication of whether the bounding polygon encompasses an area covered by the data or an area where data is not present	<i>0..1</i>	Yes fixed: "true"; where true=inclusion, false=exclusion
<i>gmd:westBoundLongitude</i>	western-most coordinate of the limit of the dataset extent, expressed in longitude in decimal degrees (positive east) (-180. <= value <= 180.)	1	
<i>gmd:eastBoundLongitude</i>	eastern-most coordinate of the limit of the dataset extent, expressed in longitude in decimal degrees (positive east) (-180. <= value <= 180.)	1	
<i>gmd:southBoundLatitude</i>	southern-most coordinate of the limit of the dataset extent, expressed in latitude in decimal degrees (positive north) (-90. <= value <= 90.)	1	
<i>gmd:northBoundLatitude</i>	northern-most, coordinate of the limit of the dataset extent expressed in latitude in decimal degrees (positive north) (-90. <= value <= 90.)	1	

Table 20: MI_Metadata.identificationInfo.geographicElement (bbox)

gmd:EX_TemporalExtent			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:extent/ TM_Primitive*	time period covered by the content of the dataset (gml:TimePeriod : gml:beginPosition , gml:endPosition)	1	

Table 21: MI_Metadata.identificationInfo.temporalElement. *)TM_Primitive: an abstract class representing a non-decomposed element of geometry or topology. This class is fully documented in ISO 19108 (see: [RD6] section B.4).

5.2.3 XML Type: gmd:DQ_DataQuality

This package contains a general assessment of the quality of the dataset. In addition, the package contains information about the sources and production processes used in producing a dataset, which is of particular importance for imagery and gridded data. For the TROPOMI L1b products the use of the contained class LI_Lineage is important for describing the sources which are either used or produced (output) in a series of process steps. The sources refer to the various L0 data products used as inputs when producing the L1b products.

gmd:DQ_DataQuality			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:scope/ gmd:DQ_Scope	the specific data to which the data quality information applies)	1	Yes See below
gmd:report/ gmd:DQ_Element	quantitative quality information for the data specified by the scope	0..n	Yes Used with cardinality 1 See below
gmd:lineage/ gmd:LI_Lineage	non-quantitative quality information about the lineage of the data specified by the scope	0..1	Yes Used with cardinality 1 See below

Table 22: MI_Metadata.dataQualityInfo

gmd:DQ_Scope			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:level	hierarchical level of the data specified by the scope.	1	Yes fixed: "dataset"
gmd:extent	information about the horizontal, vertical and temporal extent of the data specified by the scope Not used for Sentinel-5p L1b products	0..1	

Table 23: MI_Metadata.dataQualityInfo.scope

gmd:DQ_DomainConsistency			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmd:result/ gmd:DQ_Result</i>	<i>value (or set of values) obtained from applying a data quality measure or the outcome of evaluating the obtained value (or set of values) against a specified acceptable conformance quality level</i>	1..2	Yes See below

Table 24: MI_Metadata.dataQualityInfo.report. DQ_DomainConsistency implements the abstract class DQ_Element; INSPIRE requires that the metadata includes information on the degree of conformity with the implementing rules [RD12]. When the conformity to an INSPIRE Specification has been evaluated, it shall be reported as a domain consistency element (i.e. an instance of DQ_DomainConsistency) in ISO 19115 metadata. In that case, if the evaluation has passed, the metadata is conformant, otherwise it is not conformant.

gmd:DQ_ConformanceResult			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmd:specification/ gmd:CI_Citation</i>	<i>citation of product specification or user requirement against which data is being evaluated</i>	1	Yes See below
gmd:explanation	explanation of the meaning of conformance for this result	1	
gmd:pass	indication of the conformance result where 0 = fail and 1 = pass	1	

Table 25: MI_Metadata.dataQualityInfo.report.result implements the abstract class DQ_Result; Known relevant specifications include the INSPIRE Data Specification guidelines established for each INSPIRE theme. The Specification element should be given as follows: title: "INSPIRE Data Specification on <Theme Name>-Guidelines" date: dateType: publication (see also Table 24).

gmd:CI_Citation			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:title	name by which the cited resource is known	1	Yes fixed: "INSPIRE Data Specification on Atmospheric Conditions and Meteorological Geographical Features – Technical Guidelines, version 3.0"
<i>gmd:date/ gmd:CI_Date</i>	<i>reference date for the cited resource</i>	1..n	Yes fixed: date="2013-02-04"; dateType="publication"

Table 26: MI_Metadata.dataQualityInfo.report.result.specification. See also Table 24 and Table 25.

gmd:LI_Lineage			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:statement	general explanation of the data producer's knowledge about the lineage of a dataset	0..1	Yes Used with cardinality 1
<i>gmd:processStep/ gmi:LE_ProcessStep</i>	<i>information about an event or transformation in the life of the dataset including details of the algorithm and software used for processing</i>	0..1	Yes See below

Table 27: MI_Metadata.dataQualityInfo.lineage

gmi:LE_ProcessStep			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:description	description of the event, including related parameters or tolerances	1	
<i>gmd:source/ gmi:LE_Source</i>	<i>information about the source data used in creating the data specified by the scope</i>	0..n	Yes Used with cardinality n See below
<i>gmi:output/ gmi:LE_Source</i>	<i>description of the product generated as a result of the process step</i>	0..n	Yes See below
<i>gmi:processingInformation/ gmi:LE_Processing</i>	<i>comprehensive information about the procedure by which the algorithm was applied to derive geographic data from the raw instrument measurements, such as datasets, software used, and the processing environment</i>	0..1	Yes See below
<i>gmi:report/ gmi:LE_ProcessStepReport</i>	<i>report of what occurred during the process step</i>	0..n	Yes See below

Table 28: MI_Metadata.dataQualityInfo.lineage.processStep. Typically, there will be multiple occurrences of the gmd:source member, namely one for each input product (see: [RD4] for an overview of the input products).

gmi:LE_Source			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmd:description	information on data sets input to or output by the processing step	0..1	
gmi:processedLevel	processing level of the data	0..1	Yes example: "L0" or "L1b"
<i>gmd:sourceCitation/ gmd:CI_Citation</i>	<i>recommended reference to be used for the source data</i> Not used for Sentinel-5p L1b products	0..1	

gmi:LE_Source (cont'd)			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmd:sourceStep/ gmi:LE_ProcessStep</i>	<i>information about an event or transformation in the life of the dataset including details of the algorithm and software used for processing</i> Not used for Sentinel-5p L1b products	0..n	

Table 29: MI_Metadata.dataQualityInfo.lineage.processStep.source(output). The LE_Source class is used to describe both input datasets as output products (see Table 28) of the L01b processing.

gmd:CI_Citation			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmd:title</i>	<i>name by which the cited resource is known</i>	1	Yes example: "L0 Instrument data for band 1"
<i>gmd:alternateTitle</i>	<i>short name or other language name by which the cited information is known</i>	0..n	Yes Used with cardinality n example: "S5P_OFFL_ L0_ODB_1_ 20140827T103500_ 20140827T104000_ 53811_00.RAW"
<i>gmd:date/ gmd:CI_Date</i>	<i>reference date for the cited resource</i>	1..n	Yes example: date="2014-08-27"; date-Type="creation"

Table 30: MI_Metadata.dataQualityInfo.lineage.processStep.source.citation. The gmd:alternateTitle is used to specify individual input products of a set of input products. The set itself is specified in the gmd:title

gmi:LE_Processing			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmi:identifier/ gmd:MD_Identifier</i>	<i>information to identify the processing package that produced the data</i>	1	Yes fixed: "KNMI L01b processor"
<i>gmi:softwareReference/ gmd:CI_Citation</i>	<i>reference to document describing processing software</i>	0..n	Yes fixed: "L01b processor description"
<i>gmi:procedureDescription</i>	<i>additional details about the processing procedures</i> Not used for Sentinel-5p L1b products	0..1	

gmi:LE_Processing (cont'd)			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmi:documentation/ gmd:CI_Citation</i>	<i>reference to documentation describing the processing</i>	<i>0..n</i>	Yes Used with cardinality n The gmd:date value of the document citations is intentionally not set. This to indicate the last version of the document should be referenced. example: "S5P-KNMI-L01B-0009-SD-algorithm_theoretical_basis_document-8.0.0-20170601.pdf"
gmi:runTimeParameters	parameters to control the processing operations, entered at run time Not used for Sentinel-5p L1b products	0..1	
<i>gmi:algorithm/ gmi:LE_Algorithm</i>	<i>details of the methodology by which geographic information was derived from the instrument readings</i> Not used for Sentinel-5p L1b products	<i>0..n</i>	

Table 31: MI_Metadata.dataQualityInfo.lineage.processStep.processingInformation. Multiple occurrences of documentation are used here to refer to the algorithm theoretical basis document [RD19] and the input/output data specification document (this document).

gmi:LE_ProcessStepReport			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gmi:name	name of the processing report	1	Yes fixed: "L01b processing report"
gmi:description	textual description of what occurred during the process step	0..1	Fixed "L0 processed to L1b data using the KNMI TROPOMI L01b processor"
gmi:fileType	type of file that contains the processing report	0..1	Yes fixed: "netCDF-4"

Table 32: MI_Metadata.dataQualityInfo.lineage.processStep.report

5.2.4 XML Type: gmi:MI_AcquisitionInformation

The MI_AcquisitionInformation class was added in the ISO 19115-2 extension in order to provide details specific to the acquisition of imagery and gridded data. In particular, subclasses like MI_Platform and MI_Instrument provide information about the platform from which the data were collected and about the measuring devices that were used.

gmi:MI_AcquisitionInformation			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmi:instrument/ gmi:MI_Instrument</i>	<i>general information about the instrument used in data acquisition</i> Not used for Sentinel-5p L1b products	0..n	
<i>gmi:platform/ gmi:MI_Platform</i>	<i>general information about the platform from which the data were taken</i>	0..n	Yes See below

Table 33: MI_Metadata.acquisitionInformation

gmi:MI_Platform			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmi:citation/ gmd:CI_Citation</i>	<i>complete citation of the instrument</i>	0..1	
<i>gmi:identifier/ gmd:RS_Identifier</i>	<i>unique identification of the instrument</i>	1	Yes See below
<i>gmi:description</i>	<i>narrative description of the platform supporting the instrument</i>	1	Yes fixed: "Sentinel 5 Pre-cursor"
<i>gmi:sponsor/ gmd:CI_ResponsibleParty</i>	<i>organization responsible for building, launch, or operation of the platform</i> Not used for Sentinel-5p L1b products	0..n	
<i>gmi:instrument/ gmi:MI_Instrument</i>	<i>general information about the instrument used in data acquisition</i>	1..n	Yes See below

Table 34: MI_Metadata.acquisitionInformation.platform

gmd:RS_Identifier			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmd:authority/ gmd:CI_Citation</i>	<i>person or party responsible for maintenance of the namespace</i> Not used for Sentinel-5p L1b products	0..1	
<i>gmd:code</i>	<i>alphanumeric value identifying an instance in the namespace</i>	1	Yes fixed: "S5p"
<i>gmd:codeSpace</i>	<i>name or identifier of the person or organization responsible for namespace</i>	0..1	Yes fixed: "http://www.esa.int/"
<i>gmd:version</i>	<i>version identifier for the namespace</i>	0..1	

Table 35: MI_Metadata.acquisitionInformation.platform.identifier. Note: The RS_Identifier extends the MD_Identifier by adding a codeSpace and a version for the namespace. These additions address the lack of an agreed upon approach for describing a namespace using the gmd:authority/gmd:CI_Citation alone.

gmi:MI_Instrument			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gmi:citation/ gmd:CI_Citation</i>	<i>source where information about the platform is described</i> Not used for Sentinel-5p L1b products	0..1	
<i>gmi:identifier/ gmd:RS_Identifier</i>	<i>unique identification of the instrument</i>	1	Yes fixed: code="TROPOMI", codeSpace= " http://www.esa.int/ "
<i>gmi:type</i>	<i>name of the type of instrument</i>	1	Yes fixed: "TROPOMI"
<i>gmi:description</i>	<i>textual description of the instrument</i>	0..1	

Table 36: MI_Metadata.acquisitionInformation.platform.instrument

5.3 Earth observation metadata profile for Sentinel-5p

The following sections provide a comprehensive overview of the classes of the EarthObservation model and how they are customized for the TROPOMI L1b products. For the XML elements representing these classes tables are provided which describe the various fields (child elements); for each field the table provides the description (including S5p specific comments in blue), the cardinality (as defined by the EOP model) and the S5p tailoring (in blue). The fields that are printed in italics (shaded rows) are child elements representing subclasses of the model; when relevant these subclasses are described in subsequent sections, in which case it is indicated in the table. The XML elements are provided including the namespace prefix, where *eop*= <http://www.opengis.net/eop/2.1> and *gml*= <http://www.opengis.net/gml/3.2>.

5.3.1 XML Type: eop:EarthObservation

The eop:EarthObservation element is the root of every Earth observation product and a description is given in Table 37; the fields also show also the corresponding XML elements from the OGC Observations & Measurements model.

eop:EarthObservation				
Field name	Field description and S5p notes	Card'ty	S5p tailoring	
<i>gml:id</i> attribute	Mandatory identifier required by GML. Its value must be unique among all the <i>gml:id</i> attributes of the XML file. The convention to use the product identifier plus a suffix in order to have the gml:id unique inside the document.	1	Yes Value: eop:identifier + '.EO' as suffix.	
<i>om:phenomenonTime/</i> <i>gml:TimePeriod/</i> <i>gml:beginPosition</i>	Acquisition start date time; dateTime in ISO 8601 format (CCYY-MM-DDThh:mm[:ss[.cc]]Z)	1		
<i>om:phenomenonTime/</i> <i>gml:TimePeriod/</i> <i>gml:endPosition</i>	Acquisition end date time; dateTime in ISO 8601 format (CCYY-MM-DDThh:mm[:ss[.cc]]Z)	1		
<i>om:resultTime/</i> <i>gml:TimeInstant/</i> <i>gml:timePosition</i>	The time when the result becomes available; dateTime in ISO 8601 format (CCYY-MM-DDThh:mm[:ss[.cc]]Z) Not used for Sentinel-S5p L1b products	1		
<i>om:procedure/</i> <i>eop:EarthObservationEquipment</i>	<i>Platform/Instrument/Sensor used for the acquisition and the acquisition parameters</i>	1	Yes See section below on eop:Earth Observation Equipment	
<i>om:observedProperty</i>	An xlink to the observed property definition This element should use the attribute nilReason="inapplicable"	1..n	Yes Used with cardinality 1	
<i>om:featureOfInterest/</i> <i>eop:Footprint</i>	<i>Observed area on the ground or its projection i.e. the footprint of acquisition</i>	0..n	Yes See section below on eop:Footprint	
<i>om:result/</i> <i>eop:EarthObservationResult</i>	<i>Earth observation result metadata composed of the browse, mask and product description</i> Not used for Sentinel-5p L1b products	0..n		

eop:EarthObservation (cont'd)			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>eop:metaDataProperty/</i> <i>eop:EarthObservationMetaData</i>	<i>Additional external metadata about the data acquisition</i>	1	Yes See section below on eop:Earth ObservationMetaData

Table 37: <eop:EarthObservation> fields description

5.3.2 XML Type: eop:EarthObservationEquipment

The eop:EarthObservationEquipment element contains metadata relative to the mechanism used during the EarthObservation. These metadata describe on one hand the platform, instrument and sensor used for the EarthObservation and on the other hand, the acquisition parameters of this observation. The complete description of the eop:EarthObservationEquipment is given in Table 38

eop:EarthObservationEquipment			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>gml:id</i> attribute	Mandatory identifier required by GML. Its value must be unique among all the <i>gml:id</i> attributes of the XML file. The convention to use the product identifier plus a suffix in order to have the gml:id unique inside the document.	1	Yes Value: eop:identifier + '.EOE' as suffix.
<i>eop:platform/</i> <i>eop:Platform</i>	<i>Platform information</i>	1	Yes See section below on eop:Platform
<i>eop:instrument/</i> <i>eop:Instrument</i>	<i>Instrument information</i>	0..1	Yes See section below on eop:Instrument
<i>eop:sensor/</i> <i>eop:Sensor</i>	<i>Sensor information</i>	0..1	Yes See section below on eop:Sensor
<i>eop:acquisitionParameters/</i> <i>eop:Acquisition</i>	<i>Acquisition parameters</i>	0..1	Yes See section below on eop:Acquisition

Table 38: <eop:EarthObservationEquipment> fields description

5.3.3 XML Type: eop:Platform

The eop:Platform element contains metadata relative to the mechanism used during the EarthObservation, in particular the metadata describing the platform used for the EarthObservation. The complete description of the eop:Platform is given in Table 39

eop:Platform			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>eop:shortName</i>	Platform short name (e.g. Sentinel-5p)	1	Yes Fixed value: Sentinel-5p

eop:Platform (cont'd)			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
eop:serialIdentifier	Platform serial identifier Sentinel-5p has no serial identifier	0..1	
eop:orbitType	High level characterisation of main mission types taken from a codelist Values: GEO, LEO Not used for Sentinel-5p L1b products	0..1	

Table 39: <eop:Platform> fields description

5.3.4 XML Type: eop:Instrument

The eop:Instrument element contains metadata relative to the mechanism used during the EarthObservation, in particular the metadata describing the instrument used for the EarthObservation. The complete description of the eop:Instrument is given in Table 40

eop:Instrument			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
eop:shortName	Instrument (Sensor) name	0..1	Yes Used with cardinality 1 Fixed value: TROPOMI
eop:description	Instrument description Not used for Sentinel-5p L1b products	0..1	
eop:instrumentType	Instrument type Not used for Sentinel-5p L1b products	0..1	

Table 40: <eop:Platform> fields description

5.3.5 XML Type: eop:Sensor

The eop:Sensor element contains metadata relative to the mechanism used during the EarthObservation, in particular the metadata describing the sensor used for the EarthObservation. The complete description of the eop:Sensor is given in Table 41

eop:Sensor			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
eop:sensorType	Sensor type based on codelist. Values: OPTICAL, RADAR, ALTIMETRIC, ATMOSPHERIC, LIMB.	0..1	Yes Used with cardinality 1 Fixed value: ATMOSPHERIC
eop:operationalMode	Sensor mode. Possible values are mission specific and should be retrieved using codeSpace. Not used for Sentinel-5p L1b products	0..1	
eop:resolution	Sensor resolution Not used for Sentinel-5p L1b products	0..1	

eop:Sensor (cont'd)			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
eop:swathIdentifier	Swath identifier. Value list can be retrieved with codeSpace. Not used for Sentinel-5p L1b products	0..1	
<i>eop:wavelengthInformation/ eop:WavelengthInformation</i>	<i>Information about the spectral bands</i> Not used for Sentinel-5p L1b products	<i>0..1</i>	

Table 41: <eop:Sensor> fields description

5.3.6 XML Type: eop:Acquisition

The eop:Acquisition element provides the acquisition parameters of the observation. The complete description of the Acquisition is given in Table 42.

eop:Acquisition			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
eop:orbitNumber	Acquisition orbit number	0..1	Yes Used with cardinality 1
eop:lastOrbitNumber	Acquisition last orbit number Not used for Sentinel-5p L1b products	0..1	
eop:orbitDirection	Acquisition orbit direction Values: ASCENDING, DESCENDING Not used for Sentinel-5p L1b products	0..1	
eop:wrsLongitudeGrid	Neutral wrsLongitudeGrid to replace track in track/frame, K in K/J, etc. The optional attribute 'eop:codeSpace' is used to point the reference grid Not used for Sentinel-5p L1b products	0..1	
eop:wrsLatitudeGrid	Neutral wrsLatitudeGrid to replace frame in track/frame, J in K/J, etc. The optional attribute 'eop:codeSpace' is used to point the reference grid Not used for Sentinel-5p L1b products	0..1	
eop:ascendingNodeDate	UTC date and time at ascending node of orbit Not used for Sentinel-5p L1b products	0..1	
eop:ascendingNodeLongitude	Longitude at ascending node of orbit. Should be expressed in degrees. Not used for Sentinel-5p L1b products	0..1	
eop:startTimeFromAscendingNode	Start time of acquisition in milliseconds from ascending node date Not used for Sentinel-5p L1b products	0..1	
eop:completionTimeFromAscendingNode	Stop time of acquisition in milliseconds from ascending node date Not used for Sentinel-5p L1b products	0..1	
eop:orbitDuration	Actual orbit duration in milliseconds Not used for Sentinel-5p L1b products	0..1	
eop:illuminationAzimuthAngle	Mean illumination/solar azimuth angle given in degrees (i.e. uom='deg'). Not used for Sentinel-5p L1b products	0..1	

eop:Acquisition (cont'd)			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
eop:illuminationZenithAngle	Mean illumination/solar zenith angle given in degrees (i.e. uom='deg'). Not used for Sentinel-5p L1b products	0..1	
eop:illuminationElevationAngle	Mean illumination/solar elevation angle given in degrees (i.e. uom='deg'). Not used for Sentinel-5p L1b products	0..1	
eop:incidenceAngle	Acquisition global incidence angle given in degrees (i.e. uom='deg'). Not used for Sentinel-5p L1b products	0..1	
eop:acrossTrackIncidenceAngle	Acquisition across track Incidence angle given in degrees (i.e. uom='deg'). Not used for Sentinel-5p L1b products	0..1	
eop:alongTrackIncidenceAngle	Acquisition along track incidence angle given in degrees (i.e. uom='deg'). Not used for Sentinel-5p L1b products	0..1	
eop:instrumentAzimuthAngle	Mean instrument azimuth angle given in degrees (i.e. uom='deg'). Not used for Sentinel-5p L1b products	0..1	
eop:instrumentZenithAngle	Mean instrument zenith angle given in degrees (i.e. uom='deg'). Not used for Sentinel-5p L1b products	0..1	
eop:instrumentElevationAngle	Mean instrument elevation angle given in degrees (i.e. uom='deg'). Not used for Sentinel-5p L1b products	0..1	
eop:pitch	Satellite pitch angle given in degrees (i.e.uom='deg'). Not used for Sentinel-5p L1b products	0..1	
eop:roll	Satellite roll angle given in degrees (i.e. uom='deg'). Not used for Sentinel-5p L1b products	0..1	
eop:yaw	Satellite yaw angle given in degrees (i.e.uom='deg'). Not used for Sentinel-5p L1b products	0..1	

Table 42: <eop:Acquisition> fields description

5.3.7 XML Type: eop:Footprint

The eop:Footprint block contains description of the target location observed during the EarthObservation. The complete description of the Footprint is given in Table 43.

eop:Footprint			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
gml:id attribute	Mandatory identifier required by GML. Its value must be unique among all the gml:id attributes of the XML file. The convention to use the product identifier plus a suffix in order to have the gml:id unique inside the document.	1	Yes Value: eop:identifier + '.FP' as suffix.

eop:Footprint (cont'd)			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
eop:multiExtentOf	Acquisition footprint coordinates, described by a closed polygon (last point=first point), using latitude, longitude pairs. Expected structure is gml:Polygon/gml:exterior/gml:LinearRing/gml:posList. The Polygon geometry shall be encoded in the EPSG:4326 geographic coordinate reference system and the coordinate pairs shall be ordered as lat /lon. Polygons enclose areas with points listed in CCW direction.	1	Yes
eop:orientation	Determines the orientation of the coordinate pairs for the exterior boundary of the footprint polygons. Possible values are CW (clockwise), counter-clockwise (CCW) or OTHER (unspecified orientation). Note that this property is only to be provided for footprints that do not follow the normal counter-clockwise for exterior boundaries convention as defined in [RD20]. If the property is not provided, a CCW orientation for the exterior boundary will be assumed. Not used for Sentinel-5p L1b products	0..1	
eop:centerOf	Acquisition center coordinates Not used for Sentinel-5p L1b products	0..1	

Table 43: <eop:Footprint> fields description

5.3.8 XML Type: eop:EarthObservationMetaData

The eop:EarthObservationMetaDdata block contains all the metadata relative to an eop:EarthObservation that do not fit inside one of the other blocks, i.e. metadata that do not describe the time, the mechanism, the location or the result of the observation.

These metadata are mainly the EarthObservation identifier, the acquisition type and information relative to the downlink and archiving centers. The complete description of the EarthObservationMetadata is given in Table 44.

eop:EarthObservationMetaData			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
eop:identifier	Identifier for metadata item	1	Yes
eop:creationDate	creation date for the metadata item. When retrieved from a metadata catalogue, the creationDate is the date when the metadata item was ingested for the first time (i.e. inserted) in the catalogue. Not used for Sentinel-5p L1b products	0..1	

eop:EarthObservationMetaData (cont'd)			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
eop:modificationDate	Date of the last modification to the metadata item. When retrieved from a metadata catalogue, the modification-Date is the date when the metadata item was last modified (i.e. updated) in the catalogue. Not used for Sentinel-5p L1b products	0..1	
eop:doi	Digital Object Identifier identifying the product (see http://www.doi.org) Only for Sentinel-5p L1b radiance and irradiance products. Not used for Sentinel-5p L1b calibration and engineering data products.	0..1	
eop:parentIdentifier	Collection Identifier See the discussion on gmi:fileIdentifier and Table 5 in section 5.2.1	0..1	Yes
eop:acquisitionType	Used to distinguish at a high level the appropriateness of the acquisition for "general" use, whether the product is a nominal acquisition, special calibration product or other. Values: NOMINAL, CALIBRATION, OTHER Not used for Sentinel-5p L1b products	1	Yes
eop:acquisitionSubType	The broad value defined by the acquisitionType is however too restrictive, so mission specific type definition should refer to mission/ground segment dedicated codeSpace Not used for Sentinel-5p L1b products	0..1	
eop:productType	Describes the product type in case that mixed types are available within a single collection, this is a ground segment specific definition. For S5p L1b products generic product codes are used.	0..1	Yes see Table 49
eop:status	Refers to product status. Values: ARCHIVED, ACQUIRED, CANCELLED, FAILED, PLANNED, POTENTIAL, REJECTED, QUALITY-DEGRADED (<i>depricated</i>) Not used for Sentinel-5p L1b products	1	No
eop:statusSubType	Refines the status of a product when the "status" is set to "ARCHIVED". Values: ON-LINE, OFF-LINE Not used for Sentinel-5p L1b products	0..1	
eop:statusDetail	This field refers to the eop:status value. It should be used to motivate the reason of a failure, cancelation, rejection or degraded quality. Not used for Sentinel-5p L1b products	0..1	

eop:EarthObservationMetaData (cont'd)			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
<i>eop:downlinkedTo/</i> <i>eop:DownlinkInformation</i>	<i>Downlink information</i> Not used for Sentinel-5p L1b products	0..1	
<i>eop:archivedIn/</i> <i>eop:ArchivingInformation</i>	<i>Archive information</i> Not used for Sentinel-5p L1b products	0..1	
<i>eop:productQualityStatus</i>	Indicator that specifies whether the product quality is degraded or not. This optional field shall be provided if the product has passed a quality check. Values: DEGRADED, NOMINAL Not used for Sentinel-5p L1b products	0..1	
<i>eop:productQuality-DegradationTag</i>	Contains further textual information concerning the quality degradation. It shall be provided if <i>eop:productQualityStatus</i> value is DEGRADED. Possible values are mission specific and should refer to mission/ground segment dedicated codeSpace. Example of values could be "RADIOMETRY" or "GEOLOCATION". Not used for Sentinel-5p L1b products	0..1	
<i>eop:productQuality-ReportURL</i>	URL reference to an external quality report file Not used for Sentinel-5p L1b products	0..1	
<i>eop:productQuality-Degradation</i>	Quality degradation percentage (i.e. uom='%') Not used for Sentinel-5p L1b products	0..1	
<i>eop:productQuality-DegradationQuotationMode</i>	Indicator to know how the quality degradation percentage has been calculated. Values: AUTOMATIC, MANUAL Not used for Sentinel-5p L1b products	0..1	
<i>eop:histograms/</i> <i>eop:Histogram</i>	<i>Histograms</i> Not used for Sentinel-5p L1b products Not used for Sentinel-5p L1b products	0..n	
<i>eop:composedOf</i>	Link to an EO product that is part of this EO product Not used for Sentinel-5p L1b products	0..1	
<i>eop:subsetOf</i>	Link to the "father" EO product Not used for Sentinel-5p L1b products	0..1	
<i>eop:linkedWith</i>	Link to another EO product Not used for Sentinel-5p L1b products	0..1	
<i>eop:processing/</i> <i>eop:ProcessingInformation</i>	<i>Processing information</i>	0..n	Yes See section below on eop:Processing Information

eop:EarthObservationMetaData (cont'd)			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
eop:productGroupId	Holds the identifier of a particular group to which the product belongs to. Group members represent then "granules" or "portions" of end-user products that are eligible for specific aggregations (e.g. all Sentinel-2 granules having the same productGroupId can be assembled together to form a Sentinel-2 end-user product) Not used for Sentinel-5p L1b products	0..1	
<i>eop:vendorSpecific/ eop:SpecificInformation</i>	<i>Container for ad-hoc metadata that does not merit a mission specific schema or extension</i> Not used for Sentinel-5p L1b products	0..n	

Table 44: <eop:EarthObservationMetaDdata> fields description

5.3.9 XML Type: eop:ProcessingInformation

The eop:ProcessingInformation element provides information about the processing date, methods and processing center. The complete description of the eop:ProcessingInformation is given in Table 45.

eop:ProcessingInformation			
Field name	Field description and S5p notes	Card'ty	S5p tailoring
eop:processingCenter	Processing center code. Possible values are mission specific and should be retrieved using codeSpace. Values: DLR-DFD [DLR-DFD = German Aerospace Center - German Remote Sensing Data Center (Germany)]	0..1	Yes Used with cardinality 1 Fixed: DLR-DFD
eop:processingDate	Processing date time	0..1	Yes Used with cardinality 1
eop:compositeType	Type of composite of product expressed as timeperiod that the composite product covers Not used for Sentinel-5p L1b products	0..1	
eop:method	Method used to compute datalayer. (e.g. Kalman filtering, ROSE) Not used for Sentinel-5p L1b products	0..1	
eop:methodVersion	Method version (e.g. 1.0) Not used for Sentinel-5p L1b products	0..1	
eop:processorName	Processor software name (e.g. trop10b)	0..1	Yes Fixed value: trop10b
eop:processorVersion	Processor software version (e.g. 1.0)	0..1	Yes Used with cardinality 1
eop:processingLevel	Processing level applied to the product	0..1	Yes Fixed value: L1b
eop:nativeProductFormat	Native product format	0..1	Yes Fixed value: netCDF-4

eop:ProcessingInformation (cont'd)

Field name	Field description and S5p notes	Card'ty	S5p tailoring
eop:auxiliaryDataSetFileName	Name(s) of auxiliary dataset(s) used in the process Not used for Sentinel-5p L1b products	0..n	
eop:processingMode	Processing mode taken from mission specific code list. Examples of values are: NRT, NOMINAL, BACKLOGGED, REPROCESSED, VALIDATE Not used for Sentinel-5p L1b products	0..1	

Table 45: <eop:ProcessingInformation> fields description

5.4 ESA FFS metadata profile for Sentinel-5p

The ESA metadata relates to the information required for the production of the Fixed Header and the Variable Header parts of the header of the logical file as defined in the “Earth Observation Ground Station File Format Standard (EO-FFS)” standard [AD2] and the Sentinel 5 Precursor Ground Segment tailoring document [AD3]. A comprehensive description of the application of these standards for L1b products is provided in [RD4].

Only the Fixed Header part is mentioned here. The Variable Header information as defined in [AD2] is overlapping with the information provided by the LI_Lineage element (see Table 27 to Table 32) of the ISO metadata. In [RD4] a discussion can be found on the header information. An example of the header file (*.HDR) is provided in Appendix D.

Fixed_Header

Name	Class	Definition
File_Name		it is a repetition of the Logical File Name, i.e. the File Name excluding the extension.
File_Description		a 1-line description of the File Type; each mission shall define the list of official file descriptions (per File Type) in its file format standard tailoring document. (<i>fixed: “Example: Sentinel-S5p TROPOMI Level 1b Radiance product band 1 (UV Detector)”</i>)
Notes		multi-lines free text; this can be used for any type of comment, relevant to that instance of the file. (<i>fixed: “”</i>)
Mission		a 1-word description of the mission, coherent with the mission element in the File Name; each mission shall define the mission description in its file format standard tailoring document. (<i>fixed: “S5P”</i>)
File_Class		a 1-line description of the file class, coherent with the File Class element in the File Name; each mission shall define the list of official file classes in its file format standard tailoring document. (<i>example: “OFFL”, “NRTI”</i>)
File_Type		it is a repetition of the File Type element in the File Name; each mission shall define the list of official file types in its file format standard tailoring document. (<i>example: “L1B_RA_BD1”</i>)
Validity_Period	ValidityPeriodType	time coverage of the data (for content see below)
File_Version		it is a repetition of the File Version element in the File Name. Must start at 1 (not 0). (<i>Numbering scheme not applicable to L1b products, see [RD4]</i>)
Source	SourceType	information about the ground segment facility where the product was generated (for content see below)

Table 46: Fixed_Header class. See [RD4] for detailed information about these fields.

Fixed_Header.Validity_Period > ValidityPeriodType

Name	Class	Definition
Validity_Start		this is the UTC Validity Start Time, coherent with the Validity Start Time in the File Name, but in CCSDS ASCII format with time reference (i.e.: UTC=yyyy-mm-ddThh-mm-ss).
Validity_Stop		this is the UTC Validity Stop Time, coherent with the Validity Stop Time in the File Name, but in CCSDS ASCII format with time reference (i.e.: UTC=yyyy-mm-ddThh-mm-ss).

Table 47: Fixed_Header.Validity_Period

Fixed_Header.Source > SourceType

Name	Class	Definition
System		name of the Ground Segment element creating the file
Creator		name of the facility or tool, within the Ground Segment element, creating the file
Creator_Version		version of the tool
Creation_Date		this is the UTC Creation Date, in CCSDS ASCII format with time reference

Table 48: Fixed_Header.Source

5.5 CF/NetCDF metadata profile for Sentinel-5p

The CF-Metadata conventions [RD8] and the Attribute Conventions for Dataset Discovery [ER21] recommend a comprehensive set of attributes to be included as metadata elements. However, many of the metadata attributes proposed by CF-Metadata Conventions and ACDD overlap with the ISO 19115-2 standard and hence the same information can be found in these metadata

In view of the above, only a very limited set of metadata elements recommended by CF-Metadata Conventions and ACDD is used. More detailed information on the specific elements included in the TROPOMI L011b products can be found in [RD4].

Appendix A L1b products

A.1 Summary of L1b products

The L1b products are described in the *“Input/output data specification for the TROPOMI L01b data processor”* [RD4]. This document provides a comprehensive overview of all L1b products, including the data and file format specification. In particular, it provides the L1b logical file name convention which is a tailoring [AD3] of the *“Earth Observation Ground Station File Format Standard (EO-FFS)”* [AD2].

Table 49 contains an overview of all L1b products and lists for each of the products the generic product code. This generic product code is based on the Mission ID, the File Class and the File Type as defined in [AD2] and described in [RD4] for the Sentinel-5p case. As such, the generic product code can be derived from the logical file name by stripping off the File Instance ID.

Product type	Generic product code	Product description
Radiance product (Standard)	S5P_OFFL_L1B_RA_BD1	Radiance product band 1 (UV detector)
	S5P_OFFL_L1B_RA_BD2	Radiance product band 2 (UV detector)
	S5P_OFFL_L1B_RA_BD3	Radiance product band 3 (UVIS detector)
	S5P_OFFL_L1B_RA_BD4	Radiance product band 4 (UVIS detector)
	S5P_OFFL_L1B_RA_BD5	Radiance product band 5 (NIR detector)
	S5P_OFFL_L1B_RA_BD6	Radiance product band 6 (NIR detector)
	S5P_OFFL_L1B_RA_BD7	Radiance product band 7 (SWIR detector)
	S5P_OFFL_L1B_RA_BD8	Radiance product band 8 (SWIR detector)
Radiance product (Near Real Time)	S5P_NRTI_L1B_RA_BD1	Radiance product band 1 (UV detector)
	S5P_NRTI_L1B_RA_BD2	Radiance product band 2 (UV detector)
	S5P_NRTI_L1B_RA_BD3	Radiance product band 3 (UVIS detector)
	S5P_NRTI_L1B_RA_BD4	Radiance product band 4 (UVIS detector)
	S5P_NRTI_L1B_RA_BD5	Radiance product band 5 (NIR detector)
	S5P_NRTI_L1B_RA_BD6	Radiance product band 6 (NIR detector)
	S5P_NRTI_L1B_RA_BD7	Radiance product band 7 (SWIR detector)
	S5P_NRTI_L1B_RA_BD8	Radiance product band 8 (SWIR detector)
Irradiance product	S5P_OFFL_L1B_IR_UVN	Irradiance product UVN module
	S5P_OFFL_L1B_IR_SIR	Irradiance product SWIR module
Calibration product	S5P_OFFL_L1B_CA_UVN	Calibration product UVN module
	S5P_OFFL_L1B_CA_SIR	Calibration product SWIR module
Engineering product	S5P_OFFL_L1B_ENG_DB	Engineering product

Table 49: Summary of L1b products

Appendix B Example ISO 19139 metadata file

Listing 1 shows an example of the ISO 19139 metadata file for L1b products. This example has not been generated based on an actual L01b product.

Listing 1: Example ISO 19139 metadata file

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<gmi:MI_Metadata xmlns:gco="http://www.isotc211.org/2005/gco"
  xmlns:gmd="http://www.isotc211.org/2005/gmd"
  xmlns:gmi="http://www.isotc211.org/2005/gmi"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  xmlns:gmx="http://www.isotc211.org/2005/gmx"
  xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.isotc211.org/2005/gmd
  http://standards.iso.org/ittf/PubliclyAvailableStandards/ISO_19139_Schemas/gmd/
  metadataApplication.xsd http://www.isotc211.org/2005/gmi
  http://www.isotc211.org/2005/gmi/gmi.xsd">
  <gmd:fileIdentifier>
    <gco:CharacterString>S5P_OFFL_L1B_RA_BD1_20151114T112005_20151114T125934_00140
      _02_010203_20151204T093045</gco:CharacterString>
  </gmd:fileIdentifier>
  <gmd:language>
    <gmd:LanguageCode codeList="http://www.loc.gov/standards/iso639-2/"
      codeListValue="eng">eng</gmd:LanguageCode>
  </gmd:language>
  <gmd:characterSet>
    <gmd:MD_CharacterSetCode
      codeList="http://www.isotc211.org/2005/resources/Codelist/
      gmxCodelists.xml#MD_CharacterSetCode"
      codeListValue="utf8">utf8</gmd:MD_CharacterSetCode>
  </gmd:characterSet>
  <gmd:hierarchyLevel>
    <gmd:MD_ScopeCode codeList="http://www.isotc211.org/2005/resources/Codelist/
      gmxCodelists.xml#MD_ScopeCode"
      codeListValue="dataset">dataset</gmd:MD_ScopeCode>
  </gmd:hierarchyLevel>
  <gmd:contact>
    <gmd:CI_ResponsibleParty>
      <gmd:individualName>
        <gco:CharacterString>KNMI Help</gco:CharacterString>
      </gmd:individualName>
      <gmd:organisationName>
        <gco:CharacterString>KNMI</gco:CharacterString>
      </gmd:organisationName>
      <gmd:positionName>
        <gco:CharacterString>Help Desk</gco:CharacterString>
      </gmd:positionName>
      <gmd:contactInfo>
        <gmd:CI_Contact>
          <gmd:address>
            <gmd:CI_Address>
              <gmd:electronicMailAddress>
                <gco:CharacterString>info@knmi.nl</gco:CharacterString>
              </gmd:electronicMailAddress>
            </gmd:CI_Address>
          </gmd:address>
        </gmd:CI_Contact>
      </gmd:contactInfo>
    </gmd:CI_ResponsibleParty>
  </gmd:contact>

```

```
</gmd:contactInfo>
<gmd:role>
  <gmd:CI_RoleCode codeList="http://www.isotc211.org/2005/resources/Codelist/
    gmxCodelists.xml#CI_RoleCode"
    codeListValue="pointOfContact">pointOfContact</gmd:CI_RoleCode>
</gmd:role>
</gmd:CI_ResponsibleParty>
</gmd:contact>
<gmd:dateStamp>
  <gco:Date>2015-12-04</gco:Date>
</gmd:dateStamp>
<gmd:metadataStandardName>
  <gco:CharacterString>ISO 19115-2 Geographic Information - Metadata Part 2
    Extensions for imagery and gridded data</gco:CharacterString>
</gmd:metadataStandardName>
<gmd:metadataStandardVersion>
  <gco:CharacterString>ISO 19115-2:2009(E), S5P profile</gco:CharacterString>
</gmd:metadataStandardVersion>
<gmd:identificationInfo>
  <gmd:MD_DataIdentification>
    <gmd:citation>
      <gmd:CI_Citation>
        <gmd:title>
          <gco:CharacterString>S5p TROPOMI Radiance L1b product</gco:CharacterString>
        </gmd:title>
        <gmd:date>
          <gmd:CI_Date>
            <gmd:date>
              <gco:Date>2015-12-04</gco:Date>
            </gmd:date>
            <gmd:dateType>
              <gmd:CI_DateTypeCode
                codeList="http://www.isotc211.org/2005/resources/Codelist/
                  gmxCodelists.xml#CI_DateTypeCode"
                codeListValue="creation">creation</gmd:CI_DateTypeCode>
            </gmd:dateType>
          </gmd:CI_Date>
        </gmd:date>
        <gmd:identifier>
          <gmd:MD_Identifier>
            <gmd:code>
              <gco:CharacterString>S5P_OFFFL_L1B_RA_BD1_20151114T112005_20151114T125934
                _00140_02_010203_20151204T093045</gco:CharacterString>
            </gmd:code>
          </gmd:MD_Identifier>
        </gmd:identifier>
      </gmd:CI_Citation>
    </gmd:citation>
    <gmd:abstract>
      <gco:CharacterString>S5p TROPOMI instrument measures...</gco:CharacterString>
    </gmd:abstract>
    <gmd:credit>
      <gco:CharacterString>Financial support by NSO</gco:CharacterString>
    </gmd:credit>
    <gmd:pointOfContact>
      <gmd:CI_ResponsibleParty>
        <gmd:individualName>
          <gco:CharacterString>eoHelp</gco:CharacterString>
        </gmd:individualName>
      </gmd:CI_ResponsibleParty>
    </gmd:pointOfContact>
  </gmd:MD_DataIdentification>
</gmd:identificationInfo>
</gmd:MD_DataIdentification>
</gmd:MD_Identifier>
</gmd:CI_Citation>
</gmd:citation>
</gmd:abstract>
</gmd:credit>
</gmd:pointOfContact>
</gmd:CI_ResponsibleParty>
</gmd:individualName>
</gco:CharacterString>eoHelp</gco:CharacterString>
```

```
</gmd:individualName>
<gmd:organisationName>
  <gco:CharacterString>ESA</gco:CharacterString>
</gmd:organisationName>
<gmd:positionName>
  <gco:CharacterString>Order Desk</gco:CharacterString>
</gmd:positionName>
<gmd:contactInfo>
  <gmd:CI_Contact>
    <gmd:address>
      <gmd:CI_Address>
        <gmd:electronicMailAddress>
          <gco:CharacterString>eohelp@esa.int</gco:CharacterString>
        </gmd:electronicMailAddress>
      </gmd:CI_Address>
    </gmd:address>
  </gmd:CI_Contact>
</gmd:contactInfo>
<gmd:role>
  <gmd:CI_RoleCode
    codeList="http://www.isotc211.org/2005/resources/Codelist/
    gmxCodelists.xml#CI_RoleCode"
    codeListValue="distributor">distributor</gmd:CI_RoleCode>
  </gmd:role>
</gmd:CI_ResponsibleParty>
</gmd:pointOfContact>
<gmd:descriptiveKeywords>
  <gmd:MD_Keywords>
    <gmd:keyword>
      <gco:CharacterString>Atmospheric conditions</gco:CharacterString>
    </gmd:keyword>
    <gmd:type>
      <gmd:MD_KeywordTypeCode
        codeList="http://www.isotc211.org/2005/resources/Codelist/
        gmxCodelists.xml#MD_KeywordTypeCode"
        codeListValue="theme">theme</gmd:MD_KeywordTypeCode>
      </gmd:type>
    <gmd:thesaurusName>
      <gmd:CI_Citation>
        <gmd:title>
          <gco:CharacterString>GEMET - INSPIRE themes, version
            1.0</gco:CharacterString>
        </gmd:title>
        <gmd:date>
          <gmd:CI_Date>
            <gmd:date>
              <gco:Date>2008-06-01</gco:Date>
            </gmd:date>
            <gmd:dateType>
              <gmd:CI_DateTypeCode
                codeList="http://www.isotc211.org/2005/resources/Codelist/
                gmxCodelists.xml#CI_DateTypeCode"
                codeListValue="publication">publication</gmd:CI_DateTypeCode>
              </gmd:dateType>
            </gmd:CI_Date>
          </gmd:date>
        </gmd:CI_Citation>
      </gmd:thesaurusName>
```

```
</gmd:MD_Keywords>
</gmd:descriptiveKeywords>
<gmd:resourceConstraints>
  <gmd:MD_LegalConstraints>
    <gmd:useLimitation>
      <gco:CharacterString>no conditions apply</gco:CharacterString>
    </gmd:useLimitation>
    <gmd:accessConstraints>
      <gmd:MD_RestrictionCode>
        codeList="http://www.isotc211.org/2005/resources/Codelist/
gmxCodelists.xml#MD_RestrictionCode"
        codeListValue="copyright">copyright</gmd:MD_RestrictionCode>
      </gmd:accessConstraints>
    </gmd:MD_LegalConstraints>
  </gmd:resourceConstraints>
  <gmd:spatialRepresentationType>
    <gmd:MD_SpatialRepresentationTypeCode>
      codeList="http://www.isotc211.org/2005/resources/Codelist/
gmxCodelists.xml#MD_SpatialRepresentationTypeCode"
      codeListValue="grid">grid</gmd:MD_SpatialRepresentationTypeCode>
    </gmd:spatialRepresentationType>
  <gmd:language>
    <gco:CharacterString>eng</gco:CharacterString>
  </gmd:language>
  <gmd:characterSet>
    <gmd:MD_CharacterSetCode>
      codeList="http://www.isotc211.org/2005/resources/Codelist/
gmxCodelists.xml#MD_CharacterSetCode"
      codeListValue="utf8">utf8</gmd:MD_CharacterSetCode>
    </gmd:characterSet>
  <gmd:topicCategory>
    <gmd:MD_TopicCategoryCode>climatologyMeteorologyAtmosphere
    </gmd:MD_TopicCategoryCode>
  </gmd:topicCategory>
  <gmd:extent>
    <gmd:EX_Extent>
      <gmd:geographicElement>
        <gmd:EX_BoundingPolygon>
          <gmd:extentTypeCode>
            <gco:Boolean>>true</gco:Boolean>
          </gmd:extentTypeCode>
          <gmd:polygon>
            <gml:Polygon srsName="urn:ogc:def:crs:EPSG::4326">
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList>40.8344 47.3123 41.0442 48.6136 49.507 46.1166
51.1057 45.5826 50.8827 44.0264 40.8344 47.3123</gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gmd:polygon>
        </gmd:EX_BoundingPolygon>
      </gmd:geographicElement>
      <gmd:temporalElement>
        <gmd:EX_TemporalExtent>
          <gmd:extent>
            <gml:TimePeriod>
              <gml:beginPosition>2015-11-14T11:20:05Z</gml:beginPosition>
            </gml:TimePeriod>
          </gmd:extent>
        </gmd:EX_TemporalExtent>
      </gmd:temporalElement>
    </gmd:EX_Extent>
  </gmd:extent>

```

```
        </gml:endPosition>2015-11-14T12:59:34Z</gml:endPosition>
      </gml:TimePeriod>
    </gmd:extent>
  </gmd:EX_TemporalExtent>
</gmd:temporalElement>
</gmd:EX_Extent>
</gmd:extent>
</gmd:MD_DataIdentification>
</gmd:identificationInfo>
<gmd:dataQualityInfo>
  <gmd:DQ_DataQuality>
    <gmd:scope>
      <gmd:DQ_Scope>
        <gmd:level>
          <gmd:MD_ScopeCode
            codeList="http://www.isotc211.org/2005/resources/Codelist/
            gmxCodelists.xml#MD_ScopeCode"
            codeListValue="dataset">dataset</gmd:MD_ScopeCode>
          </gmd:level>
        </gmd:DQ_Scope>
      </gmd:scope>
      <gmd:report>
        <gmd:DQ_DomainConsistency>
          <gmd:result>
            <gmd:DQ_ConformanceResult>
              <gmd:specification>
                <gmd:CI_Citation>
                  <gmd:title>
                    <gco:CharacterString>INSPIRE Data Specification on Atmospheric
                    Conditions and Meteorological Geographical Features - Technical
                    Guidelines, version 3.0</gco:CharacterString>
                  </gmd:title>
                  <gmd:date>
                    <gmd:CI_Date>
                      <gmd:date>
                        <gco:Date>2013-12-10</gco:Date>
                      </gmd:date>
                      <gmd:dateType>
                        <gmd:CI_DateTypeCode
                          codeList="http://www.isotc211.org/2005/resources/Codelist/
                          gmxCodelists.xml#CI_DateTypeCode"
                          codeListValue="publication">publication</gmd:CI_DateTypeCode>
                        </gmd:dateType>
                      </gmd:CI_Date>
                    </gmd:date>
                  </gmd:CI_Citation>
                </gmd:specification>
                <gmd:explanation>
                  <gco:CharacterString></gco:CharacterString>
                </gmd:explanation>
                <gmd:pass>
                  <gco:Boolean>>true</gco:Boolean>
                </gmd:pass>
              </gmd:DQ_ConformanceResult>
            </gmd:result>
          </gmd:DQ_DomainConsistency>
        </gmd:report>
      </gmd:lineage>
```

```
<gmd:LI_Lineage>
  <gmd:statement>
    <gco:CharacterString>L1b radiance dataset produced by the DLR PDGS from
      the S5p TROPOMI L0 product</gco:CharacterString>
  </gmd:statement>
  <gmd:processStep>
    <gmi:LE_ProcessStep>
      <gmd:description>
        <gco:CharacterString>Processing of L0 to L1b data using the KNMI
          TROPOMI L01b processor</gco:CharacterString>
      </gmd:description>
      <gmd:source>
        <gmi:LE_Source>
          <gmd:description>
            <gco:CharacterString>In flight calibration key data
              product</gco:CharacterString>
          </gmd:description>
          <gmd:sourceCitation>
            <gmd:CI_Citation>
              <gmd:title>
                <gco:CharacterString>Calibration Key Data Set,
                  Semi-Static</gco:CharacterString>
              </gmd:title>
              <gmd:alternateTitle>
                <gmx:FileName>S5P_OPER_AUX_L1_CKD_20141001T000001_20151231T235959
                  _000000_01_000701_20141001T120000.h5</gmx:FileName>
              </gmd:alternateTitle>
              <gmd:date>
                <gmd:CI_Date>
                  <gmd:date>
                    <gco:Date>2015-11-14</gco:Date>
                  </gmd:date>
                  <gmd:dateType>
                    <gmd:CI_DateTypeCode
                      codeList="http://www.isotc211.org/2005/resources/Codelist/
                        gmxCodellists.xml#CI_DateTypeCode"
                      codeListValue="creation">creation</gmd:CI_DateTypeCode>
                    </gmd:dateType>
                  </gmd:CI_Date>
                </gmd:date>
              </gmd:CI_Citation>
            </gmd:sourceCitation>
          </gmi:LE_Source>
        </gmd:source>
      <gmd:source>
        <gmi:LE_Source>
          <gmd:description>
            <gco:CharacterString>L0 Band 1 UVN science
              data</gco:CharacterString>
          </gmd:description>
          <gmd:sourceCitation>
            <gmd:CI_Citation>
              <gmd:title>
                <gco:CharacterString>L0 Instrument data for band
                  1</gco:CharacterString>
              </gmd:title>
              <gmd:alternateTitle>
```

```
<gmx:FileName>S5P_OPER_L0__ODB_1_20140827T103500_20140827T104000_53811_00.RAW</gmx:FileName>
</gmd:alternateTitle>
<gmd:alternateTitle>
  <gmx:FileName>S5P_OPER_L0__ODB_1_20140827T104000_20140827T104500_53811_01.RAW</gmx:FileName>
</gmd:alternateTitle>
<gmd:alternateTitle>
  <gmx:FileName>S5P_OPER_L0__ODB_1_20140827T104500_20140827T105000_53811_02.RAW</gmx:FileName>
</gmd:alternateTitle>
<gmd:alternateTitle>
  <gmx:FileName>S5P_OPER_L0__ODB_1_20140827T105000_20140827T105500_53811_03.RAW</gmx:FileName>
</gmd:alternateTitle>
<gmd:alternateTitle>
  <gmx:FileName>S5P_OPER_L0__ODB_1_20140827T105500_20140827T110000_53811_04.RAW</gmx:FileName>
</gmd:alternateTitle>
<gmd:alternateTitle>
  <gmx:FileName>S5P_OPER_L0__ODB_1_20140827T110000_20140827T110500_53811_05.RAW</gmx:FileName>
</gmd:alternateTitle>
<gmd:date>
  <gmd:CI_Date>
    <gmd:date>
      <gco:Date>2014-08-27</gco:Date>
    </gmd:date>
    <gmd:dateType>
      <gmd:CI_DateTypeCode
        codeList="http://www.isotc211.org/2005/resources/Codelist/gmxCodeLists.xml#CI_DateTypeCode"
        codeListValue="creation">creation</gmd:CI_DateTypeCode>
      </gmd:dateType>
    </gmd:CI_Date>
  </gmd:date>
</gmd:CI_Citation>
</gmd:sourceCitation>
<gmi:processedLevel>
  <gmd:MD_Identifier>
    <gmd:code>
      <gco:CharacterString>L0</gco:CharacterString>
    </gmd:code>
  </gmd:MD_Identifier>
</gmi:processedLevel>
</gmi:LE_Source>
</gmd:source>
<gmi:output>
  <gmi:LE_Source>
    <gmd:description>
      <gco:CharacterString>TROPOMI L1b radiance product</gco:CharacterString>
    </gmd:description>
    <gmd:sourceCitation>
      <gmd:CI_Citation>
        <gmd:title>
          <gmx:FileName>S5P_OFFL_L1B_RA_BD1_20151114T112005_20151114T125934_00140_02_010203_20151204T093045.nc

```

```
        </gmx:FileName>
    </gmd:title>
    <gmd:date>
        <gmd:CI_Date>
            <gmd:date>
                <gco>Date>2015-12-04</gco>Date>
            </gmd:date>
            <gmd:dateType>
                <gmd:CI_DateTypeCode
                    codeList="http://www.isotc211.org/2005/resources/Codelist/
                    gmxCodeLists.xml#CI_DateTypeCode"
                    codeListValue="creation">creation</gmd:CI_DateTypeCode>
                </gmd:dateType>
            </gmd:CI_Date>
        </gmd:date>
    </gmd:CI_Citation>
</gmd:sourceCitation>
<gmi:processedLevel>
    <gmd:MD_Identifier>
        <gmd:code>
            <gco:CharacterString>L1b</gco:CharacterString>
        </gmd:code>
    </gmd:MD_Identifier>
</gmi:processedLevel>
</gmi:LE_Source>
</gmi:output>
<gmi:processingInformation>
    <gmi:LE_Processing>
        <gmi:identifier>
            <gmd:MD_Identifier>
                <gmd:code>
                    <gco:CharacterString>KNMI TROPOMI L01b
                    processor</gco:CharacterString>
                </gmd:code>
            </gmd:MD_Identifier>
        </gmi:identifier>
    <gmi:softwareReference>
        <gmd:CI_Citation>
            <gmd:title>
                <gco:CharacterString>L01b processor
                description</gco:CharacterString>
            </gmd:title>
            <gmd:date>
                <gmd:CI_Date>
                    <gmd:date>
                        <gco>Date>2014-12-31</gco>Date>
                    </gmd:date>
                    <gmd:dateType>
                        <gmd:CI_DateTypeCode
                            codeList="http://www.isotc211.org/2005/resources/Codelist/
                            gmxCodeLists.xml#CI_DateTypeCode"
                            codeListValue="creation">creation</gmd:CI_DateTypeCode>
                        </gmd:dateType>
                    </gmd:CI_Date>
                </gmd:date>
            </gmd:CI_Citation>
        </gmi:softwareReference>
    <gmi:documentation>
```

```
<gmd:CI_Citation>
  <gmd:title>
    <gmx:FileName>S5P-KNMI-L01B-0009-SD-algorithm_theoretical_
      basis_document-8.0.0-20170601.pdf</gmx:FileName>
  </gmd:title>
  <gmd:date>
    <gmd:CI_Date>
      <gmd:date>
        <gco:Date>2017-06-01</gco:Date>
      </gmd:date>
      <gmd:dateType>
        <gmd:CI_DateTypeCode
          codeList="http://www.isotc211.org/2005/resources/Codelist/
            gmxCodelists.xml#CI_DateTypeCode"
          codeListValue="publication">publication
        </gmd:CI_DateTypeCode>
      </gmd:dateType>
    </gmd:CI_Date>
  </gmd:date>
</gmd:CI_Citation>
</gmi:documentation>
<gmi:documentation>
  <gmd:CI_Citation>
    <gmd:title>
      <gmx:FileName>S5P-KNMI-L01B-0012-SD-input_output_data_
        specification-9.0.0-20180401.pdf</gmx:FileName>
    </gmd:title>
    <gmd:date>
      <gmd:CI_Date>
        <gmd:date>
          <gco:Date>2018-04-01</gco:Date>
        </gmd:date>
        <gmd:dateType>
          <gmd:CI_DateTypeCode
            codeList="http://www.isotc211.org/2005/resources/Codelist/
              gmxCodelists.xml#CI_DateTypeCode"
            codeListValue="publication">publication
          </gmd:CI_DateTypeCode>
        </gmd:dateType>
      </gmd:CI_Date>
    </gmd:date>
  </gmd:CI_Citation>
</gmi:documentation>
</gmi:LE_Processing>
</gmi:processingInformation>
<gmi:report>
  <gmi:LE_ProcessStepReport>
    <gmi:name>
      <gco:CharacterString>TROPOMI L01b processing
        report</gco:CharacterString>
    </gmi:name>
    <gmi:description>
      <gco:CharacterString>L0 processed to L1b data using the KNMI
        TROPOMI L01b processor</gco:CharacterString>
    </gmi:description>
    <gmi:fileType>
      <gco:CharacterString>netCDF-4</gco:CharacterString>
    </gmi:fileType>
  </gmi:LE_ProcessStepReport>
</gmi:report>
</gmi:LE_Processing>
</gmi:processingInformation>
```

```
        </gmi:LE_ProcessStepReport>
      </gmi:report>
    </gmi:LE_ProcessStep>
  </gmd:processStep>
</gmd:LI_Lineage>
</gmd:lineage>
</gmd:DQ_DataQuality>
</gmd:dataQualityInfo>
<gmi:acquisitionInformation>
  <gmi:MI_AcquisitionInformation>
    <gmi:platform>
      <gmi:MI_Platform>
        <gmi:identifier>
          <gmd:RS_Identifier>
            <gmd:code>
              <gco:CharacterString>S5p</gco:CharacterString>
            </gmd:code>
            <gmd:codeSpace>
              <gco:CharacterString>http://www.esa.int/</gco:CharacterString>
            </gmd:codeSpace>
          </gmd:RS_Identifier>
        </gmi:identifier>
        <gmi:description>
          <gco:CharacterString>Sentinel 5 Precursor</gco:CharacterString>
        </gmi:description>
        <gmi:instrument>
          <gmi:MI_Instrument>
            <gmi:identifier>
              <gmd:RS_Identifier>
                <gmd:code>
                  <gco:CharacterString>TROPOMI</gco:CharacterString>
                </gmd:code>
                <gmd:codeSpace>
                  <gco:CharacterString>http://www.esa.int/</gco:CharacterString>
                </gmd:codeSpace>
              </gmd:RS_Identifier>
            </gmi:identifier>
            <gmi:type>
              <gmi:MI_SensorTypeCode codeList="" codeListValue="UV-VIS-NIR-SWIR
                imaging spectrometer">UV-VIS-NIR-SWIR imaging
                spectrometer</gmi:MI_SensorTypeCode>
            </gmi:type>
          </gmi:MI_Instrument>
        </gmi:instrument>
      </gmi:MI_Platform>
    </gmi:platform>
  </gmi:MI_AcquisitionInformation>
</gmi:acquisitionInformation>
</gmi:MI_Metadata>
```

Appendix C Example OGC 10-157 metadata file

Listing 2 shows an example of the OGC 10-157 metadata file for L1b products. This example has not been generated based on an actual L01b product.

Listing 2: Example OGC 10-157 metadata file

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<atm:EarthObservation xmlns:eop="http://www.opengis.net/eop/2.1"
  xmlns:om="http://www.opengis.net/om/2.0"
  xmlns:ows="http://www.opengis.net/ows/2.0"
  xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  gml:id="S5P_OFFFL_L1B_RA_BD1_20151114T112005_20151114T125934_00140_02_010203_
  20151204T093045.E0" xmlns:atm="http://www.opengis.net/atm/2.1">
  <om:phenomenonTime>
    <gml:TimePeriod>
      <gml:beginPosition>2015-11-14T11:45:11Z</gml:beginPosition>
      <gml:endPosition>2015-11-14T12:15:59Z</gml:endPosition>
    </gml:TimePeriod>
  </om:phenomenonTime>
  <om:resultTime>
    <gml:TimeInstant>
      <gml:timePosition>2015-12-04T19:30:45Z</gml:timePosition>
    </gml:TimeInstant>
  </om:resultTime>
  <om:procedure>
    <eop:EarthObservationEquipment
      gml:id="S5P_OFFFL_L1B_RA_BD1_20151114T112005_20151114T125934_00140_02_010203_
      20151204T093045.EOE">
      <eop:platform>
        <eop:Platform>
          <eop:shortName>Sentinel-5p</eop:shortName>
        </eop:Platform>
      </eop:platform>
      <eop:instrument>
        <eop:Instrument>
          <eop:shortName>TROPOMI</eop:shortName>
        </eop:Instrument>
      </eop:instrument>
      <eop:sensor>
        <eop:Sensor>
          <eop:sensorType>ATMOSPHERIC</eop:sensorType>
        </eop:Sensor>
      </eop:sensor>
      <eop:acquisitionParameters>
        <eop:Acquisition>
          <eop:orbitNumber>1234</eop:orbitNumber>
        </eop:Acquisition>
      </eop:acquisitionParameters>
    </eop:EarthObservationEquipment>
  </om:procedure>
  <om:observedProperty nilReason="inapplicable"/>
  <om:featureOfInterest>
    <eop:Footprint
      gml:id="S5P_OFFFL_L1B_RA_BD1_20151114T112005_20151114T125934_00140_02_010203_
      20151204T093045.FP">
    <eop:multiExtentOf>
      <gml:MultiSurface>
```

```
<gml:surfaceMembers>
  <gml:Polygon srsName="urn:ogc:def:crs:EPSG::4326">
    <gml:exterior>
      <gml:LinearRing>
        <gml:posList>40.8344 47.3123 41.0442 48.6136 49.507 46.1166 51.1057
          45.5826 50.8827 44.0264 40.8344 47.3123</gml:posList>
      </gml:LinearRing>
    </gml:exterior>
  </gml:Polygon>
</gml:surfaceMembers>
</gml:MultiSurface>
</eop:multiExtentOf>
</eop:Footprint>
</om:featureOfInterest>
<om:result>
  <atm:EarthObservationResult
    gml:id="S5P_OFFL_L1B_RA_BD1_20151114T112005_20151114T125934_00140_02_010203_
      20151204T093045.EOR">
    <eop:product>
      <eop:ProductInformation>
        <eop:fileName>
          <ows:ServiceReference
            xlink:href="http://some.downlink.url/sentinel5_product.nc">
          </ows:ServiceReference>
          <ows:RequestMessage/>
        </ows:ServiceReference>
      </eop:fileName>
    </eop:ProductInformation>
  </eop:product>
</atm:EarthObservationResult>
</om:result>
<eop:metaDataProperty>
  <eop:EarthObservationMetaData>
    <eop:identifier>S5P_OFFL_L1B_RA_BD1_20151114T112005_20151114T125934_00140_02_
      010203_20151204T093045</eop:identifier>
    <eop:parentIdentifier>urn:ogc:def:EOP:ESA:
      SENTINEL.S5P_TROP_L1B_RAD_BD1</eop:parentIdentifier>
    <eop:acquisitionType>NOMINAL</eop:acquisitionType>
    <eop:productType>S5P_OFFL_L1B_RA_BD1</eop:productType>
    <eop:status>ARCHIVED</eop:status>
    <eop:downlinkedTo>
      <eop:DownlinkInformation>
        <eop:acquisitionStation>SVG</eop:acquisitionStation>
        <eop:acquisitionDate>2015-11-14</eop:acquisitionDate>
      </eop:DownlinkInformation>
    </eop:downlinkedTo>
    <eop:archivedIn>
      <eop:ArchivingInformation>
        <eop:archivingCenter>DLR-DFD</eop:archivingCenter>
        <eop:archivingDate>2015-11-16</eop:archivingDate>
      </eop:ArchivingInformation>
    </eop:archivedIn>
    <eop:processing>
      <eop:ProcessingInformation>
        <eop:processingCenter>DLR-DFD</eop:processingCenter>
        <eop:processingDate>2015-12-04</eop:processingDate>
        <eop:processorName>trop101b</eop:processorName>
        <eop:processorVersion>1.1.1</eop:processorVersion>
        <eop:processingLevel>L1b</eop:processingLevel>
      </eop:ProcessingInformation>
    </eop:processing>
  </eop:EarthObservationMetaData>
</eop:metaDataProperty>
</om:result>
```

```
<eop:nativeProductFormat>netCDF-4</eop:nativeProductFormat>  
</eop:ProcessingInformation>  
</eop:processing>  
</eop:EarthObservationMetaData>  
</eop:metaDataProperty>  
</atm:EarthObservation>
```

Appendix D Example EO-FFS .HDR file

Listing 3 shows an example of the .HDR file for L1b products as defined in the “Earth Observation Ground Station File Format Standard (EO-FFS)” standard [AD2]. This example has not been generated based on an actual L01b product.

Listing 3: Example .HDR file

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<Earth_Explorer_File xmlns:gco="http://www.isotc211.org/2005/gco"
  xmlns:gmd="http://www.isotc211.org/2005/gmd"
  xmlns:gmi="http://www.isotc211.org/2005/gmi"
  xmlns:gmx="http://www.isotc211.org/2005/gmx" schemaVersion="1.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.knmi.nl/s5p/1.0 Sentinel5PSchema.xsd"
  xmlns="http://www.knmi.nl/s5p/1.0">
  <Earth_Explorer_Header>
    <Fixed_Header>
      <File_Name>S5P_OFFL_L1B_RA_BD1_20151114T112005_20151114T125934_
        00140_02_010203_20151204T093045</File_Name>
      <File_Description>Sentinel-5p TROPOMI Level 1b radiance
        product</File_Description>
      <Notes/>
      <Mission>Sentinel-5P</Mission>
      <File_Class>OFFL</File_Class>
      <File_Type>L1B_RA_BD1</File_Type>
      <Validity_Period>
        <Validity_Start>UTC=2015-11-14T11:20:05</Validity_Start>
        <Validity_Stop>UTC=2015-11-14T12:59:34</Validity_Stop>
      </Validity_Period>
      <File_Version>L1B_RA_BD1</File_Version>
      <Source>
        <System>DLR PDGS</System>
        <Creator>KNMI TROPOMI L01b processor</Creator>
        <Creator_Version>1.2.3</Creator_Version>
        <Creation_Date>UTC=2015-12-04T09:30:45</Creation_Date>
      </Source>
    </Fixed_Header>
    <Variable_Header>
      <gmd:LI_Lineage>
        <gmd:statement>
          <gco:CharacterString>L1b radiance dataset produced by the DLR PDGS from the
            S5p TROPOMI L0 product</gco:CharacterString>
        </gmd:statement>
        <gmd:processStep>
          <gmi:LE_ProcessStep>
            <gmd:description>
              <gco:CharacterString>Processing of L0 to L1b data using the KNMI TROPOMI
                L01b processor</gco:CharacterString>
            </gmd:description>
            <gmd:source>
              <gmi:LE_Source>
                <gmd:description>
                  <gco:CharacterString>In flight calibration key data
                    product</gco:CharacterString>
                </gmd:description>
                <gmd:sourceCitation>
                  <gmd:CI_Citation>
                    <gmd:title>
```

```
<gco:CharacterString>Calibration Key Data Set,  
  Semi-Static</gco:CharacterString>  
</gmd:title>  
<gmd:alternateTitle>  
  <gmx:FileName>S5P_OPER_AUX_L1_CKD_20141001T000001_20151231T235959  
    _000000_01_000701_20141001T120000.h5</gmx:FileName>  
</gmd:alternateTitle>  
<gmd:date>  
  <gmd:CI_Date>  
    <gmd:date>  
      <gco>Date>2015-11-14</gco>Date>  
    </gmd:date>  
    <gmd:dateType>  
      <gmd:CI_DateTypeCode  
        codeList="http://www.isotc211.org/2005/resources/Codelist/  
gmxCodelists.xml#CI_DateTypeCode"  
        codeListValue="creation">creation</gmd:CI_DateTypeCode>  
      </gmd:dateType>  
    </gmd:CI_Date>  
  </gmd:date>  
</gmd:CI_Citation>  
</gmd:sourceCitation>  
</gmi:LE_Source>  
</gmd:source>  
<gmd:source>  
  <gmi:LE_Source>  
    <gmd:description>  
      <gco:CharacterString>LO Band 1 UVN science data</gco:CharacterString>  
    </gmd:description>  
    <gmd:sourceCitation>  
      <gmd:CI_Citation>  
        <gmd:title>  
          <gco:CharacterString>LO Instrument data for band  
            1</gco:CharacterString>  
        </gmd:title>  
        <gmd:alternateTitle>  
          <gmx:FileName>S5P_OPER_LO__ODB_1_20140827T103500_20140827T104000  
            _53811_00.RAW</gmx:FileName>  
        </gmd:alternateTitle>  
        <gmd:alternateTitle>  
          <gmx:FileName>S5P_OPER_LO__ODB_1_20140827T104000_20140827T104500  
            _53811_01.RAW</gmx:FileName>  
        </gmd:alternateTitle>  
        <gmd:alternateTitle>  
          <gmx:FileName>S5P_OPER_LO__ODB_1_20140827T104500_20140827T105000  
            _53811_02.RAW</gmx:FileName>  
        </gmd:alternateTitle>  
        <gmd:alternateTitle>  
          <gmx:FileName>S5P_OPER_LO__ODB_1_20140827T105000_20140827T105500  
            _53811_03.RAW</gmx:FileName>  
        </gmd:alternateTitle>  
        <gmd:alternateTitle>  
          <gmx:FileName>S5P_OPER_LO__ODB_1_20140827T105500_20140827T110000  
            _53811_04.RAW</gmx:FileName>  
        </gmd:alternateTitle>  
        <gmd:alternateTitle>  
          <gmx:FileName>S5P_OPER_LO__ODB_1_20140827T110000_20140827T110500  
            _53811_05.RAW</gmx:FileName>
```

```
</gmd:alternateTitle>
  <gmd:date>
    <gmd:CI_Date>
      <gmd:date>
        <gco>Date>2014-08-27</gco>Date>
      </gmd:date>
      <gmd:dateType>
        <gmd:CI_DateTypeCode>
          codeList="http://www.isotc211.org/2005/resources/Codelist/
gmxCodelists.xml#CI_DateTypeCode"
          codeListValue="creation">creation</gmd:CI_DateTypeCode>
        </gmd:dateType>
      </gmd:CI_Date>
    </gmd:date>
  </gmd:CI_Citation>
</gmd:sourceCitation>
<gmi:processedLevel>
  <gmd:MD_Identifier>
    <gmd:code>
      <gco:CharacterString>L0</gco:CharacterString>
    </gmd:code>
  </gmd:MD_Identifier>
</gmi:processedLevel>
</gmi:LE_Source>
</gmd:source>
<gmi:output>
  <gmi:LE_Source>
    <gmd:description>
      <gco:CharacterString>TROPOMI L1b radiance
product</gco:CharacterString>
    </gmd:description>
    <gmd:sourceCitation>
      <gmd:CI_Citation>
        <gmd:title>
          <gmx:FileName>S5P_OFFL_L1B_RA_BD1_20151114T112005_20151114T125934_
00140_02_010203_20151204T093045.nc</gmx:FileName>
        </gmd:title>
        <gmd:date>
          <gmd:CI_Date>
            <gmd:date>
              <gco>Date>2015-12-04</gco>Date>
            </gmd:date>
            <gmd:dateType>
              <gmd:CI_DateTypeCode>
                codeList="http://www.isotc211.org/2005/resources/Codelist/
gmxCodelists.xml#CI_DateTypeCode"
                codeListValue="creation">creation</gmd:CI_DateTypeCode>
              </gmd:dateType>
            </gmd:CI_Date>
          </gmd:date>
        </gmd:CI_Citation>
      </gmd:sourceCitation>
    <gmi:processedLevel>
      <gmd:MD_Identifier>
        <gmd:code>
          <gco:CharacterString>L1b</gco:CharacterString>
        </gmd:code>
      </gmd:MD_Identifier>
```

```
</gmi:processedLevel>
</gmi:LE_Source>
</gmi:output>
<gmi:processingInformation>
  <gmi:LE_Processing>
    <gmi:identifier>
      <gmd:MD_Identifier>
        <gmd:code>
          <gco:CharacterString>KNMI TROPOMI L01b
            processor</gco:CharacterString>
        </gmd:code>
      </gmd:MD_Identifier>
    </gmi:identifier>
    <gmi:softwareReference>
      <gmd:CI_Citation>
        <gmd:title>
          <gco:CharacterString>L01b processor
            description</gco:CharacterString>
        </gmd:title>
        <gmd:date>
          <gmd:CI_Date>
            <gmd:date>
              <gco:Date>2014-12-31</gco:Date>
            </gmd:date>
            <gmd:dateType>
              <gmd:CI_DateTypeCode
                codeList="http://www.isotc211.org/2005/resources/Codelist/
                  gmxCodelists.xml#CI_DateTypeCode"
                codeListValue="creation">creation</gmd:CI_DateTypeCode>
              </gmd:dateType>
            </gmd:CI_Date>
          </gmd:date>
        </gmd:CI_Citation>
      </gmi:softwareReference>
    <gmi:documentation>
      <gmd:CI_Citation>
        <gmd:title>
          <gmx:FileName>S5P-KNMI-L01B-0009-SD-algorithm_theoretical_
            basis_document-8.0.0-20170601.pdf</gmx:FileName>
        </gmd:title>
        <gmd:date>
          <gmd:CI_Date>
            <gmd:date>
              <gco:Date>2017-06-01</gco:Date>
            </gmd:date>
            <gmd:dateType>
              <gmd:CI_DateTypeCode
                codeList="http://www.isotc211.org/2005/resources/Codelist/
                  gmxCodelists.xml#CI_DateTypeCode"
                codeListValue="publication">publication
              </gmd:CI_DateTypeCode>
            </gmd:dateType>
          </gmd:CI_Date>
        </gmd:date>
      </gmd:CI_Citation>
    </gmi:documentation>
  <gmi:documentation>
    <gmd:CI_Citation>
```

```
<gmd:title>
  <gmx:FileName>S5P-KNMI-L01B-0012-SD-input_output_data_
    specification-9.0.0-20180401.pdf</gmx:FileName>
</gmd:title>
<gmd:date>
  <gmd:CI_Date>
    <gmd:date>
      <gco>Date>2018-04-01</gco>Date>
    </gmd:date>
    <gmd:dateType>
      <gmd:CI_DateTypeCode
        codeList="http://www.isotc211.org/2005/resources/Codelist/
          gmxCodelists.xml#CI_DateTypeCode"
        codeListValue="publication">publication
      </gmd:CI_DateTypeCode>
    </gmd:dateType>
  </gmd:CI_Date>
</gmd:date>
</gmd:CI_Citation>
</gmi:documentation>
</gmi:LE_Processing>
</gmi:processingInformation>
<gmi:report>
  <gmi:LE_ProcessStepReport>
    <gmi:name>
      <gco:CharacterString>TROPOMI L01b processing
        report</gco:CharacterString>
    </gmi:name>
    <gmi:description>
      <gco:CharacterString>L0 processed to L1b data using the KNMI TROPOMI
        L01b processor</gco:CharacterString>
    </gmi:description>
    <gmi:fileType>
      <gco:CharacterString>netCDF-4</gco:CharacterString>
    </gmi:fileType>
  </gmi:LE_ProcessStepReport>
</gmi:report>
</gmi:LE_ProcessStep>
</gmd:processStep>
</gmd:LI_Lineage>
</Variable_Header>
</Earth_Explorer_Header>
</Earth_Explorer_File>
```