



# iCOR-OLCI plugin for SNAP toolbox

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## Software User Manual

**Version 1.0:** 31/01/2019  
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## 1. Introduction

### 1.1. Scope

This document describes the installation and handling of the iCOR-OLCI plugin for SNAP. The plugin allows users to perform the iCOR atmospheric correction on OLCI images for land, inland and coastal waters.

### 1.2. ICOR for OLCI background

iCOR for OLCI Sentinel-3 is a modified implementation of the ICOR approach as already implemented in SNAP for the correction of Sentinel-2 and Landsat-8 (De Keukelaere et al. (2018)). The methodology is briefly explained below.

#### i) AOT retrieval

One of the unknown input parameters for performing the atmospheric correction is the AOT (Aerosol Optical Thickness). In iCOR we implemented an adapted version of the land based AOT retrieval technique described by Guanter et al. (2005). The methodology can be summarized as follows:

- The raw TOA image is subdivided into tiles of about  $15 \times 15$  km which are small enough to assume atmospheric homogeneity and large enough to include sufficient spectral variability.
- For each tile with a cloud and water percentage less than respectively 20% and 50%, we search for the lowest radiance value in each of the OLCI visible bands (i.e. Oa1 till Oa10). This is done for all land pixels in the tile resulting in a **dark target spectrum**. The lowest radiance values can be derived from different land pixels in the tile.
- The dark target spectrum is then used to set a first **upper AOT boundary** value for the tile:
  - The corresponding path radiance of the dark target spectrum is retrieved using the pre-calculated MODTRAN5 Look-Up-Table (LUT).
  - The AOT value leading to the path radiance closest to but not exceeding the dark spectrum in any of the visible bands becomes the tile upper AOT boundary.
- In the next step, the initial AOT estimation is refined through a multiparameter endmember inversion technique using selected end-members (ranging from bare soil to highly vegetated pixels) within the scene.
- If the macro-pixel contains too much clouds and/or the spectral reflectance variability within the macro-pixel is too small, no AOT retrieval is performed for that macro-pixel. The AOT value is then interpolated from the nearby macro-pixels for which the retrieval did succeed. Interpolation is done using an inverse weighted distance.
- Finally, a bilinear **interpolation** to the nominal pixel resolution is performed.
- In the OLCI implementation, this AOT is finally bounded over water pixels by a max AOT value. This max AOT value is calculated as the minimum of the AOT values for which the

retrieved water leaving reflectance (without adjacency correction) at Oa11(708.75 nm) and at Oa18 (885 nm) would equal zero.

### **ii) Adjacency correction SIMEC**

Optionally the SIMEC adjacency correction (Sterckx et al., 2005) can be applied over water pixels. The SIMEC adjacency correction is based on the NIR similarity (NIRsim) which states that the shape of the water spectrum in the NIR region is invariant. On the basis of this assumption the background contribution is iteratively calculated.

### **iii) Application of SVC gains**

To correct for the known positive bias in the OLCI Level-1 data, System ViCarious (SVC) gains can optionally be applied to the radiance data prior to this atmospheric correction step.

### **iv) Atmospheric correction**

After the AOT retrieval and the optional SIMEC step, the OLCI spectral bands (omitting the spectral bands affected by oxygen i.e. Oa13, Oa14 Oa15 and water vapor absorption i.e. Oa19, Oa20) are atmospherically corrected using the pre-calculated Moderate Resolution Atmospheric Transmission (MODTRAN, Berk et al., 1998) version 5 LUTs. These LUTs use as input 1) the solar and viewing geometry, 2) the terrain altitude as derived from the OLCI L1b annotation data file (i.e. geo\_coordinates.nc), 3) the retrieved AOT values and 4) water vapour and ozone concentrations as provided in the OLCI auxiliary data layers (or optionally overwritten by user input).

For water pixels, a correction for the Fresnel reflectance is applied while land pixels are assumed to be Lambertian. To deal with uncertainties in the Fresnel correction, mainly related to glint and haze effects, the water leaving reflectance at Oa21 (1020 nm) is subtracted from the retrieved water leaving reflectance. This is only performed when a pixel is not mixed (land/water) or when there are no remaining adjacency effects. This is automatically verified based on the difference in reflectance in Oa10 (681.25nm) and Oa11 (708.75nm). Furthermore, in case the reflectance at Oa21 (1020 nm) exceeds the reflectance at Oa17 (865nm), for instance due to calibration issues, this latter band is used in the correction instead of Oa21.

It should be noted that LUTs are only calculated for the nominal central wavelengths. As a Smile Correction Processor, like there is for MERIS, is not yet available in SNAP, smile related artefacts (i.e. due to change of center wavelength between camera's and pixels) might still be visible in the iCOR atmospheric correction results. see chapter 6. for more details.

## **1.3. Reader level**

This document is written for SNAP Toolbox users. The document assumes that the reader is familiar with the basic concepts in the SNAP software and its integrated processors.

## **1.4. References**

- De Keukelaere, L., Sterckx, S., Adriaensen, S., Knaeps, E., Reusen, I., Giardino, G., Brescani, M., Hunter, P., Van der Zande, D., Vaicute, D. (2018). iCOR Image Correction for Atmospheric Effects, Results for Landsat-8 OLI and Sentinel-2 MSI, *European Journal of Remote Sensing*, Vol. 51, 525-542.
- Guanter, L., 2007. New algorithms for atmospheric correction and retrieval of biophysical parameters in earth observation. Application to ENVISAT/MERIS data.
- Guanter, L., Alonso, L., Moreno, J., Member, A., 2005. A Method for the Surface Reflectance Retrieval From PROBA / CHRIS Data Over Land : Application to ESA SPARC Campaigns 43, 2908–2917.
- Richter, R., Schläpfer, D., Müller, A., 2006. An automatic atmospheric correction algorithm for visible/NIR imagery. *Int. J. Remote Sens.* 27, 2077–2085. doi:10.1080/01431160500486690
- Sterckx, S., Knaeps, E., Adriaensen, S., Reusen, I., Keukelaere, L. De, Hunter, P., 2015. Opera : an Atmospheric Correction for Land and Water. *Proc. Sentin. Sci. Work.* 3–6.
- Sterckx, S., Knaeps, S., Kratzer, S., Ruddick, K., 2014. SIMilarity Environment Correction (SIMEC) applied to MERIS data over inland and coastal waters. *Remote Sens. Environ.* doi:10.1016/j.rse.2014.06.017
- Vermote, E.F., Tanré, D., Deuzé, J.L., Herman, M., Morcrette, J.J., 1997. Second simulation of the satellite signal in the solar spectrum, 6s: an overview. *IEEE Trans. Geosci. Remote Sens.* 35, 675–686. doi:10.1109/36.581987

## 2. Software installation

### 2.1. Hardware requirements

20 GB of free disk space

### 2.2. Software requirements

OS :

- Window 7 or higher (64bit)
- Linux : Ubuntu 16.04 or Centos7 (different packages) (64bit)

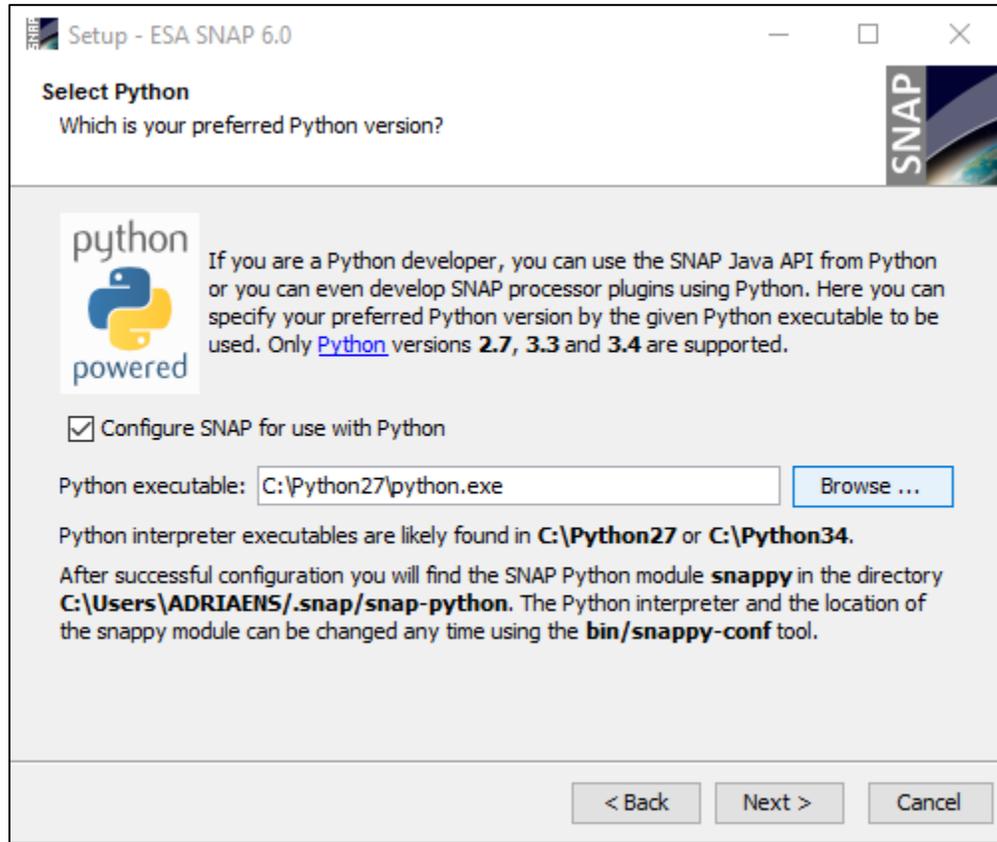
General :

- Python 2.7 – <https://www.python.org/download/releases/2.7/>
- SNAP 6.0.0 – <http://step.esa.int/main/download/>

Windows :

VS2017 x64 redistributables <https://support.microsoft.com/en-us/help/2977003/the-latest-supported-visual-c-downloads>

During the installation of SNAP, select the 'Configure SNAP for use with Python' checkbox and refer to the folder where Python 2.7 is installed (by default: C:\Python27\python.exe).



## 2.3. Download and installation

### Installation on WINDOWS

Run iCOR\_Setup.msi

A new window will pop-up iCOR Setup. Go through the installation by selecting Next → 'I accept the terms in the License Agreement' → choose the installation folder (by default: 'C:/Program Files/VITO/iCOR/' for Windows or '/opt/vito/icolor' for Linux).



### Opening the plugin in SNAP

If the tool is successfully installed, you need to provide the installation path to SNAP. Therefore, in the SNAP toolbox go to Tools → Plugins → Downloaded → Add Plugins.

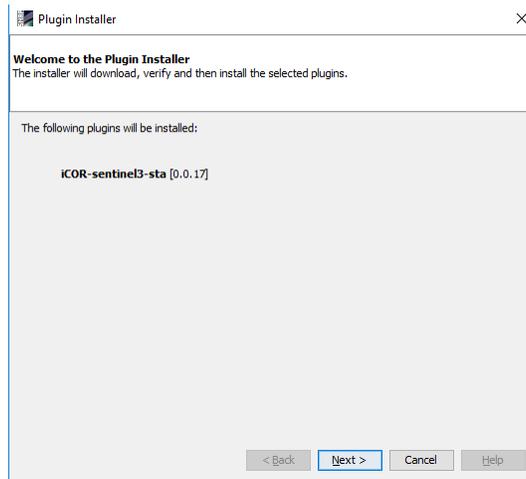
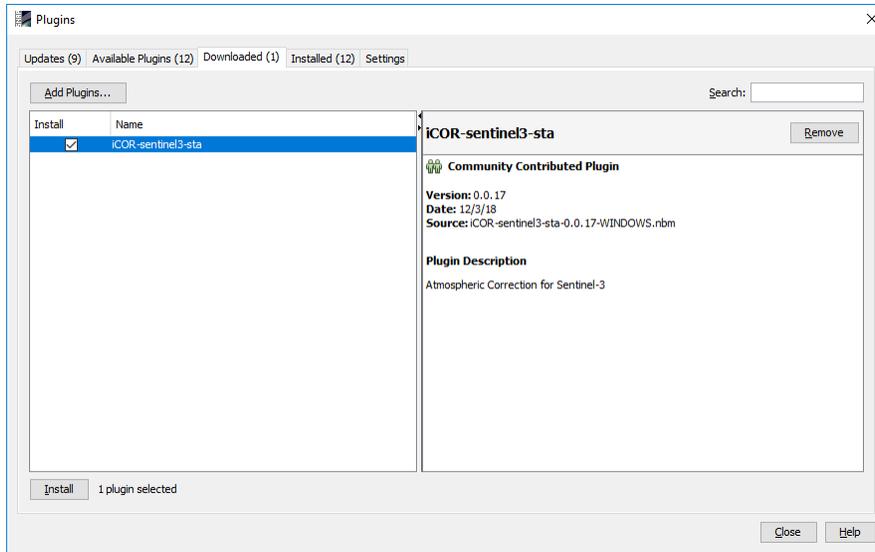
Browse to the directory where the iCOR files were downloaded, under the subdir 'sta' and select the file.

- *iCOR-sentinel3-sta-1.0.0-WINDOWS.nbm*
- *iCOR-sentinel3-sta-1.0.0-LINUX.nbm*

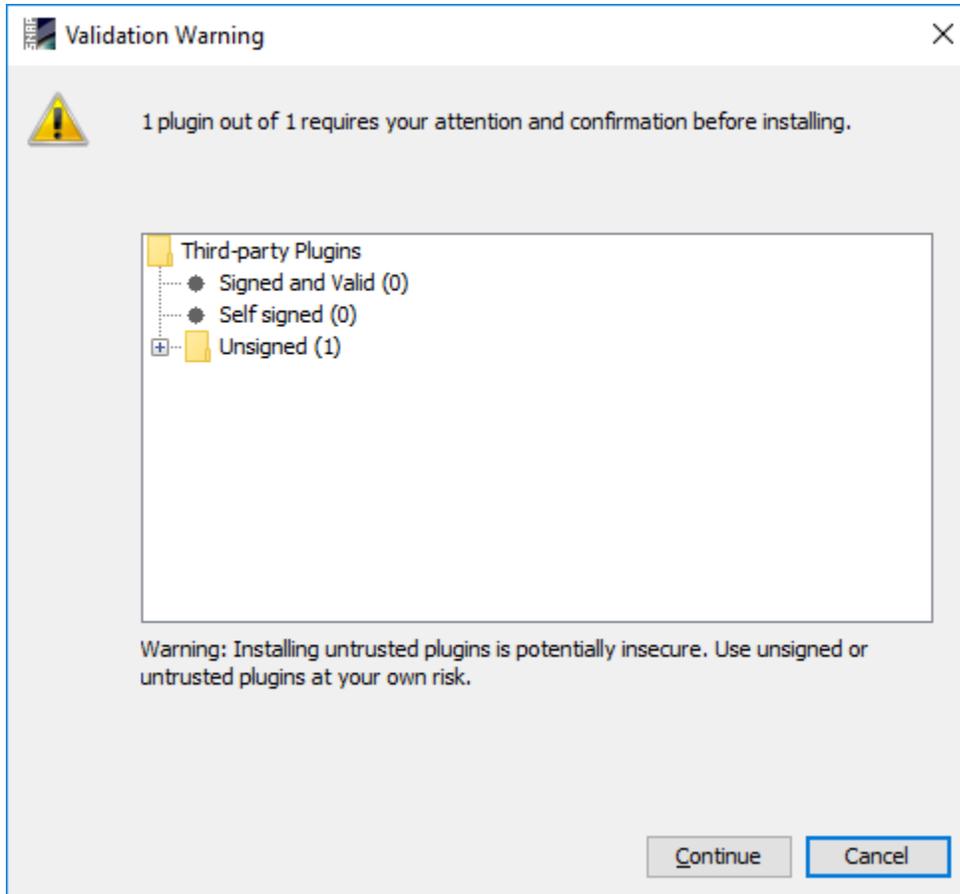
For Windows, the default directory for these files is: C:/Program Files/VITO/iCOR/sta.

For Linux, the default directory for these files is: /opt/vito/icor/sta

Select the plugin (iCOR-sentinel3-sta) and press on Install → Next → Select 'I accept the terms in the License Agreement' → Install.



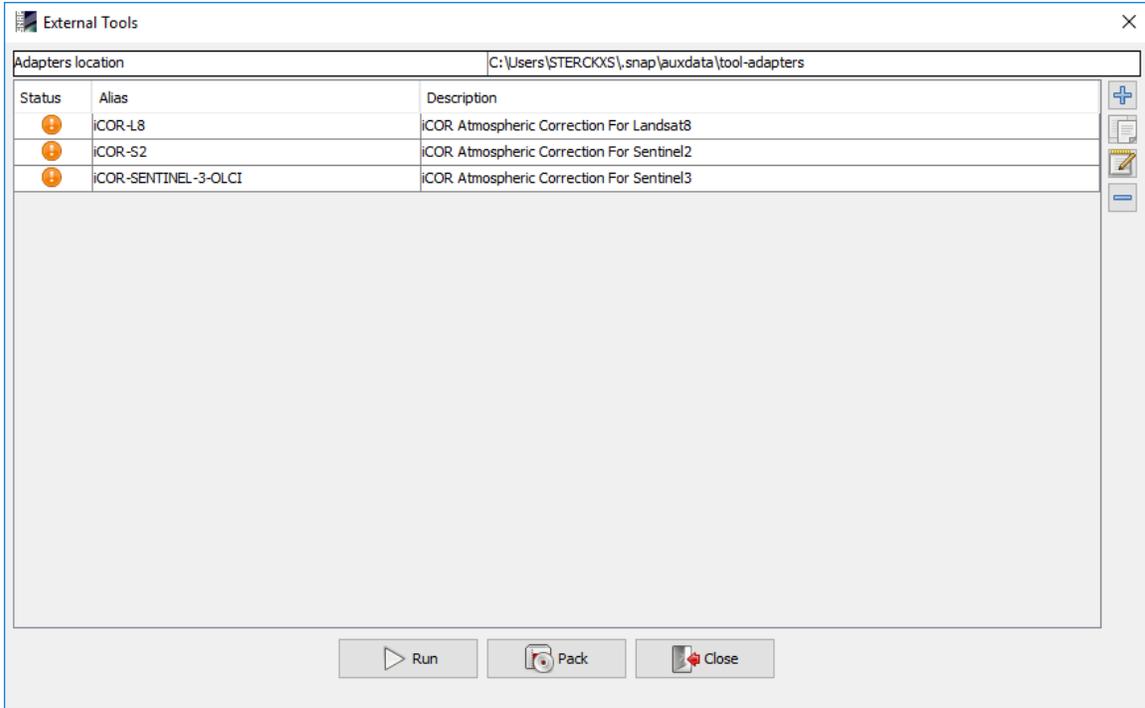
A validation Warning might pop-up:



Press Continue to continue the installation procedure.

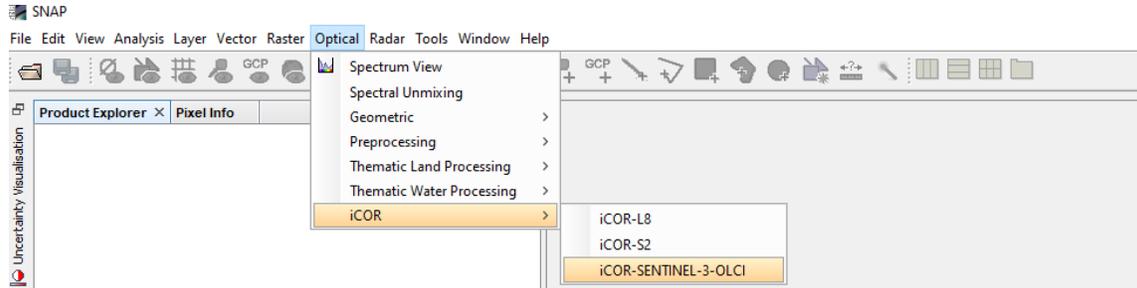
To complete the installation, restart SNAP.

If you made adaptations to the installation path of one of the software tools (python by default: C:\Python27\python.exe or iCOR by default: C:\Program Files\VITO\iCOR\), you might need to adapt the settings through Tools → Manage External Tools. A new window will pop-up where you can highlight which tool you'd like to edit.



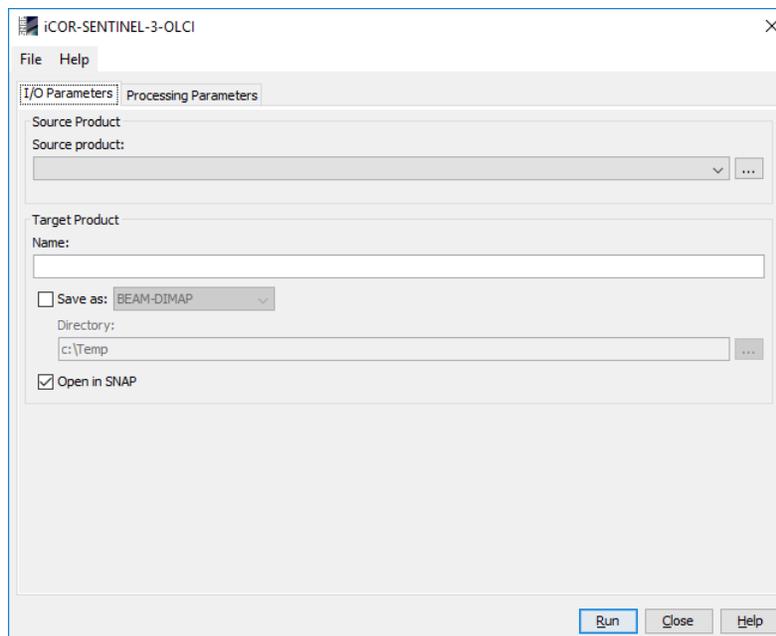
### 3. Processors

When the plugin is loaded in SNAP, the tool can be accessed through Optical → iCOR → iCOR-SENTINEL-3-OLCI.



#### 3.1. I/O parameters

In the first tab I/O parameters, you can select the OLCI image you would like to process. Please note that the OLCI data have to be unzipped first.



**Source product** : here the `xfdumanifest.xml` in the **unzipped S3A\_OL\_1\_EFR\*.SEN3** folder needs to be selected. Please note that iCOR is only able to work with OLCI Level-1 at-sensor radiances (“\*EFR”, \*EER”) in the original format.

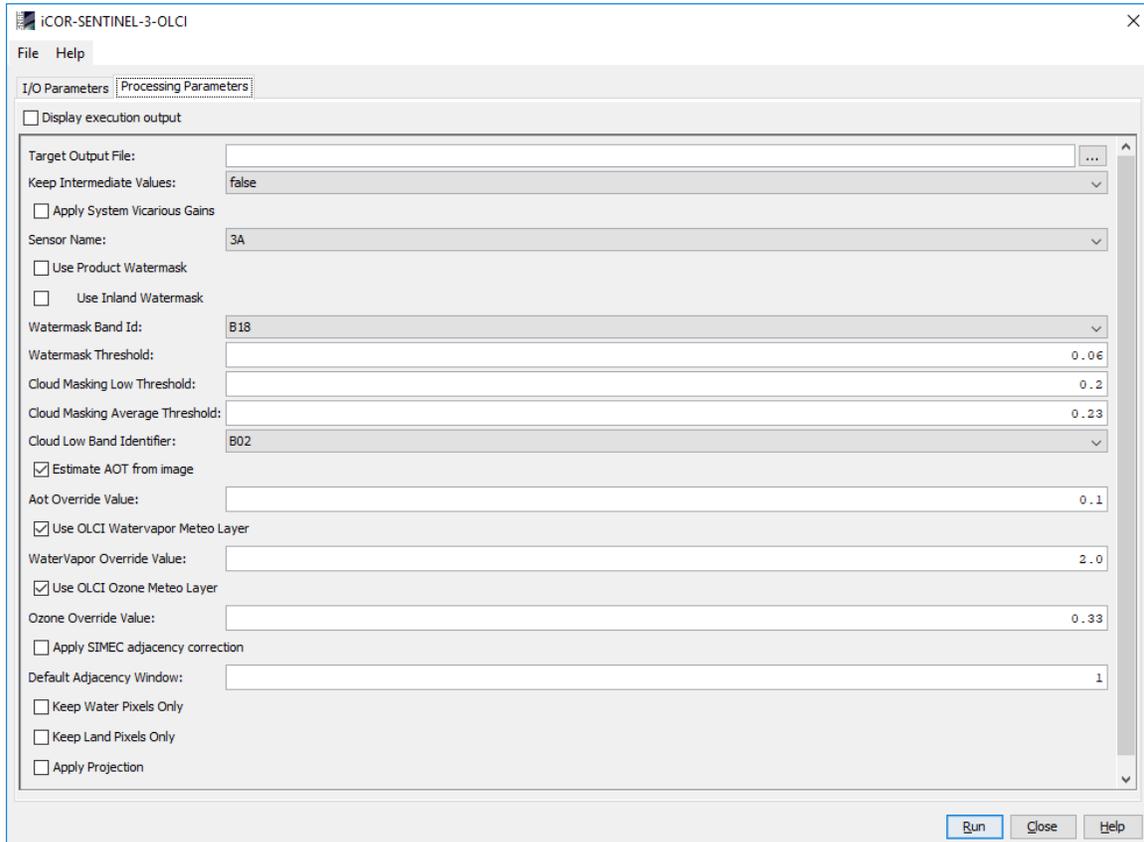
**Target product** : refers to the name of the output product as it will appear in SNAP. The default output directory (i.e. C:\Temp) and default output name (i.e. S3\*\_processed.tif) can be changed in the *Processing Parameters* tab.

**Open in Snap** : When this box is checked, the processed OLCI image will be opened in SNAP when the iCOR processing has been finished.

Although the option is available, It is not recommended to change the default output file format.

### 3.2. Processing parameters

In the second tab Processing Parameters, you can set the iCOR processing parameters.



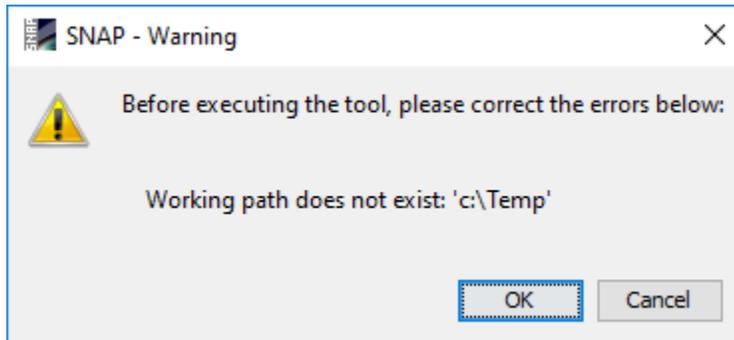
### Explanation parameters

- Display execution output:** It is advised to check this box. When this box is checked, the different steps run through by iCOR are displayed. This helps to check if there was no failure in one of the processing steps. A failure might for instance occur when the image based AOT retrieval was not able to retrieve AOT values from the scene (see WARNING **Estimate AOT from image**)

```

Running ac_runner c:\users\admin\appdata\local\temp\atconfwdygl-conf
Failed!
Process output:
:: load config file c:\users\admin\appdata\local\temp\atconfwdygl-conf
:: open image : c:\users\admin\appdata\local\temp\icor_kxkqmf_proc\33A_OL_1_EFR_20190128T183548_20190128T183738_20190130T055509_0110_040_369_4500_LN1_0_NT_002_SEN3_aot_land.tif
|
| 0% 10 20 30 40 50 60 70 80 90 100%
| |-----|-----|-----|-----|-----|-----|-----|-----|-----|
| |-----|-----|-----|-----|-----|-----|-----|-----|-----|
| |-----|-----|-----|-----|-----|-----|-----|-----|-----|
|
:: image does not contain valid values
-----
Traceback (most recent call last):
  File "c:\Program Files\VITO\iCOR\src\icor.py", line 52, in process_product
    icor_sentinel3.process(context, product, working_folder)
  File "c:\Program Files\VITO\iCOR\src\icor_sentinel3.py", line 439, in process
    "valid_inputs" = aot_quarter_output + "\n"
  File "c:\Program Files\VITO\iCOR\src\icor_context.py", line 500, in invoke_ac_runner_check
    raise Exception("process failed" + cmd)
Exception: process failed + cmd
  
```

- Target output file:** By default the output file will be stored under “c:\Temp\” with as default output name: “S3\*\_processed.tif”. Users can change the default output directory to another existing directory. The output name can also be changed. The “C:\Temp” directory needs to exist. If not, the following warning will pop up :



- Keep Intermediate Files:** This option enables the saving of intermediate products which are used in the atmospheric correction process. These products are:
  - Water mask
  - Cloud mask
  - AOT

During processing all intermediate files are stored into the processing folder, as well as a “\_config.log” file where all processing parameters are stored. This folder can be accessed and browsed for inspection.

Example (for Windows users):

c:\users\[username]\appData\Local\Temp\icor\_3efxwh\_proc\

After the final step in the processing, this folder will be deleted.

When failure has occurred, useful information can be derived from the remains in these folders.

When the ‘keep\_intermediate’ option is selected, temporary files will be stored in the target output location, besides the target output file.

- Apply System Vicarious Gains:** When this box is checked the System Vicarious Gains (SVC) are applied to the at-sensor radiance data prior to the atmospheric correction. Users can adapt the SVC gains by modifying the S3A.csv and S3B.csv files stored under “C:\Program Files\VITO\iCOR\bin\Sensor\_Sentinel3\s3\_svc”. Please note that as currently SVC gains for S3B are not yet available all values in the S3B.csv are set to “1”. The default SVC gains for S3A are listed in Table 1.

• **Table 1 OLCI S3A SVC gains**

Band	$\lambda$ centre (nm)	SVC gain
Oa1	400	0.9798
Oa2	412.5	0.9718
Oa3	442.5	0.9747
Oa4	490	0.9781

Oa5	510	0.9827
Oa6	560	0.9892
Oa7	620	0.9922
Oa8	665	0.992
Oa9	673.75	0.9943
Oa10	681.25	0.9962
Oa11	708.75	0.996
Oa12	753.75	1.003
Oa13	761.25	1
Oa14	764.375	1
Oa15	767.5	1
Oa16	778.75	1.005
Oa17	865	1
Oa18	885	0.996
Oa19	900	1
Oa20	940	1
Oa21	1 020	0.914

- **Sensor Name:** by default set to S3A. Needs to be set to S3B if an OLCI image of S3B is selected.
- **Water mask settings**
  - **Use Product Water Mask:** when this option is selected, the static water mask derived from the OLCI Level 1b flags is used to delineate the water pixels in the image. By default water body detection is based on a threshold value in a single band (see below).
    - **Use Inland Water Mask:** this box can only be checked when also the Use Product Water Mask box is checked. When checked, the SIMEC adjacency correction is only applied to inland water pixels identified from the static inland water mask derived from the OLCI Level 1b flags. This option might be of interest to users not interested in coastal waters because processing time will be reduced (SIMEC not applied to coastal waters).
  - **Water mask Band Id:** If the Use Product Water Mask is not set, the water mask is obtained using a threshold value on a single band. The default setting is using band Oa18 at 885 nm. Users can change here the band used to create a land/water mask.
  - **Watermask Threshold:** Defines the threshold value for the TOA reflectance for the water mask. If the value is below the threshold, the pixel is identified as a water pixel, otherwise it is a land pixel.
- **Cloud mask settings**
  - The cloud mask is created using multiple threshold levels. A pixel is identified as a cloud if it fulfils following requirements:

$$TOA_{reflectance}^{Cloud\ Low\ BAND\ ID} > Threshold_{Cloud\ Mask\ Low}$$

AND

Average\_TOAreflectance<sub>VISbands</sub> > Threshold<sub>Cloud Mask Average</sub>

As such, the parameters stand for

- **Cloud Mask Low Threshold** – Threshold value for the cloud low ID band. If this value is exceeded, one of the requirements of defining a cloud pixel is fulfilled.
  - **Cloud Low Band Identifier** – Band ID used to check the Cloud Mask Low Threshold value.
  - **Cloud Mask Average Threshold** – Threshold value for the average TOA reflectance in the VIS range (Oa1 till Oa 10). If this value is exceeded, one of the requirements of defining a cloud pixel is fulfilled.
- **Estimate AOT from image:** Checking this box enables the image based AOT retrieval as explained in paragraph 1.2.

**WARNING:** The image based AOT retrieval requires the presence of land pixel and sufficient spectral variability in the scene. The image-based AOT retrieval might fail if scene is dominated by for instance water, clouds, deserts or snow. In this case a failure message is given in the execution window when the “display execution output” is checked. In this case the user has to disable “Estimate AOT from image” (by unchecking the box) and insert of fixed value in “AOT override value” box.

```
Running ac_runner c:\users\adriaens\appdata\local\temp\atccconfhdgk.conf
Failed!
Process output:
-----
| :: load config file c:\users\adriaens\appdata\local\temp\atccconfhdgk.conf
| :: open image : c:\users\adriaens\appdata\local\temp\icor_kxkqmf_proc\53A_OL_1_EFR____20190128T183548_20190128T183738_20190130T055509_0110_040_369_4500_LN1_0_NT_002_SEN3_aot_land.tif
|
| 0% 10 20 30 40 50 60 70 80 90 100%
| [====]====[====]====[====]====[====]====[====]====[====]====[====]====[====]====[====]====
|
| :: image does not contain valid values
-----
Traceback (most recent call last):
  File "c:\Program Files\VITO\ICOR\src\icor.py", line 52, in process_product
    icor.sentinel3.process(context, product, working_folder)
  File "c:\Program Files\VITO\ICOR\src\icor\sentinel3.py", line 439, in process
    "valid_input" + aot_quanter_output + "\n"
  File "c:\Program Files\VITO\ICOR\src\icor\context.py", line 500, in invoke_ac_runner_check
    raise Exception("process failed" + cwd)
```

- **AOT Override Value:** you can choose to disable the image based AOT retrieval by unchecking the *Estimate AOT from image* box and insert a fixed AOT value for the whole scene.
- **Use OLCI water Vapor Meteo Layer:** By default the box is checked and the water vapour concentration as provided in the OLCI auxiliary data layers is used in the atmospheric correction. Users can uncheck the box and provide a fixed water vapor value in the next line.
- **Water Vapor Override Value:** If the *Use OLCI water Vapor Meteo Layer* is not checked, a fixed water vapor value, to be used for the whole scene, can be specified here.
- **Use OLCI Ozone Meteo Layer:** By default the box is checked and the ozone concentrations as provided in the OLCI auxiliary data layers is used in the atmospheric correction. Users can uncheck the box and provide a fixed water vapor value in the next line

- **Ozone Override Value:** If the *Use OLCI Ozone Meteo Layer* is not checked, a fixed ozone value, to be used for the whole scene, can be specified here.
- **Apply SIMEC Adjacency correction:** if the box is checked, the SIMEC adjacency correction is applied to water pixels as explained in paragraph 1.2. If both *Use Product Water Mask* and *Use Inland Water Mask* were checked, SIMEC is only applied to the inland water pixels retrieved from the static inland water mask OLCI Level 1b flags
- **Default Adjacency Window:** an option is provided in iCOR to perform an adjacency correction using a fixed range. The extent of this range or the window size can be set by the user. The units are number of pixels (N). The weighted average within the NxN box is considered for the adjacency correction. By default N is set to 1, and no adjacency correction is applied over land. Please note that if the *Apply SIMEC Adjacency correction* box is checked, SIMEC will be applied to the water pixels and not the fixed range adjacency correction. The fixed range correction will only be applied to the pixels not considered in the SIMEC algorithm such as land pixels.
- **Keep Water Pixels Only:** when checked, the final output image will only contain the water-leaving reflectance for those pixels identified as water. Land and cloud pixels will be masked.
- **Keep Land Pixels Only :** when checked, the final output image will only contain the surface reflectance for land pixels. Water and cloud pixels will be masked.
- **Apply projection:** when checked the final output image is projected

## OUTPUT

For water pixels, iCOR calculates the water-Leaving reflectance and for all other pixels the surface reflectance. The reflectance is retrieved for all OLCI bands except those affected by atmospheric gaseous absorption (Oa13, Oa14, Oa15, Oa19, and Oa20). Therefore the ICOR output product contains 16 spectral bands.

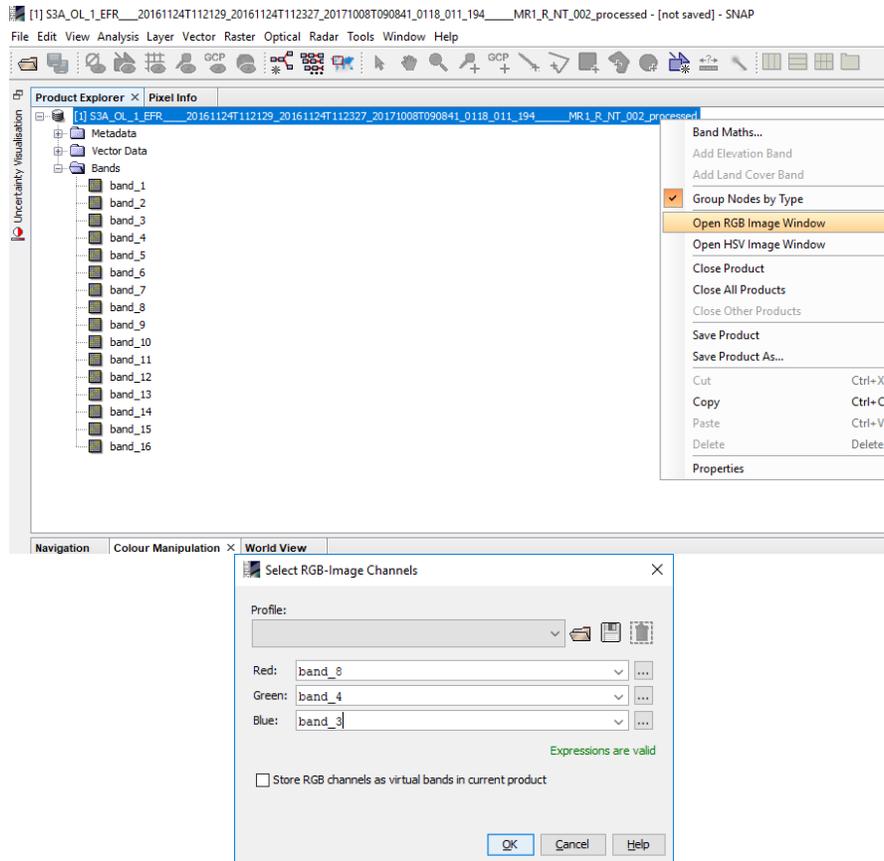
Original OLCI Band	Band number	$\lambda$ centre (nm)
Oa1	Band1	400
Oa2	Band2	412.5
Oa3	Band3	442.5
Oa4	Band4	490
Oa5	Band5	510
Oa6	Band6	560
Oa7	Band7	620
Oa8	Band8	665
Oa9	Band9	673.75
Oa10	Band10	681.25
Oa11	Band11	708.75
Oa12	Band12	753.75

Oa16	Band13	778.75
Oa17	Band14	865
Oa18	Band15	885
Oa21	Band16	1 020

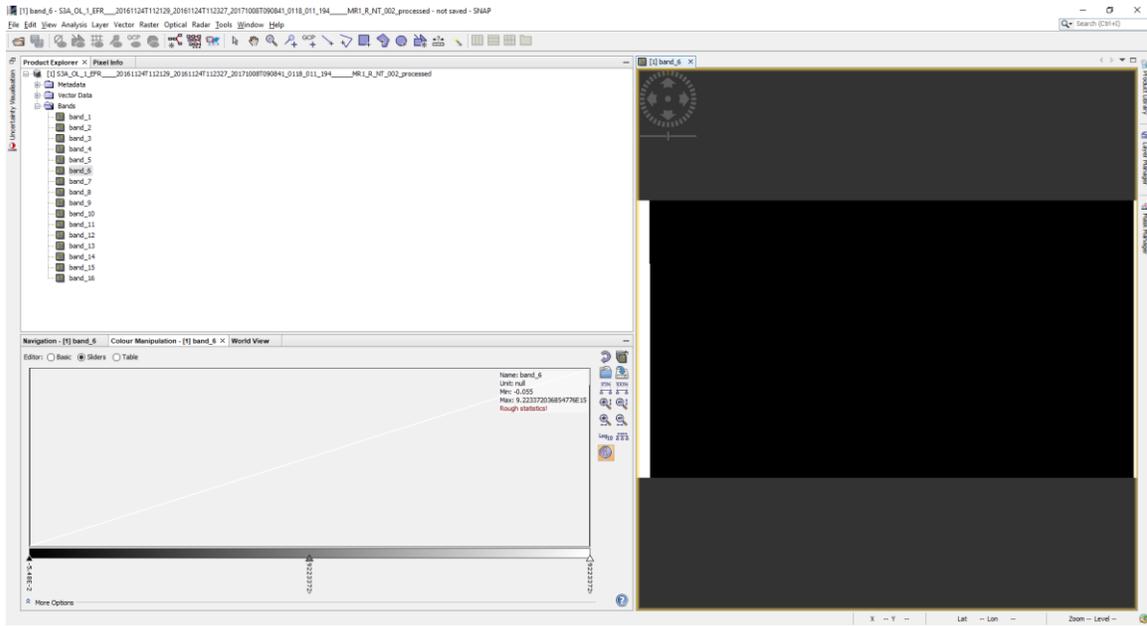
## Visualisation in SNAP

The output can be further analysed using SNAP or other image processing environments. Here we explain how to visualise the image in SNAP.

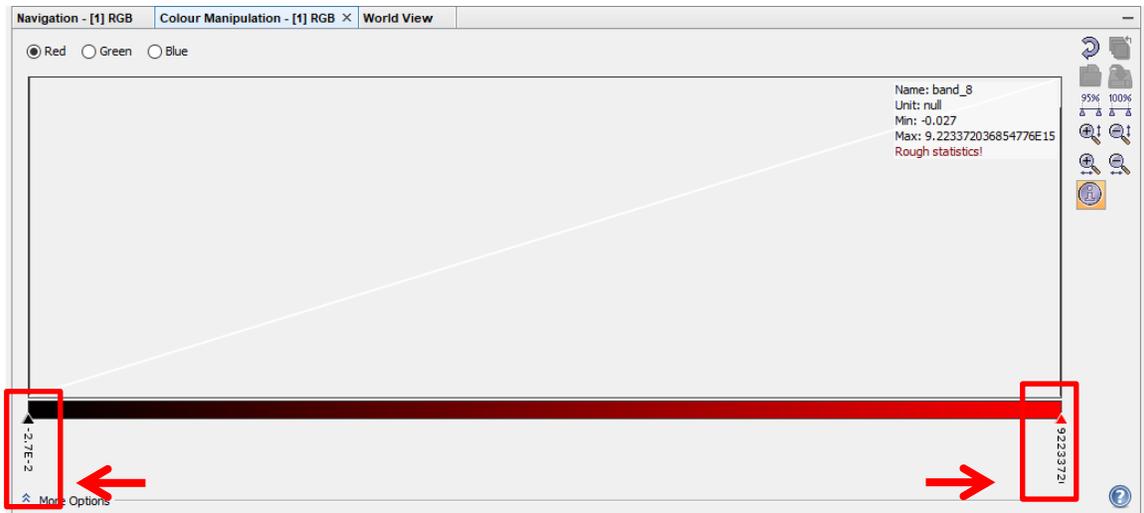
Select the image of interest in the Product explorer, go to the Window tab and select *Open RGB Image window*. A new window will pop-up where you can select the appropriate band settings.

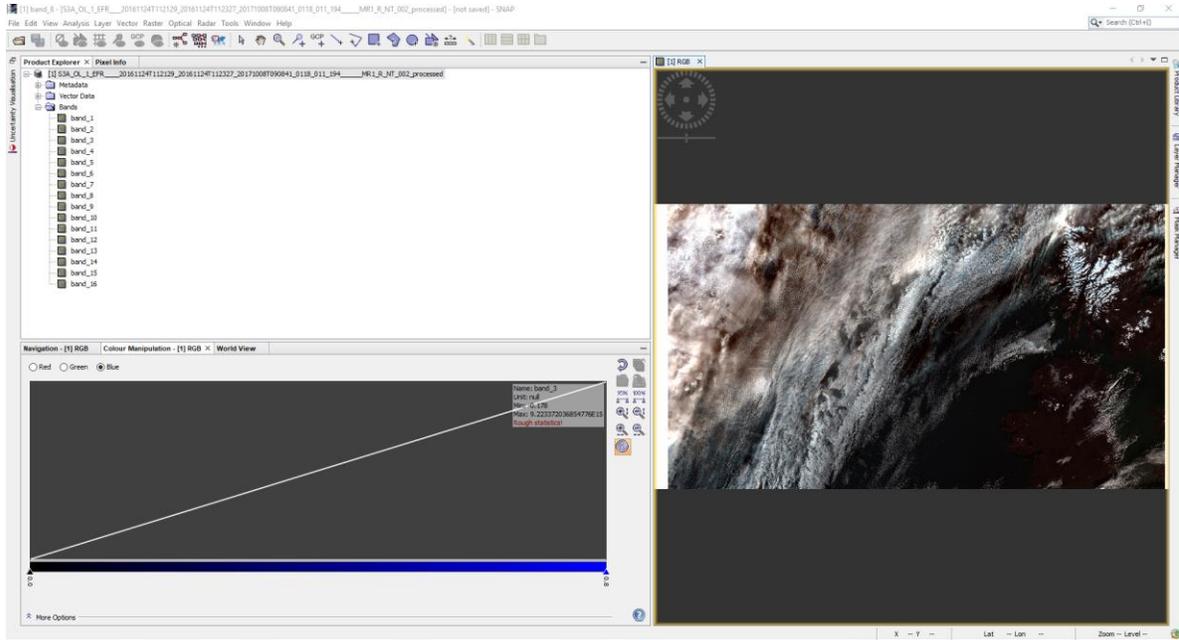


In first instance you might get an image with only black and white colours, since iCOR sets invalid pixels at max float.



To change this, go to the Colour Manipulation window (View → Tools Windows → Colour Manipulation) and change the range of values for the different colour bands (red, green and blue). Double click on the value at the end of the colour bar (highlighted in red in the following figure) and change to more appropriate values (eg. 0 – 0.8). Press enter.





#### 4. Processing time

iCOR is a computational intensive tool. Consequently, other programmes might run slow meanwhile and the required time needed to process one image can take a while (in the order of 30 to 120 minutes) depending on the scene content and processing steps selected). Mainly the AOT-retrieval and SIMEC steps are time consuming.

#### 5. Failures

iCOR failure can occur due to different reasons:

- The image-based AOT retrieval might fail if scene is dominated by only water, clouds, deserts or snow. In this case a failure message is given in the execution window when the display execution output is checked. In this case the user has to disable “Estimate AOT from image” (by unchecking the box) and insert of fixed value in ‘AOT override value’ box.

```
Running ac_runner c:\users\adri\appdata\local\temp\atconfwidyk.conf
Failed!
Process output:
:: Load config file c:\users\adri\appdata\local\temp\atconfwidyk.conf
:: open image : c:\users\adri\appdata\local\temp\icor_kkkqf_proc\53A_OL_1_EFR____20190128T183548_20190128T183738_20190130T055509_0110_040_369_4500_LN1_0_NT_002_SEN3_aot_land.tif
0% 10 20 30 40 50 60 70 80 90 100%
|-----|-----|-----|-----|-----|-----|-----|-----|
:: image does not contain valid values
-----
Traceback (most recent call last):
  File "c:\Program Files\VITO\iCOR\src\icor.py", line 52, in process_product
    icor_sentine13.process(context, product, working_folder)
  File "c:\Program Files\VITO\iCOR\src\icor_sentine13.py", line 439, in process
    "valid_inputs" + aot_granter_output + "\n"
  File "c:\Program Files\VITO\iCOR\src\icor\context.py", line 500, in invoke_ac_runner_check
    raise Exception("process failed" + cmd)
```

- Paths are not properly defined (See download and installation)
- Python 2.7 was not installed

- For windows: VS2017 redistributables not installed (see 2.2)
- Not enough disk space available for processing. iCOR generates during processing a lot of intermediate data. It is therefore recommended to have about 20 GB of free disk space for running iCOR.

## 6. Known issues

iCOR LUTs are calculated for the OLCI nominal central wavelengths. However, it is known that the center wavelengths vary between the five camera's and between pixels (the so-called spectral smile). Spectral smile artefacts might be visible in the iCOR results. A change in reflectance might be observed when crossing the camera boundaries (Figure 1, Figure 2).

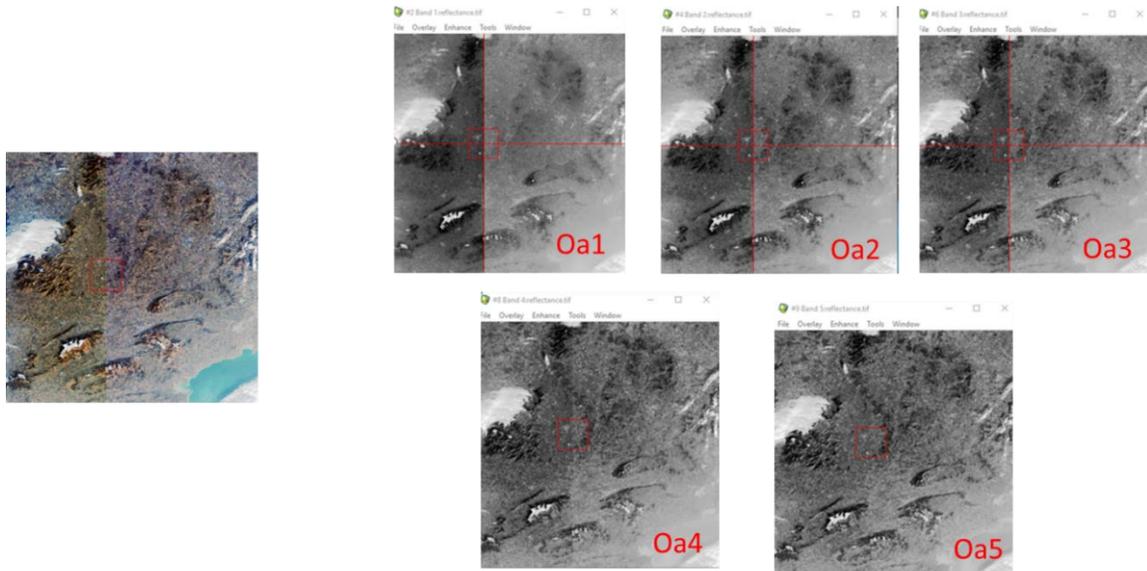


Figure 1 Example spectral smile artefact over land

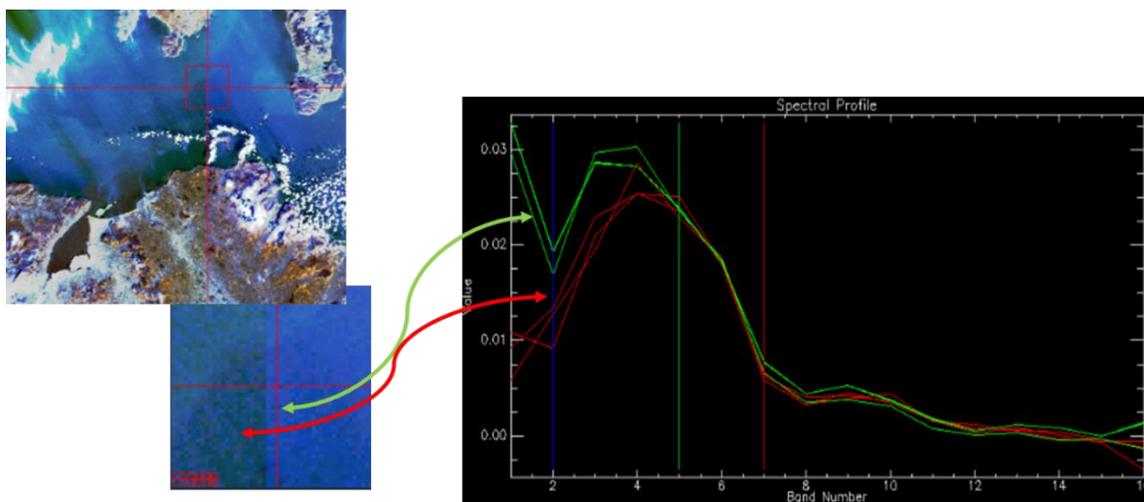


Figure 2 Example of spectral smile artefact over water

## **Acknowledgement**

The research leading to the development of the iCOR atmospheric correction tool for OLCI has received funding from ESA-ESRIN under the iCOR4S3 contract.