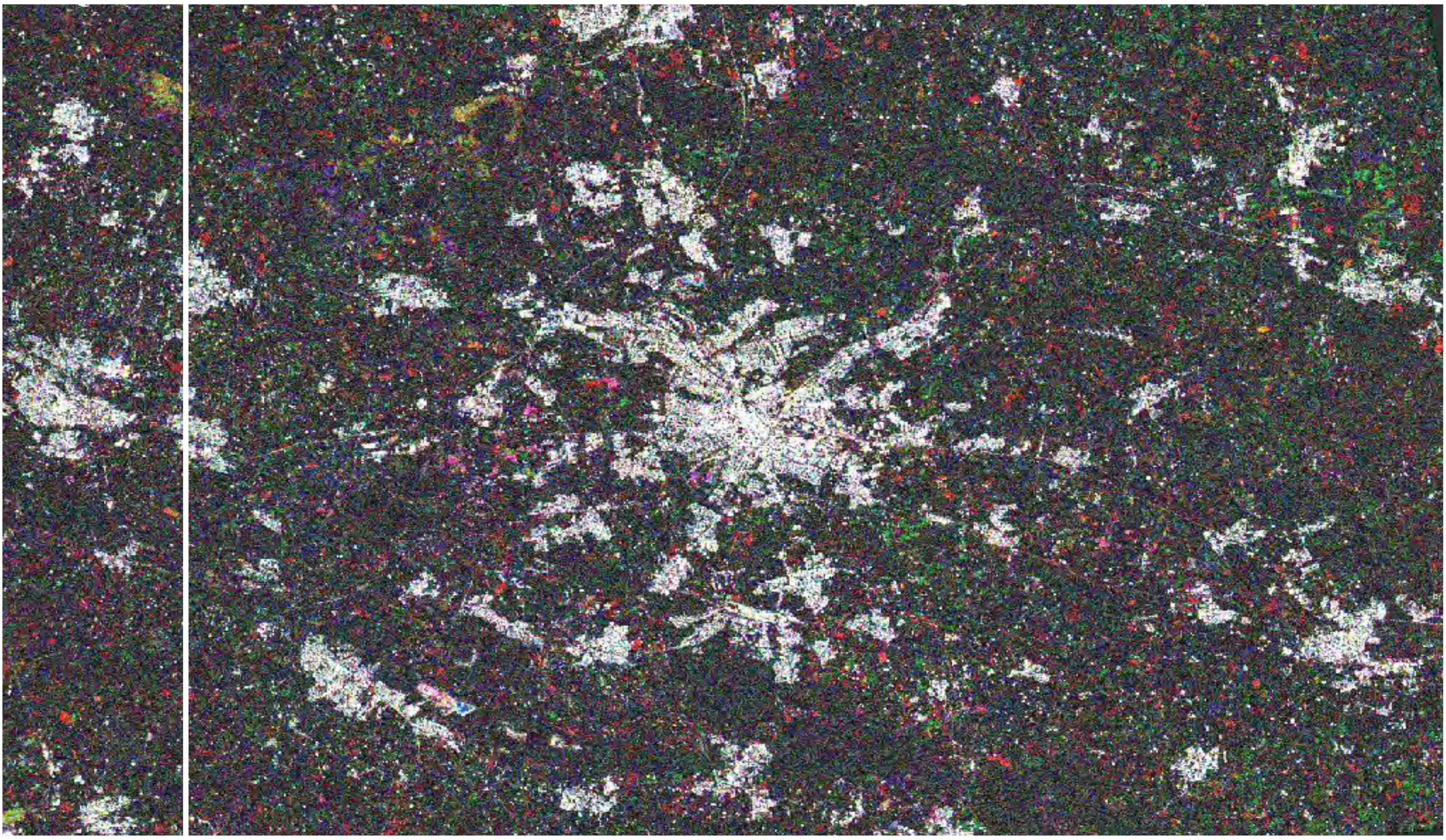

TRAINING KIT – LAND06

URBAN CLASSIFICATION WITH SENTINEL-1
Case Study: Germany, 2018

Research and User Support for Sentinel Core Products

The RUS Service is funded by the European Commission, managed by the European Space Agency and operated by CSSI and its partners.

Authors would be glad to receive your feedback or suggestions and to know how this material was used. Please, contact us on training@rus-copernicus.eu

Cover images produced by RUS Copernicus

The following training material has been prepared by Serco Italia S.p.A. within the RUS Copernicus project.

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Table of Contents

1 Introduction to RUS

The Research and User Support for Sentinel core products (RUS) service provides a free and open scalable platform in a powerful computing environment, hosting a suite of open source toolboxes pre-installed on virtual machines, to handle and process data derived from the Copernicus Sentinel satellites constellation.

In this tutorial, we will employ RUS to run a supervised classification using the Random Forest algorithm and Sentinel-1 SLC data as input data over an area in Bochum, Germany.

2 Urban mapping – background

As the world is facing a large increase in population, reliable information on urban areas is required to assist and help in the decision-making process. Different methods can be used to gather this information but satellite earth observation offers a suitable approach based on the coverage and type of data that are provided.

A few years ago, the European Union (EU) started an ambitious program, Copernicus, which includes the launch of a new family of earth observation satellites known as the Sentinels. Amongst other applications, this new generation of remote sensing satellites will improve the observation, identification, mapping, assessment, and monitoring of urban areas and their dynamics at a range of spatial and temporal resolutions.

3 Training

Approximate duration of this training session is one hour.

The Training Code for this tutorial is LAND06. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the RUS portal and open a User Service request from Your RUS service > Your dashboard.

3.1 Data used

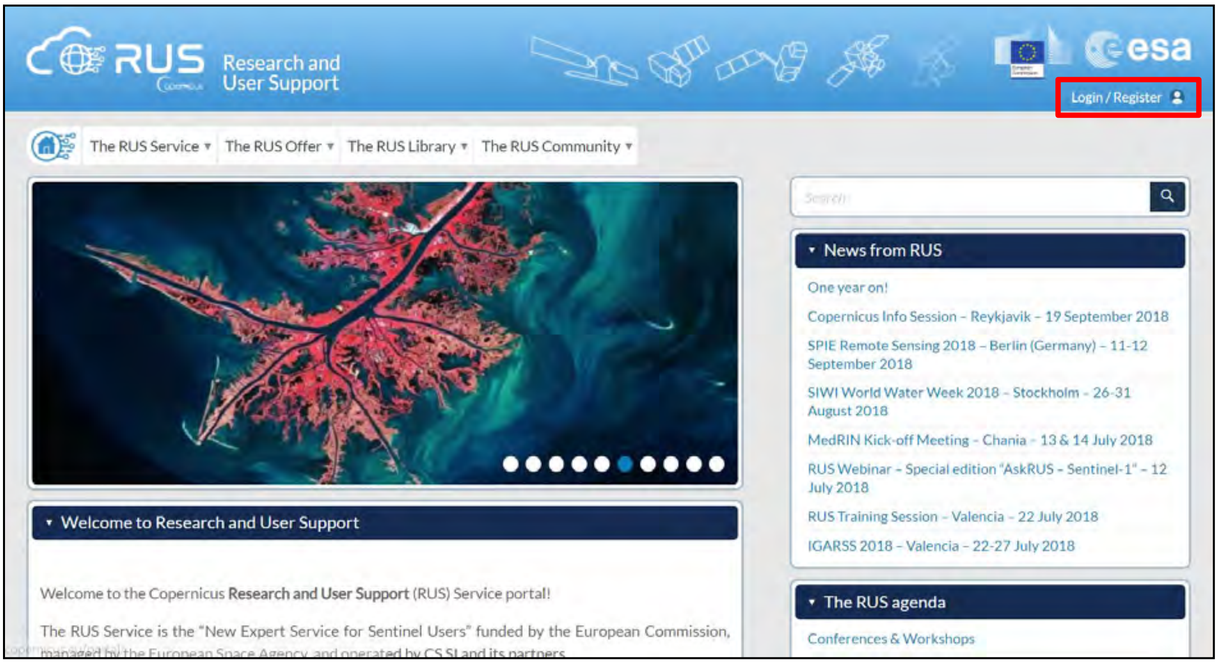
- 10 Sentinel-1A images acquired from April until July 2018 [downloadable at https://scihub.copernicus.eu/ using the .meta4 file provided in the Original folder of this exercise]
- Pre-processed data stored locally *@/shared/Training/LAND06_UrbanClassification_Germany/AuxData/*

3.2 Software in RUS environment

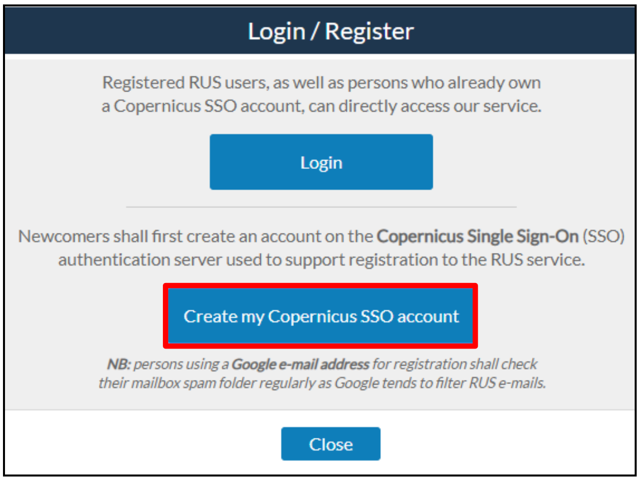
Internet browser, SNAP + S1 Toolbox

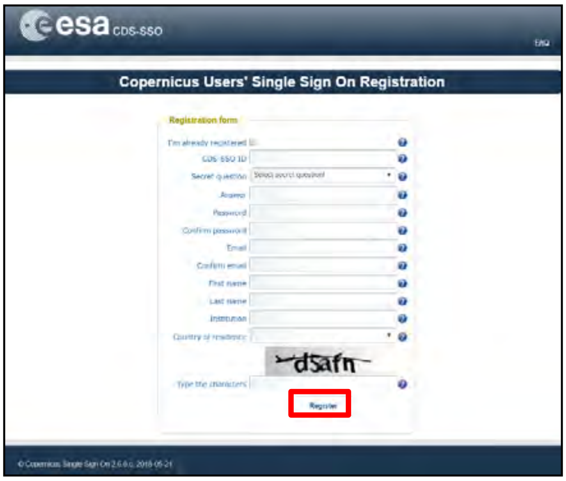
4 Register to RUS Copernicus

To repeat the exercise using a RUS Copernicus Virtual Machine (VM), you will first have to register as a RUS user. For that, go to the RUS Copernicus website (www.rus-copernicus.eu) and click on ***Login/Register*** in the upper right corner.



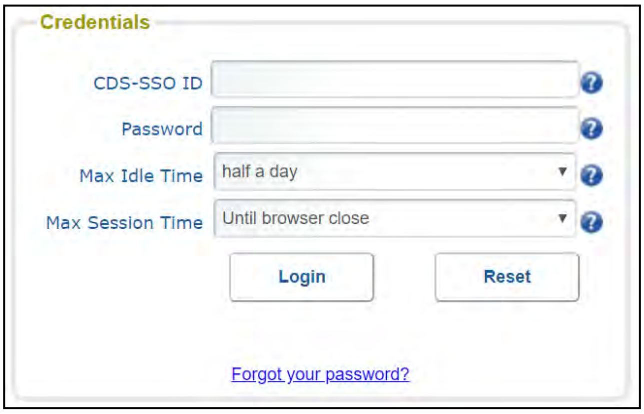
Select the option ***Create my Copernicus SSO account*** and then fill in ALL the fields on the **Copernicus Users' Single Sign On Registration**. Click ***Register***.



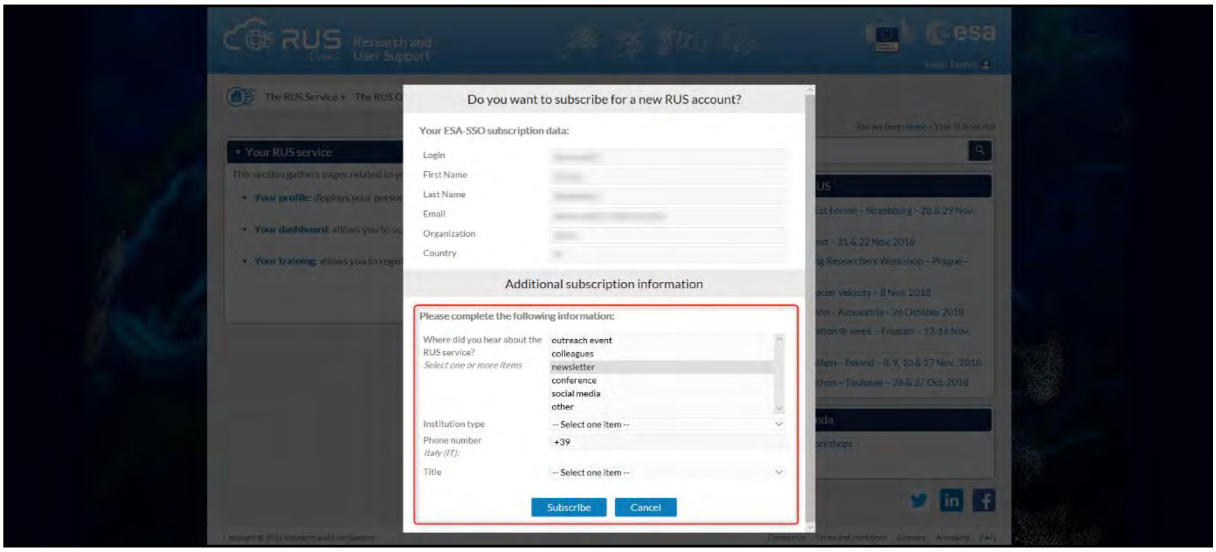


Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the e-mail to activate your account.

You can now return to https://rus-copernicus.eu/, click on ***Login/Register***, choose ***Login*** and enter your chosen credentials.

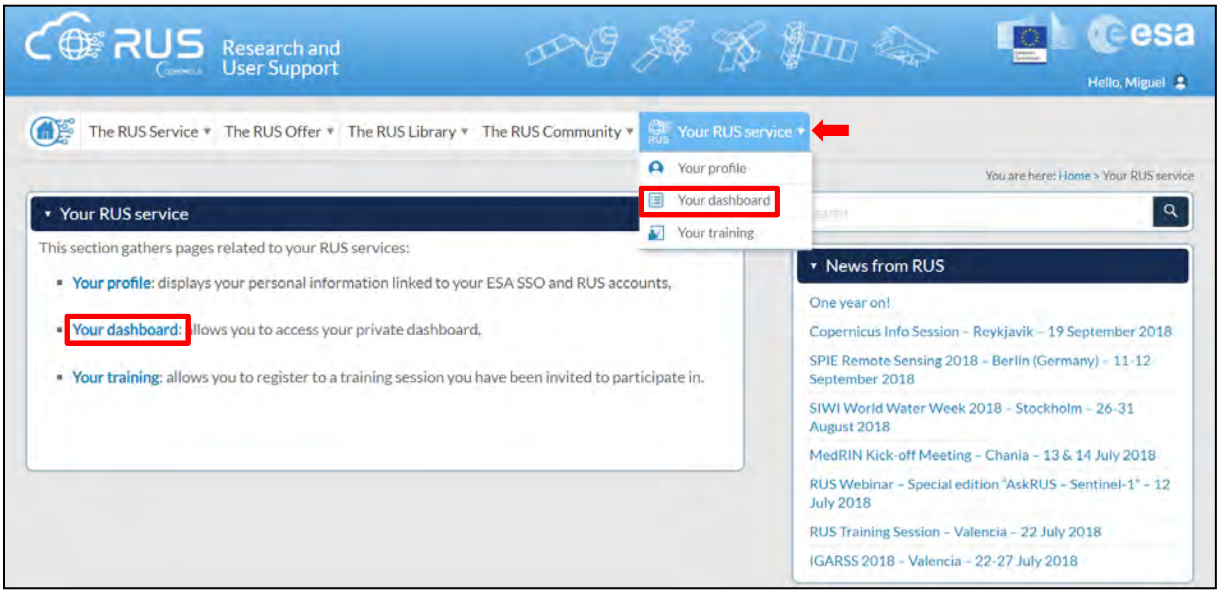


Upon your first login you will need to enter some details. You must fill all the fields.

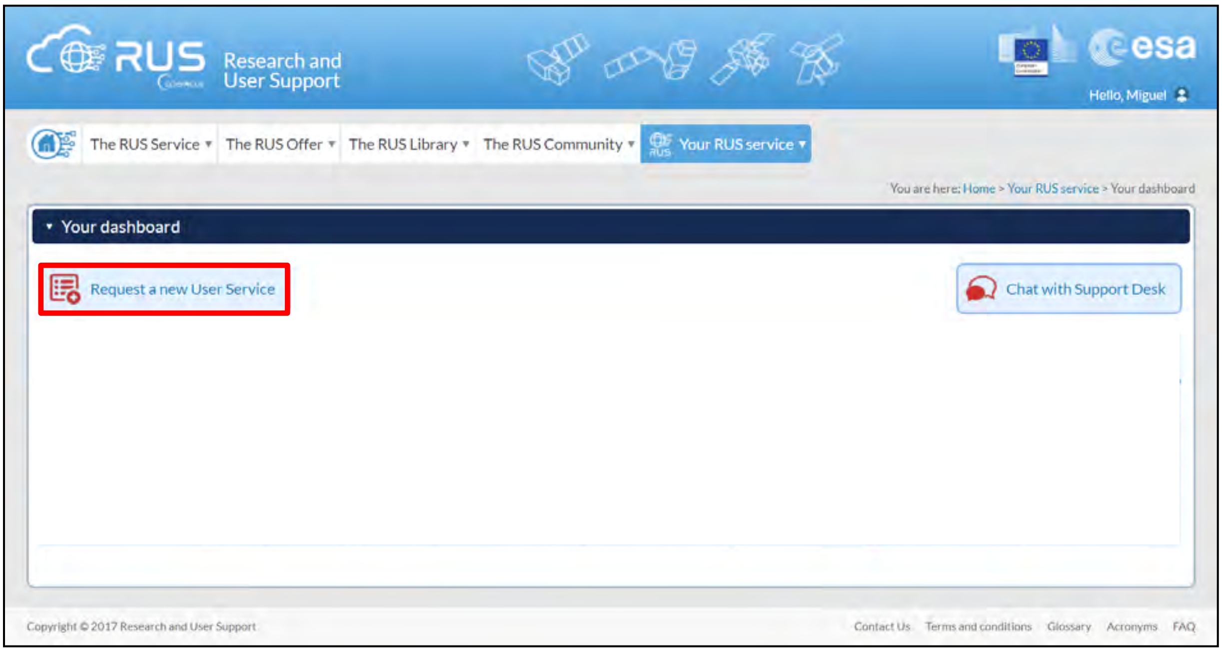


5 Request a RUS Copernicus Virtual Machine

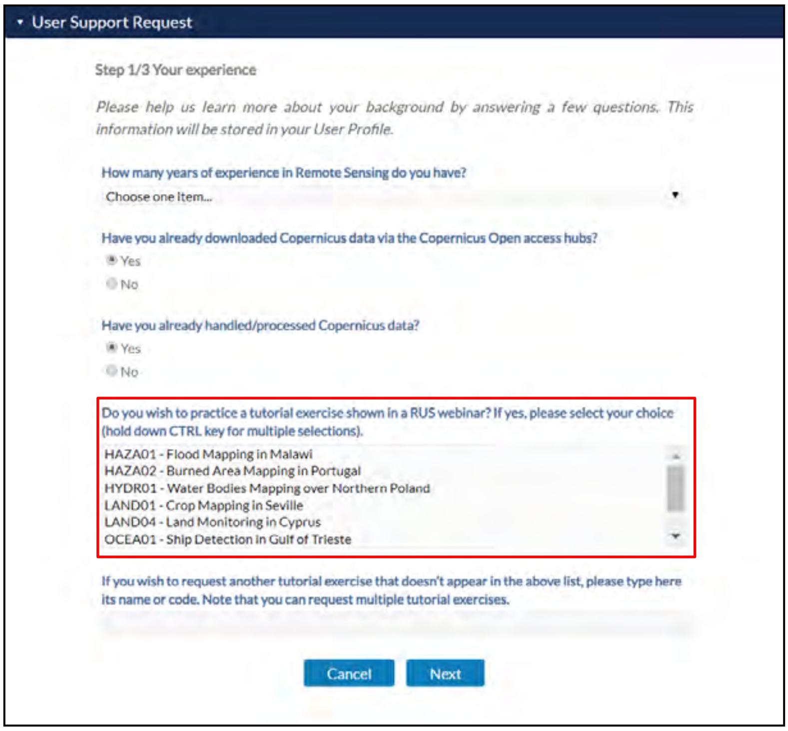
Once you are registered as a RUS user, you can request a RUS Virtual Machine to repeat this exercise or work on your own projects using Copernicus data. For that, log in and click on ***Your RUS Service → Your Dashboard***.



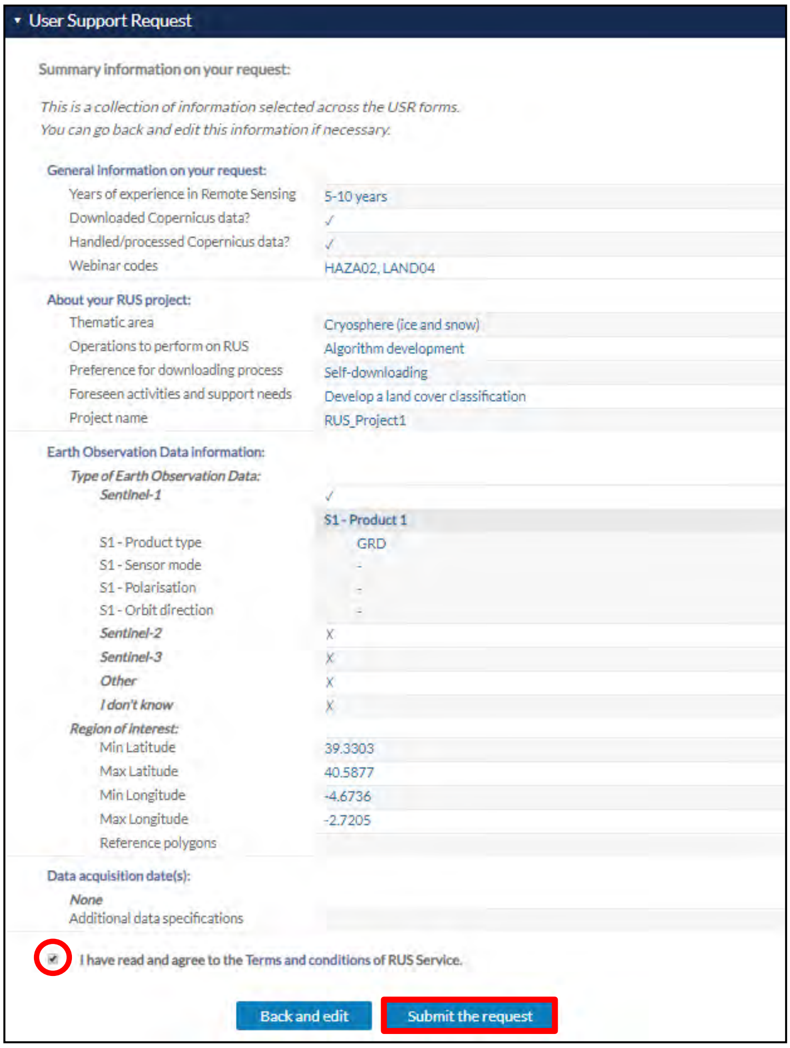
Click on ***Request a new User Service*** to request your RUS Virtual Machine. Complete the form so that the appropriate cloud environment can be assigned according to your needs.



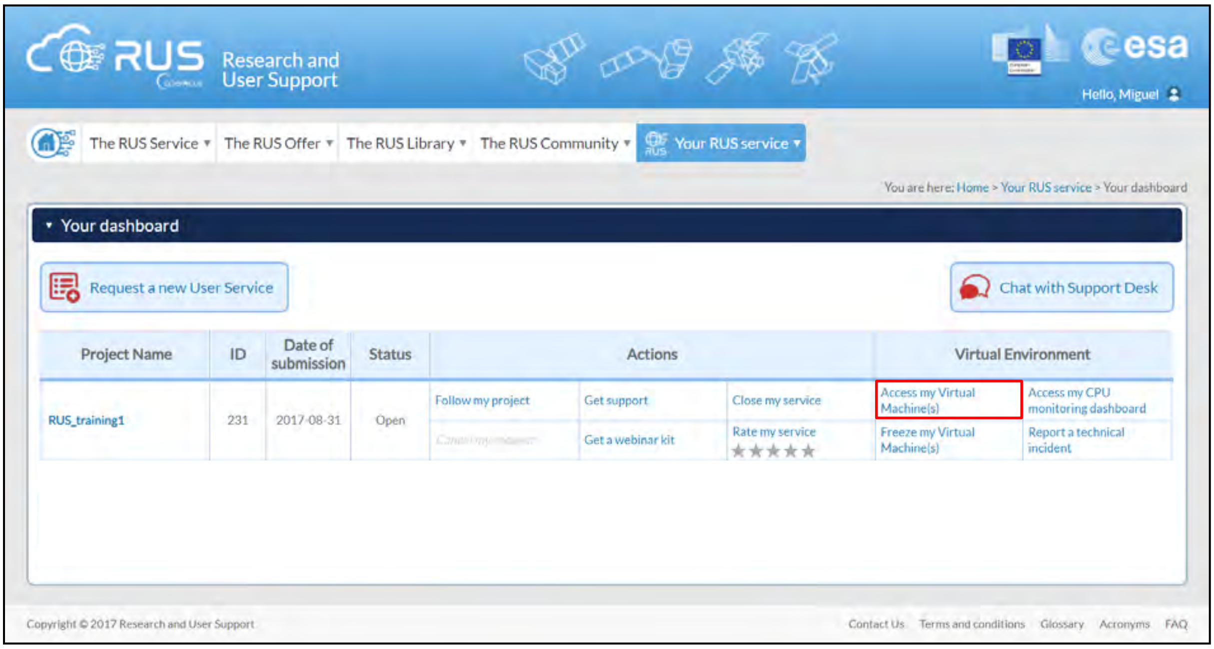
If you want to repeat this tutorial (or any previous one) select the one(s) of your interest in the appropriate field.



Complete the remaining steps, check the terms and conditions of the RUS Service and submit your request once you are finished.



Further to the acceptance of your request by the RUS Helpdesk, you will receive a notification email with all the details about your Virtual Machine. To access it, go to ***Your RUS Service → Your Dashboard*** and click on ***Access my Virtual Machine***.



Fill in the login credentials that have been provided to you by the RUS Helpdesk via email to access your RUS Copernicus Virtual Machine.

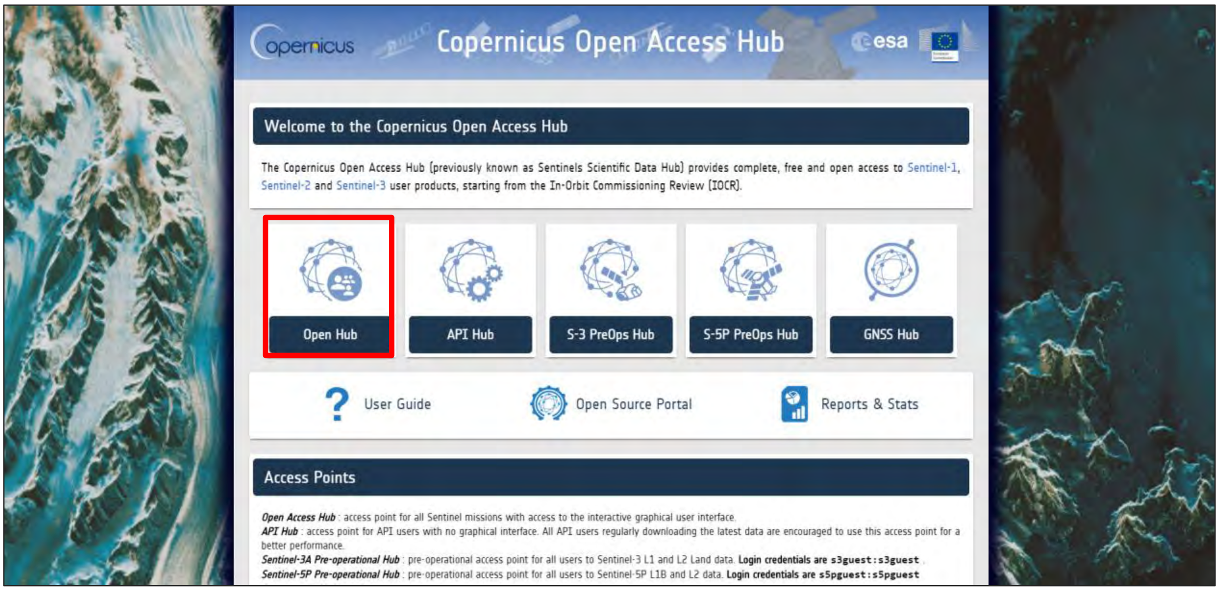
This is the remote desktop of your Virtual Machine.

6 Step by step

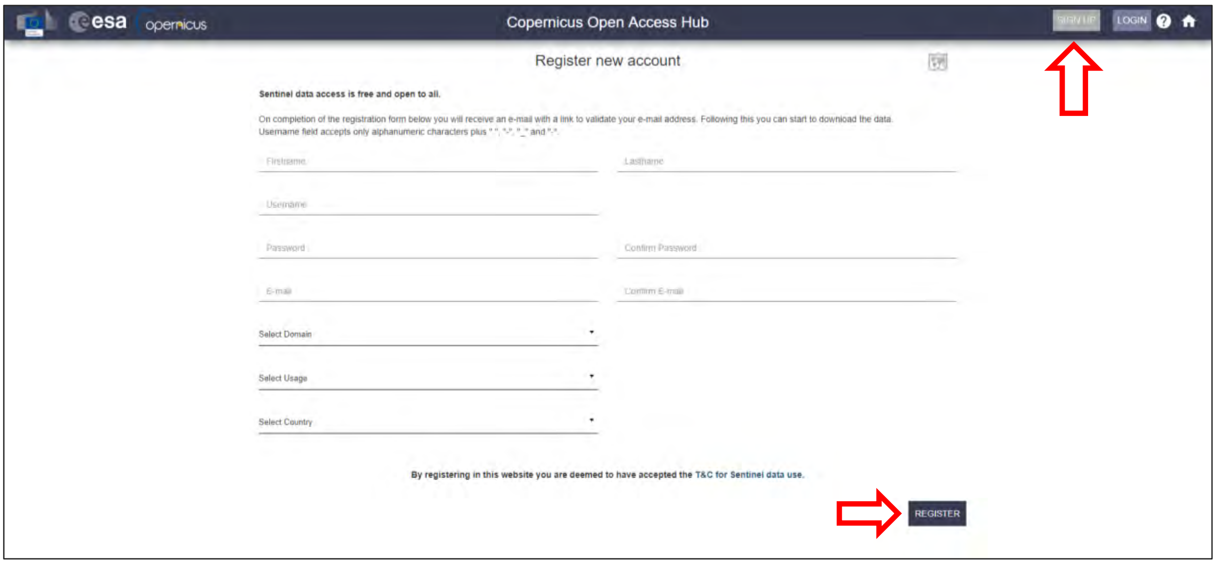
6.1 *Data download – ESA SciHUB*

Before starting the exercise, make sure you are registered in the Copernicus Open Access Hub so that you can access the free data provided by the Sentinel satellites.

Go to https://scihub.copernicus.eu/



Go to *Open Hub*. If you do not have an account, sign up in the upper right corner, fill in the details and click register.



You will receive a confirmation email on the e-mail address you have specified: open the email and click on the link to finalize the registration.

Once your account is activated – or if you already have an account – log in.

6.2 *Download data*

In this exercise, we will analyze 10 Sentinel-1A images during 2018. The following table shows the date and reference of the images that will be used:

SATELLITE	DATE	IMAGE ID
Sentinel-1A	2018-04-12	S1A_IW_SLC__1SDV_20180412T171648_20180412T171715_021437_024E95_BDA1
	2018-04-24	S1A_IW_SLC__1SDV_20180424T171648_20180424T171715_021612_02540A_BB21
	2018-05-06	S1A_IW_SLC__1SDV_20180506T171649_20180506T171716_021787_025996_98AB
	2018-05-18	S1A_IW_SLC__1SDV_20180518T171649_20180518T171716_021962_025F27_A15C
	2018-05-30	S1A_IW_SLC__1SDV_20180530T171650_20180530T171717_022137_0264C8_5D94
	2018-06-11	S1A_IW_SLC__1SDV_20180611T171651_20180611T171718_022312_026A3D_BBFC
	2018-06-23	S1A_IW_SLC__1SDV_20180623T171652_20180623T171719_022487_026F7C_450E
	2018-07-05	S1A_IW_SLC__1SDV_20180705T171652_20180705T171719_022662_027499_1B8F
	2018-07-17	S1A_IW_SLC__1SDV_20180717T171653_20180717T171720_022837_0279EC_5E5E
	2018-07-29	S1A_IW_SLC__1SDV_20180729T171654_20180729T171721_023012_027F72_97F6

To improve the data acquisition process, we will use a download manager (See NOTE 1) that will take care of downloading all products that will be used in this exercise. The metadata of the Sentinel products are contained in a *products.meta4* file created using the 'Cart' option of the Copernicus Open Access Hub.

> NOTE 1: A download manager is a computer program dedicated to the task of downloading possibly unrelated stand-alone files from (and sometimes to) the Internet for storage. For this exercise, we will use aria2. Aria2 is a lightweight multi-protocol & multi-source command-line download utility. More info at: https://aria2.github.io/

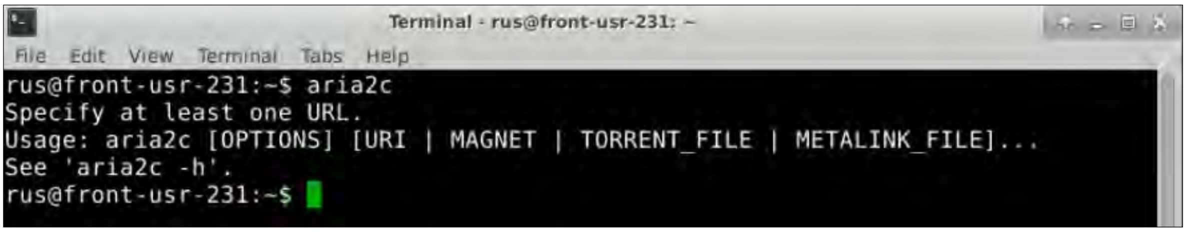
The *products.meta4* file containing the links to the Sentinel-1 products to be downloaded can be created following the methodology explained in NOTE 2. Follow the instructions and create your cart file, download it and save it in the following path:

Path: */shared/Training/LAND06_UrbanClassification_Germany/Original/*

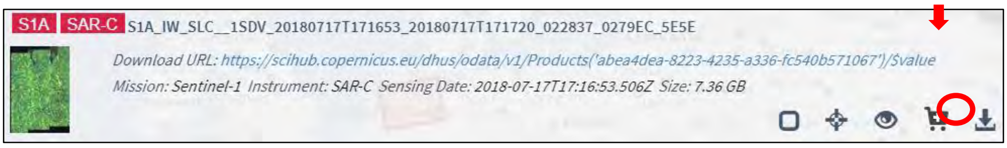
Before using the downloading manager and the .meta4 file, let's test if *aria2* is properly installed in the Virtual Machine. To do this, open the Command Line (in the bottom of your desktop window) and type the following and press *Enter:*

```
aria2c
```

If *aria2* is properly installed, the response should be as follows. If the response is *'-bash aria2c: command not found'* it means *aria2* is not installed (See NOTE 3).



NOTE 2: The Copernicus Open Access Hub allows you to add products to a 'Cart'. For that, perform a query; select the desired products from the result list and click on the 'Add Product to Cart' icon - . To find the appropriate images, copy-paste the image ID specified in the table (pg. 11) in the search box of the Copernicus Open Access Hub.



To view the products present in the cart just click anytime on the User Profile icon on top right corner of the screen and then on "Cart". To download the cart click on "Download Cart" on the bottom right of the page. A download window will pop up, asking the user confirmation to save a .meta4 file named *'products.meta4'*. This file contains all the metalinks of the products.

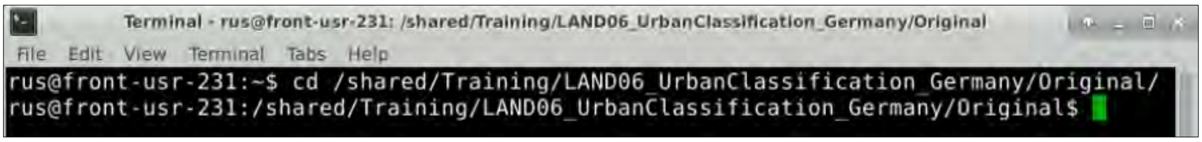
NOTE 3: If **(and only if)** the response is *'-bash aria2c: command not found'*, you need to install aria2. In the command line, type: *sudo apt-get install aria2*

When requested, type: Y

Once finished, test the installation as explanied before.

Once *aria2* is ready to use, we can start the download process. For that, we need to navigate to the folder where the *products.meta4* is stored. Type the following command in the terminal and run it.

```
cd /shared/Training/LAND06_UrbanClassification_Germany/Original/
```



Next, type the following command (in a single line) to run the download tool. Replace *username* and *password* (keep the quotation marks) with your login credentials for Copernicus Open Access Hub (COAH). Do not clear your cart in the COAH until the download process is finished.

```
aria2c --http-user='username' --http-passwd='password' --check-certificate=
false --max-concurrent-downloads=2 -M products.meta4
```

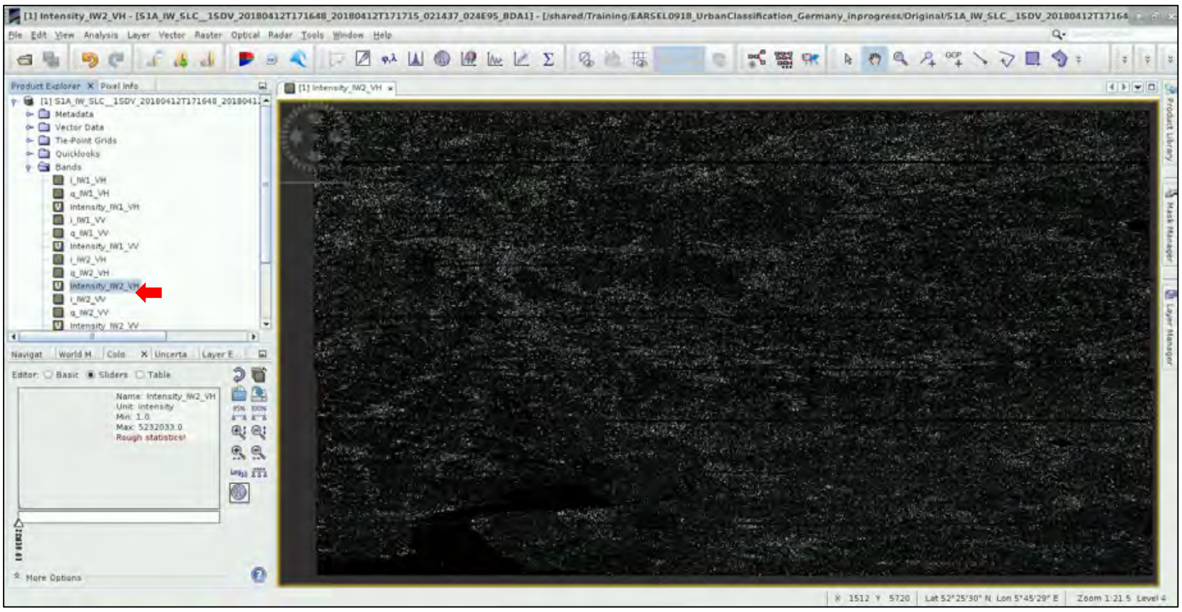
The Sentinel products will be saved in the same path where the *products.meta4* is stored.

6.3 Sentinel-1 SNAP Preprocessing

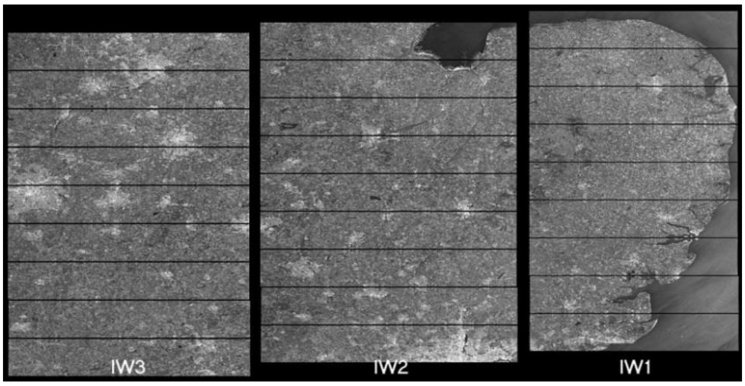
Once the Sentinel-1 images are downloaded, we need to run some pre-processing steps before they can be used for the classification. For this purpose, we will use the SNAP software. In *Applications -> Processing* open **SNAP Desktop**; click **Open product**, navigate to the following path and open the two first S1 images (2018-04-12 and 2018-04-24)

Path: */shared/Training/LAND06_UrbanClassification_Germany/Original/*

The opened product will appear in Product Explorer. Click + to expand the contents of the first image, then expand the *Bands* folder and click on *Intensity_IW2_VH* to visualize it. (See NOTE 4).



NOTE 4: The Interferometric Wide (IW) swath mode captures three sub-swaths using Terrain Observation with Progressive Scans SAR (TOPSAR). Each sub-swath image consists of a series of bursts. The input product contains 3 IW bands, and 8 bursts. Mexico City is located on the IW3 sub-swath of the



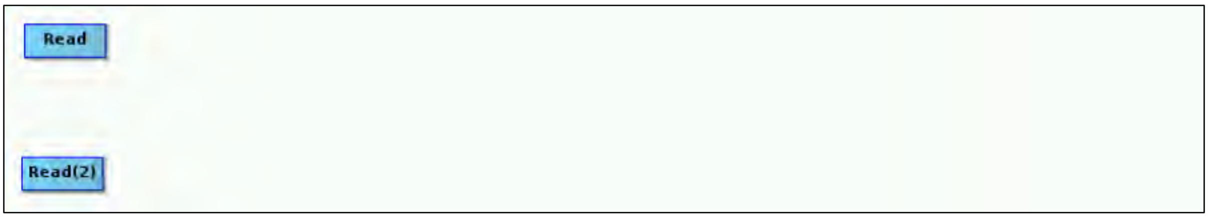
Credits: ESA User Guides for Sentinel-1 SAR

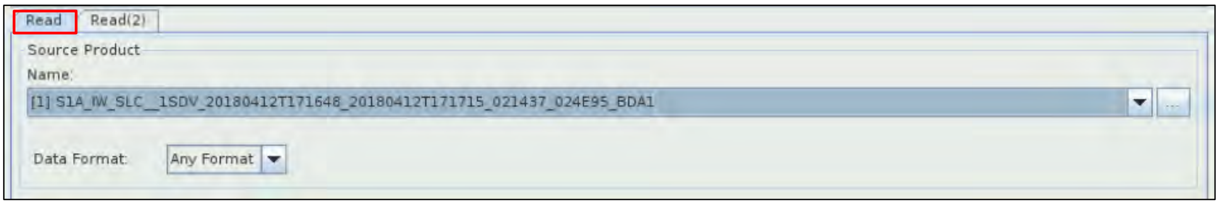
In order to process this and the other Sentinel-1 images, we will take advantage of the batch processing option available in SNAP. In this way, we can define a specific processing chain and apply it to several images in an automatic way. This allows reducing processing time and storage requirement since no intermediate steps are created. Only the final product is physically saved.

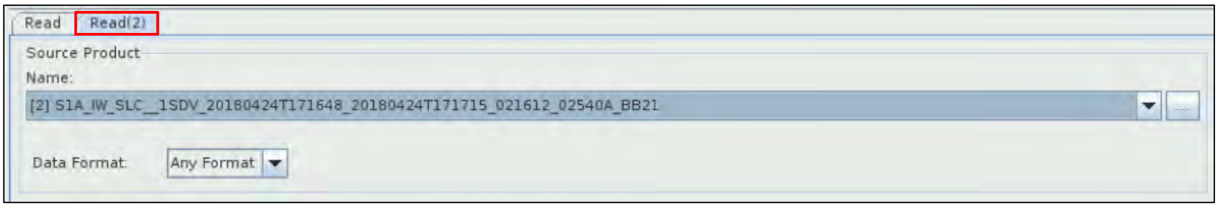
Before running batch processing, it is necessary to create a graph containing all the processing steps. Go to *Tools -> Graph Builder.* So far, the graph only has two operators: Read (to read the input) and Write (to write the output). By right-clicking on the white space at the top panel, you can add an operator while a corresponding tab is created and added at the bottom panel. To avoid confusion, delete the *Write* operator.

6.3.1 Read

In this analysis, we will derive coherence using as input two independent Sentinel-1A products. Due to this, we need to add a second *Read* operator. For that, right click and go to *Add -> Input-Output -> Read.*). The corresponding tabs are created and added on the bottom panel. In the first *Read* tab set the first image ([1] – 2018-04-12) as input. In the second *Read(2)* tab, set the second image ([2] – 2018-04-24) as input.



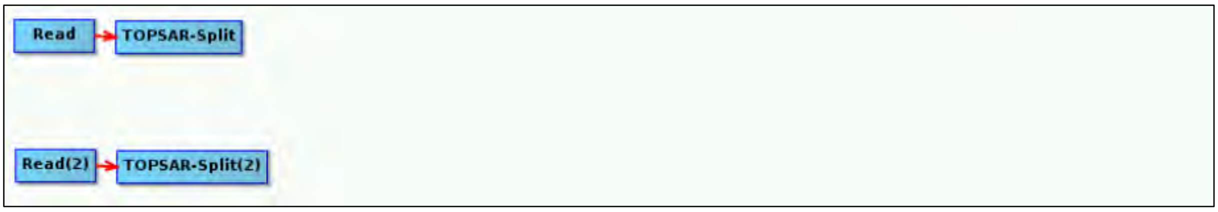




6.3.2 TOPSAR-Split

Since the area of interest is included in 2 bursts of the Sentinel-1 image, there is no need to process the whole sub-swath with the 8 bursts (See NOTE 5). The extraction of Sentinel-1 TOPSAR bursts will be made per acquisition and per sub-swath. This process will reduce the processing time in the following processing steps and it is recommended when the analysis is focused only over a specific area. To add the TOPSAR-Split operators, right click and go to *Add -> Radar -> Sentinel-1 TOPS -> TOPSAR-Split.* Connect the operators as shown below by clicking to the right side of the **Read** operator and dragging the red arrow towards the TOPSAR-Split operator.

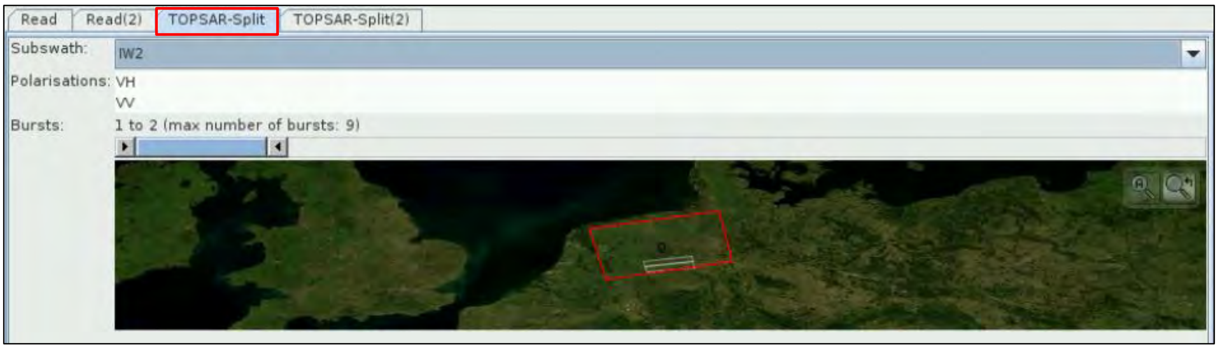
NOTE 5: The extraction of bursts in a sub-swath covering the area of interest may differ in Sentinel-1 images acquired on different dates.

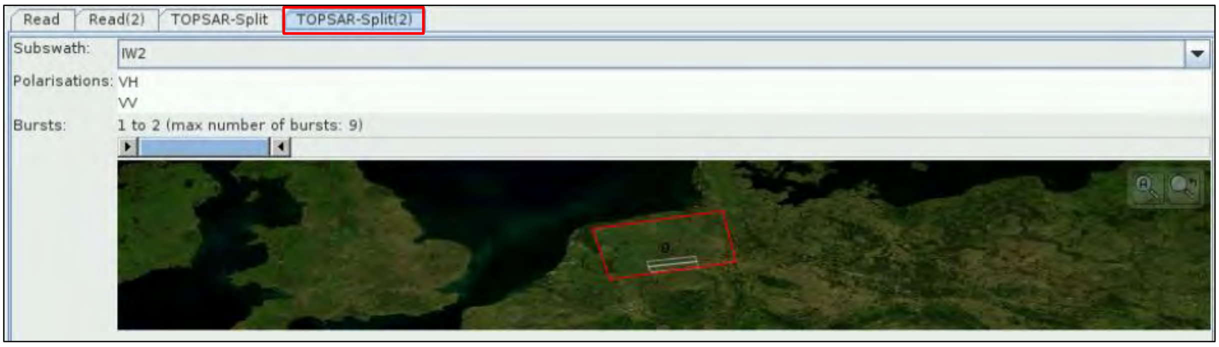


In the *TOPSAR-Split* tabs, make sure to select the following parameters:

- Subswath: **IW2**
- Bursts: **1 to 2** (To do so, click on and drag it to the left until you reach *Burst 2)*

Do not click on any polarization. By default both are selected.

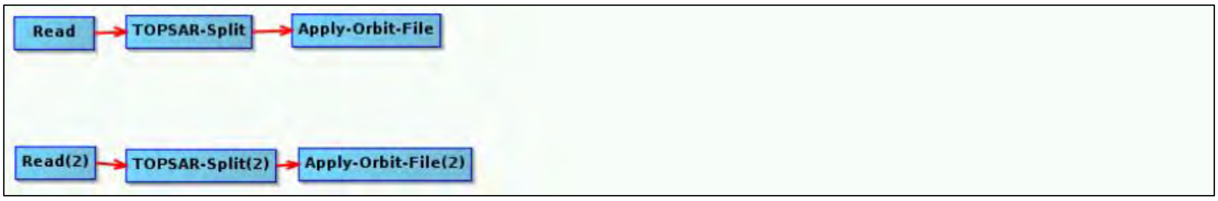




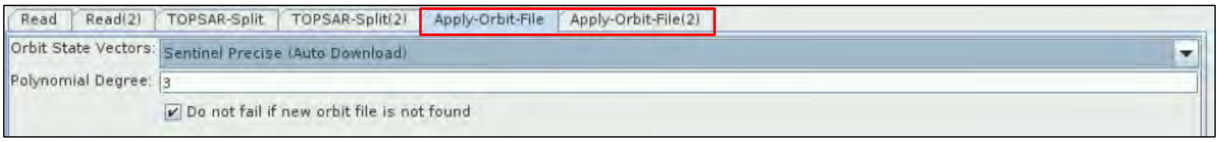
6.3.3 Apply Orbit File

Next, we will update the orbit metadata (See NOTE 6) of the product to provide accurate satellite position and velocity information. To add the operators to our graph, right click and go to *Add -> Radar -> Apply-Orbit-File*. Connect the *Apply-Orbit-File* operators as shown below.

NOTE 6: The orbit state vectors provided in the metadata of a SAR product are generally not accurate and can be refined with the precise orbit files, which are available days-to-weeks after the generation of the product. The orbit file provides accurate satellite position and velocity information. Based on this information, the orbit state vectors in the abstract metadata of the product are updated. (*SNAP Help*)

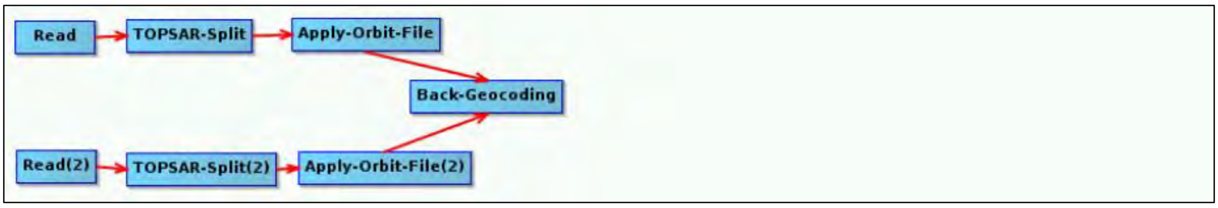


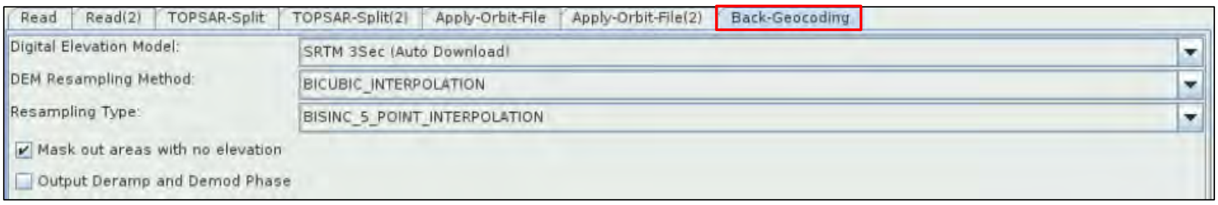
In the corresponding tabs, keep the default settings and click the option *Do not fail if new orbit file is not found.*



6.3.4 Back Geocoding

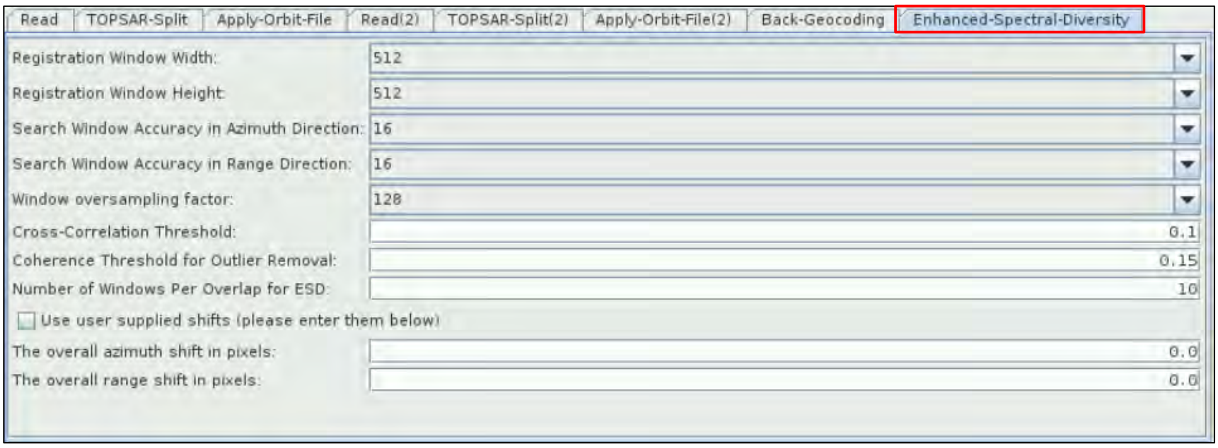
Now we will co-registers the two S-1 SLC split products (master and slave) of the same sub-swath using the orbits of the two products and a Digital Elevation Model (DEM). To add the operator, go to *Add-> Radar -> Corregistration -> S1 TOPS Corregistration -> Back-Geocoding.* Set the two *Apply Orbit File* operators as input. In the corresponding parameters tab, leave the default values.





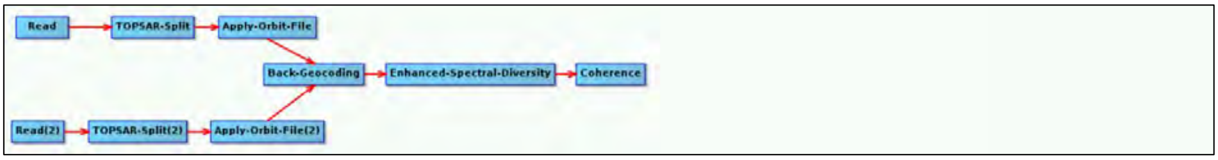
6.3.5 Enhanced Spectral Diversity

This operator first estimates a constant range offset for the whole sub-swath of the split S-1 SLC image using incoherent cross-correlation. Then, estimates a constant azimuth offset for the whole sub-swath using an Enhanced Spectral Diversity (ESD) method. Finally, it performs range and azimuth corrections for every burst using the range and azimuth offsets previously estimated. Right click and go to *Radar -> Coregistration -> S-1 TOPS coregistration -> Enhanced-Spectral-Diversity.* Connect the *Back-Geocoding* operator as shown below and leave all the parameters as default in the *Enhanced-Spectral-Diversity* tab.



6.3.6 Coherence

Next, we will add the operator to derive the coherence image (See NOTE 7). Right click and go to *Add -> Radar -> Interferometric -> Products -> Coherence.* Connect the *Coherence* operator as shown below, select the option *Subtract flat-earth phase* and change the *Square pixel* parameter to 20.

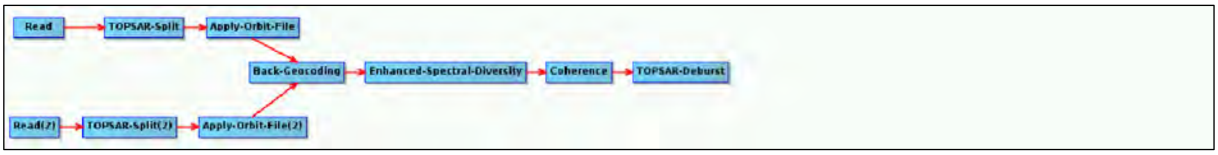


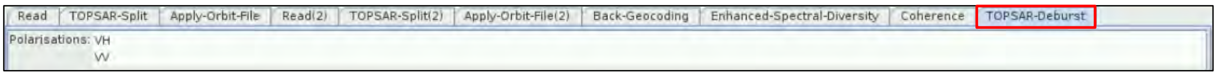
NOTE 7: Coherence is the fixed relationship between waves in a beam of electromagnetic (EM) radiation. Two wave trains of EM radiation are coherent when they are in phase. That is, they vibrate in unison. In terms of the application to things like RADAR, the term coherence is also used to describe systems that preserve the phase of the received signal.

6.3.7 TOPSAR Deburst

We continue the processing steps with Sentinel-1 TOPSAR Deburst. We have seen that each sub-swath image consists of a series of bursts, where each burst has been processed as a separate SLC image. The individually focused complex burst images are included, in azimuth-time order, into a single sub-swath image with black-fill demarcation in between. There is sufficient overlap between adjacent bursts and between sub-swaths to ensure the continuous coverage of the ground. The images for all bursts in all sub-swaths are resampled to a common pixel spacing grid in range and azimuth while preserving the phase information.

To add the TOPSAR-Deburst operator, go to *Add -> Radar -> Sentinel-1 TOPS -> TOPSAR-Deburst*. In the TOPSAR-Deburst tab, select Polarizations: VV. Connect the *Coherence* operator as shown below and keep all the parameters as default.



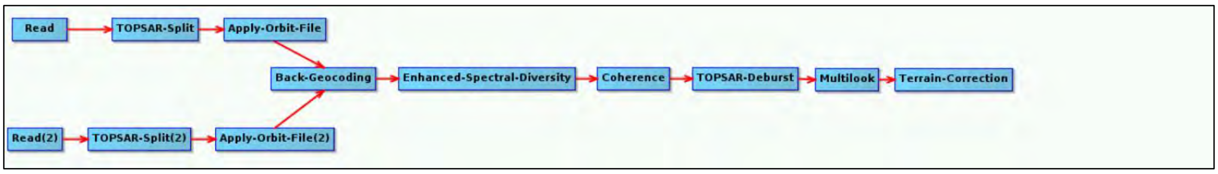


6.3.8 Multi-look

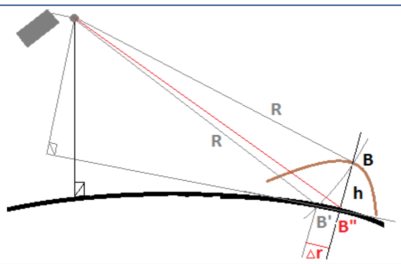
As the original SAR image contains inherent speckle noise, multilook processing is applied at this moment to reduce the speckle appearance and to improve the image interpretability. To add the Multilook operator go to *Add -> Radar -> Multilook*. Connect it to the *TOPSAR-Deburst* operator and keep the default parameters.

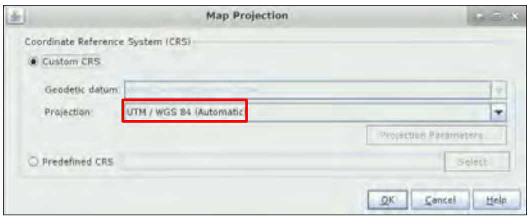
6.3.9 Terrain correction

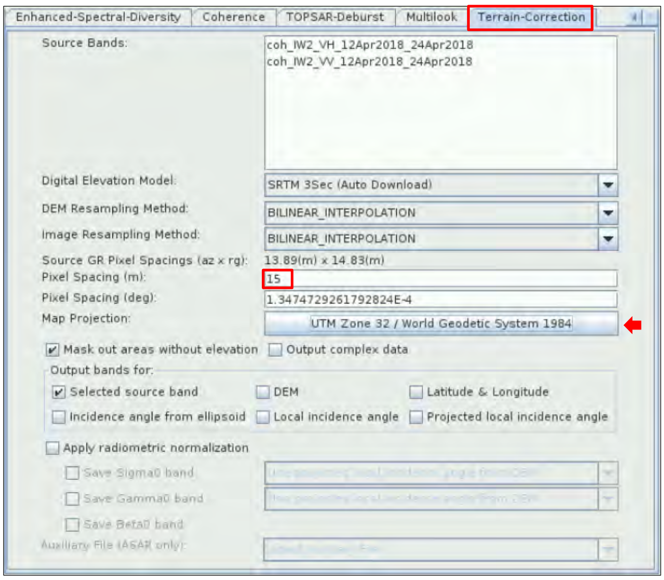
Our data are still in radar geometry, moreover due to topographical variations of a scene and the tilt of the satellite sensor, the distances can be distorted in the SAR images. Therefore, we will apply terrain correction to compensate for the distortions and reproject the scene to geographic projection (See NOTE 8). To add the operator to our graph, right click and go to *Add -> Radar -> Geometric -> Terrain Correction -> Terrain-Correction*. Connect it to the *Multilook* operator, change the pixel spacing to 15 at the corresponding tab and make sure you select *UTM / WGS 84 (Automatic)* as Map Projection.



NOTE 8: The geometry of topographical distortions in SAR imagery is shown on the right. Here we can see that point **B** with elevation **h** above the ellipsoid is imaged at position **B'** in SAR image, though its real position is **B"**. The offset **Δr** between **B'** and **B"** exhibits the effect of topographic distortions. *(SNAP Help)*

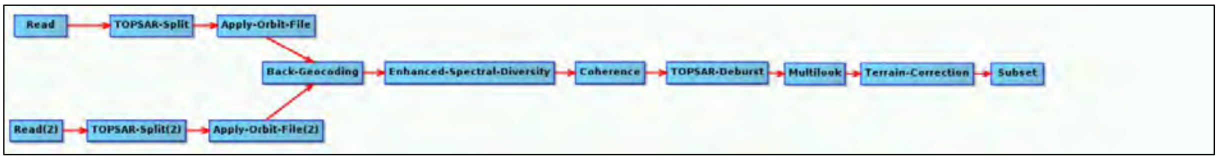




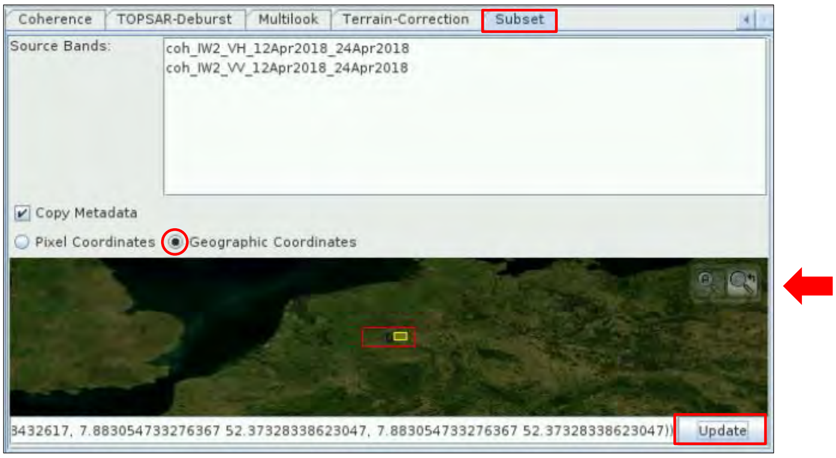


6.3.10 Subset

Next, we need to reduce the spatial extent to focus on our study area. For that, add the *Subset* operator. Right-click and go to *Add -> Raster -> Geometric -> Subset.* Connect it to the *Terrain-Correction* operator. Select the option *Geographic Coordinates* and copy/paste the following coordinates in Well-Known-Text format. Click *Update* to load them and Zoom in to the area.




```
POLYGON ((7.883054797352848 52.37328212685329, 8.210910785692109 52.37592581845208,
   8.214610329430705 52.1670955892227, 7.888290792013983 52.16447160649477,
   7.883054797352848 52.37328212685329))
```



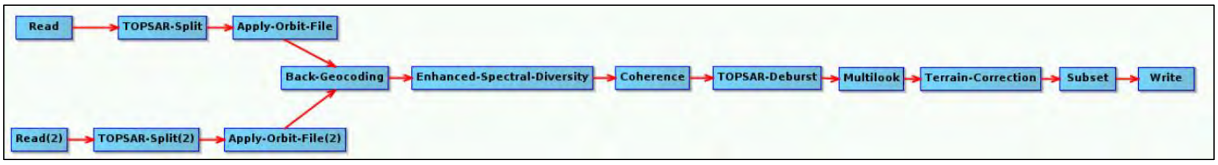
Zoom in

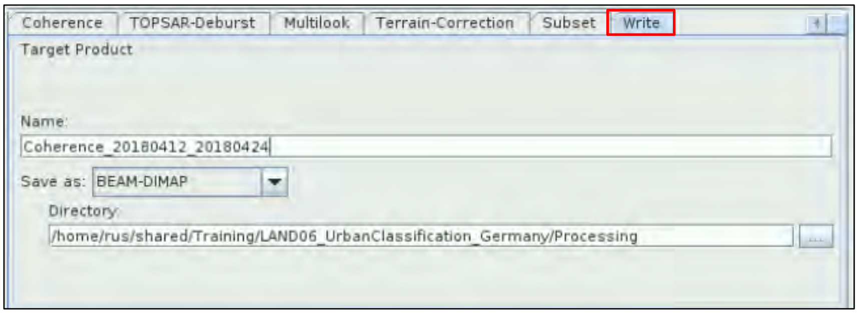
6.3.11 Write

Finally, we need to properly save the output. For that, we first need to add the W*rite* operator to our graph. Right click and go to *Add -> Input-Output -> Write*. Connect the *Write* operator to the *Subset* operator. In the *Write* tab, make sure you set the following name and directory.

Name: *Coherence_20180412_20180424*

Path: */shared/Training/LAND06_UrbanClassification_Germany/Processing/*





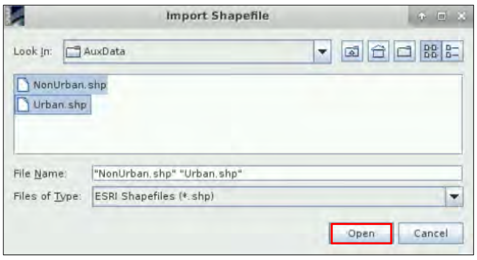
Once finished, click on the *Save* icon. Navigate to the following path and save the graph as ***1_S1_Splt_Orb_Cor_Coh_Deb_ML_TC.xml***. Then, click *Run* to start the processing. It can take some time depending on your VM specifications (3 hours approx. in a 16GB RAM and 4 cores VM).

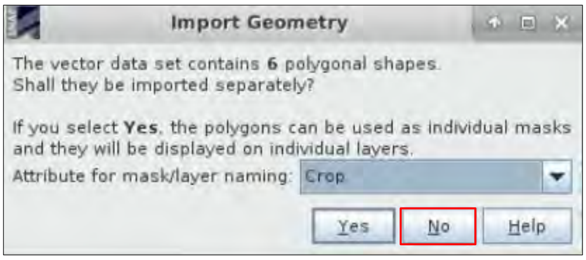
Path: */shared/Training/LAND06_UrbanClassification_Germany/AuxData/*

6.4 Import vector data

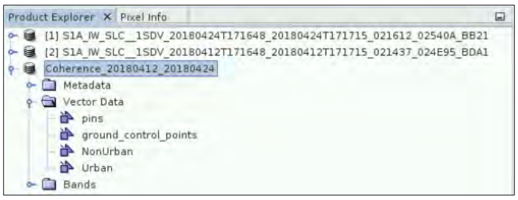
To prepare the data for the classification, the shapefile of the training areas has to be imported. Select the *Coherence_20180412_20180424* product in the product explorer and go to *Vector -> Import -> ESRI Shapefile*. Navigate to the following path and click *Open* after selecting all the files. Click *No* in the import geometry dialog.

Path: */shared/Training/LAND06_UrbanClassification_Germany/AuxData/*



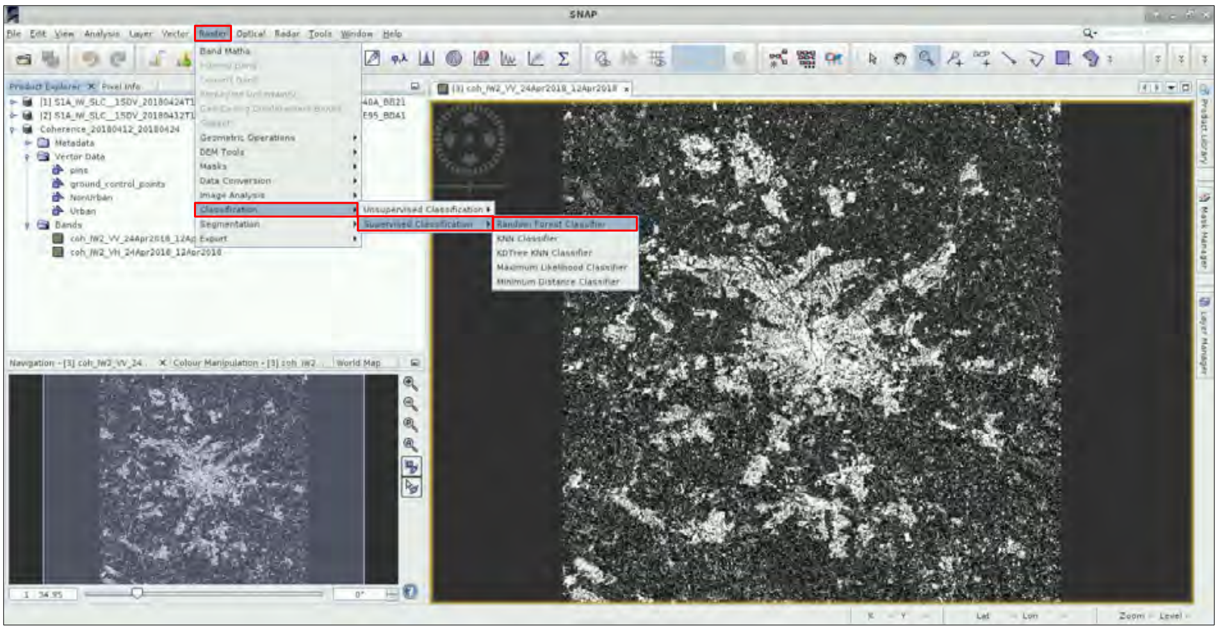


Once the vector data have been imported, do not forget to save the changes. **Right click** on the subset product (index [3]) and click on **Save Product.** The vector data folder of the subset product should look like the following image. Expand the product and open the Vector Data folder to check it.

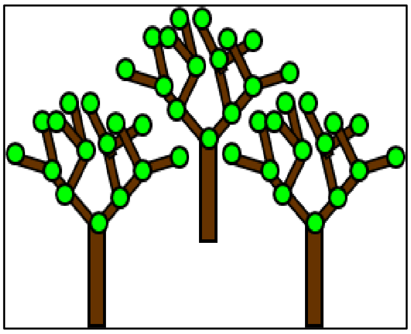


6.5 Random Forest Classification

For this exercise, the Random Forest classification algorithm will be used (See NOTE 9).



Click on *Raster -> Classification -> Supervised Classification -> Random Forest Classifier*



NOTE 9: The Random Forest algorithm is a machine learning technique that can be used for classification or regression. In opposition to parametric classifiers (e.g. Maximum Likelihood), a machine learning approach does not start with a data model but instead learns the relationship between the training and the response dataset. The Random Forest classifier is an aggregated model, which means it uses the output from different models (trees) to calculate the response variable.

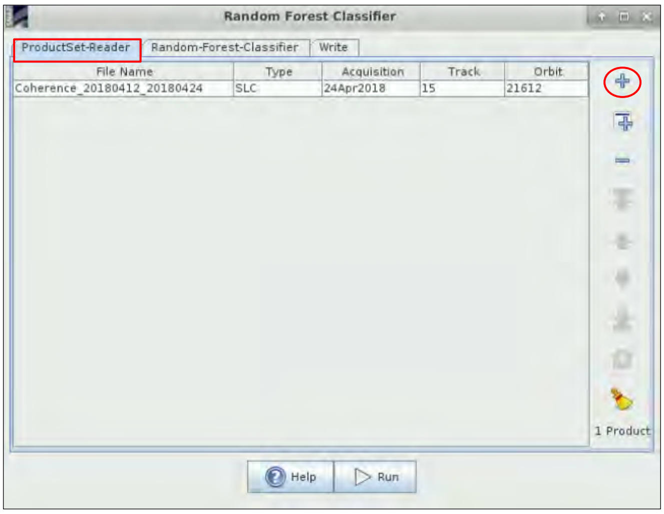
Decision trees are predictive models that recursively split a dataset into regions by using a set of binary rules to calculate a target value for classification or regression purposes. Given a training set with *n* number of samples and *m* number of variables, a random subset of samples *n* is selected with replacement (bagging approach) and used to construct a tree. At each node of the tree, a random selection of variables *m* is used and, out of these variables, only the one providing the best split is used to create two sub-nodes.

By combining trees, the forest is created. Each pixel of a satellite image is classified by all the trees of the forest, producing as many classifications as number of trees. Each tree votes for a class membership and then, the class with the maximum number of votes is selected as the final class.

More information about Random Forest can be found in Breiman, 2001.

In the *ProductSet*-Reader tab, click on the symbol. Navigate to the following path and select the coherence image as input (*Coherence_20180412_20180424).*

Path: */shared/Training/LAND06_UrbanClassification_Germany/Processing/*

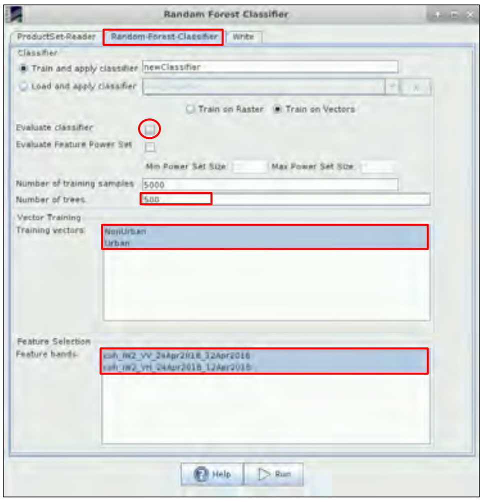


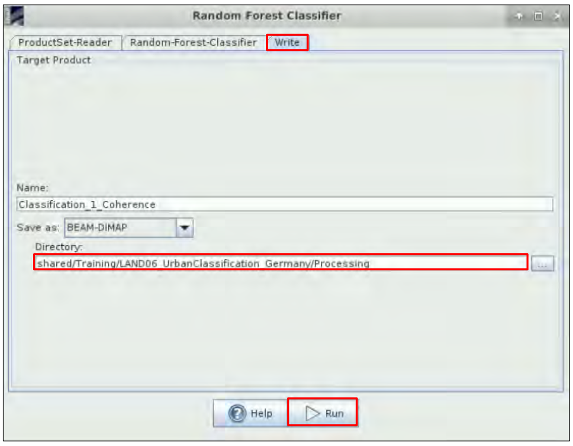
Move to the *Random-Forest-Classifier* tab and set the following parameters:

- Uncheck the Evaluate classifier option
- Set the number of trees to 500
- Select all the shapefiles as training vectors
- Select all the bands as feature bands

Click now on the *Write* tab, set the Output folder to the following path, and specify the output name according to the number of coherence images used*: Classification_1_Coherence*. Finally, click *Run*.

Path: */shared/Training/LAND06_UrbanClassification_Germany/Processing/*

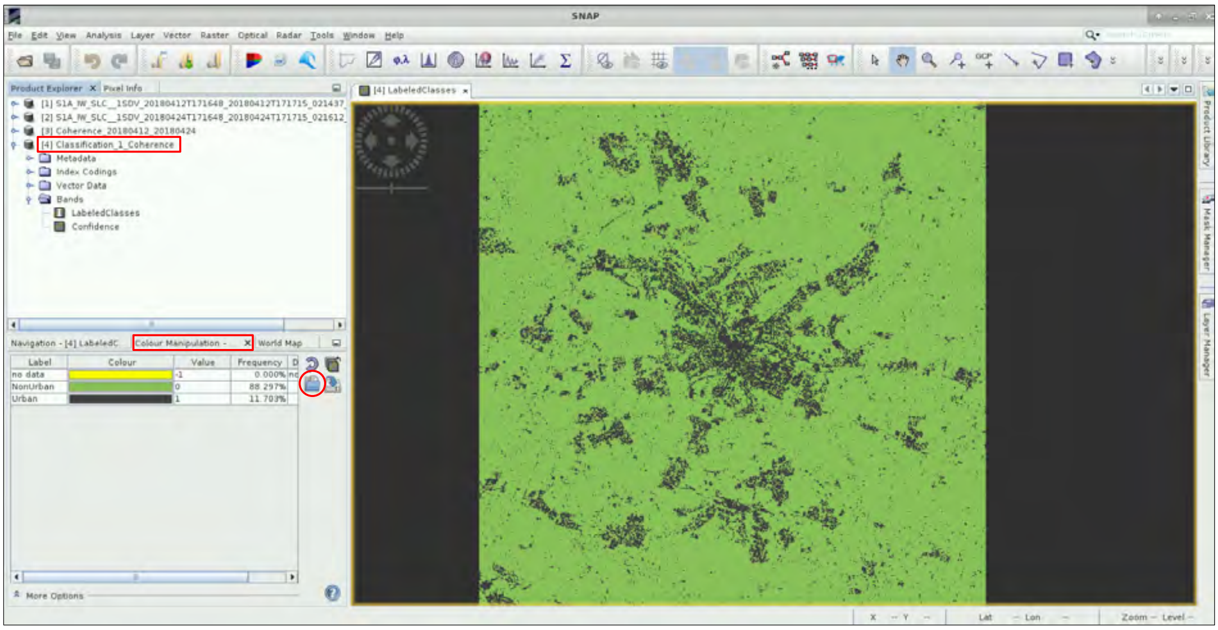




To visualize the result, expand the *Bands* folder in the *Classification_1_Coherence* product and double click on *LabelledClasses.* You can change the colours by clicking on the *Colour Manipulation tab* located in the lower left corner or by clicking on *View -> Tool Windows -> Colour manipulation.*

Select your own colours or click on the ‘Import colour palette’ icon ( ). Navigate to the following path and select the *RF_Colour.cpd* file.

Path: */shared/Training/LAND06_UrbanClassification_Germany/AuxData/*

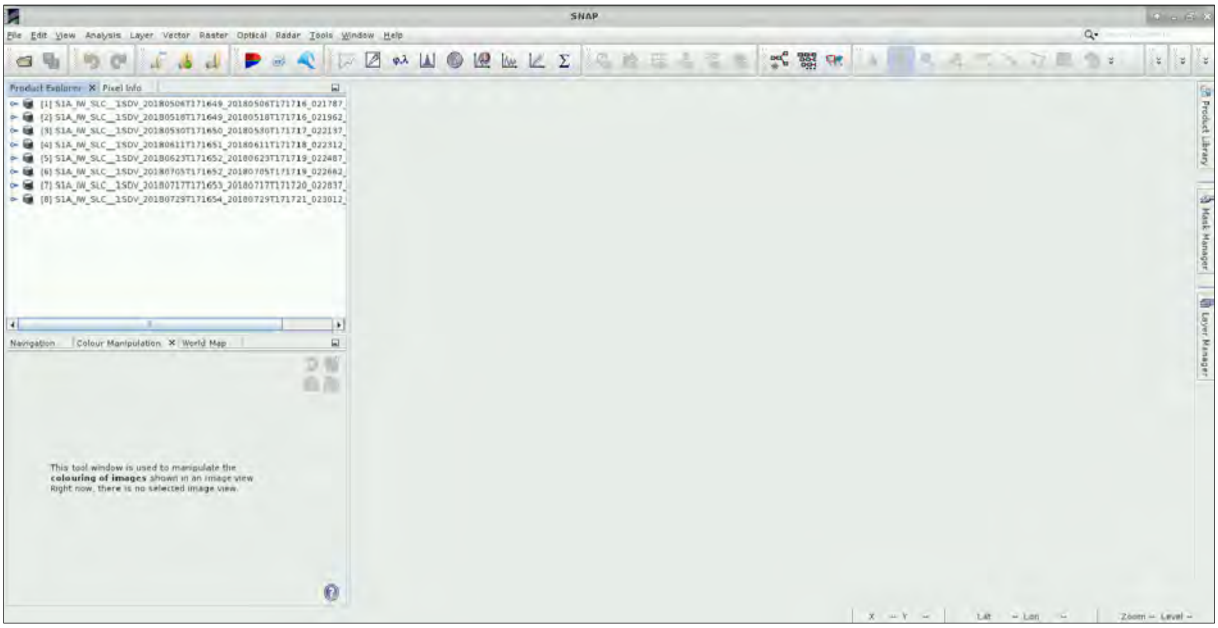


7 Extra Steps

7.1 *Coherence images*

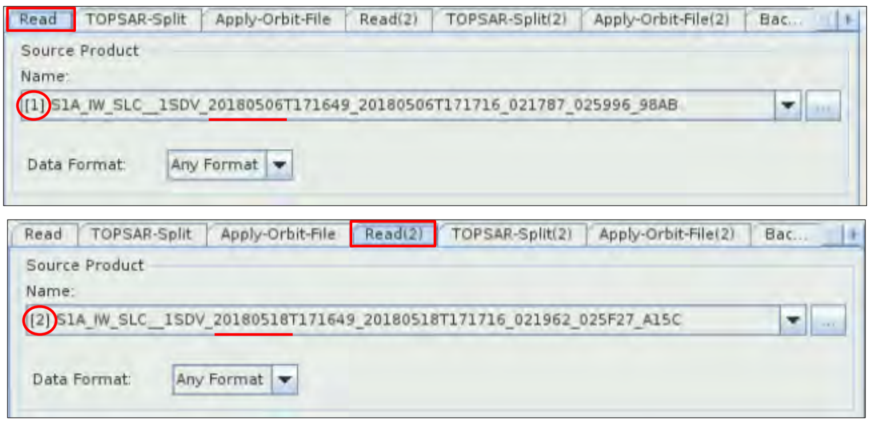
The result produced by using a single coherence image can be improved if more coherence products are used for the classification. For this, we first have to produce them by following the same approach as before. In SNAP, close all previous products, go to *File -> Open product,* navigate to the following path and open the remaining 8 Sentinel-1 images that have not been used before. (2018-05-06 | 2018-05-18 | 2018-05-30 | 2018-06-11 | 2018-06-23 | 20180705 | 20180717 | 20180729)

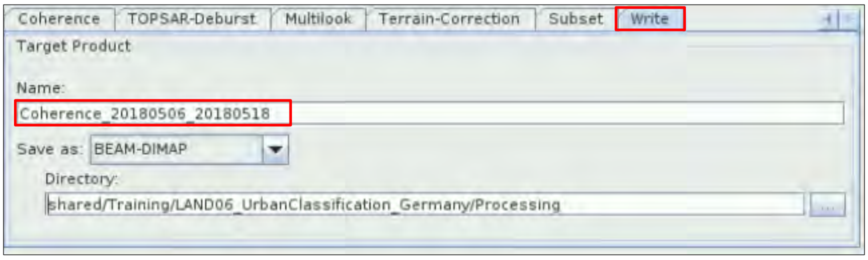
Path: */shared/Training/LAND06_UrbanClassification_Germany/Original/*



Next, go to *Tools -> GraphBuilder* click on *Load*, navigate to the following path and open the *1_S1_Splt_Orb_Cor_Coh_Deb_ML_TC.xml* graph file. Change the following parameters and click *Run.* Remember that processing this graph may take some time depending on your VM specifications.

- *Read* tab → Make sure to select the Sentinel-1 product from 2018-05-06 (index [1]).
- *Read(2) tab* → Select the Sentinel-1 product from 2018-05-18 (index [2]).
- W*rite* tab → Change the output name to *Coherence_20180506_20180518*





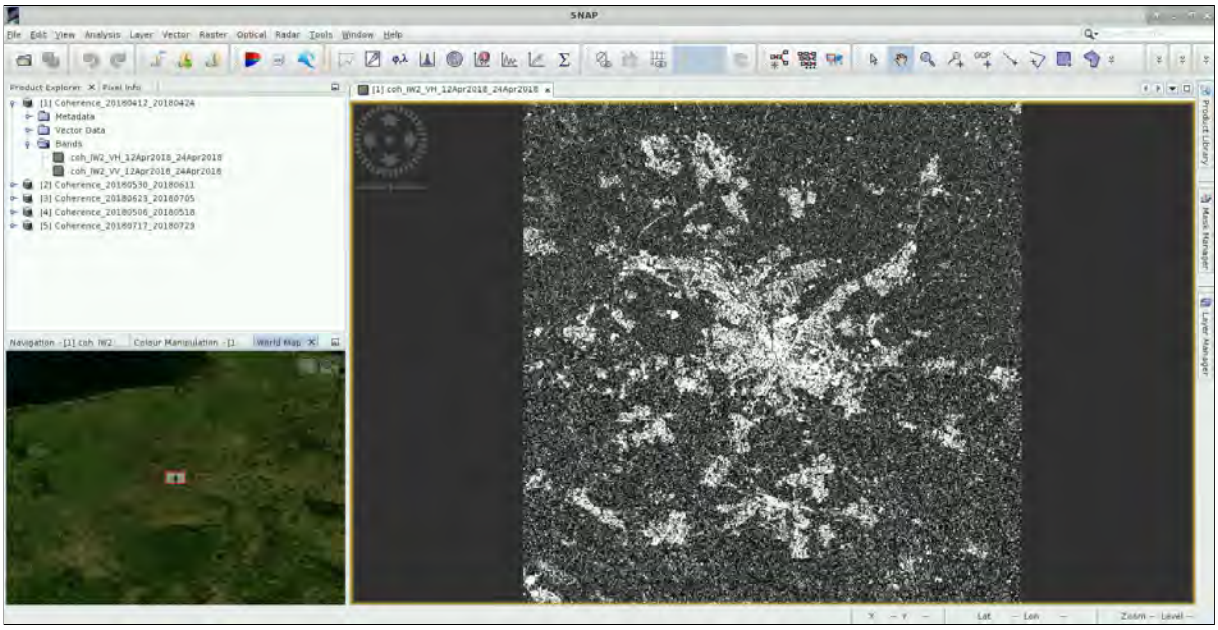
Once finished, repeat the same procedure for the remaining pair of images. Please note that since this graph is computationally demanding, you may need to close and open SNAP in order to release memory before processing a new pair of Sentinel-1 SLC products.

Read → 2018-05-30 [3] | *Read(2)* → 2018-06-11 [4] | *Write* → *Coherence_20180530_20180611*

Read → 2018-06-23 [5] | *Read(2)* → 2018-07-05 [6] | *Write* → *Coherence_20180623_20180705*

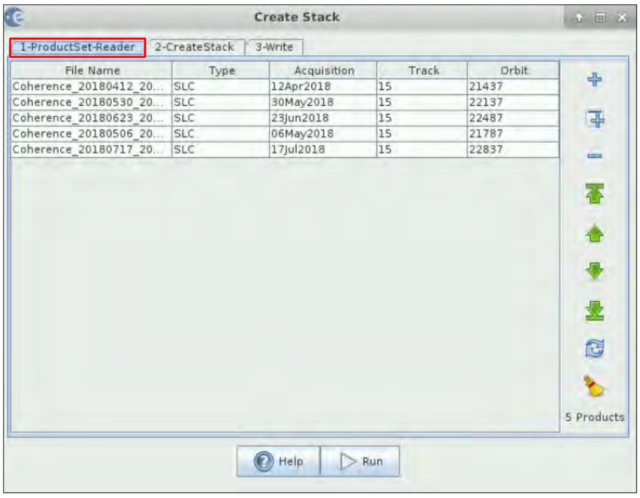
Read → 2018-07-17 [7] | *Read(2)* → 2018-07-29 [48] | *Write* → *Coherence_20180717_20180729*

After all the coherence images have been produced, close all the products in SNAP except for the 5 coherence images.



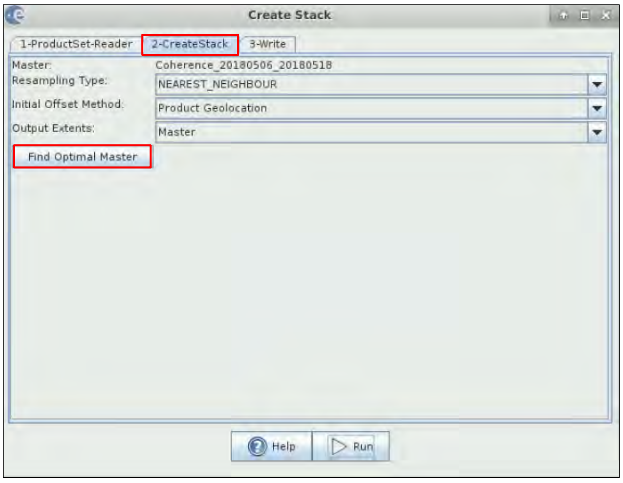
7.2 *Create Stack*

To use all the images as input for the Random Forest classification, we first need to stack all the products together. For that, go to *Radar -> Corresgistration -> Stack Tools -> Create Stack.* In the *ProductSet-Reader* tab, click at the  icon to add the opened products. Click also at the  icon to update the metadata information.



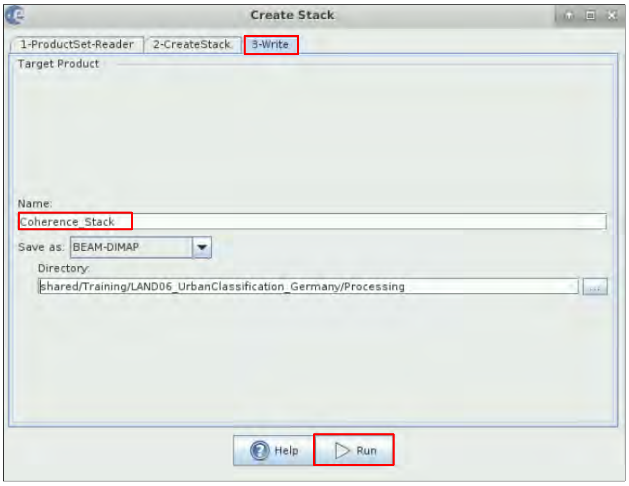
Move now to the *CreateStack* tab and set the following parameters and click on the *Find Optimal Master* button.

- Resampling type: *NEAREST_NEIGHBOR*
- Initial offset method: *Product Geolocation*



In the *Write* tab, change the output name to *Coherence_Stack* and make sure the output directory is set to the following path and then click *Run*.

Path: */shared/Training/LAND06_UrbanClassification_Germany/Processing/*

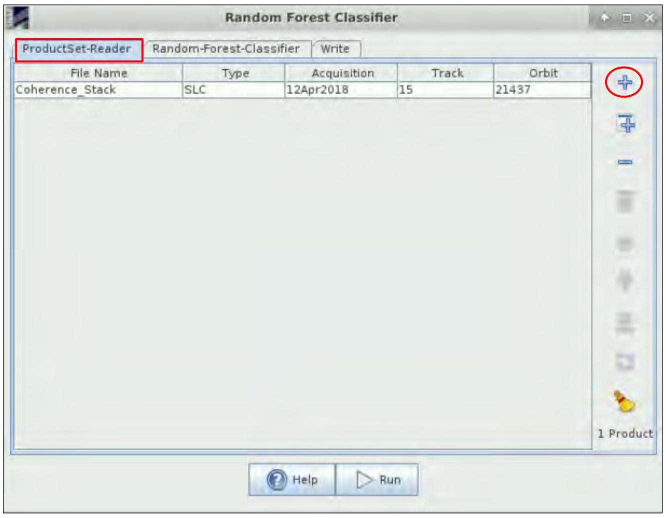


7.3 *Multi-temporal Random Forest classification*

Once the images are stacked, we can use them as input for the classification. Click on *Raster -> Classification -> Supervised Classification -> Random Forest Classifier*

In the *ProductSet*-Reader tab, click on the symbol. Navigate to the following path and select the stacked product as input (*Coherence_Stack).*

Path: */shared/Training/LAND06_UrbanClassification_Germany/Processing/*

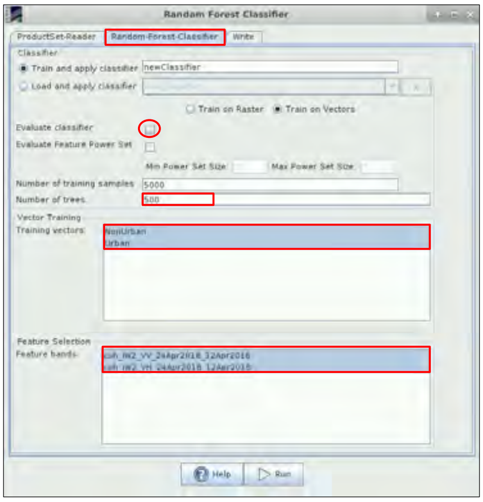


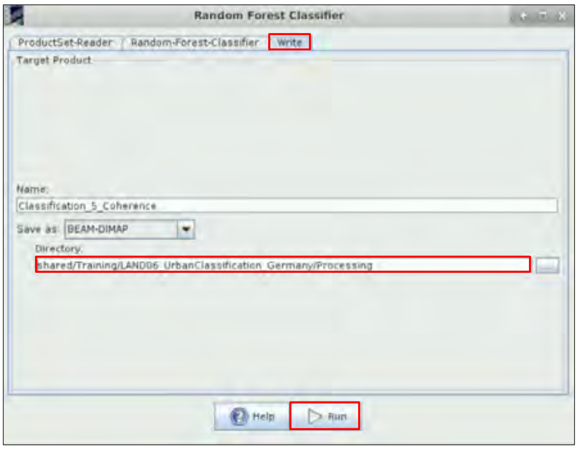
Move to the *Random-Forest-Classifier* tab and set the following parameters:

- Uncheck the Evaluate classifier option
- Set the number of trees to 500
- Select all the shapefiles as training vectors
- Select all the bands as feature bands

Click now on the *Write* tab, set the Output folder to the following path, and specify the output name according to the number of coherence images used*: Classification_5_Coherence*. Finally, click *Run*.

Path: */shared/Training/LAND06_UrbanClassification_Germany/Processing/*

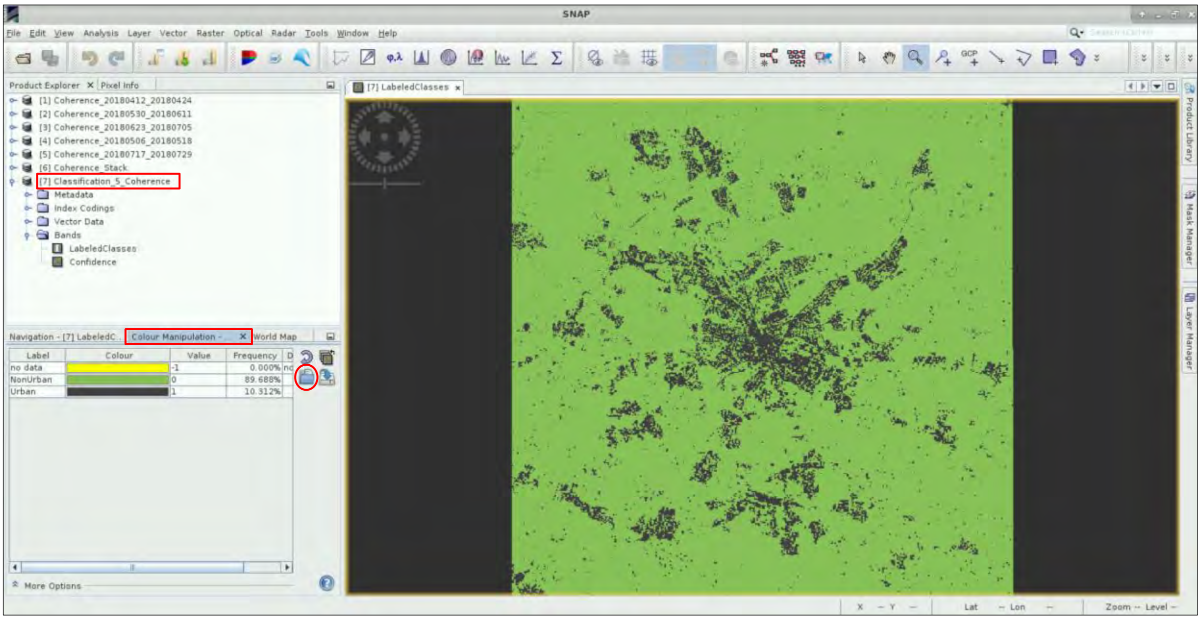




To visualize the result, expand the *Bands* folder in the *Classification_5_Coherence* product and double click on *LabelledClasses.* You can change the colours by clicking on the *Colour Manipulation tab* located in the lower left corner or by clicking on *View -> Tool Windows -> Colour manipulation.*

Select your own colours or click on the ‘Import colour palette’ icon ( ). Navigate to the following path and select the file *RF_Colour.cpd*.

Path: */shared/Training/LAND06_UrbanClassification_Germany/AuxData/*



THANK YOU FOR FOLLOWING THE EXERCISE!

8 Further reading and resources

Sentinel-1 User Guide

https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar

Sentinel-1 Technical Guide

https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-1-sar

InSAR Principles – ESA

http://www.esa.int/About_Us/ESA_Publications/InSAR_Principles_Guidelines_for_SAR_Interferometry_Processing_and_Interpretation_br_ESA_TM-19

Breiman, L. (2001). Random Forests. *Machine Learning, 45, 5–32, 45*(1), 5–32.

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