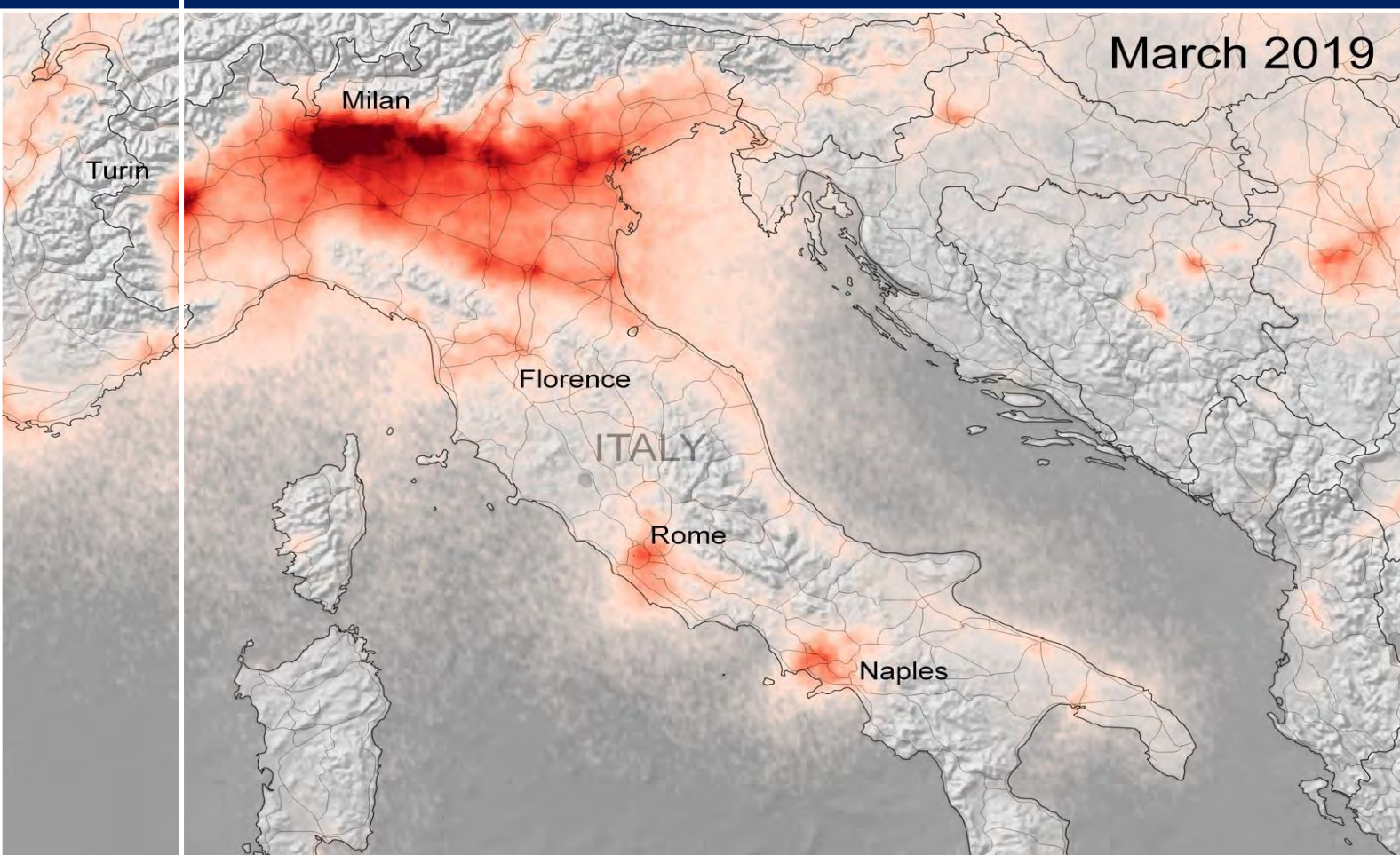


RUS

Copernicus



TRAINING KIT – ATM002

MONITORING POLLUTION WITH SENTINEL-5p

Case Study: Italy 2019-2020



Research and User Support for Sentinel Core Products

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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

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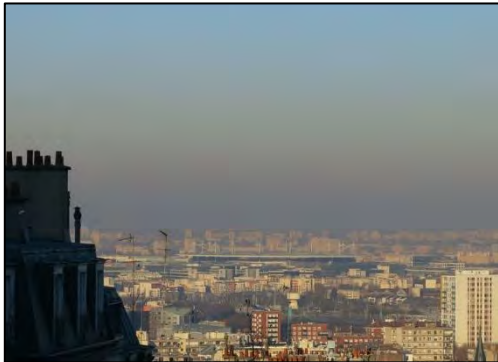
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1 Introduction to RUS

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 monitor pollution using Sentinel-5p products as input data and python code.

2 Air quality – background



Air pollution. Credits: Wikipedia Commons

Air pollution is a major environmental health problem that affects people in developed and developing countries alike. With millions of people dying prematurely every year as a direct result of poor air quality, it has never been more important to monitor the air we breathe.

Pollutants enter the air from a range of sources, although they are mainly a result of motor vehicle and industrial combustion processes. Governments and decision-makers rely heavily on satellite data and computer models to show how pollution accumulates and how it is carried in the air so that they can develop appropriate mitigation strategies.

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, NO₂, SO₂, O₃, aerosols...) with a great accuracy and spatial resolution. It also provides measurement continuity with precedent and ongoing atmospheric spatial missions (OMI, IASI and SCHIAMACHY).

3 Training

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

The Training Code for this tutorial is ATMO02. 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

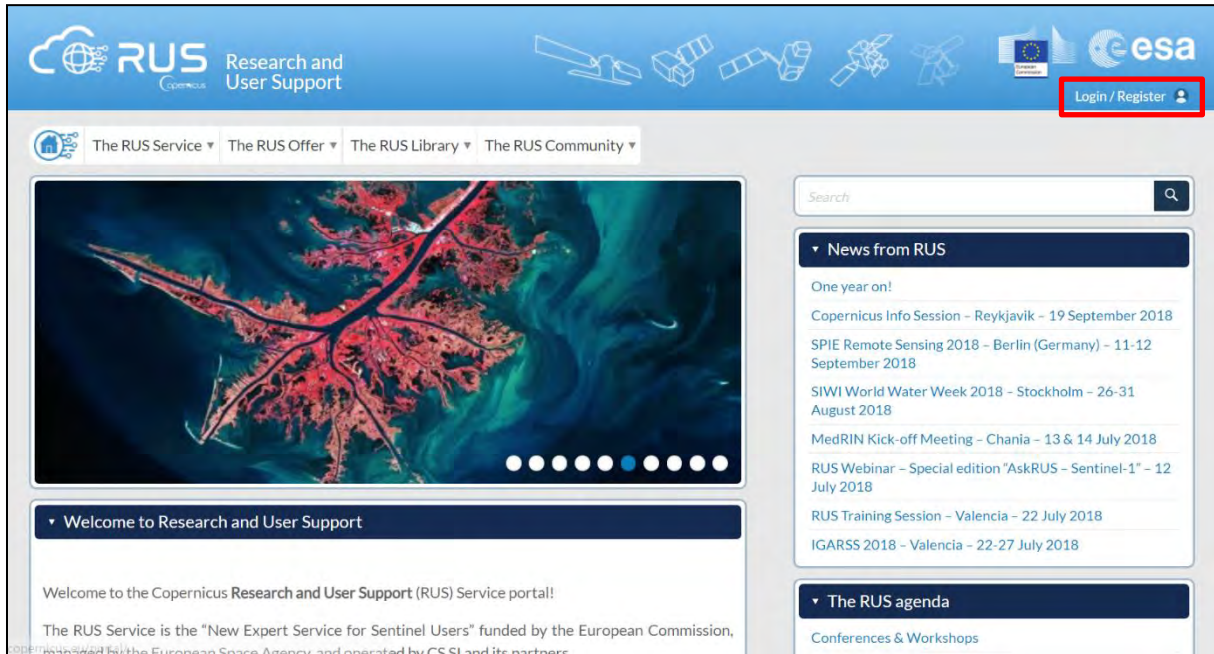
- 92 Sentinel-5p images acquired during March 2019 and March 2020
- Pre-processed data stored locally
`@/shared/Training/ATMO02_MonitoringPollution_Italy/AuxData/`

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.

Login / Register

The registration system to access the RUS service platform has moved toward the COPERNICUS Single Sign On authentication server.

- New Users who have not yet registered to the RUS portal shall first create a COPERNICUS SSO account.

Note that your Copernicus SSO account will be activated only after the reception of the third email sent by the Copernicus service. We advise you to consult [this document](#) and [this page](#) to facilitate your registration procedure.

REGISTER COPERNICUS SSO account

Users who already have a COPERNICUS SSO account can login here:

Login

Close

Credentials

CDS-SSO ID

Password

Max Idle Time

half a day

Max Session Time

Until browser close

Login

Reset

[Forgot your password?](#)

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

Do you want to subscribe for a new RUS account?

Your ESA-SSO subscription data:

Login

First Name

Last Name

Email

Organization

Country

Additional subscription information

Please complete the following information:

Where did you hear about the RUS service?
Select one or more items

outreach event
colleagues
newsletter
conference
social media
other

Institution type
Phone number
(Italy IT):

Title

Subscribe Cancel

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**.

Hello, Miguel

You are here: Home > Your RUS service

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

Your profile
Your dashboard
Your training

Your RUS service

This section gathers pages related to your RUS services:

- Your profile:** displays your personal information linked to your ESA SSO and RUS accounts,
- Your dashboard:** allows you to access your private dashboard,
- Your training:** allows you to register to a training session you have been invited to participate in.

News from RUS

One year on!

Copernicus Info Session - Reykjavik - 19 September 2018

SPIE Remote Sensing 2018 - Berlin (Germany) - 11-12 September 2018

SIWI World Water Week 2018 - Stockholm - 26-31 August 2018

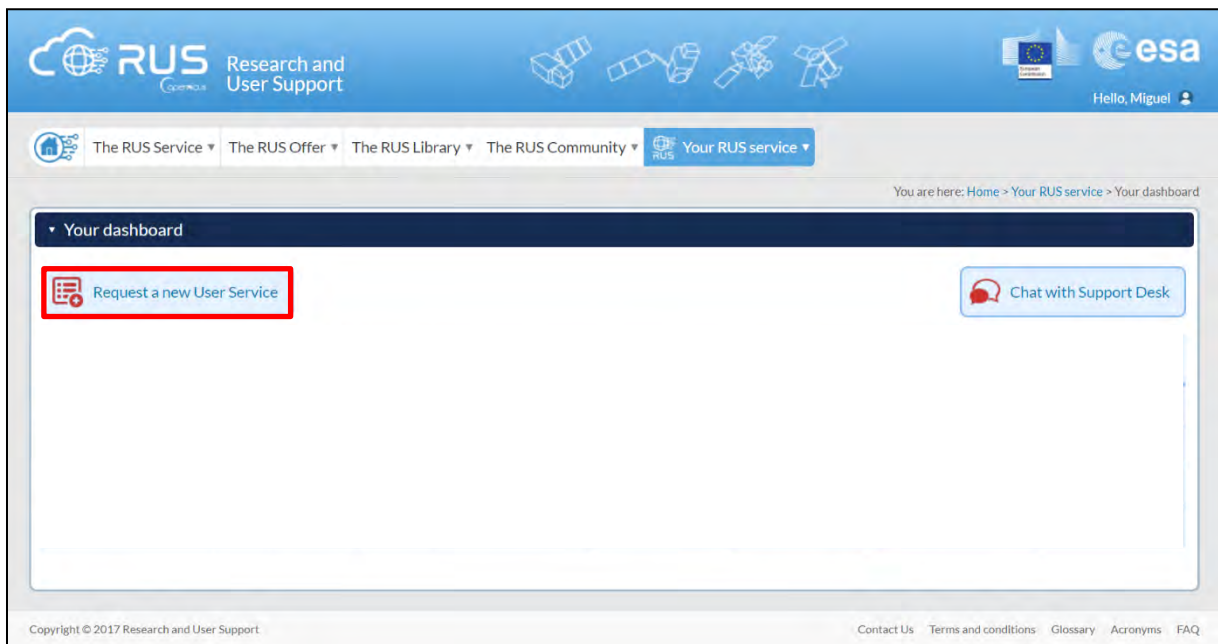
MedRIN Kick-off Meeting - Chania - 13 & 14 July 2018

RUS Webinar - Special edition "AskRUS - Sentinel-1" - 12 July 2018

RUS Training Session - Valencia - 22 July 2018

IGARSS 2018 - Valencia - 22-27 July 2018

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.

The image shows a 'User Support Request' form, specifically Step 1/3: 'Your experience'. The form is titled 'User Support Request' and has a subtitle 'Step 1/3 Your experience'. It asks the user to 'Please help us learn more about your background by answering a few questions. This information will be stored in your User Profile.' The form contains several questions: 'How many years of experience in Remote Sensing do you have?' with a dropdown menu; 'Have you already downloaded Copernicus data via the Copernicus Open access hubs?' with radio buttons for 'Yes' and 'No'; 'Have you already handled/processed Copernicus data?' with radio buttons for 'Yes' and 'No'. A red rectangular box highlights a section titled 'Do you wish to practice a tutorial exercise shown in a RUS webinar? If yes, please select your choice (hold down CTRL key for multiple selections)'. This section contains a list of tutorial exercises: HAZA01 - Flood Mapping in Malawi, HAZA02 - Burned Area Mapping in Portugal, HYDR01 - Water Bodies Mapping over Northern Poland, LAND01 - Crop Mapping in Seville, LAND04 - Land Monitoring in Cyprus, and OCEA01 - Ship Detection in Gulf of Trieste. Below this list is a text input field for requesting other tutorial exercises not in the list. At the bottom of the form are 'Cancel' and 'Next' buttons.

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

User Support Request

Summary information on your request:

This is a collection of information selected across the USR forms.
You can go back and edit this information if necessary.

General information on your request:

Years of experience in Remote Sensing

5-10 years

Downloaded Copernicus data?

✓

Handled/processed Copernicus data?

✓

Webinar codes

HAZA02, LAND04

About your RUS project:

Thematic area

Cryosphere (ice and snow)

Operations to perform on RUS

Algorithm development

Preference for downloading process

Self-downloading

Foreseen activities and support needs

Develop a land cover classification

Project name

RUS_Project1

Earth Observation Data information:

Type of Earth Observation Data:

Sentinel-1

✓

S1 - Product type

S1 - Product 1

S1 - Sensor mode

GRD

S1 - Polarisation

-

S1 - Orbit direction

-

Sentinel-2

X

Sentinel-3

X

Other

X

I don't know

X

Region of Interest:

Min Latitude

39.3303

Max Latitude

40.5877

Min Longitude

-4.6736

Max Longitude

-2.7205

Reference polygons

Data acquisition date(s):

None

Additional data specifications

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

Back and edit

Submit the request

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**.

Research and User Support

Hello, Miguel

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

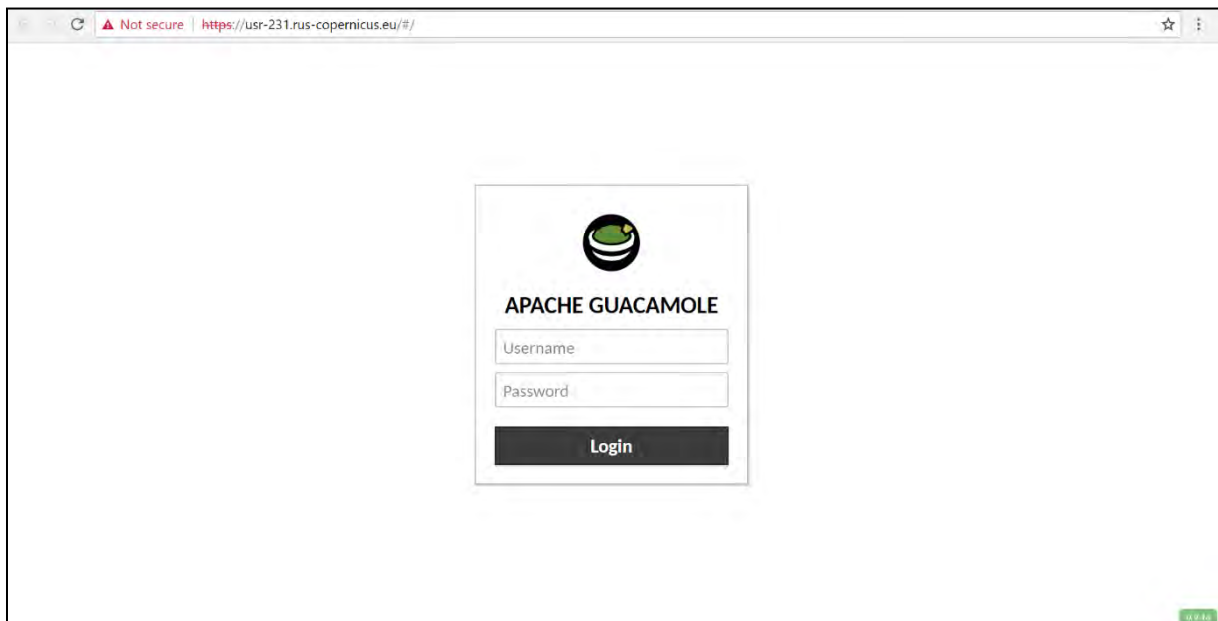
Chat with Support Desk

Project Name	ID	Date of submission	Status	Actions			Virtual Environment	
RUS_training1	231	2017-08-31	Open	Follow my project	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.



This is the remote desktop of your Virtual Machine.

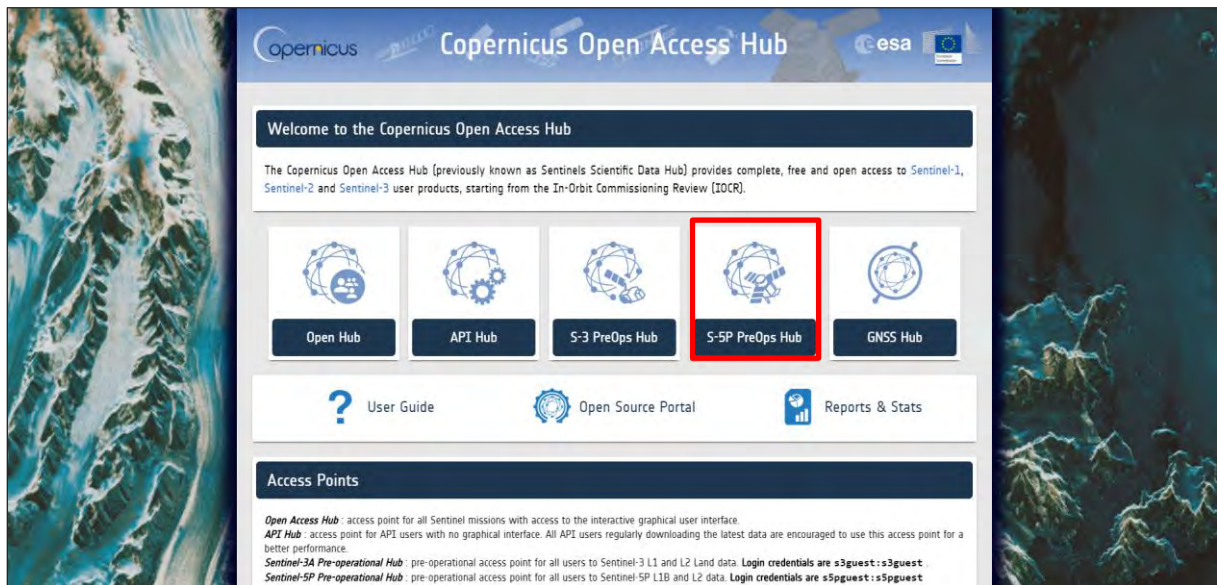


6 Step by step

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.

The image shows the 'Register new account' form on the Copernicus Open Access Hub. The form includes fields for 'Firstname', 'Lastname', 'Username', 'Password', 'Confirm Password', 'E-mail', 'Confirm E-mail', 'Select Domain', 'Select Usage', and 'Select Country'. A red arrow points to the 'REGISTER' button at the bottom right of the form. Above the form, there's a message stating that Sentinel data access is free and open to all, and that users will receive a confirmation email with a link to validate their address.

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 (April 2020), Sentinel-5p products are still only accessible through the Sentinel-5p Pre-Operations Data Hub. To download S-5p products, log in using *s5pquest* 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 March 2019. Define the study area over the city of Milan, in the north of Italy. 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.

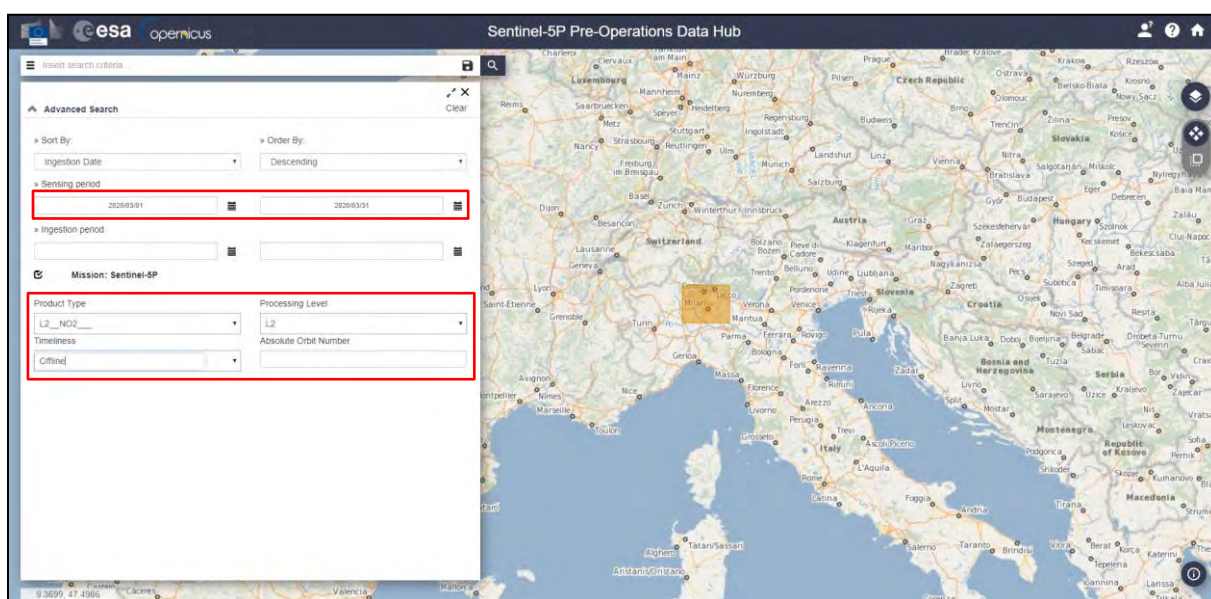
Sensing period: From 2020/03/01 to 2020/03/31 (repeat for 2019/03/01 to 2019/03/31 afterwards)


Check Mission: Sentinel-5p

Product type: L2__NO2

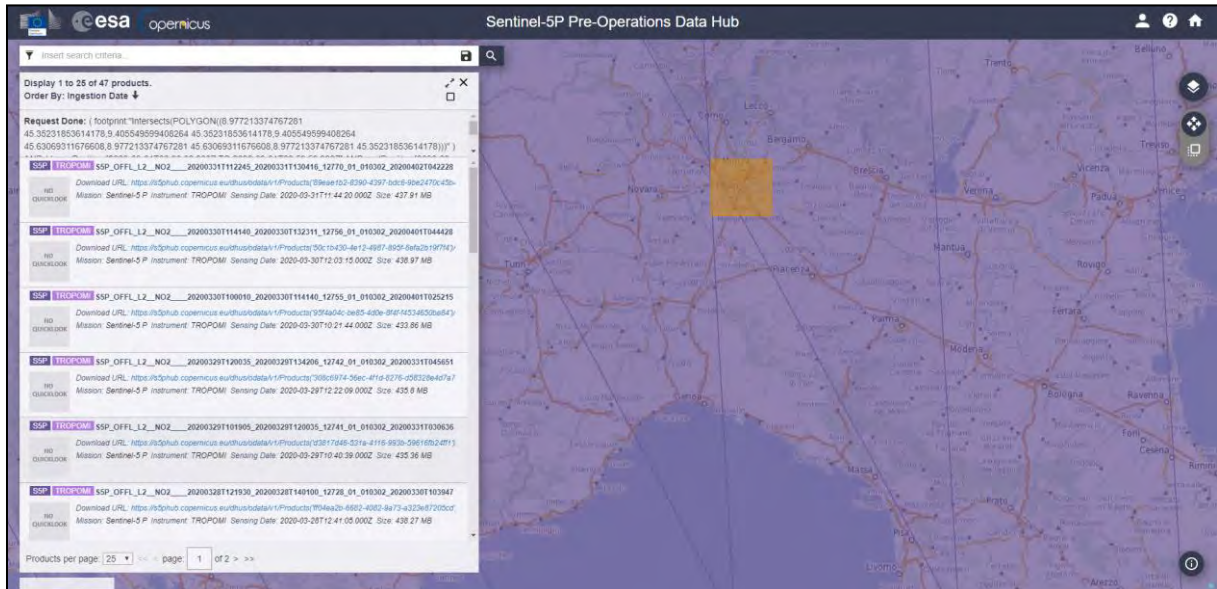
Processing level: L2


Timeliness: Offline




In this case the search returns 47 results. Download all the products (products will be saved in `/home/rus/Downloads`), repeat the procedure for 2019 and move them to the following path (See  NOTE 2 and 3).



Path: `/shared/Training/ATMO02_MonitoringPollution_Italy/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](https://www.unidata.ucar.edu/).

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).

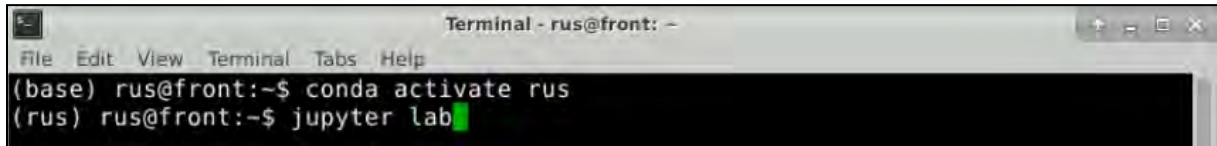
```
conda env create -f /shared/Training/ATMO02_MonitoringPollution_Italy/AuxData/rus.yml
```

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

```
conda activate rus
```



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 *ATMO02_MonitoringPollution_Italy.ipynb*

```
jupyter lab
```

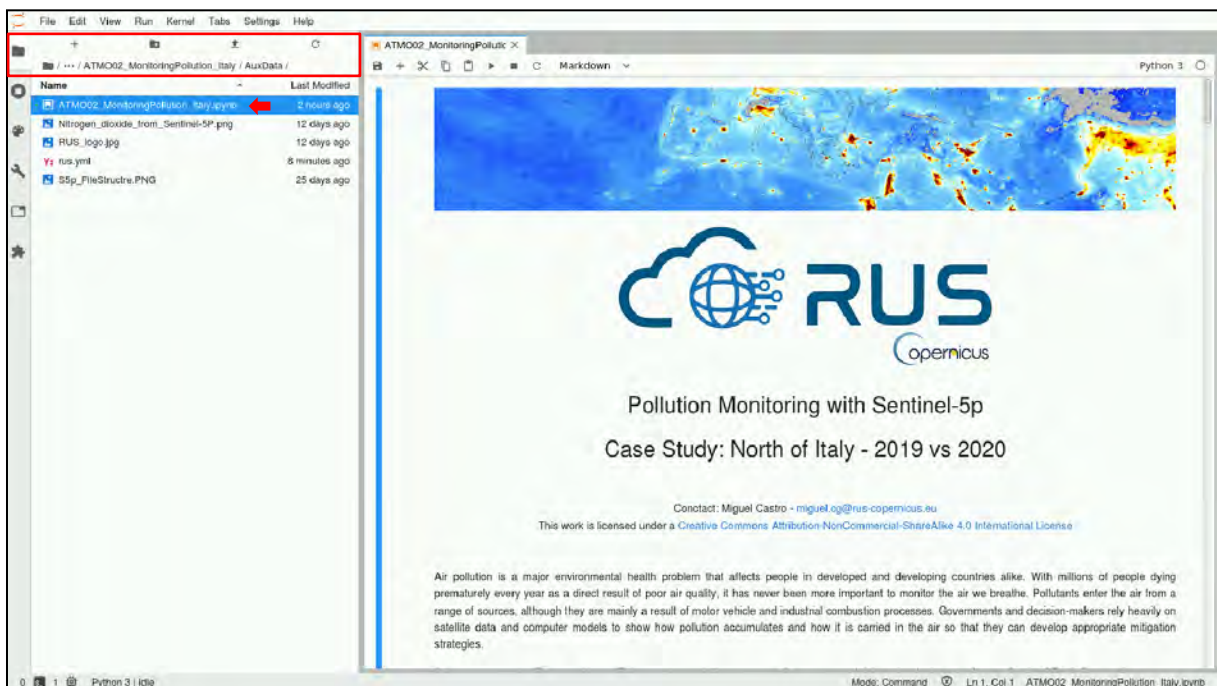



```
Terminal - rus@front: ~
File Edit View Terminal Tabs Help
(base) rus@front:~$ conda activate rus
(rus) rus@front:~$ jupyter lab
```

Path: /shared/Training/ATMO02_MonitoringPollution_Italy/Original/

 **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/>

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