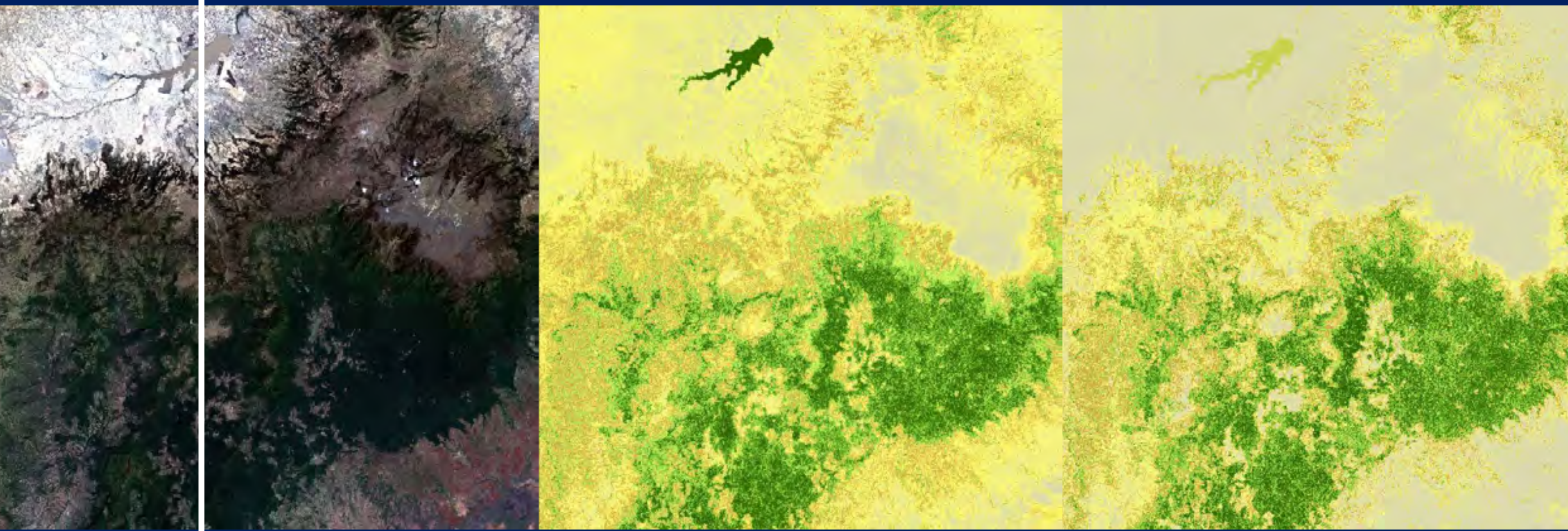

TRAINING KIT – PY02

ESTIMATION OF FOREST ABOVE-GROUND BIOMASS WITH SENTINEL-2

Case Study: Ethiopia, 2017

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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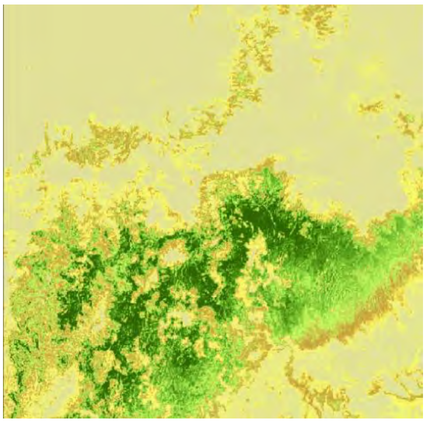
Table of Contents

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 webinar we will employ RUS to run linear and non-linear machine learning regression models in order to estimate values of above-ground biomass in forest area in Ethiopia. As input data we will use Sentinel-2 product.

2 Forest above-ground biomass estimation – background



Above-ground biomass over the study area in Ethiopia retrieved from ESA BCCI database (https://catalogue.ceda.ac.uk/uuid/84403d09cef3485883158f4df2989b0c)

Forests cover more than 31% of the total land area in the Earth *(FAO, 2020).* Forest ecosystem do not only provide a shelter for animals and maintain biodiversity but also supply the oxygen, provide timber and are preferred places for recreation. They play very important role in global carbon cycle as they store approximately 861 gigatons of carbon totally *(WRI, 2021)* from which 42% in live biomass (above and below ground biomass). Tropical forests are known as the greatest carbon stock containers, they account for only 30% of total global forest cover but contain about 50% of the world's forest carbon stock.

Above-ground biomass is very important parameter in forest management as it allows to estimate forest resources and the dynamics of these resources. It has it's crucial role in the studies of carbon cycle and the capabilities of carbon storage, as well as in the climate change debate. Because of its importance, forest biomass has been measured by foresters since decades, so different approaches exist to make these estimations. These methods mostly include field measurements which are believed to be the most accurate, but also time-consuming and costly taking into account the labor needed. Remote sensing technology enables the accounting of forest biomass. Among most commonly used sensors applied to forest above-ground biomass estimation we can list LIDAR, UAV, RADAR but also airborne hyperspectral images or satellite-based optical data are used.

In this webinar we will examine the possibility to estimate above-ground biomass in forested area in Ethiopian forest: Harenna Forest and Bale Mountains National Park. For estimation we will be using a combination of Sentinel-2 derived vegetation indices. As a reference in the estimation process we will use publicly available database produced by the ESA Biomass Climate Change Initiative for the year 2017 *(Santoro, M., Cartus, O., 2021).* We will estimate the above-ground biomass on the selected area in Africa using different machine learning methods: multiple linear regression, and non-linear random forest regression model. At the end of the exercise we will see differences in output of both models and produce biomass maps which can be used in the future to for example predict carbon amount stored in the forest.

3 Training

Approximate duration of this training session is **one and a half** hour.

The Training Code for this tutorial is PY02. If you wish to practice the exercise described below within the RUS Virtual Environment, register the RUS portal and open a User Service request from your RUS service -> Your dashboard.

3.1 Data used

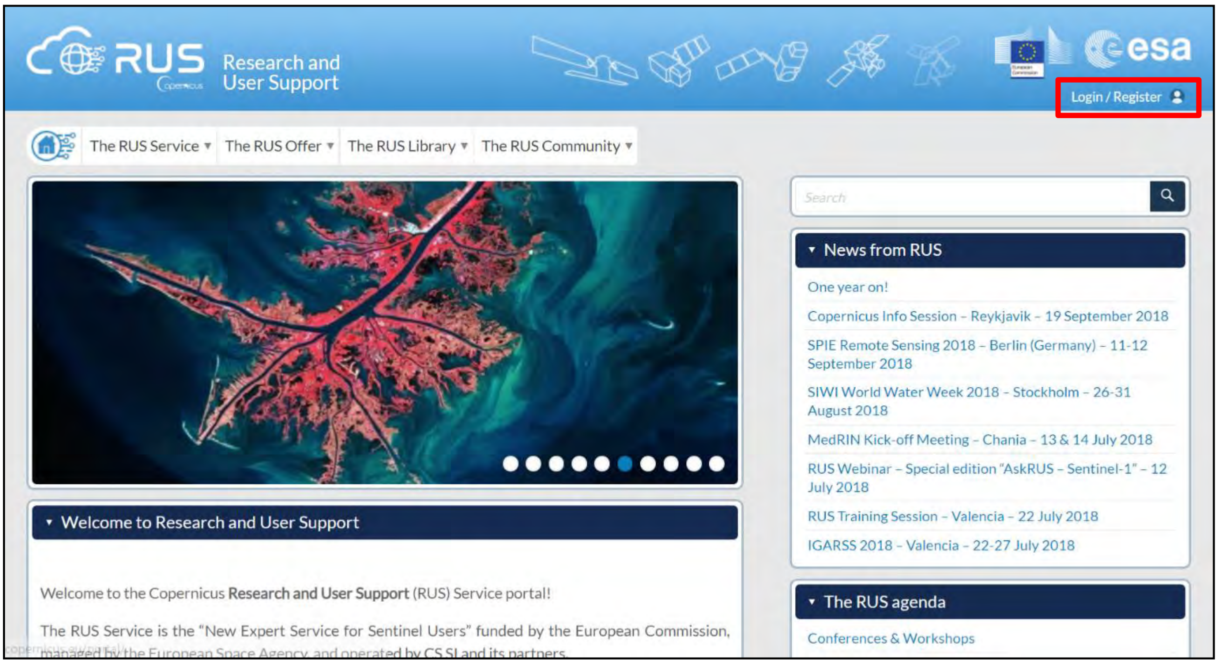
- 1 Sentinel-2A image acquired during January 2017, full name of the product: **S2A_MSIL1C_20170119T074231_N0204_R092_T37NEH_20170119T075734**
- Pre-processed data stored locally *@/shared/Training/PY02_ForestBiomass_Sentinel2/AuxData/*

3.2 Software in RUS environment

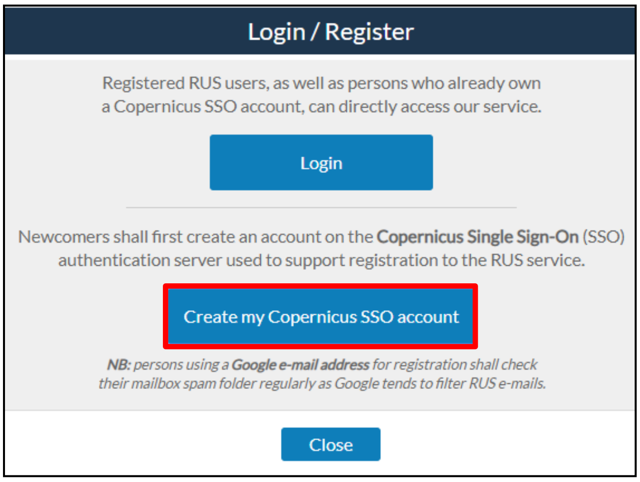
Internet browser, Jupyter Lab, Python, Anaconda, *snappy, Sen2Cor280*

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.

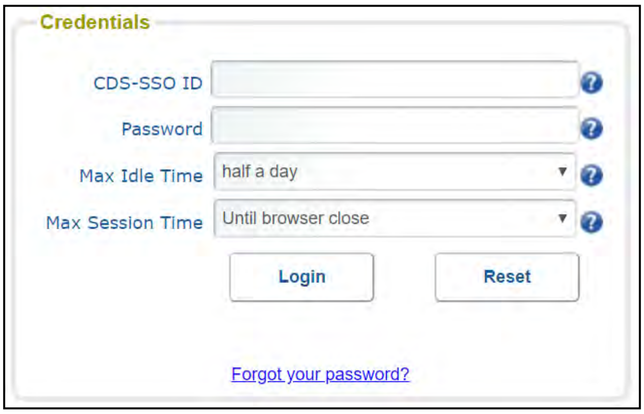


Select the option ***Create my Copernicus SSO account*** and then fill in ALL the fields on the **Copernicus Users' Single Sign On Registration**. Click ***Register***.

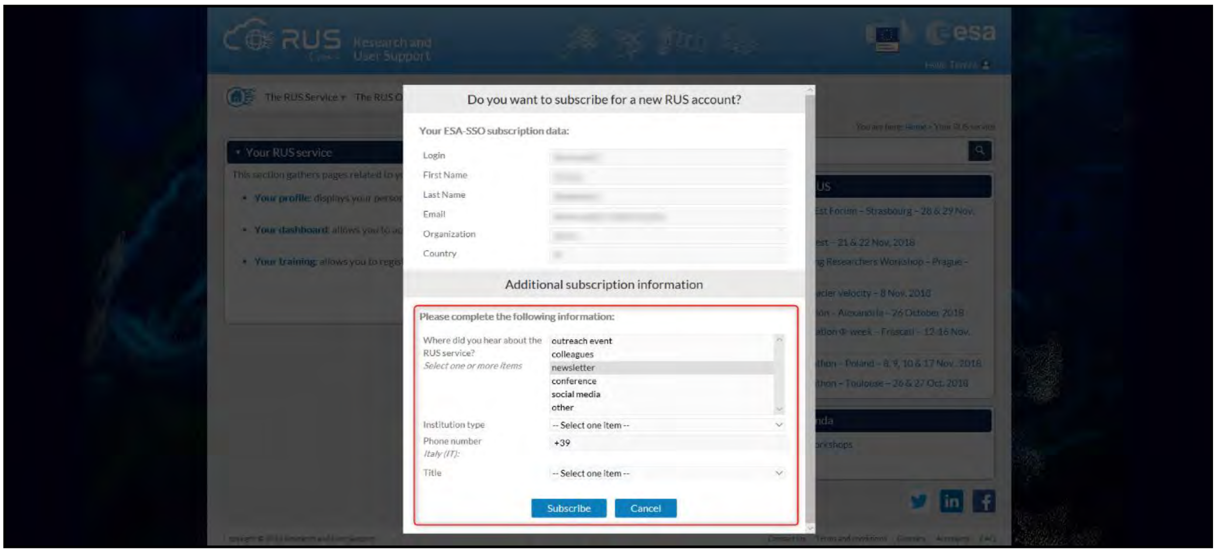


Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the e-mail to activate your account.

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

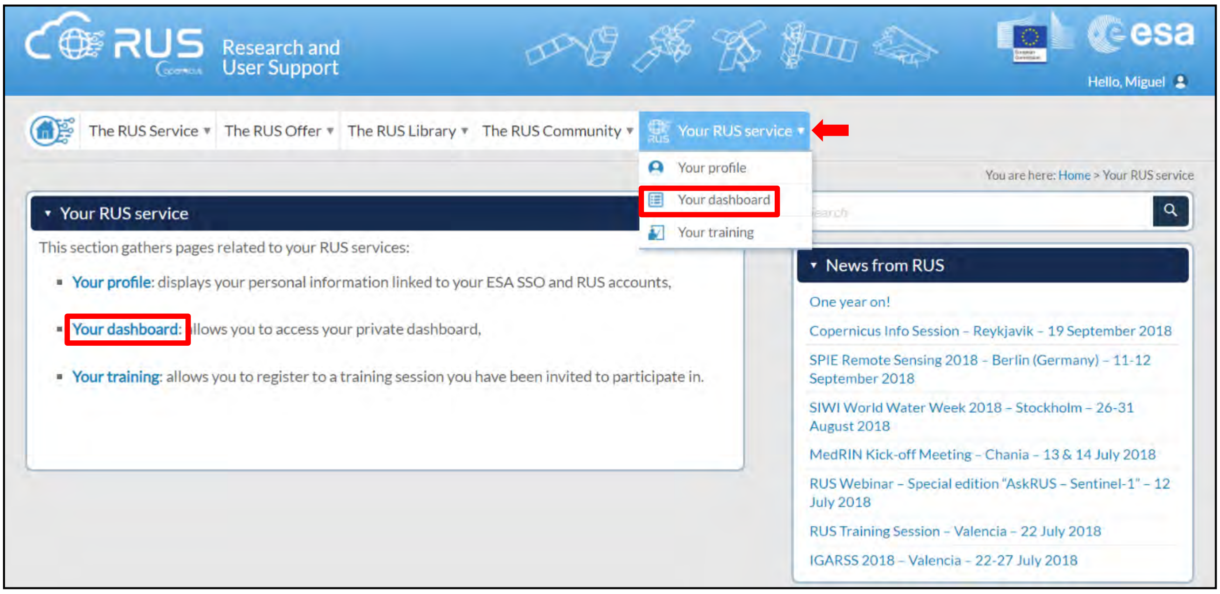


Upon your first login you will need to enter some details. You must fill all the fields.

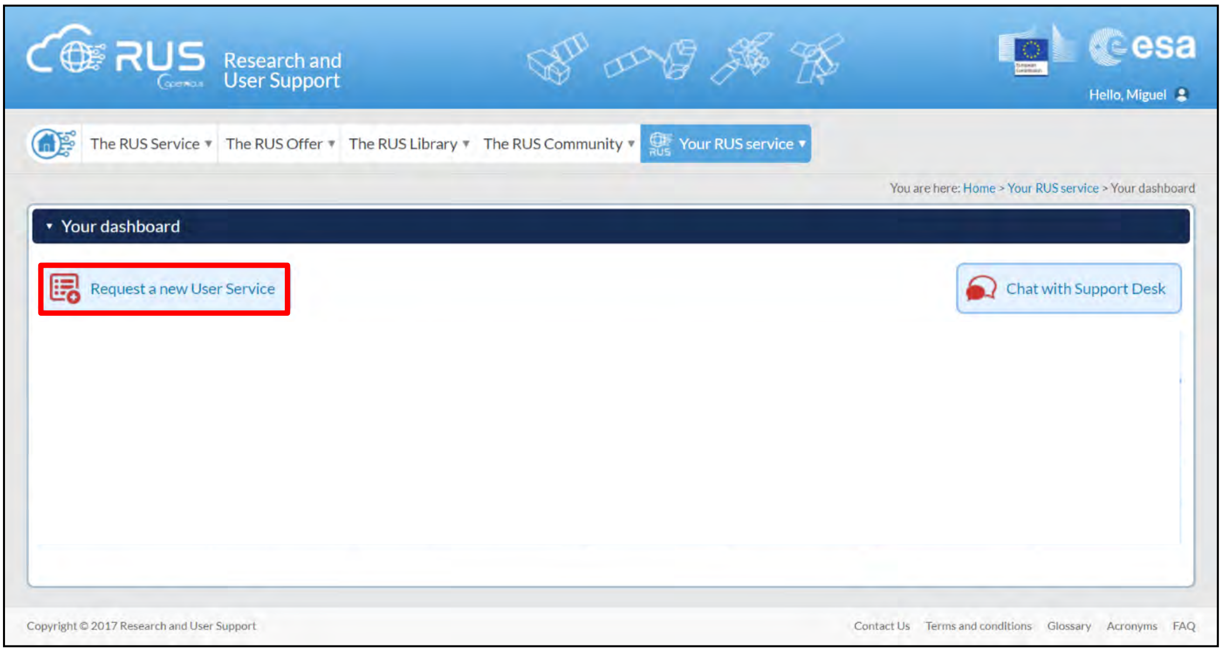


5 Request a RUS Copernicus Virtual Machine

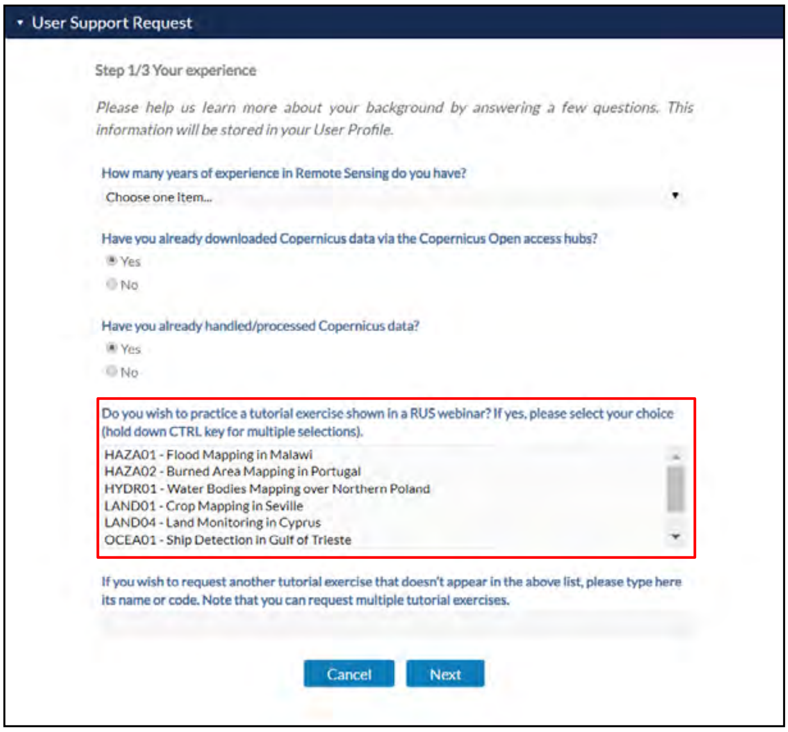
Once you are registered as a RUS user, you can request a RUS Virtual Machine to repeat this exercise or work on your own projects using Copernicus data. For that, log in and click on ***Your RUS Service → Your Dashboard***.



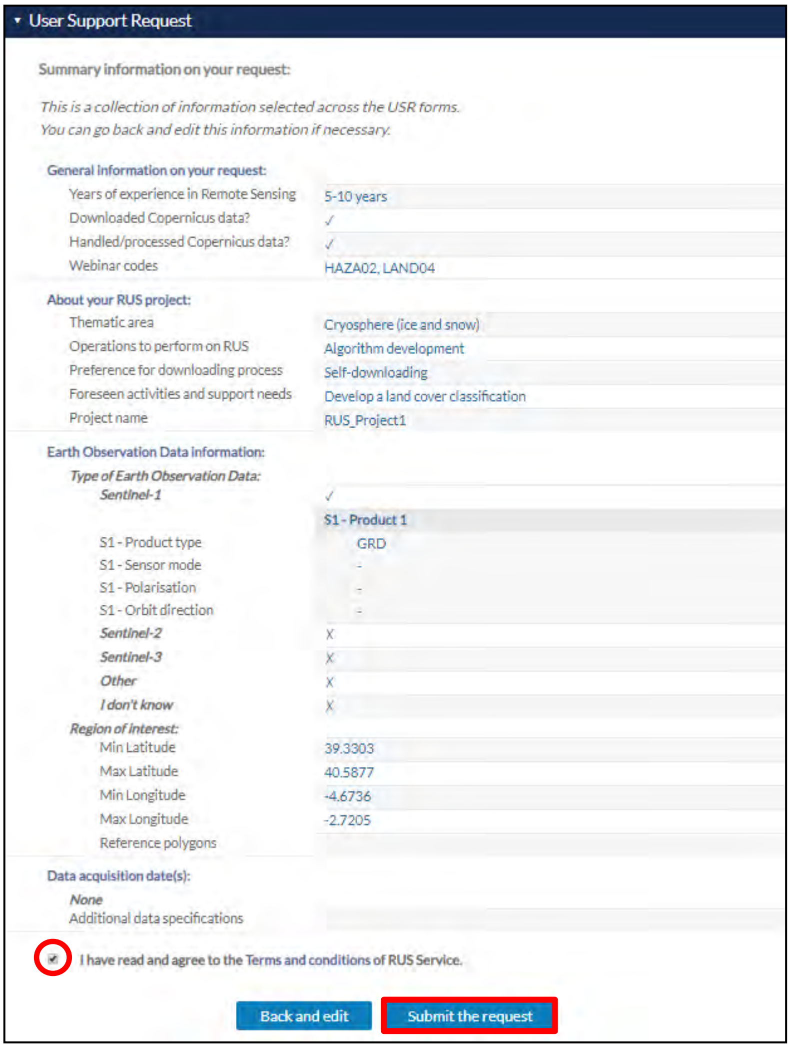
Click on ***Request a new User Service*** to request your RUS Virtual Machine. Complete the form so that the appropriate cloud environment can be assigned according to your needs.



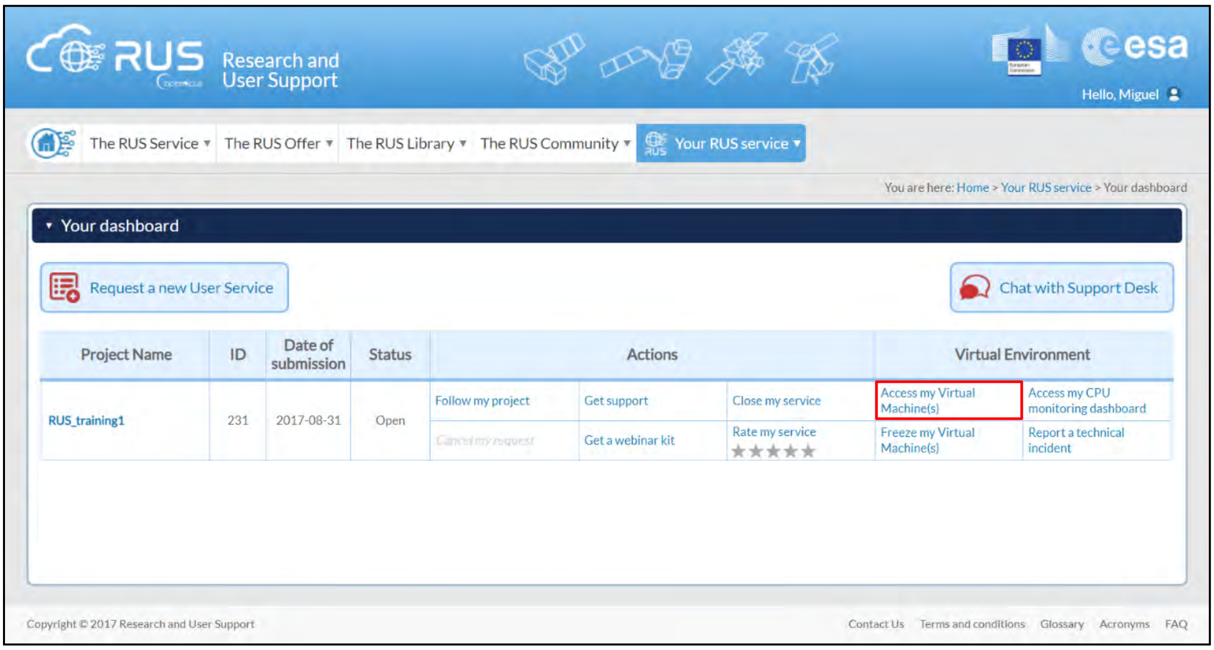
If you want to repeat this tutorial (or any previous one) select the one(s) of your interest in the appropriate field.



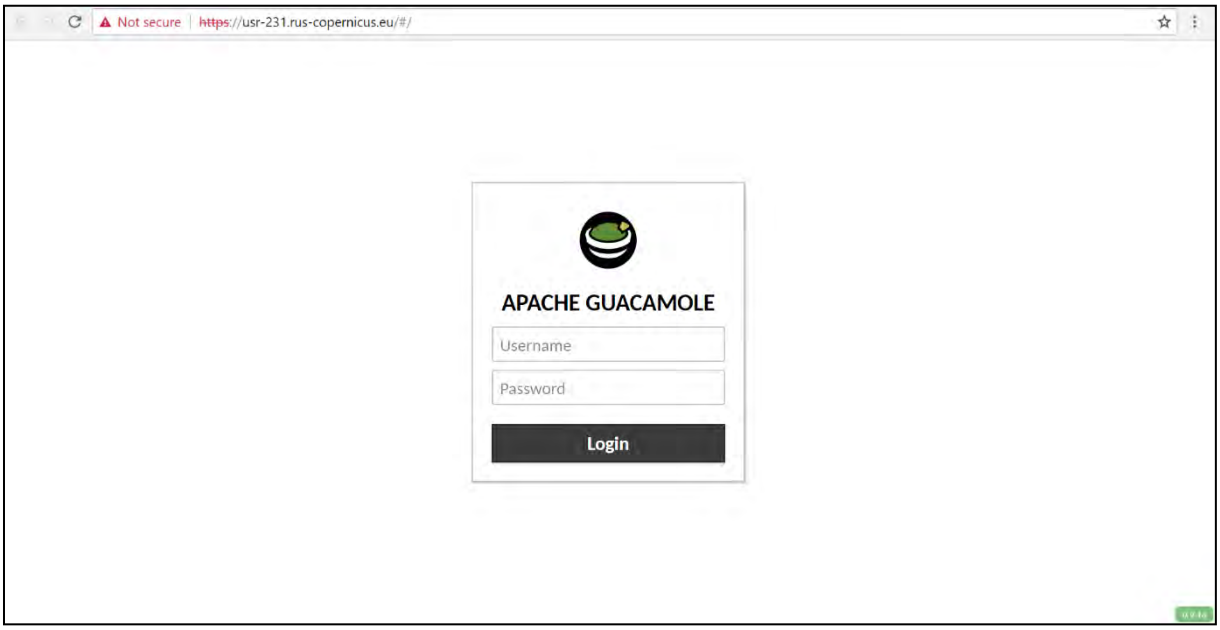
Complete the remaining steps, check the terms and conditions of the RUS Service and submit your request once you are finished.



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.

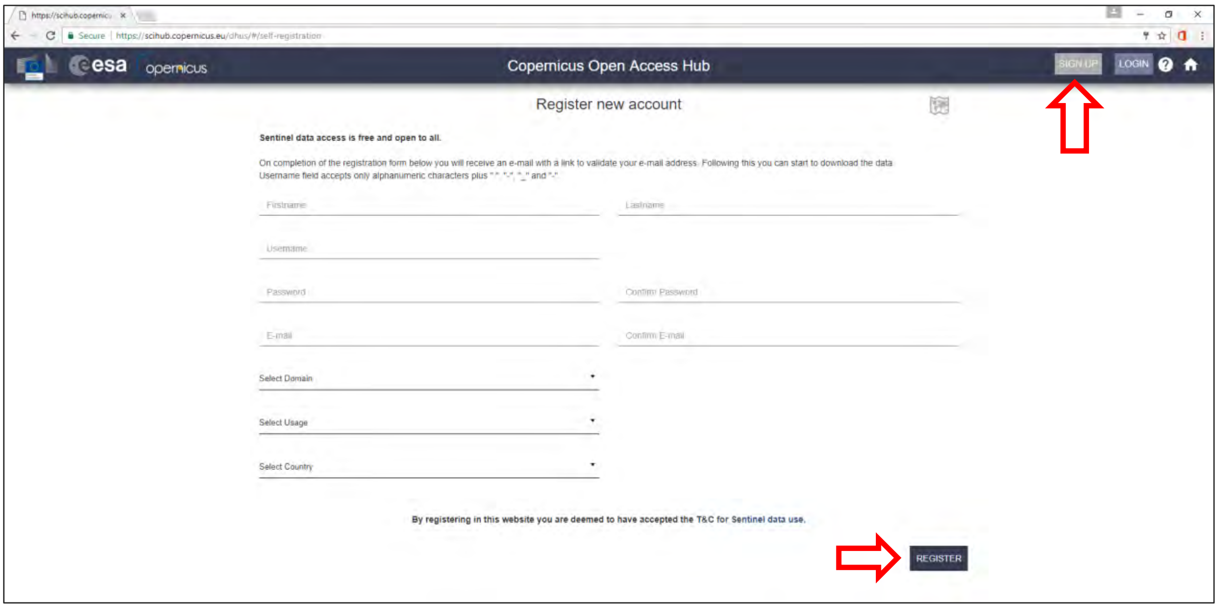
6 Step by step

6.1 Data download – ESA SciHUB

Before starting the exercise, we need to make sure that we are registered in the Copernicus Open Access Hub so that we 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 please 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.

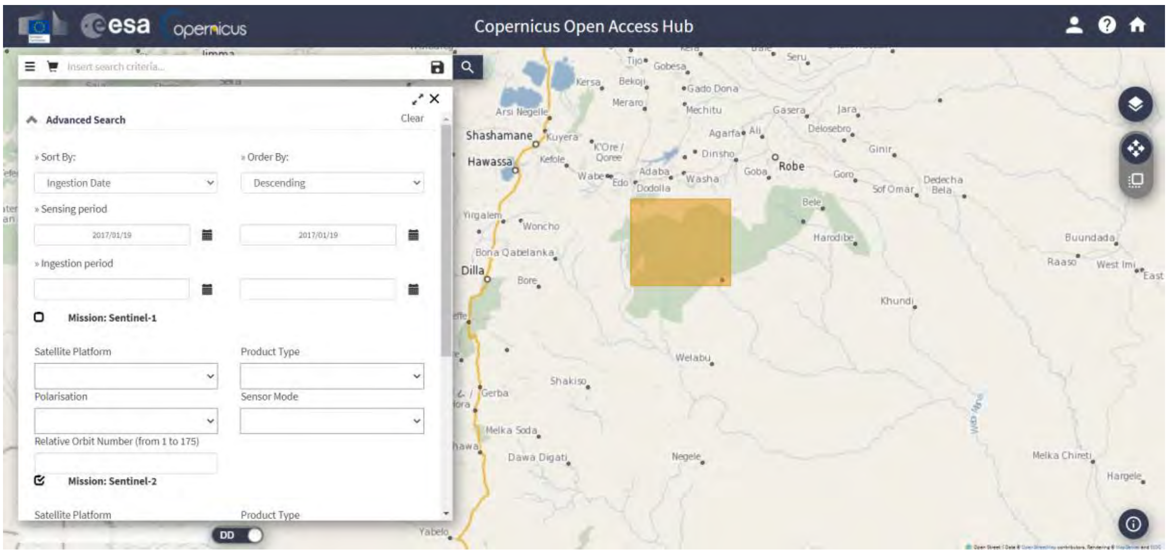
Once your account is activated – or if you already have an account – log in.

6.2 Download data

In this exercise, we will describe the procedure to download the Sentinel-2 product. Make sure you repeat the same procedure and download the product for January 2017 for our area of interest. First of all you need to define the study area over the central-southern forest area in Ethiopia (as presented below). Then, open the search menu by clicking to the left part of the search bar (☰) and specify the parameters below. Press the search button (🔍) after that.

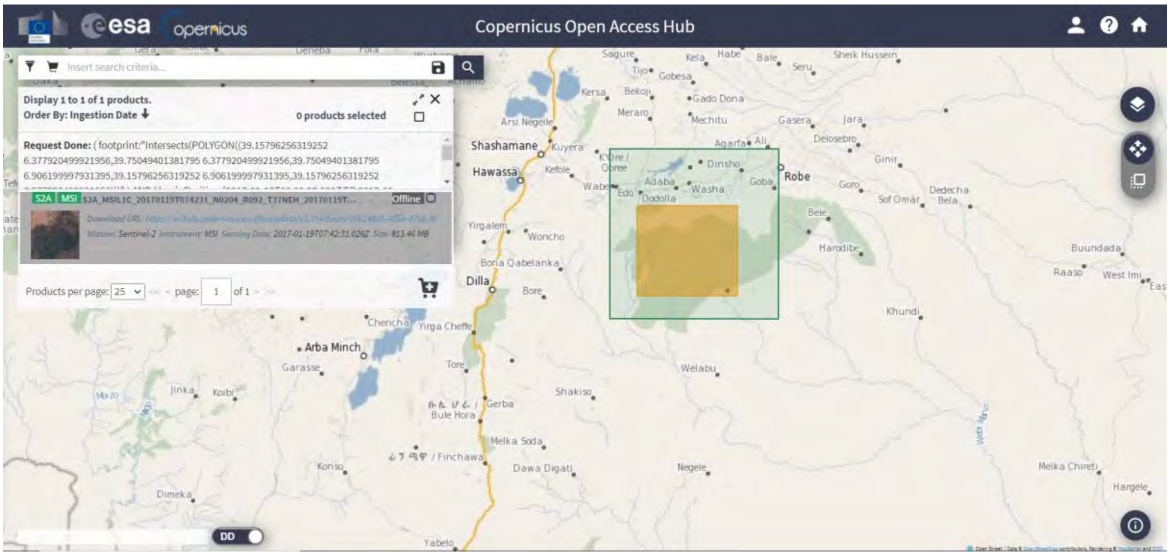
Sensing period: From 2017/01/19 to 2017/01/19

Check mission: Sentinel-2

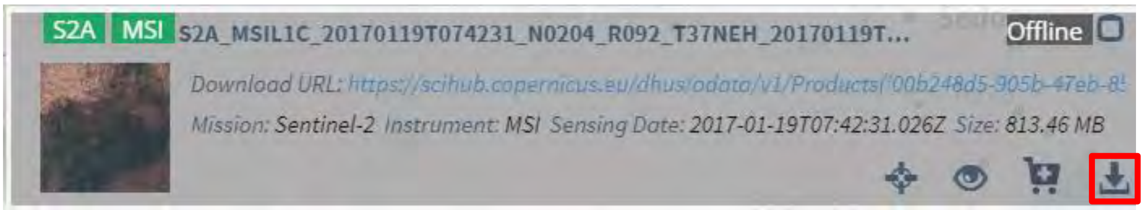


In this case the search returns 1 results. Full product name is: **S2A_MSIL1C_20170119T074231_N0204_R092_T37NEH_20170119T075734.** This product does not have atmospheric correction applied so later we will need to convert it to atmospherically corrected product.

Download the product (it will be saved in */home/rus/Downloads*) and move it to the following path: */shared/Training/PY02_ForestBiomass_Sentinel2/Original/*. (See NOTE 1).



NOTE 1: Due to ESA policy on the availability of Sentinel data on Copernicus Open Access Hub and to ensure the continued access to all Sentinel data at all time, the Long-Term Archive (LTA) Access has been implemented to roll-out the oldest data from the online access. More information about the LTA can be found in the following links:
https://scihub.copernicus.eu/userguide/#LTA_Long_Term_Archive_Access
https://scihub.copernicus.eu/userguide/LongTermArchive.



To download a product from the LTA, click on the Download Product icon - . A confirmation message will appear informing you that your request has been queued and the product added to your Cart.

You will have to manually check your Cart from time to time to know when the product is available to be downloaded (no automatic notification will be sent). Once online, the product will remain available for 4 days until been roll-out to the LTA again.
Please note that every user account is only allowed to request 1 offline product every 30 minutes, if there is free space in the queue. The number of concurrent requests for offline products from all users is limited. You may receive an error when trying to download. If so, try again later.

6.3 *Anaconda environment installation*

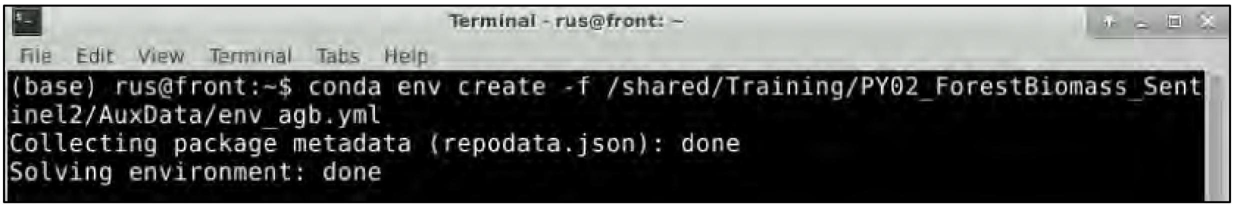
In this exercise we will use *snappy* module, *Senc2Cor plugin* and Python code in JupyterLab to perform atmospheric correction (*Sen2Cor in Python),* process the image (resampling, subset, band combinations – with *snappy)*, calculate vegetation indices and at the end perform machine learning regression models. However, before starting the analysis, we need to set up both the Anaconda environment and the snappy module to work (See NOTE 2 and NOTE 3).

NOTE 2: Project Jupyter is a non-profit, open-source project, born out of the IPython Project in 2014 as it evolved to support interactive data science and scientific computing across all programming languages. Notebook documents (or “notebooks”, all lower case) are documents produced by the Jupyter Notebook App, which contain both computer code (e.g. python) and rich text elements (paragraph, equations, figures, links, etc…). Notebook documents are both human-readable documents containing the analysis description and the results (figures, tables, etc..) as well as executable documents which can be run to perform data analysis. More info at: www.jupyter.org

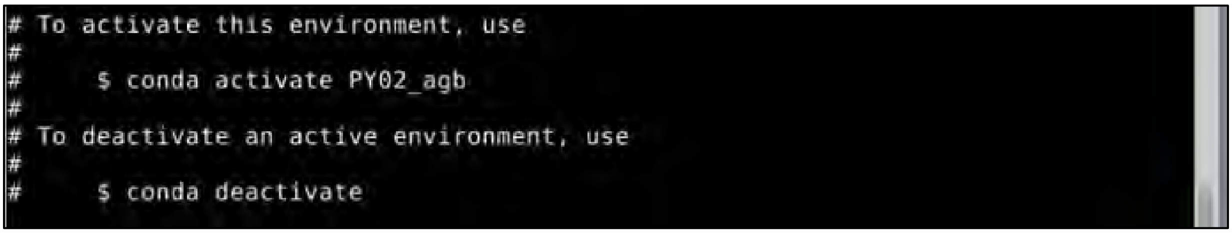
NOTE 3: Python is an interpreted, high-level, general-purpose programming language. Created by Guido van Rossum and first released in 1991, Python's design philosophy emphasizes code readability through use of significant whitespace. Its language constructs and object-oriented approach aim to help programmers write clear, logical code for small and large-scale projects. Python is dynamically typed and garbage-collected. It supports multiple programming paradigms, including procedural, object oriented, and functional programming. Python is often described as a "batteries included" language due to its comprehensive standard library. More info at: www.python.org
Anaconda is a free and open-source distribution of the Python and R programming languages for scientific computing (data science, machine learning applications, large-scale data processing, predictive analytics, etc.), that aims to simplify package management and deployment. Package versions are managed by the package management system *conda*. More info at: https://www.anaconda.com/distribution/

To create the same conda environment as the one used for the creation of this training material open Terminal in your RUS Virtual Machine and copy-paste the following command. Then, press *Enter* to run it (this step may take several minutes, do not interrupt it). The conda environment will be called PY02_agb.

```
conda env create -f
/shared/Training/PY02_ForestBiomass_Sentinel2/AuxData/env_agb.yml
```



. . .



Next, we will generate the *snappy* module in that environment so that it can be called and used later.

6.4 snappy module generation

SNAP provides the Python module snappy which allows you to access the SNAP Java API from Python. snappy requires either a SNAP installation or a SNAP build. The following instructions will guide you through the installation process to have snappy working in the RUS Copernicus Virtual Machine. Generic instructions on how to install snappy can be found in the following website: https://senbox.atlassian.net/wiki/spaces/SNAP/pages/24051781/Using+SNAP+in+your+Python+programs

To start, open a Terminal window and navigate to the bin folder inside the SNAP installation directory (in RUS Copernicus Virtual Machines - */usr/local/snap/).*

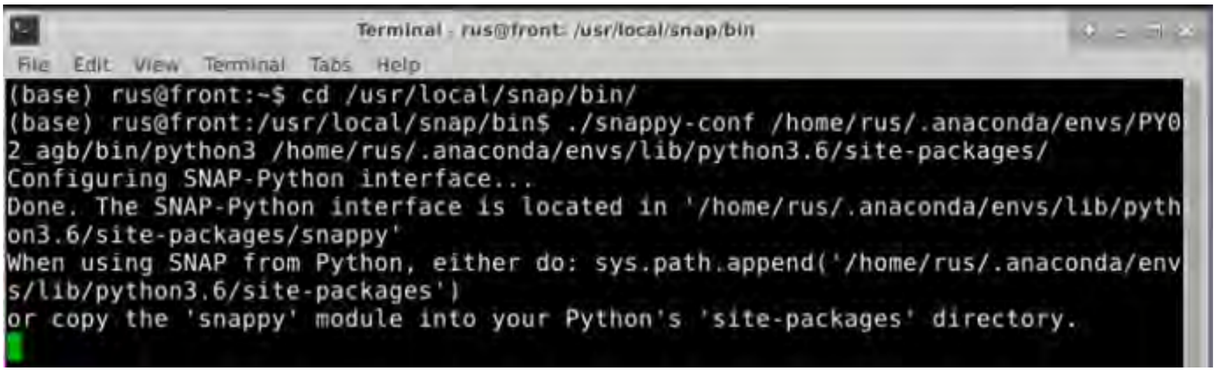
```
cd /usr/local/snap/bin
```

Next, we will generate the Python module snappy configured for the current SNAP installation and the Python interpreter of choice set in the *<python-exe>* parameter. In addition, instead of generating it in the default folder *(.snap/snap-python* in the home directory), we will place it in the site-package folder of our recently created conda environment. For that, we will make use of the *<snappy-dir>* parameter (see NOTE 4).

NOTE 4: The parameter must be the full path to the Python interpreter executable which you want to use with SNAP (supported versions are 2.7, 3.3 to 3.6

Following the previous command in Terminal, copy-paste the next one and press *Enter.*

```
./snappy-conf /home/rus/.anaconda/envs/PY02_agb/bin/python3 /home/rus/.anac
onda/envs/PY02_agb/lib/python3.6/site-packages/
```



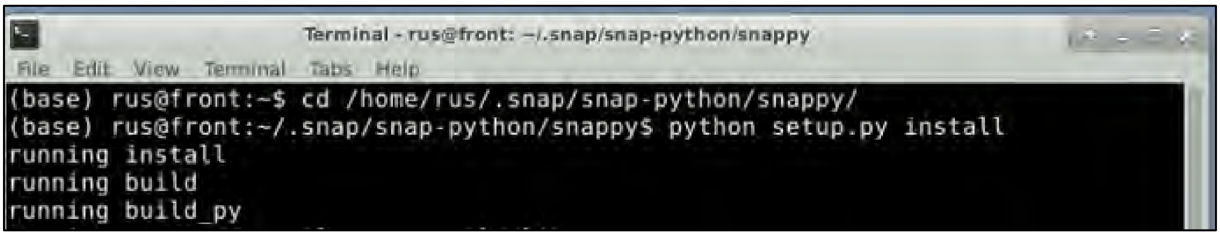
When the message starting with “Done” appears, but the code does not seem to finish, press CTRL+C.

Then change the directory to the directory where we have just generated the snappy python module:

```
cd /home/rus/.snap/snap-python/snappy/
```

And finally, we will install the generated module by running the following command:

```
python setup.py install
```



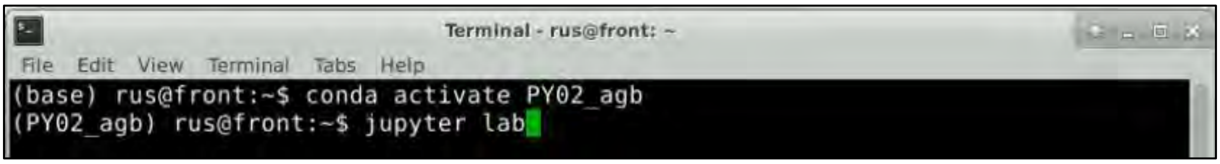
6.5 Performing the exercise using Sentinel-2 data in JupyterLab

Once the *snappy* module has been properly generated, we can start our exercise. Activate the *PY02_agb* conda environment by running the following script in a new Terminal window.

```
conda activate PY02_agb
```

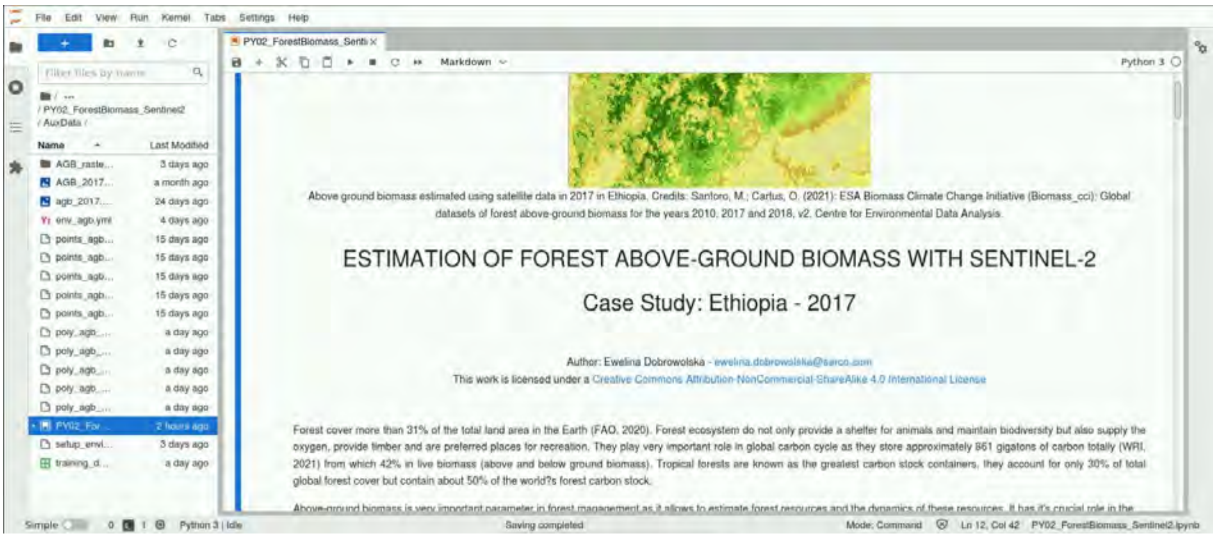
Next, write *"jupyter lab"* and press enter to launch the application. When the environment is activated you will see that the *(base)* at the beginning of the line has changed to (*PY02_agb).*

Once open, navigate to the following path inside the Jupyter Lab and open the file *PY02_ForestBiomass_Sentinel2.ipynb*



Path → */shared/Training/ PY02_ForestBiomass_Sentinel2 /AuxData/*

Once the interface opens, double click on the notebook *PY02_ForestBiomass_Sentinel2.ipynb* to open the next tab. The next steps of this exercise are described in detail in the notebook.

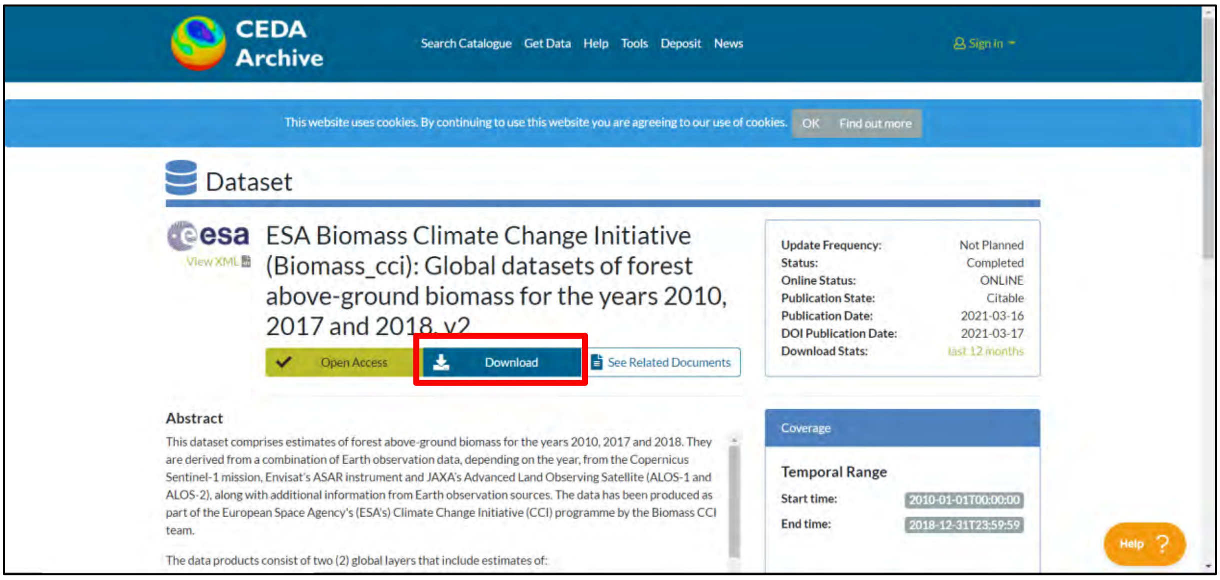


Follow the instructions there to proceed with the training.

7 Additional clarifications

7.1 Download reference Above-ground biomass dataset

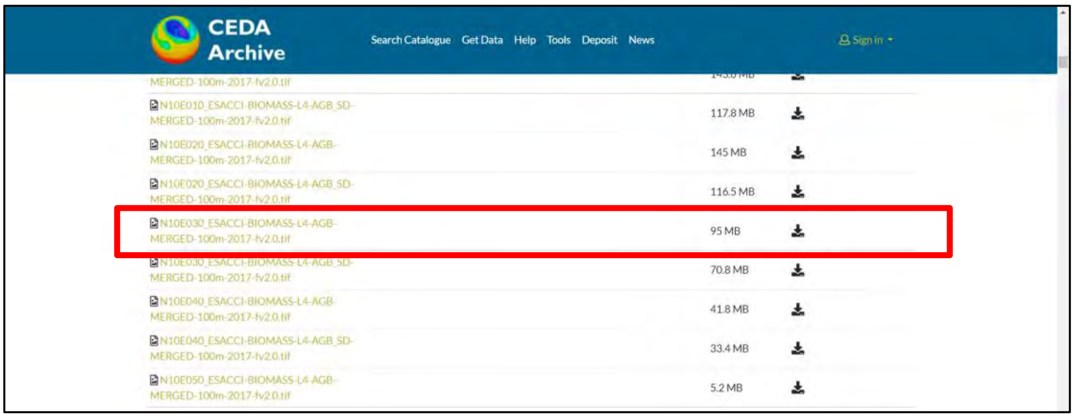
For this exercise the Above-ground biomass dataset has been downloaded and prepared for you. As a reference data for this exercise we are using a publicly available Global above-ground biomass database prepared by ESA Biomass Climate Change Initiative (Biomass_cci), which can be accessed under the link: https://catalogue.ceda.ac.uk/uuid/84403d09cef3485883158f4df2989b0c



Press ***Download*** to retrieve reference raster database. Select ***"geotiff"*** as the format of images we want to use.

Now navigate to the year ***2017***.

Database consists of raster tiles which cover all the globe and represent Above-ground biomass values in tons/ha represented by pixels in resolution of 100 m. To download correct tile you need to know the geographical position of you study area. We are going to use database for Ethiopia so we will search for the tile which covers area at 10 degrees North latitude and 30 degrees East longitude.



Downloaded original product is stored in the Path: */shared/Training/PY02_ForestBiomass_Sentinel2/AuxData/2017_N10E030_ESACCI_BIOMASS_L4-AGB-MERGED-100m-2017-fv2.tif*

THANK YOU FOR FOLLOWING THE EXERCISE!

8 Further reading and resources

Askar, Nuthammachot, N., Phairuang, W., Wicaksono, P., & Sayektiningsih, T. (2018). Estimating aboveground biomass on private forest using sentinel-2 imagery. Journal of Sensors. https://doi.org/10.1155/2018/6745629

Haywood, A., Stone, C., & Jones, S. (2018). The potential of sentinel satellites for large area aboveground forest biomass mapping. International Geoscience and Remote Sensing Symposium (IGARSS), 2018-July(July), 9030–9033. https://doi.org/10.1109/IGARSS.2018.8517597

Khan, M. R., Khan, I. A., Baig, M. H. A., Liu, Z. jia, & Ashraf, M. I. (2020). Exploring the potential of Sentinel-2A satellite data for aboveground biomass estimation in fragmented Himalayan subtropical pine forest. Journal of Mountain Science, 17(12), 2880–2896. https://doi.org/10.1007/s11629-019-5968-8

Pham, T., Yoshino, K., Le, N.N., & Bui, D. (2018). Estimating aboveground biomass of a mangrove plantation on the Northern coast of Vietnam using machine learning techniques with an integration of ALOS-2 PALSAR-2 and Sentinel-2A data. *International Journal of Remote Sensing, 39*, 7761 - 7788. DOI: 10.1080/01431161.2018.1471544

Santoro, M.; Cartus, O. (2021): ESA Biomass Climate Change Initiative (Biomass_cci): Global datasets of forest above-ground biomass for the years 2010, 2017 and 2018, v2. Centre for Environmental Data Analysis, 17 March 2021. doi:10.5285/84403d09cef3485883158f4df2989b0c. Database can be access: https://data.ceda.ac.uk/neodc/esacci/biomass/data/agb/maps/v2.0/.

FAO. (2020). Global Forest Resources Assessment 2020 – Key findings. Rome. https://doi.org/10.4060/ca8753en

World Resources Institute. (2021) Global Forest Watch – accessed 17 July 2021. https://www.wri.org/initiatives/global-forest-watch

8.1 SW resources

Python tutorial: Python for beginners

Jupyter Notebook Documentation: **Documentation**

SNAP and snappy: https://approach.readthedocs.io/en/latest/setup.html

Sen2Cor Plugin: https://step.esa.int/main/snap-supported-plugins/sen2cor/

RUS training on processing data with python and snappy for Anaconda and Jupyter Notebook introduction.

8.2 Additional resources of information about global biomass distribution

ESA Biomass Climate Change Initiative (Biomass_cci): Global datasets of forest above-ground biomass for the years 2010, 2017 and 2018, v2
https://catalogue.ceda.ac.uk/uuid/84403d09cef3485883158f4df2989b0c
Pan-tropical biomass map: http://lucid.wur.nl/
ESA DUE Globbiomass project: https://globbiomass.org/products/global-mapping/
Comparing Global Carbon Maps application on the Ecometrica Mapping Platform: https://carbonmaps.ourecosystem.com/interface/

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