

COPER RUS Copernicus



TRAINING KIT – ATMO01

AIR QUALITY MONITORING WITH SENTINEL-5p











Research and User Support for Sentinel Core Products

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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 air quality using Sentinel-5p products as input data.

2 Air quality – background



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, NO22, SO22, O33, 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 ATMO01. 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

- 13 Sentinel-5p images acquired on May 17th 2019
- Pre-processed data stored locally @/shared/Training/ATMO01_AirQuality_Global/AuxData/

3.2 Software in RUS environment

Internet browser, BEAT + QGIS

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 (<u>www.rus-copernicus.eu</u>) and click on *Login/Register* in the upper right corner.

| CORRUS Research and User Support | 🕼 🚜 💽 Login/Register s |
|---|---|
| The RUS Service * The RUS Offer * The RUS Library * The RUS Community * | |
| | Seath |
| | News from RUS |
| The second se | 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 |
| Welcome to Research and User Support | RUS Training Session – Valencia – 22 July 2018 |
| | IGARSS 2018 - Valencia - 22-27 July 2018 |
| Welcome to the Copernicus Research and User Support (RUS) Service portal! | The RUS agenda |
| The RUS Service is the "New Expert Service for Sentinel Users" funded by the European Commission, | Conferences & Workshops |

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 email to activate your account.

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

| Login / Register | Credentials | | | |
|--|---|--|--------|---|
| 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 enail sent by the Copernicus vervice. 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 | CDS-SSO ID Password Max Idle Time Max Session Time | half a day Until browser close Login Reset Eorgot your password? | ¥ ¥ | 0 |

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

| | RUS Research and Gene User Support | | | Here Travil 🛔 |
|--------------|---|--|----------------------|---------------------------|
| (m)s n | e RUSService + The RUS C Do you | a want to subscribe for a new RUS acc | ount? | |
| | Your ESA-SSO sub | scription data: | You are for | ng Hand - Your D. Storten |
| * Your | RUS service Login | | | Q |
| This section | on gathers pages related to ye First Name | | | |
| - You | corofile displays your person Last Name | The second se | US | |
| | Email | and the second se | Est Forirm - Strasb | ourg - 28 & 29 Nov. |
| - You | dashboard allows you'ld an Organization | and the second s | est-21 & 22 Nov. | ana l |
| · You | Country Country | | | njolnop - Prague - |
| | | Additional subscription information | | |
| | | | vcier Velocity - 8 N | |
| | Please complete th | e following information: | | 76 Outobes 2018 |
| | Where did you hear | | ation @ week - Fre | stall - 12-16 Nov. |
| | RUS service? Select one or more h | colleagues tems newsletter | Hum - Pokind - 6.1 | 10.6.17 Nov. 2018 |
| | | conference | itton - Toulouse- | 26-5-27 Oct. 2018 |
| | | social media other | | |
| | Institution type | - Select one item | 🗸 nda | |
| | Phone number Italy (IT): | +39 | prestops | 1 Star |
| | Title | - Select one item | × | |
| | | | | |

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** \rightarrow **Your Dashboard**.

| CORRUS Research and User Support | \$ 75 I | Helto, Miguel 🔒 |
|----------------------------------|--|--|
| | Your RUS service Your profile Your dashboard | You are here: Home > Your RUS service |
| | | 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 - Sentinei-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.

| CORRUS Research and User Support | Helio, Miguel 😩 |
|--|--|
| The RUS Service * The RUS Offer * The RUS Library * The RUS Community * 👯 Your RUS service * | |
| ★ Your dashboard | You are here: Home > Your RUS service > Your dashboard |
| Request a new User Service | Chat with Support Desk |
| Copyright © 2017 Research and User Support | Contact Us Terms and conditions Glossary Actonyms FAQ |

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

| Step 1/3 Your experience | |
|---|-------------|
| Please help us learn more about your background by answering a few que information will be stored in your User Profile. | estions, Ti |
| How many years of experience in Remote Sensing do you have? | |
| Choose one Item | |
| Have you already downloaded Copernicus data via the Copernicus Open access hubs? | |
| Yes | |
| © No | |
| Have you already handled/processed Copernicus data? | |
| * Yes | |
| © No | |
| Do you wish to practice a tutorial exercise shown in a RUS webinar? If yes, please select yo (hold down CTRL key for multiple selections). | our choice |
| HAZA01 - Flood Mapping in Malawi | |
| HAZA02 - Burned Area Mapping in Portugal HYDR01 - Water Bodies Mapping over Northern Poland | - 1 |
| LAND01 - Crop Mapping in Seville | |
| LAND04 - Land Monitoring in Cyprus OCEA01 - Ship Detection in Guif of Trieste | |

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

| 'his is a collection of information selected 'ou can go back and edit this information | | |
|---|-------------------------------------|--|
| | | |
| General information on your request: | | |
| Years of experience in Remote Sensing | 5-10 years | |
| Downloaded Copernicus data? Handled/processed Copernicus data? | 1 | |
| Webinar codes | V HAZA02, LAND04 | |
| About your RUS project: | hazadz, zarody | |
| Thematicarea | 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 | 1 | |
| | S1-Product 1 | |
| S1 - Product type | GRD | |
| S1 - Sensor mode | 4 | |
| S1 - Polarisation | a | |
| S1 - Orbit direction | | |
| Sentinel-2 | x | |
| Sentinel-3 | X | |
| Other | x | |
| I don't know | × | |
| Region of Interest: Min Latitude | 39,3303 | |
| Max Latitude | 40.5877 | |
| Min Longitude | -4.6736 | |
| Max Longitude | -4,6730 | |
| Reference polygons | -2.7203 | |
| Data acquisition date(s): | | |
| None | | |
| Additional data specifications | | |

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**.

| | | | | | | | You are here: Home > | Your RUS service > Your dash |
|-----------------|-------------|------------|--------|-------------------|-------------------|------------------|---------------------------------|---------------------------------------|
| Your dashboard | | | | | | | | |
| Request a new L | Jser Servie | ce | | | | | | Chat with Support Desk |
| | | Date of | | | | | | |
| Project Name | ID | submission | Status | | Actions | | Virtual | Environment |
| S | | 1000 | | Follow my project | Get support | Close my service | Access my Virtual Machine(s) | Access my CPU monitoring dashboard |
| RUS_training1 | 231 | 2017-08-31 | Open | | Get a webinar kit | Rate my service | Freeze my Virtual Machine(s) | Report a technical incident |

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.

| Copernicus Op | en Access Hub | |
|--|--|----------|
| Register n | ew 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 valida Username field accepts only aphanumenic characters plus "", "s", "_a", and ".". | te your e-mail address. Following this you can start to download the data. | _ |
| Firetrame. | Lasijiame | |
| Username | | |
| Parsword | Confirm Password | |
| | | |
| 5-mai | Continn E-Inau | |
| Select Domain • | | |
| Select Usage | | |
| Select Country. | | |
| | | |
| By registering in this website you are deemed | to have accepted the T&C for Sentinei 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 (June 2019), 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.



Since we are targeting the production of global maps, we do not need to define a specific study area in our search. Open the search menu by clicking to the left part of the search bar (\equiv) and specify the parameters below. Press the search button (\bigcirc) after that.

Sensing period: From 2019/05/17 to 2019/05/17 Check Mission: Sentinel-5p Product type: L2__AER_AI Processing level: L2 Timeliness: Offline

| | Sentinel-5P Pre-Operations Data Hub |
|--|--|
| Insert search criteria | B Q Athenes |
| Advanced Search | |
| Sort By: order By: order By: Descending Sensing period | Construction Const |
| 2019/05/17 | Caritational Lithuesia Praza Uranova U |
| > Ingestion period E G Mission: Sentinel-SP | Interest Units Parties Data Repairs Clear Netters II Netters III Netters III Netters III Netters IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII |
| Product Type Processing Level L2_AER_AI I Timeliness Absolute Orbit Number | Zurch S Kartan Nessang Der Ling Strain Winger Creating Heitager Strain |
| Offline · | Australia Control Cont |

In this case the search returns 13 results. Download all the products (products will be saved in */home/rus/Downloads*) and move them to the following path.

Path: /shared/Training/ATMO01_AirQuality_Global/Original/



In this case the search returns 13 results. Download all the products (products will be saved in */home/rus/Downloads*) and move them to the following path (See \sim NOTE 2 and 3).

Path: /shared/Training/ATMO01_AirQuality_Global/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 <u>UniData website</u>.

6.2 VISAN – open and explore data

In this exercise we will use the Basic Envisat Atmospheric Toolbox (BEAT) toolbox to analyse the Sentinel-5p data and run our analysis. The ESA Atmospheric Toolbox project (BEAT) aims to provide scientists with tools for ingesting, processing, and analyzing atmospheric remote sensing data.

The project consists of several components, with the main components being CODA, HARP, and VISAN. These components are made available by means of several software packages.

- CODA: allows direct reading access to product data, supporting a very wide range of products. All product file data is accessible via the CODA C library. On top of this, there are several interfaces available to directly ingest product data using e.g. Fortran, IDL, MATLAB, and Python.
- HARP: toolset for ingesting, processing and inter-comparing satellite or model data against correlative data. The toolset provides a set of command line tools, a library of analysis functions, and direct import/export interfaces for Python, IDL, and MATLAB. By appropriately

chaining calls to the HARP command line tools one can preprocess satellite and correlative data such that the two datasets that need to be compared end up having the same temporal/spatial grid, same data format/structure, and same physical unit.

 VISAN: cross-platform visualization and analysis application for atmospheric data. The application uses the Python language as the means through which you provide commands to the application. The Python interfaces for CODA and HARP are included so you can directly ingest product data from within VISAN (HARP interfaces will be added once the HARP Python interface becomes available). Finally, VISAN provides some very powerful visualization functionality for 2D and world plots.

The primary instruments supported by BEAT are Tropomi (Sentinel-5P), GOME-2 and IASI (MetOp), OMI, TES and MLS (Aura), GOMOS, MIPAS, and SCIAMACHY (ENVISAT), and GOME (ERS-2). More information on the BEAT project can be found at <u>http://www.stcorp.nl/beat/</u>

In the desktop, double click on the VISAN icon - 2 - to open it. The command line interface will appear together with the help window (if it is the first time you use VISAN, read the help window and close it afterwards).



In the *File* menu, click on *Browse Product*, navigate to the following path and open the first Sentinel-5p product – S5P_OFFL_L2_AER_AI_20190517**T005850**_20190517**T024020**_08238_01_010301_20190523T002750.nc Path: /shared/Training/ATMO01 AirQuality Global/Original/

| USAN 1.11.2 | | Browse Product File | (2) |
|--|-------------------|--|--------------|
| Edit Help | La Colorada | A CONTRACTOR OF A CONTRACTOR | |
| Copyright (C) 2002-2018 S[6]T. The Netherlands. 2 | 🗶 🔔 shared | Training ATMO01_AirQuality_Global Original | |
| Welcome to the VISAN/Python Control Shell. | Places | Name | * Size Modif |
| VISAN 3.18.1 (Python 2.7.11, NumPy 1.11.0, CODA 2.19, HARP 1.3, BEAT 6.10.2) | Q, Search | S5F_0FTL_L2_AER_AL_Z0030517T005850_Z0180517T024020_087 | |
| 335 | O Recently Lined: | 55P_OFFL_12_AER_AI_20190517T024020_20190517T042150_082 | |
| | đ na | 55P_OFFL_L2_AER_AI_20190517T042150_20190517T060320_0824 | |
| | Desktop | 55P_OFFL_L2_AER_AI_20190517T060320_20190517T074450_0824 55P_OFFL_L2_AER_AI_20190517T074450_20190517T092621_0824 | |
| | The System | 55P OFFL L2_AER_AI_20190517T092621_20190517T110751_0824 | |
| | Download | 55P OFFL L2 AER AI 20190517T110751 20190517T124921 0824 | |
| | Trainley | 55P_OFFL_L2_AER_AI_20190517T124921_20190517T143051_0824 | |
| | Common. | . S5P_OFFL_L2_AER_AI_20190517T143051_20190517T161221_0824 | |
| | | S5P_OFFL_L2_AER_AI_20190517T161221_20190517T175351_0824 S5P_OFFL_L2_AER_AI_20190517T175351_20190517T193521_0824 | |
| | | 55P OFFL L2 AER AI 20190517T193521 20190517T211651 0824 | |
| | | 55P_OFFL_L2_AER_AL_20190517T211651_20190517T225821_082 | |
| | | | |
| | | - | All file |

Once opened, VISAN gives you the option to navigate the Sentinel-5p product (*PRODUCT* folder) and access metadata (*METADATA* folder) information. The *PRODUCT* folder contains data of interest as 2D arrays (Aerosol index, error estimates, quality index...). The *SUPPORT_DATA* subfolder contains additional and auxiliary data (geolocation flags, lat/lon bounds, satellite position, etc.). Within the *PRODUCT* folder, select the *aerosol_index_340_380* file.

| nie. | | | | SSP_OFF | LLZ_AER | 1 20190517 | 11005850_20 | 1905177024 | 20_08238_ | 1_010301_20 | 190523700 | 2750.nc | | | | | 1 | - 181 |
|---------------|--------------------------|---------------|--|---------------------|-------------|------------|-------------|-------------|---------------------|-------------|-------------|-------------|-------------|--------------|-------------|-------------|--------------|--------|
| | RODUCT/aerosol_Index_ | 340_380 | | | | | | | | | | | | | | | | |
| - Iproducti | METADATA | aerosol | index_340_3 _index_340_3 _index_354_3 _index_354_3 ime _pixel | 380_precisio 388 | | | | | | | | | | | | | | |
| Allers data i | | Plot | | | | | | | | | | | | | | | _ | |
| | | | | | | | | | | | | | | | | | | |
| | 0 1 | Z | 3 | 4 | 5 | 6 | 7 | H | .9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 11 |
| 924 | -1.4052311 -1.72575 | | | | | | | | | | | | | | | | | |
| 925 | -1.8045659(-1.85713) | | | | | | | | | | | | | | | | | |
| 929 | -1.9607464(-1.91278) | | | | | | | | | | | | | | | | | |
| 928 | -1.98928531.76343 | | | | | | | | | | | | | | | | | |
| 929 | -1.9486991 -1.31963 | | | | | | | | | | | | | | | | | |
| 930 | -1.92328421-1.505583 | 261-1.2687754 | -1.30155981 - | 0 9132993. | -0.6117553 | -0.8698759 | .1.2880537 | -1.0507884 | -0 2484885 | 0.09187062 | -0.0954861 | -0.4773360 | -0.9322637. | -1.4102598 | 1.9182629 | -2 0841605 | -1 4262309(- | 0.81 |
| 931 | -1.41306791-1.36330 | 721.23188030 | 0.7822796 | 0.3422847 | -0.4986866 | -0.9574146 | 0.9111711 | 0.2284446 | 0.43615180 | 0.65756660 | 0.21848048 | -0.2949461 | -0.7534089 | 1.1895434 | 1.6370030 | -1.5573321 | -1.0093255(- | 0.60 |
| 932 | -0.8687927 -0.79599- | 460.64085321 | 0.3973698. | 0.5292275 | -0.7664962 | -0.7816340 | E-0.4595454 | -0.09928364 | 0.33509150 | 0.21530783 | -0.2353549 | -0.5928354 | -0.8762764 | -1.27102921 | 1.2766062 | 0.8279163 | -0.7753422. | 0.89 |
| 933 | -0.6499129! -0.52558 | 111-0.5972362 | -0.7758852: - | 0.79106371 | -0.7341004 | -0.5693043 | -0.0887132 | 0.30148258 | 0.28669756 | 0.10288140 | -0.31752004 | -0.8891016 | 1.36795520 | -1.5941787! | 1.3358752 | -1.3100628 | -1.3597021 | 1,23 |
| | -0.6258311: -0.50186 | 92(-0.6408638 | +0.82789541 - | 0.6835227(| -0.4865058 | -0,2066869 | 0.22913956 | 0.14941902 | 0.2649024 | -0.7309584 | -1.1844428 | -1.6235848 | -1.8132319/ | -1.8619019 | 1.5758849 | -1.48657810 | -1.5407243 | 1,48 |
| 934 | | | . metocta n. | 0.3923952 | 0.00483044 | 0,33919698 | 8-0.0085099 | e-0.6948330 | -1,1650600 | -1.5825195 | -1.7467246 | -1 6299461 | -1.5950055 | -1.6856869 | 1,4279043 | -1.0520739 | -0.8371701 | 0,51 |
| | -0.5749143' -0.67615 | 53-0.7482994 | -M-D45 3 7 3 11 - | | | | | | | 3.0043000 | 8.5121A1A | ALC: TARGET | 4 0.040555 | 1.00.0000000 | | | | |
| 934 | -0.5749143! -0.67615 | | | 0.003430.02 | 0.020322556 | 6-3020333 | n a stratta | | a service a service | | | | | | at accuracy | N 1303 130 | - A BARDINA | 0.0.00 |
| 934 935 | alati tala tali sita asa | | | 0.0034000 | 0.04534550 | A. 3696353 | | | | | | | | | | A 1903112. | . A MICANI | |
| 934 935 | alati tala tali sita asa | | | 0-60546000 | 0.04574350 | 6.3686353 | | | | | | | | | | | - A MEATON | |

Click on the *2D Grid* to visualize the 2D array. For each variable, it is possible to check the whole product (all rows/columns), a specific row/column and its attributes (*Attributes* tab).

Next, click on the 2D Plot. Set the x-axis coordinates to 0; 614; 0 to visualize a 2D plot.



After visualizing the data as an array and 2D graph, we will create a 3D visualization of the product. Close the browse product window on the main VISAN page and go to *File -> Harp Import*. This menu will create the Python command to perform an import on a product.

In the *Path* option, navigate to the following path and select the same product as before (Sixth from the top - S5P_OFFL_L2__AER_AI_20190517T092621_20190517T110751_08243_01_010301_20190523T085237.nc)

Path: /shared/Training/ATMO01_AirQuality_Global/Original/

The *Operations* tab gives the possibility to provide a single string where individual operations are separated by a semi colon (i.e. 'latitude>-55[degree_north];bin()'). For this exercise, leave the Operations tab empty (See \square NOTE 4).

NOTE 4: HARP provides a simple expression syntax with which one can specify operations that need to be performed on a product. A list of operations is always provided as a single string where individual operations are separated by a semi-colon (;). Each operation can be either a comparison filter, a membership test filter, or a function call. Strings used in operations should be quoted with double quotes. More information at: http://stcorp.github.io/harp/doc/html/operations.html

The *Ingestion options* gives the option to ingest different variables from the Sentinel-5p product to the HARP converted product (i.e. which aerosol index to keep in the ingested product). For this exercise, leave the Ingestion options empty (See INOTE 5).

NOTE 5: HARP can ingest data from various types of products. HARP will try to automatically determine the product type of each file that you pass to the ingest function. An error will be raised if the product type of a file cannot be determined. For each ingestion, HARP will return a single HARP product. Each variable in a HARP product represents a specific quantity (e.g. O3 number density, cloud fraction, altitude, longitude, latitude, time, et cetera). You can customize which variables you want to include using the include() and exclude() operations that can be passed to the ingest function. More information at: http://stcorp.github.io/harp/doc/html/ingestions/

Next, in the *Variable* name tab, write *S5p_AER* to name the imported product. Finally, click *Import*. The python command used can be seen in the main VISAN window.

| | M | Import product using Harp | • × | |
|---|-----------------------------------|---|---------------------------------------|--------|
| | file path : | S5P_OFFL_L2AER_AI_20190517T092621_20190517 | T110751_082 | |
| | operations : | | | |
| | ingestion options : | | | |
| | variable name : S5p | _AER | | |
| | | Import Cancel | | |
| V File Edit Help | | VISAN 3.18.1 | | + - E |
| | 02-2018 S[&]T, The Netherlands. | | | |
| 3 Welcome to the VI | ISAN/Python Control Shell. | | | |
| 5 VISAN 3.18.1 (Pyt | thon 2.7.11, NumPy 1.11.0, CODA 2 | .19, HARP 1.3, BEAT 6.10.2) | | |
| 7 >>> S5p_AER = har r"/shared/Trainir 8 | | nal/S5P_OFFL_L2AER_AI_20190517T092621_20190517T | 110751_08243_01_010301_20190523T08523 | 7.nc") |

Once the product has been imported, we can use specific code to manipulate and visualize the data. In the VISAN window write the following command and press enter. (See 1 NOTE 6).

NOTE 6: Much of VISAN's functionality is provided by Python and the Numpy package, which are both part of VISAN. For an overview of the functions provided please look at the Python and Numpy documentation. More information at http://www.stcorp.nl/beat/doc/visan/reference.html

wplot(S5p_AER)





To move on the VISAN World Plot window, maintain the left button of your mouse and move it in the appropriate direction. To zoom in/out, maintain the right button of the mouse and move it to the top/bottom of the window. Invalid data is present in the poles.

You can change the display settings (color table, color bar, projection, etc.). For that, go to *View -> Properties* in the plot window and change the parameters according to your preference. When changing a parameter, press the *ENTER* key of your keyboard to validate the change.

6.3 Level 3 Aerosol Index gridded product

With the objective to create a world map of the aerosol index, we first need to process the Sentinel-5p Level 2 products to keep a single grid per orbit (level 3 - L3). The conversion is done combining several operators in a single call. The sub-chapters below give more information on each step.

6.3.1 HARP bin_spatial operation

The HARP bin_spatial() tool maps all time samples onto a regular spatial lat/lon grid for all variables in a product. It follows a specific sequence of parameters shown below:

bin_spatial(lat_edge_length,lat_edge_offset,lat_edge_step,lon_edge_length,lon_edge_offset,lon_ed
ge_step)

For example:

bin_spatial(271,-55,0.5,721,-180,0.5)

The choice of the spatial resolution (lat/lon_edge_step) and the boundaries (lat/lon_edge_offset, lat/lon_edge_length) can be chosen by the user. Please note that a higher spatial resolution and a larger area of interest increase the processing time (See \sum NOTE 7).



6.3.2 HARP derive operation

When spatially binning a product with *bin_spatial()*, only the lat/lon_bounds of the grid cells will be saved in the output product. To write the lat/lon center coordinates of the spatial grid in the output we use the *derive* operation.

Example: 'derive(longitude{longitude}); derive(latitude{latitude})'

6.3.3 HARP Comparison filter operation

This operator filters a dimension for all variables in the product such that items for which the value of the provided variable does not match the expression get excluded.

Example: 'latitude>-55 [degree_north]; longitude <70 [degree_east]'</pre>

6.3.4 HARP Convert Command line tool

Once the concept of the steps we will combine is clear, we will use the command line tool to combine all of them and apply it to our product. The tool allows to define a list of operations (in our case, *bin_spatial()*; *derive()*; *comparison*) to apply to each product using the -a parameter, to define ingestion options using the -o parameter and to define the output format using the -f parameter (the default NETCDF format will be used in this exercise).

Example:

- -a 'bin_spatial(...);derive(...)'
- -o 'wavelength_ratio=354_338nm'

harpconvert -a 'operations_list' -o 'ingestion_option' input_file output_Directory/output_file

To run the command, go to the following path where all the input Sentinel-5p level 2 UV Aerosol Index products are stored. Right click anywhere on the folder and select *Open Terminal Here*.

Path: /shared/Training/ATMO01_AirQuality_Global/Original/

| File Edit View Go | Original - File Manager | * _ * * |
|---|--|---------|
| The set of the set | Help /shared/Training/ATMO01_AirQuality_Global/Original/ | c |
| DEVICES This System PLACES This Desktop Tealing Downloads Tealing ATMO03_airqu Common NETWORK Strowse Network | SSP_OFFL_L2_AER_AI_20190517T005850_20190517T0424020_08238_01_010301_20190523T002750.nc SSP_OFFL_L2_AER_AI_20190517T002580_20190517T042150_08238_01_010301_20190523T05049.nc SSP_OFFL_L2_AER_AI_20190517T06250_0190517T06450_08244_01_010301_20190523T05049.nc SSP_OFFL_L2_AER_AI_20190517T09620_1090517T09450_08244_01_010301_20190523T05127.nc SSP_OFFL_L2_AER_AI_20190517T09620_10190517T019521_08244_01_010301_20190523T051237.nc SSP_OFFL_L2_AER_AI_20190517T09520_10190517T101951_002450_01_010301_20190523T051237.nc SSP_OFFL_L2_AER_AI_20190517T109521_0190517T11051_002450_01_010301_20190523T105137.nc SSP_OFFL_L2_AER_AI_20190517T109521_0190517T11521_00244_01_010301_20190523T105153.nc SSP_OFFL_L2_AER_AI_20190517T116351_20190517T15351_00245_01_010301_20190523T15550.nc SSP_OFFL_L2_AER_AI_20190517T115351_20190517T15351_00247_01_010301_20190523T15550.nc SSP_OFFL_L2_AER_AI_20190517T15351_20190517T12551_00244_01_010301_20190523T15550.nc SSP_OFFL_L2_AER_AI_20190517T15351_20190517T12551_00244_01_010301_20190523T15550.nc SSP_OFFL_L2_AER_AI_20190517T15351_20190517T12551_00244_01_010301_20190523T15550.nc SSP_OFFL_L2_AER_AI_20190517T15351_20190517T12551_00244_01_010301_20190523T15550.nc SSP_OFFL_L2_AER_AI_20190517T15351_20190517T25521_00250_01_010301_20190523T15550.nc SSP_OFFL_L2_AER_AI_20190517T15351_20190517T25521_00250_01_010301_20190523T15550.nc SSP_OFFL_L2_AER_AI_20190517T15351_20190517T25521_00250_01_010301_20190523T15550.nc SSP_OFFL_L2_AER_AI_20190517T15351_20190517T25521_00250_01_010301_20190523T203820.nc SSP_OFFL_L2_AER_AI_20190517T21651_20190517T25521_00250_01_010301_20190523T203820.nc SSP_OFFL_L2_AER_AI_20190517T2351_20190517T25521_00250_01_010301_20190523T203820.nc SSP_OFFL_L3_AER_AI_20190517T23551_20190517T25521_00250_01_010301_20190523T203820.nc SSP_OFFL_L3_AER_AI_20190517T23551_20190517T25521_00250_01_010301_20190523T203820.nc SSP_OFFL_L3_AER_AI_20190517T23551_00250_00_0103001_20190523T203820.nc SSP_OFFL_L3_AER_AI_20190517T23551_00250_00_0100301_20190523T203820.nc SSP_OFFL_L3_AER_AI_20190517T23551_0025 | |
| | Example for a custom action | |

Copy/Paste the following command in the Terminal window and press *Enter* to run it. The output directory where the result will be saved has been set to the following path:

Path: /shared/Training/ATMO01_AirQuality_Global/Processing/L3_GriddedProducts/

harpconvert -a 'latitude > -55 [degree_north]; latitude < 80 [degree_north]; bin_spatial(271,-55,0.5,7 21,-180,0.5); derive(latitude {latitude}); derive(longitude {longitude})' /shared/Training/ATMO01_Air Quality_Global/Original/S5P_OFFL_L2_AER_AI_20190517T092621_20190517T110751_08243_01_0 10301_20190523T085237.nc /shared/Training/ATMO01_AirQuality_Global/Processing/L3_GriddedPr oducts/Converted_Product.nc

Once run, go to *File -> Harp import* in the main VISAN window to import the output product and visualize it. In the file path, navigate to the output path specify before and select the output product.

Leave the *operations* and *ingestion options* as default and change the *variable name* to *AER_L3*. Next, click *Import*.

| V | Import product using Harp | ÷×. |
|------------------|---------------------------|-----|
| file pat | h : Converted_Product.nc | - |
| operation | | |
| ingestion option | s: | |
| variable nam | P AER_L3 | |
| | Import 🔞 Cancel | |

As before, once the product has been imported, we can use specific code to manipulate and visualize the data. In the VISAN window write the following command and press enter (See 1 NOTE 8).

| wplot(AER_L3.latitude.data,AER_L3.longitu | de.data,AER_L3.ab | osorbing_aerosol_index.da | ata) |
|---|-------------------|---------------------------|---------|
| VISAN 3.19.1 Copyright (1, 2002-2018 5(6)T, The Netherlands. Velcome to the VISAN/Python Control Shell. VISAN 3.18.1 (Python 2.7.11, NumPy 1.11.0, COOA 2.19, HARP 1.3, BEAT 6.10.2) *** ARE L3 = harp.import product(**** uplot(AER L3.latitude.data,AER L3.longitude.data,AER L3.absorbing aerosol_int *** uplot(AER L3.latitude.data,AER L3.longitude.data,AER L3.absorbing aerosol_int ************************************ | | USAN World Piet | |
| | -4.00341 | | 1.93849 |

NOTE 8: Go to *View -> Properties* to change the display settings such as the color bar name, min/max values, color palette, etc. in the

6.4 Daily averaged Aerosol Index product

Sentinel-5p Offline products are delivered as single file orbits. To create a world map using the all the products available within a day, they all need to be processed as explained before and merged. Once each Sentinel-5p product is processed to keep a single grid per orbit, we will concatenate all the output files to create a World Map.

For this we will use the HARPMERGE operator, which combines multiple products from files or directory by appending them across the time dimension and storing the result into a single output file. When running HARPMERGE, we will include to code to:

- Define a list of operations to apply to each product before it is appended (-a): same processing as HARPCONVERT done in the previous chapter
- Define a list of operations to apply to the merged product (-ap): operation to properly export the merged product. The *bin()* operation will average each of the lat/lon grid cells over time

so that we have {1,lat,lon} elements. The *squash(time, (latitude, longitude))* will remove the *time=1* dimension created by the *bin()* operation from lat/lon variables to have proper georeferenced products for further use in other software (i.e. QGIS, Panoply...)

In addition, ingestion options (-o) and output format (-f) could be defined

harpmerge -ap 'operations_list' -a 'operations_list' -o 'ingestion_option' input_file output_Directory/ output_file

Go to the following path where all the input Sentinel-5p level 2 UV Aerosol Index products are stored. Right click anywhere on the folder and select *Open Terminal Here*.

Path: /shared/Training/ATMO01_AirQuality_Global/Original/

| | Original - File Manager | 1 - E 1 |
|--|--|---------|
| File Edit View Go | | |
| 2 2 2 E | /shared/Training/ATMO01_AirQuality_Global/Original/ | c |
| DEVICES Ris System PLACES Ins Ins Dewrloads Tash Dewrloads Ins Taimny Ins AtM003_airQu. Common NETWORK Strowse Network | SSP_OFFL_L2_AER_AI_20190517T005850_20190517T0424020_08238_01_010301_20190523T002750.nc SSP_OFFL_L2_AER_AI_20190517T04250_0190517T042150_08234_01_010301_20190523T05049 nc SSP_OFFL_L2_AER_AI_20190517T04250_0190517T064250_08244_01_010301_20190523T05049 nc SSP_OFFL_L2_AER_AI_20190517T092621_08244_01_010301_20190523T05109 nc SSP_OFFL_L2_AER_AI_20190517T092621_02042_01_010301_20190523T05127 nc SSP_OFFL_L2_AER_AI_20190517T092621_02042_01_010301_20190523T051237 nc SSP_OFFL_L2_AER_AI_20190517T092621_02042_01_010301_20190523T051237 nc SSP_OFFL_L2_AER_AI_20190517T109261_20190517T11051_00844_01_010301_20190523T10344 nc SSP_OFFL_L2_AER_AI_20190517T109261_020451_010201_20190523T112488 nc SSP_OFFL_L2_AER_AI_20190517T116212_1090517T115351_08244_01_010301_20190523T15457 nc SSP_OFFL_L2_AER_AI_20190517T115351_20190517T125351_08244_01_010301_20190523T15457 nc SSP_OFFL_L2_AER_AI_20190517T115351_20190517T125351_08244_01_010301_20190523T15457 nc SSP_OFFL_L2_AER_AI_20190517T115351_20190517T125351_08244_01_010301_20190523T15457 nc SSP_OFFL_L2_AER_AI_20190517T115351_20190517T125351_08244_01_010301_20190523T15457 nc SSP_OFFL_L2_AER_AI_20190517T115351_20190517T12551_08245_01_010301_20190523T15457 nc SSP_OFFL_L2_AER_AI_20190517T115351_20190517T21551_08245_01_010301_20190523T15457 nc SSP_OFFL_L2_AER_AI_20190517T115351_20190517T22551_08245_01_010301_20190523T15457 nc SSP_OFFL_L2_AER_AI_20190517T115351_20190517T23551_08245_01_010301_20190523T15457 nc SSP_OFFL_L2_AER_AI_20190517T121551_20190517T23551_08250_01_010301_20190523T12650 nc SSP_OFFL_L2_AER_AI_20190517T211551_20190517T23551_08245_01_010301_20190523T203820 nc SSP_OFFL_L2_AER_AI_20190517T231551_20190517T23551_08250_01_010301_20190523T203820 nc SSP_OFFL_L3_AER_AI_20190517T231551_20190517T23551_08250_01_010301_20190523T203820 nc SSP_OFFL_L3_AER_AI_20190517T231551_000517T23550_00517055550_005 SSP_OFFL_L3_AER_AI_20190517T231551_005177105551_0050_0103001_20190523T203820 nc SSP_OFFL_L3_AER_AI_20190517T231551_0050_00517755550_005 SSP_OFFL_L3_AER_AI_20190517T231551_0050 | |
| | Example for a custom action | |

Copy/Paste the following command in the *Terminal* window and press *Enter* to run it. The code will create an average World Map for latitudes between [-55,80] for UV Aerosol Index on the 17/05/2019 for the 354/388 wavelength pair. The output directory where the result will be saved has been set to the following path:

Path: /shared/Training/ATMO01_AirQuality_Global/Processing/L3_GriddedProducts/

harpmerge -ap 'bin(); squash(time, (latitude,longitude))' -a 'latitude > -55 [degree_north]; latitude < 8 0 [degree_north]; bin_spatial(271,-55,0.5,721,-180,0.5); derive(longitude {longitude}); derive(latitude {latitude})' S5P_OFFL_L2_AER*.nc /shared/Training/ATMO01_AirQuality_Global/Processing/L3_Gri ddedProducts/Global_AER_L3.nc

Once run, go to *File -> Harp import* in the main VISAN window to import the output product and visualize it. In the file path, navigate to the output path specify before and select the output product. Leave the *operations* and *ingestion options* as default and change the *variable name* to *L3_Global*. Next, click *Import*.

| V | Import product using Harp | ÷× |
|---------------------|---------------------------|----|
| file path : | Global_AER_L3.nc | - |
| operations : | | |
| ingestion options : | | 1 |
| variable name : | L3_Global | |
| | Import Cancel | |

As before, once the product has been imported, we can use specific code to manipulate and visualize the data. In the VISAN window write the following command and press enter.

wplot(L3_Global.latitude.data,L3_Global.longitude.data,L3_Global.absorbing_aerosol_ index.data)



Single orbit products have been re-gridded and properly concatenated into a single averaged Aerosol Index product (See 1 NOTE 9).

NOTE 9: For no apparent reasons some spots over the ocean have high aerosol index values caused by the sun glint. Pixels affected by sun glint can be filtered out by applying a quality filter when executing the HARPMERGE command line tool (*-absorbing_aerosol_index_validity > 80*) (0: worst quality | 100: full quality).

6.5 Monitoring fire using Aerosol Index

Taking advantage of the Sentinel-5p temporal resolution, in this section we will explore the capabilities to monitor a fire event in California (U.S.A.) using the aerosol index level 2 product.

The 2018 wildfire season was the deadliest and most destructive wildfire season on record in California, with a total of 8,527 fires burning an area of 766,439 ha. In November 2018, strong winds aggravated conditions in another round of large, destructive fires that occurred across the state. This new batch of wildfires included the Woolsey Fire and the Camp Fire, becoming both California's deadliest and most destructive wildfire on record.

Close the *Terminal* window. In the file browser, navigate to the following path, right click anywhere in the folder and click on *Open Terminal Here* (See 2000 NOTE 10).

Path: /shared/Training/ATMO01_AirQuality_Global/Original/Fire_California/

NOTE 10: Images for this exercise must be downloaded in advanced. Go to <u>8.1 Extra data download</u> – <u>Fire monitoring</u> and follow the instructions.

Copy/Paste the following command in the Terminal window and press *Enter* to run it. The output directory where the result will be saved has been set to the following path:

Path: /shared/Training/ATMO01_AirQuality_Global/Processing/Fire_California/

harpmerge -a 'latitude > 32 [degree_north]; latitude < 42 [degree_north]; longitude > -126 [degree_e ast]; longitude < -116 [degree_east]; absorbing_aerosol_index_validity>80; bin_spatial(101,32,0.1,10 1,-126,0.1); derive(longitude {longitude});derive(latitude {latitude})' S5P_OFFL_L2_AER*.nc /shared/ Training/ATMO01_AirQuality_Global/Processing/Fire_California/I3_AER_AI_20191102_20191121.nc

In this case, the *-ap 'bin(); squash(time, (latitude,longitude))'* command is not used as we want to keep the time dimension in the merged product to create an animated plot.

Next, go to *File -> Harp import* in the VISAN window to import the output product and visualize it. In the file path, navigate to the output path specify before and select the output product. Leave the *operations* and *ingestion options* as default and change the *variable name* to *Fire*. Next, click *Import*.

| | *10010800 |
|--------------------------------|--------------------------------|
| 13_AER_AI_20191102_20191121.nc | |
| | 1 |
| | |
| e | |
| | 13_AER_AI_20191102_20191121.nc |

As before, once the product has been imported, we can use specific code to manipulate and visualize the data. In the VISAN window write the following command and press enter.

wplot(Fire)

To create the animated plot, in the plot window go to *View -> Properties*. In the *Plot* tab, change the title to: *Camp fire (California 02-21 November 2018) UV Aerosol Index*. Next, navigate to the Camp Fire location (California, U.S.A.) and zoom in using your mouse (you can also set the coordinates as shown in the screenshot).

In the *Dataset -> Color Bar* tab, change the following parameters:

- Color bar tittle: Absorbing aerosol index (354/388 nm)
- Number of labels: 5
- Range Min: -5
- Range Max: 5

In the Attributes tab you can visualize the timeframe of the product being displayed.

| Datasets Plot | Datasets Plot |
|---|---|
| absorbing_aerosol_index ‡ | Plot Title: Camp fire (California 02-21 Novem |
| Attributes Color Table Color Bar | Projection: 3D 🛟 |
| Color Bar Title: absorbing aerosol index (35) | Center of Projection |
| Number of labels: 5 | View Center and Zoom |
| Range | Lat: 36.60 Lon: -121.7 |
| Min: -5 Max: 5 | Zoom: 24.0 |

At the bottom of the VISAN world plot window, select the *Loop* option. Set the *Speed* to 1 and press *Play*. The plot displays the evolution of the generated aerosol plume.



6.6 Tropospheric vertical NO2 column

6.6.1 Daily averaged tropospheric NO₂ vertical column

To explore the capabilities of Sentinel-5p to detect and monitor other air pollutants, we will create a daily averaged tropospheric vertical NO₂ column using Sentinel-5p level 2 NO2 products. For that, close the current *Terminal* window. Open a file browser and navigate to the following path (See \square NOTE 11).

NOTE 11: Images for this exercise must be downloaded in advanced. Go to <u>8.2 Extra data download –</u> <u>NO2 Monitoring</u> and follow the instructions.

Path: /shared/Training/ATMO01_AirQuality_Global/Original/N02/

Right click anywhere in the folder and click Open Terminal Here.

Copy/Paste the following command in the Terminal window and press *Enter* to run it. The output directory where the result will be saved has been set to the following path:

Path: /shared/Training/ATMO01_AirQuality_Global/Processing/NO2/

harpmerge -ap 'bin(); squash(time, (latitude,longitude))' -a 'latitude > -55 [degree_north]; latitude < 6 0 [degree_north]; tropospheric_NO2_column_number_density_validity > 75; bin_spatial(231,-55,0.5, 721,-180,0.5); derive(longitude {longitude}); derive(latitude {latitude})' S5P_OFFL_L2__NO2*.nc /shar ed/Training/ATMO01_AirQuality_Global/Processing/NO2/l3_NO2_20190124_quality_75.nc

The command builds a daily averaged world map for latitudes between [-55,60] of tropospheric vertical column of NO₂ on 24/01/2019 with full quality data. The value of the *tropospheric_NO2_column_number_density_validity* is set to 75 as it is the recommended pixel filter to remove cloud/snow/ice covered scenes, errors and problematic retrieval.

Once run, go to *File -> Harp import* in the main VISAN window to import the output product and visualize it. In the file path, navigate to the output path specify before and select the output product. Leave the *operations* and *ingestion options* as default and change the *variable name* to *NO2*. Next, click *Import*.

| Import product using Harp | ÷ X |
|----------------------------------|----------------------------------|
| [] I3_NO2_20190124_quality_75.nc | = |
| | |
| | |
| NO2 | |
| Import 🔀 Cancel | |
| | [] I3_NO2_20190124_quality_75.nc |

As before, once the product has been imported, we can use specific code to manipulate and visualize the data. In the VISAN window write the following command and press enter.

wplot(NO2)

Single orbit products have been re-gridded and properly concatenated into a single averaged tropospheric vertical column of NO_2 products. To improve the visualization, change the *Min/Max* values of the color bar to 0 and 0.000075 mol/m² respectively.



Due to the air pollution present in urban areas, the world's major cities are highlighter (specially over China). Furthermore, due to cloud coverage, large invalid areas are visible.

6.6.2 Monthly averaged tropospheric NO₂ vertical column

In the last step, we will derive a monthly averaged tropospheric vertical NO₂ column using Sentinel-5p level 2 NO2 products. For that, close the current *Terminal* window. Open a file browser and navigate to the following path. There, all averaged daily maps of tropospheric vertical column of NO₂ for January 2019 have been created following the same method as before.

Path: /shared/Training/ATMO01_AirQuality_Global/Original/NO2_GlobalAverage/

Right click anywhere in the folder and click Open Terminal Here.

Copy/Paste the following command in the Terminal window and press *Enter* to run it. The output directory where the result will be saved has been set to the following path:

Path: /shared/Training/ATMO01_AirQuality_Global/Processing/NO2/Global/

```
harpmerge -ap 'bin(); squash(time, (latitude,longitude))' l3_201901*.nc /shared/Training/ATMO01_A irQuality_Global/Processing/NO2/Global/l3_NO2_201901_quality_75.nc
```

The command builds a monthly averaged world map for latitudes between [-55,60] of tropospheric vertical column of NO₂

Once run, go to *File -> Harp import* in the main VISAN window to import the output product and visualize it. In the file path, navigate to the output path specify before and select the output product. Leave the *operations* and *ingestion options* as default and change the *variable name* to *NO2_month*. Next, click *Import*.

| V | Import product using Harp | • X |
|---------------------|--------------------------------|-----|
| file path : | [] I3_NO2_201901_quality_75.nc | |
| operations : | |) |
| ingestion options : | | 1 |
| variable name : | NO2 month | |
| | Import Cancel | |

As before, once the product has been imported, we can use specific code to manipulate and visualize the data. In the VISAN window write the following command and press enter.

wplot(NO2_month)

Daily averaged products have been properly concatenated into a single monthly averaged tropospheric vertical column of NO_2 products. To improve the visualization, change the *Min/Max* values of the color bar to 0 and 0.000075 mol/m² respectively.



8 Extra steps

8.1 Extra data download - Fire monitoring

To download the data for the fire monitoring exercise go to the Sentinel-5p Pre-Operations Data Hub, log in as explained before and copy paste the following product names in the search bar. Then, click on search and download to product. Once downloaded (in home/rus/downloads) move it to the following path.

Path: /shared/Training/ATMO01_AirQuality_Global/Original/Fire_California/



| Date | Product ID |
|------------|---|
| 2018-11-02 | S5P_OFFL_L2AER_AI_20181102T204153_20181102T222322_05469_01_010200_20181108T200727 |
| 2018-11-03 | S5P_OFFL_L2AER_AI_20181103T202245_20181103T220415_05483_01_010200_20181109T194206 |
| 2018-11-04 | S5P_OFFL_L2AER_AI_20181104T200338_20181104T214507_05497_01_010200_20181110T192244 |
| 2018-11-05 | S5P_OFFL_L2AER_AI_20181105T194430_20181105T212600_05511_01_010200_20181111T190324 |
| 2018-11-06 | S5P_OFFL_L2AER_AI_20181106T192523_20181106T210652_05525_01_010200_20181112T184406 |
| 2018-11-07 | S5P_OFFL_L2AER_AI_20181107T204745_20181107T222915_05540_01_010200_20181113T201448 |
| 2018-11-08 | S5P_OFFL_L2AER_AI_20181108T202838_20181108T221007_05554_01_010200_20181114T195528 |
| 2018-11-09 | S5P_OFFL_L2AER_AI_20181109T200931_20181109T215100_05568_01_010200_20181115T193606 |
| 2018-11-10 | S5P_OFFL_L2AER_AI_20181110T195023_20181110T213153_05582_01_010200_20181116T191647 |
| 2018-11-11 | S5P_OFFL_L2AER_AI_20181111T193116_20181111T211246_05596_01_010200_20181117T185728 |
| 2018-11-12 | S5P_OFFL_L2AER_AI_20181112T191210_20181112T205339_05610_01_010200_20181118T183807 |
| 2018-11-14 | S5P_OFFL_L2AER_AI_20181114T201526_20181114T215655_05639_01_010200_20181120T193926 |

| 2018-11-16 | S5P_OFFL_L2AER_AI_20181116T193712_20181116T211842_05667_01_010200_20181122T185737 |
|------------|---|
| 2018-11-17 | S5P_OFFL_L2AER_AI_20181117T191806_20181117T205936_05681_01_010200_20181123T184418 |
| 2018-11-18 | S5P_OFFL_L2AER_AI_20181118T204029_20181118T222159_05696_01_010200_20181124T200555 |
| 2018-11-20 | S5P_OFFL_L2AER_AI_20181120T200217_20181120T214347_05724_01_010200_20181126T192906 |
| 2018-11-21 | S5P_OFFL_L2AER_AI_20181121T194311_20181121T212441_05738_01_010200_20181127T191033 |

8.2 Extra data download - NO2 Monitoring

To download the data for the NO2 monitoring exercise go to the Sentinel-5p Pre-Operations Data Hub, log in as explained before and copy paste the following product names in the search bar. Then, click on search and download to product. Once downloaded (in home/rus/downloads) move it to the following path.

| Date | Product ID |
|------------|---|
| 2019-01-24 | S5P_OFFL_L2NO220190124T010650_20190124T024820_06635_01_010202_20190130T024317 |
| | S5P_OFFL_L2NO220190124T024820_20190124T042951_06636_01_010202_20190130T043730 |
| | S5P_OFFL_L2NO220190124T042951_20190124T061121_06637_01_010202_20190130T061522 |
| | S5P_OFFL_L2NO220190124T061121_20190124T075251_06638_01_010202_20190130T080926 |
| | S5P_OFFL_L2NO220190124T075251_20190124T093421_06639_01_010202_20190130T094112 |
| | S5P_OFFL_L2NO220190124T093421_20190124T111551_06640_01_010202_20190130T113605 |
| | S5P_OFFL_L2NO220190124T111551_20190124T125722_06641_01_010202_20190130T143915 |
| | S5P_OFFL_L2NO220190124T125722_20190124T143852_06642_01_010202_20190130T151234 |
| | S5P_OFFL_L2NO220190124T143852_20190124T162022_06643_01_010202_20190130T161125 |
| | S5P_OFFL_L2NO220190124T162022_20190124T180152_06644_01_010202_20190130T182515 |
| | S5P_OFFL_L2NO220190124T180152_20190124T194322_06645_01_010202_20190130T201724 |
| | S5P_OFFL_L2NO220190124T194322_20190124T212452_06646_01_010202_20190130T214447 |
| | S5P_OFFL_L2NO220190124T212452_20190124T230622_06647_01_010202_20190131T080338 |
| | S5P_OFFL_L2NO220190124T230622_20190125T004753_06648_01_010202_20190131T004111 |

Path: /shared/Training/ATMO01_AirQuality_Global/Original/N02/

THANK YOU FOR FOLLOWING THE EXERCISE!

Further reading and resources 9

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

<u>Tropomi</u>

http://www.tropomi.eu/

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