EXERCISE 9 – TUTORIAL

Air quality monitoring using Sentinel-5 data – practicals, using SNAP software

1 | Exercise outline

In this exercise, we will:

- Define suitable search criteria (time range, area, satellite, satellite product, visualization type) and compare images from different sensors in EO Browser for a case study in air pollution

- Explore impact of Covid-19 on different cities in Europe

- Interpret Sentinel-5P NO2 maps in SNAP

- Context information with Sentinel-2
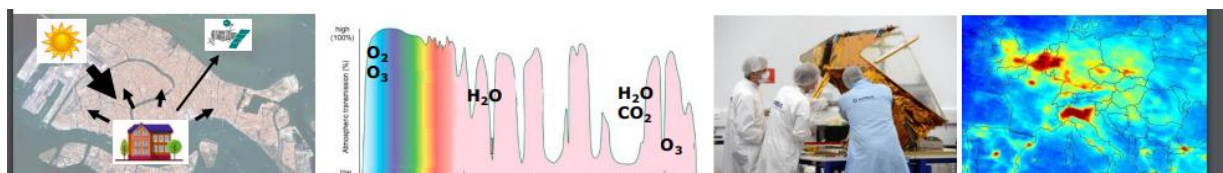
- Monitor volcanic emissions with Sentinel-5P

2 | Background

Nitrogen dioxide (NO2) is a common air pollutant that plays a big role in the formation of smog and acid precipitation. Over 90% of the overall nitrogen oxide emissions are released into the air during the combustion of diverse fuel types.

There has been a notable increase in the amount of satellite data specifically related to air pollution. In particular, satellite instruments for observing the lower troposphere have significantly improved. Space radiometers, like MODIS, GOES, AVHRR and TOMS have proven very useful in measuring aerosols and air pollutants across large areas. The latest generation spectrometers, such as TROPOMI, are capable of detecting NO2 and other pollutants in urban areas.
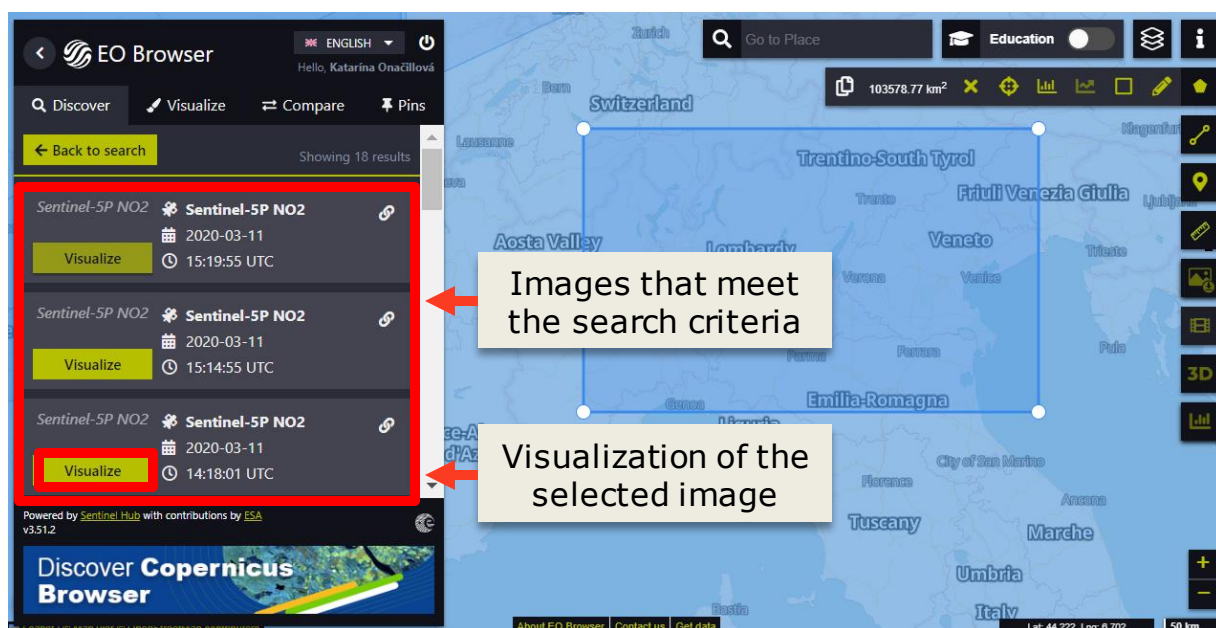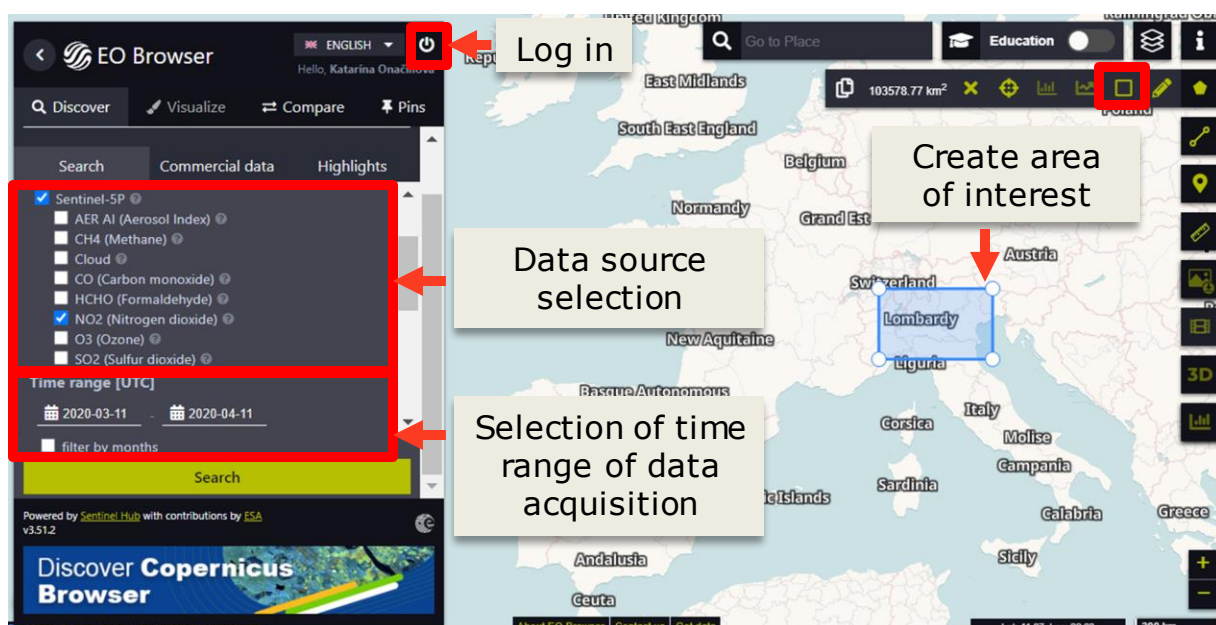
TROPOMI (Tropospheric Monitoring Instrument) is part of the payload on the ESA Sentinel-5 Precursor (Sentinel-5P) satellite, designed for the monitoring of Earth's atmosphere. It is an imaging spectrometer utilizing passive sun backscatter technology, allowing for the capture of imagery across eight bands, ranging from ultraviolet (UV) and visible to near-infrared (NIR) and shortwave infrared (SWIR) spectral domains. This instrument boasts a spatial resolution of 7×3.5 km² in both along-track and across-track dimensions. S5–P promptly delivers data on various trace gases, including O3, SO2, NO2, CO, and CH4).

Sentinel-5P played a crucial role also in monitoring changes in air quality during the COVID-19 pandemic. By capturing data on NO2 levels from space, Sentinel-5P helped scientists and authorities assess the impact of lockdown measures on air pollution. The satellite data provided valuable insights into how NO2 concentrations fluctuated in response to changes in human activities and mobility restrictions.
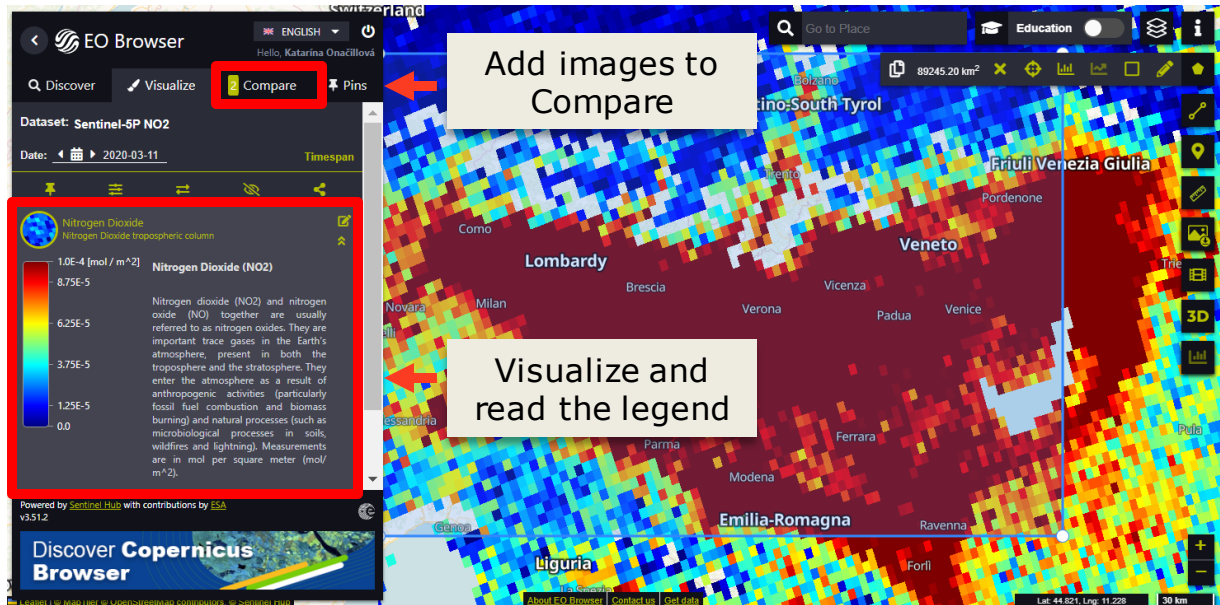
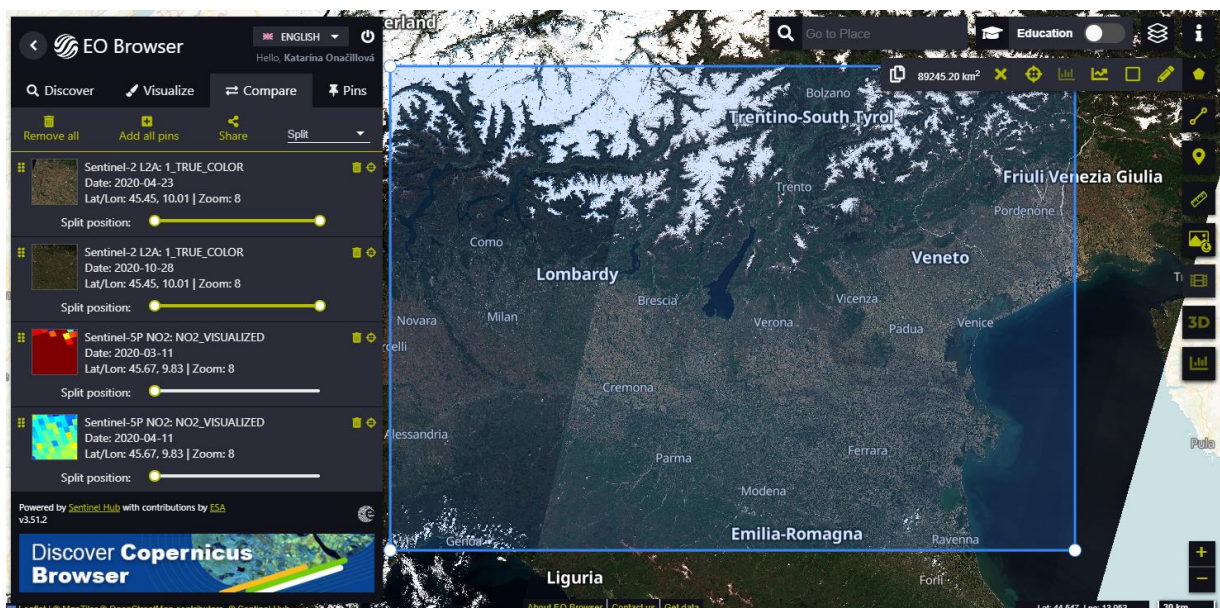## 2.1 NO2 mapping with EO Browser

1. Login (register for free) to have full access to all the tools in EO Browser: https://apps.sentinel-hub.com/eo-browser
2. Navigate to the area of northern Italy
3. Create an area of interest using polygon – draw e.g. rectangular shape
4. Select Sentinel-5P sensor and NO2 (Nitrogen dioxide)
5. Define Time range: 2020-03-11 to 2020-04-11
6. Click Search.
7. Search for the first image from 2020-03-11 and visualise it

8. Visualize the legend too
9. Add to Compare the Sentinel-5P NO2 image from 2020-03-11 by using Add to Compare function.
10. Repeat the process with the second image - last search result (2020-04-11), visualize it and Add it to Compare
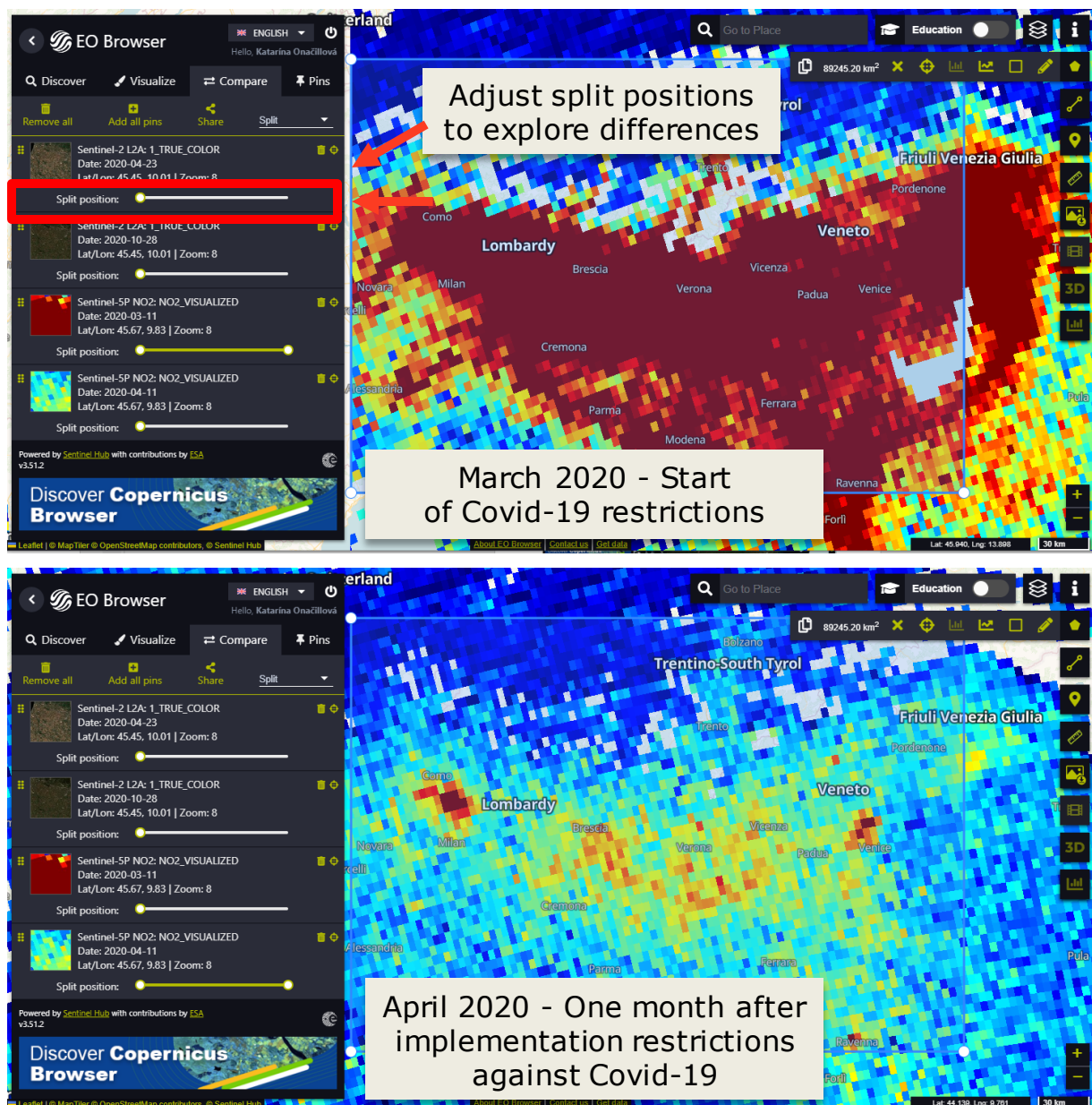

Add images to Compare

Visualize and read the legend

11. Now go back to Search tab and search for suitable cloud-free Sentinel-2 images for the same area of interest (Note: In this case it may be necessary to use two Sentinel-2 images from two different days with overlap – e.g. from 2020-04-23 and 2020-10-28) – Add them to Compare)
12. Open the Compare tab and explore images – NO2 emissions before and during the restrictions against Covid-19 and Sentinel-2 true color compositions
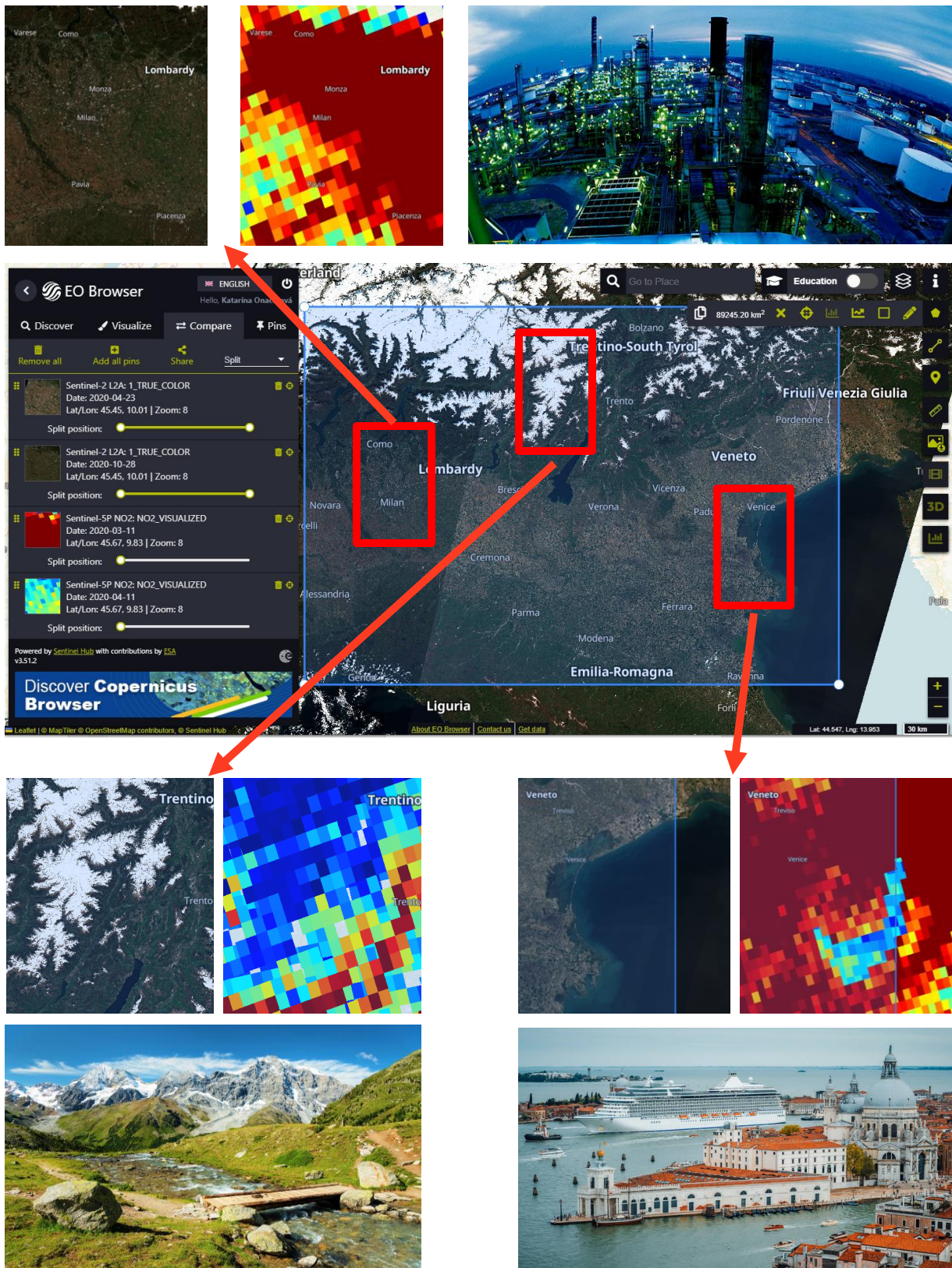
What you are seeing are the NO2 concentrations over Europe as mapped by the satellite Sentinel-5P on March (begging of Covid-19 restrictions) and April (after 1 month with Covid-19 restrictions). NO2 concentrations in clean air are close to 0 (shades of blue) and they only rise when an emission source is present. For example, large amounts of NO2 are released by the burning of fossil fuels so industry and vehicle traffic contribute to high levels of NO2 (shades of orange, red). As you can see in the image, high concentrations can be found mostly in urban areas, e.g. Milan, Treviso, Brescia, Verona. Milan is usually ranked as the worst Italian city in terms of NO2 pollution that often exceeds the mean annual concentration European limit value.
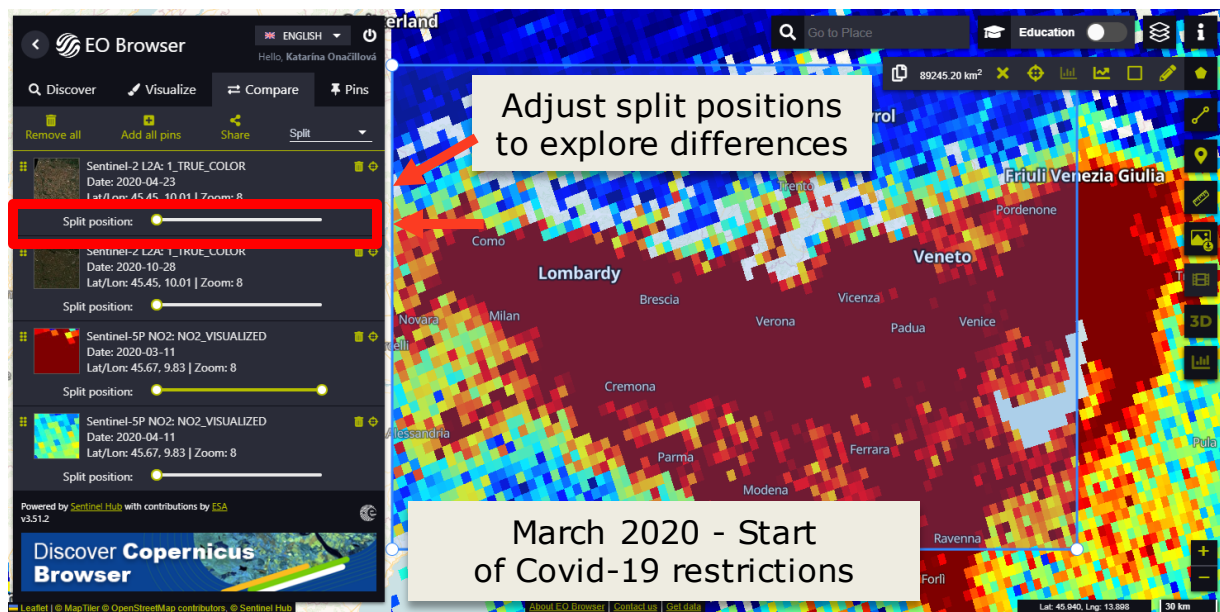
As we can see, one month after the restrictions hold against Covid-19 made an impact visible on concentrations of NO2. The satellite data provided valuable insights into how NO2 concentrations fluctuated in response to changes in human activities and mobility restrictions.

March 2020 - Start of Covid-19 restrictions

April 2020 - One month after implementation restrictions against Covid-19

Now let's explore also data from Sentinel-2 for better understanding of the scene. The Sentinel-5P image covers a larger area than the Sentinel-2 image. Therefore we use two Sentinel-2 images, which loverlap only a bit with each other, and which allow us to cover a larger part of Italy when we put them together. In this way we have more areas of comparison between the two satellites.

Note: Observe also that many pixels in the image are empty. That is because these pixels couldn't be retrieved for example due to clouds. Since the pixels are also quite large (one S-5P pixel covers an area of 7km*7km) it gets difficult to interpret this image. Let's use data from Sentinel-2 for better understanding of the scene.

2.2 Monitoring volcanic emissions with Sentinel-5P

Volcanic eruptions are potent agents of change, impacting nearby landscapes and water. They can temporarily alter the Earth's climate by releasing sulfuric acid droplets into the stratosphere. Proximity to volcanoes may necessitate permanent evacuations, and even distant areas may experience damage to cities, crops, etc.

Ninety-nine percent of the gas molecules released during a volcanic eruption consist of water vapor (H_2O), carbon dioxide (CO_2), and sulfur dioxide (SO_2). The remaining one percent comprises small quantities of hydrogen sulfide, carbon monoxide, hydrogen chloride, hydrogen fluoride, and other minor gas species, as noted by the US Geological Survey (USGS).

Copernicus Sentinel-5P Volcanic Sulfur Dioxide

Maps of volcanic SO2 concentrations

This online platform uses data from the Copernicus Sentinel-5P satellite and shows the daily sulfur dioxide concentrations coming primarily from volcanic sources.
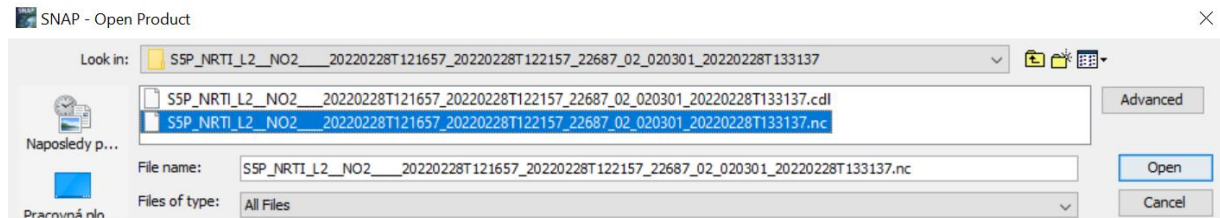
Lava flows in the Halema'uma'u crater among several active vent sources as the Kilauea volcano erupts in Hawaii on June 7, 2023.
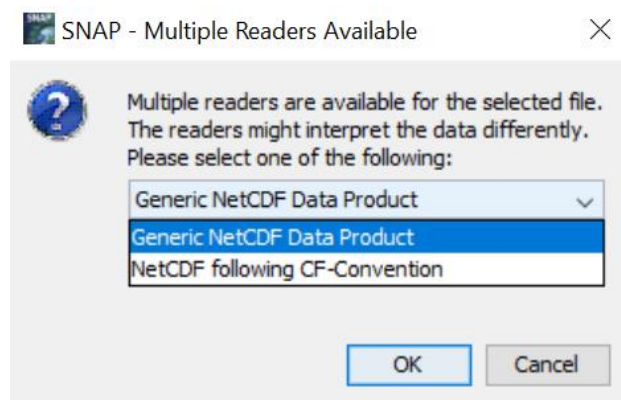
2.3 NO2 mapping in SNAP
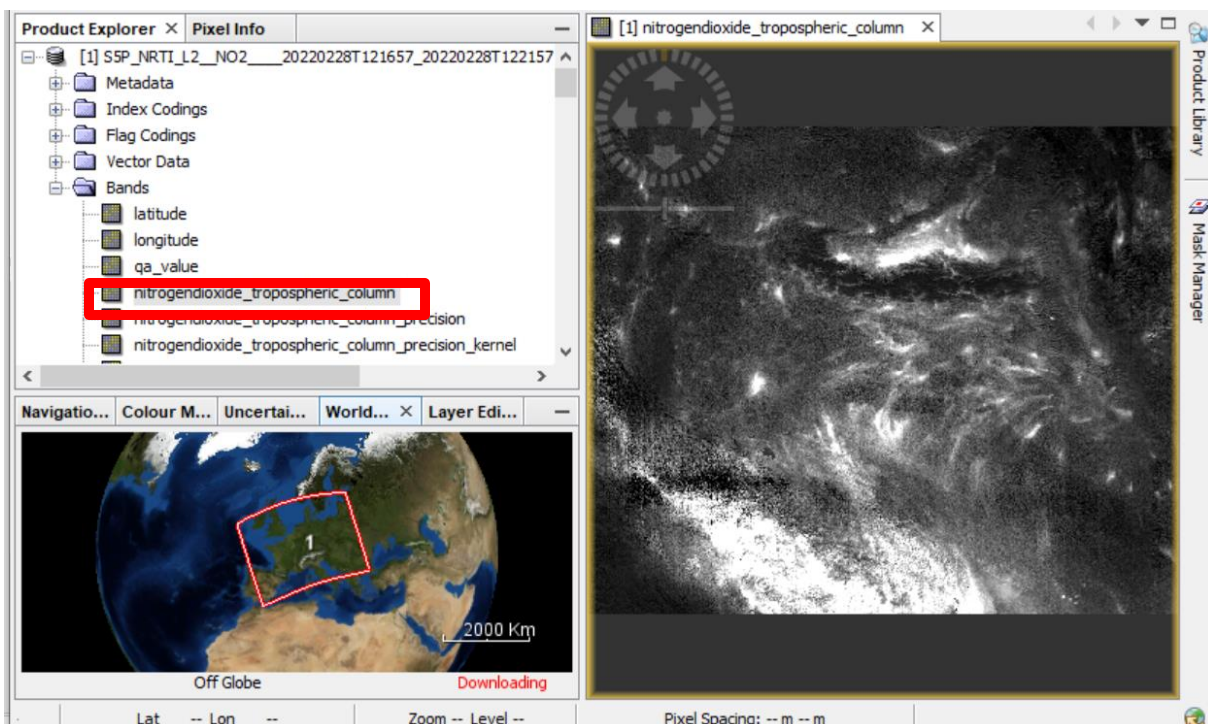
Let´s explore NO2 concentrations over Europe in SNAP:

We can open a Sentinel-5P image navigating to File – Open Product – open the product with the .nc extension:

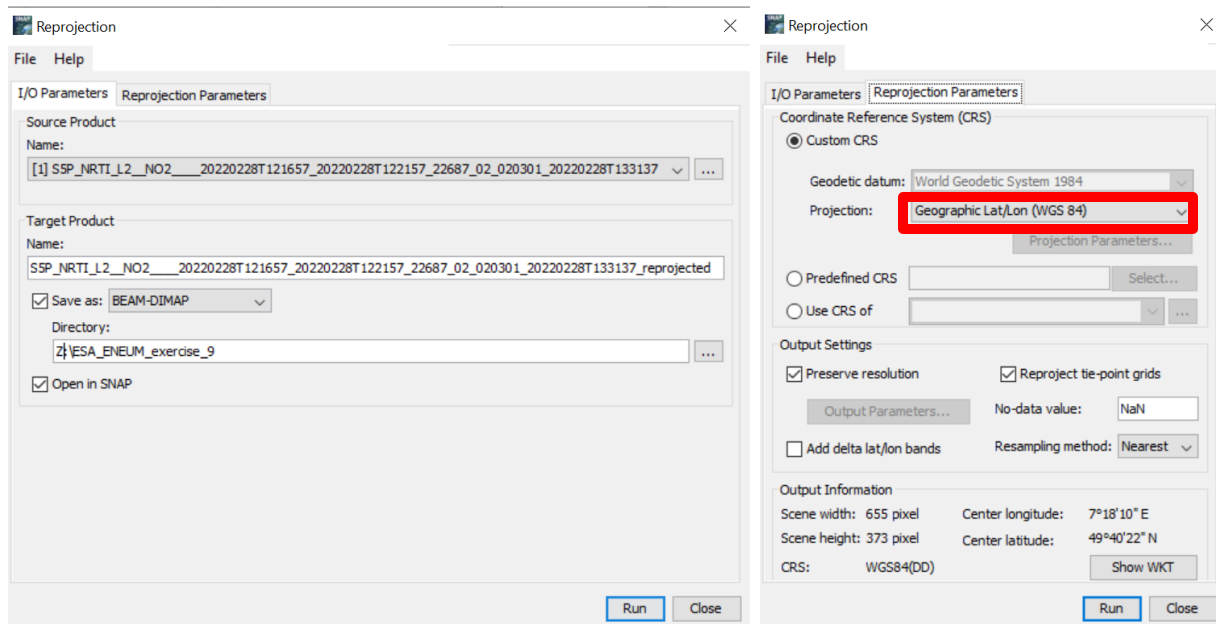Select one of the following readers for the selected sile to open it.

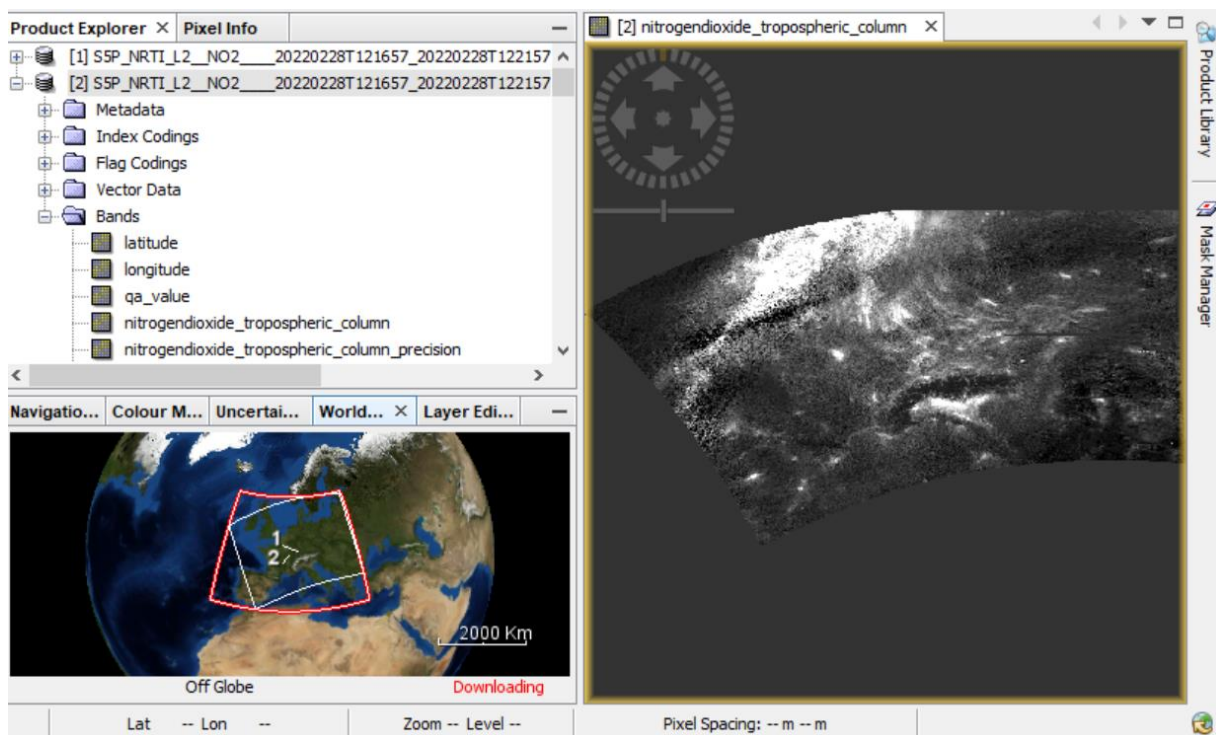
Double click on selected layer that we want to visualise

Raster – Geometric – Reprojection
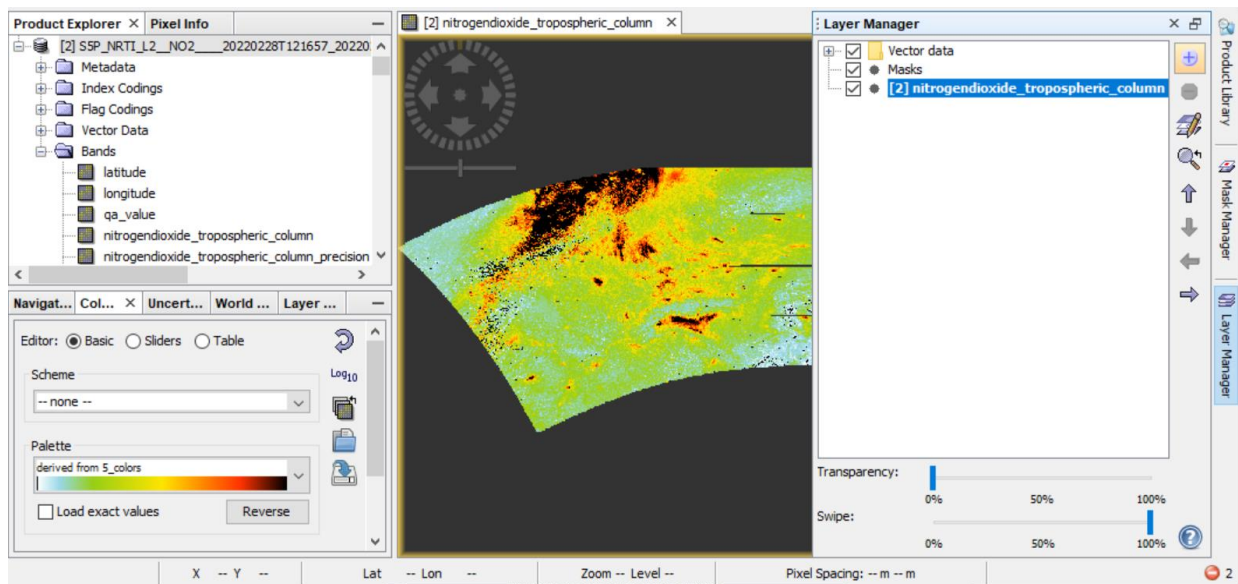
Select Custom CRS – WGS84:
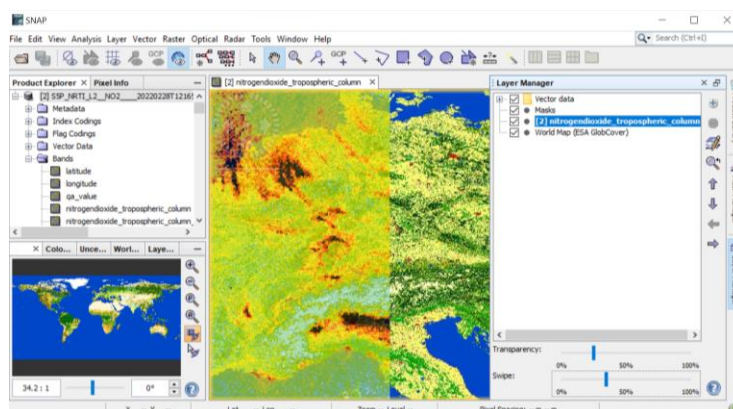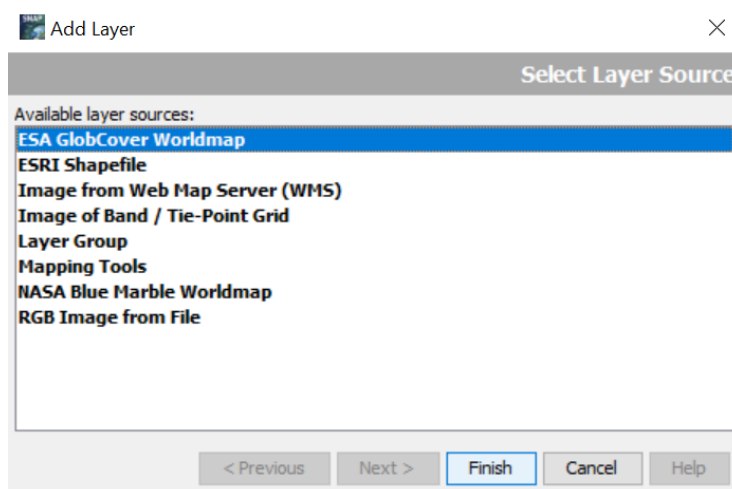

Let´s open new reprojected product

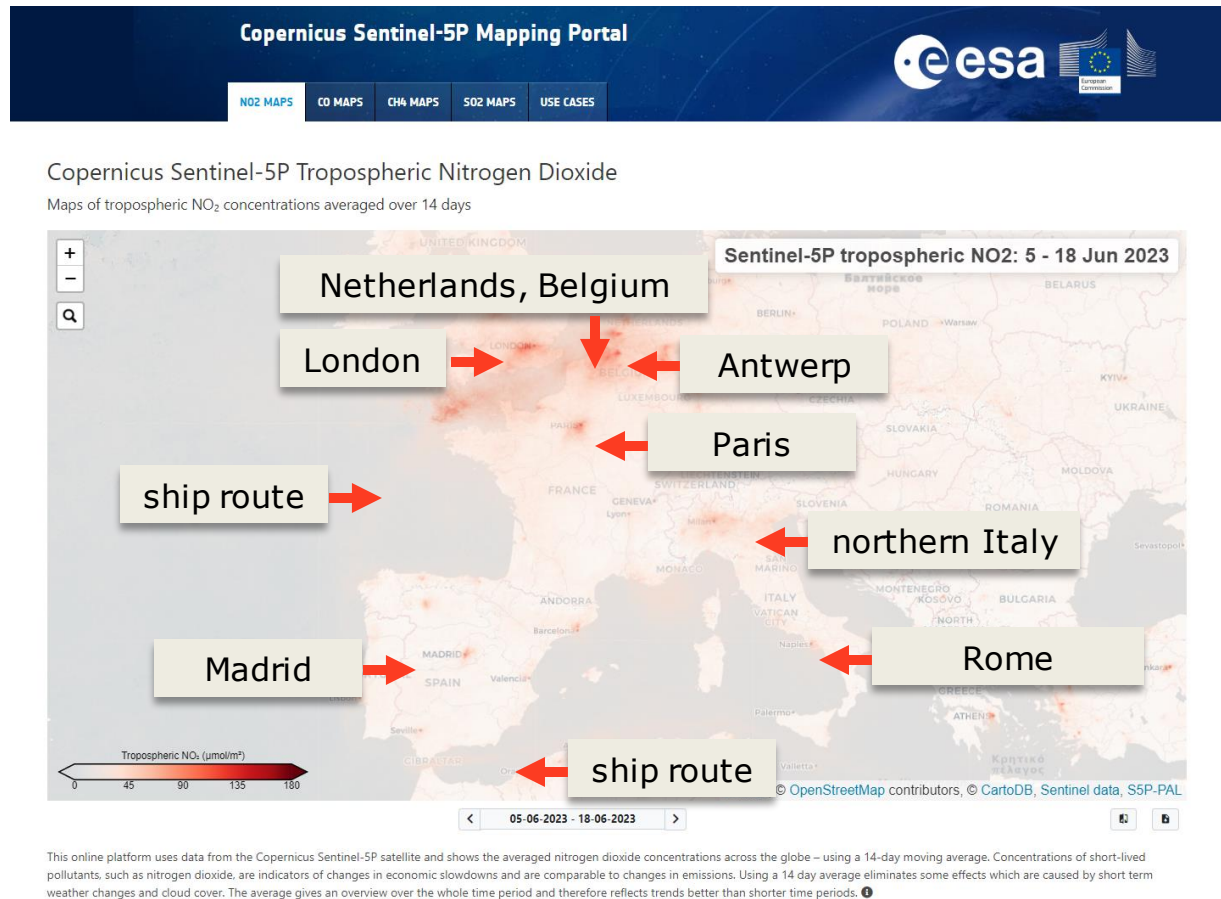Raster – Geometric – Reprojection

Select Custom CRS – WGS84:

Let´s open new reprojected product. View the final NO2 raster in QGIS. Compare it with e.g. land cover mask.
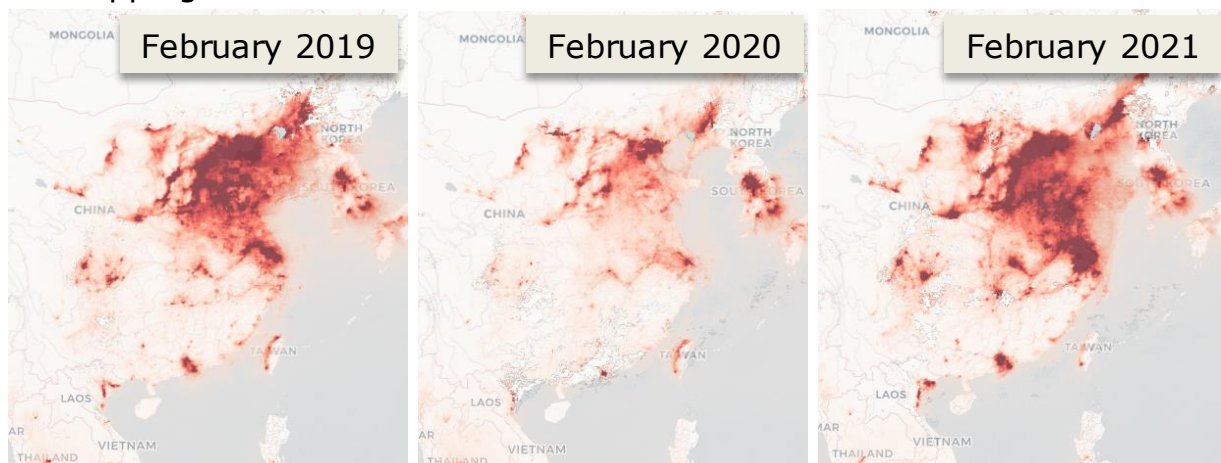
2.4 NO2 mapping with Copernicus Sentinel-5P Mapping Portal

Let´s explore NO2 concentrations over Europe using Copernicus Sentinel-5P Mapping Portal:

Try to identify cities, regions with high concentrations of NO2 and ship routes according NO2 concentrations on the map.

Let´s explore NO2 concentrations over China using Copernicus Sentinel-5P Mapping Portal:

For more information, see the lecture: 9. Air quality monitoring using Sentinel-5 data

THANK YOU FOR FOLLOWING THE EXERCISE!