

# 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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## 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 (O<sub>3</sub>, CO, NO<sub>2</sub>, SO<sub>2</sub>, 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

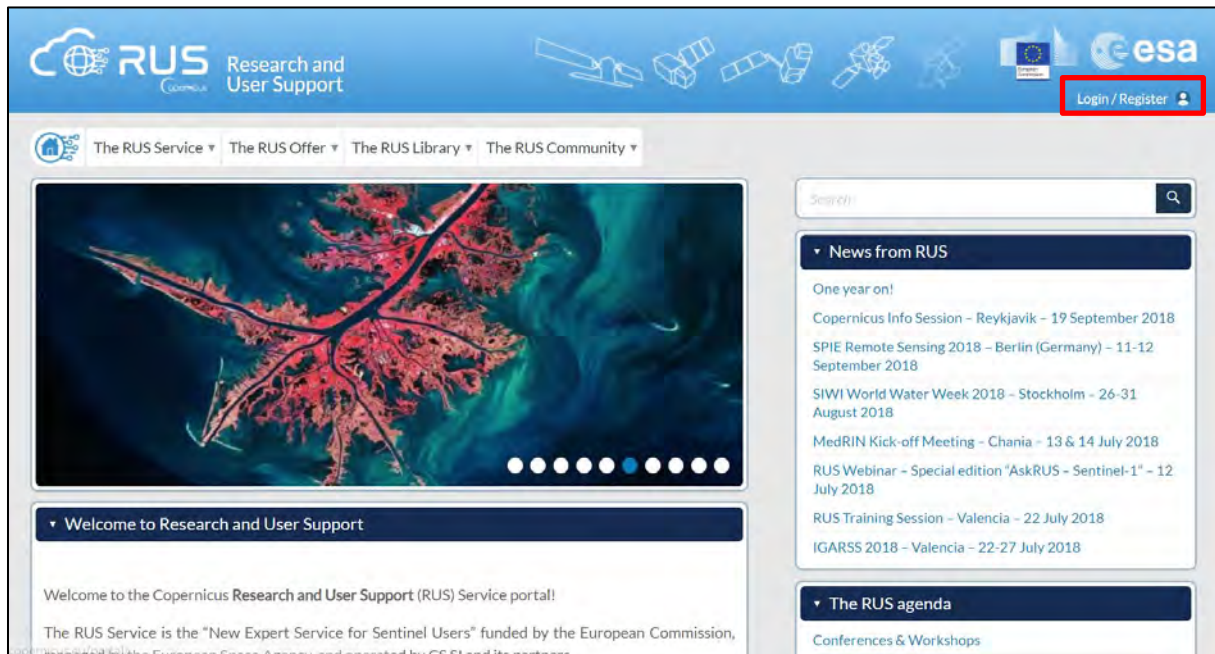
- 24 Sentinel-5P UV Absorbing Aerosol (AER\_AI) Index products acquired between July 29<sup>th</sup> and August 9<sup>th</sup> over South Turkey (see section 6.1)  
[downloadable @ <https://scihub.copernicus.eu/>]
- 28 Sentinel-5P Carbon Monoxide (CO) products acquired between July 27<sup>th</sup> and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

The left screenshot shows the 'Login / Register' page. It has a blue header with the text 'Login / Register'. Below the header, there is a section for registered users with a 'Login' button. Below that, there is a section for newcomers with the text 'Newcomers shall first create an account on the Copernicus Single Sign-On (SSO) authentication server used to support registration to the RUS service.' and a red box around the 'Create my Copernicus SSO account' button. At the bottom, there is a 'Close' button.

The right screenshot shows the 'Copernicus Users' Single Sign On Registration' form. It has a blue header with the text 'esa CDS-SSO' and 'Copernicus Users' Single Sign On Registration'. Below the header, there is a 'Registration form' section with various input fields: 'I'm already registered?', 'CDS SSO ID', 'Secret question', 'Answer', 'Password', 'Confirm password', 'Email', 'Confirm email', 'First name', 'Last name', 'Institution', 'Country of residence', and 'Type the characters'. A red box highlights the 'Register' button at the bottom right of the form.

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.

The left screenshot shows the 'Login / Register' page. It has a blue header with the text 'Login / Register'. Below the header, there is a section for the registration system with the text 'The registration system to access the RUS service platform has moved toward the COPERNICUS Single Sign On authentication server.' and a list of bullet points. Below that, there is a section for users who already have a COPERNICUS SSO account with the text 'Users who already have a COPERNICUS SSO account can login here:' and a red box around the 'Login' button. At the bottom, there is a 'Close' button.

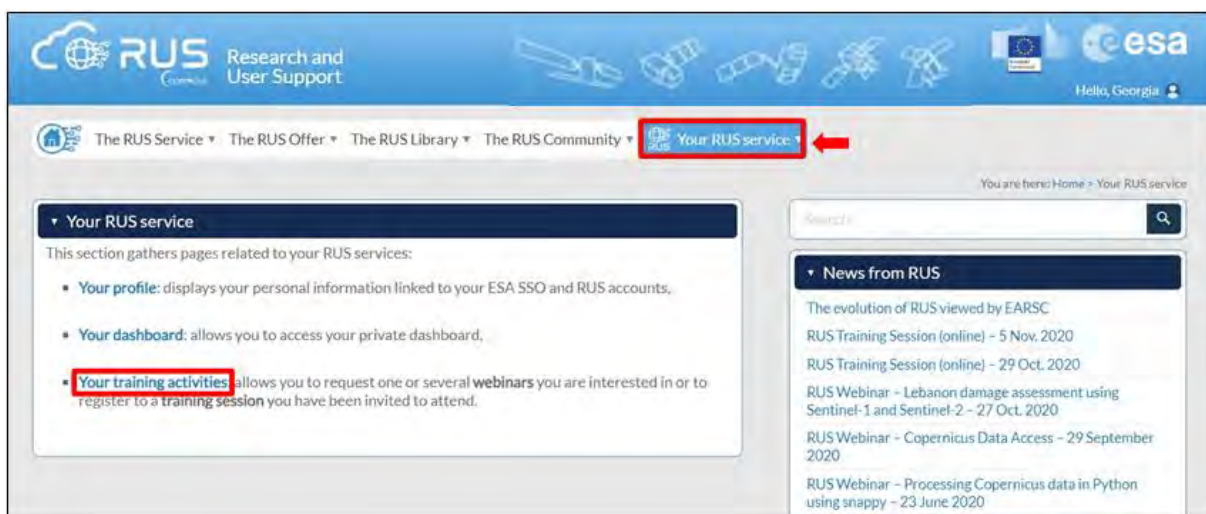
The right screenshot shows the 'Credentials' page. It has a blue header with the text 'Credentials'. Below the header, there are input fields for 'CDS-SSO ID', 'Password', 'Max Idle Time', and 'Max Session Time'. Below these fields, there are 'Login' and 'Reset' buttons. A red box highlights the 'Login' button. At the bottom, there is a link 'Forgot your password?'.

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.

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Hello, Simon

The RUS Service The RUS Offer The RUS Library The RUS Community Your RUS service

You are here: Home > Your RUS service > Your training activities

**Your training activities**

Webinar Training Request

You wish to practice a tutorial exercise shown in a RUS webinar?  
Please select your choice

Select one or more items:

- CRYO03 - Snow Cover Mapping with Sentinel-2
- CRYO04 - Sea Ice Monitoring with Sentinel-1
- ATMO01 - Air Quality Monitoring with Sentinel-5P
- ATMO02 - Monitoring Pollution with Sentinel-5P
- ATMO03 - Volcanic Emissions with Sentinel-5P
- ATMO05 – Fire Emissions Monitoring with Sentinel-5P**

☐ I have read and agree to the Terms and conditions of RUS Service.

Request Webinar Training

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.

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Hello, Georgia

The RUS Service The RUS Offer The RUS Library The RUS Community Your RUS service

You are here: Home > Your RUS service > Your dashboard

**Your dashboard**

Request a new User Service

Chat with Support Desk

Project Name	ID	Date of submission	Status	Actions			Virtual Environment	
RUS_training1			Open	Follow my project	Get support	Close my service	<b>Access my Virtual Machine(s)</b>	Access my CPU monitoring dashboard
				Cancel my request	Get a webinar kit	Rate my service ★★★★★	Freeze my Virtual Machine(s)	Report a technical incident
Study_Case_1	1698	2018-05-07	Closed	View history	Get support	Close my service	Access my Virtual Machine(s)	Access my CPU monitoring dashboard
				Cancel my request	Get a webinar kit	Rate my service	Freeze my Virtual Machine(s)	Report a technical incident

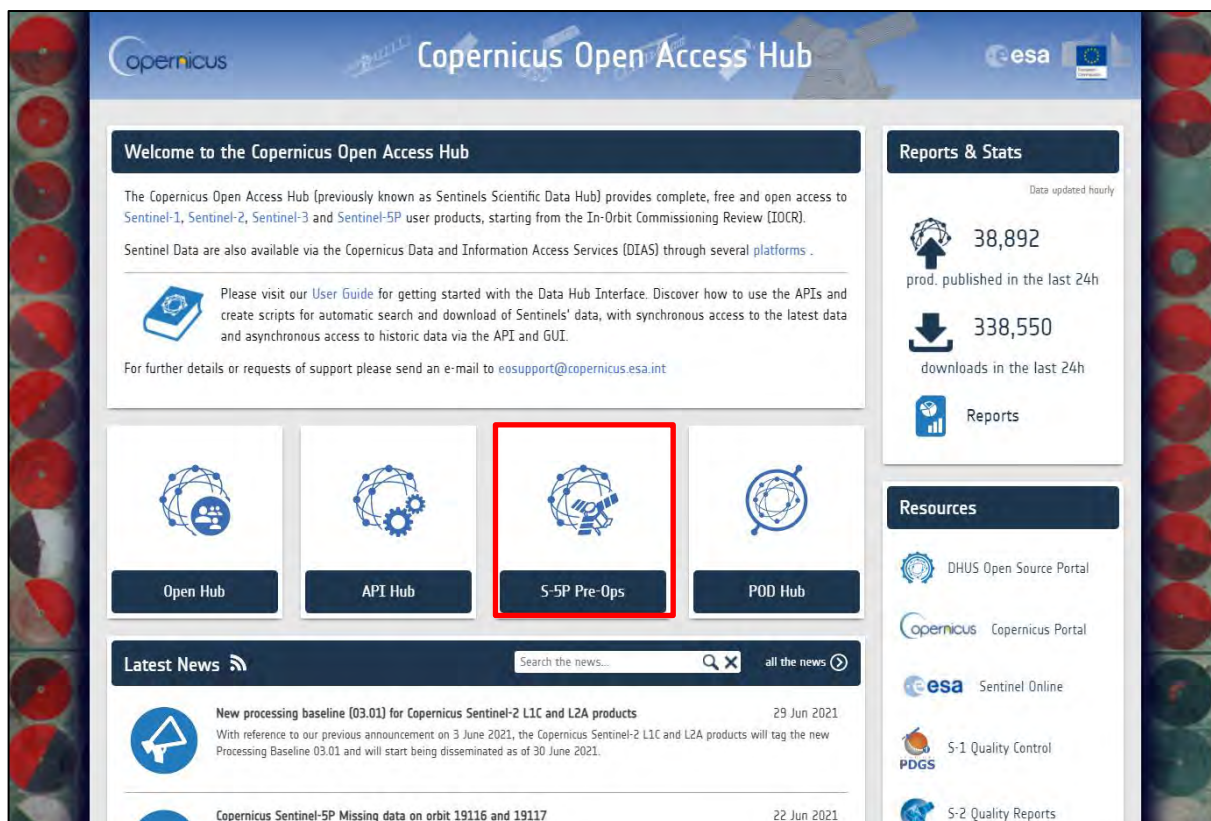
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Contact Us Terms and conditions Glossary Acronyms FAQ

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








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.

The screenshot shows the 'Register new account' form. The form has the following fields: Firstname, Lastname, Username, Password, Confirm Password, E-mail, Confirm E-mail, Select Domain, Select Usage, and Select your country. There are also checkboxes for 'I agree with the Terms and Conditions' and 'I agree to receive emails from Copernicus'. A red arrow points to the user icon in the top right corner, and another red arrow points to the 'REGISTER' button at the bottom right.




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

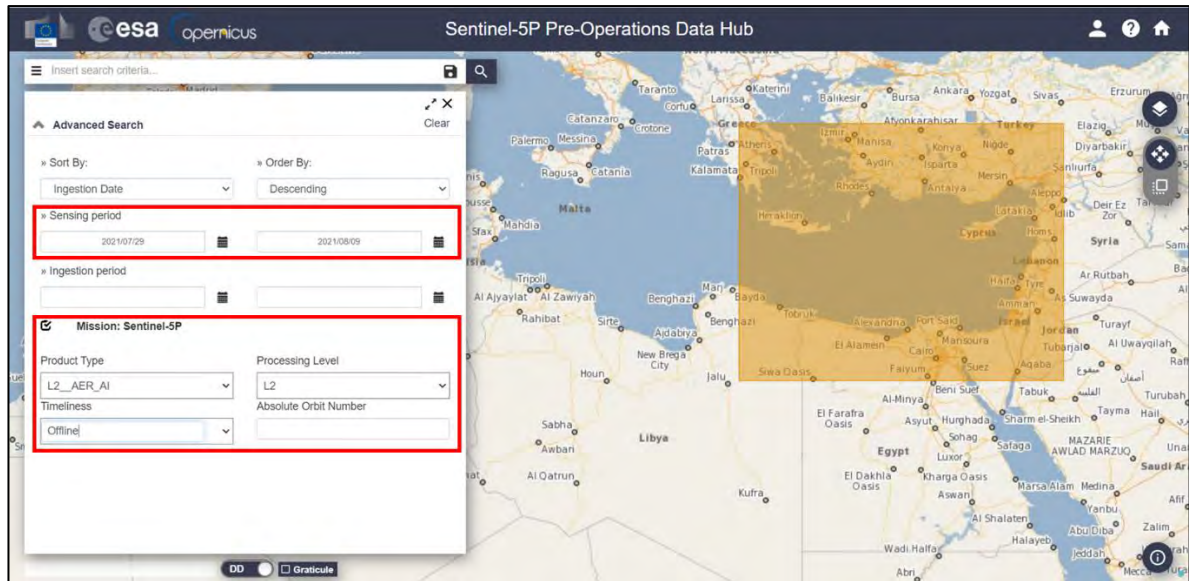
**Check mission:** Sentinel-5P

**Product type:** L2\_\_AER\_AI

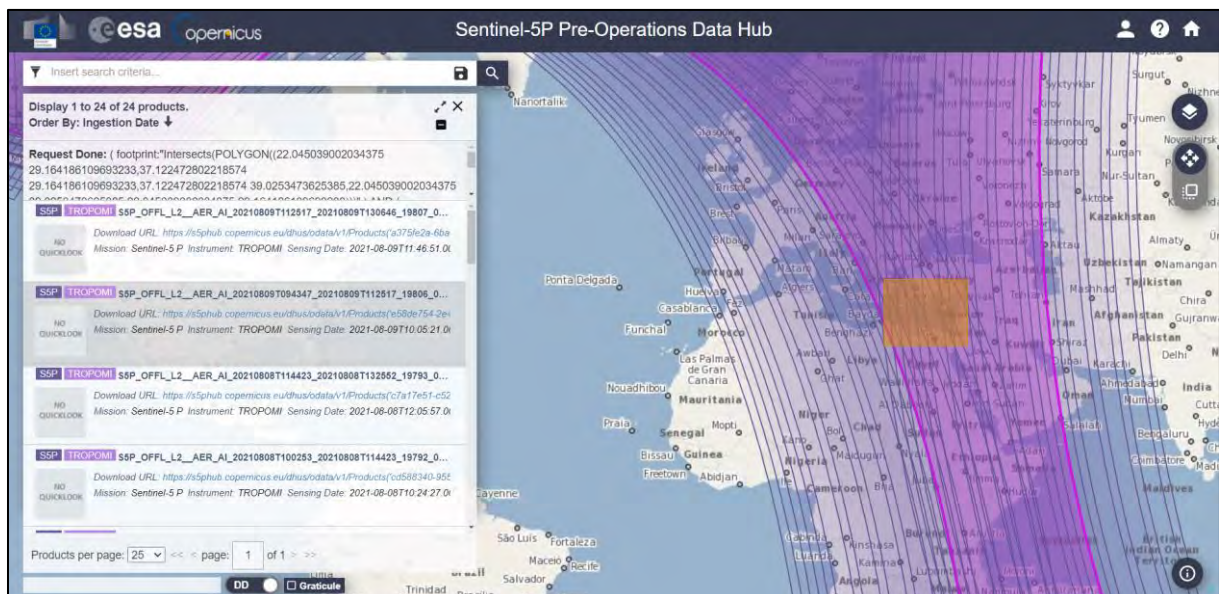
**Processing level:** L2

**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/`

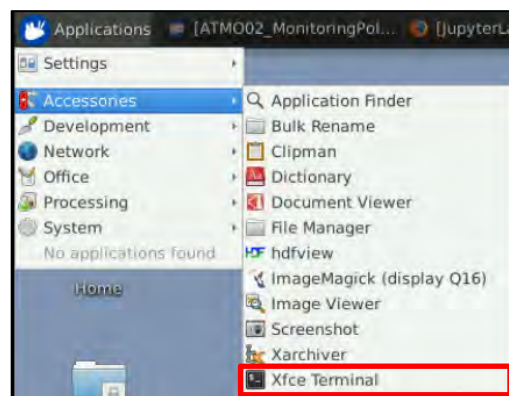
NOTE 2: Sentinel-5P counts 14 orbits per day. Due to the starting (d) and end acquisition time (d+1) during the last orbit, when looking for all the products of a day the result may output 13 products instead of 14. To complete the global coverage, you may need to increase by one day the sensing time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

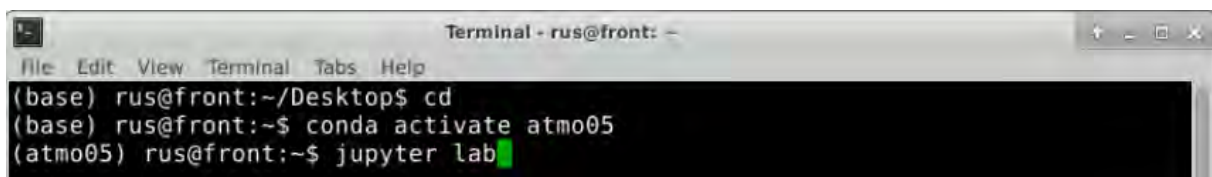


```
conda env create -f /shared/Training/ATMO05_FireEmissions_Turkey/AuxData/atmo05.yml
```

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.



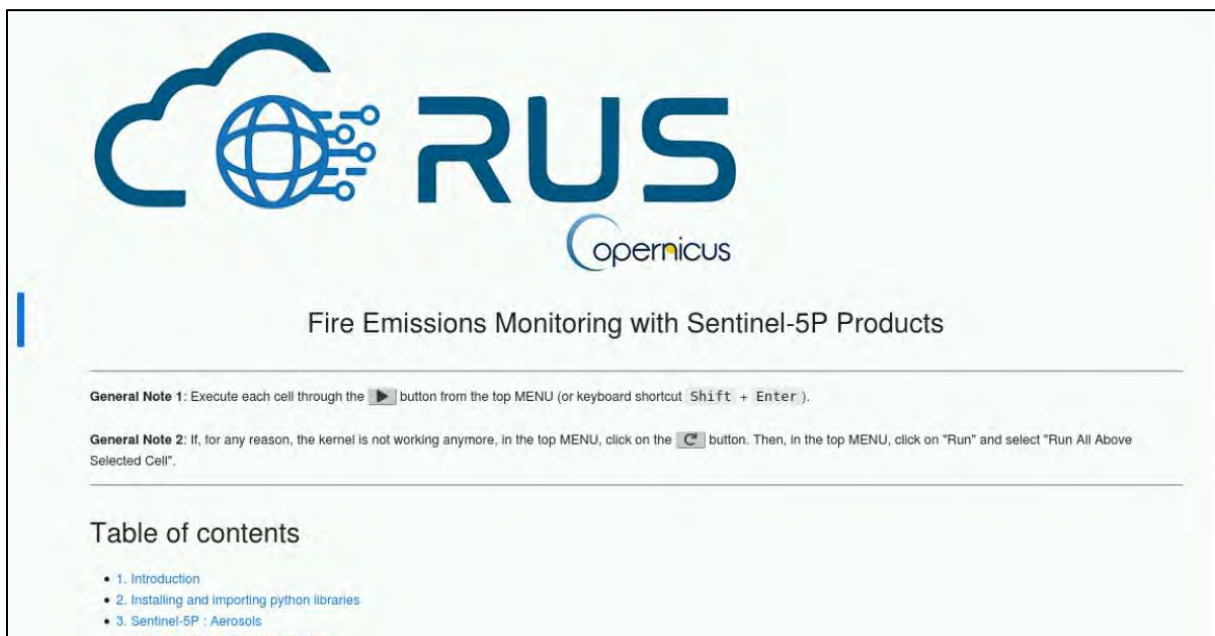


Once open, navigate to the following path inside the JupyterLab GUI and open the file *Code\_ATMO05.ipynb*

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](http://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/>



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Fire Emissions Monitoring with Sentinel-5P Products

**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
  - 3.1. Download Sentinel-5P data

 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](http://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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