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Tutorial: Working with Sentinel-2 products

RUS & SNAP





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AGENDA

- ➔ 1. Introduction to RUS
- ➔ 2. Introduction to SNAP
- ➔ 3. Downloading and opening a Sentinel-2 image
- ➔ 4. Processing a Sentinel-2 product: vegetation monitoring
 - ➔ Preprocessing
 - ➔ NDVI and LAI
- ➔ 5. Automate processing using GPT



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1. Introduction to RUS



COPERNICUS RESEARCH & USER SUPPORT (RUS) **AN ESA/EU FUNDED SERVICE**



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RUS Service - What for?

- **Foster the handling and processing of data from Copernicus missions by the Academic, scientific, R&D community, SMEs**
- **Mitigate the “digital divide” affecting Copernicus data access and exploitation**
- **Enhance and support the initiatives aiming at supporting Copernicus uptake**





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RUS Service - How?

- **Offering unique access to free data and ICT resources to scale up R&D and early prototyping activities over large amounts of Sentinel products**
- **Providing a specialized user helpdesk accompanying the service users in their activities with technical advice from a team of skilled experts**
- **Offering open hands-on training sessions in Europe**
 - Customized technical training
 - Training programme dedicated to future “trainers”





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RUS Service – For whom?

- **Research users** Scaling up of algorithms on large amounts of core products
- **Expert users** Process large amount of core products using Free and Open-Source Software (FOSS) or Commercial Off The Shelf (COTS) tools
- **University classes** Use Sentinel core products with either own algorithms, FOSS or COTS
- **Specific research/user communities** (e.g. EU Member States, Commission Services, Third Countries, SMEs, H2020 projects...) Request dedicated support to facilitate uptake of Sentinel core products





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RUS Service - Tasks

Provide and manage resources for the service users

- Sentinel and Copernicus Contributing Missions data
 - open also to other data sources (e.g. Landsat, ALOS)
- Toolboxes and software needed for data processing and prototyping activities
 - possibility to install also own tools
- Virtualised and scalable computing resources (VM or VM clusters) provided by dedicated cloud providers

Support ownership of Copernicus space component by end-users

- Capacity building
- Generic user training and training of Copernicus trainers





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RUS Service - Levels

The RUS Service has been designed to accommodate as much as possible user needs and provide the appropriate support and ICT resources

- User requests are analysed in order to estimate this support and these resources
- User requests are answered following a 3-level classification
 - Basic support service (Level A), 1-3 month duration
 - Development support service (Level B), 1-6 month duration
 - Processing support service (Level C), 1-12 month duration





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RUS Service – Typical VM Content

❖ Processing environment

- Sentinel-1/2/3 Toolboxes
- SNAP4Cloud (built-on Apache Ignite)
- Support tools
 - Sen2Cor
 - Sen2Three
 - SMOS Toolbox
 - Orfeo Toolbox
 - BRAT Toolbox
 - Rugged library
 - OpenCV
 - GDAL library
 - NCO
 - NETCDF
 - OpenJPG
 - Image Magick
 - QGis

❖ Development environment

- Eclipse Mars
- GCC
- Cmake
- Maven
- Git
- R
- Eclipse Mars plugins
 - Pydev
 - CDT (C/C++ IDE)
 - StatEt
 - Cmaked
 - EGit



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RUS Service – Training activities

Proposed training plan for RUS service

- Through different event types
 - Invited (turnkey events)
 - Co-hosted (contribution to existing events)
 - Fully organised events
- Through existing networks (Copernicus Info sessions - NEREUS, REC, UNOSAT, FAO, UNEP, EARSC, EARSEL...)
- Organisation
 - Duration : from 1 day to a full 5-days course
 - Focus on Europe
 - 27 face-to-face events to be planned over 3 years





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RUS Service and You



Non Commercial activities



Students, trainers, researchers, decision-makers, general public

Free access



Powerful computing environment with scalable VM and full support

Support



Expertise to visualize, interpret geospatial information

Process



Process large Sentinel datasets possible for any user

Training



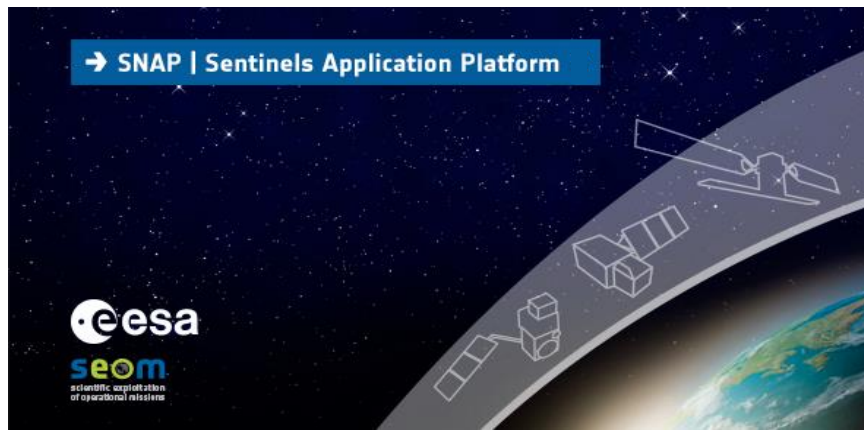
Face-to-face sessions and webinars for all users





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2. Introduction to SNAP



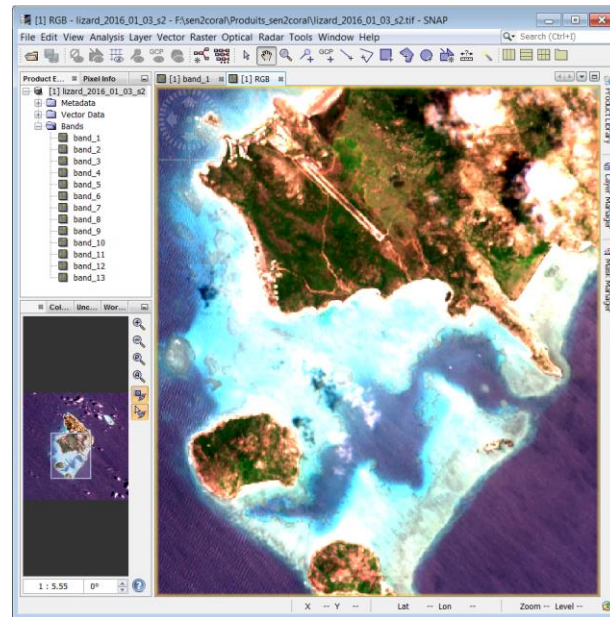
SENTINEL APPLICATION PLATFORM



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SNAP – What is ?

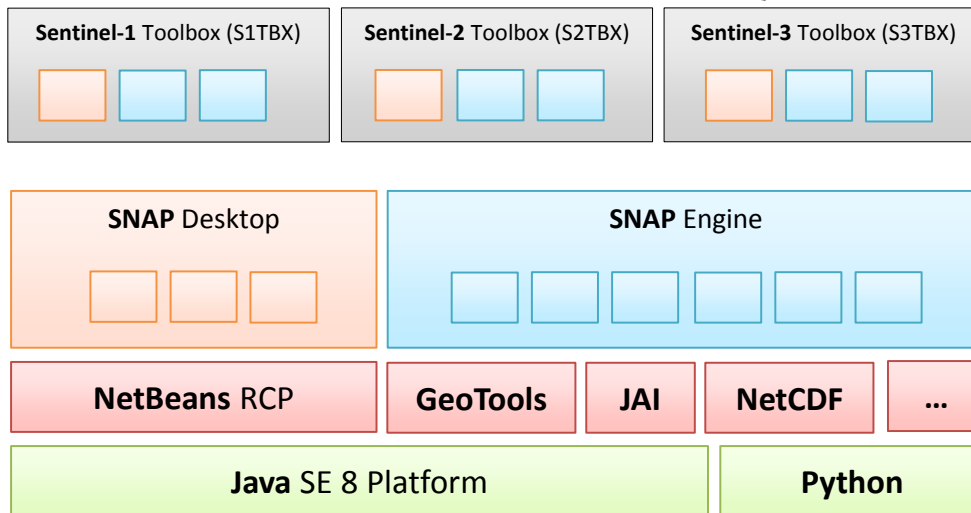
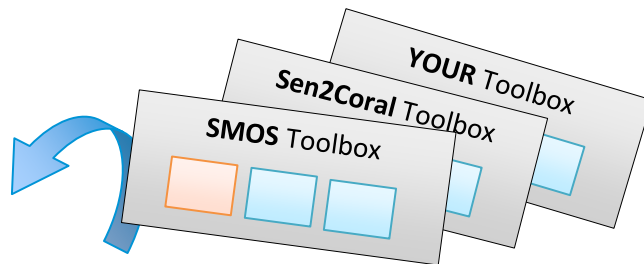
- An **open-source**, flexible and re-usable scientific Toolbox
- Based on the strong software heritage of BEAM & NEST
- With specific Sentinel data **exploitation tools**
- **Multi-mission** :
 - Sentinel-1/2/3
 - Envisat, MODIS, SeaWIFS, ...
 - AVHRR, SMOS, Chris-PROBA, SPOT VGT, ...
 - LANDSAT, RapidEye, SPOT
 - Generic formats : NetCDF, GeoTIFF, HDF...
- **Modular and extensible**





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SNAP – Architecture





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SNAP – Core features

- Common architecture and **data model** for all Toolboxes
- Very fast **image display and navigation** even of giga-pixel images
- Graph Processing Framework (**GPF**)
- Advanced **layer management** allows adding and manipulation of new overlays such as images of other bands, images from WMS servers or ESRI shapefiles
- Flexible **band arithmetic** using arbitrary mathematical expressions
- Accurate **reprojection** and **ortho-rectification** to common map projections
- **Geo-coding** and **rectification** using ground control points
- Automatic SRTM **DEM** download and tile selection
- **Multithreading** and **Multi-core** processor support



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SNAP – Extensibility

- **Java** as the native language. A Java API to
 - Develop your own application (cli or gui)
 - Extend the existing application by adding modules
- **Python** as a main extension language.
 - SNAPPY: The Python API mimics the Java API
 - Write your own Python scripts leveraging on SNAP
 - Extend SNAP by developing modules in Python (numpy, scipy, ...). Useful for bridging your C/C++ library
- **Standalone Tools Adapter** module
 - Use your own cli tools as if they were a native SNAP module
 - GDAL, Orfeo Toolbox, Sen2Cor, Sen2Three, ...

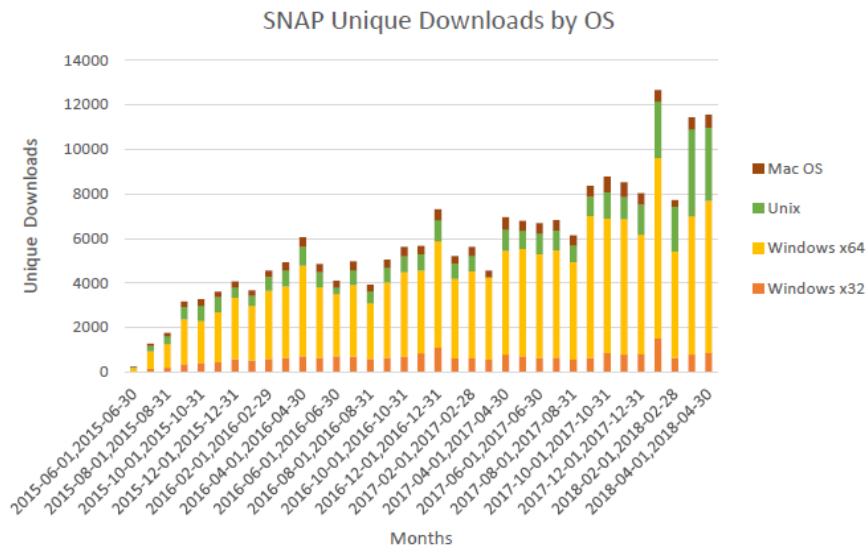




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SNAP – Community

- Our website : step.esa.int
 - Get it : <http://step.esa.int/main/download/>
 - Ask questions, discuss anything SNAP or Sentinel data related : <http://forum.step.esa.int>
 - Tutorials, News, Links, related software, ...



step forum

all categories ▾ Categories Latest New Unread Top

Category Topics

s1tbx

20 / week

The S1 Toolbox category regroups all threads about the Sentinel-1 Toolbox, as SAR readers or processors.

■ Problem Reports
■ Interferometry
■ Polarimetry

s2tbx

11 / week

The S2 Toolbox category regroups all threads about the Sentinel-2 Toolbox as Sentinel-2 product readers and product manipulation, Sentinel-2 processors as L2A processor for atmospheric correction, L3 processor for temporal synthesis, etc.

■ sen2cor
■ sen2three

s3tbx

1 / week

The S3 Toolbox category regroups all threads about the Sentinel-3 Toolbox as readers and processors for Sentinel-3 OLCI & SLSTR L1 & L2.

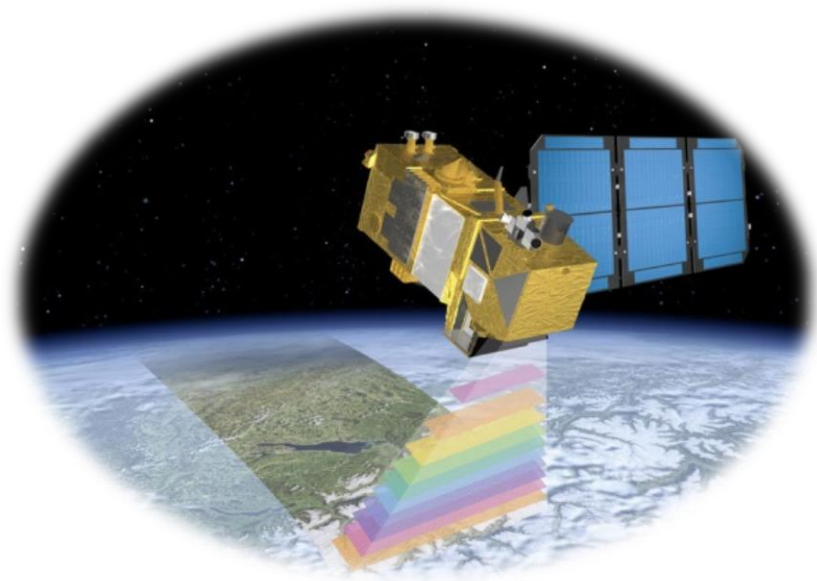
snap

7 / week



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3. Downloading and opening a S2 image





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3. Downloading a S2 product

The screenshot shows the Copernicus Open Access Hub interface. The browser address bar displays <https://scihub.copernicus.eu/dhus/#/home>. The page title is "Copernicus Open Access Hub". A search bar at the top left contains the text "Insert search criteria...". Below the search bar, a list of search results is displayed, showing 1 to 16 of 16 products. The results are ordered by ingestion date. The first result is a Sentinel-2 MSI product with a footprint covering Phoenix, AZ. The second result is another Sentinel-2 MSI product with a footprint covering Phoenix, AZ. The third result is a Sentinel-2 MS2 product with a footprint covering Phoenix, AZ. The fourth result is another Sentinel-2 MS2 product with a footprint covering Phoenix, AZ. The map on the right shows the Phoenix, AZ area with a green polygon indicating the search footprint. The map includes labels for various locations such as Surprise, Peoria, Glendale, Scottsdale, Phoenix, Mesa, Gilbert, Chandler, Tortilla Mountain (1489m), Pinal Peak (2389m), White Hills (782m), Eloy, Casa Grande, Florence, and Jerky Butte (1385m). The map also shows the Salween River, Agua Fria River, and Agua Chica River. The map is overlaid with a grid and a scale bar.

Display 1 to 16 of 16 products.
Order By: Ingestion Date ↓

Request Done: (footprint:"Intersects(POLYGON((-112.06522662695981 33.08020563430439,-112.05853387344982 33.08020563430439,-112.05853387344982 33.08674794941449,-112.06522662695981

Product ID	Download URL	Mission	Instrument	Sensing Date
S2A_MSLIC_20180420T175911_N0206_R041_T12SVB_20180420T213...	https://scihub.copernicus.eu/dhus/odata/v1/Products/'f7847f33.08020563430439,-112.05853387344982 33.08020563430439,-112.05853387344982 33.08674794941449,-112.06522662695981	Sentinel-2	MSI	2018-04-20T17:59:11.026Z
S2A_MSLIC_20180420T175911_N0206_R041_T12SUB_20180420T213...	https://scihub.copernicus.eu/dhus/odata/v1/Products/'ec71f722.08020563430439,-112.05853387344982 33.08020563430439,-112.05853387344982 33.08674794941449,-112.06522662695981	Sentinel-2	MSI	2018-04-20T17:59:11.026Z
S2B_MSLIC_20180418T180919_N0206_R084_T12SVB_20180418T215...	https://scihub.copernicus.eu/dhus/odata/v1/Products/'61a52618.08020563430439,-112.05853387344982 33.08020563430439,-112.05853387344982 33.08674794941449,-112.06522662695981	Sentinel-2	MSI	2018-04-18T18:09:19.027Z
S2B_MSLIC_20180418T180919_N0206_R084_T12SUB_20180418T215...	https://scihub.copernicus.eu/dhus/odata/v1/Products/'7ccdb180.08020563430439,-112.05853387344982 33.08020563430439,-112.05853387344982 33.08674794941449,-112.06522662695981	Sentinel-2	MSI	2018-04-18T18:09:19.027Z

25 << page: 1 of 1 >> CLOSE

Pan Box Polygon Clear



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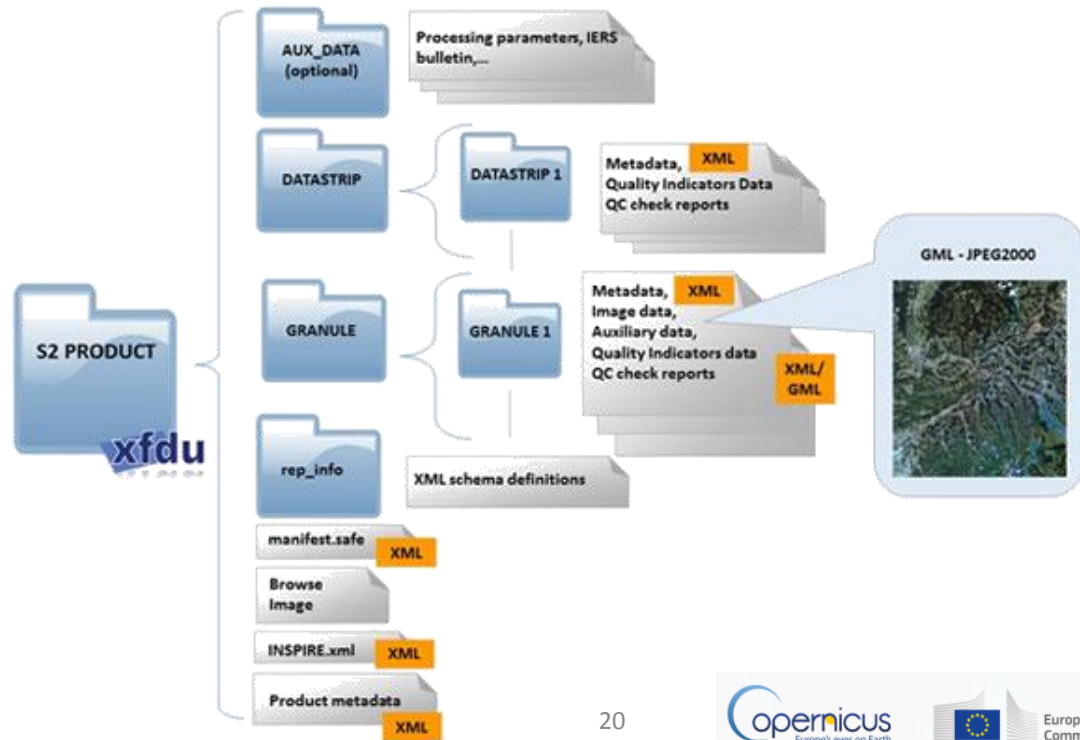
Opening a S2 product

Open a Sentinel 2 product:

S2A_OPER_PRD_MSIL1C_PDMC_20160424T021342_R084_V20160423T182433_20160423T182433.SAFE

See product content

- Metadata
- VectorData
- Bands
- Masks

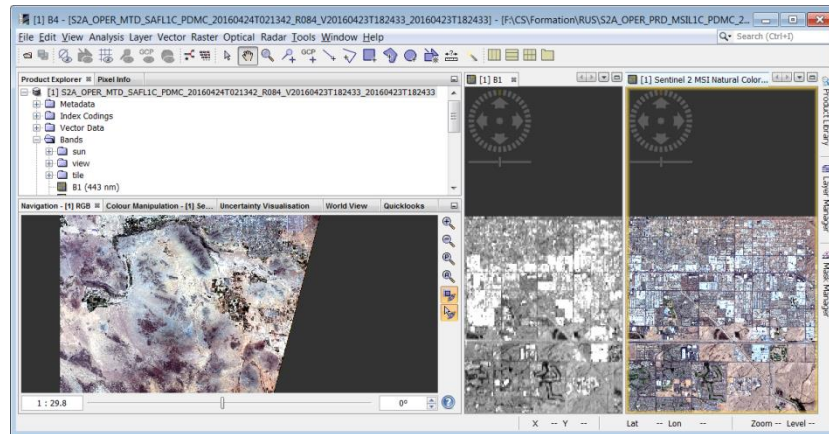




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Analyzing the product

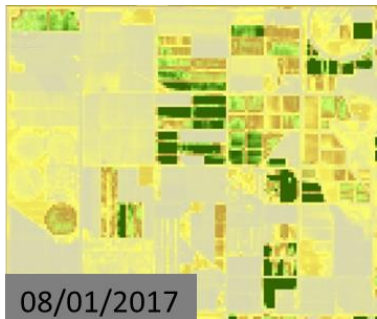
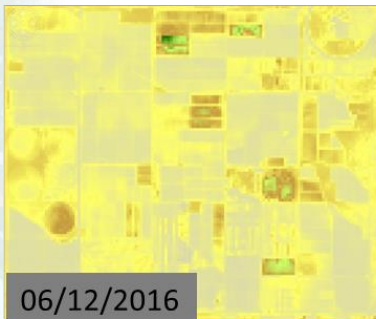
- **Open B1**
- **Display an RGB composite: right click on product, choose profile**
- **Multi-size**
- **Tile window**
- **Metadata**
- **Use the navigation view to spatially link both window**
- **View level: pyramids**
- **Add layers**





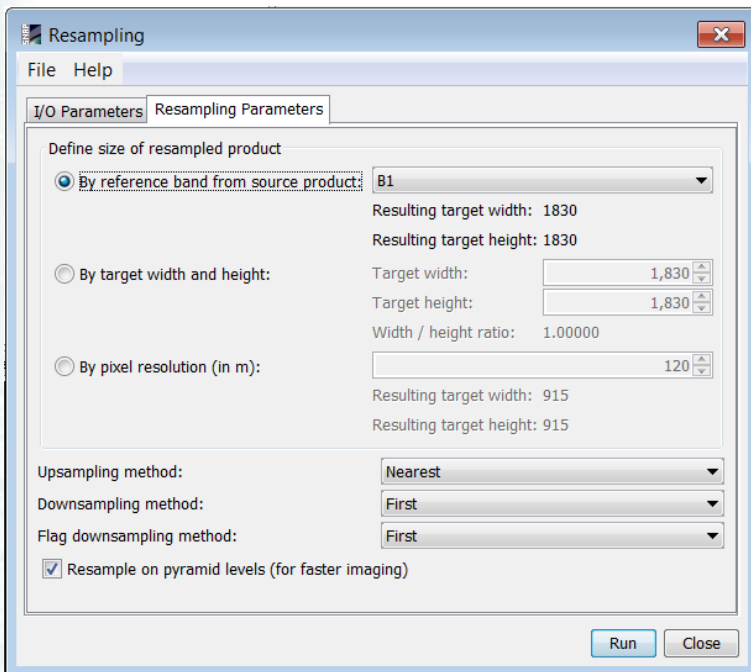
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4. Processing a S2 product: vegetation





- Atmospheric corrections?
- Resample
- Subset



Resampling

File Help

I/O Parameters Resampling Parameters

Define size of resampled product

By reference band from source product: **B1**

Resulting target width: 1830
Resulting target height: 1830

By target width and height: Target width: 1,830
Target height: 1,830
Width / height ratio: 1.00000

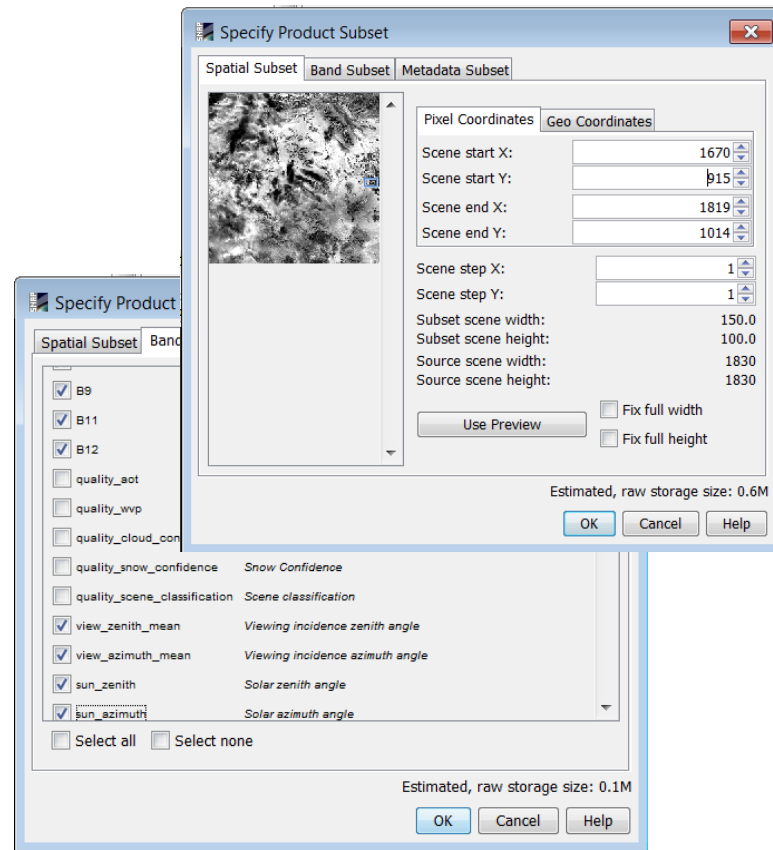
By pixel resolution (in m): 120

Resulting target width: 915
Resulting target height: 915

Upsampling method: Nearest
Downsampling method: First
Flag downsampling method: First

Resample on pyramid levels (for faster imaging)

Run Close



Specify Product Subset

Spatial Subset Band Subset Metadata Subset

Pixel Coordinates Geo Coordinates

Scene start X: 1670
Scene start Y: 115
Scene end X: 1819
Scene end Y: 1014

Scene step X: 1
Scene step Y: 1

Subset scene width: 150.0
Subset scene height: 100.0
Source scene width: 1830
Source scene height: 1830

Use Preview Fix full width Fix full height

Estimated, raw storage size: 0.6M

OK Cancel Help

Spatial Subset Band Subset

B9
 B11
 B12

quality_aot
 quality_wvp
 quality_cloud_con
 quality_snow_confidence Snow Confidence
 quality_scene_classification Scene classification

view_zenith_mean Viewing incidence zenith angle
 view_azimuth_mean Viewing incidence azimuth angle
 sun_zenith Solar zenith angle
 sun_azimuth Solar azimuth angle

Select all Select none

Estimated, raw storage size: 0.1M

OK Cancel Help

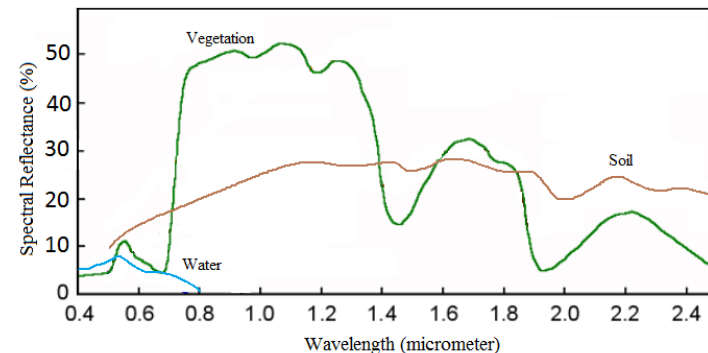


Spectral signature

- Reflectance/emittance as a function of wavelength. The spectral signature of an object is a function of the incidental EM wavelength and material interaction with that section of the electromagnetic spectrum.
- Each material has a unique signature, therefore it can be used for material classification

Radiometric Indices

- Convenient way to resume information
- Exploit the particular spectral properties of vegetation
- Depend on spectral response of the sensors
- Potentially unlimited number of combinations

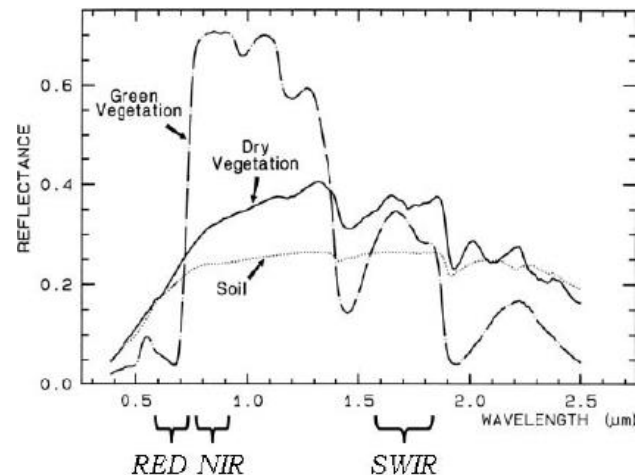




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NDVI (Normalized Diff.Vegetation index)

- The spectral signature of vegetation shows a abrupt rise of the reflection level at 0,7 μm . So much more active the chlorophyll of the plants, so much bigger is the rise
- The NDVI composes a measurement for the photosynthetic activity and is strongly in correlation with density and vitality of the vegetation.
- The normalizing reduces topographic and atmospheric effects and enables the simultaneous examination of a wide area.

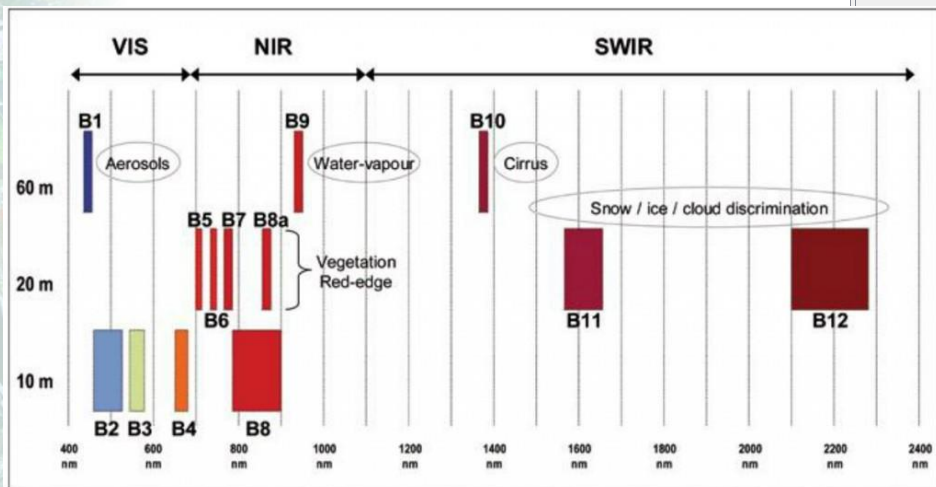
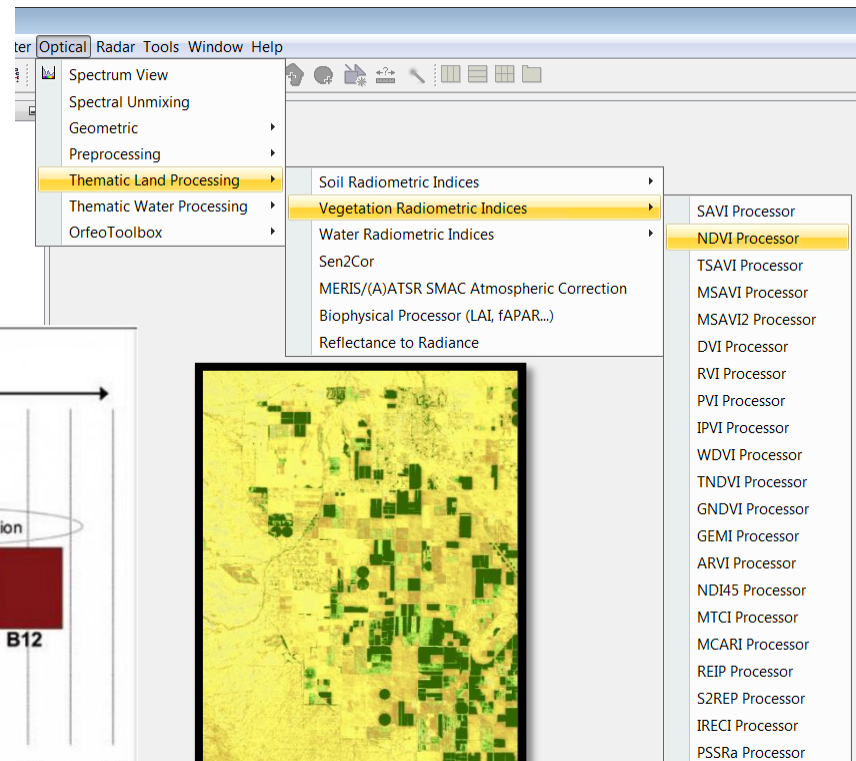


$$\text{NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})}$$



Vegetation index in SNAP

- Via **BandMaths**
- Via **Vegetation Radiometric Indices:**





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B i o p h y s i c a l p a r a m e t e r s

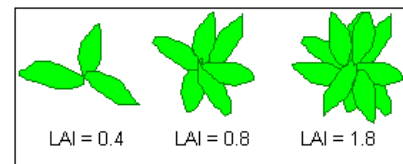
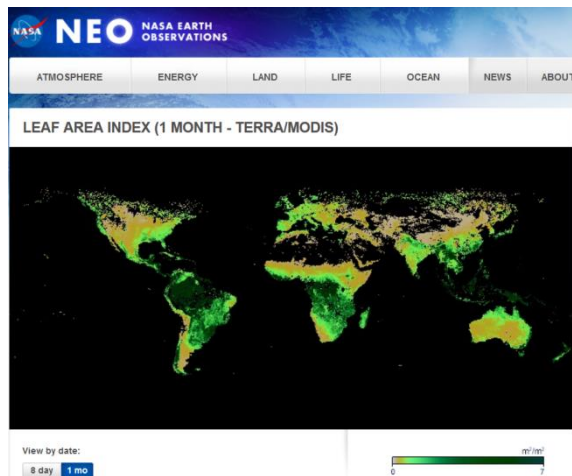
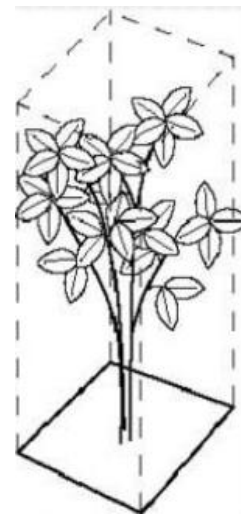
- **Absolute quantification** of the biomass and the nitrogen nutrition, via calculation of different indicators:
 - fCover - green cover fraction
 - FAPAR - fraction of absorbed photosynthetically active radiation
 - LAI - leaf area index
 - Chlorophyll content
- **Robust and independent** from observation conditions
- Complex processing algorithms



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Leaf Area Index

- The half the total developed area of green leaves per unit of ground horizontal surface area [units: $m^2 m^{-2}$]
- Determines the size of the interface for exchange of energy
- Indication of canopy density, biomass
- Can be used to predict productivity and crop growth

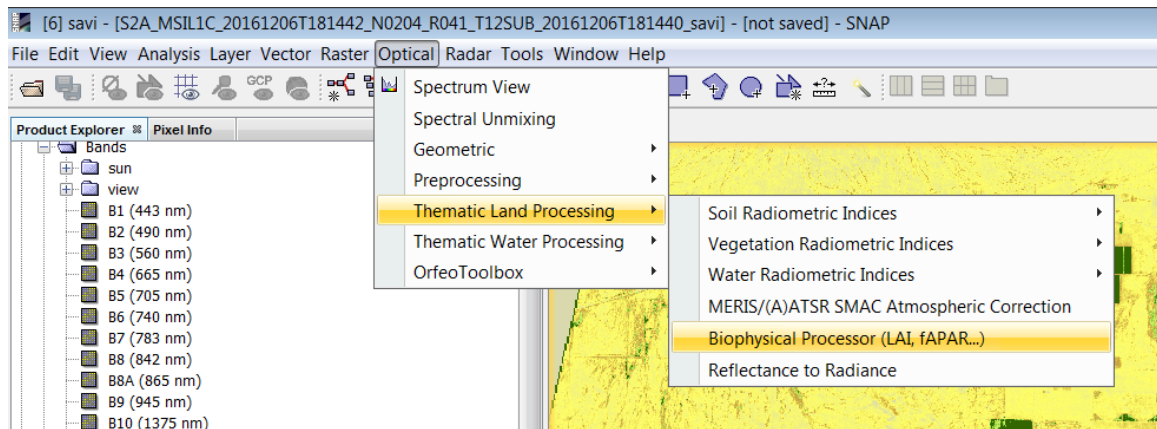




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Compute LAI in SNAP

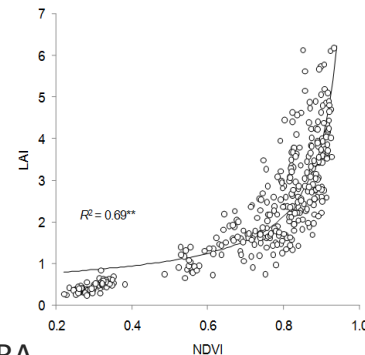
- **Biophysical processor**





Empirical methods

- Establishment of a statistical relationship between a vegetation index or the reflectance and a biophysical variables

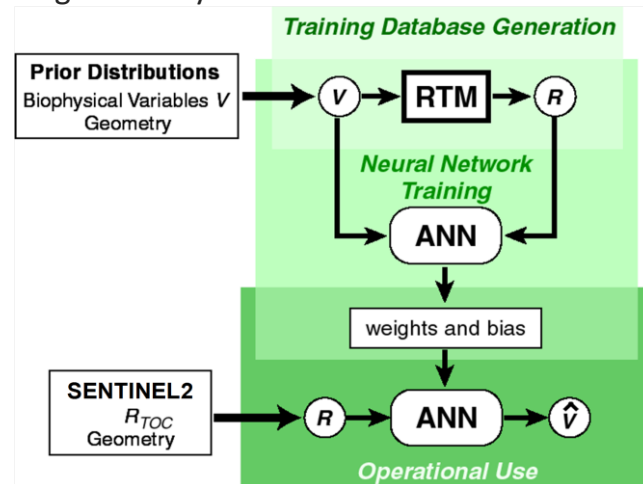


Physical methods

- By solving the radiative transfer equations
- Use of radiative transfer model:
 - PROSPECT: leaf model
 - SAIL: canopy model
 - PROSAIL: combination, simple, the most used

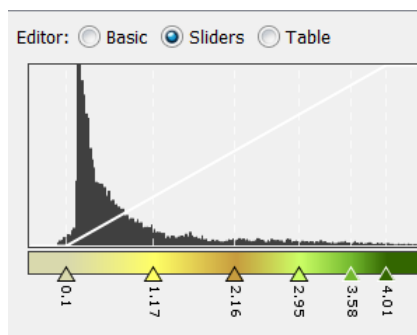
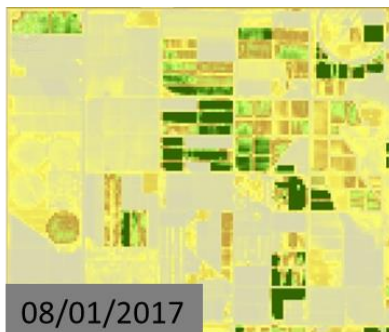
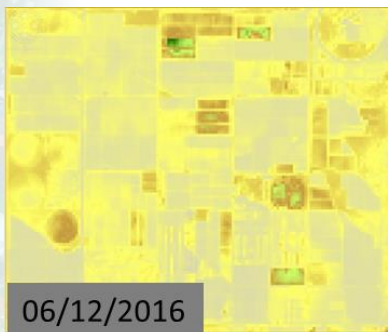
Hybrid methods

Algorithm by INRA





- Repeat processes to obtain the LAI with the other L2A available images.
- Is there an evolution in the crops?





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5. Automate Processing using GPT





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Graph Builder

The screenshot shows the SNAP Graph Builder window. The main workspace contains a workflow graph with five steps connected by red arrows: **Read** → **Resample** → **Subset** → **BiophysicalOp** → **Write**. Below the graph, there is a configuration panel for the selected step, which is **Read**. The configuration includes a menu bar with **Read**, **Write**, **Resample**, **Subset**, and **BiophysicalOp**. The **Source Product** section has a **Name:** dropdown menu with the value **S2A_MSIL1C_20171122T105341_N0206_R051_T31TCG_20171122T131313** and a **Data Format:** dropdown menu set to **Any Format**. At the bottom of the configuration panel are buttons for **Load**, **Save**, **Clear**, **Note**, **Help**, and **Run**. The background of the main window shows a satellite map of a river valley.



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Building a graph

- **Export to xml file**
- **Analyze the graph file**
- **Is it possible to reconfigure it and use it for automate processing?**



Graph Processing Tool (GPT)

- Execute operators via command-line
- Execute graphs (stored as XML files)

Usage:

```
gpt <op>|<graph-file> [options] [<source-file-1> <source-file-2> ...]
```

Description:

This tool is used to execute SNAP raster data operators in batch-mode. The operators can be used stand-alone or combined as a directed acyclic graph (DAG). Processing graphs are represented using XML. More info about processing graphs, the operator API, and the graph XML format can be found in the SNAP documentation.

Arguments:

<code><op></code>	Name of an operator. See below for the list of <code><op></code> s.
<code><graph-file></code>	Operator graph file (XML format).
<code><source-file-i></code>	The <code><i></code> th source product file. The actual number of source file arguments is specified by <code><op></code> . May be optional for operators which use the <code>-S</code> option.



Main option

- **-h** :Displays command usage. If <op> is given, the specific operator usage is displayed.
- **-t <file>** : The target file. Default value is 'target.dim'.
- **-S<source>=<file>** : Defines a source product. <source> is specified by the operator or the graph. In an XML graph, all occurrences of $\${<source>}$ will be replaced with references to a source product located at <file>.
- **-P<name>=<value>** : Defines a processing parameter, <name> is specific for the used operator or graph

First steps

Run: `gpt NdviOp -h`

Run NdviOp with the Sentinel-2 L2 product at 60 m



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G P T - D e m o

Modify the 'biophysical' graph file for accepting input parameters

Create an script for launching the script with different products

Integrate the downloading into the script