COPERNICUS SPACE COMPONENT SENTINEL OPTICAL IMAGING

MISSION PERFORMANCE CLUSTER SERVICE

# Sen2Cor and Sen2Water Input-Output Data Definition


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## Changes Log

| Version | Date | Changes |
|---|---|---|
| 1.0.0 | 2014-03-27 | Creation |
| 2.3.0 | 2016-11-25 | Update for Sen2Cor V.2.3.0 |
| 2.4.0 | 2017-07-18 | Update for Sen2Cor V.2.4.0 |
| 2.6.0 | 2018-02-23 | Updates for Sen2Cor V.2.6.1:<br>Updated all GIPP Schemes and description<br>Resolved RIDS from TAS. |
| 2.7.0 | 2018-09-21 | Updates for Sen2Cor V.2.7.0: added GIPPs for Database compression factor and disabling of terrain correction with DEM. Added further command line parameters for determining database location. |
| 2.8.0 | 2019-01-29 | Updates for Sen2Cor V.2.8.0: removed parameter Nr_Processes and added parameters Nr_Treads and Ac_Dem_P2p_Val |
| 2.9.0 | 2020-07-01 | Updates for Sen2Cor V.2.9.0: added parameters for Section Region_Of_Interest and Force_Exit_On_DEM_Errors |
| 2.10.0 | 2021-12-13 | Updates for Sen2Cor V.2.10: updated with all the new input and output information from PSD-14.9 and Evolutionary Upgrades. |
| 2.10.02 | 2021-04-19 | Updates mirroring changes within Sen2Cor 2.10.02 |
| 2.11.0 | 2022-11-21 | Updates mirroring changes within Sen2Cor 2.11 |
| 3.0.0 | 2023-08-31 | MSI L2 processor with extended scope of Sen2Cor and Sen2Water |
| 3.1 | 2024-01-17 | Sen2Water processors modified to use ancillary data included in MSI L1C and Copernicus 90m DEM |
| I1r1 | 2024-12-04 | Updates with Sen2Water implementation |

## List of Changes

| Version | Section | Answers to RID | Changes |
|---|---|---|---|
| 3.1 | 4.2 | - | Idepix modified to use Copernicus DEM. |
| | 4.3.3 | - | C2RCC modified to use Copernicus DEM.<br>C2RCC uses ancillary data included in MSI L1C. |
| | 4.4.2, 4.4.3 | - | ACOLITE modified to use ancillary data included in MSI L1C. |
| | 4.5.2 | - | POLYMER modified to use ancillary data included in MSI L1C. |

| | | | |
|---|---|---|---|
| | 4.6.4 | - | Flag values of pixel_class adapted to current implementation.<br>Flag values of sen2water_flags defined according to current impl. |
| I1r1 | 4.2<br><br>4.7.3<br>4.8.4 | | New section on inputs and outputs of TOA Glint Correction<br><br>Flag value OUT_OF_BOUNDS_SATURATED renamed to AC_OUT_OF_BOUNDS (Sen2Water v0.5 onwards) |

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# 1 Introduction

## 1.1 Purpose and scope

This Input Output Data Definition (IODD) document defines the inputs and outputs of the different modules or steps of the Sen2Cor and Sen2Water and combined processing chains. Inputs comprise main data products, ancillary data, and parameters either as Ground Image Processing Parameters (GIPP) XML or as attribute values. Outputs are in most cases intermediate data products that serve as input to subsequent steps of the chain.

This IODD distinguishes Sen2Cor and Sen2Water. Sen2Cor is split into the steps of scene classification, the steps of atmospheric correction with AOT and WV retrieval, several additional processes, and the generation of quality masks. Sen2Water is split into resampling, pixel identification, different AC modules, and blending.

There has been a predecessor [OMPC.TPZG.IOD.001 2022] of this document for Sen2Cor which has been transferred mainly unmodified into section 3. Similarly to [OMPC.TPZG.IOD.001 2022], his version of the document covers Sen2Cor 2.10 and updates for 2.11 with the corrective, perfective maintenance and evolutions [OMPC-TPZG-SRN-003].

This document now covers the planned initial version of Sen2Water, and it also contains the description of the merged Level 2 data product. This description will be migrated to the PSD as soon as the PSD will be updated in the course of the Sen2Water project.

Related documents identify requirements for Sen2Water [MSI L2 SDD 2023]. The Software Design Document [MSI L2 SDD 2023] defines functional elements and software structures of Sen2Cor and Sen2Water. The Algorithm Theoretical Basis Document [MSI L2 ATBD 2023] defines the algorithms of the functional elements.

## 1.1 References

The following documents are referenced in this document.

| Document ID | Description | Version |
|---|---|---|
| OMPC.TPZG.IOD.001 2022 | Sen2Cor 2.11.00 Input Output Data Definition, Optical Mission Performance Centre, ESA, November 2023 | 2.11 |
| MSI L2W RD 2023 | Sen2Water Requirements Document, OMPC.BC.RD-MSI-L2, Optical Mission Performance Centre, ESA, October 2023 | 1.0 |
| MSI L2 ATBD 2023 | Sen2Cor and Sen2Water Algorithm Theoretical Basis Document, OMPC.TPGZ-BC.ATBD-MSI-L2, Optical Mission Performance Centre, ESA, October 2023 | 1.0 |

| Document ID | Description | Version |
|---|---|---|
| S2-PDGS-MPC-L2A-ATBD | Sentinel-2 MSI - Level 2A Products, Algorithm Theoretical Basis Document | 2.10 |
| MSI-L2-SDD 2023 | Sen2Cor and Sen2Water Software Design Document, OMPC.TPGZ-BC.SDD-MSI-L2, Optical Mission Performance Centre, ESA, October 2023 | 1.0 |
| S2-PSD | Sentinel-2 Products Specification Document, *S2-PDGS-TAS-DI-PSD,* ESA | 14.9 |
| S2-PDGS-MPC-L2A-PFS | Sentinel-2 MSI – Product Format Specification | 14.9 |
| OMPC-TPZG-SUM-001 | Sentinel-2 MSI – Level 2A Prototype Processor Installation and User Manual | 2.11 |
| OMPC-TPZG-SRN-003 | Sentinel-2 MSI – Level 2A Prototype Processor Software Release Note | 2.11 |

## 1.2 Acronyms

The following acronyms are used within this document:

| Acronym | Description |
|---|---|
| ATBD | Algorithm Theoretical Basis Document |
| C2RCC | Case-2 Regional Coast Colour |
| CAMS | Copernicus Atmospheric Monitoring Service |
| CGLOPS | Copernicus Global Land Service |
| CMEMS | Copernicus Marine Service |
| ESA | European Space Agency |
| HR-OC | High Resolution Ocean Colour |
| IODD | Input Output Data Definition |
| L1C | Level 1C |
| L2 | Level 2 |
| L2A | Level 2A |
| L2W | Level 2 Water |
| MSI | MultiSpectral Instrument |
| OMPC | Optical Mission Performance Centre |

| Acronym | Description |
|---|---|
| PDGS | Payload Data Ground Segment |
| RD | Requirements Document |
| S2W | Sen2Water |
| SAFE | Standard Archive Format for Europe |
| SDD | Software Design Document |
| SNAP | Sentinel Application Platform (and Sentinel Toolboxes) |

## 1.3 Document overview

After this formal introduction

Section 2 describes the Sentinel-2 MSI L1C data product that is the main input of both Sen2Cor and Sen2Water. The two formats are the end user product (EUP) for the stand-alone versions and the granule product data item (PDI) format for the PDGS processor.

Section 3 identifies input, output, and parameters of the steps of the Sen2Cor processing chain. The steps are scene classification, the different steps of atmospheric correction, quality mask creation, and product generation.

Section 4 describes the inputs, metadata, auxiliary data, parameters, and outputs of the steps of Sen2Water. These steps are resampling, pixel identification, the three atmospheric correction steps, a selection and blending step, and a final formatting step.

Section 5 defines inputs and outputs of the combined Sen2Cor and Sen2Water processor, mainly by reference to previous sections.

Section 6 defines the combined L2A data product. This section will later be moved to the PSD.

# 2 The L1C PDI and EUP input data products

This section describes the Sentinel-2 MSI L1C data product that is the main input of both Sen2Cor and Sen2Water. Sen2Cor and Sen2Water will run in two configurations, one as part of the PDGS L2 processor, and one with each running stand-alone by end users. In the PDGS L2 processor the granule Product Data Item (PDI) format is the L1C input. In the stand-alone configurations or the End User Product EUP format is main input of the processors.

***Table 2-1 – L1C Image data specification***

| **Name** | **Level-1C** |
|---|---|
| Parent Product | L1C, TOA Reflectance |
| Coverage | Regional. 110 km x 110 km |
| Packaging | MGRS Tiles (same area coverage as Level 1C input data) |
| Geo-location accuracy | Identical to the level 1C geo-location performance |
| Frequency | 5 days repeat cycle with two Sentinel-2 satellites |
| Format | JPEG2000 |
| Unit | Dimensionless, Unsigned Integer 15 bit |
| Calibration and Range | Quantification value: 10000<br>Radiometric offset: 1000<br>i.e.: Digital Numbers [1000 , 11000], representing radiometric reflectance values from 0.0 to 1.0<br>Reflectance = (DN – 1000) / 10000 |
| Sampling | 16 bit/pixel |
| **Channels and Resolution** | **Resolution (m)** |
| B1 (443nm) | 60 |
| B2 (490nm) | 10 |
| B3 (560nm) | 10 |
| B4 (665nm) | 10 |
| B5 (705nm) | 20 |
| B6 (740nm) | 20 |
| B7 (783nm) | 20 |
| B8 (842nm) | 10 |
| B8a (865nm) | 20 |
| B9 (945nm) | 60 |
| B10 (1375) | 60 |
| B11 (1610nm) | 20 |
| B12 (2190nm) | 20 |

Processing baseline 04.00 or higher is suitable for the data processor. This includes NRT products since 2022-01-25 and reprocessed products of earlier acquisition times.

## 2.1 Logical structure

The Sentinel-2 MSI L1C input data product is defined in (MSI-PSD, 2021). It contains

- Top-of-atmosphere reflectances in 10m (B2, B3, B4, B8), 20m (B5, B6, B7, B8A, B11, B12), and 60m (B1, B9, B10), encoded as 16 bit unsigned integer
- Masks for detector and quality information per band, with the same resolution as the respective band, and a snow/ice mask and cloud mask at 60m resolution
- SZA and SAA on a 5 km tie-point grid
- VZA and VAA, one pair per band (13) and detector (12), on a 5 km tie-point grid, partially filled
- ECMWF auxiliary data TCO3, TCWV, MSL pressure, 10u and 10v wind components, relative humidity on a tie-point grid with 9x9 pixels.
- CAMS auxiliary data aod550, geopotential z, bcaod550, duaod550, omaod550, ssado550, suaod550, aod469, aod670, aod865, aod1240 on a tie-point gird with 9x9 pixels
- A quicklook RGB with a resolution lowered by a factor of 32 (343x343 pixels) and a full resolution RGB
- Product level metadata with acquisition information, processing information, radiometric offsets per band, reflectance conversion parameters, band characteristics, product-level quality information

Product level metadata and the quicklook are included in the EUP format but not in the PDI format of the L1C.

## 2.2 Physical structure

The Sentinel-2 MSI L1C is provided in SAFE format with the physical layout of the directory structure as follows (shown by an example, EUP format):

```
S2A_MSIL1C_20230610T110621_N0509_R137_T31UCU_20230610T144925.SAFE/
├── DATASTRIP
│   └── DS_2APS_20230610T144925_S20230610T110622
│       ├── MTD_DS.xml
│       └── QI_DATA
│           ├── FORMAT_CORRECTNESS.xml
│           ├── GENERAL_QUALITY.xml
│           ├── GEOMETRIC_QUALITY.xml
│           ├── RADIOMETRIC_QUALITY.xml
│           └── SENSOR_QUALITY.xml
├── GRANULE
│   └── L1C_T31UCU_A041604_20230610T110622
│       ├── AUX_DATA
│       │   ├── AUX_CAMSFO
```

```
│   │   └── AUX_ECMWFT
│   ├── IMG_DATA
│   │   ├── T31UCU_20230610T110621_B01.jp2
│   │   ├── T31UCU_20230610T110621_B02.jp2
│   │   ├── T31UCU_20230610T110621_B03.jp2
│   │   ├── T31UCU_20230610T110621_B04.jp2
│   │   ├── T31UCU_20230610T110621_B05.jp2
│   │   ├── T31UCU_20230610T110621_B06.jp2
│   │   ├── T31UCU_20230610T110621_B07.jp2
│   │   ├── T31UCU_20230610T110621_B08.jp2
│   │   ├── T31UCU_20230610T110621_B09.jp2
│   │   ├── T31UCU_20230610T110621_B10.jp2
│   │   ├── T31UCU_20230610T110621_B11.jp2
│   │   ├── T31UCU_20230610T110621_B12.jp2
│   │   ├── T31UCU_20230610T110621_B8A.jp2
│   │   └── T31UCU_20230610T110621_TCI.jp2
│   ├── MTD_TL.xml
│   └── QI_DATA
│       ├── FORMAT_CORRECTNESS.xml
│       ├── GENERAL_QUALITY.xml
│       ├── GEOMETRIC_QUALITY.xml
│       ├── MSK_CLASSI_B00.jp2
│       ├── MSK_DETFOO_B01.jp2
│       ├── ...
│       ├── MSK_DETFOO_B12.jp2
│       ├── MSK_DETFOO_B8A.jp2
│       ├── MSK_QUALIT_B01.jp2
│       ├── ...
│       ├── MSK_QUALIT_B12.jp2
│       ├── MSK_QUALIT_B8A.jp2
│       ├── SENSOR_QUALITY.xml
│       └── T31UCU_20230610T110621_PVI.jp2
├── HTML
│   ├── banner_1.png
│   ├── banner_2.png
│   ├── banner_3.png
│   ├── star_bg.jpg
│   ├── UserProduct_index.html
│   └── UserProduct_index.xsl
├── INSPIRE.xml
├── manifest.safe
├── MTD_MSIL1C.xml
├── rep_info
│   └── S2_User_Product_Level-1C_Metadata.xsd
└── S2A_MSIL1C_20230610T110621_N0509_R137_T31UCU_20230610T144925-ql.jpg
```

The example is generic in the sense that only the product name, the datastrip name, and the granule name are specific for a data product item. The structure is related to the content as follows:

- The DATASTRIP directory contains metadata of the (larger) datastrip.
- The GRANULE/<name> directory contains tile metadata (angles, XML format)
- The IMG_DATA subdirectory of the granule contains the main bands in JPEG2000 format.
- The QI_DATA subdirectory of the granule contains masks in JPEG2000 format

- The AUX_DATA subdirectory of the granule contains dynamic auxiliary data in GRIB format.
- The product-level metadata is provided as XML file on the top level.

In the PDI format the product level metadata, quicklook image, datastrip directory are missing.

The schema of the tile metadata XML file MTD_TL.xml is provided in (MSI-PSD, 2021) in section 3.11.3.1. The file contains sun zenith angle and sun azimuth angle on a tie-point grid. It contains incidence zenith and azimuth angle for each of the 13 bands and within each band for several detectors each partially covering the scene on the same coarse-grained grid.

The schema of the product level metadata XML file MTD_MSIL1C.xml is provided in (MSI-PSD, 2021) section 4.9.7.1 .The file contains sections with general metadata, geometric information, auxiliary data, and quality indicators. Within the general information there is the radiometric offset list to be applied when reading TOA reflectance values. For the PDI format the offset information must be derived from the product baseline version. (It had changed from version 04.00 onwards.)

## 2.3 Naming convention

Names of L1C single-tile EUR input products follow a naming convention defined in (MSI-PSD, 2021) section 4.9.11 .

`MMM_MSIL1C_YYYYMMDDTHHMMSS_Nxxyy_ROOO_Txxxxx_<Product Discriminator>`

where:

- `MMM`: is the mission ID (S2A/S2B)
- `YYYYMMDDTHHMMSS`: is the Datatake Sensing Time
- `xxyy`: identifies the current processing baseline
- `OOO`: is the relative orbit number
- `Txxxxx`: is the tile ID
- `<Product Discriminator>`: this field guarantees the uniqueness of the Single Tile product name; its value is the Level-1C Single Tile product CREATION DATE in the format yyyymmddThhmmss.

Example:

`S2A_MSIL1C_20230610T110621_N0509_R137_T31UCU_20230610T144925`

The PDI-formatted products are named using the following convention:

`MMM_cccc_MSI_L1C_TL_ssss_YYYYMMDDTHHMMSS_Afffffff_Txxxxx_Nxxyy`

where (in addition to the above replacements):

- `cccc`: file class, OPER or TEST
- `ssss`: site/centre, e.g. 2APS
- `ffffff`: is the absolute orbit number

Example:

`S2A_OPER_MSI_L1C_TL_2APS_20230412T055106_A040756_T48TUT_N05.09`

# 3 Inputs and outputs of steps of Sen2Cor

This chapter identifies input, output, and parameters of the steps of the Sen2Cor processing chain. The steps are scene classification, the different steps of atmospheric correction, quality mask creation, and product generation. For Sen2Cor step parameters are provided in a GIPP file. A reference sub-section at the end of this section describes additional GIPP expert settings.

This chapter is an extract from the current L2A IODD referenced hereafter: [OMPC.TPZG.IOD.001 2022] - i1r0 - Sen2Cor 2.11.00 IODD (2022), Sen2Cor 2.11.00 Input Output Data Defintiion. Telespazio, OMPC, ESA

Please refer to the original IODD document for complete description of the Sen2Cor stand-alone processor.

## 3.1 Parameters and auxiliary data of the Sen2Cor module

This section lists I/O data and parameters that are related to the basic operation of the processor.

### 3.1.1 GIPP

GIPPs are configured in an XML file named `L2A_GIPP.xml`, located in the <cfg> subdirectory of the Sen2Cor home directory which is specified by the environment variable $SEN2COR_HOME, and can be configured by the user. Exceptions, which should not be configured by standard users, are marked with an asterisk (*).

The file is subsequently copied into the AUX_DATA subfolder of the corresponding granule for documentation purposes.

Within this IODD the GIPP are listed within their current processing context. Figure 3-1 and Table 3-1 show and describe the GIPP, which are common for the overall processing. Specific GIPPs are listed in the corresponding subsections separated for each sub-processing step.

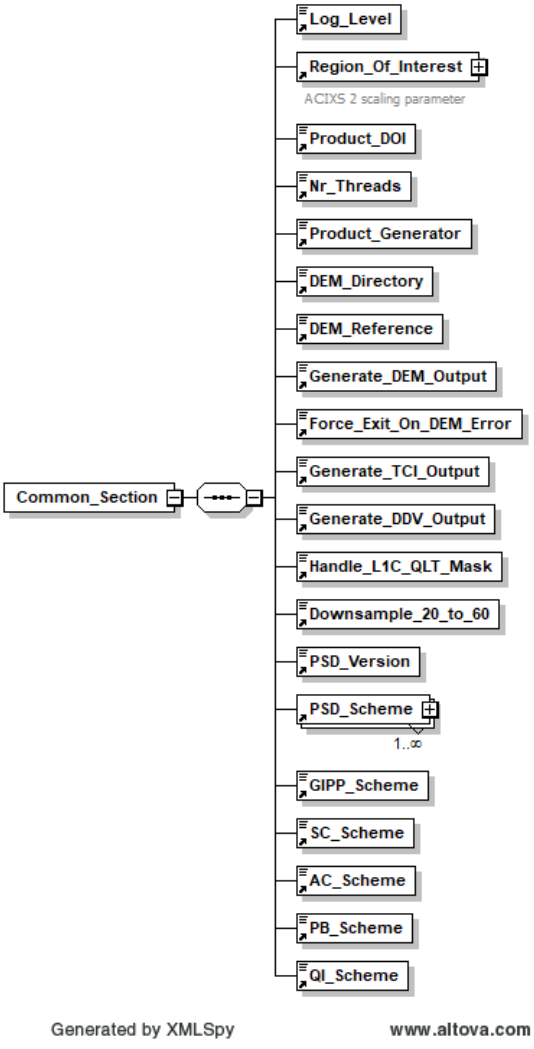


***Figure 3-1 – GIPP of Common Section***

*Table 3-1 – Common GIPP*

| Field Name | Documentation | Type |
|---|---|---|
| Log_Level | Verbosity level of the tracing output, located in the GRANULE/<GRANULE>/QI_DATA folder. | Enumerator:<br>NOTSET, DEBUG, INFO, WARNING, ERROR, CRITICAL |
| Region_Of_Interest | This section has been established with release 2.9.0. It contains four parameters which define a configurable Region of Interest (ROI):<br>• row0<br>• col0<br>• nrow_win<br>• ncol_win<br><br>row0, col0, nrow_win and ncol_win must be integer divisible by 6, to prevent rounding errors for downsampling. See SUM for Details. | Choice:<br>Off, AUTO or:<br>Unsigned Integer Values [0:10979]<br>if row0 == OFF: a standard processing without ROI detection is performed;<br>if row0 == AUTO: a region of interest is detected automatically via an algorithm;<br>Else:<br>row0, col0: specify the midpoint of the region of interest, nrow_win, ncol_win define a rectangle around the midpoint within a frame of 10980 x 10980 pixel |
| Product DOI (Since Sen2Cor 2.10) | DOI: Digital Object Identifier. This Object identifier is implemented since Sen2Cor 2.10 for PSD Versions 14.7 and above. The URL shall be inserted as a configuration item in this entry (The official URL is provided by ESA) | URL |
| Nr_Threads | This parameter allowing the usage of multithreading to speed up the reading of the L1C input images. above). It is set to AUTO by default, which detects the amount of usable threads by calling cpu_count(). If the user does not want this feature or want to set the amount of threads individually, the parameter can be changed between a value of 1 (which is single thread processing, as before) up to 8. | Choice:<br>AUTO or:<br>Unsigned Integer Value [1:8] |
| Product Generator<br>(Since Sen2Cor 2.10) | This parameter foresees the usage of the PDGS PSD converter in the toolbox mode.<br>Not yet implemented. | Choice:<br>Directory where the converter is located or 'NONE' |

| Field Name | Documentation | Type |
|---|---|---|
| DEM_Directory | Location of optional Digital Elevation Map: can be either a directory in the sen2cor home folder or 'NONE'. If NONE, no DEM will be used.<br>Example: 'dem/srtm'. DEM will be searched in:<br><SEN2COR_HOME>/dem/srtm | Choice:<br>NONE or String (relative directory path) |
| DEM_Reference | If no suitable DEM is found in the DEM directory, the processor tries to download a DEM from the given reference.<br>-Copernicus DEM<br>Sen2Cor 2.11 supports the downloadable Copernicus DEM in a specific format. The link is provided in the [OMPC-TPZG-SUM-001]<br>-SRTM<br>the freely available CGIAR 90 m resolution DEM, which can be downloaded following:<br>http://data_public:GDdci@data.cgiar-csi.org/srtm/tiles/GeoTIFF<br>https://srtm.csi.cgiar.org/disclaimer/ | URL |
| Generate_DEM_Output | FALSE: no DEM output, TRUE: store DEM in the AUX data directory | FALSE or TRUE |
| Force_Exit_On_DEM_Error | This parameter has been established with release 2.9.0: if set to FALSE, processing continues with a flat surface, if a DEM is not found or cannot be downloaded. If set to TRUE, processing will be stopped. | FALSE or TRUE |
| Generate_TCI_Output | FALSE: no TCI output, TRUE: store TCI in the IMAGE data directory | FALSE or TRUE |
| Generate_DDV_Output | FALSE: no DDV output, TRUE: store DDV in the QI_DATA directory | FALSE or TRUE |
| Handle_L1C_QLT_Mask<br>(Since Sen2Cor 2.10) | FALSE: no handling of the L1C Quality Mask. TRUE: handling L1C Quality Mask | FALSE or TRUE |
| Downsample_20_to_60 | TRUE: create additional 60m bands when 20m is processed | FALSE or TRUE |

| Field Name | Documentation | Type |
|---|---|---|
| PSD_Version (Sen2Cor 2.10.01 and up) | Special entry for forcing a special PSD version to be processed. DEFAULT: automatic detection of the PSD version. | DEFAULT or PSD version |
| PSD_Scheme (*) | List of supported PSD Versions:<br>V 14.2 – V.14.6 (Sen2Cor 2.9.0)<br>V 14.9 (Sen2Cor 2.10)<br>Properties:<br>• Version: The PSD Versions<br>• PSD_Reference: the names of the available PSD schemes<br>Names:<br>UP_Scheme_1C: <name><br>UP_Scheme_2A: <name><br>Tile_Scheme_1C <name><br>Tile_Scheme_2A <name><br>DS_Scheme_1C: <name><br>DS_Scheme_2A: <name><br>Remark: these schemes are used for validation of the in- and output metadata. The configuration should not be changed by the user | XML List of strings |
| GIPP_Scheme (*) | Name of the xsd scheme for the base GIPP (this file, used for validation purposes) | String (filename). Default is L2A_GIPP |
| SC_Scheme (*) | Name of the xsd scheme for the expert calibration GIPP for scene classification (used for validation purposes, not foreseen to be configured by standard uses). | String (filename). Default is: L2A_CAL_SC_GIPP |
| AC_Scheme (*) | Name of the xsd scheme for the expert calibration GIPP for the atmospheric correction (used for validation purposes, not foreseen to be configured by standard uses). | String (filename). Default is:L2A_CAL_AC_GIPP |
| PB_Scheme (*) | Name of the xsd scheme for the Processing Baseline. | String (filename). Default is:L2A_PB-_GIPP |
| QI_Scheme(*) (Sen2Cor 2.10.01) | Name of the xsd scheme for the L2A_Quality report | String (filename). Default is:L2A_QUALITY |

For a full list of all types, parameters, and default values, please consult the embedded PDF in the 3.6.4.

### 3.1.2 Metadata

Metadata (Table 3-2) are read out directly from the Level 2A Tile metadata XML file after being generated from the corresponding Level-1C User product.

*Table 3-2 – Metadata input fields (see L2A-PFS for details)*

| Field Name | Documentation | Type |
|---|---|---|
| ZENITH_ANGLE | Incidence angles | Floating point 32 bit |
| AZIMUTH_ANGLE | Incidence angles | Floating point 32 bit |
| Zenith | Grids for Zenith Viewing Incidence Angle values (0 - 70°) | Floating point array 32 bit |
| Azimuth | Grids for Azimuth Viewing Incidence Angle values (0 – 360°) | Floating point array 32 bit |
| QUANTIFICATION_VALUE | Digital Number of L1C Input bands, dimensionless, 0 :10.000 corresponds to TOA reflectance 0 : 1 | Unsigned Integer |
| ECMWF_DATA_REFERENCE | Filename of the ECMWF data located in the GRANULE/AUX_DATA folder | String (filename) |
| Radiometric_Offset_List (Sen2Cor 2.10) | List of band dependent radiometric offset | Integer |

### 3.1.3 Auxiliary Data

*Table 3-3 – Aux_Data*

| Field Name | Documentation | Type |
|---|---|---|
| DEM | Digital Elevation Map, user configurable image data located in $SEN2COR_HOME, directory, configurable via L2A_GIPP, see Table 3-1 – Common GIPP<br>Unit: m | Input in GeoTiff or Dted format (dt1, dt2)<br>In output of Sen2Cor, as OpenJPEG is only able to store unsigned integer values, an offset of +10.000 is applied to each DEM allowing for negative heights. The scale of the DEM is thus (meter – 10.000).<br>Integer, 16 bit |

| Field Name | Documentation | Type |
|---|---|---|
| AUX_ECMWF, located in the GRANULE/AUX_DATA folder | Raster data of Block Size 9:9 in GRIB Format, 6 Bands, specifying:<br>B1: Precipitable water content [kg/m^2]<br>B2: Mean sea level pressure [Pa]<br>B3: Total column ozone Dobson [kg/m^2]<br>B4: 10m U wind component [m/s]<br>B5: 10m V wind component [m/s]<br>B6: Relative humidity [%] | Float 64 |
| AUX_CAMSxx<br>(Since Sen2Cor 2.10) | Raster data of Block Size 9:9 in GRIB Format, 11 bands of which the following are used:<br>-Total Aerosol Optical Depth at 550nm (aod550);<br>- Surface Geopotential (z) | Float 64 |

### 3.1.4 QI Data

***Table 3-4 – QI_Data***

| Field Name | Documentation | Type |
|---|---|---|
| MSK_QUALIT_BXX<br>(Sen2Cor 2.10) | List of band-depended quality masks to populate the L2A SCL defective pixel class. | Integer (0,1) |

### 3.1.5 Output Data

Outputs are classified specifically for the corresponding procedures in the equivalent sections for the sub modules.

### 3.1.6 Command Line Parameters

In the following Table 3-5, the list of the command line parameters can be found. Lists are provided for both the PDGS and Toolbox modes.

***Table 3-5 – Command Line Parameters***

**Command Line Parameters ("Toolbox" mode. L1C product as input_dir)**

```
L2A_Process --h
usage: L2A_Process.py [-h] [--mode MODE] [--resolution {10,20,60}]
                      [--datastrip DATASTRIP] [--tile TILE]
                      [--output_dir OUTPUT_DIR] [--work_dir WORK_DIR]
                      [--img_database_dir IMG_DATABASE_DIR]
                      [--res_database_dir RES_DATABASE_DIR]
                      [--processing_centre PROCESSING_CENTRE]
                      [--archiving_centre ARCHIVING_CENTRE]
                      [--processing_baseline PROCESSING_BASELINE] [--raw]
                      [--tif] [--sc_only] [--sc_classic] [--sc_cog]
                      [--cr_only] [--debug] [--GIP_L2A GIP_L2A]
                      [--GIP_L2A_SC GIP_L2A_SC] [--GIP_L2A_AC GIP_L2A_AC]
                      [--GIP_L2A_PB GIP_L2A_PB]
                      input_dir
Sen2Cor. Version: 2.11.00, created: 2022.10.20, supporting Level-1C product version 14.2 - 14.9.
positional arguments:
  input_dir             Directory of Level-1C input
optional arguments:
  -h, --help            show this help message and exit
  --mode MODE           Mode: generate_datastrip, process_tile
  --resolution {10,20,60}
                        Target resolution, can be 10, 20 or 60m. If omitted,
                        only 20 and 10m resolutions will be processed
  --datastrip DATASTRIP
                        Datastrip folder
  --tile TILE           Tile folder
  --output_dir OUTPUT_DIR
                        Output directory
  --work_dir WORK_DIR   Work directory
  --img_database_dir IMG_DATABASE_DIR
                        Database directory for L1C input images
  --res_database_dir RES_DATABASE_DIR
                        Database directory for results and temporary products
  --processing_centre PROCESSING_CENTRE
                        Processing centre as regex: ^[A-Z_]{4}$, e.g "SGS_"
  --archiving_centre ARCHIVING_CENTRE
                        Archiving centre as regex: ^[A-Z_]{4}$, e.g. "SGS_"
  --processing_baseline PROCESSING_BASELINE
                        Processing baseline in the format: "dd.dd", where
```

```
                    d=[0:9]
--raw               Export raw images in rawl format with ENVI hdr
--tif               Export raw images in TIFF format instead of JPEG-2000
--sc_only           Performs only the scene classification at 60 or 20m
                    resolution
--sc_classic        Performs scene classification in Sen2Cor 2.9 mode
--sc_cog            Export SCL image in COG format instead of JPEG_2000
--cr_only           Performs only the creation of the L2A product tree, no
                    processing
--debug             Performs in debug mode
--GIP_L2A GIP_L2A   Select the user GIPP
--GIP_L2A_SC GIP_L2A_SC  Select the scene classification GIPP
--GIP_L2A_AC GIP_L2A_AC Select the atmospheric correction GIPP
--GIP_L2A_PB GIP_L2A_PB  Select the processing baseline GIPP
```

## 3.2 Scene Classification

### 3.2.1 Input Data

L1C Image data as specified in Section 2, resampled to the requested resolution of 60, 20, 10 m.

### 3.2.2 GIPP

Figure  shows the GIPP of the Scene Classification Module, while Table 3-6 describes the related input.

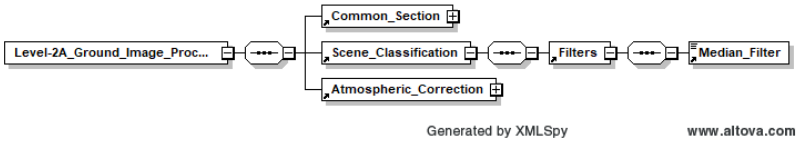


*Figure 3-2 – GIPP of Scene Classification*

For a full list of all types, parameters and default values, please consult the embedded PDF in 3.6.4. With Sen2Cor 2.11 the improved Scene Classification Evolution is used as default. User can switch to the classic algorithm by the command line –sc_classic. From Sen2Cor 2.10, the dedicated optional command line (--sc_cog) saves the Scene Classification output in COG (Cloud Optimized Geotiff) format.

*Table 3-6 – GIPP of Scene Classification*

| Field Name | Documentation | Type |
|---|---|---|
| Median_Filter | Digital Filter for smoothing of Classification map. | Unsigned Integer, recommended values 0:3, Default: 0 |

#### 3.2.2.1 Expert Level

GIPP for the Scene Classification on Expert Level are separated from the standard User level and are collected in a different file, named `L2A_CAL_SC_GIPP.xml`. Whereas `L2A_GIPP.xml` is a pure user configuration file and thus is available for a standard user, the Expert level GIPPs are reserved for testing and calibration campaigns. Wrong calibrations might lead to heavy performance artefacts. The description of these parameters is thus postponed to Section 3.6 and standard users are warned to leave these calibration parameters untouched. For a full list of all GIPPs including their types, values, and ranges, please consult the embedded PDF in section 3.6.4.

### 3.2.3 Metadata

Quality Information data on Tile level are part of the Tile metadata as summarized in Figure . The Entries represent the percentage of classified pixels as listed for Table 3-9, related to the total amount of data pixels (100 %).

Quality Information data on User Product level are part of the User product Metadata. The structure follows the QI Data on tile level as displayed in Figure . Additional metadata are specified in Section 3.1.2 and Table 3-27.

### 3.2.4 Cython Library

Since Sen2Cor 2.10, a new scene classification has been implemented. This requires a dedicated library (`topographicshadows_cython_03`) that is provided for each available operating system.

### 3.2.5 Auxiliary Data

The ESACCI-LC for Sen2Cor data package is prepared for users of Sen2Cor version starting with sen2Cor 2.5.5 which want to benefit from the last improvements of Sen2Cor Cloud Screening and Classification module. This auxiliary data information is used in Sen2Cor to improve the accuracy of Sen2Cor classification over water, urban and bare areas and to have a better handling of false detection of snow pixels.

**Version 2.10 (and up):**

**For users of Sen2cor since version 2.10 (and up), the updated tar file ESACCI-LC-L4-ALL-FOR-SEN2COR-2.10.tar is available for download from this location:**

https://earth.esa.int/eogateway/ftp/Sentinel-2/ESACCI-LC-L4-ALL-FOR-SEN2COR-2.10.tar.gz

The updated tar file including the updated snow monthly climatology shall be extracted at the following location of Sen2cor installation: '$SEN2COR_BIN/aux_data'.

It contains two files and one directory:

**- ESACCI-LC-L4-LCCS-Map-300m-P1Y-2015-v2.0.7.tif**

**- ESACCI-LC-L4-WB-Map-150m-P13Y-2000-v4.0.tif**

***- ESACCI-LC-L4-Snow-Cond-500m-MONTHLY-2000-2012-v2.4***

In L2A_CAL_SC_GIPP.xml, the reference to the Snow climatology has been updated with the replacement of the ESA CCI Snow Weekly Condition by a derived Snow Monthly climatology.

<ESACCI_SnowCondition_Map_Dir>ESACCI-LC-L4-Snow-Cond-500m-MONTHLY-2000-2012-v2.4</ESACCI_SnowCondition_Map_Dir>

**Versions 2.5.5, 2.8, 2.9:**

The original ESACCI-LC for Sen2Cor data package (ESACCI-LC-L4-ALL-FOR-SEN2COR.zip) is available for download from this location:

***http://maps.elie.ucl.ac.be/CCI/viewer/download.php***

This zip file shall then be extracted at this location of Sen2Cor installation: '***$SEN2COR_BIN/aux_data/.***'
It contains two files and one directory:

- ***ESACCI-LC-L4-LCCS-Map-300m-P1Y-2015-v2.0.7.tif***

***- ESACCI-LC-L4-WB-Map-150m-P13Y-2000-v4.0.tif***

***- ESACCI-LC-L4-Snow-Cond-500m-P13Y7D-2000-2012-v2.0***

Example on a Ubuntu (Linux) installation:

***$ ls Sen2Cor-02.08.00-Linux64/lib/python2.7/site-packages/sen2cor/aux_data***

***ESACCI-LC-L4-LCCS-Map-300m-P1Y-2015-v2.0.7.tif***

***ESACCI-LC-L4-Snow-Cond-500m-P13Y7D-2000-2012-v2.0***

***ESACCI-LC-L4-WB-Map-150m-P13Y-2000-v4.0.tif***

Example on a Windows 7 installation:

***>dir Sen2Cor-02.08.00-Linux64/lib/python2.7/site-packages/sen2cor/aux_data***

***ESACCI-LC-L4-LCCS-Map-300m-P1Y-2015-v2.0.7.tif***

***ESACCI-LC-L4-Snow-Cond-500m-P13Y7D-2000-2012-v2.0***

***ESACCI-LC-L4-WB-Map-150m-P13Y-2000-v4.0.tif***

***Notes:***

*Note1: Please note that a Digital Elevation Model (DEM) is a pre-requisite for using ESACCI_LC information in the Scene Classification algorithm. In the case SRTM DEM is used, latitudes higher > 60 deg N (and lower < 60 deg S) are not covered by the SRTM DEM, therefore no ESACCI_LC information will be used for these latitudes. Standard Scene Classification algorithm will then be applied.*

***Note2: Please note that it is possible to use symbolic links in this aux_data folder if you prefer to copy those auxiliary files to another data folder. (unix command: ln –s, windows command: mklink)***

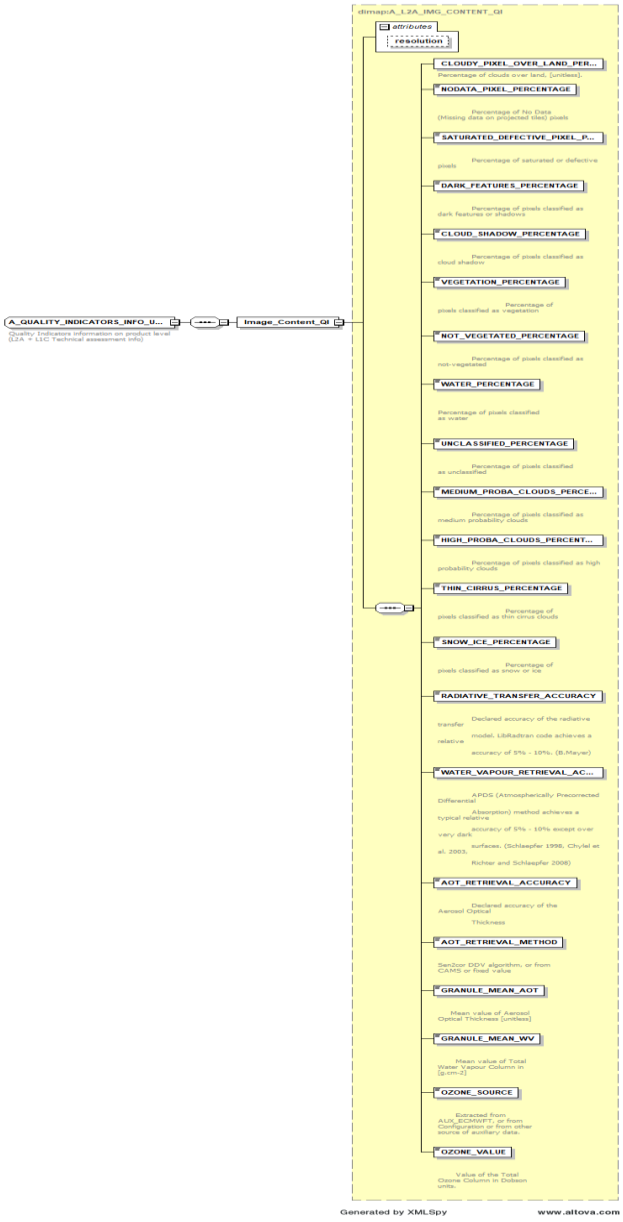


***Figure 3-3 – QI Data of Tile and User Product Metadata***

### 3.2.6 Output Data

*Table 3-7 – Cloud Probability map*

| Cloud Probability [QI Data] | |
|---|---|
| Unit | percentage |
| Range | 0 - 100 |
| Sampling | 8 bit/sample |
| Resolution | 60 m, 20 m |

*Table 3-8 – Snow Probability map*

| Snow Probability [QI Data] | |
|---|---|
| Unit | percentage |
| Range | 0 – 100 |
| Sampling | 8 bit/sample |
| Resolution | 60 m, 20 m |

*Table 3-9 – Scene Classification*

| Scene Classification [Image Data] | |
|---|---|
| Unit | enumeration |

| Scene Classification [Image Data] | |
|---|---|
| Range | 0 – No Data (Missing data on projected tiles) (black)<br>1 – Saturated or defective pixel (red)<br>2 – Cast Shadows (very dark grey)<br>3 – Cloud shadows (dark brown)<br>4 – Vegetation (green)<br>5 – Not vegetated (dark yellow)<br>6 – Water (dark and bright) (blue)<br>7 – Unclassified (dark grey)<br>8 – Cloud medium probability (grey)<br>9 – Cloud high probability (white)<br>10 – Thin cirrus (very bright blue)<br>11 – Snow or ice (very bright pink) |
| Sampling | 8 bit/sample |
| Resolution | 60 m, 20 m |

## 3.3 Atmospheric Correction

### 3.3.1 Input Data

L1C Image data as specified in Section 2, resampled to the requested resolution of 60, 20, 10 m. Scene Classification as specified in Section 3.2 resampled to the requested resolution of 60, 20, 10 m.

### 3.3.2 GIPP

Figure  shows the overall GIPP of the Atmospheric Correction Module. Table 3-10 reports the GIPP selection for the look-up tables.

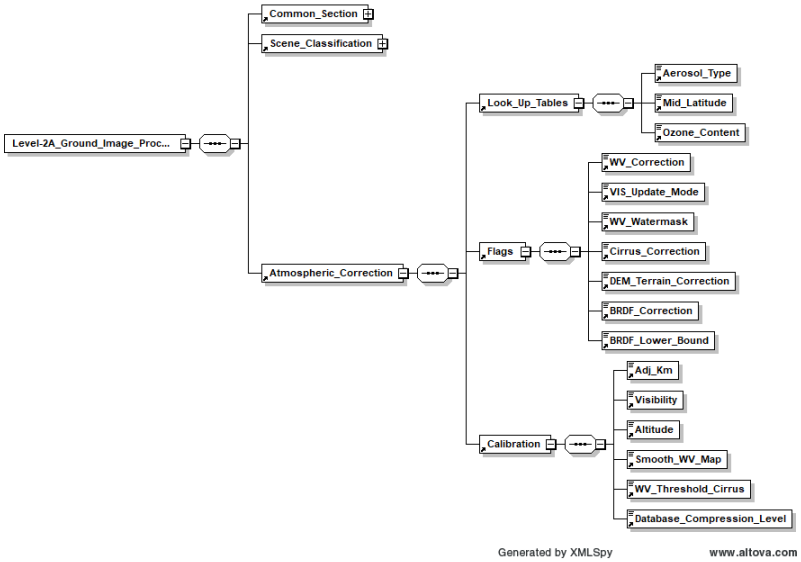


*Figure 3-4 – GIPP for Atmospheric Correction Module*

*Table 3-10 – GIPP for selection of Look_Up_Tables*

| Field Name | Documentation | Type |
|---|---|---|
| Aerosol_Type | The aerosol type used for atmospheric correction: a selection of AUTO will perform an automated aerosol type determination for this parameter as described in the SUM for Section 2.2.2.2.2. Default is: RURAL. | Choice: RURAL, MARITIME, AUTO |
| Mid_Latitude | The mid latitude used for atmospheric correction a selection of AUTO will perform an automated aerosol type determination for this parameter as described in the SUM for Section 2.2.2.2.2. default is: SUMMER | Choice: SUMMER, WINTER, AUTO |

<table>
<tr><th>Field Name</th><th>Documentation</th><th>Type</th></tr>
<tr><td>Ozone_Content, Summer</td><td>The atmospheric temperature profile and ozone content for Mid_Latitude Summer Atmosphere.<br>Default is: 0, which takes the best approximation from the ECMWFT metadata in the AUX_DATA folder of the input product. Otherwise the user can set the following numerical values:<table><tr><th>Dobson Units</th></tr><tr><td>250</td></tr><tr><td>290</td></tr><tr><td>331 (standard MS)</td></tr><tr><td>370</td></tr><tr><td>410</td></tr><tr><td>450</td></tr></table></td><td>Choice as given</td></tr>
<tr><td>Ozone_Content, Winter</td><td>The atmospheric temperature profile and ozone content for Mid_Latitude Summer Atmosphere.<br>Default is 0, which takes the best approximation from the ECMWFT metadata in the AUX_DATA folder of the input product. Otherwise the user can set the following numerical values:<table><tr><th>Dobson Units</th></tr><tr><td>250</td></tr><tr><td>290</td></tr><tr><td>330</td></tr><tr><td>377 (standard MW)</td></tr><tr><td>420</td></tr><tr><td>460</td></tr></table></td><td>Choice as given</td></tr>
</table>

For a full list of all types, parameters, and default values, please consult the embedded PDF in section **Error! Reference source not found.**.

#### 3.3.2.1 Expert Level

GIPP for the Atmospheric Correction on Expert Level are separated from the standard User level and are collected in a different file, named `L2A_CAL_AC_GIPP.xml`. Whereas L2A_GIPP.xml is a pure user configuration file and thus is available for a standard user, the Expert level GIPPs are reserved for testing and calibration campaigns. Wrong calibrations might lead to heavy performance artefacts. The description of these parameters is thus postponed to Section 3.6 and standard users are warned to leave these calibration parameters untouched. For a full list of all GIPPs including their types, values and ranges, please consult the embedded PDF in section **Error! Reference source not found.**.

### 3.3.3 Metadata

NA

### 3.3.4 Auxiliary Data (Look Up Tables)

The algorithm for the atmospheric correction relies on a database of radiative transfer calculations using the DISORT 8-stream algorithm combined with the correlated k method. This has been converted to atmospheric LUTs based on the freely available `libRadtran` library.

***Table 3-11 – Parameter space for atmospheric correction***

| Parameter | Range | Increment / grid points |
|---|---|---|
| Solar zenith angle | 0 -70° | 10° |
| Sensor view angle | 0 -10° | 10° |
| Relative azimuth angle | 0 -180° | 30° (180°= backscatter) |
| Ground elevation | 0 -2.5 km | 0.5 km |
| Visibility | 5 -120 km | 5, 7, 10, 15, 23, 40, 80, 120 km |
| Water vapour, summer | 0.4 -5.5 cm | 0.4, 1.0, 2.0, 2.9, 4.0, 5.0 cm |
| Water vapour, winter | 0.2 -1.5 cm | 0.2, 0.4, 0.8, 1.1 cm |

The baseline processing uses the mid-latitude summer (MS) atmospheric temperature / humidity profile with scaled water vapour columns of 0.4, 1.0, 2.0, 2.9, 4.0, and 5.0 cm (sea level geometry). A separate LUT file is used for each water vapour concentration. The baseline aerosol type is rural (continental). Calculations are performed for the ground elevations 0 – 2.5 km above sea level, in steps of 0.5 km. The default value of the ozone content is 331 DU (for sea level, decreasing with elevation). The water vapour dependent LUTs are used during the per-pixel water vapour retrieval for Sentinel-2 scenes.

The baseline LUTs are compiled for the rural aerosol and the mid-latitude summer (MS) atmosphere with its corresponding ozone column (331 DU for sea level). Other LUTs are selectable via configuration.

Water vapour columns are calculated using an equidistant 100 m grid.

LUT file name conventions: a name consists of 16 characters or numbers followed by the extension '.atm'. The first character defines the atmospheric temperature profile (h=summer, w=winter) and ozone content, followed by '99000' (indicating the symbolic satellite height of 99,000 m), followed by '_', then 'wvxy' where xy is the sea-level water vapour column, followed by '_' and a 4 letter aerosol identifier '_rura'.

*Table 3-12 – LUT file naming conventions*

| **Examples:** | |
|---|---|
| h99000_wv29_rura.atm | MS atmosphere, water vapour=2.9 cm, rural, ozone=331 DU |
| w99000_wv11_rura.atm | MW atmosphere, water vapour=1.1 cm, rural, ozone=377 DU |
| Names for other aerosol types are coded with 4 letters, e.g.: | |
| h99000_wv29_mari.atm | MS, water vapour=2.9 cm, maritime, ozone=331 DU |
| h99000_wv29_urba.atm[1] | MS, water vapour=2.9 cm, urban, ozone=331 DU |
| h99000_wv29_dese.atm[1] | MS, water vapour=2.9 cm, desert, ozone=331 DU |

The content are the following 6 radiative transfer functions for different atmospheric conditions, view angles 0° (nadir) and 10° off-nadir, and a range of solar geometries and relative azimuth angles.

*Table 3-13 – Structure and format of the atmospheric LUT files*

| **Column** | | **Content** |
|---|---|---|
| 1. | Lp | path radiance |
| 2. | Edf | diffuse flux at the sensor = (Tdir + Tdif)*Edif (where Edif is the diffuse solar flux at the ground) |
| 3. | Edr | direct (beam) irradiance at the sensor= (Tdir + Tdif) * Tsun * E<br>Where:<br>Tsun is the sun-to-ground direct transmittance,<br>E = extra-terrestrial solar irradiance |
| 4. | Tdir | direct transmittance ground-to-sensor |
| 5. | Tdif | diffuse transmittance ground-to-sensor |
| 6. | s | spherical albedo of atmosphere |

- The radiance, irradiance, and flux values are calculated for an earth-sun distance of 1 astronomical unit.

[1] Currently not compiled

- Each LUT file stores the radiative transfer functions as float numbers in the binary platform independent XDR format.
- The Thuillier-2003 extra-terrestrial solar irradiance spectrum is used for the calculation of the LUTs (see Ref. Thuillier et al. 2003). It has been provided by ESA expressed in $mW.m^{-2}.nm^{-1}$ resampled at 1 nm.

LUTs are calculated for:

- ne = 6 elevations (0-2.5 km, increment 0.5 km),
- nz = 8 solar zenith angles (0-70°, increment 10°),
- nv = 8 visibilities (5, 7, 10, 15, 23, 40, 80, 120 km), and
- nb bands: nb=12 for the 60 m data; nb=12 for the 20 m data; nb=4 for the 10 m data of Sentinel-2.

The sequence of data is arranged in a file with 104 columns and nz*nv*nb lines:

***Table 3-14 – Column structure of atmospheric LUT files***

| Column | Content |
|---|---|
| column 1 | Solar zenith angle (first 0°, last 70°) |
| column 2 | Visibility (first 5 km, last 120 km) |
| columns 3 – 8 | Lp, Edf, Edr, Tdr, Tdf, s (nadir view), elevation=0 km |
| columns 9 – 19 | Edf, Edr, Tdr, Tdf, Lp for 7 rel. azimuth angles 0(30)180°, at sensor view angle 10°, elevation = 0 km |
| columns 20 – 104 | Columns 3 – 19 are repeated 5 times for the remaining elevations 0.5 to 2.5 km (increment 0.5 km) |

Note: the spherical albedo s is the same for nadir and 10° off-nadir, therefore it is stored only once.

The contents of the file are written as a simple float binary array LUT=fltarr(2+17 * ne, nz, nv, nb) where the 17 radiative transfer functions are calculated for different parameter sets with ne (first=fastest loop = elevation), nz (second loop = solar zenith), nv (third loop = visibility) and nb (last loop = spectral band).

All Look Up Tables are located in two folders named lib_S2A and lib_S2B (for Sentinel 2A and/or Sentinel 2B satellite) in the sen2cor subdirectory and should never be changed or removed from a standard user, as they are essential for a proper atmospheric correction.

### 3.3.5 Output Data

Outputs are specified in the following subsections for the individual sub modules.

### 3.3.6 Aerosol Optical Thickness Retrieval

The aerosol optical thickness (τ) is defined as the integrated extinction coefficient over a vertical column of atmosphere of unit cross section. Extinction coefficient is the fractional depletion of radiance per unit path length (also called attenuation for radar frequencies). Example in formula:

$$I = I_0 (e^{-\tau})$$

If not enough Dense Dark Vegetation (DDV) pixels are available, Sen2Cor 2.11 switches to external sources. Starting with L1C Processing baseline (PB) 4.00, Total Aerosol Optical Thickness is provided as input in the L1C product in the Granule/Tile/Aux_data where the related Copernicus Atmosphere Monitoring Service (CAMS) file is present. Sen2Cor 2.11 retrieves from this file the *aerosol optical thickness* at 550 nm and the *geopotential (z)*.

#### 3.3.6.1 Input Data

Band subset as specified in Section 2, resampled to corresponding resolution of 60, 20, 10 m (see Table 3-15 – Band subsets).

***Table 3-15 – Band subsets***

| CAMSxx | Purpose in L2A Processing context |
|---|---|
| B2 (490nm): 10 m | Sensitive to Vegetation Aerosol Scattering |
| B4 (665nm): 10 m | Max Chlorophyll absorption |
| B12 (2190nm): 20 m | AOT determination |

Input retrieval in Sen2Cor 2.11 from the CAMS auxiliary file in case the number of DDV pixels is less than 1% (see Table 3-16).

***Table 3-16 – CAMS auxiliary input***

| Variable and Raster Band number | Purpose in L2A processing context |
|---|---|
| AOD550 | To retrieve the visibility map/index |
| Geopotential (z) | To retrieve the visibility map/index |

#### 3.3.6.2 GIPP

Figure 3-5 – GIPP for selection of Look_Up_Tables, shows the GIPP of the Atmospheric Correction Module for the selection of the Look Up Tables (LUTs).

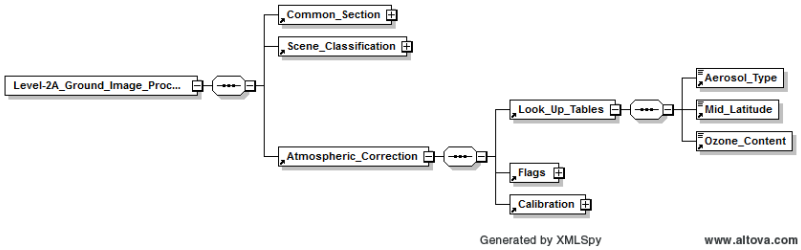


***Figure 3-5 – GIPP for selection of Look_Up_Tables***

#### 3.3.6.3 Metadata

Metadata are specified in Table 3-2.

#### 3.3.6.4 Output Data

***Table 3-17 – Aerosol Optical Thickness (AOT) map***

| Aerosol Optical Thickness (AOT) Map [Image Data] | |
|---|---|
| Unit | Unit less |
| Range | AOT = DN / 1000 |
| Sampling | 16 bit/pixel |
| Resolution | 60 m, 20 m, 10 m (resampled from 20 m) |

### 3.3.7 Water Vapour Retrieval

WV retrieval over land is performed with the Atmospheric Pre-corrected Differential Absorption algorithm (APDA) which is applied to the two Sentinel-2 bands B8A, and B9 (Fig. 4). Band 8A is the reference channel in an atmospheric window region. Band B9 is the measurement channel in the absorption region. The absorption depth is evaluated by calculating the radiance for an atmosphere with no WV, assuming that the surface reflectance for the measurement channel is the same as for the reference channel. The absorption depth is then a measure of the WV column content.

Typical ranges of water vapour columns are (sea-level-to space):

***Table 3-18 – WVP columns***

| Conditions | WVP (cm) |
|---|---|
| tropical | 3 - 5 |
| midlatitude, summer | 2 - 3 |
| dry summer, spring, fall | 1 – 1.5 |
| dry desert or winter | 0.3 – 0.8 |

#### 3.3.7.1 Input Data

Band subsets are specified in Section 2, resampled to corresponding resolution of 60, 20 m.

***Table 3-19 – Band subsets***

| Channels and Resolution | Purpose in L2A processing context |
|---|---|
| B8A (865nm): 20 m | Used for water vapour absorption (reference channel) |
| B9 (945nm): 60 m | Water Vapour absorption atmospheric correction (measurement channel) |

#### 3.3.7.2 GIPP

***Table 3-20 – GIPP input fields***

| Field Name | Documentation | Type |
|---|---|---|
| WV_Correction | 0: no water vapour correction<br>1: water vapour correction using band B8A | Enumerator<br>0,1 as stated, default: 1 |
| WV_Watermask | A choice to set the water vapour values for water pixels:<br>0 = not replaced,<br>1 = average water vapour value of land pixels is assigned to water pixels,<br>~~2 = line average of water vapour of land pixels is assigned to water pixels.~~<br>Only available with WV_Correction mode 1 | Enumerator<br>1,2, as stated<br>1: default<br>2: for future use, currently unused |
| Smooth_WV_Map | smooth water vapour map [m] | Floating point, 32 bit, default: 100 m |

#### 3.3.7.3 Metadata

None

#### 3.3.7.4 Output Data

*Table 3-21 – Water Vapour Map*

| Water Vapour Map [Image Data] | |
|---|---|
| Unit | Dimensionless |
| Range | 0.3 – 6.5 cm |
| Sampling | 16 bit |
| Resolution | 60 m, 20 m, 10 m |

### 3.3.8 Cirrus Correction

#### 3.3.8.1 Input Data

*Table 3-22 – Band subset*

| Channels and Resolution | Purpose in L2A processing context |
|---|---|
| B10 (1375): 60 m | Detection of thin cirrus for atmospheric correction |

#### 3.3.8.2 GIPP

*Table 3-23 – Inputs parameter cirrus correction*

| Field Name | Documentation | Type |
|---|---|---|
| Cirrus_Correction | Flag for cirrus removal<br>TRUE: enabled<br>FALSE: disabled | Restricted string, TRUE / FALSE as stated |
| WV_Threshold_Cirrus | Water Vapour threshold to switch cirrus algorithm off [%] | Floating point value, 32 bit, default: 0.25 |

#### 3.3.8.3 Metadata

None

#### 3.3.8.4 Output Data

Contribution of cirrus correction to BOA surface reflectance for individual channels as listed in Section 3.3.10. The Cirrus band itself will be omitted in the Level 2A output, as it does not contain surface reflectance information and no direct user output.

### 3.3.9 Terrain Correction

#### 3.3.9.1 Input Data

See metadata Section 3.3.9.3 below.

#### 3.3.9.2 GIPP

*Table 3-24 – GIPP terrain correction*

| Field Name | Documentation | Type |
|---|---|---|
| DEM_Directory | Directory where DEM will be expected (located under $S2L2APPHOME). If set to 'false', no terrain correction will be performed. Example: 'dem/srtm' | Formatted string |
| DEM_Reference | Example: http://data_public:GDdci@data.cgiar-csi.org/srtm/tiles/GeoTIFF/ | Formatted string |
| DEM_Terrain_Correction | Boolean Flag for using DEM for terrain correction. Otherwise only used for scene classification and AOT | Formatted string |
| Altitude | Assumed altitude if no DEM is present [km] | Floating point value, 32 bit, default: 0.10, equals 100 m |

| Field Name | Documentation | Type |
|---|---|---|
| BRDF_Correction | Empirical BRDF correction with factor (G) according to following equation:<br>$G = \{ \cos(\beta_i) / \cos(\beta_T) \}^b \geq g$ (eq. 1)<br>where:<br>$\beta_i$: local solar zenith angle (from metadata, Section 1.1.3).<br>$\beta_T$: threshold for surface reflectance (determined programmatically).<br>b: exponent, set via options below.<br>g: Lower boundary of BRDF correction factor, recommended between 0.2 and 0.25 (see next parameter, below).<br><br>Options to be selected (Exponent b):<br>0: no empirical BRDF correction (or flat terrain)<br>1: correction with cosine of local solar zenith angle (eq. 1 with b=1)<br>2: correction with sqrt(cos) of local solar zenith angle (eq. 1 with b=1/2)<br>correction). | Enumerator<br>0, 1, 2 |
| BRDF_Lower_Bound | Lower boundary of BRDF correction factor, should be between 0.2 and 0.25. | Float, default 0.22 |

#### 3.3.9.3 Metadata

- DEM (as specified in the GIPP, will be internally prepared and adapted to geo-positional coordinates obtained from the JPEG-2000 image headers)
- Terrain Shadow Map (calculated internally via GDAL)
- Slope Map (calculated internally via GDAL)
- Aspect Map (calculated internally via GDAL)

#### 3.3.9.4 Output Data

Corrections of BOA surface reflectance retrieval for bands B01 – B12, except B10) as listed in Section 3.3.10. No separate user output.

### 3.3.10 Surface Reflectance

#### 3.3.10.1 Input Data

**60, 20 m Resolution**

- Full set of Bands as specified in Section2, Table 2-1, (except Band 8) resampled to corresponding resolution;
- Aerosol Map as specified in Table 3-17;
- Water Vapour Map as specified in Table 3-21;
- (Optional) Cirrus correction as specified in Section 3.3.8.4;
- (Optional) Terrain correction as specified in Section 3.3.9.4.

**10 m Resolution**

- Bands 2,3,4,8 as specified in Section 2, Table 2-1, no resampling;
- Resampled Aerosol Map as specified in Table 3-17;
- Water Vapour Map as specified in Table 3-21;
- (Optional) Terrain correction as specified in Section 3.3.9.4

#### 3.3.10.2 GIPP

*Table 3-25 – GIPP surface reflectance*

| Field Name | Documentation | Type |
|---|---|---|
| Adj_Km | Range of adjacency effect (reflected radiation from neighbourhood) in [km] | Floating point, 32 bit, Default: 1.0 |

#### 3.3.10.3 Metadata

None

#### 3.3.10.4 Output Data

*Table 3-26 – Outputs surface reflectance*

| Name | Level-2A |
|---|---|
| Product | L2A, BOA Reflectance or Surface reflectance |
| Coverage | Regional. 110 km x 110 km |
| Packaging | MGRS Tiles (same area coverage as Level 1C input data) |
| Geo-location accuracy | Identical to the level 1C geo-location performance |

| Name | Level-2A |
|---|---|
| Frequency | 5 days repeat cycle with two Sentinel-2 satellites |
| Format | OpenJPEG 2.1.2 details @60 m processing:<br>`Codestream, export Band 1, res 60m:`<br>`SOC marker segment @ (1866, 0)`<br>`SIZ marker segment @ (1868, 41)`<br>`Profile: no profile`<br>`Reference Grid Height, Width: (1830 x 1830)`<br>`Vertical, Horizontal Reference Grid Offset: (0 x 0)`<br>`Reference Tile Height, Width: (192 x 192)`<br>`Vertical, Horizontal Reference Tile Offset: (0 x 0)`<br>`Bitdepth: (16,)`<br>`Signed: (False,)`<br>`Vertical, Horizontal Subsampling: ((1, 1),)`<br>`COD marker segment @ (1911, 18)`<br>`Coding style:`<br>`Entropy coder, with partitions`<br>`SOP marker segments: False`<br>`EPH marker segments: False`<br>`Coding style parameters:`<br>`Progression order: LRCP`<br>`Number of layers: 1`<br>`Multiple component transformation usage: no transform specified`<br>`Number of resolutions: 6`<br>`Code block height, width: (4 x 4)`<br>`Wavelet transform: 5-3 reversible`<br>`Precinct size: ((64, 64), (64, 64), (64, 64), (64, 64), (64, 64), (64, 64))`<br>`Code block context:`<br>`Selective arithmetic coding bypass: False`<br>`Reset context probabilities on coding pass boundaries: False`<br>`Termination on each coding pass: False`<br>`Vertically stripe causal context: False`<br>`Predictable termination: False`<br>`Segmentation symbols: False`<br>`QCD marker segment @ (1931, 19)`<br>`Quantization style: no quantization, 2 guard bits`<br>`Step size: [(0, 16), (0, 17), (0, 17), (0, 18), (0, 17), (0, 17), (0, 18), (0, 17), (0, 17), (0, 18), (0, 17), (0, 17), (0, 18), (0, 17), (0, 17), (0, 18)]`<br>`CME marker segment @ (1952, 37)` |
| Unit | Dimensionless, Unsigned Integer |
| Calibration and Range | 1 / 10.000: i.e.: Digital Numbers 0 : 10.000, representing radiometric reflectance values from 0.0 to 1.0 |
| Sampling | 16 bits / pixel |
| **Input resolution** | **Generated output resolution** |
| B1 (443nm): 60 m | 60 m, 20 m (since Sen2Cor 2.10) |
| B2 (490nm): 10 m | 60 m, 20 m, 10 m |

| Name | Level-2A |
|---|---|
| B3 (560nm): 10 m | 60 m, 20 m, 10 m |
| B4 (665nm): 10 m | 60 m, 20 m, 10 m |
| B5 (705nm): 20 m | 60 m, 20 m |
| B6 (740nm): 20 m | 60 m, 20 m |
| B7 (783nm): 20 m | 60 m, 20 m |
| B8 (842nm): 10 m | 10 m |
| B8a (865nm): 20 m | 60 m, 20 m |
| B9 (945nm): 60 m | 60 m |
| B10 (1375): 60 m | No output generated as it does not contain surface information |
| B11 (1610nm): 20 m | 60 m, 20 m |
| B12 (2190nm): 20 m | 60 m, 20 m |

## 3.4 Quality Mask

Since version 2.10, Sen2Cor supports and handles L1C quality masks in raster format describing invalid pixels in the L1C input data.

### 3.4.1 Input Data

`L1C_product/GRANULE/tile_id/QI_DATA/` contain `MSK_QUALIT_BXX.jp2` (where XX is the ID of the bands) type files. The files with the affected bands are open and a mask is created.

### 3.4.2 GIPP

The L2A_GIPP.xml configuration file contains a new parameter: 'Handle_L1C_QLT_Mask' that has to be set to 'TRUE' if the user wants to use the Quality Mask.

### 3.4.3 Metadata

Sen2Cor reads from the file `GENERAL_QUALITY.xml` (present in the folder `L1C_product/GRANULE/tile_id/QI_DATA/`) if loss of data is reported. In the affirmative case, it reads the list of the affected bands. Below, an example of a <check> from a GENERAL_QUALITY.xml reporting data loss and affected bands.

```
<check>
 <inspection creation="2018-01-19T21:58:24.747Z" duration="276" execution="2018-01-
19T21:58:24.762Z" id="Data_Loss"
item="S2B_OPER_MSI_L1C_TL_MTI__20180119T211945_A004558_T07LEK_N02.06"
itemURL="/dpc/data/phoebus-share/PHOEBUS-
3.4.1/wp_in_progress/l1c_20180119_17/app_data/steps_data/L1C/TILE/S2B_OPER_MSI_L1C_TL_
MTI__20180119T211945_A004558_T07LEK_N02.06/" name="Check TECQUA for data loss "
priority="5" processingStatus="done" status="FAILED"/>
<message contentType="text/plain">There is data loss in this tile.</message>
<extraValues>
<value name="Affected Bands">B06 B07 B08 B09 B10 B11 B8A</value>
</extraValues>
</check>
```

### 3.4.4 Output Data

The generated mask will be visible in all the L2A *.jp2 output (for example the *_TCI_*.jp2 file).

## 3.5 Product Generation

### 3.5.1 Input Data

All outputs from previous sections.

### 3.5.2 Output Data

The generated output is dependent on the command line input as shown below. The output products itself are described and specified in detail in [S2-PDGS-MPC-L2A-PFS] and thus not repeated here.

#### 3.5.2.1 Datastrip Generation

Command Line Parameter:

```
L2A_Process --mode=generate_datastrip --datastrip=L1C_DATASTRIP
        --output_dir=L2A_OUTPUT_DIR --work_dir=WORK_DIR --processing_centre=PROCESSING_CENTRE
        --archiving_centre=ARCHIVING_CENTRE --GIP_L2A_PB=GIP_L2A_PB (optional)
        --resolution=RESOLUTION (optional)
```

Generates a datastrip with optional processing baseline settings, which can be used as input for the next step of processing a single tile.

Input product should be in SAFE standard format. Output product will have the datastrip directory in SAFE standard format as well, all other components like metadata and reports will be generated in SAFE compact format.

#### 3.5.2.2 Tile Generation

Command Line Parameter:

```
L2A_Process --mode=process_tile --datastrip=L2A_DATASTRIP --tile=L1C_TILE
        --output_dir=L2A_OUTPUT_DIR --work_dir=WORK_DIR --GIP_L2A_PB=GIP_L2A_PB (optional)
        --resolution=RESOLUTION (optional) --img_database_dir=IMG_DATABASE_DIR (optional)
        --res_database_dir=RES_DATABASE_DIR (optional)
```

Processes a tile with optional database locations and optional processing baseline settings, using a generated L2A datastrip as input. Database directories have been split into two different entities, one for the L1C image inputs, which will be kept in read only mode and a second database for the resampled auxiliary and intermediate products, which always will be overwritten and removed during the successive processing steps.

Input product should be in SAFE standard format. Output product will have the tile directory in SAFE standard format as well, all other components like metadata images and reports will be generated in SAFE compact format.

#### 3.5.2.3 EUP Generation (Toolbox Mode)

Command Line Parameter:

```
L2A_Process input
usage: L2A_Process L1C_USER_PRODUCT --GIP_L2A_PB=GIP_L2A_PB (optional)
        --resolution=RESOLUTION (optional)
```

Processes an End User Product with optional processing baseline settings, using an L1C End User product of PSD Version 14.9 as input. Input product should be V.14.9 SAFE compact format. Output product will also be generated in SAFE compact format. Older products below PSD 14.6 will no longer be supported. Since Sen2Cor Version 2.10, Sen2Cor converts product below PSD 14.6 to PSD 14.6.

#### 3.5.2.4 Additional Output (since Sen2cor 2.11, PSD >= 14.9)

Since Sen2cor 2.10 (PSD>=14.9), additional output comprises:

1- Additional L2A Quality parameters have been added to the already existing parameter in the L2A tile metadata in the 'Quality_Indicator_Info' section. These include:

- Cloudy_pixel_over_land_percentage;
- AOT_retrieval_method;
- Granule_mean_AOT;
- Granule_mean_wv;
- Ozone_Source;
- Ozone_Value.

2- Provision of the L2A Quality Report (see Figure ): the new L2A_Quality.xml report provides quality indicators information derived during the L2A process. They are separated in three main groups (that are subsequently divided into several subsections):

- Scene Class Quality Indicators;
- Atmospheric Correction Quality Indicators;
- Auxiliary Data Quality indicators.

A detailed description can be found at the end of the document in section 3.6.4.

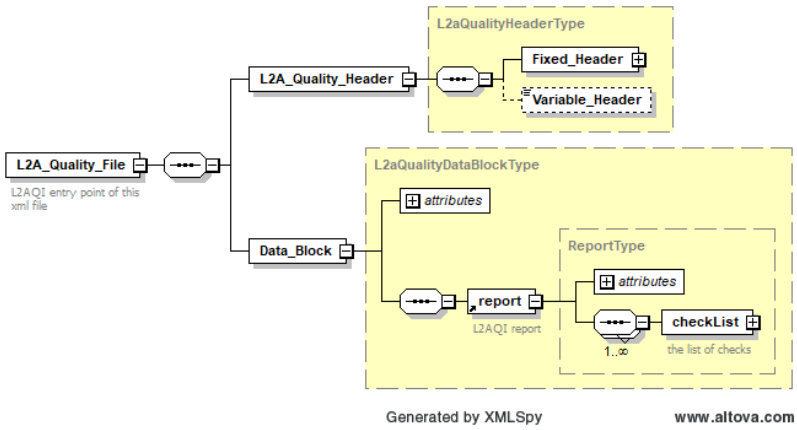


***Figure 3-6 – General schema of the new L2A_Quality file***

Below an example of a L2A_Quality file:

<?xml version="1.0" encoding="UTF-8"?>

-<L2A_Quality_File xsi:schemaLocation="http://gs2.esa.int/DATA_STRUCTURE/l2aqiReport L2A_QUALITY.xsd" xmlns="http://gs2.esa.int/DATA_STRUCTURE/l2aqiReport" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">

-<L2A_Quality_Header>

-<Fixed_Header>

<File_Name>L2A_QUALITY</File_Name>

<File_Description>Quality information obtained from Sen2Cor</File_Description>

<Notes/>

<Mission>S2B</Mission>

<!-- This can be set to OPER or USER dependent on PDGS or Toolbox mode -->

<File_Class>OPER</File_Class>

<File_Type>L2A_QLINFO</File_Type>

-<Validity_Period>

<Validity_Start>UTC=2015-06-22T00:00:00</Validity_Start>

<Validity_Stop>UTC=2100-01-01T00:00:00</Validity_Stop>

</Validity_Period>

<File_Version>1</File_Version>

-<Source>

<System>Sen2Cor</System>

<Creator>Sen2Cor</Creator>

<Creator_Version>2.10</Creator_Version>

<Creation_Date>UTC=2021-10-12T08:13:50</Creation_Date>

</Source>

</Fixed_Header>

</L2A_Quality_Header>

-<Data_Block type="xml">

-<report date="2021-10-12T00:00:00Z" globalStatus="PASSED" gippVersion="2.10.0">

-<checkList>

<parentID>L2A_SC</parentID>

<name>SCENE_CLASS_QUALITY</name>

<version>2.10</version>

<item
url="/Users/Shared/Testdata/FCP_TEST/45RVP/TL/input/S2B_OPER_MSI_L1C_TL_VGSR_20211004T094631_A021913_T30QVE_N79.90/GRANULE/S2B_OPER_MSI_L2A_TL_VGSR_20211004T113819_A021913_T30QVE_N79.90/AUX_DATA"
name="S2B_OPER_MSI_L2A_TL_VGSR_20211004T113819_A021913_T30QVE_N79.90" className="PDI Level 2A Tile Folder"
class="http://www.esa.int/s2#pdi_level_2a_tile_container"/>

-<check>

<message contentType="text/plain">"Percentage of classified pixels"</message>

-<extraValues>

<value name="CLOUDY_PIXEL_PERCENTAGE">1.970349</value>

<value name="CLOUDY_PIXEL_OVER_LAND_PERCENTAGE">1.970349</value>

<value name="DEGRADED_MSI_DATA_PERCENTAGE">0.023900</value>

<value name="NODATA_PIXEL_PERCENTAGE">0.000000</value>

<value name="SATURATED_DEFECTIVE_PIXEL_PERCENTAGE">0.000000</value>

<value name="DARK_FEATURES_PERCENTAGE">0.000000</value>

<value name="CLOUD_SHADOW_PERCENTAGE">0.000000</value>

<value name="VEGETATION_PERCENTAGE">0.000000</value>

<value name="NOT_VEGETATED_PERCENTAGE">98.029649</value>

<value name="WATER_PERCENTAGE">0.000000</value>

<value name="UNCLASSIFIED_PERCENTAGE">0.000000</value>

<value name="MEDIUM_PROBA_CLOUDS_PERCENTAGE">0.000000</value>

<value name="HIGH_PROBA_CLOUDS_PERCENTAGE">0.000000</value>

<value name="THIN_CIRRUS_PERCENTAGE">1.970349</value>

<value name="SNOW_ICE_PERCENTAGE">0.000000</value>

</extraValues>

</check>

</checkList>

-<checkList>

<parentID>L2A_AC</parentID>

<name>ATMOSPHERIC_CORRECTION_QUALITY</name>

<version>2.10</version>

<item
url="/Users/Shared/Testdata/FCP_TEST/45RVP/TL/input/S2B_OPER_MSI_L1C_TL_VGSR_20211004T094631_A021913_T30QVE_N79.90/GRANULE/S2B_OPER_MSI_L2A_TL_VGSR_20211004T113819_A021913_T30QVE_N79.90/AUX_DATA"
name="S2B_OPER_MSI_L2A_TL_VGSR_20211004T113819_A021913_T30QVE_N79.90" className="PDI Level 2A Tile Folder"
class="http://www.esa.int/s2#pdi_level_2a_tile_container"/>

-<check>

<message contentType="text/plain">Atmospheric correction quality values</message>

-<extraValues>

<value name="AOT_RETRIEVAL_ACCURACY">0.000000</value>

<value name="GRANULE_MEAN_AOT">0.407783</value>

<value name="WV_RETRIEVAL_ACCURACY">0.000000</value>

<value name="GRANULE_MEAN_WV">2.194568</value>

<value name="OZONE_VALUE">261.249328</value>

<value name="START_VISIBILITY_KM">40.000000</value>

<value name="VISIBILITY_FROM_DDV_KM">40.000000</value>

<value name="FINAL_VISIBILITY_KM">16.620000</value>

<value name="AVERAGE_SOLAR_ZENITH_ANGLE">17.590239</value>

<value name="DDV_PIXEL_PERCENTAGE">0.000000</value>

<value name="DDV_REFLECTANCE_RANGE">0.000000</value>

<value name="BLUE_PATH_RADIANCE_RESCALING_FACTOR">1.000000</value>

</extraValues>

</check>

-<check>

<message contentType="text/plain">Atmospheric correction quality control</message>

-<extraValues>

<!-- WV_RETRIEVAL_METHOD: SEN2COR_APDA -->

<value name="WV_RETRIEVAL_METHOD">SEN2COR_APDA</value>

<!-- AOT_RETRIEVAL_METHOD: SEN2COR_DDV | CAMS | DEFAULT -->

<value name="AOT_RETRIEVAL_METHOD">CAMS</value>

<value name="VISIBILITY_LESS_THAN_5_KM">False</value>

<value name="AOT_ABOVE_1">False</value>

<value name="GRANULE_WV_ABOVE_5_CM">False</value>

</extraValues>

</check>

-<check>

<message contentType="text/plain">Percentage of negative BOA pixels</message>

-<extraValues>

<value name="B01">0.000000</value>

<value name="B02">0.000000</value>

<value name="B03">0.000000</value>

<value name="B04">0.000000</value>

<value name="B05">0.000000</value>

<value name="B06">0.000000</value>

<value name="B07">0.000000</value>

<value name="B08">0.000000</value>

<value name="B8A">0.000000</value>

<value name="B11">0.000000</value>

<value name="B12">0.000000</value>

</extraValues>

</check>

-<check>

<message contentType="text/plain">Look up table file list</message>

-<extraValues>

<value name="LUT_DATA_FILES">['f99000_wv20_rura.atm']</value>

</extraValues>

</check>

</checkList>

-<checkList>

<parentID>L2A_AUX</parentID>

<name>AUX_DATA_QUALITY</name>

<version>2.10</version>

<item
url="/Users/Shared/Testdata/FCP_TEST/45RVP/TL/input/S2B_OPER_MSI_L1C_TL_VGSR_20211004T094631_A021913_T30QVE_N79.90/GRANULE/S2B_OPER_MSI_L2A_TL_VGSR_20211004T113819_A021913_T30QVE_N79.90/AUX_DATA"
name="S2B_OPER_MSI_L2A_TL_VGSR_20211004T113819_A021913_T30QVE_N79.90" className="PDI Level 2A Tile Folder"
class="http://www.esa.int/s2#pdi_level_2a_tile_container"/>

-<check>

<message contentType="text/plain">AUX related parameters</message>

-<extraValues>

<!-- DEM_TYPE: SRTM_90 | DTED_90 | COPERNICUS_90 -->

<value name="DEM_TYPE">SRTM_90</value>

<value name="DEM_MEAN_ALTITUDE_KM">0.278077</value>

<value name="DEM_MEAN_SLOPE">1.1955457</value>

<value name="GROUND_ELEVATION_ABOVE_3_KM">False</value>

<value name="SOLAR_ZENITH_ANGLE_ABOVE_70_DEG">False</value>

<!-- OZONE_SOURCE: AUX_ECMWFT | CONFIG | OTHER -->

<value name="OZONE_SOURCE">AUX_ECMWFT</value>

</extraValues>

</check>

-<check>

<message contentType="text/plain">AUX data file list</message>

-<extraValues>

<value name="AUX_DATA_FILES">['srtm_36_09.tif']</value>

</extraValues>

</check>

</checkList>

</report>

</Data_Block>

</L2A_Quality_File>

## 3.6 GIPP additional settings

### 3.6.1 GIPP Expert Parameters for Scene Classification

The default expert parameters for the Scene Classification are located in a file named L2A_CAL_SC_GIPP.xml, located in the cfg folder of the sen2cor subdirectory within the Sen2Cor package. They can be overwritten with an external configuration referred to via command line (see section 3.1.6).

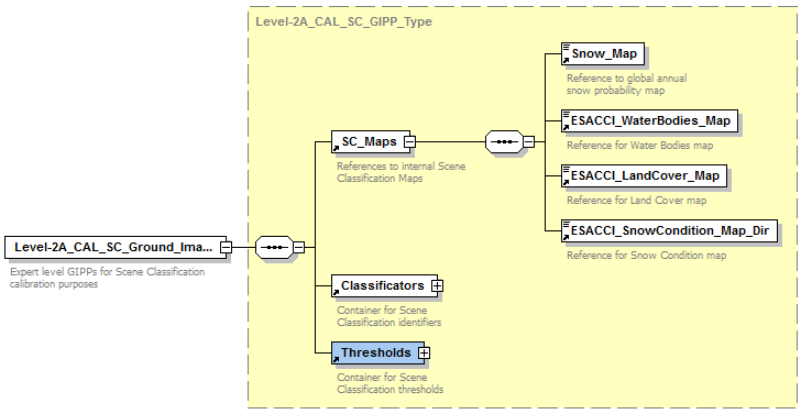


***Figure 3-7 – Processing Baseline GIPP***

For a full list of all types, parameters, and default values, please consult the embedded PDF in section 3.6.4.

### 3.6.2 GIPP Expert Parameters for Atmospheric Correction

The default expert parameters for the Atmospheric Correction are located in a file named L2A_CAL_AC_GIPP.xml, located in the cfg folder of the sen2cor subdirectory within the Sen2Cor package. They can be overwritten with an external configuration referred to via command line (see section 3.1.6).

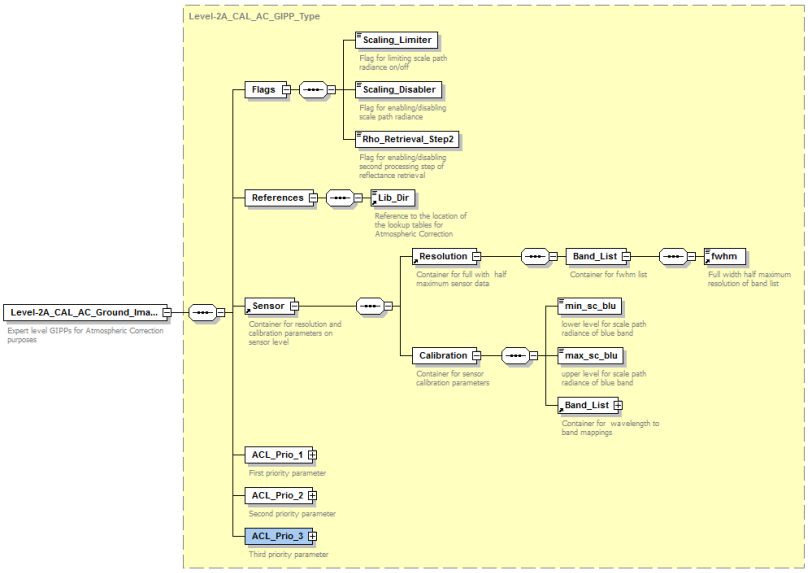


***Figure 3-8 – Processing Baseline GIPP***

For a full list of all types, parameters and default values, consult the embedded GIPP PDF in Section 3.4.

### 3.6.3 GIPP Processing Baseline Parameters

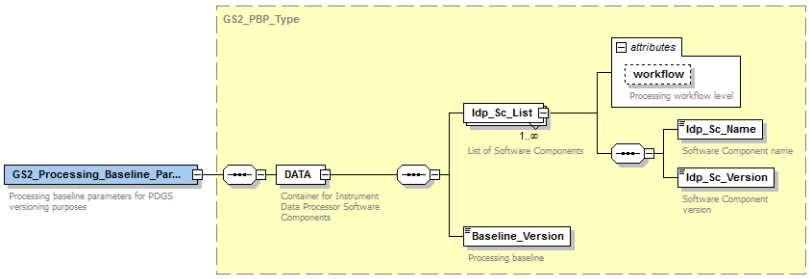


***Figure 3-9 – Processing Baseline GIPP***

*Table 3-27 – Processing Baseline GIPP*

| Field Name / Attribute | Documentation | Type |
|---|---|---|
| DATA | Container for Instrument Data Processor Software Components | Complex |
| IDp_Sc_List | List of Software Components | Complex |
| workflow | Processing workflow level | String |
| IDp_Sc_Name | Software Component name | String |
| IDp_Sc_Version | Software Component version | String |
| Baseline_Version | Processing baseline | Double |

Adding an optional xml input in the format of a processing baseline allows overwriting the corresponding fields in the metadata and filenames.

For a full list of all types, parameters, and default values, please consult the embedded PDF in section 3.6.4.

### 3.6.4 Additional Documentation

The full reference of all GIPPs is contained in the embedded PDF document. GIPPs 2.10 are embedded, as there are no differences with those operating in the current released version of Sen2Cor 2.11.

# 4 Inputs and outputs of steps of Sen2Water

This section describes the inputs, metadata, auxiliary data, parameters, and outputs of the steps of Sen2Water. These steps are resampling, pixel identification, the three atmospheric correction steps, a selection and blending step, and a final formatting step. Note that some of the intermediates are virtual, i.e. not available as physical items. Steps can be chained (by SNAP GPT) such that the output of one step is used in-memory as input of the next. Nevertheless, we describe the outputs of all steps for explanation purposes.

## 4.1 Detector-aware resampling

S2Resampling is an operator of the Sentinel Toolbox. It reads the multi-resolution MSI L1C input data product and resamples the TOA reflectances to a common resolution, in this case to 60m. It further determines viewing angles per pixel considering the different detectors contributing to a band.

In case of the PDI format input a modified reader is used that does not expect the product level metadata file. Missing information like reflectance offsets are provided by the reader itself considering the baseline of the product.

### 4.1.1 Input data

The S2Resampling step reads the MSI L1C described in section 2, in particular the TOA reflectance bands, detector masks, the angle bands, and product level metadata, in particular the reflectance offsets per band.

### 4.1.2 Parameters

S2Resampling has formal parameters. Their values are fixed for this processing chain. The parameters can either be provided as command line parameters of the gpt command or in XML as part of a GPT graph processing specification.

***Table 4-1: Parameters of Sen2Water's S2Resampling step***

| Parameter | Description | Value for Sen2Water |
|---|---|---|
| resolution | The output resolution, one of '10', '20', '60' | 60 |
| downsampling | The method used for aggregation (downsampling to a coarser resolution). Value must be one of 'First', 'Min', 'Max', 'Mean', 'Median'. | Mean |
| flagsDownsampling | The method used for aggregation (downsampling to a coarser resolution) of flags. Value must be one of 'First', 'FlagAnd', 'FlagOr', 'FlagMedianAnd', 'FlagMedianOr'. | First |

| Parameter | Description | Value for Sen2Water |
|---|---|---|
| upsampling | The method used for interpolation (upsampling to a finer resolution). Value must be one of 'Nearest', 'Bilinear', 'Bicubic' | Bilinear |
| resampleOnPyramidLevels | This setting will increase performance when viewing the image, but accurate resamplings are only retrieved when zooming in on a pixel. | false |

### 4.1.3 Output data

The output of the S2Resampling step contains the 13 bands resampled to 60m and viewing angles interpolated using detector information per band and pixel. Other bands are passed from the L1C.

***Table 4-2: Output bands of Sen2Water's S2Resampling step***

| Band | Description | Resolution |
|---|---|---|
| B1<br>…<br>B12 | 13 bands, encoded as ushort, with CF-compliant metadata for offset and scale factor | 60m, grid of 1830x1830 pixels |
| sun_zenith<br>sun_azimuth | sun angles | 60m, grid of 1830x1830 pixels |
| view_zenith_B1<br>…<br>view_zenith_B12<br>view_azimuth_B1<br>…<br>view_azimuth_B12 | viewing angles per band, derived from detector-specific angles | 60m, grid of 1830x1830 pixels |
| view_zenith_mean<br>view_azimuth_mean | Mean viewing angles | 60m, grid of 1830x1830 pixels |
| ancillary_lost_B1<br>ancillary_degraded_B1<br>msi_lost_B1<br>msi_degraded_B1<br>defective_B1<br>nodata_B1<br>partially_corrected_crosstalk_B1<br>saturated_l1a_B1<br>… | flags per band | 60m, grid of 1830x1830 pixels |

| Band | Description | Resolution |
|---|---|---|
| …_B12 | | |
| opaque_clouds<br>cirrus_clouds<br>snow_ice_areas | L1C flags | 60m, grid of 1830x1830 pixels |
| detector_footprint_B1<br>…,<br>detector_footprint_B12 | detector footprint per band | 60m, grid of 1830x1830 pixels |
| lat<br>lon | pixel coordinates | 60m, grid of 1830x1830 pixels |
| aod550<br>bcaod550<br>omaod550<br>ssaod550<br>suaod550<br>aod469<br>aod670<br>aod865<br>aod1240<br>tco3<br>tcwv<br>msl<br>z<br>r<br>_0u<br>_0v | dynamic auxiliary data (aod, atmospheric parameters) provided as coarse-grained tie-point grid covering the product. | tie-point grid of 9x9 pixels |
| crs | CF attributes for geo-coding, in UTM projection | scalar |

Not all of these bands are used by subsequent processing steps. Details are provided with each processor below.

## 4.2 TOA Glint Correction

TOA Glint Correction (TGC) is an extension function of the ACOLITE software. It uses angles and the embedded ECMWF ancillary data for de-striping images that suffer from sun glint.

### 4.2.1 Input data

TGC uses the resampled L1C of the previous step and the dynamic ancillary data of the L1C as input.

***Table 4-3: Input bands of Sen2Water's TOA Glint Correction step***

| Bands used | Comment | |
|---|---|---|
| B1<br>…<br>B13 | | |
| sun_zenith<br>sun_azimuth | | |
| view_zenith_B1<br>…<br>view_zenith_B12<br>view_azimuth_B1<br>…<br>view_azimuth_B12 | viewing angles per band, derived from detector-specific angles | 60m, grid of 1830x1830 pixels |
| aod550<br>tco3<br>msl<br>u10<br>v10<br>aux_lat<br>aux_lon | dynamic auxiliary data provided as coarse-grained tie-point grid covering the product. | tie-point grid of 9x9 pixels |
| lat<br>lon | Either lat and lon or crs is required for geo-coding. | |

### 4.2.2 Output data

Outputs of TGC are corrected bands B1 ... B12.

***Table 4-4: Output bands of Sen2Water's TOA Glint Correction step***

| Band | Description | Resolution |
|---|---|---|
| B1<br>…<br>B13 | | |

## 4.3 Pixel identification

Pixel identification is done with the SNAP Idepix processor of the Sentinel toolbox.

### 4.3.1 Input data

Pixel identification uses the resampled L1C of the previous step as input.

***Table 4-5: Input bands of Sen2Water's pixel identification step***

| Bands used | Comment |
|---|---|
| B1<br>…<br>B13 | |
| sun_zenith<br>sun_azimuth | |
| view_zenith_mean<br>view_azimuth_mean | |
| lat<br>lon | Either lat and lon or crs is required for geo-coding. |
| crs | Either lat and lon or crs is required for geo-coding. |

### 4.3.2 Auxiliary data

Idepix uses a DEM as auxiliary data. The Copernicus 90m DEM is used with Idepix in Sen2Water by default. Tiles required are downloaded automatically from

```
https://copernicus-dem-90m.s3.eu-central-1.amazonaws.com
```

Alternative DEMs that can be used with Idepix are "SRTM_3sec", "SRTM 1Sec HGT" (used by CGLOPS), "GETASSE30" (used by HR-OC, and by CGLOPS for regions beyond 60 degrees north). Tiles required are automatically downloaded from

```
https://download.esa.int/step/auxdata/dem/SRTM90/tiff
http://step.esa.int/auxdata/dem/SRTMGL1/
http://step.esa.int/auxdata/dem/GETASSE30/
```

Idepix further uses a static water mask. It is downloaded from

```
http://step.esa.int/auxdata/watermask/images
```

There are five files:

```
50m.zip

150m.zip

GC_water_mask.zip
```

```
MODIS_north_water_mask.zip
MODIS_south_water_mask.zip
```

They are included in the auxiliary dataset of Sen2Water.

### 4.3.3 Parameters

Idepix has formal parameters. Their values are fixed for this processing chain. The parameters can either be provided as command line parameters of the gpt command or in XML as part of a GPT graph processing specification.

***Table 4-6: Parameters of Sen2Water's pixel identification step Idepix***

| Parameter | Description | Value for Sen2Water |
|---|---|---|
| computeCloudShadow | Whether to determine cloud shadow | true |
| computeMountainShadow | Whether to determine mountain shadow | true |
| computeCloudBuffer | Whether to extend clouds by a buffer | true |
| cloudBufferWidth | The width of the 'safety buffer' around a pixel identified as cloudy. | 2 |
| computeCloudBufferFor CloudAmbiguous | Whether to consider cloud-ambiguous as cloud for cloud buffer determination | true |
| copyFeatureValues | Write all feature values to the target product | false |
| copyToaReflectances | Write TOA reflectances to the target product | false |
| demName | The digital elevation model | 'Copernicus 90m Global DEM' |

### 4.3.4 Output data

The output is a single band with flag masks encoded as packed bits according to the CF convention.

***Table 4-7: Output bands of Sen2Water's pixel identification step***

| Band | Description | Resolution |
|---|---|---|
| pixel_classif_flags | Combination of flags, represented as int32, with CF flag masks attributes | 60m, grid of 1830x1830 pixels |

pixel_classif_flags is a combination of values of Table 4-8.

***Table 4-8: Idepix flag masks***

| Bit | Value | Flag name | Description |
|---|---|---|---|
| 1 | 1 | IDEPIX_INVALID | Invalid pixels |
| 2 | 2 | IDEPIX_CLOUD | Pixels either cloud_sure or cloud_ambiguous |

| | | | |
|---|---|---|---|
| 3 | 4 | IDEPIX_CLOUD_AMBIGUOUS | Semi transparent clouds, or clouds where the detection level is uncertain |
| 4 | 8 | IDEPIX_CLOUD_SURE | Fully opaque clouds with full confidence of their detection |
| 5 | 16 | IDEPIX_CLOUD_BUFFER | A buffer of n pixels around a cloud. n is a user parameter. Applied to pixels masked as 'cloud' |
| 6 | 32 | IDEPIX_CLOUD_SHADOW | Pixel is affected by a cloud shadow (combination of shifted cloud mask in cloud gaps and dark clusters coinciding with a corrected shifted cloud mask) |
| 7 | 64 | IDEPIX_SNOW_ICE | Clear snow/ice pixels |
| 8 | 128 | IDEPIX_BRIGHT | Bright pixels |
| 9 | 256 | IDEPIX_WHITE | White pixels |
| 10 | 512 | IDEPIX_COASTLINE | Pixels at a coastline (not defined for Sentinel-2) |
| 11 | 1024 | IDEPIX_LAND | Land pixels identified by the used land/water mask (default SRTM) |
| 12 | 2048 | IDEPIX_CIRRUS_SURE | Cirrus clouds with full confidence of their detection |
| 13 | 4096 | IDEPIX_CIRRUS_AMBIGUOUS | Cirrus clouds, or clouds where the detection level is uncertain |
| 14 | 8192 | IDEPIX_CLEAR_LAND | Clear land pixels |
| 15 | 16384 | IDEPIX_CLEAR_WATER | Clear water pixels |
| 16 | 32768 | IDEPIX_WATER | Water pixels identified by the used land/water mask (default SRTM) |
| 17 | 65536 | IDEPIX_BRIGHTWHITE | 'Bright white' pixels |
| 18 | 131072 | IDEPIX_VEG_RISK | Pixels with vegetation risk |
| 19 | 262144 | IDEPIX_MOUNTAIN_SHADOW | Pixel is affected by mountain shadow |
| 20 | 524288 | IDEPIX_POTENTIAL_SHADOW | Potentially a cloud shadow pixel |
| 21 | 1048576 | IDEPIX_CLUSTERED_CLOUD _SHADOW | Cloud shadow identified by clustering algorithm |

## 4.4 C2RCC atmospheric correction

### 4.4.1 Input data

C2RCC uses the resampled L1C of the first step as input.

***Table 4-9: Input bands of Sen2Water's C2RCC atmospheric correction step***

| Band | Description | Resolution |
|---|---|---|
| B1<br>…<br>B12 | 13 bands, encoded as ushort, with CF-compliant metadata for offset and scale factor | 60m, grid of 1830x1830 pixels |
| sun_zenith<br>sun_azimuth | sun angles | 60m, grid of 1830x1830 pixels |
| view_zenith_mean<br>view_azimuth_mean | Mean viewing angles | 60m, grid of 1830x1830 pixels |
| tco3<br>msl | dynamic auxiliary data (atmospheric parameters) provided as coarse-grained tie-point grid covering the product. | tie-point grid of 9x9 pixels |
| lat<br>lon | pixel coordinates | 60m, grid of 1830x1830 pixels |
| crs | CF attributes for geo-coding, in UTM projection | scalar |

### 4.4.2 Auxiliary data

C2RCC has been modified to use the Copernicus 90m DEM for elevation. The DEM to be used is set by a parameter. The same tiles already provided for Idepix are required. Tiles required are downloaded automatically from

```
https://copernicus-dem-90m.s3.eu-central-1.amazonaws.com
```

C2RCC had formerly used the GETASSE30 DEM for elevation for HR-OC and CGLOPS. It was downloaded from

```
http://step.esa.int/auxdata/dem/GETASSE30/
```

C2RCC uses the dynamic ancillary data for ozone and pressure contained in the L1C. This is switched on by a parameter.

C2RCC is also able to use external dynamic auxiliary data from TOSOMI with variable "ozone" and NCEP with variable "press". It interpolates spatio-temporally if two files are provided, one before and one after the time of acquisition. The files are automatically downloaded from

```
https://oceandata.sci.gsfc.nasa.gov/cgi/getfile/
```

This is not used in Sen2Water.

### 4.4.3 Parameters

C2RCC has formal parameters. Their values are fixed for this processing chain. The parameters can either be provided as command line parameters of the gpt command or in XML as part of a GPT graph processing specification.

***Table 4-10: Parameters of Sen2Water's atmospheric correction step C2RCC***

| Parameter | Description | Value for Sen2Water |
|---|---|---|
| netSet | Set of neuronal nets for algorithm. Value must be one of 'C2RCC-Nets', 'C2X-Nets', 'C2X-COMPLEX-Nets'. Default value is 'C2RCC-Nets'. | 'C2RCC-Nets' |
| alternativeNNPath | Path to an alternative set of neuronal nets. Use this to replace the standard set of neuronal nets. | |
| validPixelExpression | Defines the pixels which are valid for processing. Default value is 'B8 > 0 && B8 < 0.1'. | `! nan(B1) and ! nan(B2) and ! nan(B3) and ! nan(B4) and ! nan(B5) and ! nan(B6) and ! nan(B7) and ! nan(B8) and ! nan(B8A) and ! nan(B9) and ! nan(B10) and ! nan(B11) and ! nan(B12) and B1>=0 and B2>=0 and B3>=0 and B4>=0 and B5>=0 and B6>=0 and B7>=0 and B8>=0 and B8A>=0 and B9>=0 and B10>=0 and B11>=0 and B12>=0` |
| atmosphericAuxDataPath | Path to the atmospheric auxiliary data directory. Use either this or the specified products on the I/O Parameters tab. If the auxiliary data is not available at this path, the data will automatically be downloaded. | |
| useEcmwfAuxData | Use ECMWF auxiliary data (msl and tco3) from the source product, if available. | true |
| elevation | Used as fallback if elevation could not be taken from DEM. Valid interval is (0, 8500). Parameter unit is 'm'. | 0 |
| ozone | The value used as ozone if not provided by auxiliary data. Valid interval is (0, 1000). Parameter unit is 'DU'. | 330 |

| Parameter | Description | Value for Sen2Water |
|---|---|---|
| press | The surface air pressure at sea level if not provided by auxiliary data. Valid interval is (800, 1040). Parameter unit is 'hPa'. | 1000 |
| salinity | The value used as salinity for the scene. Valid interval is (0.000028, 43). Parameter unit is 'PSU'. | 35.0 |
| temperature | The value used as temperature for the scene. Valid interval is (0.000111, 36). Parameter unit is 'C'. | 15.0 |
| outputAcReflectance | Sets parameter 'outputAcReflectance' to <boolean>. | true |
| outputAsRrs | Write remote sensing reflectances instead of water leaving reflectances. | false |
| outputUncertainties | Sets parameter 'outputUncertainties' to <boolean>. | false |
| demName | The digital elevation model | 'Copernicus 90m Global DEM' |

### 4.4.4 Output data

The output is a set of bands with atmospherically corrected water-leaving reflectances.

***Table 4-11: Output bands of Sen2Water's C2RCC atmospheric correction step***

| Band | Description | Resolution |
|---|---|---|
| rhow_B1 | water-leaving reflectance at 443 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhow_B2 | water-leaving reflectance at 490 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhow_B3 | water-leaving reflectance at 560 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhow_B4 | water-leaving reflectance at 665 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhow_B5 | water-leaving reflectance at 705 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhow_B6 | water-leaving reflectance at 740 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhow_B7 | water-leaving reflectance at 783 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |

| Band | Description | Resolution |
|---|---|---|
| rhow_B8A | water-leaving reflectance at 865 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| c2rcc_flags | quality flags of the atmospheric correction | 60m, grid of 1830x1830 pixels |

c2rcc_flags is a combination of values of Table 4-12.

***Table 4-12: C2RCC flag masks***

| Bit | Value | Flag name | Description |
|---|---|---|---|
| 1 | 1 | Rtosa_OOS | The input spectrum to the atmospheric correction neural net was out of the scope of the training range and the inversion is likely to be wrong |
| 2 | 2 | Rtosa_OOR | The input spectrum to the atmospheric correction neural net out of training range |
| 3 | 4 | Rhow_OOR | One of the inputs to the IOP retrieval neural net is out of training range |
| 4 | 8 | Cloud_risk | High downwelling transmission is indicating cloudy conditions |
| 5 | 16 | Iop_OOR | One of the IOPs is out of range |
| 6 | 32 | Apig_at_max | Apig output of the IOP retrieval neural net is at its maximum. This means that the true value is this value or higher. |
| 7 | 64 | Adet_at_max | Adet output of the IOP retrieval neural net is at its maximum. This means that the true value is this value or higher. |
| 8 | 128 | Agelb_at_max | Agelb output of the IOP retrieval neural net is at its maximum. This means that the true value is this value or higher. |
| 9 | 256 | Bpart_at_max | Bpart output of the IOP retrieval neural net is at its maximum. This means that the true value is this value or higher. |
| 10 | 512 | Bwit_at_max | Bwit output of the IOP retrieval neural net is at its maximum. This means that the true value is this value or higher. |
| 11 | 1024 | Apig_at_min | Apig output of the IOP retrieval neural net is at its minimum. This means that the true value is this value or lower. |
| 12 | 2048 | Adet_at_min | Adet output of the IOP retrieval neural net is at its minimum. This means that the true value is this value or lower. |
| 13 | 4096 | Agelb_at_min | Agelb output of the IOP retrieval neural net is at its minimum. This means that the true value is this value or lower. |
| 14 | 8192 | Bpart_at_min | Bpart output of the IOP retrieval neural net is at its minimum. This means that the true value is this value or lower. |

| | | | |
|---|---|---|---|
| 15 | 16384 | Bwit_at_min | Bwit output of the IOP retrieval neural net is at its minimum. This means that the true value is this value or lower. |
| 16 | 32768 | Rhow_OOS | The Rhow input spectrum to IOP neural net is probably not within the training range of the neural net, and the inversion is likely to be wrong. |
| 17 | 65536 | Kd489_OOR | Kd489 is out of range |
| 18 | 131072 | Kdmin_OOR | Kdmin is out of range |
| 19 | 262144 | Kd489_at_max | Kdmin is at max |
| 20 | 524288 | Kdmin_at_max | Kdmin is at max |
| 21 | 2147483648 | Valid_PE | The operators valid pixel expression has resolved to true |

The IOP and Kd flags are not relevant for Sen2Water.

## 4.5 ACOLITE atmospheric correction

### 4.5.1 Input data

ACOLITE uses the resampled L1C of the first step as input.

***Table 4-13: Input bands of Sen2Water's ACOLITE atmospheric correction step***

| Band | Description | Resolution |
|---|---|---|
| B1<br>…<br>B12 | 13 bands, encoded as ushort, with CF-compliant metadata for offset and scale factor | 60m, grid of 1830x1830 pixels |
| sun_zenith<br>sun_azimuth | sun angles | 60m, grid of 1830x1830 pixels |
| view_zenith_mean<br>view_azimuth_mean | Mean viewing angles | 60m, grid of 1830x1830 pixels |
| tco3<br>tcwv<br>msl<br>u10<br>v10 | dynamic auxiliary data (atmospheric parameters) provided as coarse-grained tie-point grid covering the product. | tie-point grid of 9x9 pixels |
| lat<br>lon | pixel coordinates | 60m, grid of 1830x1830 pixels |

### 4.5.2 Auxiliary data

ACOLITE can use dynamic auxiliary data for ozone, water vapour, pressure, and wind speed, and a DEM for elevation. It uses sensor-specific LUTs as static auxiliary data.

ACOLITE has been modified to use the dynamic auxiliary data contained in the L1C.

The atmospheric auxiliary data for CGLOPS formerly has been retrieved from

https://oceandata.sci.gsfc.nasa.gov

This is not used in Sen2Water.

ACOLITE has been modified to be able to use the 90m DEM as the other Sen2Water processors.

The Copernicus 90m DEM is downloaded in tiles the first time they are used from

https://registry.opendata.aws/copernicus-dem/

Lookup tables are downloaded by ACOLITE on their first use from

https://github.com/acolite/acolite_luts

to local directories

ACOLITE-LUT-202102-Reverse/S2A_MSI

ACOLITE-LUT-202102/S2A_MSI

RSKY-202102/S2A_MSI

ACOLITE-LUT-202102-Reverse/S2B_MSI

ACOLITE-LUT-202102/S2B_MSI

RSKY-202102/S2B_MSI

They are included in the auxiliary dataset of Sen2Water.

### 4.5.3 Parameters

Parameters of ACOLITE control the internal algorithms to apply. They are constant for Sen2Water.

```
## ACOLITE settings for full tile processing, HR-OC
## Last update on 12-06-2023 (dd-mm-yyyy) generic ACOLITE

#inputfile=
#output=

## tiled processing
dsf_aot_estimate=tiled

## use resolved geometry but don't save all the parameters
resolved_geometry=True
dsf_write_tiled_parameters=False

## 60 m output resolution
s2_target_res=60
```

```
## optional glint correction
dsf_residual_glint_correction=True
dsf_residual_glint_correction_method=default
dsf_residual_glint_wave_range=1500,2400
glint_force_band=None
glint_mask_rhos_wave=1600
glint_mask_rhos_threshold=0.05
glint_write_rhog_ref=False
glint_write_rhog_all=False

## tile dimensions in pixels
## 60m x 400 = 24 km
dsf_tile_dimensions=400,400

## options from Vanhellemont 2020
#dsf_interface_reflectance=True
dsf_interface_reflectance=False
dsf_interface_option=default

## exclude SWIR from DSF
dsf_wave_range=400,900

## LUTs
luts=ACOLITE-LUT-202110-MOD1,ACOLITE-LUT-202110-MOD2
luts_pressures=500,750,1013,1100

limit=None
slicing=True

ancillary_data=False
s2_auxiliary_default=True
s2_auxiliary_interpolate=True
rgb_rhot=False
rgb_rhos=False
```

### 4.5.4 Output data

The output is a set of bands with atmospherically corrected water-leaving reflectances.

***Table 4-14: Output bands of Sen2Water's ACOLITE atmospheric correction step***

| Band | Description | Resolution |
|---|---|---|
| rhos_443 | water-leaving reflectance at 443 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhos_492 | water-leaving reflectance at 490 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhos_560 | water-leaving reflectance at 560 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhos_665 | water-leaving reflectance at 665 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhos_704 | water-leaving reflectance at 705 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |

| Band | Description | Resolution |
|---|---|---|
| rhos_740 | water-leaving reflectance at 740 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhos_783 | water-leaving reflectance at 783 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhos_833 | water-leaving reflectance at 833 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhos_865 | water-leaving reflectance at 865 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhos_945 | water-leaving reflectance at 945 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhos_1614 | water-leaving reflectance at 1614 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| rhos_2202 | water-leaving reflectance at 2202 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| l2_negatives | quality flag of the atmospheric correction | 60m, grid of 1830x1830 pixels |

## 4.6 POLYMER atmospheric correction

### 4.6.1 Input data

POLYMER uses the resampled L1C of the first step as input.

***Table 4-15: Input bands of Sen2Water's POLYMER atmospheric correction step***

| Band | Description | Resolution |
|---|---|---|
| B1<br>…<br>B12 | 13 bands, encoded as ushort, with CF-compliant metadata for offset and scale factor | 60m, grid of 1830x1830 pixels |
| sun_zenith<br>sun_azimuth | sun angles | 60m, grid of 1830x1830 pixels |
| view_zenith_B1<br>…<br>view_zenith_B12<br>view_azimuth_B1<br>…<br>view_azimuth_B12 | viewing angles per band, derived from detector-specific angles | 60m, grid of 1830x1830 pixels |

| Band | Description | Resolution |
|---|---|---|
| view_zenith_mean<br>view_azimuth_mean | Mean viewing angles | 60m, grid of 1830x1830 pixels |
| tco3<br>tcwv<br>msl | dynamic auxiliary data (atmospheric parameters) provided as coarse-grained tie-point grid covering the product. | tie-point grid of 9x9 pixels |
| lat<br>lon | pixel coordinates | 60m, grid of 1830x1830 pixels |

Polymer gets an Idepix mask as additional input. This mask is generated from the Idepix output by a bandmaths operation with SNAP using the expression

```
pixel_classif_flags.IDEPIX_INVALID or
pixel_classif_flags.IDEPIX_CLOUD or
pixel_classif_flags.IDEPIX_CLOUD_AMBIGUOUS or
pixel_classif_flags.IDEPIX_CLOUD_SURE or
pixel_classif_flags.IDEPIX_CLOUD_BUFFER or
pixel_classif_flags.IDEPIX_CLOUD_SHADOW or
pixel_classif_flags.IDEPIX_SNOW_ICE or
pixel_classif_flags.IDEPIX_LAND or
pixel_classif_flags.IDEPIX_CIRRUS_SURE or
pixel_classif_flags.IDEPIX_CIRRUS_AMBIGUOUS or
pixel_classif_flags.IDEPIX_VEG_RISK
```

The output must be a single band "mask" with uint8 data type in HDF4. POLYMER has been updated to accept a NetCDF4 file instead of HDF4 for this mask.

### 4.6.2 Auxiliary data

POLYMER uses ozone, surface pressure, and wind speed dynamic auxiliary data. POLYMER has been updated to use the dynamic auxiliary data contained in the L1C.

The auxiliary data for CGLOPS formerly was from NASA/Goddard's Global Modelling and Assimilation Office GMAO. It is downloaded from OBPG. Alternatively, POLYMER can download ERA5 data. Neither of them are used in Sen2Water.

### 4.6.3 Parameters

The parameters control the algorithms applied by POLYMER. They are constant for Sen2Water.

```
{
    'min_abs': -2,
    'bounds': [[-2, 4], [-2, 3.5]],
    'initial_points': [[x,y] for x in [-2,-1,0,1] for y in [0,1]] + [[1,2],[2,2]],
    'bands_corr': [443,490,560,665,705,740,783,865,1610],
    'bands_oc':   [443,490,560,665,705,740,783,865,1610],
    'weights_corr': [1,1,1,1,1,1,1,1,0.01],
    'weights_oc':   [1,1,1,1,1,1,1,1,0.01],
    "external_mask": "idepix_mask_for_polymer.hdf",  # to use the IdePix mask
```

```
    "thres_Rcloud": -1,  # to deactivate Polymer's cloud mask
    "thres_Rcloud_std": -1, # to deactivate Polymer's cloud mask
    "bands_rw": [443,490,560,665,705,740,783,842,865,945,1375,1610,2190]
}
```

The Idepix mask for polymer is calculated with a valid pixel expression from the Idepix output:

```
pixel_classif_flags.IDEPIX_INVALID
or pixel_classif_flags.IDEPIX_CLOUD
or pixel_classif_flags.IDEPIX_CLOUD_AMBIGUOUS
or pixel_classif_flags.IDEPIX_CLOUD_SURE
or pixel_classif_flags.IDEPIX_CLOUD_BUFFER
or pixel_classif_flags.IDEPIX_CLOUD_SHADOW
or pixel_classif_flags.IDEPIX_SNOW_ICE
or pixel_classif_flags.IDEPIX_LAND
or pixel_classif_flags.IDEPIX_CIRRUS_SURE
or pixel_classif_flags.IDEPIX_CIRRUS_AMBIGUOUS
or pixel_classif_flags.IDEPIX_VEG_RISK
```

### 4.6.4 Output data

The output is a set of bands with atmospherically corrected water-leaving reflectances.

***Table 4-16: Output bands of Sen2Water's POLYMER atmospheric correction step***

| Band | Description | Resolution |
|---|---|---|
| Rw443 | water-leaving reflectance at 443 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| Rw490 | water-leaving reflectance at 490 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| Rw560 | water-leaving reflectance at 560 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| Rw665 | water-leaving reflectance at 665 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| Rw705 | water-leaving reflectance at 705 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| Rw740 | water-leaving reflectance at 740 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| Rw783 | water-leaving reflectance at 783 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| Rw842 | water-leaving reflectance at 842 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| Rw865 | water-leaving reflectance at 865 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |

| Band | Description | Resolution |
|---|---|---|
| Rw945 | water-leaving reflectance at 945 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| Rw1375 | water-leaving reflectance at 1375 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| Rw1610 | water-leaving reflectance at 1610 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| Rw2190 | water-leaving reflectance at 2190 nm, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| bitmask | quality flags of the atmospheric correction | 60m, grid of 1830x1830 pixels |

The bitmask is a combination of values of Table 4-12.

***Table 4-17: POLYMER flag masks***

| Bit | Value | Flag name | Description |
|---|---|---|---|
| 1 | 1 | LAND | Land mask |
| 2 | 2 | CLOUD_BASE | Polymer's basic cloud mask |
| 3 | 4 | L1_INVALID | Invalid level1 pixel |
| 4 | 8 | NEGATIVE_BB | (deprecated flag) |
| 5 | 16 | OUT_OF_BOUNDS | Retrieved marine parameters are outside valid bounds |
| 6 | 32 | EXCEPTION | A processing error was encountered |
| 7 | 64 | THICK_AEROSOL | Thick aerosol flag |
| 8 | 128 | HIGH_AIR_MASS | Air mass exceeds 5 |
| 10 | 512 | EXTERNAL_MASK | Pixel was masked using external mask |
| 11 | 1024 | CASE2 | Pixel was processed in "case2" mode |
| 12 | 2048 | INCONSISTENCY | |
| 13 | 4096 | ANOMALY_RWMOD_BLUE | |

A pixel is considered valid if bitmask & 1023 == 0 .

## 4.7 Selection and blending

### 4.7.1 Input data

This step uses the outputs of pixel identification and the three atmospheric correction steps as input.

***Table 4-18: Inputs of Sen2Water's selection and blending step***

| Band | Description | Resolution |
|---|---|---|
| pixel_classif_flags | Combination of flags, represented as int32, with CF flag masks attributes | 60m, grid of 1830x1830 pixels |
| rhow_B1<br>…<br>rhow_B8A | water-leaving reflectance from C2RCC, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| c2rcc_flags | quality flags of C2RCC atmospheric correction | 60m, grid of 1830x1830 pixels |
| rhos_443<br>…<br>rhos_2190 | water-leaving reflectance from ACOLITE, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| l2_negatives | quality flag of ACOLITE atmospheric correction | 60m, grid of 1830x1830 pixels |
| Rw443<br>…<br>Rw2190 | water-leaving reflectance from POLYMER, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| bitmask | quality flags of POLYMER atmospheric correction | 60m, grid of 1830x1830 pixels |

### 4.7.2 Auxiliary data

Selection and blending uses a derived static ocean mask as auxiliary input. The derived static mask distinguishes:

| **Zone** | **Pixels included** |
|---|---|
| 1 | Land (without dynamic water detection) |
| 2 | Land close to ocean coast ($d_2$ km buffer, with dynamic water identification) |
| 3 | Land close to inland water ($d_3$, with dynamic water identification) |
| 4 | Open ocean (without dynamic vegetated land identification) |
| 5 | Ocean close to coast ($d_5$ km buffer, with dynamic vegetated land identification) |
| 6 | Inland water without contact to ocean (with dynamic vegetated land identification) |
| 7 | Inland water in transition zone to ocean ($d_7$ km buffer, for blending and dynamic land identification)<br><br>The mask in this zone uses additional bits to encode the pixel distance to the fictive coastal line as additional information used for blending. (If more than 5 bits are required for this then the |

| | |
|---|---|
| | mask is encoded such that one bit distinguishes zone 7 from the other zones and the remaining bits either encode the zone or the distance.) |

The derived static ocean mask identifies a transition area between ocean water and inland water at river mouths and estuaries. Certain zones further restricts dynamic water and land detection to correct for changes in the coastline. The derivation of the mask is defined in [OMPC.TPZG-BC.ATBD 2023], section 5.2. It is subject to further analysis in the next phase of the project.

The ocean mask is provided as granules in 60m and UTM projection for all Sentinel-2 granules Tnnxxx.

### 4.7.3 Parameters

***Table 4-19: Parameters of Sen2Water's selection and blending step***

| Parameter | Description | Value for Sen2Water |
|---|---|---|
| output_flags | Whether to add sen2water_flags and pixel_classif_flags to the output | true |

### 4.7.4 Output data

The output of the selection and blending step is a set of bands with water-leaving reflectances and up to three flag variables, a simple-to-use flag-values mask as in Sen2Cor, and two variables for the detailed pixel identification and atmospheric correction results.

***Table 4-20: Outputs of Sen2Water's selection and blending step***

| Band | Description | Resolution |
|---|---|---|
| Rw443<br>Rw490<br>Rw560<br>Rw665<br>Rw705<br>Rw740<br>Rw783<br>Rw842<br>Rw865<br>Rw945<br>Rw1375<br>Rw1610<br>Rw2190 | water-leaving reflectance, represented as float32, NaN as fill value | 60m, grid of 1830x1830 pixels |
| pixel_class | Flag values for | 60m, grid of 1830x1830 pixels |
| sen2water_flags | Combination of flags, represented as int32, with CF flag masks attributes | 60m, grid of 1830x1830 pixels |

| Band | Description | Resolution |
|---|---|---|
| pixel_classif_flags | Combination of flags, represented as int32, with CF flag masks attributes | 60m, grid of 1830x1830 pixels |

Pixel_class is a flag_value coding of simple alternative classes, defined in Table 4-12.

Commented [SC1]: Missing reference

***Table 4-21: pixel_class mask alternative values***

| Value | Flag name | Description |
|---|---|---|
| 0 | NO_DATA | |
| 1 | CLEAR_LAND | |
| 2 | CLEAR_OCEAN_WATER | |
| 3 | CLEAR_INLAND_WATER | |
| 4 | SNOW_ICE | |
| 5 | CIRRUS | |
| 6 | CLOUD_OR_MOUNTAIN_SHADOW | |
| 7 | AMBIGUOUS_CLOUD | |
| 8 | CLOUD | |
| 9 | AC_OUT_OF_BOUNDS | |

sen2water_mask contains flags of atmospheric correction quality, including information which algorithms have been used for a pixel. Details are listed in Table 4-22. They may be revisited in the next phase of algorithm integration.

***Table 4-22: sen2water_flags mask combination values***

| Bit | Value | Flag name | Description |
|---|---|---|---|
| 1 | 1 | c2rcc_oor | C2RCC contributes and its flags report out-of-range |
| 2 | 2 | acolite_negatives | ACOLITE contributes and optical bands are negative |
| 3 | 4 | polymer_invalid | POLYMER contributes and one of the seven flags is set |
| 4 | 8 | with_c2rcc | C2RCC contributes |
| 5 | 16 | with_acolite | ACOLITE contributes |
| 6 | 32 | with_polymer | POLYMER contributes |

pixel_classif_flags is the set of masks of Idepix defined in section 4.3.4 .

## 4.8 Output formatting

### 4.8.1 Input data

the output data of the previous step

### 4.8.2 Auxiliary data

none

### 4.8.3 Command line parameters

none

### 4.8.4 Output data

Each L2W data item is a single NetCDF4 file. The structure of the L2W data product is defined in NetCDF Common Data Language (CDL) format with dimensions, variables, variable attributes, and product level "global" attributes.

The dimensions correspond to the extent of the L1C granule input in 60m resolution. It is 1830 x 1830 pixels.

```
netcdf \S2A_MSIL2W_20230601T104021_N0509_R008_T31UFU_20230601T191959 {
dimensions:
        time = 1 ;
        row = 1830 ;
        column = 1830 ;
```

The water leaving reflectances Rw are named according to their wavelengths, Rw443 to Rw2190.

> There currently is no standard name in the CF standard name table for water-leaving reflectances. If we manage to propose a definition to CF we will add it to the variable attributes.

```
variables:
        uint16 Rw443(time, row, column) ;
                Rw443:long_name = "Atmospherically corrected angular dependent water leaving reflectance" ;
                Rw443:units = "1" ;
                Rw443:wavelength = 443.f ;
                Rw443:_FillValue = 0 ;
                Rw443:scale_factor = 0.0001 ;
                Rw443:add_offset = -0.1 ;
        uint16 Rw490(time, row, column) ;
                Rw490:long_name = "Atmospherically corrected angular dependent water leaving reflectance" ;
                Rw490:units = "1" ;
                Rw490:wavelength = 490.f ;
                Rw490:_FillValue = 0 ;
                Rw490:scale_factor = 0.0001 ;
                Rw490:add_offset = -0.1 ;
        uint16 Rw560(time, row, column) ;
                Rw560:long_name = "Atmospherically corrected angular dependent water leaving reflectance" ;
                Rw560:units = "1" ;
                Rw560:wavelength = 560.f ;
```

```
        Rw560:_FillValue = 0 ;
        Rw560:scale_factor = 0.0001 ;
        Rw560:add_offset = -0.1 ;
    uint16 Rw665(time, row, column) ;
        Rw665:long_name = "Atmospherically corrected angular dependent water leaving reflectance" ;
        Rw665:units = "1" ;
        Rw665:wavelength = 665.f ;
        Rw665:_FillValue = 0 ;
        Rw665:scale_factor = 0.0001 ;
        Rw665:add_offset = -0.1 ;
    uint16 Rw705(time, row, column) ;
        Rw705:long_name = "Atmospherically corrected angular dependent water leaving reflectance" ;
        Rw705:units = "1" ;
        Rw705:wavelength = 705.f ;
        Rw705:_FillValue = 0 ;
        Rw705:scale_factor = 0.0001 ;
        Rw705:add_offset = -0.1 ;
    uint16 Rw740(time, row, column) ;
        Rw740:long_name = "Atmospherically corrected angular dependent water leaving reflectance" ;
        Rw740:units = "1" ;
        Rw740:wavelength = 740.f ;
        Rw740:_FillValue = 0 ;
        Rw740:scale_factor = 0.0001 ;
        Rw740:add_offset = -0.1 ;
    uint16 Rw783(time, row, column) ;
        Rw783:long_name = "Atmospherically corrected angular dependent water leaving reflectance" ;
        Rw783:units = "1" ;
        Rw783:wavelength = 783.f ;
        Rw783:_FillValue = 0 ;
        Rw783:scale_factor = 0.0001 ;
        Rw783:add_offset = -0.1 ;
    uint16 Rw842(time, row, column) ;
        Rw842:long_name = "Atmospherically corrected angular dependent water leaving reflectance" ;
        Rw842:units = "1" ;
        Rw842:wavelength = 842.f ;
        Rw842:_FillValue = 0 ;
        Rw842:scale_factor = 0.0001 ;
        Rw783:add_offset = -0.1 ;
    uint16 Rw865(time, row, column) ;
        Rw865:long_name = "Atmospherically corrected angular dependent water leaving reflectance" ;
        Rw865:units = "1" ;
        Rw865:wavelength = 865.f ;
        Rw865:_FillValue = 0 ;
        Rw865:scale_factor = 0.0001 ;
        Rw865:add_offset = -0.1 ;
    uint16 Rw945(time, row, column) ;
        Rw945:long_name = "Atmospherically corrected angular dependent water leaving reflectance" ;
        Rw945:units = "1" ;
        Rw945:wavelength = 945.f ;
        Rw945:_FillValue = 0 ;
        Rw945:scale_factor = 0.0001 ;
        Rw945:add_offset = -0.1 ;
    uint16 Rw1375(time, row, column) ;
        Rw1375:long_name = "Atmospherically corrected angular dependent water leaving reflectance" ;
        Rw1375:units = "1" ;
        Rw1375:wavelength = 1375.f ;
        Rw1375:_FillValue = 0 ;
        Rw1375:scale_factor = 0.0001 ;
        Rw1375:add_offset = -0.1 ;
    uint16 Rw1610(time, row, column) ;
```

```
                Rw1610:long_name = "Atmospherically corrected angular dependent water leaving reflectance" ;
                Rw1610:units = "1" ;
                Rw1610:wavelength = 1610.f ;
                Rw1610:_FillValue = 0 ;
                Rw1610:scale_factor = 0.0001 ;
                Rw1610:add_offset = -0.1 ;
        uint16 Rw2190(time, row, column) ;
                Rw2190:long_name = "Atmospherically corrected angular dependent water leaving reflectance" ;
                Rw2190:units = "1" ;
                Rw2190:wavelength = 2190.f ;
                Rw2190:_FillValue = 0 ;
                Rw2190:scale_factor = 0.0001 ;
                Rw2190:add_offset = -0.1 ;
```

The pixel class is represented by a set of alternative values, similar to SCL of Sen2Cor, but with a focus to discriminate water from non-water.

The final set of values will be defined in the next phase. It will be based on an analysis of pixel_classif_flags, c2rcc_flags, acolite_flags, polymer_bitmask and their merging.

```
        byte pixel_class(time, row, column) ;
                pixel_class:long_name = "Pixel classification and algorithm flags" ;
                pixel_class:flag_meanings = "NO_DATA CLEAR_LAND CLEAR_OCEAN_WATER
CLEAR_INLAND_WATER SNOW_ICE CIRRUS CLOUD_OR_MOUNTAIN_SHADOW AMBIGUOUS_CLOUD CLOUD
AC_OUT_OF_BOUNDS" ;
                pixel_class:flag_values = "0,1,2,3,4,5,6,7,8,9" ;
                pixel_class:_FillValue = 0

       uint sen2water_flags(time, row, column) ;
               string sen2water_flags:long_name = "quality flags"
;               string sen2water_flags:flag_meanings = "c2rcc_oor acolite_negatives
polymer_invalid with_c2rcc with_acolite with_polymer" ;
               sen2water_flags:flag_masks = 1U, 2U, 4U, 8U, 16U, 32U ;

       short pixel_classif_flags(time, row, column) ;
               pixel_classif_flags:flag_meanings = "IDEPIX_INVALID IDEPIX_CLOUD
IDEPIX_CLOUD_AMBIGUOUS IDEPIX_CLOUD_SURE IDEPIX_CLOUD_BUFFER IDEPIX_CLOUD_SHADOW IDEPIX_SNOW_ICE
IDEPIX_BRIGHT IDEPIX_WHITE IDEPIX_COASTLINE IDEPIX_LAND IDEPIX_MOUNTAIN_SHADOW" ;
               pixel_classif_flags:flag_masks = 1s, 2s, 4s, 8s, 16s, 32s, 64s, 128s,
256s, 512s, 1024s, 2048s ;
               pixel_classif_flags:flag_descriptions = "Invalid pixels\tPixels which
are either cloud_sure or cloud_ambiguous\tSemi transparent clouds, or clouds where the
detection level is uncertain\tFully opaque clouds with full confidence of their
detection\tA buffer of n pixels around a cloud. n is a user supplied parameter.
Applied to pixels masked as \'cloud\'\tPixel is affected by a cloud shadow\tClear
snow/ice pixels\tBright pixels\tWhite pixels\tPixels at a coastline\tLand
pixels\tPixel is affected by a mountain/hill shadow" ;
```

The coordinates are a single time value and the CRS to determine geographic coordinates of each pixel.

```
        double time(time) ;
                time:standard_name = "time" ;
                time:axis = "T" ;
                time:calendar = "Gregorian" ;
                time:units = "seconds since 2000-01-01 00:00:00" ;
        byte crs ;
                crs:crs_wkt = "..." ;
```

```
                crs:i2m = "..." ;
```

The product level attributes provide metadata on identification, creation, temporal coverage, tracability, and quality statistics.

```
// global attributes:
        :id = "S2A_MSIL2W_20230601T104021_N0509_R008_T31UFU_20230601T191959" ;
        :date_created = "20230602T052612Z" ;
        :tracking_id = "cccf93c6-b9a4-4869-bbec-d58195a2e2e2" ;
        :title = "Sentinel-2 MSI water reflectances" ;
        :institution = "Brockmann Consult GmbH, ACRI, Telespazio, RBINS, HYGEOS for ESA" ;
        :source = "Sentinel-2 MSI L1C" ;
        :processor = "Sen2Water 1.0" ;
        :product_version = "01.00" ;
        :history = "SNAP-9 S2Resampling; Idepix 9.0; Acolite 20221114; C2RCC 9.0; Polymer 4.17beta; HROC L2W 20201223" ;
        :input = "S2A_MSIL1C_20230601T104021_N0509_R008_T31UFU_20230601T191959" ;
        :auxiliary = "Copernicus Global 90m DEM; ..." ;
        :parameters = "resolution=60; ..." ;
        :statistics = "clear_land=...; clear_ocean=...; clear_inland_water=...; cloud_over_inland_water=...; snow_ice_...=..." ;
        :references = "https://step.esa.int/main/snap-supported-plugins/sen2cor/" ;
        :license = "License to Use Copernicus Products" ;
        :summary = "The Sen2Water product has been processed from Sentinel-2 MSI L1C by pixel identification, atmospheric
correction with different processors, and selection or blending for ocean and inland water pixels." ;
        :keywords = "reflectance, surface water, ocean optics, Copernicus" ;
        :keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Science keywords" ;
        :Conventions = "CF-1.10" ;
        :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention" ;
        :contact = "https://step.esa.int/main/snap-supported-plugins/sen2cor/" ;
        :project = "OPT-MPC Sen2Water" ;
        :cmd_data_type = "Grid" ;
        :platform = "Sentinel-2" ;
        :sensor = "MSI" ;
        :spatial_resolution = "60m" ;
        :time_coverage_start = "20230601T104021Z" ;
        :time_coverage_stop = "20230601T104021Z" ;
        :start_date = "01-JUN-2023 10:40:21.000000" ;
        :stop_date = "01-JUN-2023 10:40:21.000000" ;
        :auto_grouping = "Rw*" ;
}
```

The complete list of statistics counts (see [MSI L2 ATBD 2023]) is:

clear_ocean_count
clear_inland_water_count
clear_land_count
snow_ice_ocean_count
snow_ice_inland_water_count
snow_ice_land_count
cloud_ocean_count
cloud_inland_water_count

cloud_land_count
valid_ocean_count
valid_inland_water_count
valid_land_count
valid_count

All_variables of the L2W data product that have row and column dimensions shall be chunked in 610 x 610 pixel blocks. Example for `Rw443`:

```
Rw443:_Storage = "chunked" ;
Rw443:_Shuffle = "true" ;
Rw443:_ChunkSizes = 1, 610, 610 ;
Rw443:_DeflateLevel = 5 ;
```

The naming of the Sen2Water output follows the pattern

`MMM_MSIL2W_YYYYMMDDTHHMMSS_Nxxyy_ROOO_Txxxxx_<Product Discriminator>`

where:

- MMM: is the mission ID (S2A/S2B)
- YYYYMMDDTHHMMSS: is the Datatake Sensing Time
- xxyy: identifies the current processing baseline of the L1C input
- OOO: is the relative orbit number
- Txxxxx: is the tile ID
- <Product Discriminator>: this field guarantees the uniqueness of the Single Tile product name; its value is the L2W product CREATION DATE in the format yyyymmddThhmmss. In the PDGS configuration the output file name can be renamed to align it to the creation date of the product.

Example:

`S2A_MSIL2W_20230601T104021_N0509_R008_T31UFU_20230601T191959`

## 4.9 Contributions to the L2A output product

Contributions of the L2W data product to the combined L2A data product are:

- The NetCDF4 file as a whole, to be added as one element to the SAFE structure of the L2A
- Metadata that is provided in the global metadata above, in particular the statistics (see previous subsection), but also the auxiliary data that has been used
- Optionally more quality parameters that can be extracted from the flag bands of L2W

# 5 Inputs and outputs of the combined L2 processor

This section defines inputs and outputs of the combined Sen2Cor and Sen2Water processor.

## 5.1 Input data

The main input of the combined processor is the L1C described in section 2.

It is input to both submodules Sen2Cor and Sen2Water.

The combined L2 processor works with the following L1C PDIs in input:

- DATASTRIP PDI, e.g. DS_2APS_20230610T144925_S20230610T110622
- GRANULE PDI, e.g. L1C_T31UCU_A041604_20230610T110622

## 5.2 Auxiliary data

The auxiliary data used by the combined processor is the sum of all auxiliary inputs of all steps of both processors. It is:

- The dynamic auxiliary data included in the L1C.
- The Copernicus Global 90m DEM
- CCI Land Cover classification map
- CCI Land Cover water bodies map
- CCI Land Cover snow/ice climatology
- Water mask of the Sentinel Toolboxes (unless harmonised with CCI water bodies mask)
- Static lookup tables for ACOLITE
- Sen2Water ocean-inland-transition zone mask in granules geometry at 60m

## 5.3 GIPP Parameters

Parameters of the combined Sen2Cor and Sen2Water processor are the sum of parameters of Sen2Cor and Sen2Water. The parameters are configured as GIPP xml files. For the combined processor the GIPP of Sen2Cor is extended by a top-level element Sen2Water with the Sen2Water specific parameters. These are:

| Parameter Name | Default value | Description |
|---|---|---|
| demName | "Sentinel Global 90m DEM" | one of "Sentinel Global 90m DEM", "SRTM 1sec", "GETASSE30" |
| auxiliarySource | "L1C" | one of "L1C", "OBPG", "none" |

| Parameter Name | Default value | Description |
|---|---|---|
| outputFlags | true | Whether to write pixel_classif_flags and sen2water_flags to the output |
| auxdataDir | "auxdata" | Cache directory for auxiliary data either provided or dynamically downloaded when first used |

## 5.4 Output data

The output data of the combined processor is the L2A product. It includes the outputs of Sen2Cor and aquatic reflectances. The logical and physical structure will be defined in the future PSD. Until the PSD is updated the combined product is defined in the next section.

# 6 The combined L2A data product (see also PSD)

This section defines the combined L2A data product. This section will later be moved to the PSD.

The combined L2 processor shall outputs L2A PDIs as follow:

- DATASTRIP PDI, e.g. DS_2APS_20230610T144925_S20230610T110622
- GRANULE PDI, e.g. L2A_T31UCU_A041604_20230610T110622

L2A PDIs that are later used to create the final L2A End-User-Product (EUP) for dissemination to the users.

## 6.1 Logical structure

The logical structure shall mainly preserve the current L2A Product Structure [S2-PSD] and shall comply with an updated L2A Products Specification Document (and associated SAFE and Schema) and linked to a dedicated Processing Baseline (e.g. PB 06.00).

The output of Sen2Water described in section 4.9, i.e. the L2W NetCDF4 file, shall be embedded within the L2A Product granule in the following subfolder: IMG_DATA --> R60m (see section 6.2)

## 6.2 Physical structure

The new Sentinel-2 MSI L2A shall be provided in SAFE format with the physical layout of the directory structure as follows (shown by an example, EUP format) with additional file located in IMG_DATA --> R60m folder:

```
S2A_MSIL2A_20230610T110621_N0509_R137_T31UCU_20230610T165306.SAFE
├── DATASTRIP
│   └── DS_2APS_20230610T165306_S20230610T110622
│       ├── MTD_DS.xml
│       └── QI_DATA
│           ├── FORMAT_CORRECTNESS.xml
│           ├── GENERAL_QUALITY.xml
│           ├── GEOMETRIC_QUALITY.xml
│           ├── RADIOMETRIC_QUALITY.xml
│           └── SENSOR_QUALITY.xml
├── GRANULE
│   └── L2A_T31UCU_A041604_20230610T110622
│       ├── AUX_DATA
│       │   ├── AUX_CAMSFO
│       │   └── AUX_ECMWFT
│       ├── IMG_DATA
│       │   ├── R10m
│       │   │   ├── T31UCU_20230610T110621_AOT_10m.jp2
│       │   │   ├── T31UCU_20230610T110621_B02_10m.jp2
│       │   │   ├── T31UCU_20230610T110621_B03_10m.jp2
│       │   │   ├── T31UCU_20230610T110621_B04_10m.jp2
│       │   │   ├── T31UCU_20230610T110621_B08_10m.jp2
│       │   │   ├── T31UCU_20230610T110621_TCI_10m.jp2
│       │   │   └── T31UCU_20230610T110621_WVP_10m.jp2
│       │   ├── R20m
```

```
│   │   │   ├── T31UCU_20230610T110621_AOT_20m.jp2
│   │   │   ├── T31UCU_20230610T110621_B01_20m.jp2
│   │   │   ├── T31UCU_20230610T110621_B02_20m.jp2
│   │   │   ├── T31UCU_20230610T110621_B03_20m.jp2
│   │   │   ├── T31UCU_20230610T110621_B04_20m.jp2
│   │   │   ├── T31UCU_20230610T110621_B05_20m.jp2
│   │   │   ├── T31UCU_20230610T110621_B06_20m.jp2
│   │   │   ├── T31UCU_20230610T110621_B07_20m.jp2
│   │   │   ├── T31UCU_20230610T110621_B11_20m.jp2
│   │   │   ├── T31UCU_20230610T110621_B12_20m.jp2
│   │   │   ├── T31UCU_20230610T110621_B8A_20m.jp2
│   │   │   ├── T31UCU_20230610T110621_SCL_20m.jp2
│   │   │   ├── T31UCU_20230610T110621_TCI_20m.jp2
│   │   │   └── T31UCU_20230610T110621_WVP_20m.jp2
│   │   └── R60m
│   │       ├── T31UCU_20230610T110621_AOT_60m.jp2
│   │       ├── T31UCU_20230610T110621_B01_60m.jp2
│   │       ├── T31UCU_20230610T110621_B02_60m.jp2
│   │       ├── T31UCU_20230610T110621_B03_60m.jp2
│   │       ├── T31UCU_20230610T110621_B04_60m.jp2
│   │       ├── T31UCU_20230610T110621_B05_60m.jp2
│   │       ├── T31UCU_20230610T110621_B06_60m.jp2
│   │       ├── T31UCU_20230610T110621_B07_60m.jp2
│   │       ├── T31UCU_20230610T110621_B09_60m.jp2
│   │       ├── T31UCU_20230610T110621_B11_60m.jp2
│   │       ├── T31UCU_20230610T110621_B12_60m.jp2
│   │       ├── T31UCU_20230610T110621_B8A_60m.jp2
│   │       ├── T31UCU_20230610T110621_SCL_60m.jp2
│   │       ├── T31UCU_20230610T110621_TCI_60m.jp2
│   │       ├── T31UCU_20230610T110621_WVP_60m.jp2
│   │       └── T31UCU_20230610T110621_AQU_60m.nc
│   ├── MTD_TL.xml
│   └── QI_DATA
│       ├── FORMAT_CORRECTNESS.xml
│       ├── GENERAL_QUALITY.xml
│       ├── GEOMETRIC_QUALITY.xml
│       ├── L2A_QUALITY.xml
│       ├── MSK_CLASSI_B00.jp2
│       ├── MSK_CLDPRB_20m.jp2
│       ├── MSK_CLDPRB_60m.jp2
│       ├── MSK_DETFOO_B01.jp2
│       ├── MSK_DETFOO_B02.jp2
│       ├── MSK_DETFOO_B03.jp2
│       ├── MSK_DETFOO_B04.jp2
│       ├── MSK_DETFOO_B05.jp2
│       ├── MSK_DETFOO_B06.jp2
│       ├── MSK_DETFOO_B07.jp2
│       ├── MSK_DETFOO_B08.jp2
│       ├── MSK_DETFOO_B09.jp2
│       ├── MSK_DETFOO_B10.jp2
│       ├── MSK_DETFOO_B11.jp2
│       ├── MSK_DETFOO_B12.jp2
│       ├── MSK_DETFOO_B8A.jp2
│       ├── MSK_QUALIT_B01.jp2
│       ├── MSK_QUALIT_B02.jp2
│       ├── MSK_QUALIT_B03.jp2
│       ├── MSK_QUALIT_B04.jp2
│       ├── MSK_QUALIT_B05.jp2
│       ├── MSK_QUALIT_B06.jp2
│       ├── MSK_QUALIT_B07.jp2
```

```
│           ├── MSK_QUALIT_B08.jp2
│           ├── MSK_QUALIT_B09.jp2
│           ├── MSK_QUALIT_B10.jp2
│           ├── MSK_QUALIT_B11.jp2
│           ├── MSK_QUALIT_B12.jp2
│           ├── MSK_QUALIT_B8A.jp2
│           ├── MSK_SNWPRB_20m.jp2
│           ├── MSK_SNWPRB_60m.jp2
│           ├── SENSOR_QUALITY.xml
│           └── T31UCU_20230610T110621_PVI.jp2
├── HTML
│   ├── banner_1.png
│   ├── banner_2.png
│   ├── banner_3.png
│   ├── star_bg.jpg
│   ├── UserProduct_index.html
│   └── UserProduct_index.xsl
├── INSPIRE.xml
├── manifest.safe
├── MTD_MSIL2A.xml
├── rep_info
│   ├── S2_PDI_Level-2A_Datastrip_Metadata.xsd
│   ├── S2_PDI_Level-2A_Tile_Metadata.xsd
│   └── S2_User_Product_Level-2A_Metadata.xsd
└── S2A_MSIL2A_20230610T110621_N0509_R137_T31UCU_20230610T165306-ql.jpg
```

## 6.3 Metadata

In term of Metadata content, the following information shall be embedded within the MTD_TL.xml:

- Flag for correct execution of Sen2Water

In case Sen2Water is correctly executed the following information may be added:

- Cloud cover over Water percentage
  In current L2A, "CLOUDY_PIXEL_OVER_LAND_PERCENTAGE" is present
  In new L2A, "CLOUDY_PIXEL_OVER_WATER_PERCENTAGE" can be added
- Land / Water ratio or Land / Ocean / Inland water percentages
- C2RCC, ACOLITE, POLYMER, BLENDING flags
- Additional metadata that is provided in the global metadata of the NetCDF4 file, like the statistics and the auxiliary data used during sen2water processing.

Metadata at product level (MTD_MSIL2A.xml):

It shall be evaluated which MTD_TL.xml information is propagated, by the L2A EUP packager, up to the product metadata file MTD_MSIL2A.xml.

## 6.4 Naming convention

The new L2A naming convention shall follow the convention of the actual L2A Product [S2-PSD]. The 'AQU' is proposed as specific TAG for the aquatic data and .nc as file extension for L2W NetCDF4 file:

```
<Tile>_<Datatake_Sensing_Time>_<Band_Index>_<Resolution>.nc
```

where

```
Band_Index = 'AQU'
```

Examples of a S2 L2A Aquatic Reflectance filename:

```
T31UCU_20230610T110621_AQU_60m.nc
```