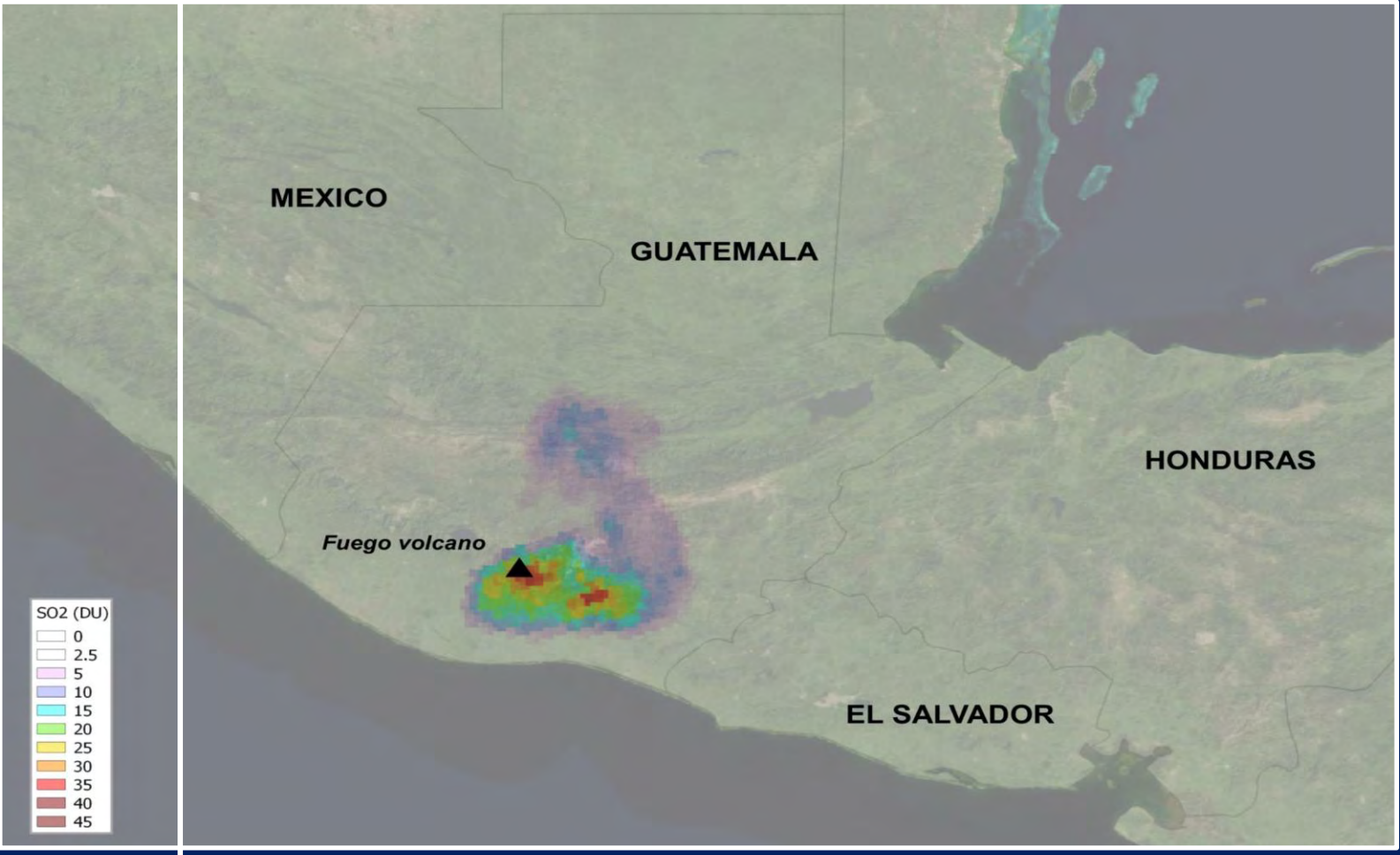


TRAINING KIT – ATMO03

VOLCANIC EMISSIONS WITH SENTINEL-5p
Case Study: Volcán de Fuego, Guatemala 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 image credits: ESA

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

Date of publication: February 2021

Version: 1.1

Suggested citation:

Serco Italia SPA (2021). *Volcano monitoring with Sentinel-5p (version 1.1).* Retrieved from RUS Lectures at https://rus-copernicus.eu/portal/the-rus-library/learn-by-yourself/

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 map SO_2 originated during the eruption of Volcán de Fuego in Guatemala at the beginning of June 2018 using Sentinel-5p products as input data and python code.

2 Volcanic eruption – background

Volcano eruption. Credits: Pexel

Volcanic eruptions are one of Earth's most dramatic and violent agents of change. Not only can powerful explosive eruptions drastically alter land and water for tens of kilometres around a volcano, but tiny liquid droplets of sulfuric acid erupted into the stratosphere can change our planet's climate temporarily. Eruptions often force people living near volcanoes to abandon their land and homes, sometimes forever. Farther away, cities, crops, industrial plants, transportation systems, airplanes, and electrical grids can still be damaged by tephra, ash, lahars, and flooding. Ninety-nine percent of the gas molecules emitted during a volcanic eruption are water vapor (H2O), carbon dioxide (CO2), and sulfur dioxide (SO2). The remaining one percent is comprised of small amounts of hydrogen sulfide, carbon monoxide, hydrogen chloride, hydrogen fluoride, and other minor gas species (USGS).

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 Sentinels. Sentinel-5p provides timely data on a multitude of trace gases (CO, NO22, SO22, O33, aerosols…) with a great accuracy and spatial resolution.

3 Training

Approximate duration of this training session is **one** hour.

The Training Code for this tutorial is ATMO03. 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

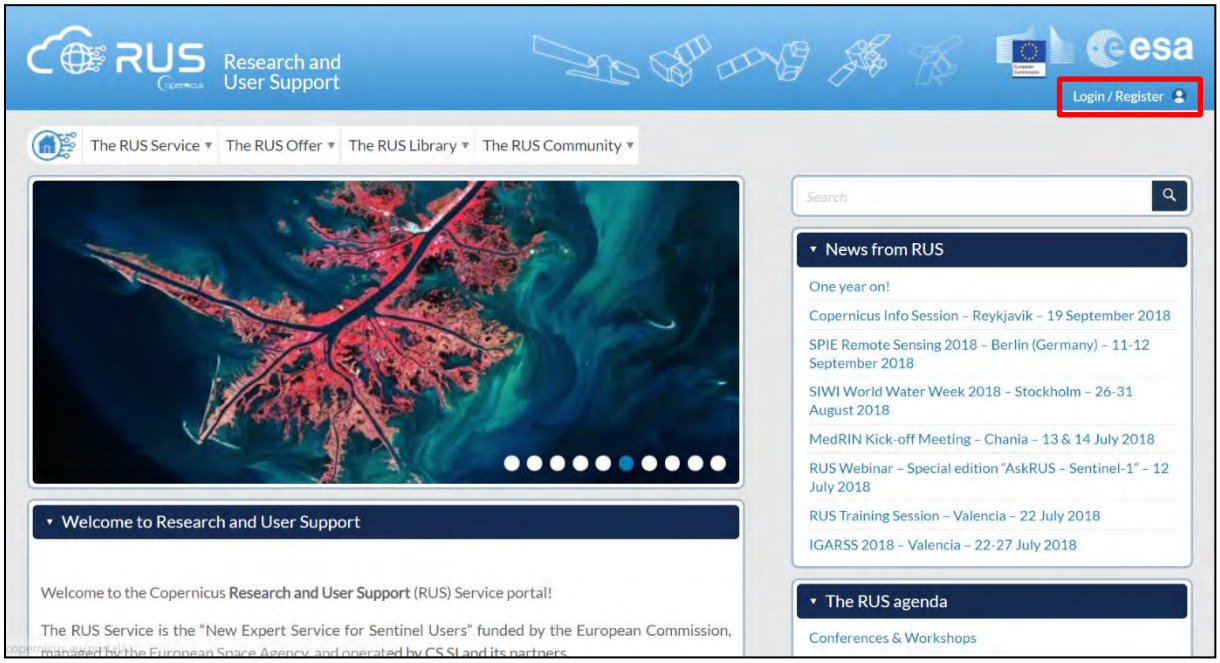
- 3 Sentinel-5p images acquired during June 2018
- Pre-processed data stored locally
  @/shared/Training/ATMO03_VolcanoEmissions_Guatemala/AuxData/

3.2 Software in RUS environment

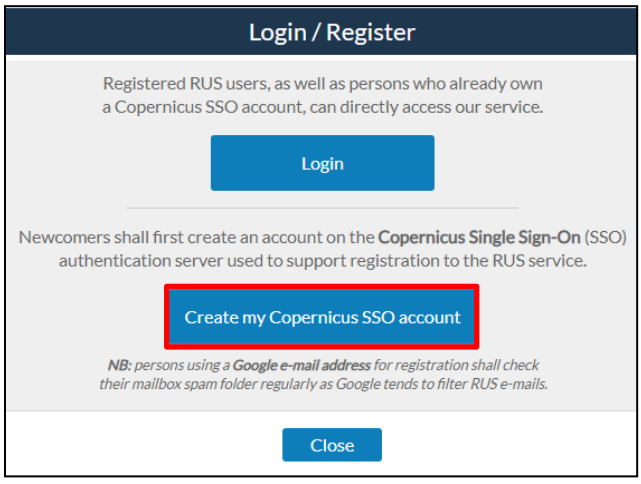
Internet browser, JupyterLab, Python, Anaconda

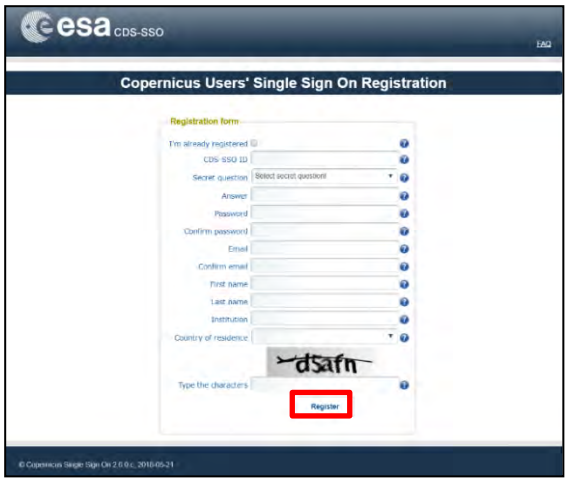
4 Register to RUS Copernicus

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.



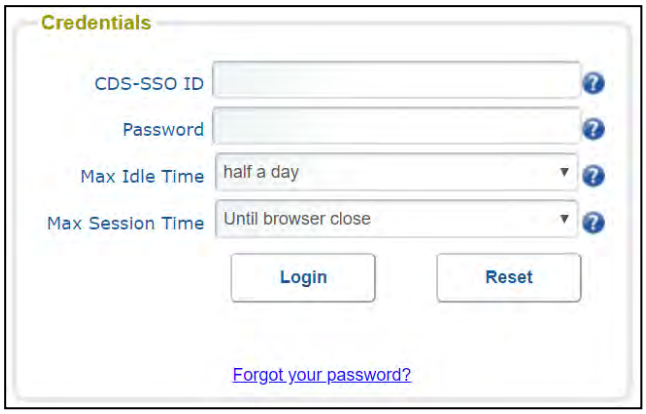
Select the option ***Create my Copernicus SSO account*** and then fill in ALL the fields on the **Copernicus Users' Single Sign On Registration**. Click ***Register***.



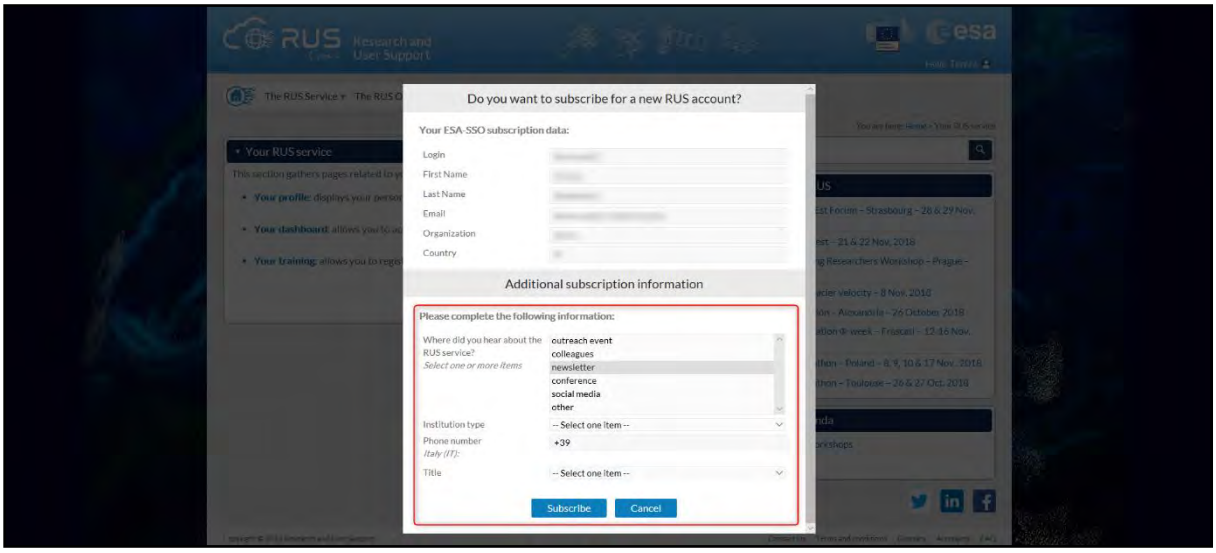


Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the e-mail to activate your account.

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

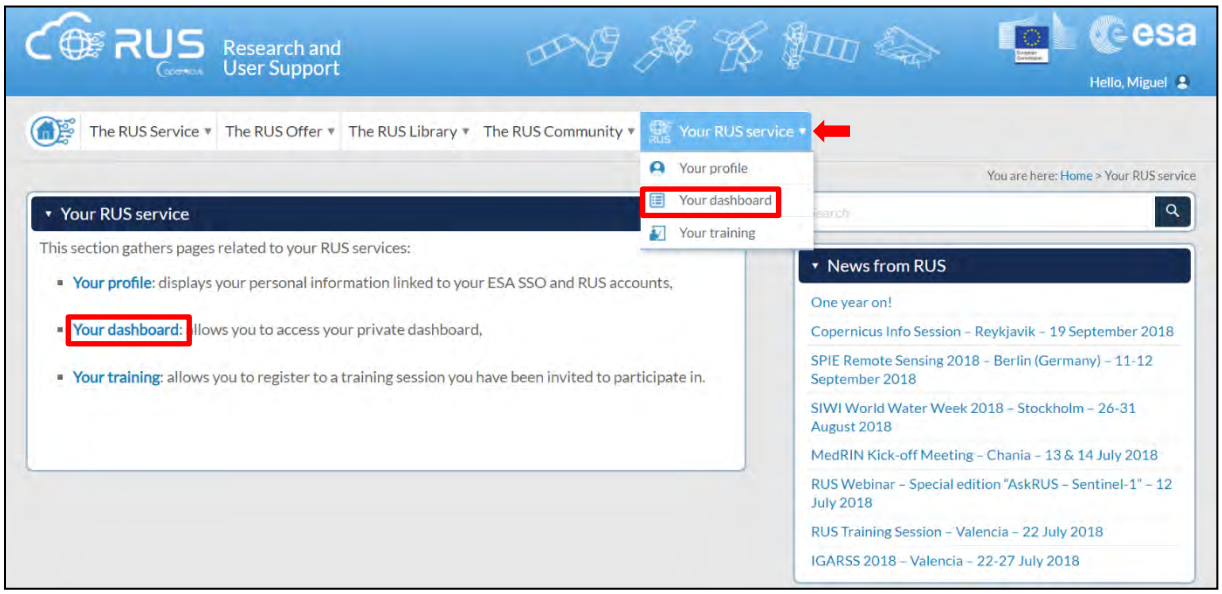


Upon your first login you will need to enter some details. You must fill all the fields.

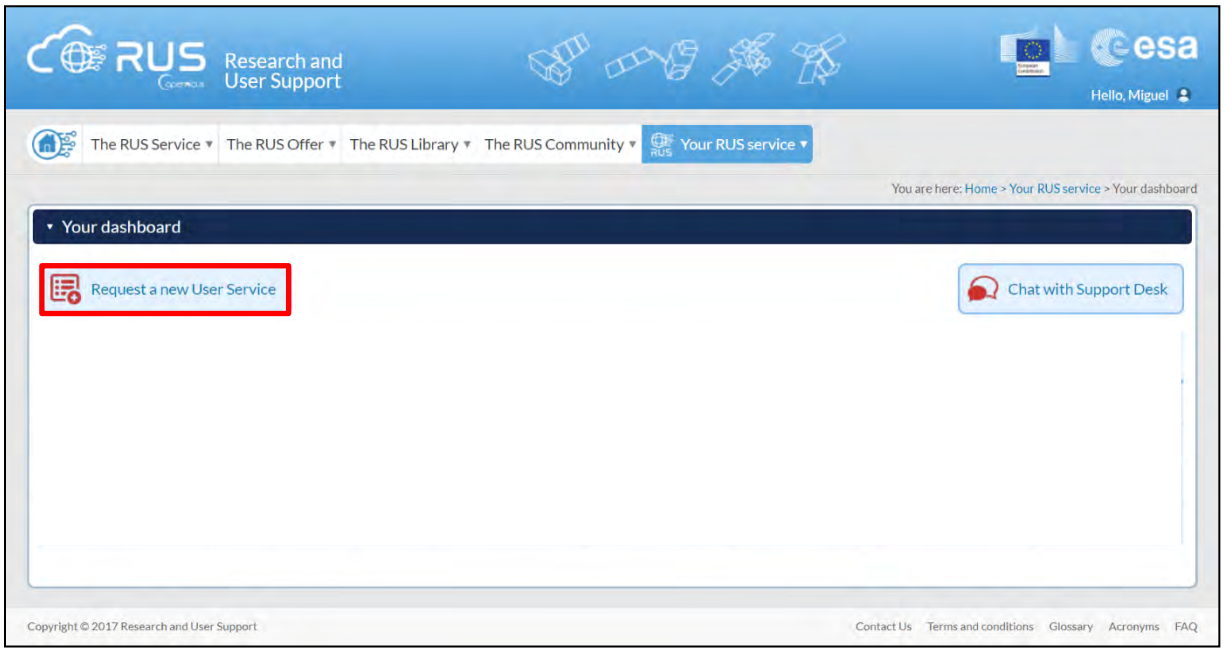


5 Request a RUS Copernicus Virtual Machine

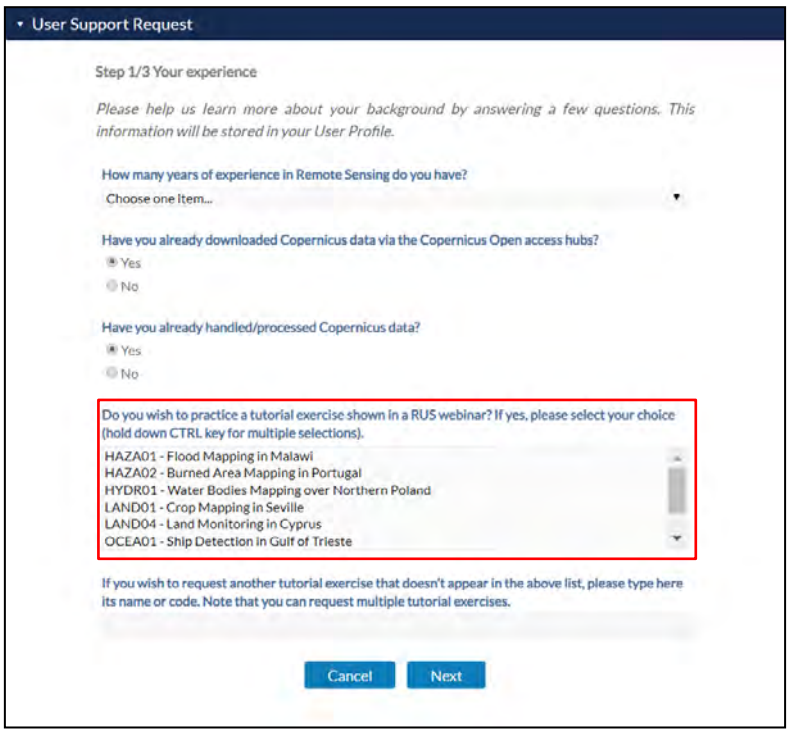
Once you are registered as a RUS user, you can request a RUS Virtual Machine to repeat this exercise or work on your own projects using Copernicus data. For that, log in and click on ***Your RUS Service*** → ***Your Dashboard***.



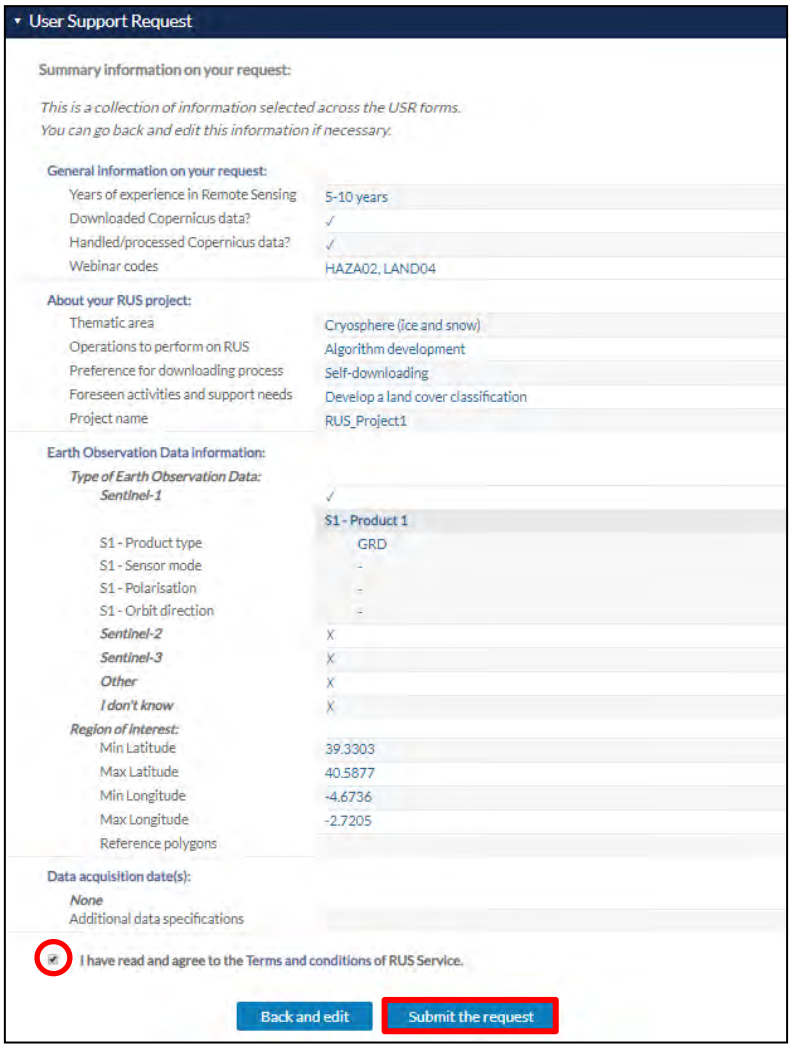
Click on ***Request a new User Service*** to request your RUS Virtual Machine. Complete the form so that the appropriate cloud environment can be assigned according to your needs.



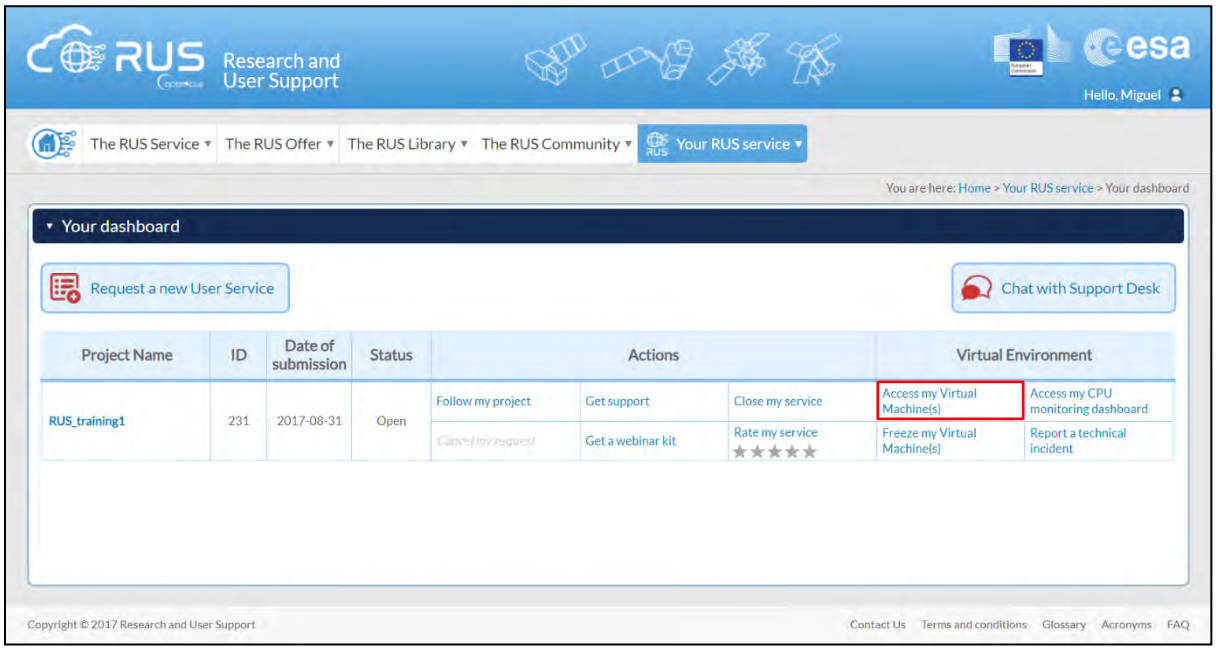
If you want to repeat this tutorial (or any previous one) select the one(s) of your interest in the appropriate field.



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.

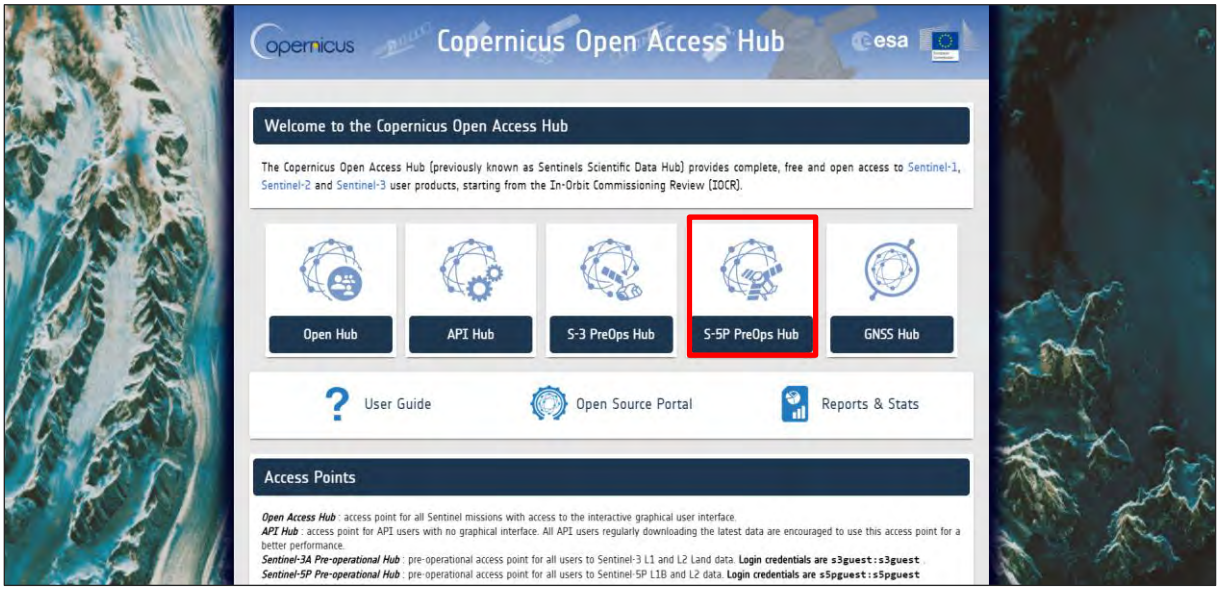
This is the remote desktop of your Virtual Machine.

6 Step by step

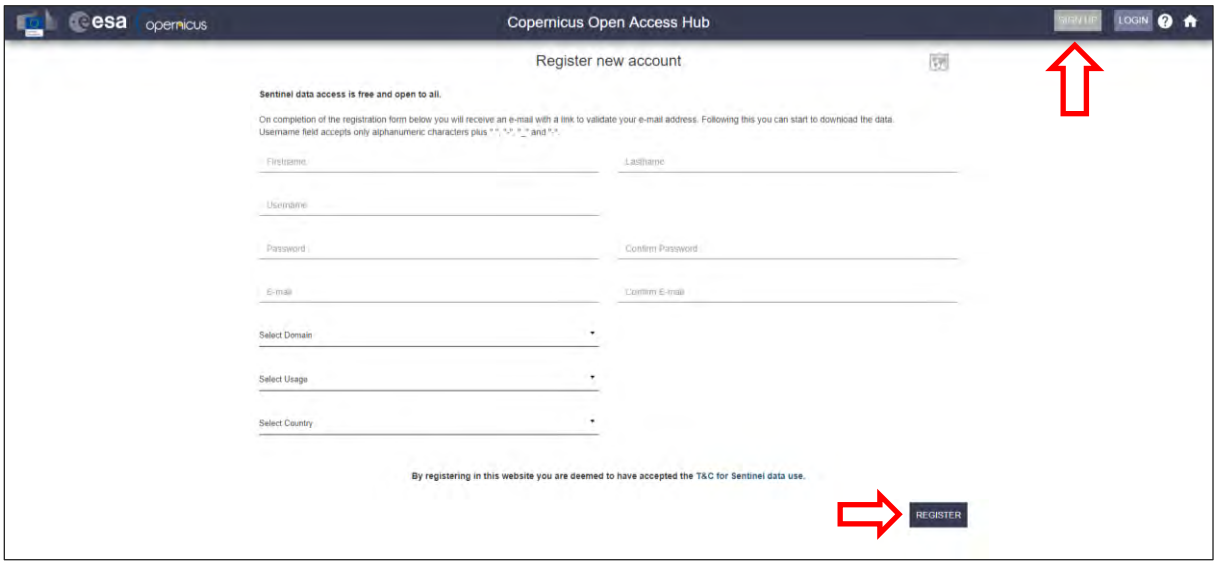
6.1 Data download – ESA SciHUB

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.



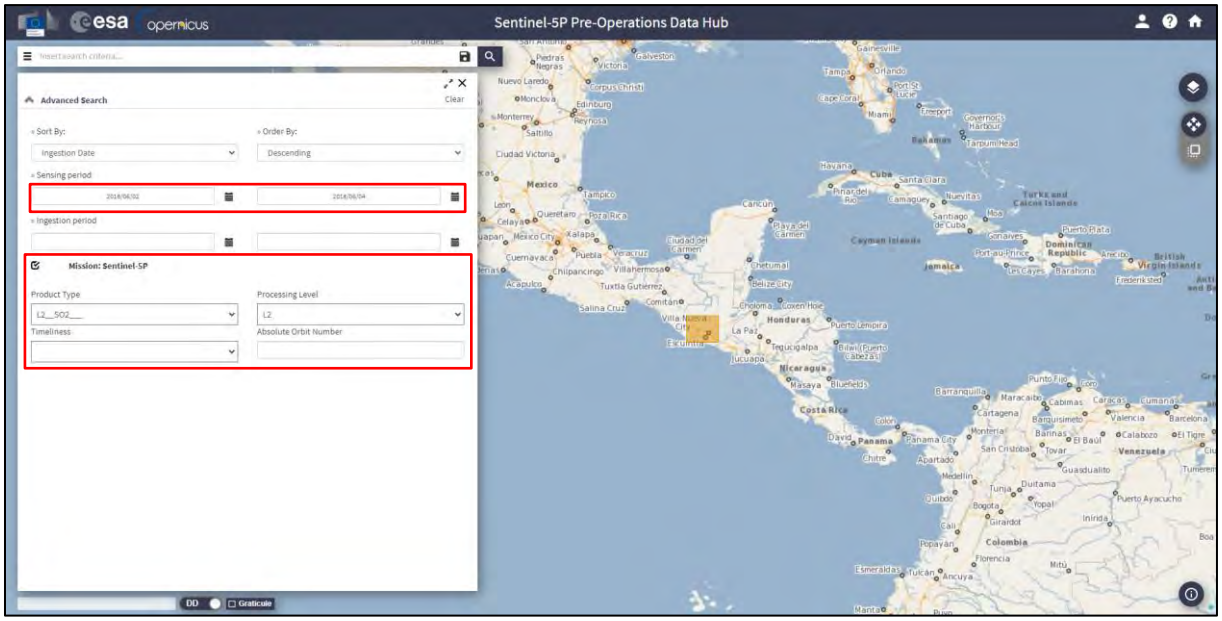
You will receive a confirmation email on the e-mail address you have specified: open the email and click on the link to finalize the registration.

Once your account is activated – or if you already have an account – log in (See NOTE 1).

NOTE 1: At the time of creation of this tutorial (February 2021), Sentinel-5p products are still only accessible through the Sentinel-5p Pre-Operations Data Hub. To download S-5p products, log in using *s5pguest* as username and password. In the near future, products will be moved to the regular Copernicus Open Access Hub where you will be requested to log in with your own credentials. For that, create an account as explained previously.

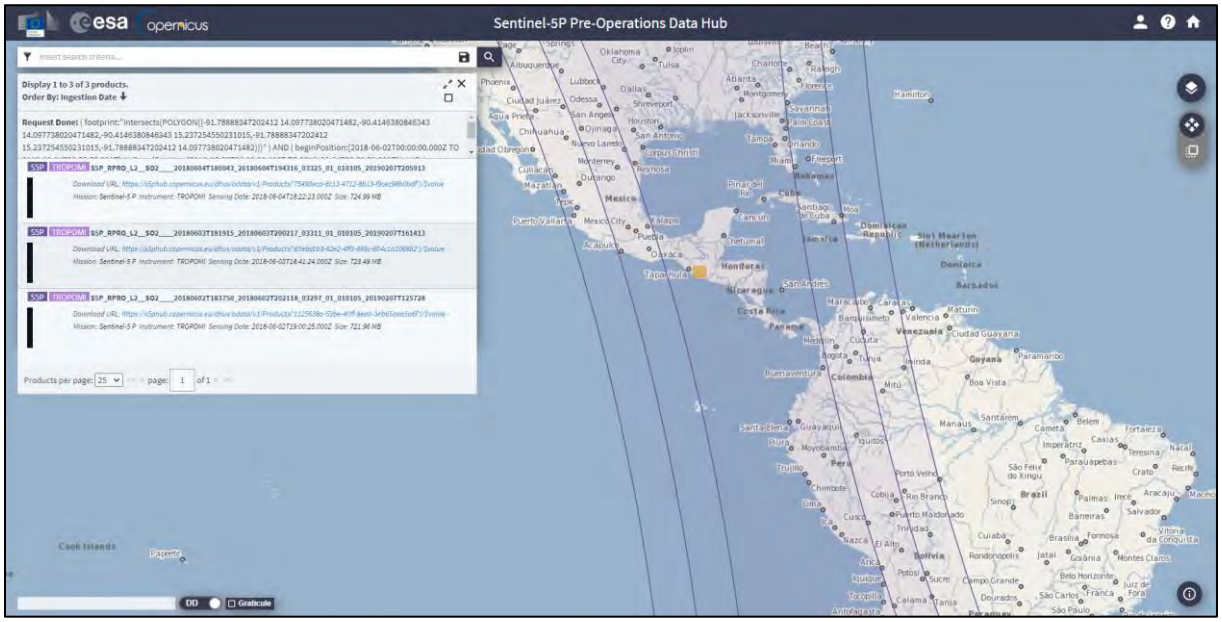
In this guide, we describe the procedure to download the Sentinel-5p images for 2020. Make sure you repeat the same procedure and download the products for June 2018. Define the study area over Guatemala City. Then, open the search menu by clicking to the left part of the search bar (☰) and specify the parameters below. Press the search button (🔍) after that.

Sensing period: From 2018/06/02 to 2018/06/04
Check Mission: Sentinel-5p
Product type: L2__SO2
Processing level: L2



In this case the search returns 3 results. Download all the products (products will be saved in */home/rus/Downloads)* and move them to the following path (See NOTE 2 and 3).

Path: */shared/Training/ATMO03_VolcanoEmissions_Guatemala/Original/*



NOTE 2: Sentinel-5p counts 14 orbits per day. Due to the starting (d) and end acquisition time (d+1) during the last orbit, when looking for all the products of a day the result may output 13 products instead of 14. To complete the global coverage, you may need to increase by one day the sensing time to find the last product.

NOTE 3: Sentinel-5p products are delivered as netCDF files. The Network Common Data Form, or netCDF, is an interface to a library of data access functions for storing and retrieving data in the form of arrays. An array is an n-dimensional (where n is 0, 1, 2, ...) rectangular structure containing items which all have the same data type (e.g., 8-bit character, 32-bit integer). A scalar (simple single value) is a 0-dimensional array. a large amount of free software as well as commercial or licensed packages is available at the UniData website.

6.2 Sentinel-5p Python Processing - Jupyter Notebook

Further processing and instructions to continue the analysis of Sentinel-5p images will be performed using Python code in JupyterLab (Anaconda Distribution) (see NOTE 4 and NOTE 5) provided with this training kit.

We will open JupyterLab by launching it from a specific conda environment that is provided to you. For that, open Terminal in your RUS Virtual Machine and copy-paste the following script. Then, press *Enter* to run it (this step may take several minutes, be patient).

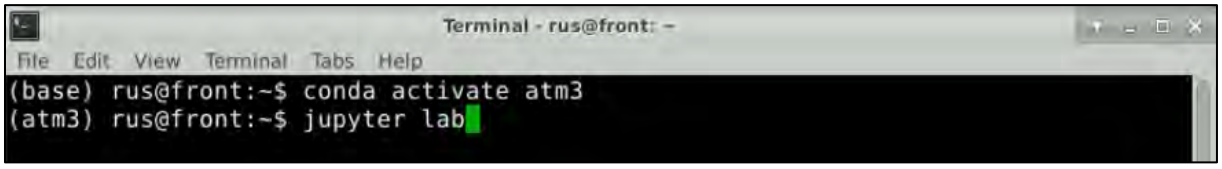
```
conda env create -f /shared/Training/ATMO03_VolcanoEmissions_Guatemala/AuxData/enviro
nment.yml
```

Once the process is finished, activate the environment by running the following script in Terminal.

```
conda activate atm3
```

Next, write Jupyter Lab and press enter to launch the application. Once open, navigate to the following path inside the JupyterLab GUI and open the file *Code_ATMO03.ipynb*

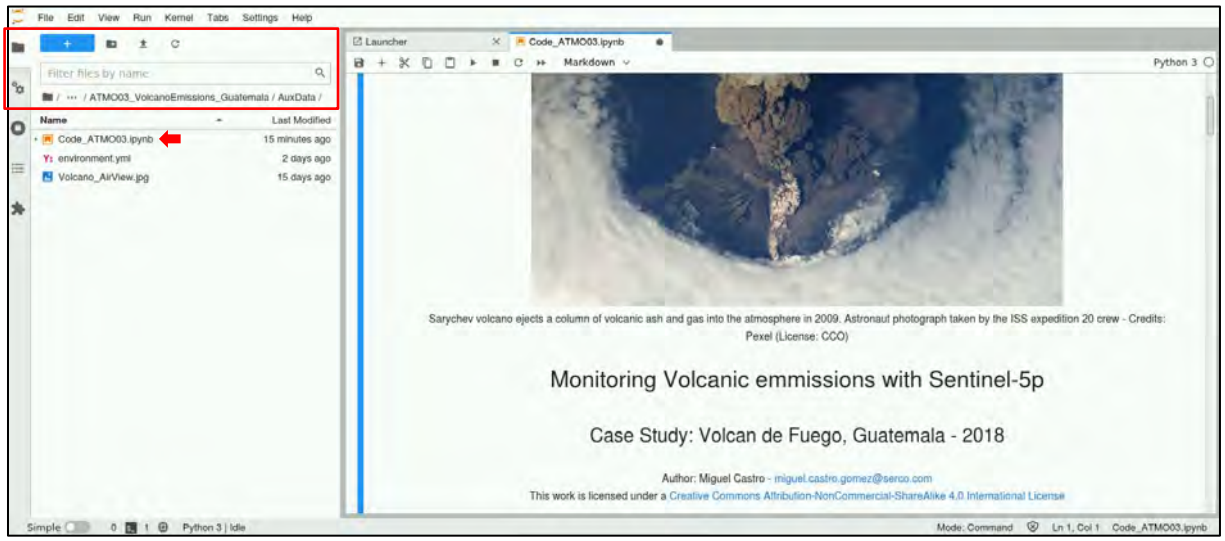
```
jupyter lab
```



Path: /shared/Training/ATMO03_VolcanoEmissions_Guatemala/AuxData/

NOTE 4: 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/



NOTE 5: 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

Follow the instructions in the JupyterLab Notebook to continue the exercise.

THANK YOU FOR FOLLOWING THE EXERCISE!

7 Further reading and resources

Sentinel-5 User Guide

https://sentinel.esa.int/web/sentinel/user-guides/sentinel-5p-tropomi

Sentinel-5 Technical Guide

https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-5p/products-algorithms

Tropomi

http://www.tropomi.eu/

FOLLOW US!!!

 @RUS-Copernicus

 RUS-Copernicus

 RUS-Copernicus

 RUS Copernicus Training

 RUS-Copernicus website

 RUS-Copernicus Training website