

RUS
Copernicus



TRAINING KIT – ATMO05

FIRE EMISSIONS MONITORING WITH SENTINEL-5P

Case Study: Turkish wildfires, August 2021



Research and User Support for Sentinel Core Products

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Table of Contents

1	Introduction to RUS.....	3
2	Wildfire emissions monitoring from space - background	3
3	Training.....	4
3.1	Data used.....	4
3.2	Software in RUS environment	4
4	Register to RUS Copernicus	4
5	Request a RUS Copernicus Virtual Machine to repeat a Webinar	6
6	Step by step	8
6.1	Data download – ESA SciHUB.....	8
6.2	Sentinel-5P Python Processing – Jupyter Notebook	12
7	Further reading and resources	14

1 Introduction to RUS

The **R**esearch and **U**ser **S**upport 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 acquired by the Copernicus Sentinel satellites constellation.

In this tutorial, we will assess and monitor the aerosol and gas plumes emitted by the 2021 Turkish wildfires using processed Sentinel-5P products. We will carry out this study using Python code in the Jupyter notebook environment on a RUS virtual machine.

2 Wildfire emissions monitoring from space - background

Copernicus is the European Union's Earth Observation programme. It greatly relies on observations from various satellites called the Sentinels. Each Sentinel mission has its own specificities and addresses various environmental and societal needs. Combined together, the measurements collected by these satellites give us a precise, reliable and near-real time view of numerous key indicators on the state of our environment.

The Sentinel-5P (S5P) mission launched in 2017 screens the Earth atmosphere to quantify different pollutants (O₃, CO, NO₂, SO₂, aerosols...) with a great accuracy and a high spatial resolution. The observations sensed by the TROPOspheric Monitoring Instrument (TROPOMI) on board S5P are free of use and provide global information on air quality, greenhouse gas emissions as well as detailed elements to detect and assess the impact of polluting events.



In particular, when a record-breaking heatwave hit the mediterranean basin in the middle of summer 2021, the measurements recorded by S5P were of prime interest to detect and assess the severity of the emissions resulting from the gigantic wildfires that broke out at many different locations. These dramatic events lasted for several weeks, ravaged hundreds of thousands of hectares of forests and released thick smoke and toxic gases in our atmosphere.

These direct emissions of toxic pollutants can have dramatic effects on the first responders and local residents. Moreover, atmospheric transport may carry the wildfire plumes very far away from the emitting sources which can lead to harmful exposures for populations sometimes living thousands of kilometres away from the fires. Monitoring the wildfire emissions and their direction is hence fundamental to implement mitigation plans. With its global coverage and frequent time revisit,

TROPOMI constitutes a privileged tool to accurately detect and monitor the heavy aerosol plumes and carbon monoxide emissions generated by the forest fires.

3 Training

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

The Training Code for this tutorial is **ATMO05**. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the [RUS portal](#) to request a Virtual Machine. Go to **Your RUS Service → Your training activities and Request a Webinar Training**.

3.1 Data used

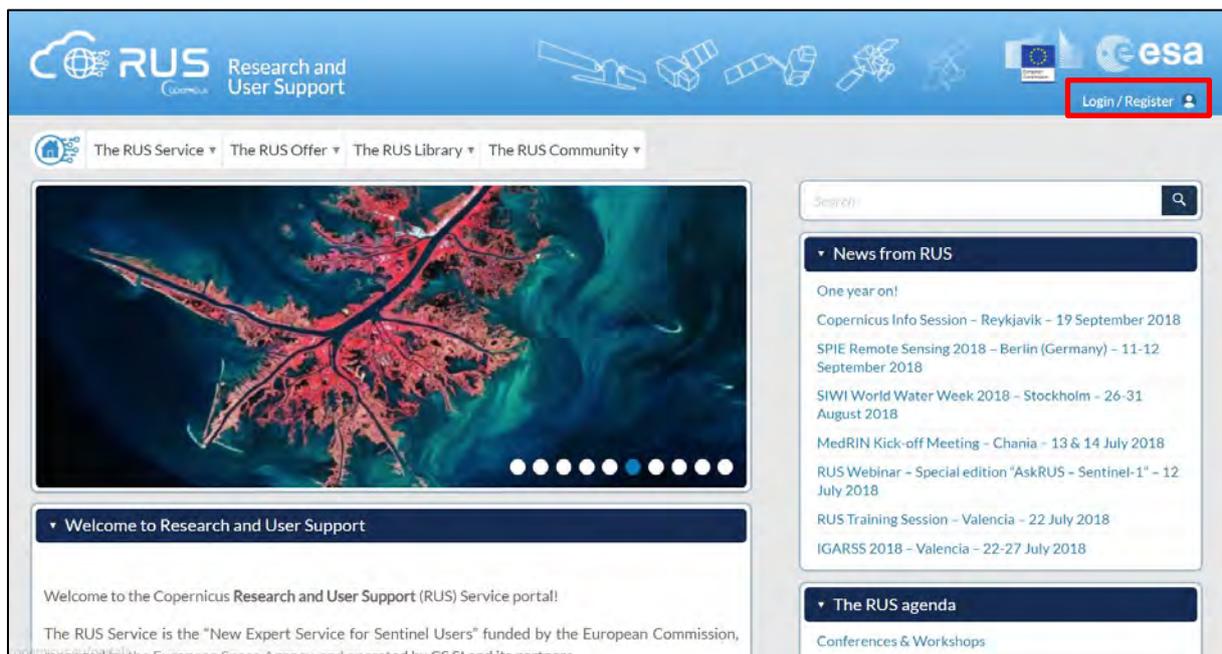
- 24 Sentinel-5P UV Absorbing Aerosol (AER_AI) Index products acquired between July 29th and August 9th over South Turkey (see section 6.1)
[downloadable @ <https://scihub.copernicus.eu/>]
- 28 Sentinel-5P Carbon Monoxide (CO) products acquired between July 27th and August 9th over South Turkey

3.2 Software in RUS environment

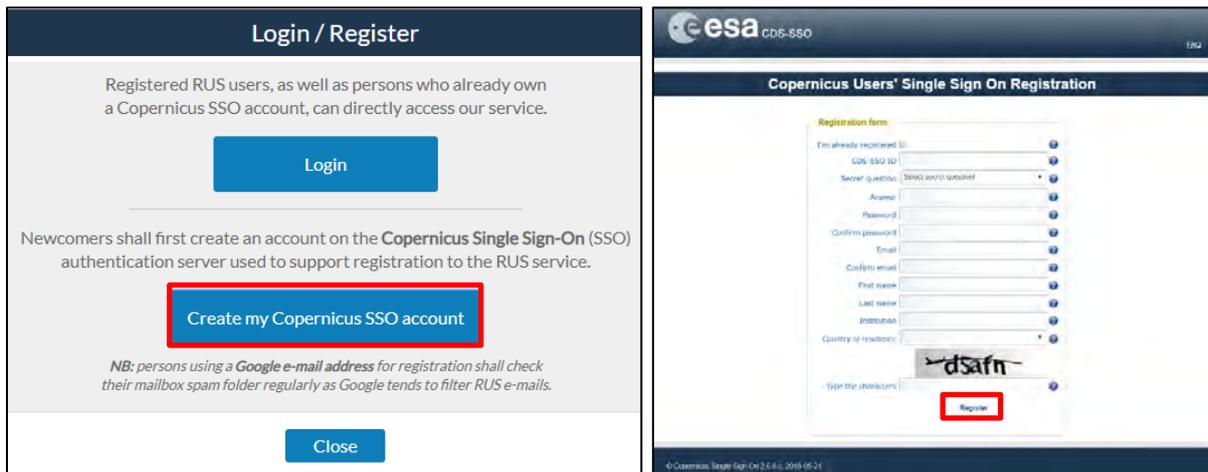
Internet browser, JupyterLab, Python

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.

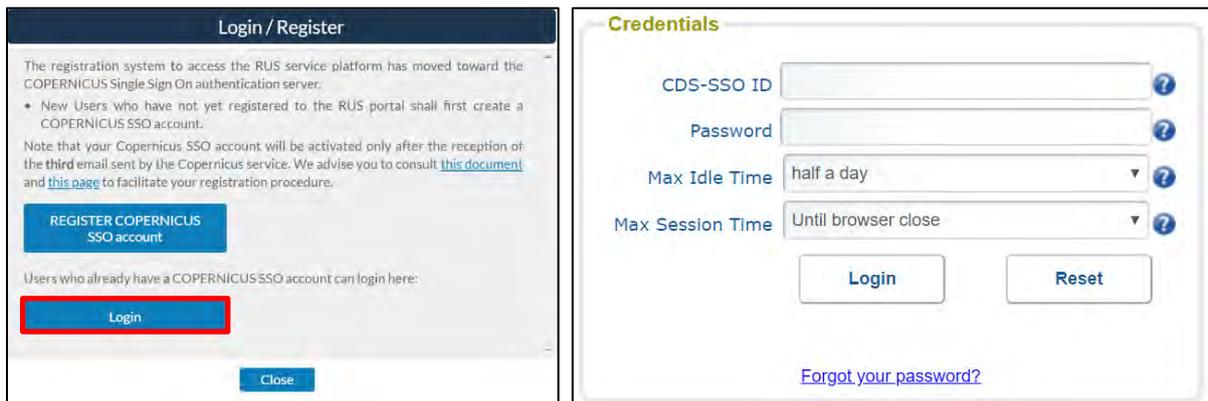


Select the option **Create my Copernicus SSO account** and then fill in ALL the fields on the **Copernicus Users' Single Sign On Registration**. Click **Register**.

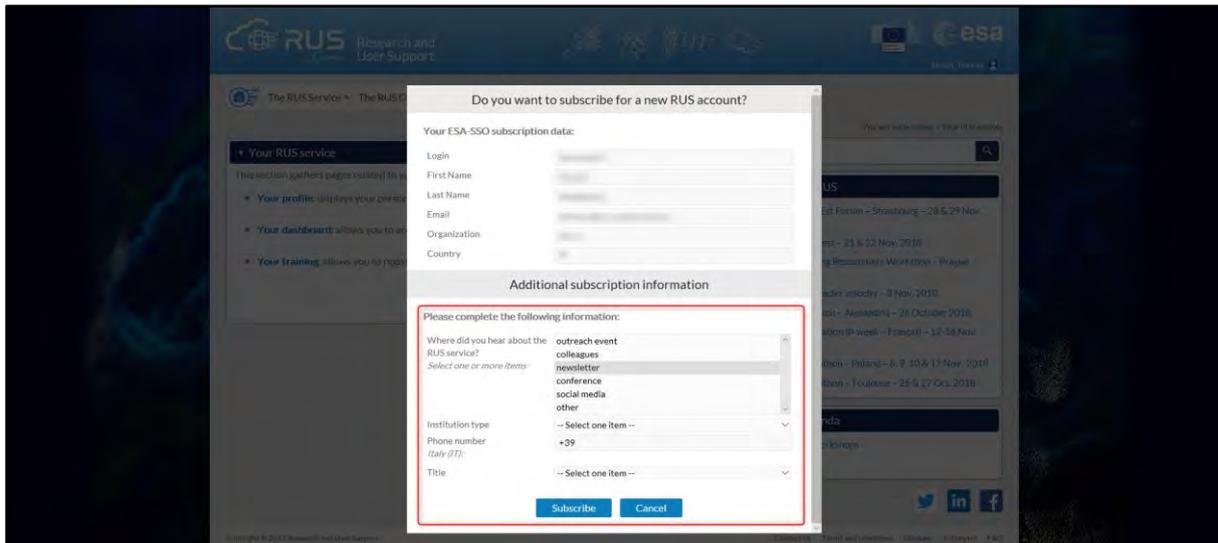


Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the e-mail to activate your account.

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.

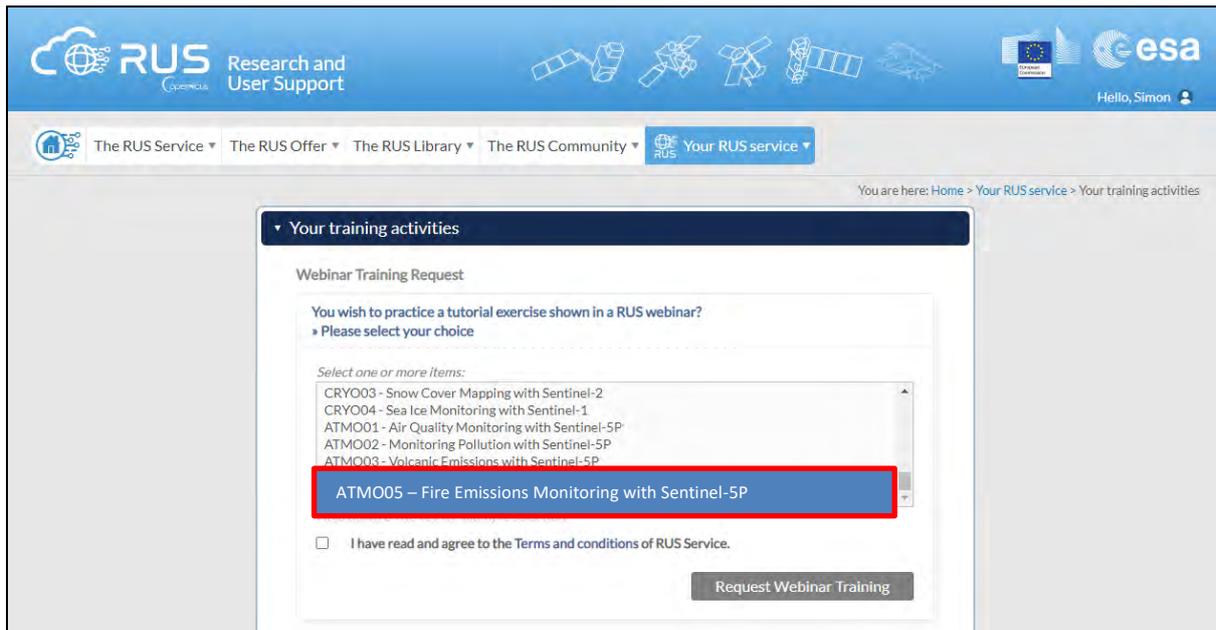


5 Request a RUS Copernicus Virtual Machine to repeat a Webinar

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 training activities**.



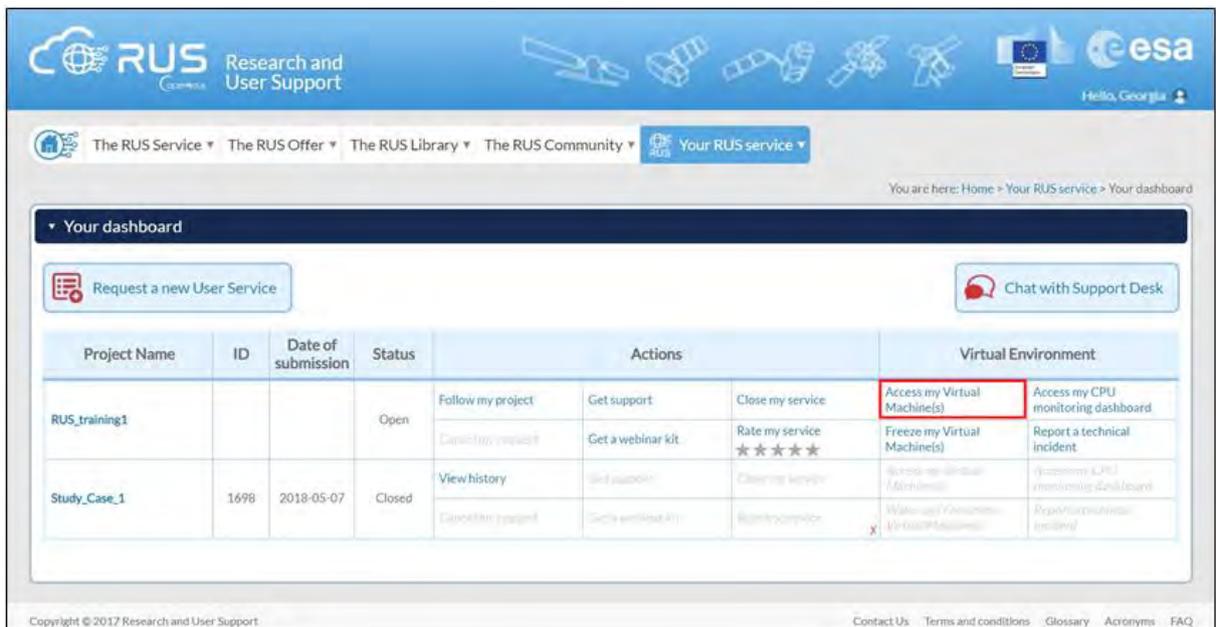
Select **ATMO05 – Fire Emissions Monitoring with Sentinel-5P**, check the field “I have read and agree to the Terms and conditions of RUS Service” and then click on **Request Webinar Training** to request your RUS Virtual Machine.



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**.

NOTE: If the **“Access my Virtual Machine”** is greyed out, please access your VM from the direct link you have received at the email informing you about the creation of your VM.



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

opernicus Copernicus Open Access Hub esa

Welcome to the Copernicus Open Access Hub

The Copernicus Open Access Hub (previously known as Sentinels Scientific Data Hub) provides complete, free and open access to Sentinel-1, Sentinel-2, Sentinel-3 and Sentinel-5P user products, starting from the In-Orbit Commissioning Review (IOCR).

Sentinel Data are also available via the Copernicus Data and Information Access Services (DIAS) through several platforms .

Please visit our [User Guide](#) for getting started with the Data Hub Interface. Discover how to use the APIs and create scripts for automatic search and download of Sentinels' data, with synchronous access to the latest data and asynchronous access to historic data via the API and GUI.

For further details or requests of support please send an e-mail to esosupport@copernicus.esa.int

Reports & Stats

Data updated hourly

38,892 prod. published in the last 24h

338,550 downloads in the last 24h

Reports

Resources

- DHUS Open Source Portal
- Copernicus Portal
- Sentinel Online
- S-1 Quality Control
- S-2 Quality Reports

Latest News

New processing baseline (03.01) for Copernicus Sentinel-2 L1C and L2A products 29 Jun 2021

Copernicus Sentinel-5P Missing data on orbit 19116 and 19117 22 Jun 2021

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.

Register new account

Sentinel data access is free and open to all.

On completion of the registration form below you will receive an e-mail with a link to validate your e-mail address. Following this you can start to download the data.

Username field accepts only lowercase alphanumeric characters plus "." and "-"

Password field accepts only alphanumeric characters plus "!", "@", "#", "\$", "%", "&", "*", "(", ")", "=", "+", ":", ";", "<", ">", "–", "—", "‘", "’"

Password fields minimum length is 8 characters

Firstname: _____ Surname: _____

Username: _____

Password: _____ Confirm Password: _____

E-mail: _____ Confirm E-mail: _____

Select Domain: _____

Select Usage: _____

Select your country: _____

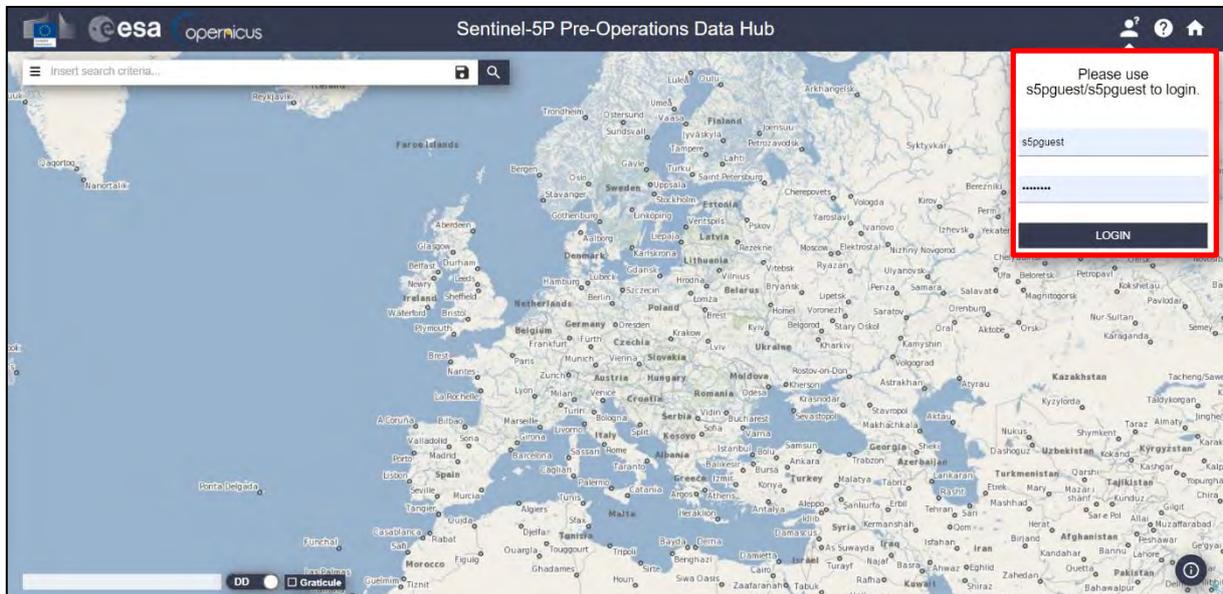
By registering in this website you are deemed to have accepted the T&C for Sentinel data use.

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 (November 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 manually download the Sentinel-5P Aerosol images for 29/07/2021 – 09/08/2021. Later on in the webinar, we will show a useful method to retrieve the products automatically following user defined criterions. It is still important to know the functioning of the sciHub graphic interface as it offers a nice display of the geographical hold of the products as well as a convenient way of exploring the files without actually downloading them.

When on the sciHub map, zoom in to Turkey and define the study area using the  button (approximate area – orange rectangle). 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.

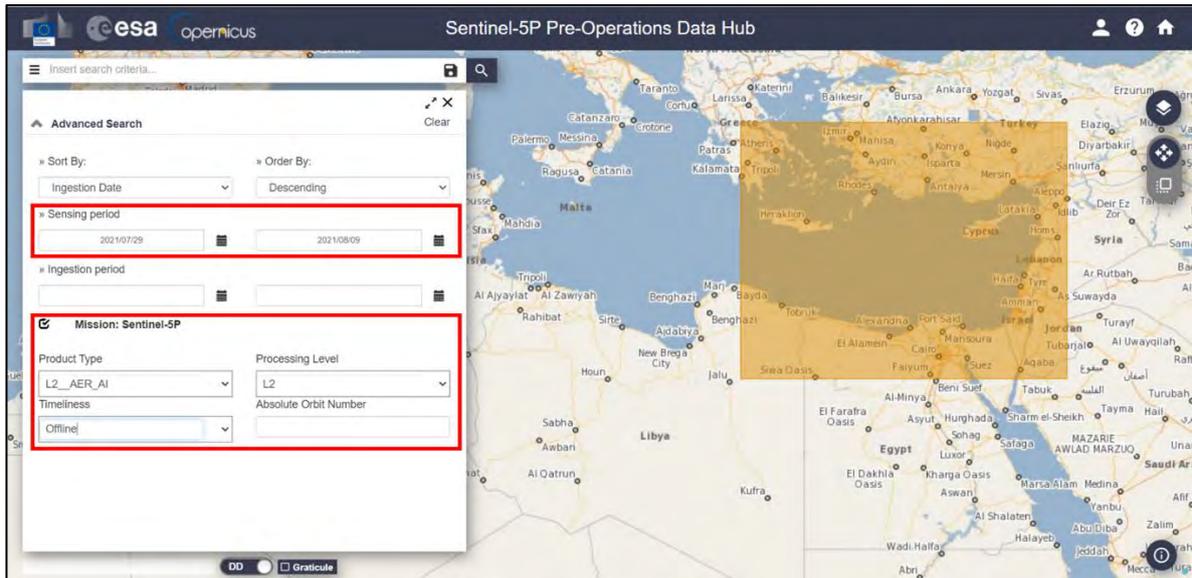
Sensing period: From 2021/07/29 to 2020/08/09

Check mission: Sentinel-5P

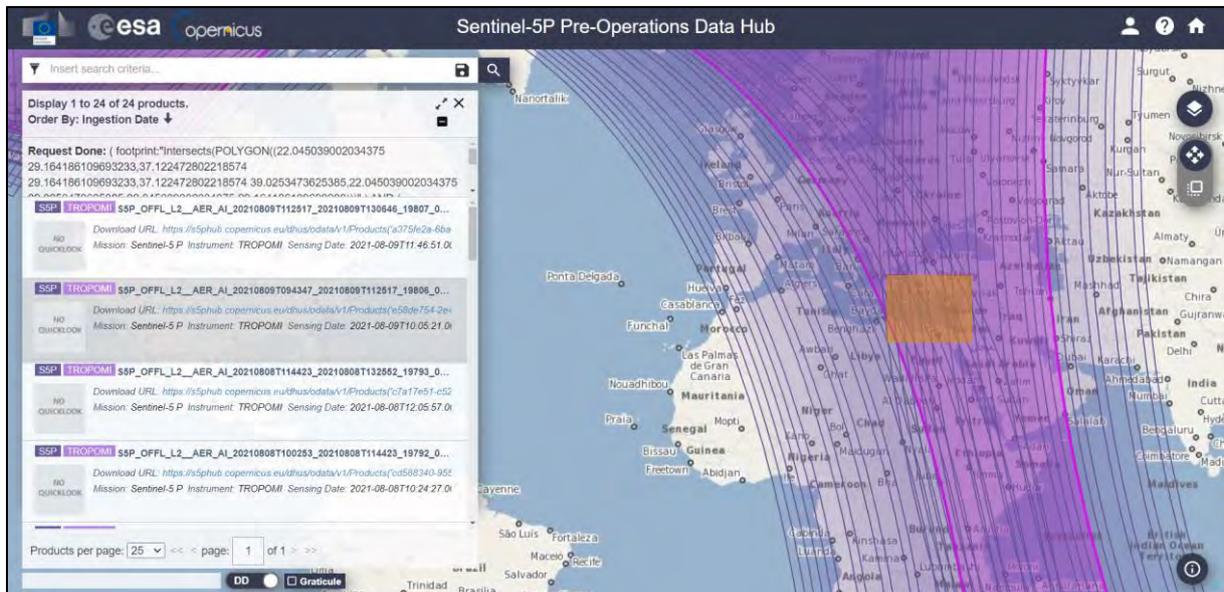
Product type: L2__AER_AI

Processing level: L2

Timeliness: Offline



In this case, the search returns 24 results. It may vary by one to three products according to the exact area of interest you defined. It does not matter too much as we have defined the orange rectangle significantly bigger than our actual area of interest.



You can download all products (they will be saved in `/home/rus/Downloads`) and move them to the following path (See NOTE 2 and 3). If you do not want to manually retrieve the products one by one, we will download them automatically a bit later.

Path: `/shared/Training/ATMO05_FireEmissions_Turkey/Original/S5P_AER_AI/`

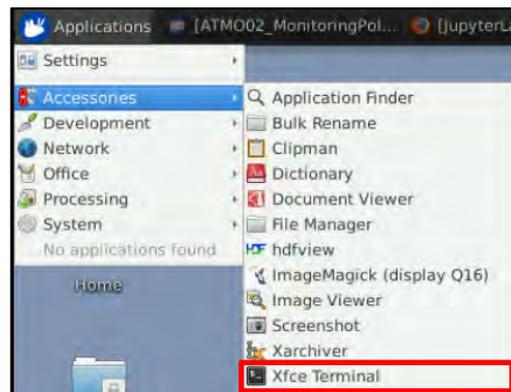
NOTE 2: Sentinel-5P counts 14 orbits per day. Due to the starting (d) and end acquisition time (d+1) during the last orbit, when looking for all the products of a day the result may output 13 products instead of 14. To complete the global coverage, you may need to increase by one day the sensing time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

NOTE 3: Sentinel-5P products are delivered as netCDF files. There is a single NetCDF file per orbit. *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 (From NetCDF User's Guide).* 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. To open a Terminal, go to *Applications* → *Accessories* and hit **Xfce 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).

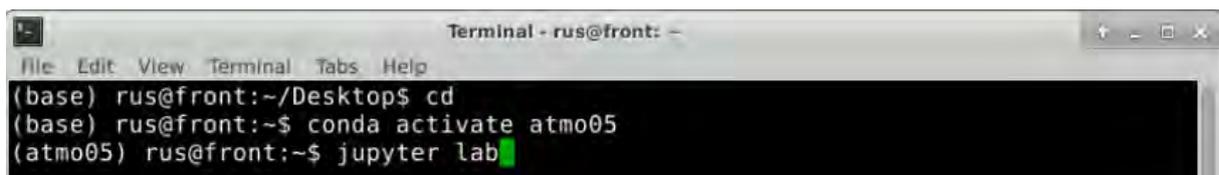


```
conda env create -f /shared/Training/ATMO05_FireEmissions_Turkey/AuxData/atmo05.yml
```

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

```
conda activate atmo05
```

Next write jupyter lab and press enter to launch the application.

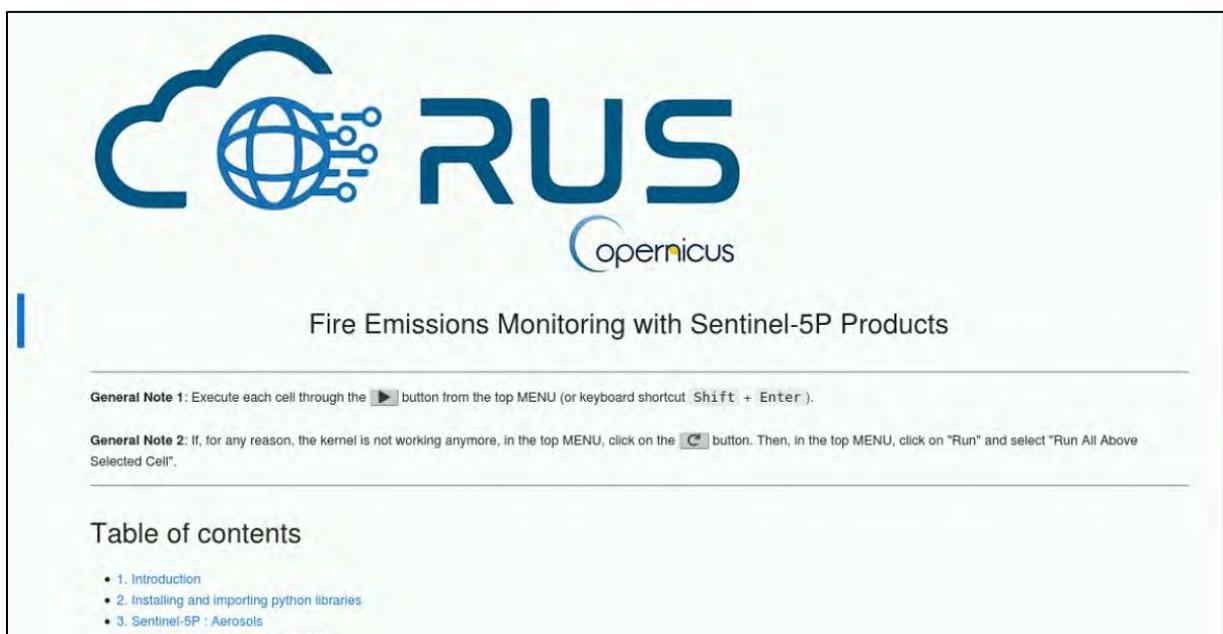


Once open, navigate to the following path inside the JupyterLab GUI and open the file *Code_ATMO05.ipynb*

Path:/shared/Training/ATMO05_FireEmissions_Turkey/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/>



General Note 1: Execute each cell through the ▶ button from the top MENU (or keyboard shortcut Shift + Enter).

General Note 2: If, for any reason, the kernel is not working anymore, in the top MENU, click on the ☒ button. Then, in the top MENU, click on "Run" and select "Run All Above Selected Cell".

Table of contents

- 1. Introduction
- 2. Installing and importing python libraries
- 3. Sentinel-5P : Aerosols

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-5P User Guide](#)

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

[Sentinel-5P Technical Guide](#)

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

[Tropomi](#)

<http://www.tropomi.eu/>

[Sentinel-5P L2 UV Aerosol Index Product User Manual](#)

<https://sentinel.esa.int/documents/247904/2474726/Sentinel-5P-Level-2-Product-User-Manual-Aerosol-Index-product>

[Sentinel-5P L2 Carbon Monoxide Product User Manual](#)

<https://sentinels.copernicus.eu/documents/247904/2474726/Sentinel-5P-Level-2-Product-User-Manual-Carbon-Monoxide.pdf/dc93c3ae-6c77-4673-8fe7-459635aba4a3?t=1625591189226>

[The European Forest Fire Information System \(EFFIS\)](#)

<https://effis.jrc.ec.europa.eu/apps/effis.statistics.portal/seasonal-trend/NOTEU/TR>

[The Copernicus Sentinel-5P Mapping Portal](#)

<https://maps.s5p-pal.com/>

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