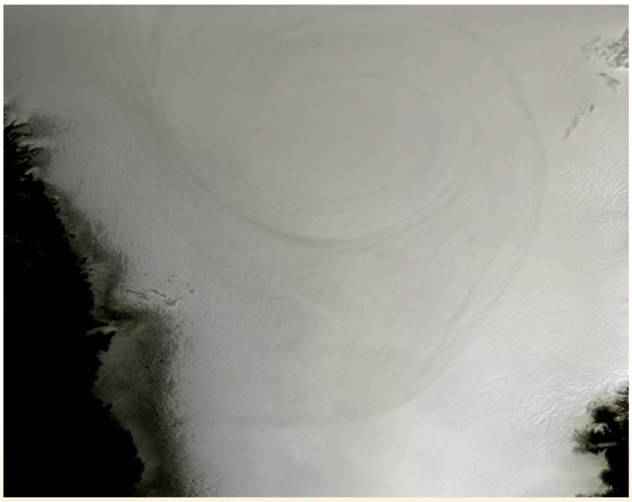

SEOM S3 for Snow - Software User Manual

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1 Introduction

1.1 Project background

The SEOM Sentinel-3 for Science, Land Study 1: SNOW (referred as 'S3-SNOW' in the following) is "to develop, implement and validate algorithms for deriving several key snow parameters from Sentinel 3 optical satellite data, appropriate for addressing ESA's Cryosphere challenge C3 : "Seasonal snow, lake/river ice and land ice, their effect on the climate system, water resources, energy and carbon cycles: the representa<on of terrestrial cryosphere in land surface, atmosphere and climate models". See [1] for details.

1.2 Purpose and Scope

This document is the User Manual for the SNAP processors written in Java which have been developed in the frame of the S3-SNOW project. Its purpose is to describe in detail how to obtain, install and operate these processors. Also, a comprehensive overview of the related data products (input as well as intermediate and final products) is provided.

The explicit structure of the document is as follows:

- Chapter 1 is this introduction.
- Chapter 2 gives an overview of the SNAP S3-SNOW processors.
- Chapter 3 describes all relevant S3-SNOW products.
- Chapter 4 explains how to get and install the processing software.
- Chapter 5 explains how to run the processing software.

1.3 References

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1.4 Acronyms and Abbreviations

Acronym	Definition
ATBD	Algorithm Theoretical Basis Document
BC	Brockmann Consult
BEAM	Basic ERS & Envisat (A)ATSR and Meris Toolbox
BOA	Bottom-of-atmosphere
BOAR	Bottom-of-atmosphere reflectance
BRR	Bottom-of-atmosphere Rayleigh Reflectance
CCI	Climate Change Initiative
CLI	Command Line Interface
DEM	Digital Elevation Model
ESA	European Space Agency
GIMP	Greenland Ice Mapping Project
GPF	Graph Processing Framework
GUI	Graphical User Interface
IdePix	Identification of Pixels
JDK	Java Development Kit
MERIS	Medium Resolution Imaging Spectrometer
NBM	NetBeans Module
NDSI	Normalised Difference Snow Index
NetCDF	Network Common Data Form
OLCI	Ocean and Land Colour Instrument
PPA	Probability of Photon Absorption
SEOM	Scientific Exploitation of Operational Missions
SNAP	Sentinel Application Platform
SPP	Snow Properties Processor
SUM	Software User Manual
TOA	Top Of Atmosphere

2 The SNAP S3-SNOW Processors

2.1 Overview

The key goal of the S3-SNOW project regarding software development, production and dissemination was to implement the proposed algorithms for several key snow parameters from Sentinel-3 OLCI data in free and easily accessible open source toolboxes, notably and foremost ESA's SNAP toolbox. During the implementation process, all processing software was distributed within the consortium in frequent cycles for the purpose of a comprehensive validation from an appropriate OLCI database containing products covering a variety of selected snow-covered areas. All SNAP S3-SNOW processors are available as SNAP plugins and can be run within SNAP on any supported platform (Windows, Linux, MacOS). The procedure for installation and operation is described in this chapter.

2.2 Theoretical Background

The motivation and theoretical background for the retrieval of key snow parameters is summarized in the S3-SNOW project proposal [1]. The underlying algorithms are described in detail in the corresponding project ATBD [2].

2.3 Processing Environment

As said, the S3-SNOW processors are available as SNAP plugins and can be run within SNAP on any supported platform (Windows, Linux, MacOS). The chapter *Software Installation* describes in more detail how to install the plugins in SNAP.

2.4 Processing Components

The SNAP S3-SNOW processing software consists of the following components and auxiliary datasets:

- *snap-core* module
- *snap-gpf* module
- *s3tbx-idepix-olci* plugin (specific version for S3-SNOW)
- *s3tbx-olci-o2corr* plugin
- *s3tbx-snow* plugin
- *snap-slope* plugin
- GIMP Digital Elevation Model for Greenland
- lookup tables for OLCI O2 correction

These components are described in more detail in the following subsections.

2.4.1 The Sentinel Application Platform (SNAP)

A common architecture for all Sentinel Toolboxes has been jointly developed by Brockmann Consult, Array Systems Computing and C-S called the Sentinel Application Platform (SNAP).

The SNAP architecture is ideal for Earth Observation processing and analysis due to various technological innovations as well as approved concepts from the BEAM toolbox. Most of the software components listed above make use of various SNAP core capabilities.

A good starting point for much more detailed information is the SNAP homepage [4], and also the comprehensive help documentation integrated in the SNAP desktop application.

2.4.2 The SNAP Graph Processing Framework

One of the key components in SNAP is the Graph Processing Framework (GPF) for creating user-defined processing chains. All provided S3-SNOW processors make use of this framework.

Within SNAP, the term data processor refers to a software module which creates an output product from one or more input products configured by a set of processing parameters. The GPF framework was originally developed for the BEAM toolbox, the precursor of SNAP. Since the early days of BEAM, a number of data processors have been developed; some of them are standard modules while others are contributed by 3rd parties. All of these data processors have been developed using a dedicated processing framework which was already part of the first version of BEAM.

Based on the experience collected within a number of projects, the SNAP authors have developed what is now the SNAP Graph Processing Framework. The GPF provides all the features inherited from BEAM, but adds a number of new ones for developers and reduces the amount of source code to write while drastically improving its readability and maintainability.

Much more detailed information on the SNAP GPF is provided by the specific GPF help documentation integrated in the SNAP desktop application.

2.4.3 The OLCI Snow Properties Processor

The Snow Properties Processor (SPP) is the key component for the processing in S3-SNOW. The processor provides the implementation of the algorithms for the various snow properties of interest. These algorithms are also described in detail in [2].

As input, the processor requires an OLCI L1b product (original or being Rayleigh corrected in a preprocessing step). Optionally, an IdePix pixel classification product (see below) can be provided as additional input. The output is a set of snow properties of interest, defined by the user via processing parameters. This is described in detail in the chapter *How to use the S3-SNOW Processors*.

2.4.4 The IdePix OLCI Pixel Classification Processor

IdePix (Identification of Pixels) is a pixel classification tool which has been developed by BC originally for BEAM and has been used for a variety of projects. It was transferred to SNAP and is continuously being further developed.

Among the supported sensors is OLCI, which made IdePix the most appropriate candidate for cloud and snow identification in the S3-SNOW project.

Originally, IdePix has been developed as an internal component of the SNAP Sentinel-3 toolbox. To increase flexibility, the sub-processors for the various sensors were recently extracted to make them available as separate plugins. One of these plugins is the IdePix Sentinel-3 OLCI processor. The processor described here is a special version of this plugin, being adapted for the specific needs for a pixel classification within S3-SNOW. This allows to more easily provide special user options which are ultimately not needed in other projects than S3-Snow, and in return leave out other options which are not relevant for S3-Snow.

The IdePix classification algorithm for Sentinel-3 OLCI is based on a neural network approach. A common neural net is used for both land and water pixels. As input for the neural net, the square roots of the OLCI TOA reflectances (obtained from an internal radiance-to-reflectance conversion) at all 21 wavelengths are used. As output, the neural net finally provides per pixel one of the properties 'cloud sure', 'cloud ambiguous', 'cloud' (which means sure OR ambiguous), or 'snow/ice'.

Although the IdePix classification for OLCI has been tested and successively improved within various activities, some limitations and weaknesses in cloud detection (most of them well known from other existing cloud masking approaches) could not be solved to 100%. Among these is the distiction of cloud and snow/ice, which is very important for the usage for S3-SNOW, and which has shown to be often rather poor. Therefore, a new approach to detect clouds over snow/ice has been introduced in the IdePix OLCI version for S3-SNOW which makes use of the O2 correction algorithm provided by R.Preusker (Spectral Earth, Berlin), and which has been implemented in the OLCI O2 Correction Processor (see next section). As additional output, a binary band 'cloud_over_snow' is provided.

The pixel classification with IdePix is an optional processing step in S3-SNOW (although recommended in most cases), applied on the same OLCI L1b products which are being considered for the snow properties retrieval.

2.4.5 The OLCI O2 Correction Processor

The OLCI O2 Correction Processor provides a 'harmonisation' of O2 wavebands, which means a modification of the effective transmittances in O2A wavebands 13, 14 and 15 to their values which would be measured at their mean wavelengths and with nominal bandwidth. The corresponding algorithm was provided by R.Preusker (Spectral Earth, Berlin) and is described in detail in [2]. Among various outputs, the processor provides the rectified and desmiled transmission for OLCI waveband 13 (761.25nm) which is used by the IdePix classification for the detection of clouds over snow (previous subsection).

2.4.6 The SNAP Slope Processor

The Slope Processor provides pixelwise terrain slope and aspect angle from an arbitrary input product containing a band with terrain height (i.e. a DEM product). In addition, the variance of elevation over a 3x3 pixel window is provided. For S3-SNOW this processor is provided as utility tool, as slope and aspect are often useful information for the validation of snow properties.

2.4.7 The GIMP Digital Elevation Model for Greenland

A Digital Elevation Model for Greenland has been generated within the GIMP project. This product has been post-processed by BC and is provided in GeoTIFF format with a resolution of ~90m. As only layer in this product, the DEM altitude given in metres is provided. The altitude is e.g. used as input by the OLCI O2 Correction Processor. The GIMP DEM product is illustrated in Figure 2.1.

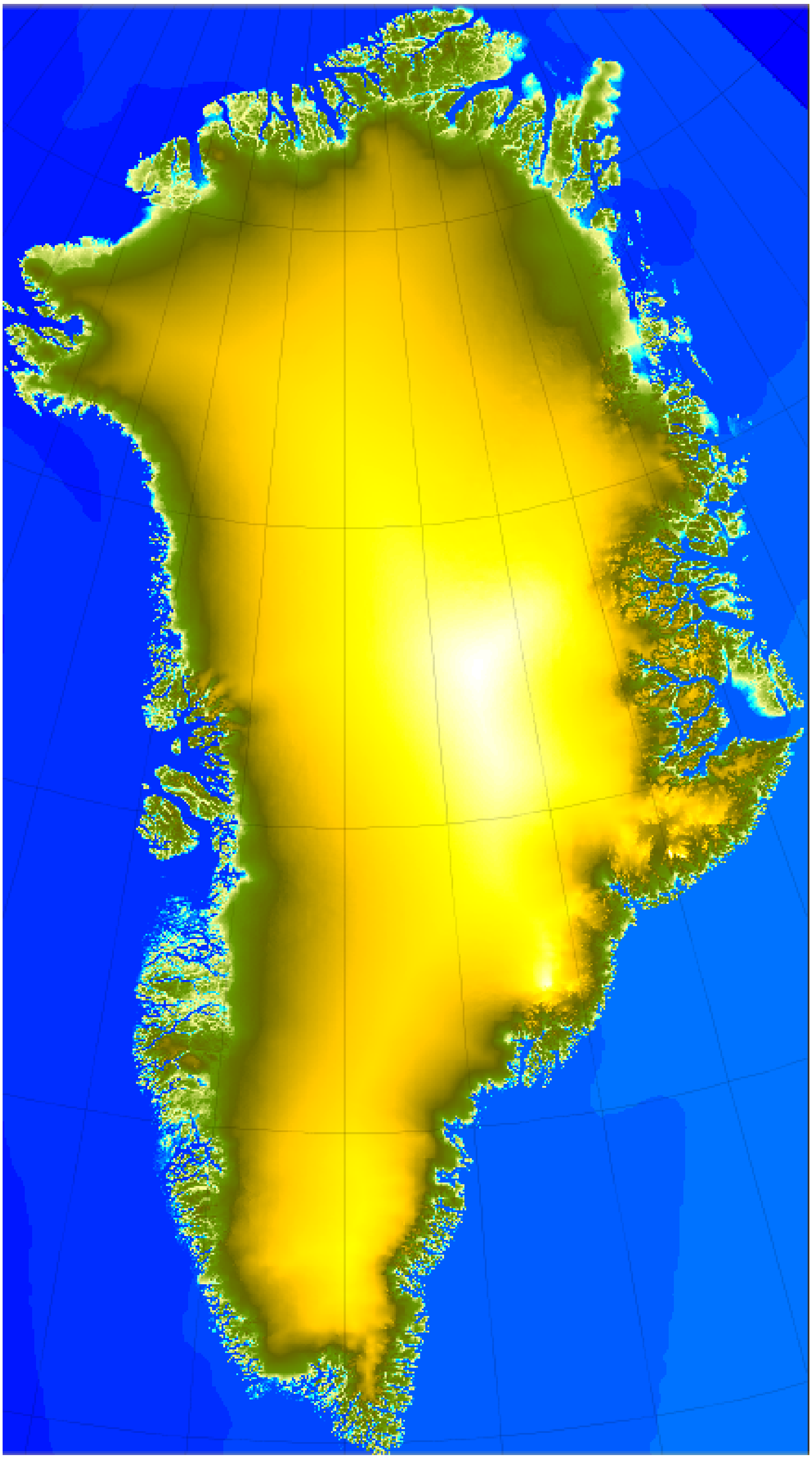


Figure 2.1: Illustration of the GIMP DEM for Greenland.

Using the SNAP Slope Processor, this product can be used as input to derive the corresponding slope and aspect.

2.4.8 Lookup Tables

Various lookup tables are used for the OLCI O2 correction, which in return is part of the IdePix OLCI pixel classification, all described in more detail in [2]. These lookup tables are not provided separately, but as an internal part of the OLCI O2 correction processor plugin.

2.5 Processing Flow

The overall processing flow and the interaction of the S3-SNOW components are illustrated in Figure 2.2.

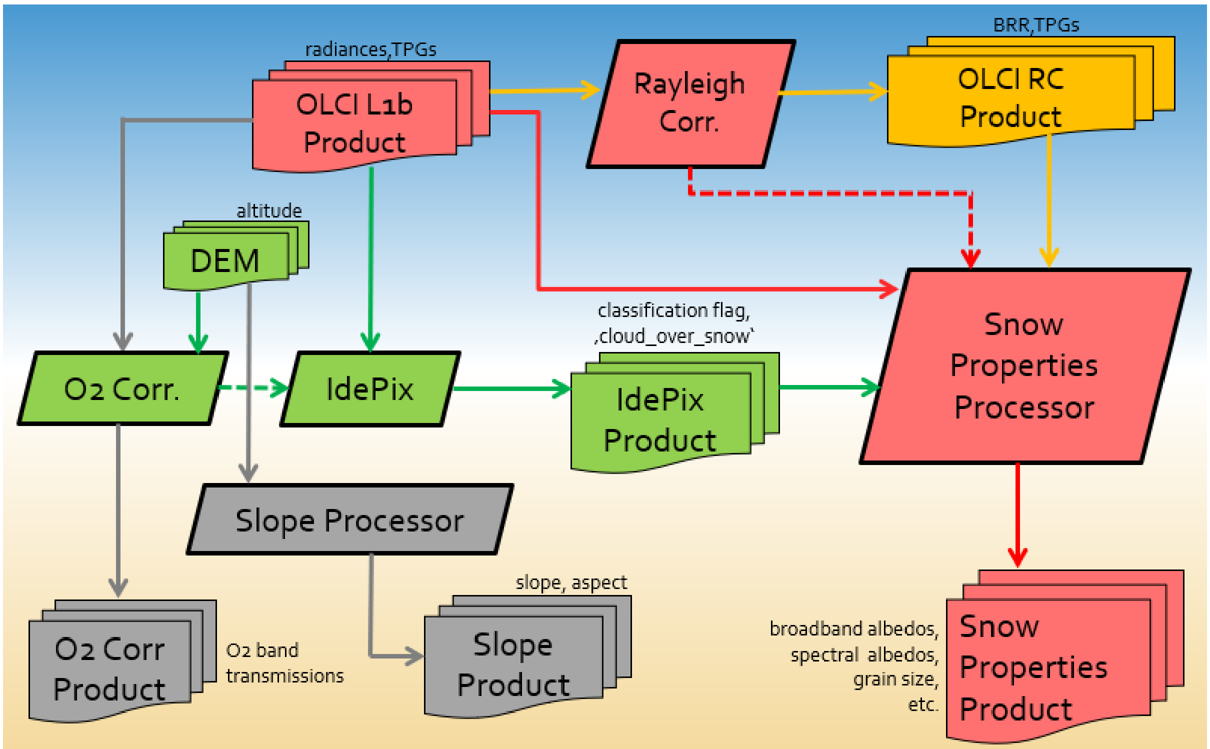


Figure 2.2: Processing flow of the S3-SNOW processors. See text for details.

The colour and arrow scheme in the diagram has the following meaning:

- **red** : The standard processing flow for snow properties retrieval. The red boxes indicate the mandatory input products and processing modules: An OLCI L1b radiances product is used as input product for the SPP. Internally, BRRs are computed from a call of the SNAP Rayleigh Correction Processor, which in return are used for the retrieval of the various snow properties.
- **orange** : Alternative processing flow for snow properties retrieval: An OLCI BRR product is used as input product for the SPP. This BRR product has been computed independently in a preprocessing step, directly using the Rayleigh Correction Processor.
- **green** : Optional processing, i.e. cloud classification: An OLCI L1b radiances product is used as input product for the IdePix Pixel Classification Processor. The IdePix output product can then be used as optional second input product for the SPP. Internally, IdePix calls the O2 Correction Processor to obtain the O2 waveband transmissions being used to generate the improved cloud classification band 'cloud_over_snow'. An optional DEM product can be used as input for the O2 Correction Processor. If no DEM is specified by the user, the altitude band from the Olci L1b product is used.

- **grey** : Additional processing options, not directly used in the snow properties retrieval. I.e., O2 correction and slope/aspect computation, as outlined above.
- **solid arrows** : indicate input/output to/from a processing module
- **dashed arrows** : indicate internal calls of one processing module into another

3 The S3-SNOW Products

3.1 Overview

This section will give an overview of all input, intermediate, optional and final products used and generated by the SNAP S3-SNOW processors introduced in the previous chapter.

3.2 Input Products

3.2.1 OLCI L1b TOA Radiance Product

Both reduced and full resolution OLCI L1b TOA radiance products can be used as input data. Tables 3.1 to 3.4 give an overview of OLCI L1b bands, tie point grids and L1b flag coding, respectively. A more detailed description of the OLCI standard L1b product is given in [3]. (Note that in SNAP terminology, the term ‘bands’ does not only refer to ‘spectral bands’ (i.e., 1-21 for OLCI), but for all raster data quantities read or written by SNAP.)

Table 3.1: OLCI bands in L1b product

Name in product	Unit	Type	Description
Oa<nn>_radiance; n=01,..,21	mW/(m^2*sr*nm)	float32	TOA radiance in band <nn>
lambda0_band_<nn>; n=01,..,21	nm	float32	Central wavelength in band <nn>
FWHM_band_<nn>; n=01,..,21	nm	float32	Bandwidth in band <nn>
solar_flux_band_<nn>; n=01,..,21	mW/(m^2*nm)	float32	Solar flux in band <nn>
quality_flags	dl (flag band)	int32	L1b quality flags
altitude	m	float32	Altitude
latitude	degrees	float32	Latitude
longitude	degrees	float32	Longitude
frame_offset	dl	float32	Resampling frame offset
detector_index	dl	float32	Detector index

Table 3.2: OLCI instrument channels.

Channel	Wavelength (nm)
1	400.0
2	412.5
3	442.5
4	490
5	510
6	560
7	620
8	665
9	673.75
10	681.25
11	708.75
12	753.75
13	761.25
14	764.375
15	767.5
16	778.75
17	865
18	885
19	900
20	940
21	1020

Table 3.3: OLCI tie point grids in L1b product.

Name in product	Unit	Type	Description
TP_latitude	deg	float32	Latitude of the tie points
TP_longitude	deg	float32	Longitude of the tie points
SZA	deg	float32	Sun zenith angle
SAA	deg	float32	Sun azimuth angle
OZA	deg	float32	View zenith angle
OAA	deg	float32	View azimuth angle
horizontal_wind_vector_1	m/s	float32	Zonal wind component
horizontal_wind_vector_2	m/s	float32	Meridional wind component
total_columnar_water_vapour	kg/m^2	float32	Total column of water vapour
sea_level_pressure	hPa	float32	Mean sea level pressure
ozone	kg/m^2	float32	Total ozone
humidity	%	float32	Relative humidity

Table 3.4: OLCI L1b flag coding.

Bit	Flag	Description
0-20	saturated_Oa<21-nn>	Band <nn> is saturated
21	dubious	Pixel is cosmetic
22	sun_glint_risk	Pixel has been duplicated
23	duplicated	Pixel has glint risk
24	cosmetic	Pixel is suspect
25	invalid	Pixel is over land,
26	straylight_risk	Pixel is bright
27	bright	Pixel is part of a coastline
28	tidal_region	Pixel is suspect
29	fresh_inland_water	Pixel is over land
30	coastline	Pixel is bright
31	land	Pixel is part of a coastline

3.2.2 OLCI L1b Bottom-of-Rayleigh Reflectances (BRR) Product

As an alternative to the OCLI L1b radiance products, the Snow Properties Processor also accepts as input BRR[1] products which have been generated in a pre-processing step using the SNAP Rayleigh Correction Processor. This processor can be accessed from the SNAP Desktop application as shown in Figure 3.1.

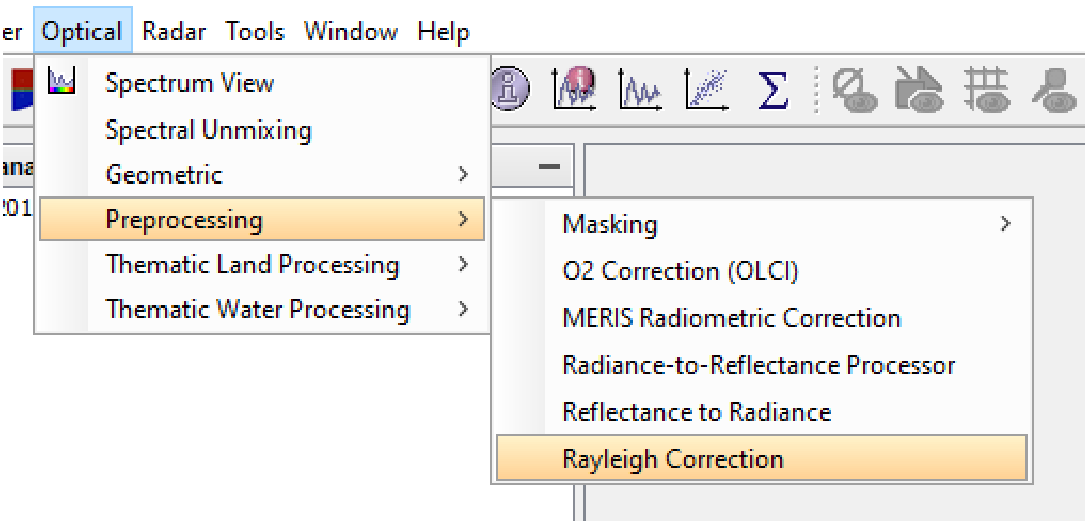


Figure 3.1: Access to Rayleigh Correction Processor in SNAP Desktop.

The Rayleigh Correction Processor is a SNAP build-in component. For a detailed description see the corresponding SNAP help documentation. For BRR products to be used with the Snow Properties Processor, BRR for spectral bands 1, 6, 17 and 21 (400nm, 560, 865 and 1020nm) must be generated,

[1] Physically, the term ‘BRR’ used in the Rayleigh Correction Processor should better be called ‘BOAR’ (Bottom-of-atmosphere reflectance). The BOAR is derived from Top-of-atmosphere reflectance by correction for molecular scattering and absorption.

and in addition the BRRs for all other spectral bands of interest. In Figure 3.2, the parameter settings to generate BRR in bands 1, 6, 17 and 21, and in addition bands 9 and 10, are shown.

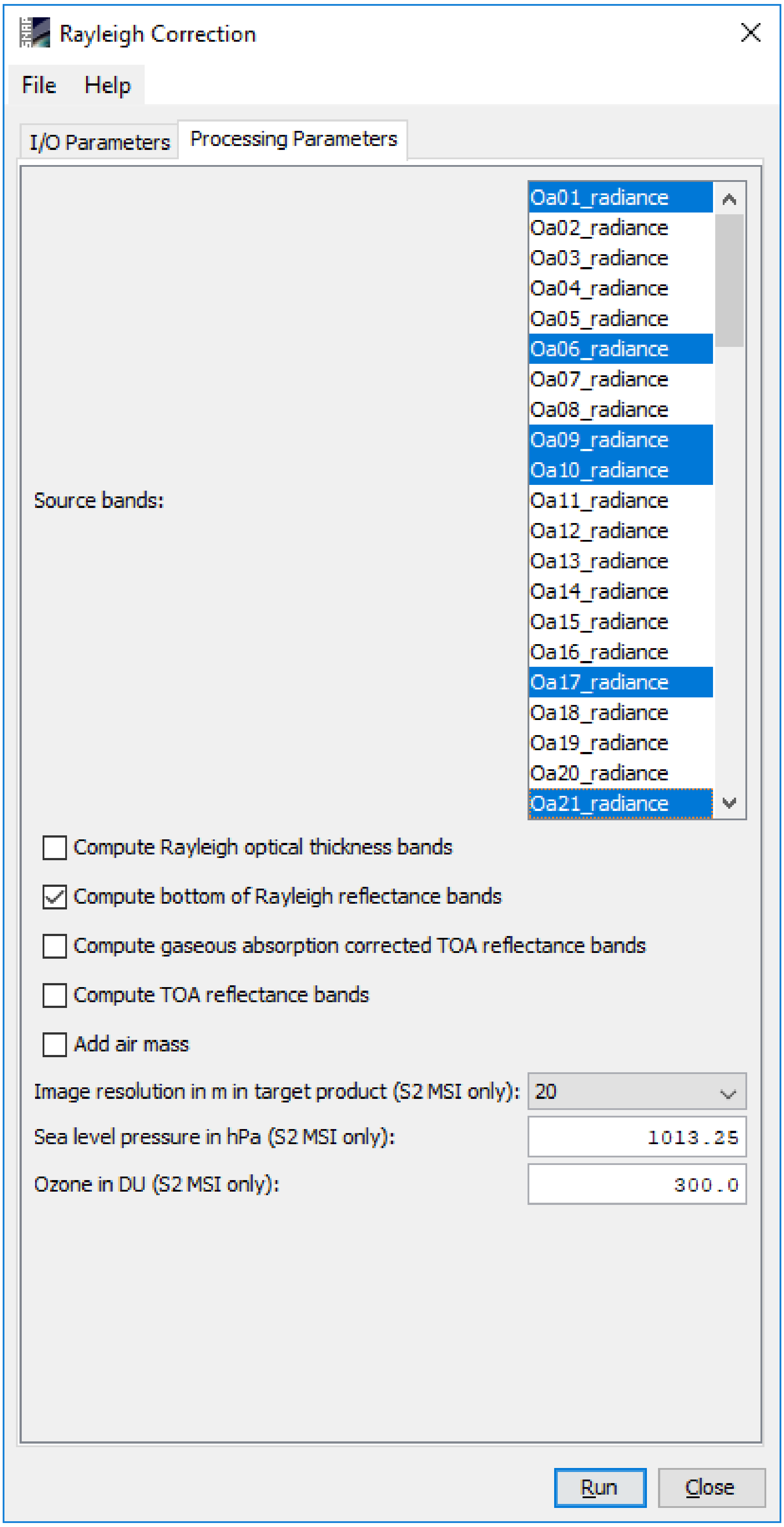


Figure 3.2: Rayleigh Correction: parameters for the generation of BRR in spectral bands 1, 5, 17 and 21, and in addition in spectral bands 9 and 10.

The bands in the resulting BRR product are listed in Table 3.5.

Table 3.5: Bands in BRR product

Name in product	Unit	Type	Description
rBRR_01	dl	float32	Bottom-of-Rayleigh reflectance for band 1 (400nm)
rBRR_05	dl	float32	Bottom-of-Rayleigh reflectance for band 5 (510nm)
rBRR_17	dl	float32	Bottom-of-Rayleigh reflectance for band 17 (865nm)
rBRR_21	dl	float32	Bottom-of-Rayleigh reflectance for band 21 (1020nm)
rBRR_<nn>	dl	float32	Bottom-of-Rayleigh reflectance in band <nn> (optional)
quality_flags	dl	int32	L1b quality flags

3.3 Intermediate and Optional Products

3.3.1 SNAP IdePix Classification Product

The IdePix classification product is the result of the pixel classification performed on the OLCI L1b product. In return, the IdePix product can be used as optional input for Snow Properties Processor. The IdePix OLCI version for S3-SNOW provides an ‘extended’ classification product containing the bands listed in Table 3.6.

Table 3.6: Bands in IdePix pixel classification product

Name in product	Unit	Type	Description
Oa21_reflectance	dl	float32	TOA reflectance for band 21
trans_13	dl	float32	Rectified and desmiled transmission for band 13
press_13	hPa	float32	Pressure for band 13 neglecting scattering
surface_13	dl	float32	Rectified transmission for band 13 neglecting scattering
surface_pressure	hPa	float32	Pressure at altitude of the surface
altitude	m	float32	Altitude of the surface (from DEM or L1b product)
cloud_over_snow	dl	float32	Mask band indicating if there is cloud over snow
pixel_classif_flags	dl	int16	Standard IdePix classification flag band
quality_flags	dl	int32	L1b quality flags

The IdePix OLCI classification flag coding is given in Table 3.7.

Table 3.7: Bands in IdePix pixel classification product

Bit	Flag	Description
0	IDEPIX_INVALID	Pixel is invalid
1	IDEPIX_CLOUD	Pixel is either ‘cloud sure’ or ‘cloud ambiguous’
2	IDEPIX_CLOUD_AMBIGUOUS	Semi-transparent clouds, or detection is uncertain
3	IDEPIX_CLOUD_SURE	Fully opaque clouds with full confidence of detection
4	IDEPIX_CLOUD_BUFFER	A buffer of N pixels (user option) around a cloud
5	IDEPIX_CLOUD_SHADOW	Pixel is affected by a cloud shadow
6	IDEPIX_SNOW_ICE	Snow or ice pixel
7	IDEPIX_BRIGHT	Pixel is bright
8	IDEPIX_WHITE	Pixel is white
9	IDEPIX_COASTLINE	Pixel is part of a coastline
10	IDEPIX_LAND	Land pixel

3.3.2 O2 Correction Product

The O2 correction step is done as part of the IdePix pixel classification. The results of this step are used by IdePix internally, and no separate products are written in the S3-SNOW processing flow. However, as the O2 correction is also available as a standalone SNAP plugin with a separate target product, its contents are listed in Table 3.8 for completeness.

Table 3.8: *Bands in O2 Correction target product*

Name in product	Unit	Type	Description
trans_13	dl	float32	Rectified and desmiled transmission for band 13
press_13	hPa	float32	Pressure for band 13 neglecting scattering
surface_13	dl	float32	Rectified transmission for band 13
radiance_13	mW/(m^2*sr*nm)	float32	TOA radiance in band 13

3.3.3 Slope Product

A slope product is the output of the SNAP Slope Processor introduced in chapter *The SNAP S3-SNOW Processors*. As mentioned, this is an optional product which is not directly used in the S3-SNOW processing flow. For completeness, its contents are listed in Table 3.9.

Table 3.9: *Bands in Slope Processor target product*

Name in product	Unit	Type	Description
slope	degrees	float32	Terrain slope
aspect	degrees	float32	Aspect angle in [0, 360] deg
elevation_variance	degrees	float32	Variance of elevation over 3x3 pixel window
<altitude_band>	m	float32	Altitude band from input product (optional)

3.4 Final Snow Properties Product

The S3-SNOW final product contains various snow properties, depending on the processing parameters specified by the user. The maximum number of bands which can be generated is given in Table 3.10. For more detailed explanations of the physical meaning of the parameters, see [2].

Table 3.10: Bands in final S3-SNOW snow properties product

Name in product	Unit	Type	Description
albedo_bb_spherical_vis	dl	float32	Spherical albedo in broadband visible range
albedo_bb_spherical_nir	dl	float32	Spherical albedo in broadband near infrared range
albedo_bb_spherical_sw	dl	float32	Spherical albedo in broadband shortwave range
albedo_bb_planar_vis	dl	float32	Planar albedo in broadband visible range
albedo_bb_planar_nir	dl	float32	Planar albedo in broadband near infrared range
albedo_bb_planar_sw	dl	float32	Planar albedo in broadband shortwave range
albedo_spectral_spherical_<nn>	dl	float32	Spectral spherical albedo in band <nn> (max. 21 bands)
albedo_spectral_planar_<nn>	dl	float32	Spectral planar albedo in band <nn> (max. 21 bands)
rBRR_<nn>	dl	float32	BRR in band <nn> (max. 21 bands)
ppa_spectral_<nn>	dl	float32	PPA in band <nn> (max. 21 bands)
grain_diameter	mm	float32	Snow grain diameter
snow_specific_area	m^2/kg	float32	Snow specific surface area
ndbi	dl	float32	Bare ice indicator
pollution_mask	dl	float32	Pollution mask
f	1/mm	float32	Normalized snow impurity absorption coefficient at 1micron
l	mm	float32	Effective absorption length
m	dl	float32	Absorption Angstrom parameter
r_0	dl	float32	Reflectance of nonabsorbing snow layer
f_rel_err	dl	float32	Relative error of parameter f
l_rel_err	dl	float32	Relative error of parameter l
m_rel_err	dl	float32	Relative error of parameter m
r_0_rel_err	dl	float32	Relative error of parameter r_0
ndsi	dl	float32	NDSI
ndsi_mask	dl	float32	NDSI mask for snow identification
quality_flags	dl	int16	L1b quality flags
pixel_classif_flags	dl	int16	Pixel classification flags (see Table 3.7)

4 Software Installation

4.1 Overview

This chapter describes the overall S3-SNOW software installation procedure.

4.2 Usage Requirements

4.2.1 General Requirements

In general, all S3-SNOW processors require SNAP in the latest snapshot version (v7.0.0-SNAPSHOT), which comes with the S3-SNOW software delivery for all platforms (Windows, Linux, MacOS).[1]

4.2.2 Operating System

The S3-SNOW software can be run on any operating system which is suppported by SNAP (Windows, Linux, MacOS).

4.2.3 Hardware Requirements

The S3-SNOW processing system is a complex piece of software. Although the algorithms for the snow properties retrieval are mostly relatively simple, the effort for data input/output is fairly high in case of full resolution OLCI products. Therefore, up-to-date and sufficiently powerful and dimensioned hardware is strongly recommended for reliable and convenient processing.

4.3 Contents of the Processing Software Bundle

The S3-SNOW processing software consists of the following components:

- *snap-core* module: part of the SNAP installation package
- *snap-gpf* module: part of the SNAP installation package
- *s3tbx-idepix-olci*: nbm plugin file
- *s3tbx-olci-o2corr*: nbm plugin file
- *s3tbx-snow*: nbm plugin file
- *snap-slope*: nbm plugin file
- GIMP Digital Elevation Model for Greenland: GeoTIFF auxiliary file

See listing of files in Figure 4.1.

[1] This snapshot version can be replaced by the next official release (v7.0.0) when available. This will be announced on the SNAP website.

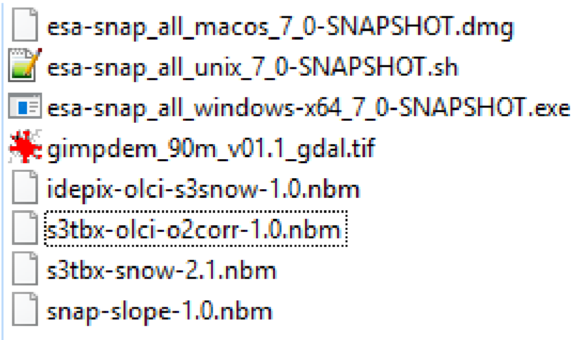


Figure 4.1: Contents of the S3-SNOW software bundle.

The processor versions were frequently incremented during the iterative development process. E.g., the current version of the Snow Properties Processor at S3-Snow project end is v2.1.

4.4 How to get the Software

The S3-SNOW processing software bundle can be obtained from the S3-SNOW ftp site hosted at BC with the following configuration:

- FTP, Port 21
- ftp.brockmann-consult.de
- username: s3snow
- password: $3Sn0W@bc
- subdirectory: software

4.5 Installation Steps

4.5.1 Installation of the SNAP Software

Download SNAP (Unix version) from the SNAP web site [4] and follow the information and instructions for installation given there.

4.5.2 Installation of the S3-SNOW Processor modules

Once SNAP has been installed, the installation of all NBM plugin files needs to be done from the 'Plugins' toolwindow in the SNAP Desktop application. This is illustrated in the figure sequence Figure 4.2 to Figure 4.5.

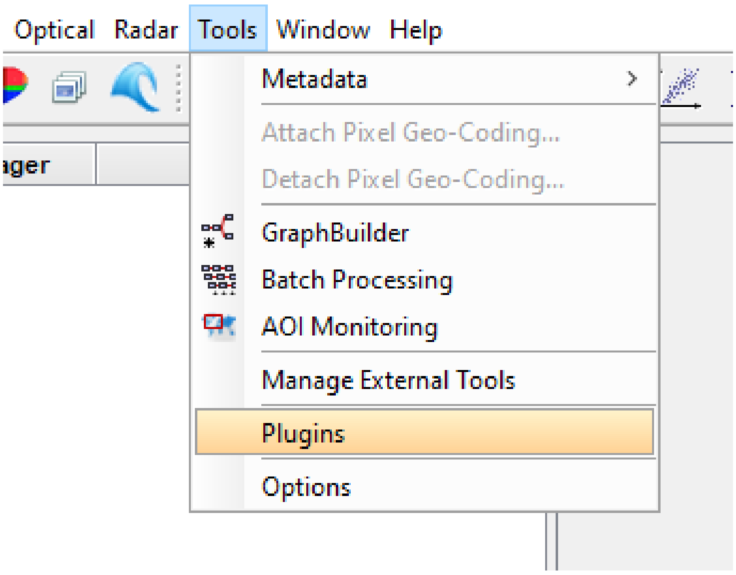


Figure 4.2: The SNAP menu entry for installation of plugins.

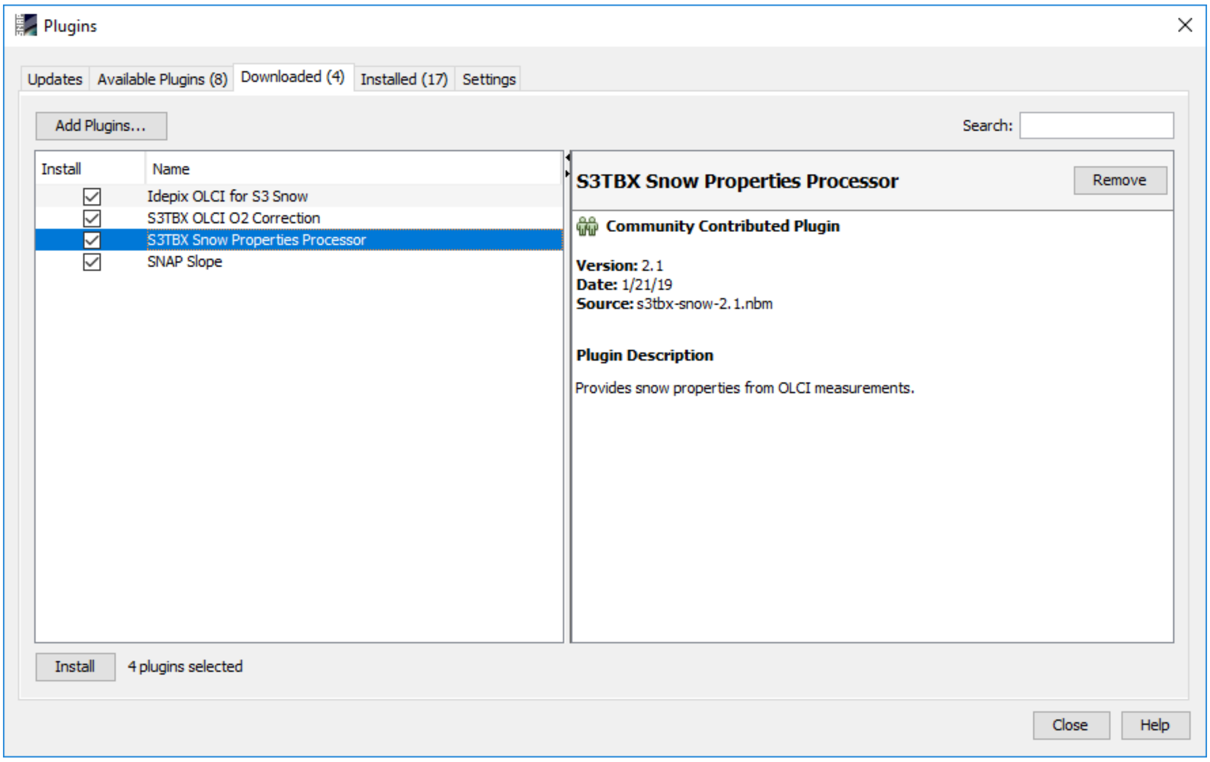


Figure 4.3: Selection of plugins to be installed.

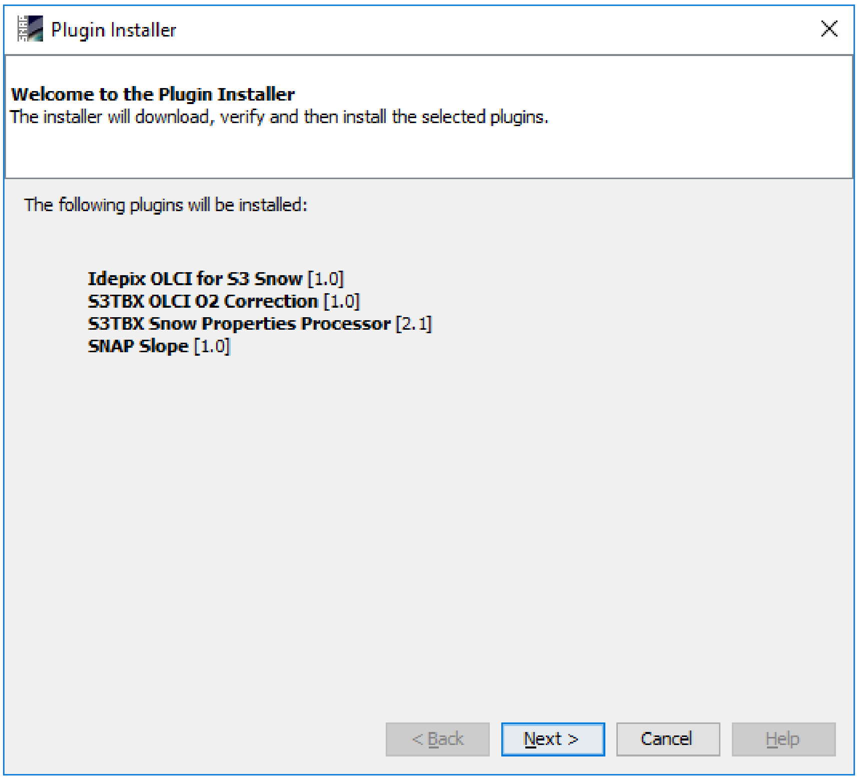


Figure 4.4: Confirmation of selected plugins (step 1 of 4).

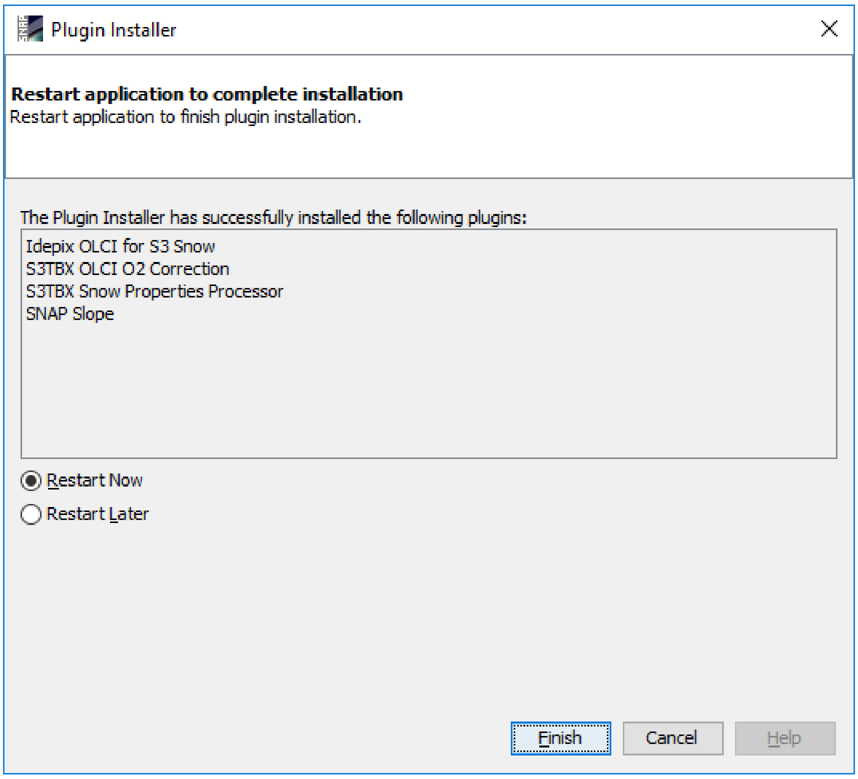


Figure 4.5: Final confirmation for restart after selection of plugins.

After restart of SNAP, the installed processors will be available from their dedicated menu entries. This will be shown in more detail in the next chapter.

5 How to use the S3-SNOW Processors

5.1 Test of the Installation

If all plugins described in chapter *Software Installation* were installed successfully in SNAP, the modules should be visible in their dedicated menus as shown in the figure sequence Figure 5.1 to Figure 5.4.

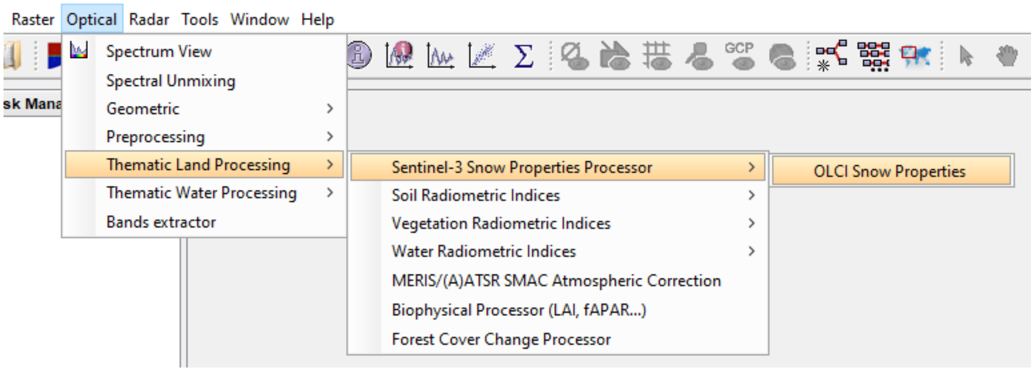


Figure 5.1: The SNAP menu entry for the SPP.

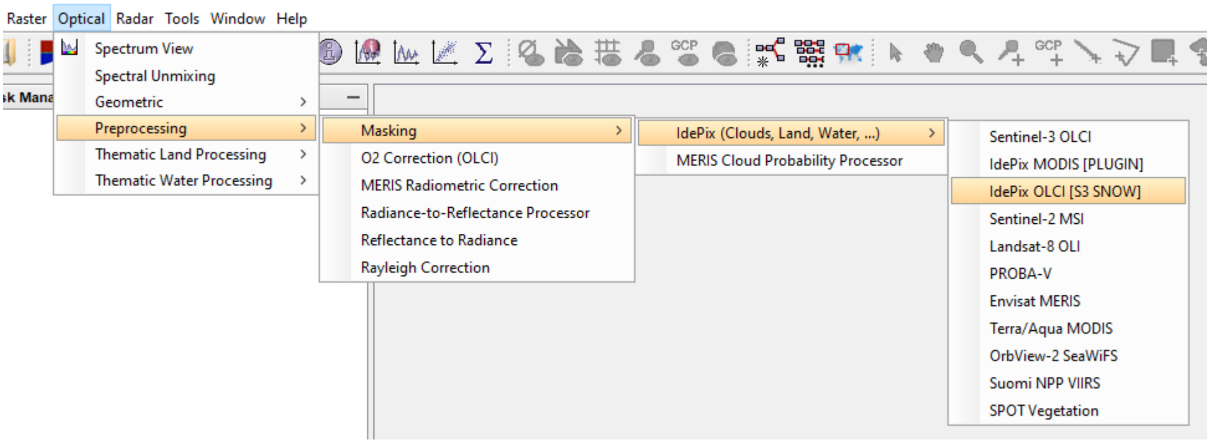


Figure 5.2: The SNAP menu entry for the IdePix Pixel ClassificationProcessor.

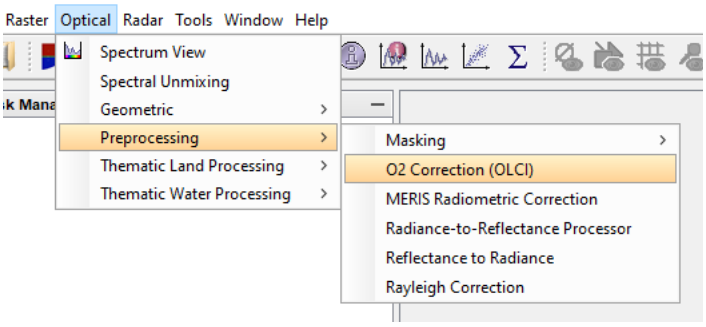


Figure 5.3: The SNAP menu entry for the O2 Correction Processor.

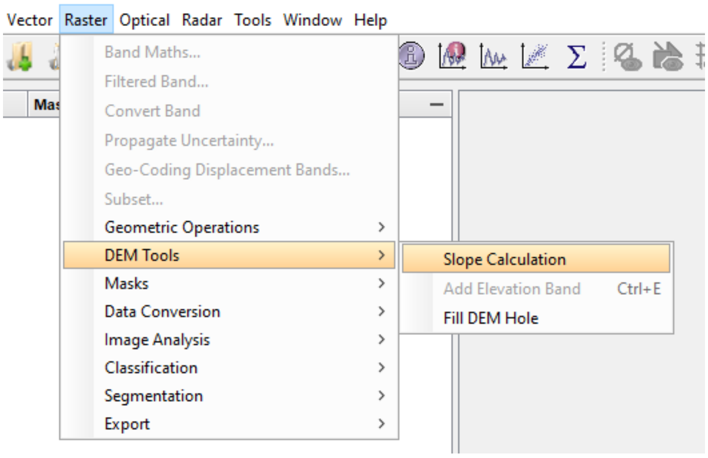


Figure 5.4: The SNAP menu entry for the Slope Processor.

5.2 Test Products

The S3-SNOW project delivery D2.4 'Task 2 Data Base' contains a variety of suitable Sentinel-3 OLCI L1b products which can be used for initial tests of the functionalities of the single processors as well as for the whole processing flow. These products can also be obtained from the S3-SNOW ftp site hosted at BC with the following configuration:

- FTP, Port 21
- ftp.brockmann-consult.de
- username: s3snow
- password: $3Sn0W@bc
- subdirectories: data/<region> (Dome-C, French Alps, Greenland, Morteratsch)

5.3 The Snow Properties Processor

5.3.1 GUI Elements

When the Snow Properties Processor is called from its menu entry, the processor GUI is displayed. It contains two tabs 'I/O Parameters' and 'Processing Parameters' (Figure 5.5).

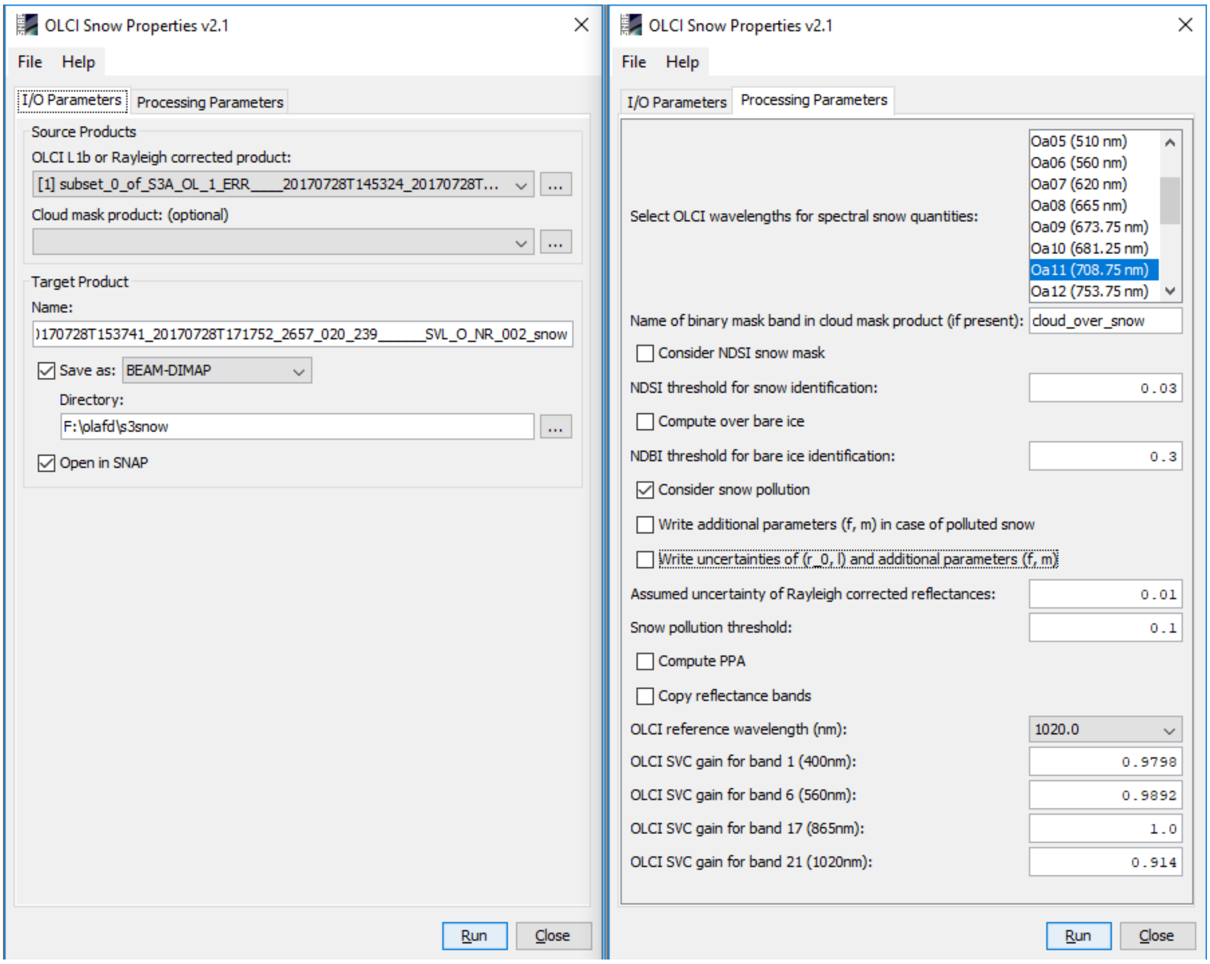


Figure 5.5: The SNAP Snow Properties Processor: I/O and processing parameters tabs.

5.3.2 Help Documentation

From the main menu bar of the processor dialog window, an 'About' dialog showing general information on the processor can also be displayed (Figure 5.6).

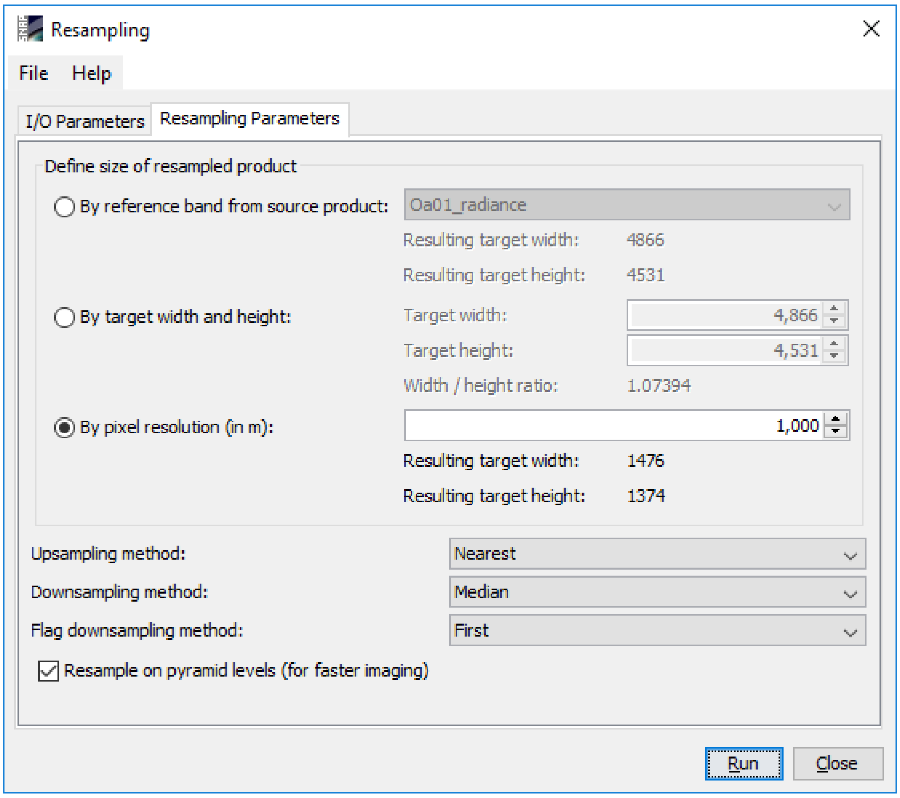


Figure 5.6: The SNAP Snow Properties Processor: 'About' dialog window.

Also from the main menu bar of the processor dialog window, the SNAP specific help documentation for this processor can be invoked (Figure 5.7, Figure 5.8). This documentation contains some general information, a description of the underlying algorithms (i.e. dedicated references), a description of the processor I/O interface, a description of the processing parameters, and a description how to run the processor from the command line.

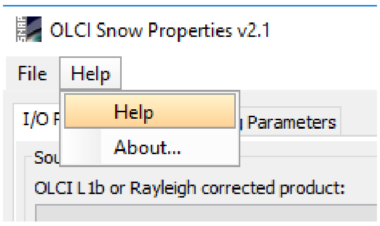


Figure 5.7: The SNAP Snow Properties Processor: Accessing the SNAP desktop help documentation.

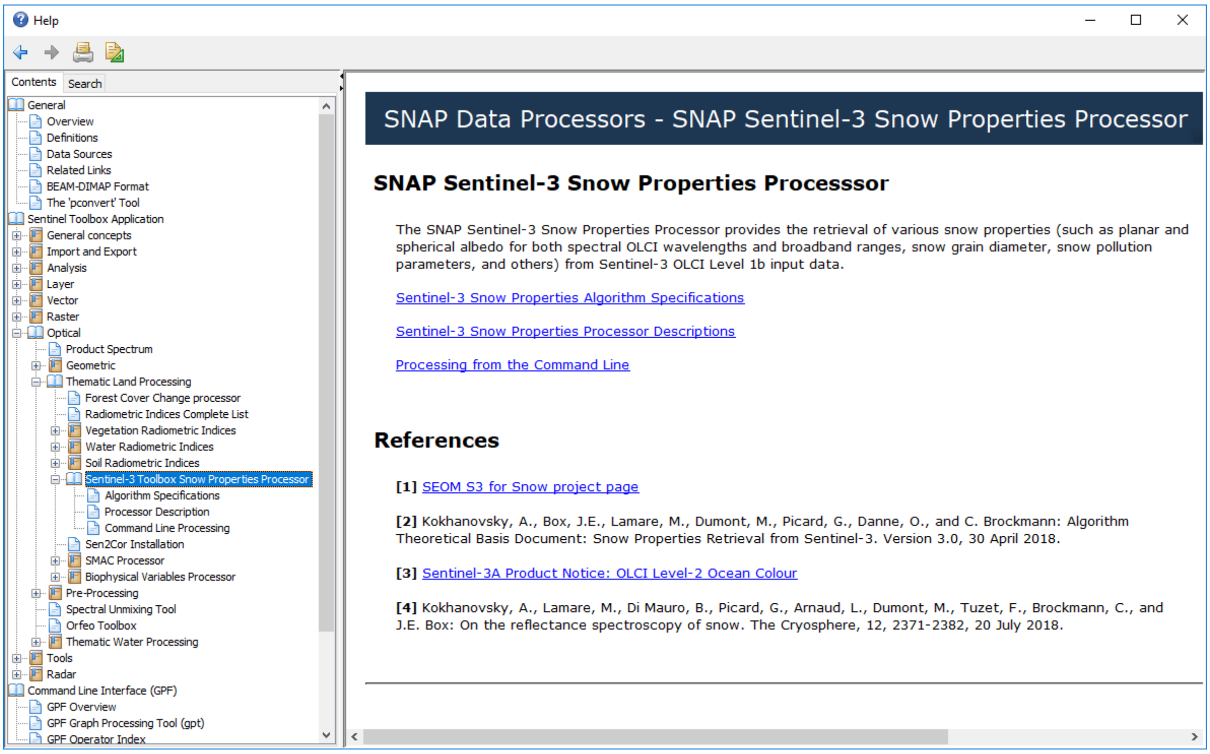


Figure 5.8: The SNAP Snow Properties Processor: Start page of the help documentation.

The text shown in Figure 5.9 describes the elements of the processor I/O tab and how to use it.

Source Product Group

OLCI L1b or Rayleigh corrected product: Used to select the OLCI L1b source product. The user can specify either an original L1b product, or a product which has been Rayleigh corrected in a preprocessing step using the SNAP Rayleigh Correction processor. Using a Rayleigh corrected product as input will save significant computation time for the snow property retrieval, but note that the Rayleigh correction product MUST contain Rayleigh corrected reflectances for spectral bands 1, 5, 17 and 21 (400, 510, 865 and 1020nm), and in addition for all manually selected spectral wavelengths (see processing parameter descriptions below). - If an original L1b product is set as input product, all required Rayleigh corrected reflectances will be computed from an internal call of the SNAP Rayleigh Correction processor.

Use the **...** button to open a data product currently not opened in the Sentinel Toolbox.

Cloud mask product (optional): Used to select an optional source product providing a cloud mask. Usually this product should have been generated in a preprocessing step using the IdePix pixel classification tool in the specific version provided within the SEOM S3 for Snow project [1], but in principle this could be any kind of product containing a mask with values 1.0 indicating cloudy pixels and 0.0 otherwise. A mandatory condition to use this option is that the cloud mask product has been generated on the same raster (i.e. the same OLCI L1b product) which is considered for the snow properties retrieval.

Target Product Group

Name: Used to specify the name of the target product.

Save to: Used to specify whether the target product should be saved to the file system. The combo box presents a list of file formats.

Open in SNAP: Used to specify whether the target product should be opened in the Sentinel Toolbox. When the target product is not saved, it is opened in the Sentinel Toolbox automatically.

Figure 5.9: The SNAP Snow Properties Processor: Usage of the I/O tab (taken from the SNAP help documentation).

The texts shown in Figure 5.10 and Figure 5.11 list the processing parameters and explains their meaning and how to use them.

Select OLCI wavelengths for spectral snow quantities:
The OLCI wavelengths considered for the retrieval of spectral snow quantities. For the selected wavelengths, the computed spectral snow quantities (i.e. spectral snow albedo, see description of processor output below) will be written as corresponding band into the target product. If no band is selected, only broadband snow quantities and other selected, wavelength-independent quantities are written to the target product.

Name of binary mask band in cloud mask product (if present):
The name of the binary mask band in cloud mask product (in case a cloud product was specified). If the IdePix pixel classification tool has been used to generate this product (the usual case), the cloud mask band has the default name 'cloud_over_snow'. If no cloud mask product was specified, this processing parameter has no effect.

Consider NDSI snow mask:
If selected, an NDSI value will be computed from Rayleigh reflectances at wavelengths 865 and 1020nm:

NDSI = (brr865 - brr1020) / (brr865 + brr1020)

The considered pixel will be interpreted as snow pixel if

- the NDSI exceeds a threshold which is given in the parameter below.
- the Rayleigh reflectance at OLCI band 1 (400nm) is greater than 0.5.

The default is 'false'.

NDSI threshold for snow identification:
If an NDSI snow mask is considered (previous parameter), the considered pixel will be interpreted as snow pixel if the NDSI exceeds the threshold specified here, and if the Rayleigh reflectance at OLCI band 1 (400nm) is greater than 0.5. The default number is 0.03.

Consider snow pollution:
If selected, a test for snow pollution is applied for the considered snow pixel. The snow pixel is regarded as 'polluted' if the Rayleigh reflectance at OLCI band 1 (400nm) is lower than the difference of a so-called 'R_0 threshold' and another user parameter 'snow pollution threshold' which is specified below. The retrieval of the 'R_0 threshold' is described in detail in the ATBD [2]. - If the snow pixel is identified as polluted, a specific snow property algorithm is applied which deviates from the clean snow retrieval. Details are described in the ATBD [2].

Write additional parameters (f, l, m, R_0) in case of polluted snow (expert option):
If selected, additional parameters related to polluted snow will be computed for the pixels identified as 'polluted' (see above) and written to the target product. The interpretation of these parameters requires detailed knowledge of the underlying algorithm, therefore this user parameter is considered as an 'expert option'. The default is 'false'.

Write uncertainties of additional parameters in case of polluted snow (expert option):
If selected together with the previous processing parameter, uncertainties of the additional parameters related to polluted snow (see previous processing parameter) will be computed for the pixels identifies as 'polluted' (see above) and written to the target product. The interpretation of these uncertainties requires detailed knowledge of the underlying algorithm, therefore this user parameter is also considered as an 'expert option'. The default is 'false'.

Figure 5.10: The SNAP Snow Properties Processor: Processing parameters (taken from the SNAP help documentation).

Assumed uncertainty of Rayleigh corrected reflectances:
The assumed uncertainty of Rayleigh corrected reflectances, used for the error propagation applied with the previous processing parameter. Default values is 0.01.

Snow pollution threshold:
Threshold for identification of polluted snow, as explained above with the processing parameter 'Consider snow pollution'. Default values is 0.1.

Compute PPA:
If selected, the spectral probability of photon absorption (PPA) is written to the target product for each selected OLCI waveelngth. The default is 'false'.

Copy reflectance bands:
If selected, the mandatory Rayleigh corrected reflectances for spectral bands 1, 5, 17 and 21 (400, 510, 865 and 1020nm), computed internally or provided with Rayleigh correction input product, and in addition the Rayleigh corrected reflectances for all manually selected spectral wavelengths are written to the target product. The default is 'false'.

OLCI reference wavelength:
Reference wavelength used in the snow property algorithms. See the ATBD [2] for details. Default value is 1020nm.

OLCI SVC gain for band 1 (400nm):
OLCI system vicarious calibration (SVC) gain for band 1 (400nm). See [3] for details and explanations. Default value is 0.9798, as proposed in [3], Table 2.

OLCI SVC gain for band 5 (510nm):
OLCI system vicarious calibration (SVC) gain for band 5 (510nm). See [3] for details and explanations. Default value is 0.9892, as proposed in [3], Table 2.

OLCI SVC gain for band 17 (865nm):
OLCI system vicarious calibration (SVC) gain for band 17 (865nm). See [3] for details and explanations. Default value is 1.0, as proposed in [3], Table 2.

OLCI SVC gain for band 21 (1020nm):
OLCI system vicarious calibration (SVC) gain for band 1 (400nm). See [3] for details and explanations. Default value is 0.914, as proposed in [3], Table 2.

Figure 5.11: The SNAP Snow Properties Processor: Processing parameters (continued, taken from the SNAP help documentation).

The text shown in Figure 5.12 describes how to use the CLI (command line interface).

Command Line Description

Since the Sentinel-3 Snow Properties processor makes use of the SNAP graph processing framework, it can be used also as a command line tool. The graph processing is invoked by the command

- ${S3TBX-INSTALL-DIR}/bin/gpt

To obtain general help on the graph processing, use the command

- ${S3TBX-INSTALL-DIR}/bin/gpt -h

Specific help on the Sentinel-3 Snow Properties processor can be obtained with

- ${S3TBX-INSTALL-DIR}/bin/gpt -h OLCI.SnowProperties

In this case, information on the usage and a list of all available parameters are given.

The Snow Properties processor parameters can also be specified via a graph xml file. A possible graph xml file could look like the following. (Note that in principle it is not necessary to explicitly set parameters if default values shall be used).

```
<graph id="SnowPropertiesTest">
    <version>1.0</version>
    <node id="slope">
        <operator>OLCI.SnowProperties</operator>
        <sources>
            <sourceProduct>${sourceProduct}</sourceProduct>
        </sources>
        <parameters>
            <ndsiThresh>0.04</ndsiThresh>
        </parameters>
        <parameters>
            <computePPA>true</computePPA>
        </parameters>
    </node>
</graph>
```

This graph can be invoked by the following call on the command line:

```
gpt <graph-file.xml> -SsourceProduct=<path-to-source-file>
```

Figure 5.12: *The SNAP Snow Properties Processor: Usage of the CLI (taken from the SNAP help documentation).*

5.4 The IdePix OLCI Pixel Classification Processor

5.4.1 GUI Elements

When the IdePix OLCI Pixel Classification is called from its menu entry, the processor GUI is displayed. As all other processors provided for S3-SNOW, it contains two tabs ‘I/O Parameters’ and ‘Processing Parameters’ (Figure 5.13).

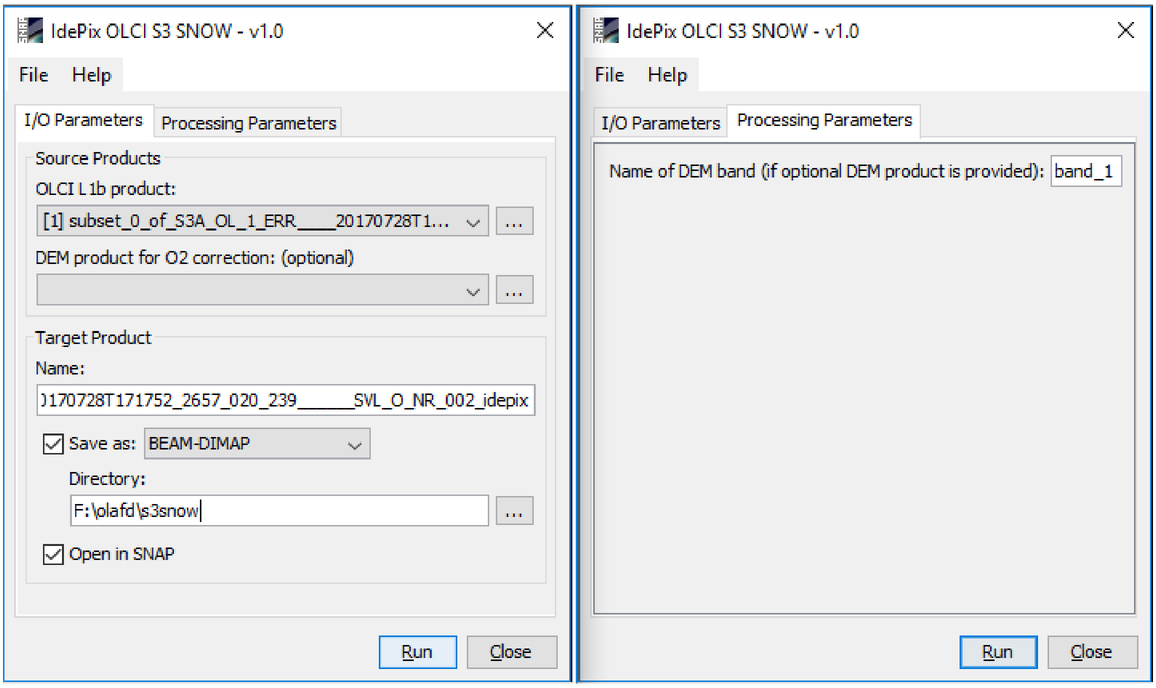


Figure 5.13: The IdePix OLCI Pixel Classification Processor: I/O and processing parameters tabs.

5.4.2 Help Documentation

As for all other processors provided for S3-SNOW, the SNAP specific help documentation for this processor can be invoked from the main menu bar of the processor dialog window. Again, this documentation contains some general information, a description of the underlying algorithms (i.e. dedicated references), a description of the processor I/O interface, a description of the processing parameters, and a description how to run the processor from the command line (Figure 5.14).

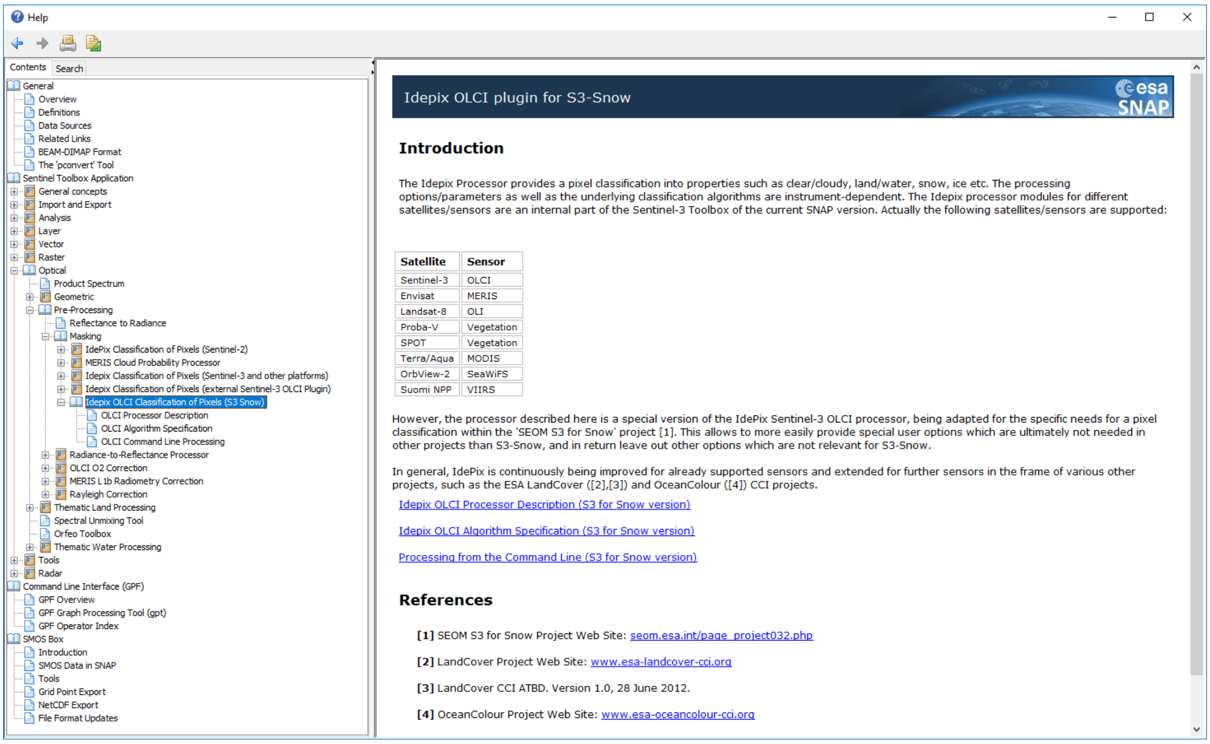
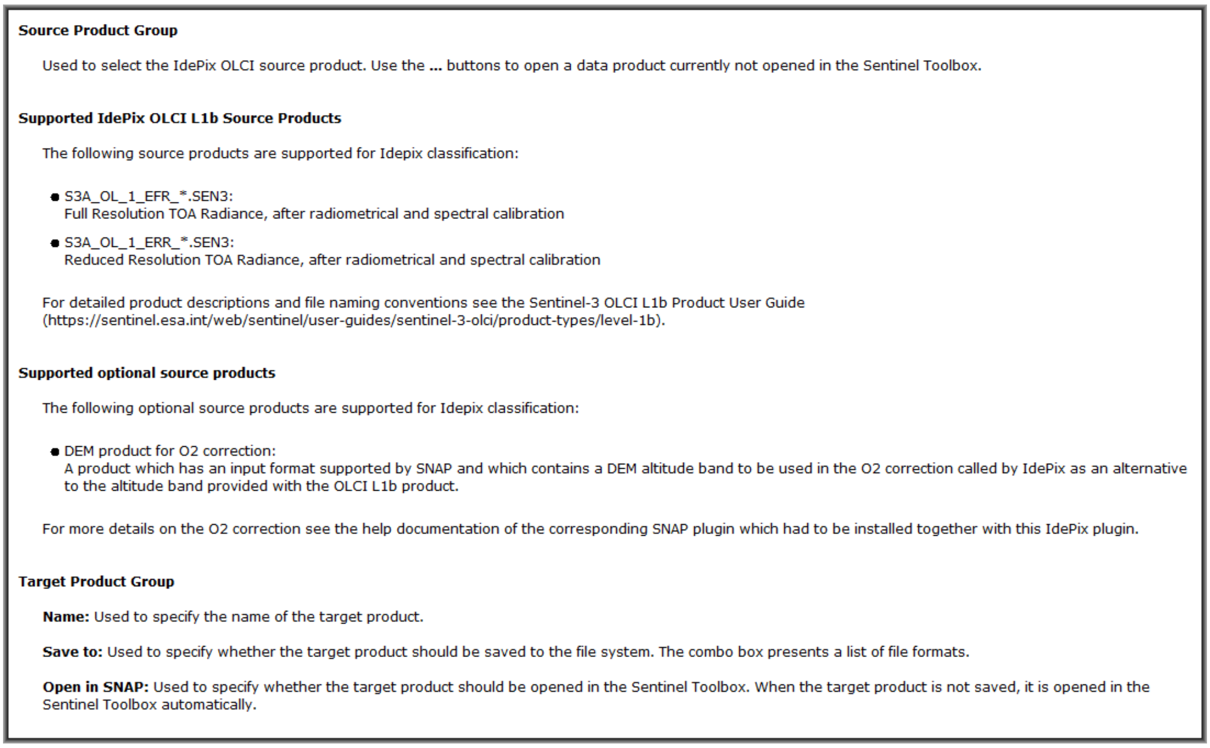


Figure 5.14: The IdePix OLCI Pixel Classification Processor: Start page of the help documentation.

The text shown in Figure 5.15 describes the elements of the processor I/O tab and how to use it.



Source Product Group

Used to select the IdePix OLCI source product. Use the **...** buttons to open a data product currently not opened in the Sentinel Toolbox.

Supported IdePix OLCI L1b Source Products

The following source products are supported for Idepix classification:

- S3A_OL_1_EFR_*.SEN3:
  Full Resolution TOA Radiance, after radiometrical and spectral calibration
- S3A_OL_1_ERR_*.SEN3:
  Reduced Resolution TOA Radiance, after radiometrical and spectral calibration

For detailed product descriptions and file naming conventions see the Sentinel-3 OLCI L1b Product User Guide (https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-olci/product-types/level-1b).

Supported optional source products

The following optional source products are supported for Idepix classification:

- DEM product for O2 correction:
  A product which has an input format supported by SNAP and which contains a DEM altitude band to be used in the O2 correction called by IdePix as an alternative to the altitude band provided with the OLCI L1b product.

For more details on the O2 correction see the help documentation of the corresponding SNAP plugin which had to be installed together with this IdePix plugin.

Target Product Group

Name: Used to specify the name of the target product.

Save to: Used to specify whether the target product should be saved to the file system. The combo box presents a list of file formats.

Open in SNAP: Used to specify whether the target product should be opened in the Sentinel Toolbox. When the target product is not saved, it is opened in the Sentinel Toolbox automatically.

Figure 5.15: The IdePix OLCI Pixel Classification Processor: Usage of the I/O tab (taken from the SNAP help documentation).

The text shown in Figure 5.16 lists the processing parameters (just one in this case) and explains their meaning and how to use them.

Name of DEM band (if optional DEM product is provided):
The name of the altitude band in the optional DEM product. Mandatory if a DEM product is provided. If no DEM product is provided, this parameter has no effect.

Figure 5.16: The IdePix OLCI Pixel Classification Processor: Processing parameters (taken from the SNAP help documentation).

The text shown in Figure 5.17 describes how to use the CLI (command line interface).

Command Line Description

Since the Idepix processor makes use of the SNAP graph processing framework, it can be used also as a command line tool. The graph processing is invoked by the command

- ${S3TBX-INSTALL-DIR}/bin/gpt

To obtain general help on the graph processing, use the command

- ${S3TBX-INSTALL-DIR}/bin/gpt -h

Specific help on the Idepix OLCI processor for S3-Snow can be obtained with

- ${S3TBX-INSTALL-DIR}/bin/gpt -h Snap.Idepix.Olci.S3Snow

In this case, information on the usage and a list of all available parameters are given. The Idepix processor parameters can also be specified via a graph xml file. E.g., a possible graph xml file for OLCI could look like the following. (Note that in principle it is not necessary to explicitly set parameters if default values shall be used).

```
<graph id="Snap.Idepix.Olci.S3Snow.Test">
    <version>1.0</version>
    <node id="idepix">
        <operator>Snap.Idepix.Olci.S3Snow</operator>
        <sources>
            <sourceProduct>${sourceProduct}</sourceProduct>
            <demProduct>${demProduct}</demProduct>
        </sources>
        <parameters>
            <demBandName>myAltitude</demBandName>
        </parameters>
    </node>
</graph>
```

This graph can be invoked by the following call on the command line:

```
gpt <graph-file.xml> -SsourceProduct=<path-to-source-file>
```

Figure 5.17: The IdePix OLCI Pixel Classification Processor: Usage of the CLI (taken from the SNAP help documentation).

5.5 The OLCI O2 Correction Processor

5.5.1 GUI Elements

When the OLCI O2 Correction is called from its menu entry, the processor GUI is displayed. Again, this processor contains two tabs ‘I/O Parameters’ and ‘Processing Parameters’ (Figure 5.18).

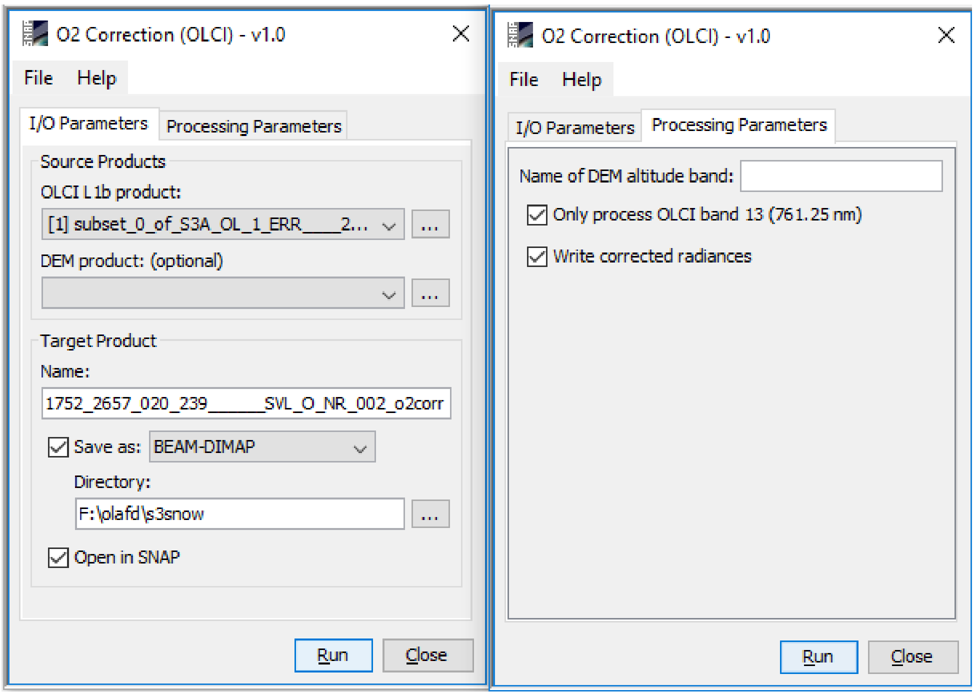


Figure 5.18: The OLCI O2 Correction Processor: I/O and processing parameters tabs.

5.5.2 Help Documentation

The help documentation can be accessed in the same way as for all other processors provided for S3-SNOW.

Layout and usage of the I/O Parameters tab are basically the same as for the IdePix OLCI Pixel Classification Processor.

The text shown in Figure 5.19 lists the processing parameters and explains their meaning and how to use them.

Name of DEM altitude band:
The name of the DEM altitude band in the optional DEM product. If no DEM product is specified, this parameter has no effect. There is no default altitude band name.

Only process OLCI band 13 (761.25nm):
If selected, only OLCI band 13 will be processed and its related outputs are written to the target product. Otherwise bands 13-15 will be processed. The default setting is 'true'. This is sufficient for many applications such as cloud screening and significantly saves processing time.

Write corrected radiances:
If set, the corrected radiances (recomputed using the retrieved effective transmittances) are written to target product. The default setting value is 'true'.

Figure 5.19: The OLCI O2 Correction Processor: Processing parameters (taken from the SNAP help documentation).

The text shown in Figure 5.20 describes how to use the CLI (command line interface).

Command Line Description

Since the Idepix processor makes use of the SNAP graph processing framework, it can be used also as a command line tool. The graph processing is invoked by the command

- ${S3TBX-INSTALL-DIR}/bin/gpt

To obtain general help on the graph processing, use the command

- ${S3TBX-INSTALL-DIR}/bin/gpt -h

Specific help on the Idepix OLCI processor for S3-Snow can be obtained with

- ${S3TBX-INSTALL-DIR}/bin/gpt -h Snap.Idepix.Olci.S3Snow

In this case, information on the usage and a list of all available parameters are given. The Idepix processor parameters can also be specified via a graph xml file. E.g., a possible graph xml file for OLCI could look like the following. (Note that in principle it is not necessary to explicitly set parameters if default values shall be used).

```
<graph id="Snap.Idepix.Olci.S3Snow.Test">
    <version>1.0</version>
    <node id="idepix">
        <operator>Snap.Idepix.Olci.S3Snow</operator>
        <sources>
            <sourceProduct>${sourceProduct}</sourceProduct>
            <demProduct>${demProduct}</demProduct>
        </sources>
        <parameters>
            <demBandName>myAltitude</demBandName>
        </parameters>
    </node>
</graph>
```

This graph can be invoked by the following call on the command line:

```
gpt <graph-file.xml> -SsourceProduct=<path-to-source-file>
```

Figure 5.20: The OLCI O2 Correction Processor: Usage of the CLI (taken from the SNAP help documentation).

5.6 The SNAP Slope Processor

5.6.1 GUI Elements

When the Slope Processor is called from its menu entry, the processor GUI is displayed. Again, this processor contains two tabs 'I/O Parameters' and 'Processing Parameters' (Figure 5.21).

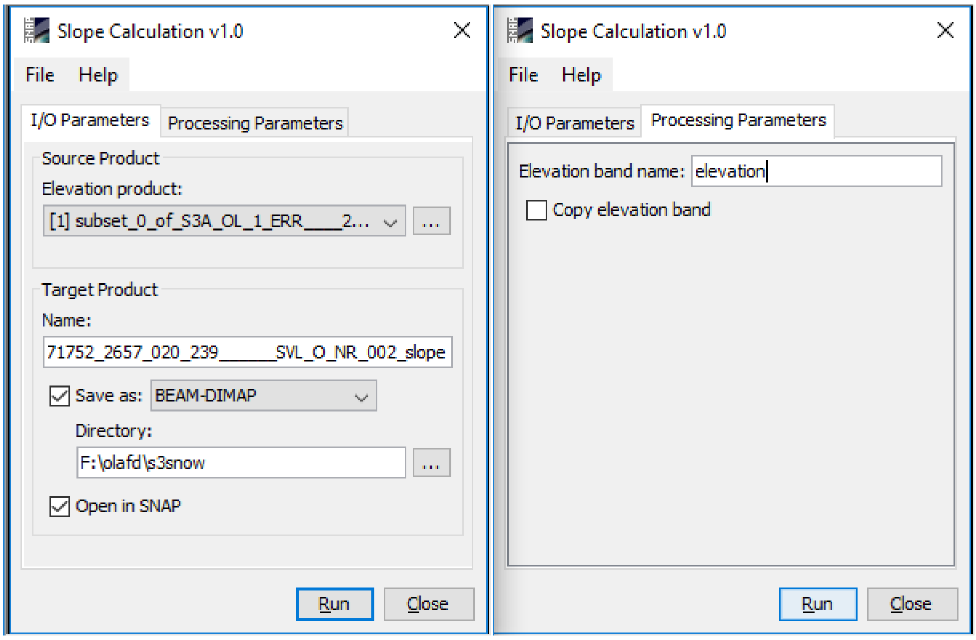


Figure 5.21: The SNAP Slope Processor: I/O and processing parameters tabs.

5.6.2 Help Documentation

The help documentation can be accessed in the same way as for all other processors provided for S3-SNOW.

Layout and usage of the I/O Parameters tab is simple and straightforward. A DEM product is expected as only input.

The text shown in Figure 5.22 lists the processing parameters and explains their meaning and how to use them.

Elevation band name:
The name of the altitude band in the source product. Default is 'elevation'.

Copy elevation band:
If selected, the altitude band is copied into the target product. Default is 'false'.

Figure 5.22: The Slope Processor: Processing parameters (taken from the SNAP help documentation).

The text shown in Figure 5.23 describes how to use the CLI (command line interface).

Command Line Description

Since the Slope Calculation processor makes use of the SNAP graph processing framework, it can be used also as a command line tool. The graph processing is invoked by the command

- ${S3TBX-INSTALL-DIR}/bin/gpt

To obtain general help on the graph processing, use the command

- ${S3TBX-INSTALL-DIR}/bin/gpt -h

Specific help on the Slope Calculation processor can be obtained with

- ${S3TBX-INSTALL-DIR}/bin/gpt -h SlopeCalculation

In this case, information on the usage and a list of all available parameters are given. The Slope Calculation processor parameters can also be specified via a graph xml file. A possible graph xml file could look like the following. (Note that in principle it is not necessary to explicitly set parameters if default values shall be used).

```
<graph id="SlopeCalculationTest">
    <version>1.0</version>
    <node id="slope">
        <operator>SlopeCalculation</operator>
        <sources>
            <sourceProduct>${sourceProduct}</sourceProduct>
        </sources>
        <parameters>
            <elevationBandName>myAltitude</elevationBandName>
        </parameters>
        <parameters>
            <copyElevationBand>true</copyElevationBand>
        </parameters>
    </node>
</graph>
```

This graph can be invoked by the following call on the command line:

```
gpt <graph-file.xml> -SsourceProduct=<path-to-source-file>
```

Figure 5.23: The Slope Processor: Usage of the CLI (taken from the SNAP help documentation).

The text shown in Figure 5.24 represents the 'Algorithm Specification', which just illustrates the simple equations how slope and aspect are computed.

Slope computation

If alt*n* with *n* = 1..9 are the altitudes consecutively numbered in a 3x3 window around the considered pixel, the slope is computed as

b = (alt3 + 2 * alt6 + alt9 - alt1 - 2 * alt4 - alt7) / 8
c = (alt1 + 2 * alt2 + alt3 - alt7 - 2 * alt8 - alt9) / 8

SLOPE = atan(sqrt(b/X * b/X + c/X * c/X))

Aspect computation

If alt*n* with *n* = 1..9 are the altitudes consecutively numbered in a 3x3 window around the considered pixel, the aspect is computed as

b = (alt3 + 2 * alt6 + alt9 - alt1 - 2 * alt4 - alt7) / 8
c = (alt1 + 2 * alt2 + alt3 - alt7 - 2 * alt8 - alt9) / 8

ASPECT = atan2(-b, -c)

This value is finally mapped onto [0..360] in order to give the aspect as angle between North direction and steepest slope,

Figure 5.24: The Slope Processor: Equations for the computation of slope and aspect.