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# S2 MPC

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## Sen2Cor Software Release Note

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*Ref. S2-PDGS-MPC-L2A-SRN-V2.3.1*



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## Change Log

Issue	Date	Reason for change	Section(s)
1.0.1	June 2014	Initial Delivery	N/A
2.0.3	May 2015	First Maintenance Patch	3.1.8
2.0.4	Oct. 2015	Urgent fix for correcting the scaling problem on the Level 2A output files	3.1.7
2.0.5	Nov. 2015	Fix for calibration problem between 60/20 and 10 m resolutions	3.1.6
2.0.6	Dez. 2015	Fix corrupted version of windows openjp2.dll Added correction parameter for sun-earth distance	3.1.5
2.1.0	Feb. 2016	Parallel processing on tile base	3.1.4
2.2.1	Apr. 2016	Integration of Look Up Tables for Summer / Winter /Rural / Water atmospheric conditions, automated ozone determination, automated aerosol / atmosphere detection, improved up- and down sampling routines, new scene classification, selection of planet DEM	3.1.3
2.3.0	Nov. 2016	Support of PSD 14.2 in parallel to PSD 13.1 and corrective maintenance fixes as described for section 3.1.2.2	3.1.2
2.3.1	Feb. 2016	Maintenance fixes as specified in section 3.1.1	3.1.1
2.3.1	Feb. 2016	Added list of known issues	3.2
2.3.1	Feb. 2016	Added list of planned evolutionary upgrades	3.3

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# 1. Introduction

## 1.1 Purpose of the document

This document is produced in the context of the SENTINEL-2 (S2) Mission Performance Centre (MPC) maintenance and evolution. Its purpose is to document the performed corrective maintenance and evolutionary upgrades applied to the Sentinel 2 Level-2A processor software named Sen2Cor, its installation and environment settings.

## 1.2 Document structure

Chapter 1 provides the introduction, describing the scope and structure of the document, and a list of applicable reference documents.

Chapter 2 describes in short the scope of the current release and the content of the delivery

Chapter 3 gives an overview on the history of the evolution and applied fixes for each release in a downward order.

Chapter 4 gives a introduction how to install and configure the software and its environment.

Chapter 5 lists the Copyright Notes

## 1.3 References

The following is a list of documents with a direct bearing on the content of this release note.

**Table 1-1: Reference Documents**

Reference	Title	Issue
[L2A-GLODEF]	S2PAD Project Glossary S2PAD-VEGA-GLO-0001	3.5
[L2A-SUM]	Sentinel-2 MSI – Level 2A Processor Installation and User Manual	2.3
[L2A-IODD]	Sentinel-2 MSI – Input Output Data Definition	1.1
[L2A-PFS]	Sentinel-2 MSI – Product Format Specification	1.7
[L2A-PDD]	Sentinel-2 MSI – Level-2A Product Definition Document	4.5
[L2A-ATBD]	Sentinel-2 MSI – Level 2A Products, Algorithm Theoretical Basis	2.0
[L2A-DPM]	Sentinel-2 MSI – Level 2A Detailed Processing Model	2.1

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## 2. Software release overview

Release 2.3.1 is a bug fix release based on release 2.3.0.

### 2.1 Delivery List

Delivery number	Description
D1	Processor software Sen2Cor-V2.3.1
D2	This release note

Details on the applied fixes are listed in section 3.1.1.

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## 3. Status of the software configuration item


### 3.1 Evolution History


#### 3.1.1 Evolution since release 2.3.0

Sen2Cor release 2.3.1 is a corrective maintenance upgrade based on release 2.3.0 and includes the fixes as described next. Section 3.2 lists the known open issues which will be fixed in the upcoming release 2.4.0, which is currently under preparation to be released during spring of this year.

##### 3.1.1.1 Corrective Maintenance

The following fixes have been applied to release 2.3.1:

Issue	Description
SIIMPC-550	<p>SRTM DEM artefacts in coastal areas: in the previous algorithm for the preparation of SRTM DEMs artefacts in coastal areas could appear. This has been improved by rearranging the processing steps.</p> 
SIIMPC-792	<p>Error in SRTM contour lines: the problem happened for terrain with gentle slopes. Contour lines are visible because the slopes had been computed after a resampling of original DEM (90m) to 10m resolution. The elevation information was stored as integer with 1m vertical resolution which leads to some steps for gentle slopes. These steps are then interpreted as steep slopes (1 m altitude difference in 10 meter pixel ~ terrain slope of 10%) and the consequence is an artificial terrain correction due to these DEM slopes processing artefacts. The implemented solution performs a cubic spline resampling in data type float before performing the slope calculation to overcome this issue.</p>

	
SIIMPC-805	Quality Indicators for cloud coverage percentage have not been properly updated in the metadata at the product level. The quality indicators on product level metadata shall give an average on all processed tiles. The calculation was incorrect due to a copy and paste error. This has been fixed.
SIIMPC-822	Under some conditions multiple entries for the B08 BAND_NAME in the metadata at 10 m resolution occur, which lead to a validation error. This has been fixed.
SIIMPC-880	If a tile contains a huge amount of water and only few parts of land, an overcorrection (black water in RGB Image) is observable (e.g.: tile S2A_MSIL1C_20170108T113441_N0204_R080_T29TNJ_20170108T113754). This deviation has been improved. A full resolution of this issue requires a redesign of the AOT calculation and is planned for upcoming releases and is listed in section 3.2.
SIIMPC-887	Program terminates abnormally if an SRTM DEM is not available for a selected tile (e.g.: srtm_34_04.tif). This has been corrected by continuing the execution with a flat surface instead.
SIIMPC-888	Cirrus correction was activated in the default configuration. This has been deactivated as issues with cirrus correction have been observed. These issues will be fixed in a later release as listed in section 3.2.

### 3.1.2 Evolution since release 2.2.1

Sen2Cor release 2.3 is an evolutionary update on top of release 2.2.1 and implements the support of PSD 14.2 in parallel to PSD 13.1 and the corrective maintenance fixes as described below for section 3.1.2.2.

#### 3.1.2.1 Evolutionary Updates

The following features have been implemented new during the course of this release:

Issue	Description
<u>SIIMPC-677</u>	Implementation of PSD V14.2 in parallel to V13.1 with following additional features: <ol style="list-style-type: none"> <li>The product naming (including the naming of folders and files</li> </ol>

	<p>inside the product structure) has been compacted to overcome the 256 characters limitation on pathnames imposed by the Windows platforms.</p> <ol style="list-style-type: none"> <li>The products distributed on the Sentinels Data Hub will embed one single tile of the tiling grid (as opposed to a set of tiles).</li> <li>A full resolution True-Colour Image (TCI) will be included in every product as a separate RGB composite image (in JPEG2000 format) and will be placed inside the Tile folder together with the original spectral band images.</li> </ol> <p>These features will only be active if a product with PSD V14 and above is found. The software is downward compatible to PSD V:13.1.</p>
<u>SIIMPC-805</u>	<p>A new Quality Indicator for cloud coverage percentage which is the sum of the percentages of “Cloud medium probability”, “Cloud High probability” and “Thin cirrus” is available if PSD Version is 14 and above.</p> <p>Additionally a reference to the origin of the L1C input is added under L2A_Product_Info in the User Product metadata. This will only be displayed if PSD is Version 14 and above.</p>

### 3.1.2.2 Corrective Maintenance

The following fixes have been applied:

Issue	Description
<u>SIIMPC-768</u>	S2Toolbox showed NAN for DN Values of 0. This occurs when negative reflectance values are clipped. Clipping has been set to 1 instead to avoid this false labelling.
<u>SIIMPC-734</u>	New type of files in L1C products: some of the recent L1C products contained .gfs files which are geolocation header files for the masks. These files are unexpected by Sen2Cor and lead to an error at the end of the processing when creating the manifest.safe file. A patch was applied to avoid this issue.
<u>SIIMPC-733</u>	Empty date in log file and “<>” characters: the display of an empty acquisition date and unwanted characters in the xml reports has been fixed.
<u>SIIMPC-702</u>	Processor hangs after creating the DEM files: problems occurred during the creation of DEM files when concurrent access from different processes on the same file generated by gdalwarp occurred. This has been fixed by using the subprocess.Popen.wait() command until the gdal call which created the according file returned.
<u>SIIMPC-687</u>	Different tilesize in converted L2A JPEG-2000 data: the tilesize for the generation of the Jp2K output files has been adapted to the parameters given for the L1C input data.
<u>SIIMPC-686</u>	In section 3.2.1 of the SUM 2.2 still the old convention for processing is stated, which contrasts to the interface changes described for section 2.4.2. This has been aligned.

<u>SIIMPC-672</u>	Handling of AUTO setting for Atmosphere configuration: in some cases, when no Dark Dense Vegetation reference pixels have been found in the input data, the automated aerosol determination failed. This has been fixed in the way that the default values for SUMMER RURAL atmospheric conditions are selected, if this case occurs.
<u>SIIMPC-611</u>	Wrong ids of srtm files for products between 60 and 65° of latitude: there was a rounding error for calculation of the latitude and longitude values for these ranges, which has been fixed.
<u>SIIMPC-599</u>	Rewriting of L1C tiles metadata: the xml parser used a prettifier which failed when L1C data are blocked for writing or write protected. This has been removed so that L1C data can be read only without affecting the execution.
<u>SIIMPC-598</u>	Fails when user does not have write permission on the L1C: as the L2A data are copied from the L1C data, these new data are also write protected which led to an error when updating these files. L2A files properties are now recursively set to be writable for the user to avoid this error.
<u>SIIMPC-577</u>	SRTM georeferencing issue: Sen2Cor uses 5x5° SRTM tiles provided by CGIAR as geotiff and 1x1° PlanetDEM tiles as dted, and resamples them on the L2A product tile grid with gdalwarp. Then the DEM and the product bands are superimposed pixel to pixel. When checking the DEMs that outputs Sen2Cor on a same product, between the two different input DEMs, a half-pixel shift was discovered. This ends to a bad resampling when using SRTM DEMs. SRTM geotiff files do apparently not respect the GDAL convention that the origin should be the upper left corner of the upper left pixel. A solution was implemented in the way to rewrite the geoinformation of the geotiff file, via shifting the origin of a half pixel in the South West direction. This improved the output considerable when using the SRTM dem which is now comparable to the Planet one.
<u>SIIMPC-573</u>	Wrong name of dted files: Digital elevation maps for dted files have been labelled wrong as srtm due to a copy and paste error. This has been fixed.
<u>SIIMPC-564</u>	PlanetDEM, stripes on final products: Mosaicking and resampling routine for the treatment and generation of PlanetDems has been separated in order to avoid artefacts on generated products, which have also been observed in the surface reflectance bands.
<u>SIIMPC-563</u>	GdalDEM errors for planet DEM in Sen2Cor 2.2.1: the treatment of the handling of intermediate products have been corrected in order to avoid errors in the generation of the planet DEM output files.
<u>SIIMPC-561</u>	Problems with concurrent access on L2A GIPP Files in root installation directories: same issue as for <u>SIIMPC-599</u> : the xml parser used a prettifier which failed when the GIPP files are blocked for writing or write protected. This has been removed so that GIPP data can be read only without affecting the execution.
<u>SIIMPC-558</u>	Geo-Location + Projection information embedded in JPEG2000 file: this is a major fix which was possible due to an upgrade of Glymur to 0.8.7 at the state of this release: this allows now to place the Geo-Location + Projection information in the same format as is used by GDAL, so that

	the L2A outputs are now in line with the L1C input data concerning geo referencing.
<u>SIIMPC-557</u>	<p>Option to set the terrain correction ON/OFF: DEMs generated by sen2cor are used for 3 different purposes:</p> <ul style="list-style-type: none"> <li>• the scene classification</li> <li>• the retrieval of AOT and WV</li> <li>• the terrain correction</li> </ul> <p>As the DEMs in generally improve the quality of the output, it is in some cases desirable to deactivate the third option of terrain correction. A configuration parameter named 'Rho_Retrieval_Step2 has been added, with the two options true and false. This has for the moment only experimental status and is only available for expert users in the calibration file L2A_CAL_AC_GIPP.</p>
<u>SIIMPC-556</u>	User DEM directory with read_only rights: as DTED DEMs are a commercial product, it is possible that these DEMs are located on a file server and are write protected. Thus a temporary directory was introduced for storing the intermediate products needed for creating the user DEMs, so that the source directory can be write protected. For SRTM DEMs this feature was not implemented, as here these products shall be able to be downloaded, so that the directory should not be write protected.
<u>SIIMPC-555</u>	Logging: Adding a timestamp to the log report filename: it is possible to generate the product multiple times for different tiles and resolutions. Thus the report file which is labelled with the product identifier was overwritten. A timestamp has been added to the report file at the time of creation. The log file will then be copied into the L2A product directory after successful processing.
<u>SIIMPC-554</u>	Logging: duplicated lines: duplicated lines have been observed in the report file. This has been fixed.
<u>SIIMPC-552</u>	Blue Path radiance rescaling routine update: Last L2A processing have shown that sometimes the Blue Path radiance rescaling routine leads to an overestimation of the blue surface reflectance (by underestimating the blue path radiance based on blue/red ratio from reference dark pixels). The implemented solution computes the mean value of the digital numbers for the whole granule in the red channel. Then all pixels are excluded as very bright surfaces which are more than 5 times larger than this mean value. This relative measure was selected because the problem was caused by adjacency correction. Adjacency correction is stronger for larger brightness differences in the image and the variable threshold adapts to the actual image.
<u>SIIMPC-551</u>	DEM data format in L2A AUX_DATA folder: DEMs can have negative values for land below the sea level. The problem is, that the current OpenJPEG library does not support signed integer values (Whereas Kakadu does). A selection of writing GeoTIFF instead of JPEG2000 is no alternative in terms of filesize for the 10 m resolution DEM. A long term solution would be to get 16-bit signed support from OpenJPEG and Glymur. The Short term solution we implemented here is adding an offset of 10.000 in order to be sure that no confusion can be

	made. Highest elevation value on Earth: ~8,848 m and lowest elevation value on dry land: ~ -418m, which would result in coding as 18848 and 9582 DN. This offset will also be stated in the User Manual.
<u>SIIMPC-550</u>	<p>Handling of SRTM NoData values: when the SRTM CGIAR V4.0 (default dem of Sen2Cor) data is imported in Sen2Cor, the NoData pixels are read with a value of (-32768). In this SRTM dataset, the sea pixels are set to NoData. There are several problems been identified with these -32768 values:</p> <p>The main problem is that there is a dem quality check in L2A_AtmosCorr that checks the peak to peak (max -min) value of the data. The resulting peak to peak value is negative and therefore the dem is judged unnecessary and not used for the Atmospheric Correction (AC). For a correct AC on coastal areas, the dem sea pixels should be set at zero. For this a land/sea mask is used.</p> <p>The implementation which was finally selected use the GDAL tools by replacing the nodata values on coastal regions with 0 before the other dem related bands are imported. So the fix occurs already on the level of the tiff input and corrects thus also the derived products for slope, aspect and shade.</p>

### 3.1.2.3 Configuration Changes

The following five changes in the configuration have been applied:

Configuration Item	Description	Value
Scaling_Limiter	limits the scaling of the path radiance for the blue channel to +/-10%.	True / false (default)
Scaling_Disabler	Disables the scaling of the path radiance for the blue channel.	True / false (default)
Rho_Retrieval_Step2	Disables the execution of step 2 of the	true (default) / false

As these configuration items are of experimental character they are located in the expert configuration file L2A\_CAL\_AC\_GIPP.xml and should not be changed by standard users.

In the user configuration file L2A\_GIPP.xml (located in the cfg subdirectory of the Sen2Cor home directory referenced by the \$SEN2COR\_HOME environment variable) the two following changes have been applied:

Configuration Item	Description	Value
Visibility	Sets the visibility default value	40.0 (default)
Cirrus_Correction	Cirrus correction has been activated as a default value	Yes

## 3.1.3 Evolution since release 2.1.0

### 3.1.3.1 Evolutionary Upgrades

#### 3.1.3.1.1 **Integration of Look Up Tables for Summer / Winter / Rural and Water atmosphere**

A set of 24 (LUTs) have been integrated to cover most of atmospheric conditions on Earth for the Sentinel-2 mission. In the SEN2COR context, a set of LUTs is composed by 6 or 4 LUT files depending on the total water vapor columns content of the atmosphere. Different LUTs are calculated for the mid-latitude summer and mid-latitude winter atmospheres, with 6 different (sea level) ozone contents, a rural and a maritime aerosol, 6 or 4 different sea level water vapor columns. For each supported water vapor level, the ground-to-space water vapor column depends on elevation according to the atmosphere temperature / humidity vertical profile provided. Details can be found in the user manual for SEN2COR 2.2.1.

SEN2COR LUTs are calculated for:

- 2 different types of aerosols (rural and maritime)
- 2 different types of atmospheres (Mid\_Latitude SUMMER and Mid\_Latitude WINTER)
- 6 different types of ozone concentrations (depending on summer or winter case)
- 6 or 4 different amounts of water vapor column (depending on summer or winter)

#### 3.1.3.1.2 **User Configuration**

The LUT selection is configurable via the three entries: Aerosol\_Type, Mid\_Latitude and Ozone\_Content in the Look\_UP\_Tables selection of the User Configuration file (L2A\_GIPP.xml) located in the cfg directory specified by the SEN2COR\_HOME environment variable. The water vapor columns are set internally.

#### 3.1.3.1.3 **Implementation of automated ozone determination**

If the Ozone\_Content is set to '0' by the user, it will be determined automatically by the processor. In that case, the measured ozone concentration is read from the L1C metadata and the LUT with the best fit for the measured ozone concentration is used.

#### 3.1.3.1.4 **Implementation of automated aerosol / atmosphere detection**

If the Aerosol\_Type and / or Mid\_Latitude are set to 'AUTO' by the user, it will be determined automatically by the processor. In that case the processor will process two (aerosol only) or four test trials before the final processing of the atmospheric correction takes place. After calculation of the scene path radiance in the blue and red region (as total minus reflected radiance, using the average

values obtained for the dark reference pixels) the ratio of  $L_p(\text{blue, scene})$  to  $L_p(\text{red, scene})$  can be compared to the corresponding ratio for the existing libRadtran aerosols (RURAL, MARITIME) or atmospheres (SUMMER, WINTER). The aerosol type for which the double ratio (dp) is closest to 1 is the best approximation for the scene and will be selected.

### 3.1.3.1.5 Improvement of the up- and down sampling routines

During the scientific evaluation campaign it has been shown, that using the previous selected methods for up and down sampling the different resolutions of the images (`scipy.ndimage.interpolation.zoom`), distortions of the colocation for equivalent pixels occurred. These routines have thus been replaced by the two routines `skimage.measure.block_reduce` for down- and `skimage.transform.resize` for up-sampling. These changes have the drawback of reducing the speed of reading of the JP2 input slightly, but improved the quality of the image data considerably.

### 3.1.3.1.6 Improvement of Scene Classification based on automated DEM selection

Previous releases of the processor had a tendency of false classification of water pixels inside of cloud borders and the correct discrimination between topographic and cloud shadow pixels. This has now been improved by taking the height information of an (optional) digital elevation map (DEM) as an additional input. To use this feature it is necessary to activate the reading of an appropriate DEM as is described in the User Manual.

### 3.1.3.2 Corrective Maintenance

#### 3.1.3.2.1 Correction of setup routines

Upgrade to Anaconda 4.0.0 and cleanup of the dependencies to fix the issue described in: <http://forum.step.esa.int/t/sen2or-install-error/1690/12>

#### 3.1.3.2.2 Correction of problems with the openjpeg2 drivers on Windows

The openjpeg DLL shipped with the previous releases of sen2cor was compiled with VC++. The DLL needs `msvcr120.dll` and `msvcpr120.dll` to load properly. These two libraries are in most cases part of the windows installation under `Windows\System32`, but in some cases and some systems, they are apparently not present. The new library provides with this release was built with mingw, and has no longer any dependency to the VC++ 120 runtime dll.

## 3.1.4 Evolution since release 2.0.6

### 3.1.4.1 New Features

#### 3.1.4.1.1 Implementation of parallelisation on tile base

SEN2COR supports now a parallel processing on tile base.

The maximum of processes can be determined via the `L2A_GIPP.xml` input configuration:



<Nr\_Processes>AUTO</Nr\_Processes>

Nr\_Processes can be an unsigned integer value specifying the number of processes intended to operate in parallel or: AUTO. If AUTO is chosen, the processor determines the number of processes automatically, using the CPU info of the given architecture.

If L2A\_Process is started with a L1C User product as the given directory argument, a series of tiles will be processed in parallel, according to the given Nr. of Processes in the L2A\_GIPP above. If the Nr of Processes is 1, only a sequential processing will take place as it was implemented in previous releases.

Memory requirements: the atmospheric correction processing for 10m resolutions uses a huge amount of memory due to the 10.000 x 10.000 pixel for each image. Multiple images must be kept at certain intervals completely in memory for performing correlations. Thus, for each processing at 10m resolution, as a general rule of thumb, a resource of at least 4 GB of memory per process should be available. Thus, unless you have a machine with sufficient memory, leave the Nr. of processes to single processing (1), otherwise memory overflow errors will occur during processing. On a 2 Core MAC / Linux workstation with 8 GB RAM, 2,8 GHz Intel i5 and 500 GB SSD, a 4 tiles parallel processing for 10m resolution images has been successfully performed. In systems which are equipped with hard disks, however more physical memory might be needed, due to swapping effects on the hard disk.

#### 3.1.4.1.2 Implementation of the Manifest generation for L2A User Product

Sen2cor now replaces the L1C manifest with its own L2A manifest on the User product level

#### 3.1.4.1.3 Implementation of single tile generation

A new feature for the processing of single tiles has been added. The pathname can now either point to a L1C user product or to a single tile of the user product.

If the argument points to a user product, all tiles of the user product will be processed subsequently. If the argument points to a single tile, only that tile will be processed. In the latter case, the configuration settings for parallel processing will be ignored.

#### 3.1.4.1.4 Relative pathname for products and single tiles

The <directory> argument of the command line can now be either a relative or an absolute pathname.

If a relative pathname is given, it is expected that the user is calling sen2cor from inside a parent directory. Sen2cor will expand the absolute pathname for that directory.

Sen2cor will use the L1C user product identifier for generating a subsequent L2A product. For this purpose, the L1C source directory must start with an identifier like 'S2A\_????\_??\_??L1C\*' which is the standard, if you download a L1C user product from the Sentinel 2 data hub. The generated product will get the identifier 'S2A\_????\_??\_??L2A\*', everything else will be inherited from the L1C source.

### 3.1.4.1.5 Upgrade of the PSD to version 13.1

Support of the Metadata Format has been upgraded from version 12.0 to version 13.1

### 3.1.4.1.6 Improvements in the generation of L2A user products

The routines for generating user products of different resolutions have been decoupled and generally improved:

- SEN2COR will now also work on existing L2A user products. This allows the generation of different resolutions in subsequent steps.
- If the user is specifying no resolution at all on the command line, all resolutions will be generated in three subsequent steps. This is the default. The selection of a 60 m resolution or 20m resolution via command line will only generate the resolution specified.
- If a resolution has already been processed for a given L2A product, sen2cor will not start a regeneration but will inform the user that this product already exists.
- The selection of a 10 m resolution requires the generation of a 20 m product. If a 20m product already exists from a previous processing, this will be taken as input, otherwise it will be generated in a first step, before the 10 m resolution product is processed. If the user wants to start from scratch, he must move, delete or rename the existing product.
- It is also possible to remove only single tiles of an existing product. These tiles will then be regenerated; the other existing tiles will be left untouched.

### 3.1.4.1.7 Implementation of PlanetDEM usage in parallel to CGIAR SRTM

See the section on Terrain Correction in the User Manual

### 3.1.4.2 Corrective Maintenance

#### 3.1.4.2.1 L2A Processor exit conventions

In previous releases SEN2COR terminated with "TRUE", after a successful processing. This has been changed now to return "0" for a successful processing and a value above 0 if processing errors occurred. The reasons for an unsuccessful termination can be found usually in the log file, except if a fatal error occurred which immediately killed the logging process.

#### 3.1.4.2.2 L2A generation error if input L1C includes only 1 band

It has been observed that the processor terminated with an error when a corrupt tile with incomplete band series was found. This has been fixed in the way that the processor will terminate the generation of this specific tile, but will continue with the generation of subsequent tiles.

### 3.1.4.2.3 Metadata file did not pass validation

The validation of the metadata has been adapted to version PSD V 13.1 and will no longer generate errors during validation, if the input data have the correct format. A warning will only occur on the processor output, if the validation fails. If validation is successful, no output will be generated on the standard output, but only in the logfile.

### 3.1.4.2.4 Issue in handling consolidated tiles

It has been observed that the processor terminated with an error when a consolidated tile was found. This has been fixed. The processing of a consolidated tile however might generate a validation warning, as consolidated tiles do not follow the metadata conventions for valid tile names.

### 3.1.4.2.5 Processor unable to process two (or more) data strips in one product

This has been corrected. Multiple data strips will now be processed and the metadata will be updated accordingly.

### 3.1.4.2.6 L2A generation error in case of black image

It has been observed that the processor terminated with an error when an image did not contain any data. The atmospheric correction cannot work on completely empty tiles. The processor will now stop the processing for the tile in question, shows a corresponding warning message and will continue with the processing of the subsequent tiles.

### 3.1.4.2.7 Issue of DEM import when DEM support is activated

In previous releases, it occurred that a DEM was not correctly generated after download. The routines for reading a DEM have been improved with respect to parallelisation.

### 3.1.4.2.8 Issues reprocessing L1C product when L2A product is already present

The routines for generating user products of different resolutions have been decoupled and generally improved:

- SEN2COR will now also work on existing L2A user products. This allows the generation of different resolutions in subsequent steps.
- If the user is specifying no resolution at all on the command line, all resolutions will be generated in three subsequent steps. This is the default. The selection of a 60 m resolution or 20m resolution via command line will only generate the resolution specified.
- If a resolution has already been processed for a given L2A product, sen2cor will not start regeneration but will inform the user that this product already exists.
- The selection of a 10 m resolution requires the generation of a 20 m product. If a 20m product already exists from a previous processing, this

will be taken as input, otherwise it will be generated in a first step, before the 10 m resolution product is processed. If the user wants to start from scratch, he must move, delete or rename the existing product.

- It is also possible to remove only single tiles of an existing product. These tiles will then be regenerated, the other existing tiles will be left untouched.

### 3.1.4.2.9 Problems with long pathnames on Windows

Windows had a path length limitation of 260 characters in the past. Unfortunately, Windows Explorer on Windows 7 x64 is still subject to this path limit. As a consequence, the very long pathnames of a typical Level-1C or Level-2A user product can sometimes not be handled correctly.

Since this release sen2cor is adapted to handle long path names on windows correctly. However there might still be problems that generated Level 2A User products (as well as the L1C input folders) cannot be removed entirely using the Windows explorer. If this is the case, the path names must be manually shortened to a length below 260 characters before removing can take place. **Please note - this is a windows limitation and not in any case related to sen2cor.**

### 3.1.4.2.10 Problem with file deletion / creation at 10 m resolution

Previous releases had a problem on Windows with a file deletion at 10 m resolution if a file already existed. This has been fixed.

The fixes described above correspond to the following entries in the JIRA database:

L2A SPR Ref.	Title
<a href="#">SIIMPC-334</a>	<a href="#">Update of PSD XSDs to version 13.1 for Sen2Cor 2.1.0</a>
<a href="#">SIIMPC-287</a>	<a href="#">L2A processor Exit Codes convention</a>
<a href="#">SIIMPC-275</a>	<a href="#">L2A generation error if input L1C include only 1 band</a>
<a href="#">SIIMPC-271</a>	<a href="#">[Meeting action] 20151130-DQM-12: Change request on L2A product format</a>
<a href="#">SIIMPC-126</a>	<a href="#">[Sen2Cor] Metadata file did not pass validation running Sen2Cor</a>
<a href="#">SIIMPC-319</a>	<a href="#">Issue on Sen2Cor in handling Consolidated Tiles</a>
<a href="#">SIIMPC-220</a>	<a href="#">Sen2Cor is not able to process a User Product containing two (or more) datastrips</a>
<a href="#">SIIMPC-274</a>	<a href="#">L2A generation error in case of black image</a>
<a href="#">SIIMPC-297</a>	<a href="#">Sen2Cor: Issue of DEM import when DEM support is activated</a>
<a href="#">SIIMPC-199</a>	<a href="#">Sen2Cor: Issue when reprocessing an L1C and L2A product is already present</a>
<a href="#">SEN2COR-39</a>	Problems with long pathnames on Windows
<a href="#">SEN2COR-40</a>	Problem with file deletion / creation at 10 m resolution

### 3.1.5 Evolution since release 2.0.5

Corrupted library for openjp2.dll on windows corrected.

Calibration factor for earth-sun-distance in reflectance to radiance conversion corrected. Radiances are computed for a fixed Earth-Sun distance of 1.0 astronomical units. This corresponds to the radiances values as stored in Sen2Cor look up tables used by the Atmospheric Correction module.

### 3.1.6 Evolution since release 2.0.4

A scaling problem and additionally a mismatch between the 10m resolution output and the 20 / 60 m resolution and a strong distortion in the 10 m processing has been observed in the Level 2A output images for previous releases as reported by several beta test users. This has been identified and fixed:

1. increasing the input sensitivity according to a new reflectance to radiance routine to be aligned with the current inputs. This also works for the new planned 10000 scaling (instead of 1000).
2. improving the Dark Dense Vegetation classification, as the algorithm erroneously classified some water as dark pixels which then contributed to the observed distortions.

For the 60 and 20 m case, a re-scaling of the path radiance was performed if scaled path radiance for the blue band differs more than 3 % from the path radiance of the standard aerosol. This routine was only called when a visibility calculation is performed as is only the case for 60 and 20 m processing.

In the 10 m case this routine was not executed, as the visibility is resampled from 20 m. Thus, for 10 m bands the scaled path radiance for the blue band (sc\_lp\_blue) always remained to 1.0 due to the different treatment of the visibility calculation (see above).

These findings explain:

1. why the observed differences only occur in some of the images: - only if sc\_lp\_blue differs more than 3% from the default of 1.0, or if sufficient amount of water pixels are found, a rescaling takes place.
2. why the effect is stronger in some of the images: - the weight of the sc\_lp\_blue goes into the correction.

3. why the differences also occur between 60 and 20m, when the 20 m visibility was resampled from the 60 m bands instead of being calculated new.

The fixes listed above had been applied and the modified scaling for the blue channel path radiance for 20 and 60 m is stored in the configuration and is then reused for rescaling also during the 10 m processing. With this modification the results for the 10 m bands as for the 20 and 60 m are in the same range as to be expected.

New LibRadtran Look up Tables generated with the 2015 spectral response are integrated in the processor and replace the previous one.

The reflectance to radiance conversion has been updated according to a review with R. Richter. It now reflects the proper scaling of the radiance values with respect to the extra-terrestrial solar irradiance ( $E_s$ ). The earth sun distance factor has been removed from the conversion formula, as the TOA radiance is already aligned.

### 3.1.7 Evolution since release 2.0.3

The three following issues have been fixed for release 2.0.4:

L2A SPR Ref.	TITLE	COMMENT
<a href="#">SIIMPC-126</a>	Metadata file did not pass validation running Sen2Cor	the warnings concerning the metadata are now redirected in the log files and do no longer occur at the command line irritating the user. The warnings itself result from an evaluation of the L1C metadata against their templates and must be fixed on the L1C metadata level.
<a href="#">SIITBX-113</a> <a href="#">SIIMPC-189</a>	Sen2Cor has a different scaling on the L2A Output	Scaling of L2A outputs is now equivalent to L1C input and is read from the metadata instead from the L2A_GIPP file.
<a href="#">SIIMPC-189</a>	Size of the L2A preview file does not correspond to L1C	Is now in JP2 format and equivalent in size to the L1C input.

### 3.1.8 Evolution since release 1.0.1

1. The reading and writing of the metadata have been updated in order to support PFS V12.

2. A syntax checker has been implemented which test the compliance of the product metadata before and after processing.
3. The following items have been implemented according to the SPR list provided by TAS: [S2-PDGS-TS-TR-027, issue: 01, date: 19/12/2014]:

L2A SPR Ref.	TITLE	COMMENT
L2A-001	Hosted Processor installation procedure	SUM chapter 3 to be updated with comments in the present report section 2.3 Re: Complete rework of the installation procedure. See chapter 3.
L2A-002	Gdal	Delivery and version compatibility with other user software shall be clarified Re: GDAL will be installed as a conda package under the umbrella of Anaconda. No dependency to any GDAL installation outside of anaconda exists, providing that the PATH variable points to '~/anaconda/bin'. These settings can be placed locally, in order not to interfere with any global python setup.
L2A-003	Anaconda	Clarification on use and installation of the tools to be provided. Re: See chapter 3.
L2A-004	Pythonpath and bashrc	Definition and setting procedure to be described. Launch by shell is mandatory. Re see chapter 3.
L2A-005	User and rights	Procedure related to user (sometimes root) and rights for L1c data to be confirmed Re: no administration rights are required, if a local installation is selected as is advised in chapter 3.
L2A-006	Output directory	Procedure to set output directory (different from input directory) to be enhanced and described. Re has been implemented and can be selected in the L2A_GIPP.xml processor configuration file.
L2A-007	Launch parameters	Procedure to set parameters at launch to be enhanced and described. Ree see section 3.2 Operation.
L2A-008	Source shell is necessary in order to set environment variable for the L2A	This is necessary in order to not modify centre user installation. This shell is updated with predefined variable during

	processor	the L2A processor installation. See L2A_Bashrc in the sen2cor user directory.
L2A-009	Execution shell is needed to start L2A processor	This shell a source environment shell and launch the real L2A processor (./bin/L2A_Process)  This is a special requirement for the PDGS. For this Purpose a Script named L2A_Process.bash has been generated in the sen2cor user directory. For operations under the S2Toolbox this script is not required.
L2A-010	No dependencies must be defined for the L2A installation except for already installed IPF/DPC dependencies	Fortunately, there is no problem with the delivered version because the dependencies are equal to those installed
L2A-011	It is needed to change or comment the ProductionRequestParameters.xsd interface	This is necessary to improve the launch of predefined version, type and options for the correct execution of the L2A processor  Re: This information is provided by the L2A_Process.bash script. This does also contain the version number, if multiple versions of the sen2cor should be launched.
L2A-012	Test data rights must be correct	It is necessary to change owner and rights after installation. It is also possible to indicate the command in the L2A SUM.  Test data are provided as a zipped tar file. Unpacking is described in the SUM. Installation in the correct environments is in the responsibility of the user.
L2A-013	L2A SUM must indicate how to uninstall the L2A processor if needed (including Anaconda)	See chapter 3.0.
L2A-014	Correct Anaconda version must be delivered with the L2A processor	Delivered Anaconda version is different from the one downloaded on internet and cannot be installed.  There are no direct requirements on the anaconda version to be used. It is suggested to install the most recent anaconda release, see section 3.1
L2A-015	Python installation 2.7 is needed but environment variable must be setting whit the 2.6 version	There is no need for any python environment setting, provided that the PATH includes a reference to anaconda/bin
L2A-016	Update of delivery note	Minor corrections to be done in the L2A-RPDN document, regarding the version of L2A-SRN and the FTP server.



### 3.2 List of Known Issues

The following issues are known and will be fixed for release 2.4.0 which currently undergoes testing and will be delivered in spring of this year.

Issue	Description
SIIMPC-793	Sen2Cor does not find a corresponding Look up Table for processing and stops the execution with an error message. This is due to a wrong initial configuration and will be resolved by implementing SIIMPC-828.
SIIMPC-802	Sen2Cor performs terrain correction, if DEM usage is specified by the user. Then it performs a check about the elevation difference and maximum slope in the image. If slopes are below 6 degrees and the maximum height difference is below 300 m, then terrain correction is skipped. Due to an error of non-excluding the background pixels in some cases a wrong classification is performed and a terrain correction sometimes is also performed for flat terrains. The effect to perform a terrain correction on flat landscapes is however rather minor so that this issue has low priority.
SIIMPC-816	If a product has 'NaN's for the Viewing_Incidence_Angles in the granule metadata, this leads the atmospheric correction to fail. The fix is to set the angular Values to 0 in the configuration and to place a warning in the report, that these values have been reset.
SIIMPC-828	The algorithm for the automatic selection of the atmosphere profile (between MidLatitude SUMMER and MidLatitude WINTER) will be improved so that it is based on latitude and date information, instead relying on AOT retrieval as it is currently implemented: With latitude = latitude of Tile Center: for Tropical/Equatorial areas ( if latitude $\in [-30; 30]$ ) <ul style="list-style-type: none"> <li>for all year long: SUMMER</li> </ul> for Northern Hemisphere ( if latitude $\in ]30; 90]$ ) <ul style="list-style-type: none"> <li>between 1st of April and 30th of September: SUMMER</li> <li>between 1st of October and 31st of March: WINTER</li> </ul> for Southern Hemisphere ( if latitude $\in [-90; -30[$ ) <ul style="list-style-type: none"> <li>between 1st of April and 30th of September: WINTER</li> <li>between 1st of October and 31st of March: SUMMER</li> </ul>
SIIMPC-890	Processor terminates erroneously with AttributeError: 'L2A_AtMCorr' object has no attribute '_dn_blu_scene_av' when processing at 20 m resolution, whereas 60 m tiles are processed successfully. Edge distortion in tiles with background pixels can lead to the execution of the DDV algorithm, although (in principle) only water and cirrus pixels are present, as the quotient of (false classified) reference pixels vs. scene pixels (without water) is sufficient to pass the test for running the DDV. During scaling of path radiance In the 60 m case, the number of reference pixels is too small so that the algorithm terminates without changing the path radiance. In the 20 m case in contrast, the number of reference pixels is sufficient, so that the algorithm continues. However, then a condition for the initialisation of the average values for the red and blue scenes is not fulfilled, which finally

	leads to the observed crash for 20 m. This can be solved by exiting the DDV algorithm at this stage, which leads to the same results as for the 60 m case.
SIIMPC-897	Atmospheric correction terminates erroneously with: <code>IndexError: index 274031 is out of bounds for axis 1 with size 1:</code>  This issue does occur under very special conditions. These conditions have been identified and fixed, but still must be tested for side effects for all conditions. Thus, it is not already part of release 2.3.1.
SIIMPC-907	Fixing a small issue for the calculation of mean solar angular angles: as the arrays of angular values obtained from the metadata have no marker for background elements, this information must be taken from the scene classification and be reflected in the calculation, if tiles are equipped with background pixels of value zero.

### 3.3 List of Evolutionary Upgrades

The following issues are foreseen to be part of evolutionary upgrades and are currently under planning. The specific release dates and versions are to be determined.

Issue	Description
SIIMPC-559	For regions with very low aerosol content, e.g. Antarctica, it should be possible to correct only for Rayleigh diffusion (AOT negligible) and water vapour (usually also very low).
SIIMPC-560	One of the issues causing chessboard effect on L2A surface reflectance between adjacent tiles is due to the failure of AOT retrieval when not enough DDV pixels are found on the L1C image. A default aerosol value (currently corresponding to a 40 km or 23 km visibility) is then applied leading to differences in surface reflectance for adjacent tiles.  To overcome this problem and to minimize the chessboard effect, it is planned to use the ECMWF meteorological information from short forecast model (AOT at 550 nm) as a fall-back for AOT estimation.  Even when AOT is calculated via the DDV algorithm the meteorological data could be used to verify the retrieval or smooth the AOT retrieved over adjacent tiles.
SIIMPC-791	As the usage of the default SRTM DEMs sometimes show poor results (e.g. over Namibia) it is planned to extend the DEM input to other providers or higher resolutions.
SIIMPC-819	Cirrus correction is currently limited to 60 and 20 m resolution. It shall be extended to 10 m.
SIIMPC-823	An improved cirrus correction needs to be implemented as the current one performs insufficient.
SIIMPC-879, 889	Sen2Cor should support Sentinel-2B products in the same way as Sentinel-2A products. Implementation of a "switch" for look up table (LUT) selection ("S2A", "S2B", "AUTO"), in order to perform the Atmospheric Correction using the LUTs adapted to the MSI instruments spectral responses (i.e. S2A or S2B).

## 4. Installation and Setup

This Application will support the three following Operating Systems:

**Linux, Mac OSX and Windows (64 bit is mandatory).**

The installation of the whole system is performed in two steps:

1. Installation or upgrade of the Anaconda Runtime Environment
2. Installation of the Processor itself.

The Sen2Cor application release 2.3 works under the umbrella of the **Anaconda** (Python 2.7) distribution package. It is tested with Anaconda2 release 4.2.

### 4.1 Anaconda Upgrade

If you have already installed Anaconda on you platform, then perform the following command via the command line:

```
C:\>conda update conda
Using Anaconda Cloud api site https://api.anaconda.org
Fetching package metadata: ....
# it should end with displaying the following information:
conda                4.2.9                py27_0
```

```
C:\>conda update anaconda
Using Anaconda Cloud api site https://api.anaconda.org
Fetching package metadata: ....
# it should end with displaying the following information:
anaconda             4.2.0                np111py27_0
```

Check the proper installation with:

```
C:\>python
Python 2.7.12 |Anaconda 4.2.0 (64-bit)| (default, Jul 2 2016, 17:42:40)
[GCC 4.4.7 20120313 (Red Hat 4.4.7-1)] on linux2
```

Dependent on your date of installation the version numbers can be higher than documented here.

You can skip the next section and continue with the setup of SEN2COR.

### 4.2 Anaconda installation from scratch

If you are new to Anaconda, then follow the steps below:

Download the recent version of the Anaconda python distribution for your operating system from: <http://continuum.io/downloads> and install it according to the default recommendations of the anaconda installer. It is strongly recommended to choose a local installation, except if you have the full administrator rights on your machine.

At the end of the installation, open a command line window and check the proper installation by typing "python." It should display:

```
C:\>python
Python 2.7.12 |Anaconda 4.2.0 (64-bit)| (default, Jul 2 2016, 17:42:40)
[GCC 4.4.7 20120313 (Red Hat 4.4.7-1)] on linux2
```

## 4.3 Deinstallation of an old SEN2COR installation

A deinstallation of an existing sen2cor installation can be performed with:

```
C:\Users\umue1lerwil>pip uninstall sen2cor
Uninstalling sen2cor-2.2.1:
  c:\users\umue1lerwil\appdata\local\continuum\anaconda2\lib\site-packages\sen2cor-
  2.2.1-py2.7.egg
  c:\users\umue1lerwil\appdata\local\continuum\anaconda2\scripts\12a_process-
  02.02.01-script.py
  c:\users\umue1lerwil\appdata\local\continuum\anaconda2\scripts\12a_process-
  02.02.01.exe
  c:\users\umue1lerwil\appdata\local\continuum\anaconda2\scripts\12a_process-2.2.1-
  script.py
  c:\users\umue1lerwil\appdata\local\continuum\anaconda2\scripts\12a_process-
  2.2.1.exe
  c:\users\umue1lerwil\appdata\local\continuum\anaconda2\scripts\12a_process-
  script.py
  c:\users\umue1lerwil\appdata\local\continuum\anaconda2\scripts\12a_process.exe

Proceed (y/n)? y
Successfully uninstalled sen2cor-2.2.1
```

If you have multiple SEN2COR releases installed, you can repeat the command until no further installations are found.

## 4.4 Sen2Cor Installation

### 4.4.1 For Windows:

Download the zip archive for release 2.3.1 from:  
<http://step.esa.int/main/third-party-plugins-2/sen2cor>

and extract it with an unzip utility.

Open the folder sen2cor-2.3.1, type "python setup.py install" and follow the instructions. The setup will install the SEN2COR application and all its dependencies under the Anaconda python distribution.

At the end of the installation you can select your home directory for the SEN2COR configuration data. This is by default: "C:\Users\

The setup script generates the following three environment variables:

**SEN2COR\_HOME** : this is the directory where the user configuration data are stored (see above). This can be changed later by you in setting the environment variable to a different location.

**SEN2COR\_BIN** : this is a pointer to the installation of the SEN2COR package. This is located in the "site-packages" folder of Anaconda. **Do not change this.**

**GDAL\_DATA** : this is a pointer to the directory where the GDAL coordinate system info is stored. This is located in the "sen2cor\cfg\gdal\_data" folder of the SEN2COR site\_package installation inside of Anaconda. **Do not change this.**

Open a new command line window, to be sure that your new environment settings are updated. From this new command line window, perform the following test:

Call the processor via "L2A\_Process --help". This will give you a list of possible further options.

If no errors are displayed, your installation was successful.

#### 4.4.2 For Linux and Mac:

Download the zipped tar file for release 2.3.1 from:

<http://step.esa.int/main/third-party-plugins-2/sen2cor>

and extract it with "tar -xvzf sen2cor-2.3.1.tar.gz"

Change the directory to the new created folder sen2cor-2.3.1, type "python setup.py install" and follow the instructions. The setup will install the SEN2COR application and all its dependencies under the anaconda python distribution.

At the end of the installation you can select your home directory for the SEN2COR configuration data. By default this is the directory where your \$HOME environment variable points to.

The setup script generates a script called "L2A\_Bashrc" and places it into your home directory. It contains the following three environment variables:

**SEN2COR\_HOME** : this is the directory where the user configuration data are stored (see above). This can be changed later by you in setting the environment variable to a different location.

**SEN2COR\_BIN** : this is a pointer to the installation of the SEN2COR package. This is located in the "site-packages" folder of the anaconda installation. **Do not change this.**

**GDAL\_DATA** : this is a pointer to the directory where the GDAL coordinate system info is stored. This is located in the "sen2cor/cfg/gdal\_data" folder of the SEN2COR site\_package installation inside of Anaconda. **Do not change this.**

These settings are necessary for the execution of the processor. There are two possibilities how you can finish the setup:

1. You can call this script automatically via your `.bashrc` or `.profile` script (OS dependent). For this purpose, add the line `source <location of your script>/L2A_Bashrc` to your script.
2. You can call this script also manually via `source L2A_Bashrc` every time before starting the processor. However this is not recommended, as it may be forgotten.

Finally, to check the installation after sourcing the `L2A_Bashrc`, call the processor via `L2A_Process --help`. This will give you a list of possible further options how to operate.

For further details how to operate the processor, read the Software User Manual.

## 5. Copyright Notes

TBD