

Exercise with EO Browser: Air Pollution (Sentinel-2, Sentinel-5P)

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- Define suitable search criteria (time range, area, satellite, satellite product, visualization type) in EO Browser for a case study in air pollution
- Interpret Sentinel-5P NO₂ maps
- Understand the different levels of processing for Sentinel-2 products (L1C and L2A)
- Get basic introduction to the concepts of satellite revisit and coverage (including orbit, swath)
- Compare images from different sensors in EO Browser

1. **Overview of Sentinel-5P**
2. Exercise with Sentinel-5P and Sentinel-2:
 1. NO₂ with Sentinel-5P
 2. Context information with Sentinel-2
 3. Comparison of both sensors

1. Overview of Sentinel-5P

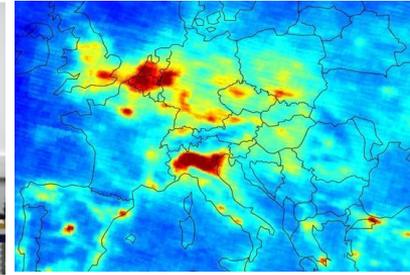
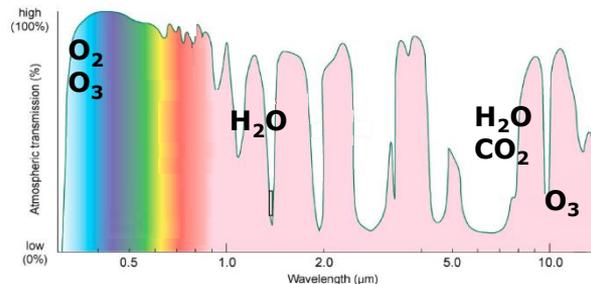
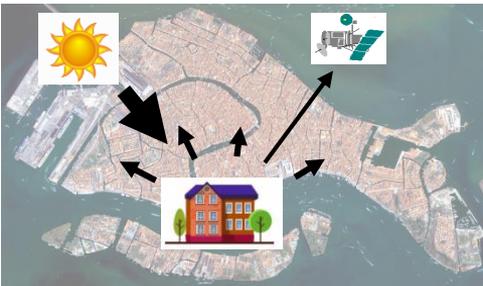
<http://www.tropomi.eu>

Sentinel-5 Precursor (S-5P) is the satellite developed in preparation for the Sentinel-5 mission that will be launched in the future. It carries only **one sensor**, called **TROPOMI**, which is the most advanced **multispectral imaging spectrometer** to date.

TROPOMI observes the **sunlight that is scattered** back to space by the surface of the Earth and by the atmosphere, and it detects the **unique fingerprints of gases** in **different parts of the electromagnetic spectrum**.

It can detect a wide range of pollutants, because it measures in the Ultra Violet, Visible, Near Infrared and Short Wave Infrared parts of the electromagnetic spectrum.

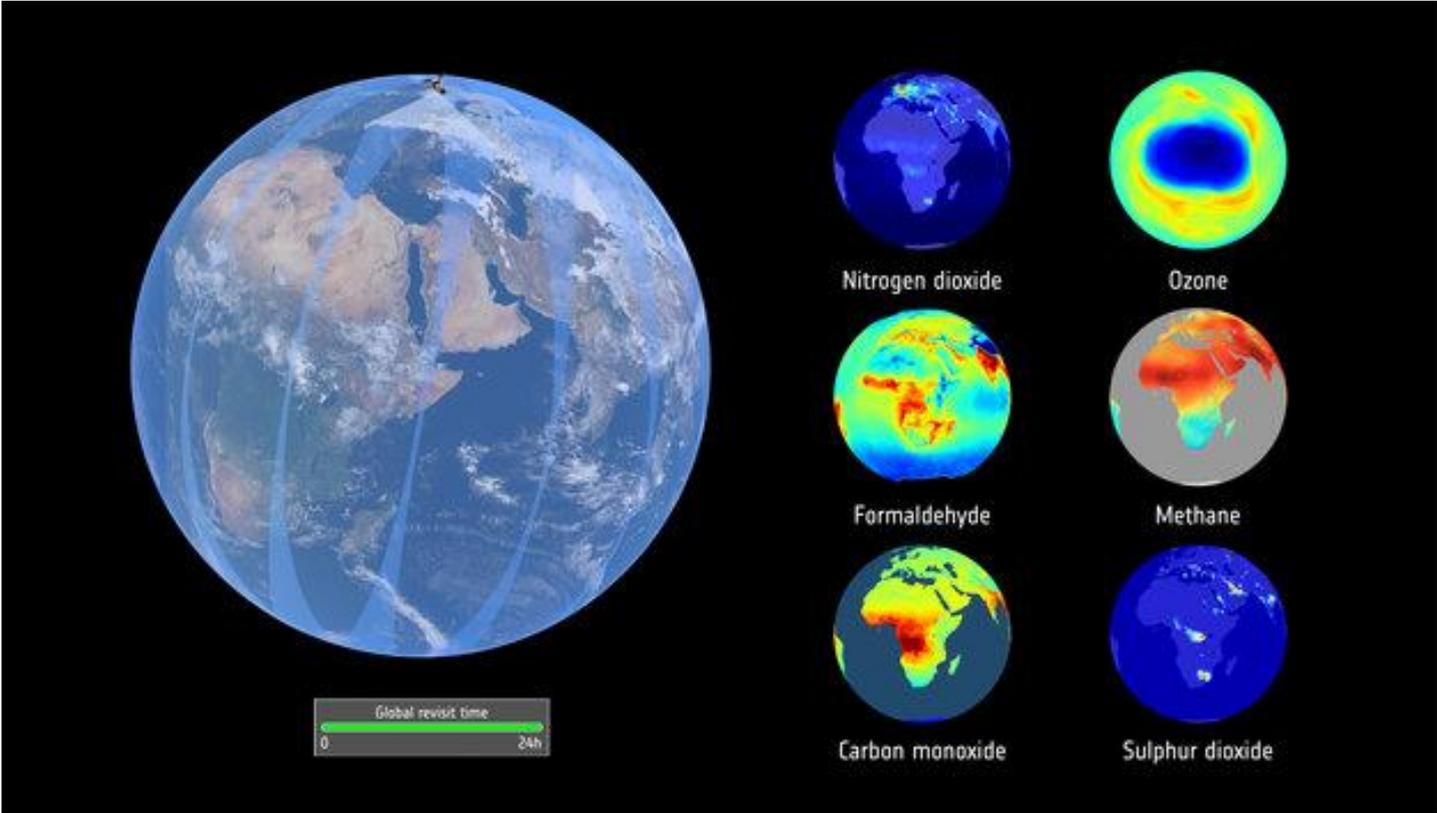
For example NO_2 , O_3 , formaldehyde, SO_2 , CH_4 , CO can be measured.



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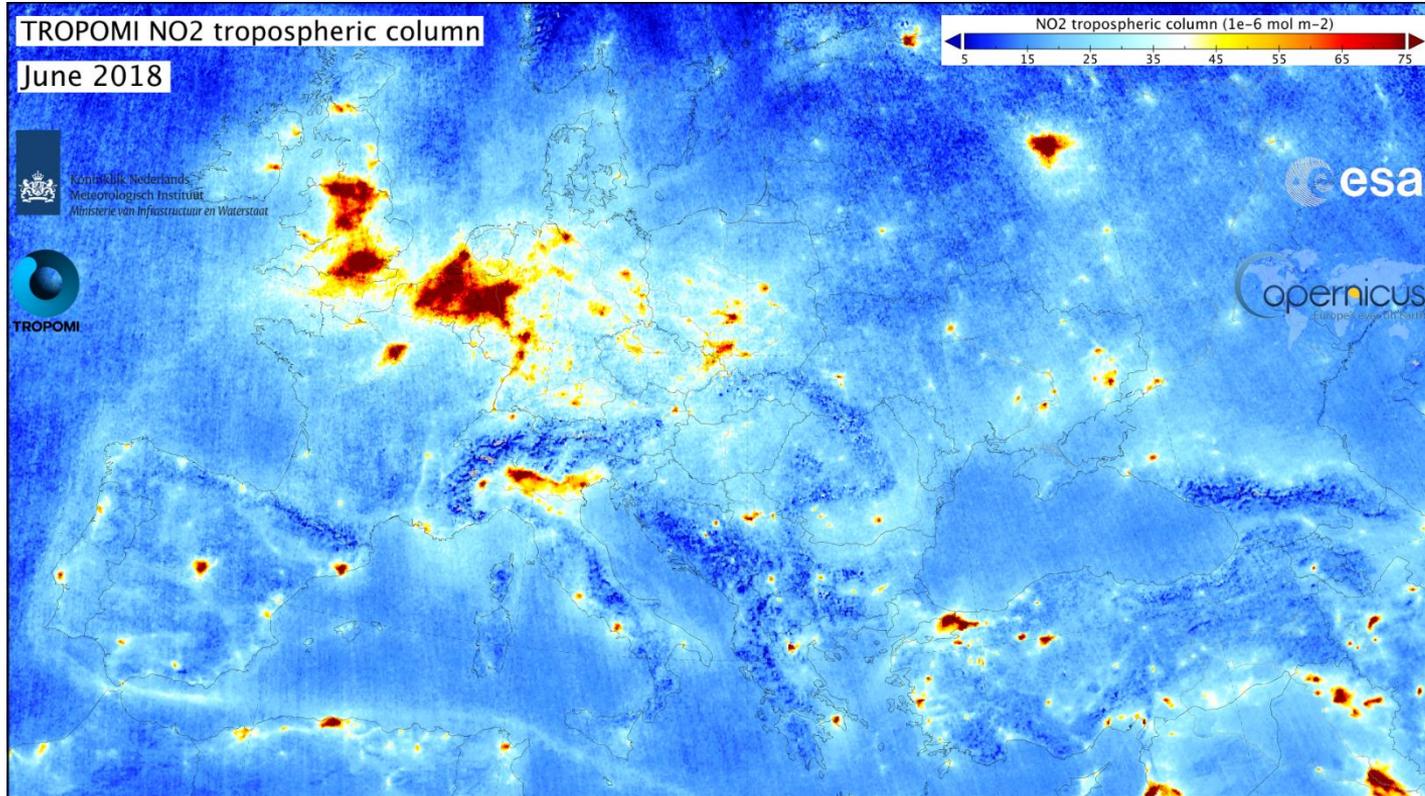
Slide 4

1. Overview of Sentinel-5P



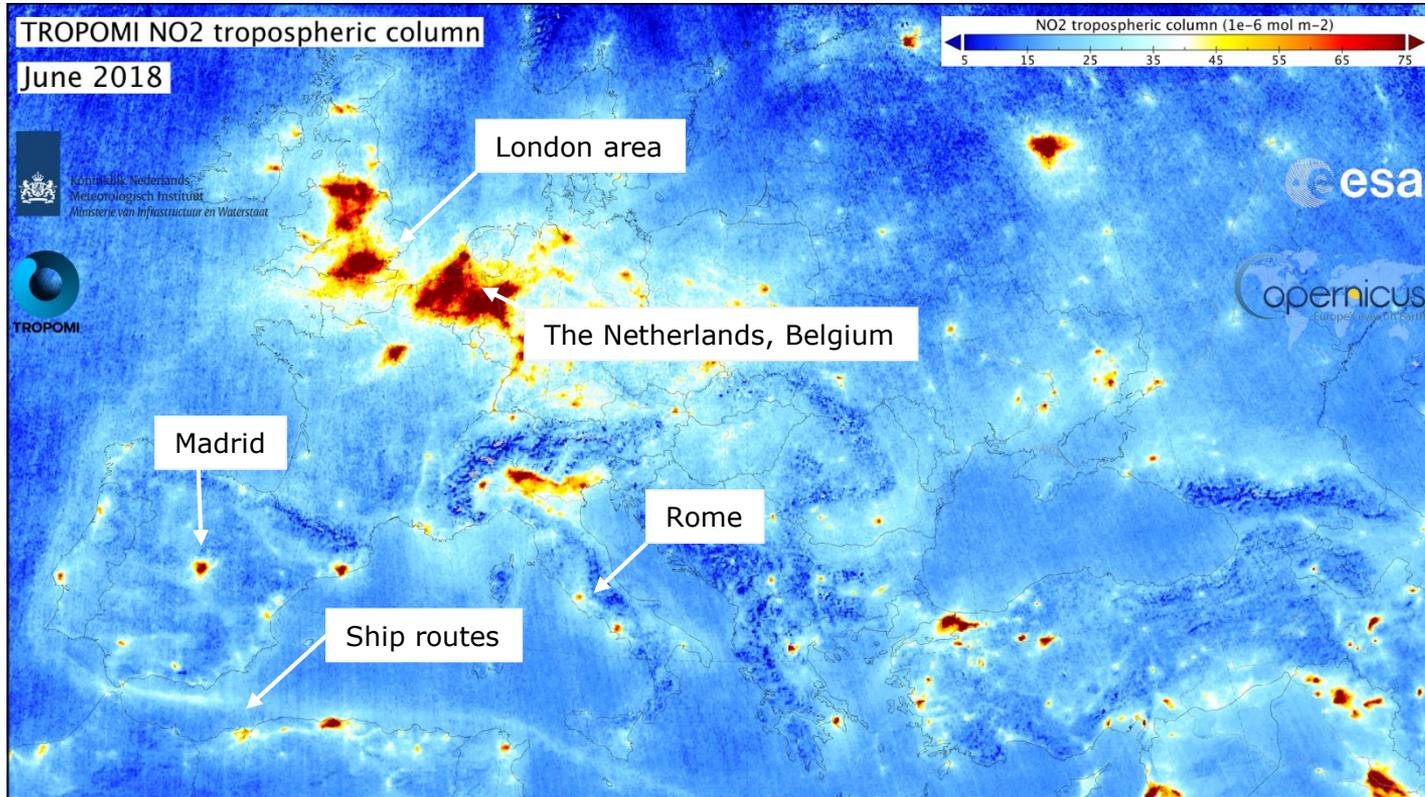
1. Overview of Sentinel-5P

NO₂ image over Europe. Cities are highlighted, can you identify them? Can you see the ship routes?



1. Overview of Sentinel-5P

NO₂ image over Europe. Cities are highlighted, can you identify them? Can you see the ship routes?



1. Overview of Sentinel-5P
2. **Exercise with Sentinel-5P and Sentinel-2:**
 1. **NO₂ with Sentinel-5P**
 2. Context information with Sentinel-2
 3. Comparison of both sensors

2. Exercise overview



We will find a **NO₂ map from Sentinel-5P**. Then we will use **Sentinel-2 (True Colour display)** to understand **which features/elements** exist in the areas where **NO₂ levels are high**.

Since the Sentinel-5P images cover larger areas than the Sentinel-2 images, we will display at the same time the images **Sentinel-2 acquired on two different days**, so as to cover **all the area of northern Italy**.



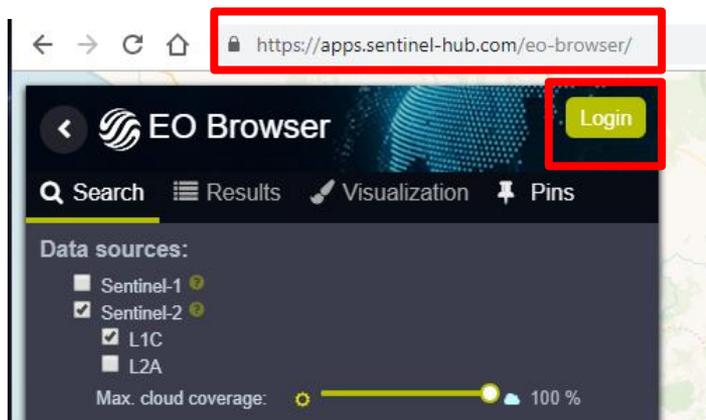
WHY?
We will look at this later in the exercise, in Note 2



2.1. NO₂ with Sentinel-5P

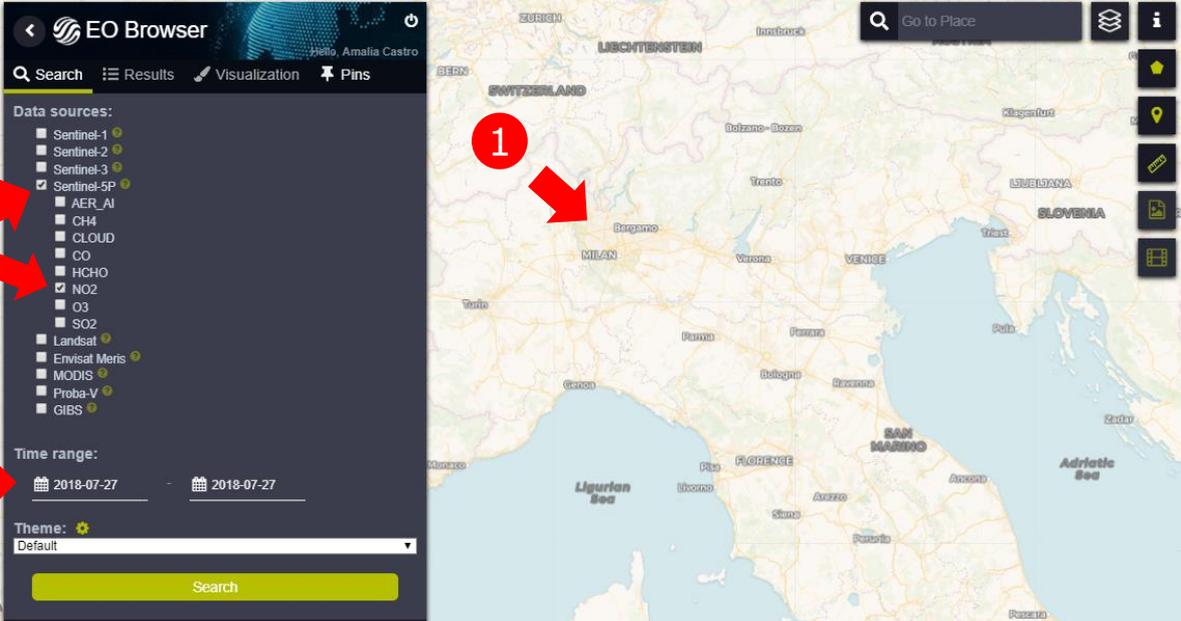
<http://apps.sentinel-hub.com/eo-browser/>

Register **for free** with an email address, to have full access to all the tools.



2.1. NO₂ with Sentinel-5P

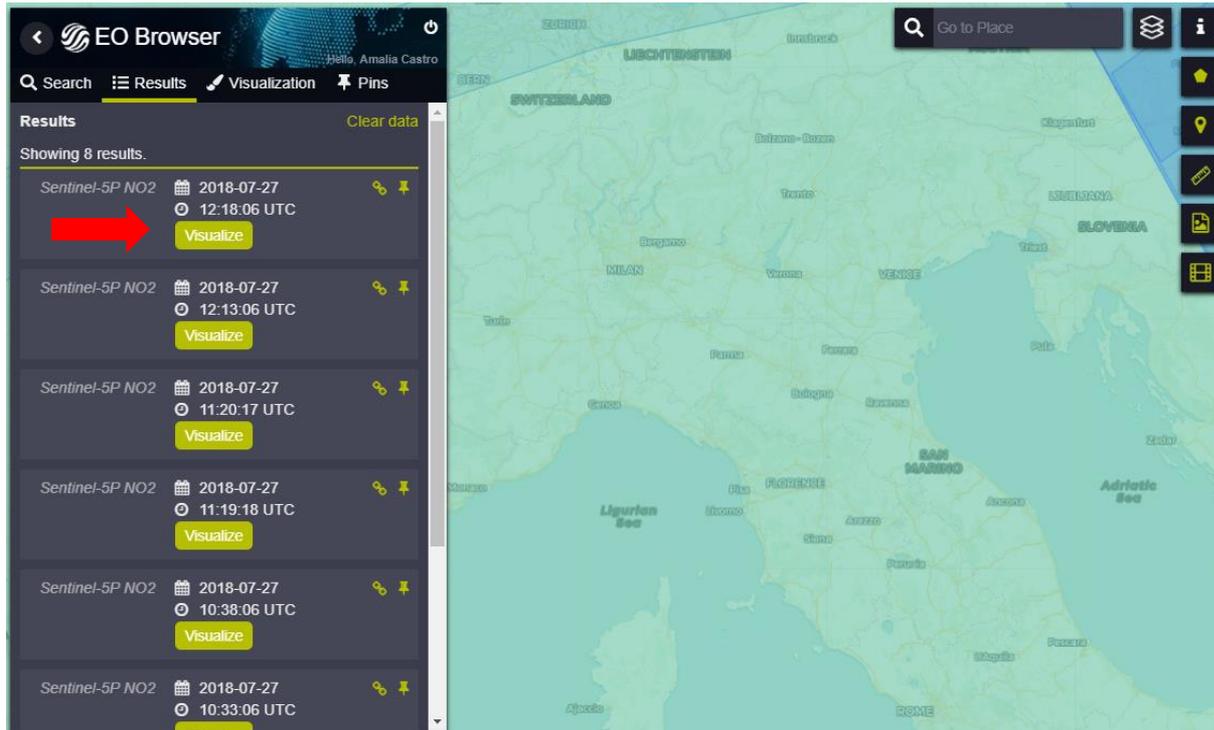
- 1. Where to search?** Navigate to the area of northern Italy (simply use your mouse to adjust the display as seen below. There is no need to upload polygons or enter coordinates).
- 2. Which sensor?** Select **Sentinel-5P (NO₂)**
- 3. When to search?** Define Time range: **2018-07-27 to 2018-07-27 (yes, the same day for both!)**
4. Click Search



The screenshot shows the EO Browser interface. On the left, the 'Data sources' panel is open, with 'Sentinel-5P' selected and 'NO2' checked. Below it, the 'Time range' is set to '2018-07-27' to '2018-07-27'. The 'Theme' is set to 'Default'. A green 'Search' button is at the bottom. On the right, a map of northern Italy is displayed, with a red circle and arrow labeled '1' pointing to the Milan area. Red arrows labeled '2', '3', and '4' point to the 'Sentinel-5P', 'NO2', and 'Search' elements respectively.

2.1. NO₂ with Sentinel-5P

We will choose the **first result** (from **12:18:06 UTC**): click **Visualize**

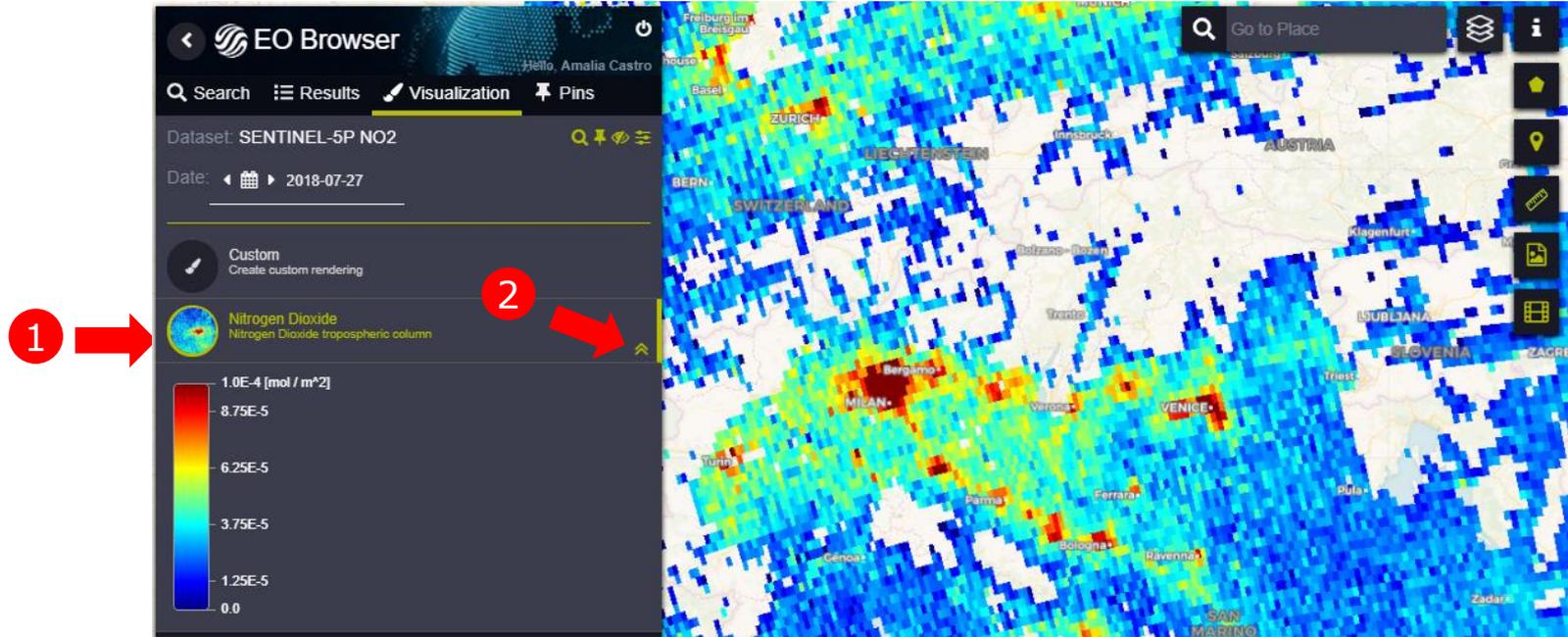


The screenshot shows the EO Browser interface. On the left, a sidebar displays search results for Sentinel-5P NO2 data. The first result is highlighted with a red arrow pointing to the 'Visualize' button. The results list includes the date 2018-07-27 and the time 12:18:06 UTC. The main map area shows a satellite view of Northern Italy, with labels for cities like Milan, Venice, and Rome, and bodies of water like the Ligurian Sea and Adriatic Sea. The interface includes a search bar at the top right and a navigation menu on the right side.

Result	Date	Time (UTC)	Action
Sentinel-5P NO2	2018-07-27	12:18:06 UTC	Visualize
Sentinel-5P NO2	2018-07-27	12:13:06 UTC	Visualize
Sentinel-5P NO2	2018-07-27	11:20:17 UTC	Visualize
Sentinel-5P NO2	2018-07-27	11:19:18 UTC	Visualize
Sentinel-5P NO2	2018-07-27	10:38:06 UTC	Visualize
Sentinel-5P NO2	2018-07-27	10:33:06 UTC	Visualize

2.1. NO₂ with Sentinel-5P

1. To display the **NO₂ map**, you may need to click on **Nitrogen Dioxide**, under **Custom**
2. Visualize the **legend** too



2.1. NO₂ with Sentinel-5P



What you are seeing are the **NO₂ concentrations over Europe** as mapped by the satellite **Sentinel-5P** on **July 27th 2018**. NO₂ concentrations in **clean air are close to 0** 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**. As you can see in the image, high concentrations can be found mostly in **urban areas**, e.g. Milan, Rome, Lyon.

Ships are another large emission source for NO₂ and other air pollutants. As you can see, Venice, which has one of **Italy's largest harbours** shows very high NO₂ levels.

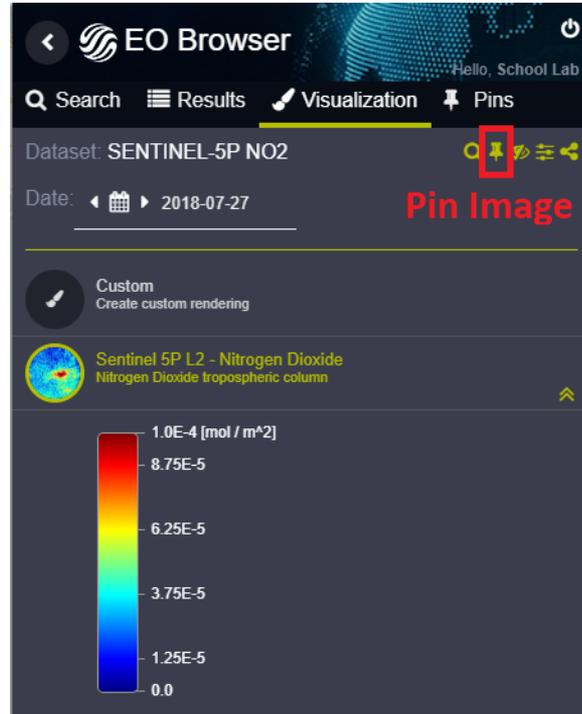
Observe also that many pixels in the image are **empty**. That is because these pixels **couldn't be retrieved** for example due to clouds. Since the pixels are also quite large (one S-5P pixel covers an area of 7km*7km) it gets difficult to interpret this image. Let's use data from **Sentinel-2 for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

But first **let's save (pin) our image!**



2.1. NO₂ with Sentinel-5P

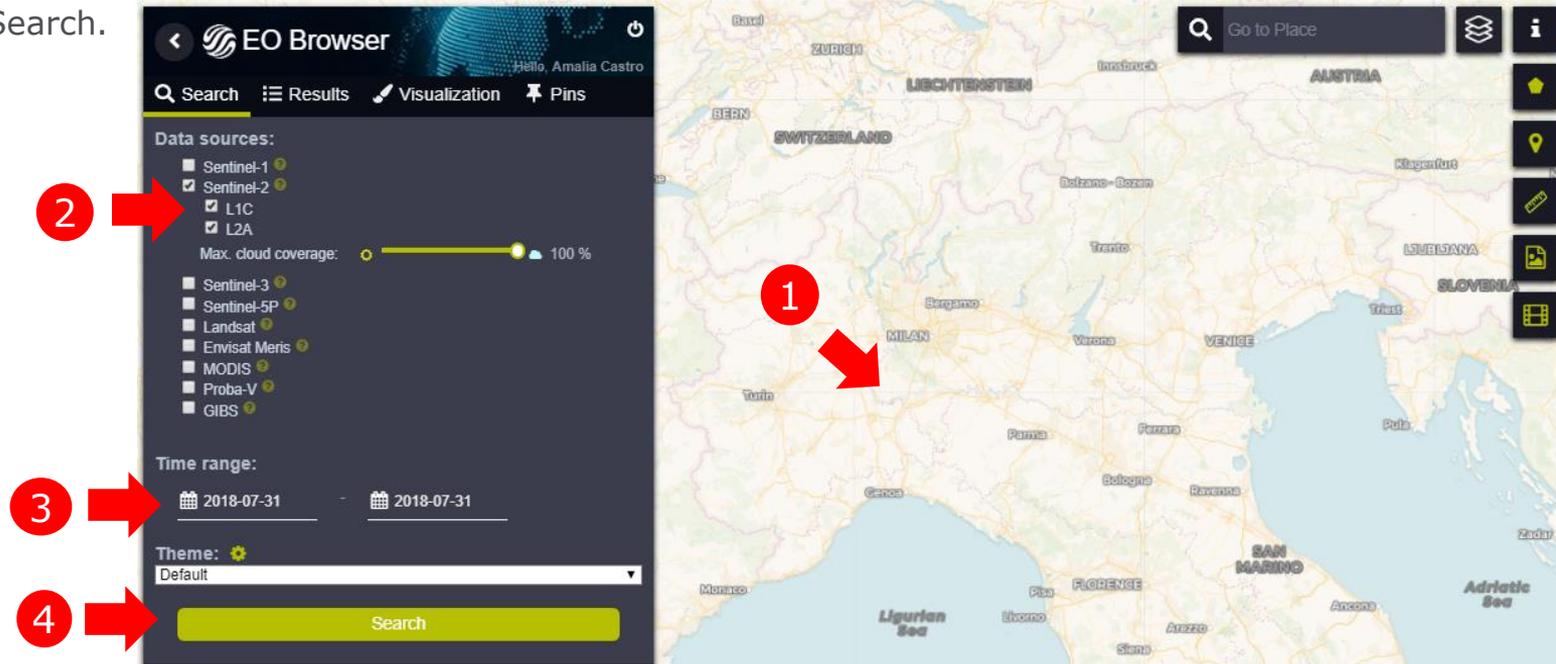
Save the Sentinel-5P NO₂ image from 2018-07-27 by using **Pin image** function.



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2.2. Context information with Sentinel-2

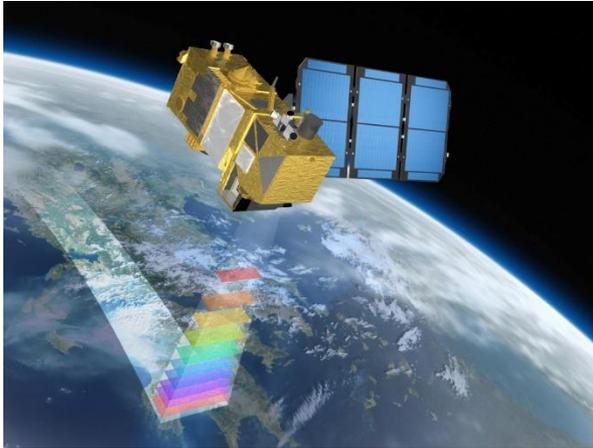
1. **Where to search?** Keep the same area as before (northern Italy)
2. **Which sensor?** Select **Sentinel-2 (both L1C & L2A)* See Note 1 in next slides**
3. **When to search?** Define Time range: **2018-07-31 to 2018-07-31 (same date for both!)**
4. Click Search.



The screenshot shows the EO Browser interface. On the left, the 'Data sources' panel is visible, with 'Sentinel-2' selected and its sub-sensors 'L1C' and 'L2A' checked. Below this, the 'Time range' is set to '2018-07-31' to '2018-07-31'. The 'Theme' is set to 'Default'. A large green 'Search' button is at the bottom of the panel. On the right, a map of northern Italy is displayed, with a red circle and arrow labeled '1' pointing to the map area. The map shows major cities like Milan, Bergamo, and Venice, and geographical features like the Ligurian Sea and Adriatic Sea.

2.2. Context information with Sentinel-2– **NOTE 1**

When the satellite acquires the image, it sends it to a **ground station**. But the image is **not yet ready to be used** because its quality is not yet good enough!



A simple explanation of this is that the image has **geometric distortions** (e.g. due to the rotation of the earth) and the values recorded are influenced by the fact that the **atmosphere absorbs** part of the radiation.

2.2. Context information with Sentinel-2– **NOTE 1**



But what does L1C and L2A mean?

As we just said, Sentinel-2 acquires an image **over a certain area**, and then sends it to a **ground station in Earth**. This image is called **Level 0**, because **no corrections** have been applied to it yet: the image still presents **distortions** that affect its geometry and the values recorded. Corrections are applied **gradually** (not all of them at once). Every time a correction is applied, we say the **level of the image increases** (e.g. Level 1-A, then Level 1-B, etc).

Level 1C (L1C) images have had **all the corrections done except for the atmospheric correction**: the distortion of the atmosphere is still present. The values represent what the satellite measures at the **top of the atmosphere** (not at the bottom of the atmosphere!).

After the algorithm that makes this last correction is applied, the outcome is called a **Level-2A product (L2A)**. L2A products therefore represent the measurement at the **BOTTOM of the atmosphere**, i.e. at the **level of the ground**.

2.2. Context information with Sentinel-2– **NOTE 1**



Ideally we would only use L2A products, but when Sentinel-2 started acquiring images, **the algorithm that creates L2A products was not applied to L1C images in an automatic way**. This means L2A images of that period do not show in EO Browser.

Users needed to apply the algorithm themselves (by downloading the L1C image, opening it in the ESA SNAP software, and using the Sen2Cor plugin in that software to create the L2A product).

It was only later on that the algorithm started being **applied automatically** to L1C products: L2A products became available **as routine** and could therefore **appear in EO Browser**.

This is the reason we prefer to select **L1C AND L2A**: to be sure that, whenever we search for an image in EO Browser, we will be able to find one. Otherwise, if we only selected L2A and we were looking for older dates (e.g. end of 2015), we may not find L2A results in EO Browser...

More info at <https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi/processing-levels> and <https://earth.esa.int/web/sentinel/user-guides/sentinel-2-msi/product-types/level-2a>

ESA SNAP Software: <https://step.esa.int/main/toolboxes/snap/>

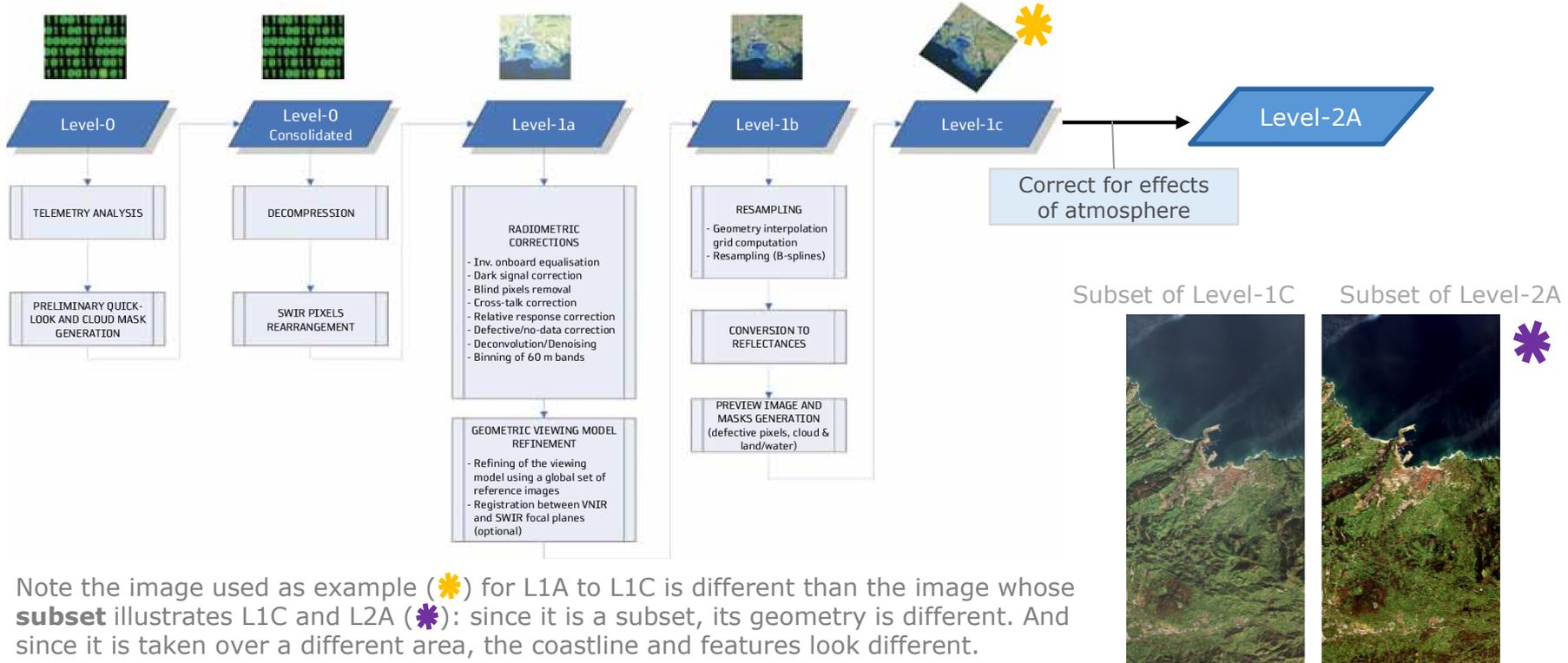
Sen2Cor plugin: <https://step.esa.int/main/third-party-plugins-2/sen2cor/>



2.2. Context information with Sentinel-2– NOTE 1

As we said, the original image received by the ground station is called a Level-0 image.

After each correction, the level increases.



Note the image used as example (*) for L1A to L1C is different than the image whose **subset** illustrates L1C and L2A (*): since it is a subset, its geometry is different. And since it is taken over a different area, the coastline and features look different.

2.2. Context information with Sentinel-2– NOTE 1

Subset of a Level-1C image (**before** correcting for the effects of the atmosphere)

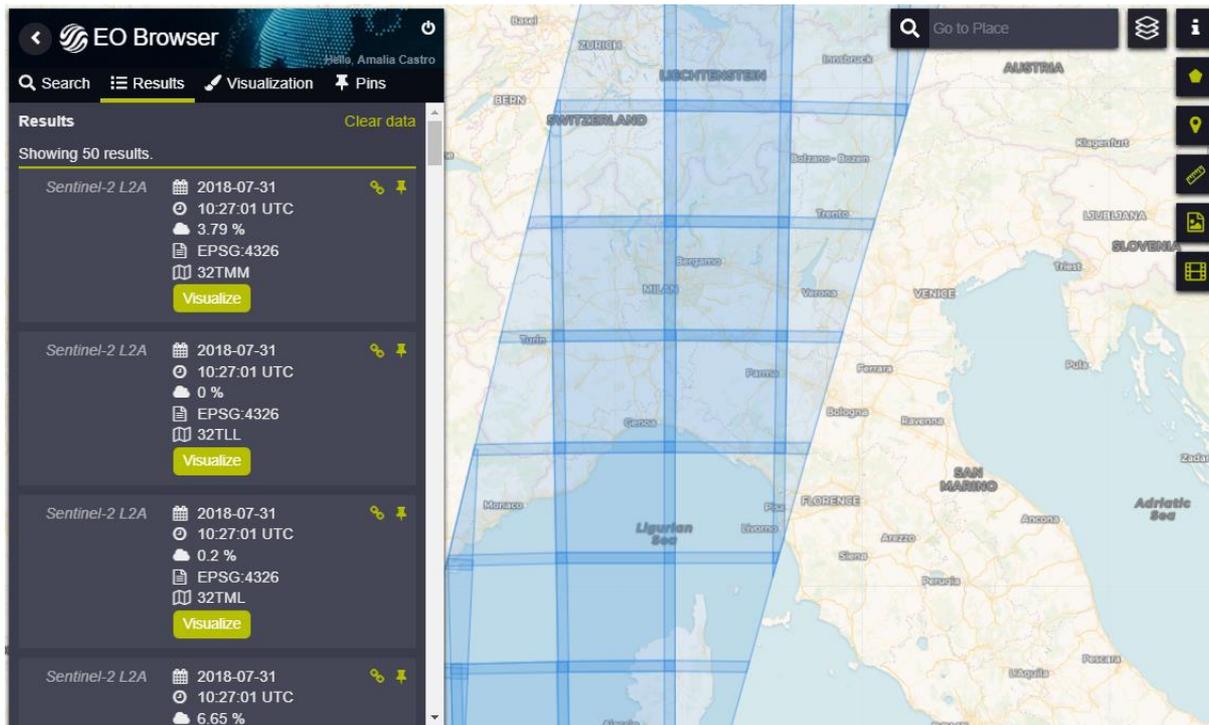


Subset of a Level-2A image (**after** correcting for the effects of the atmosphere)



2.2. Context information with Sentinel-2

Then a list of various **results** will display. Let's have a closer look at it.



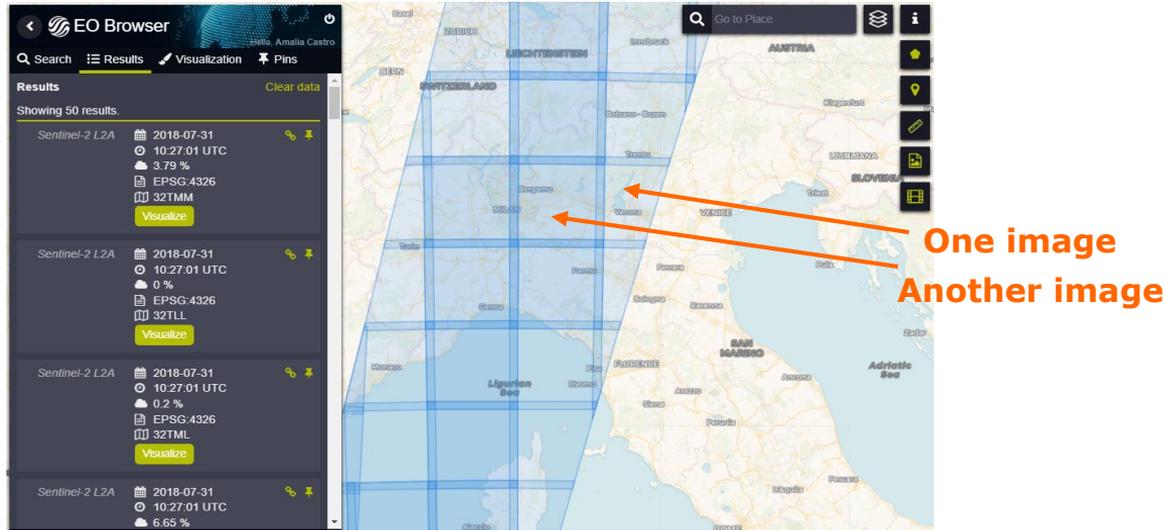
The screenshot displays the EO Browser interface. On the left, a sidebar shows search results for Sentinel-2 L2A data. The main area shows a map of Europe with a blue grid overlay. The interface includes a search bar, navigation controls, and a list of results.

Result Name	Date	Time	Cloud %	Projection	Tile ID	Action
Sentinel-2 L2A	2018-07-31	10:27:01 UTC	3.79 %	EPSG:4326	32TMM	Visualize
Sentinel-2 L2A	2018-07-31	10:27:01 UTC	0 %	EPSG:4326	32TLL	Visualize
Sentinel-2 L2A	2018-07-31	10:27:01 UTC	0.2 %	EPSG:4326	32TML	Visualize
Sentinel-2 L2A	2018-07-31	10:27:01 UTC	6.65 %			

2.2. Context information with Sentinel-2

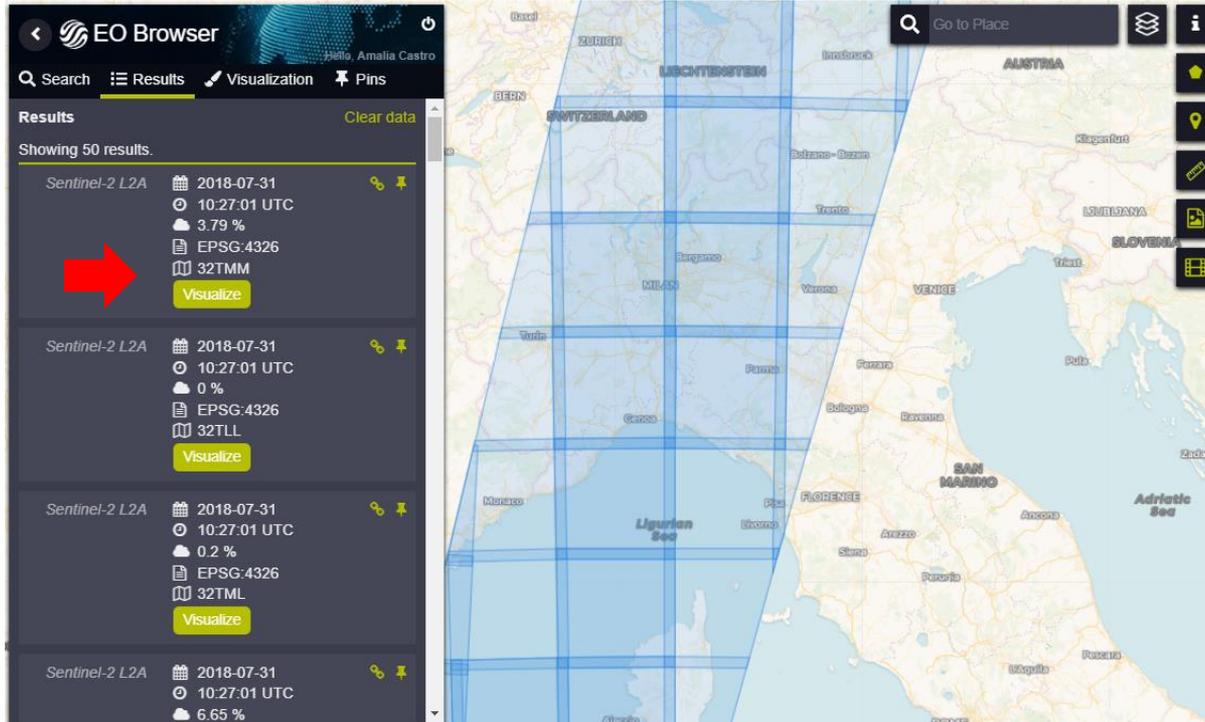
We see **all the images acquired that day in that area** by Sentinel-2. Their **footprints** appear as **blue squares** in EO Browser.

Observe images have a **small overlap** with each other: this ensures different images can be **merged together**, if needed, and ensures no areas remain uncovered.



2.2. Context information with Sentinel-2

We will choose the **first result** (from **2018-07-31 10:27:01 UTC**) with 3.79% of cloud cover: click **Visualize**.

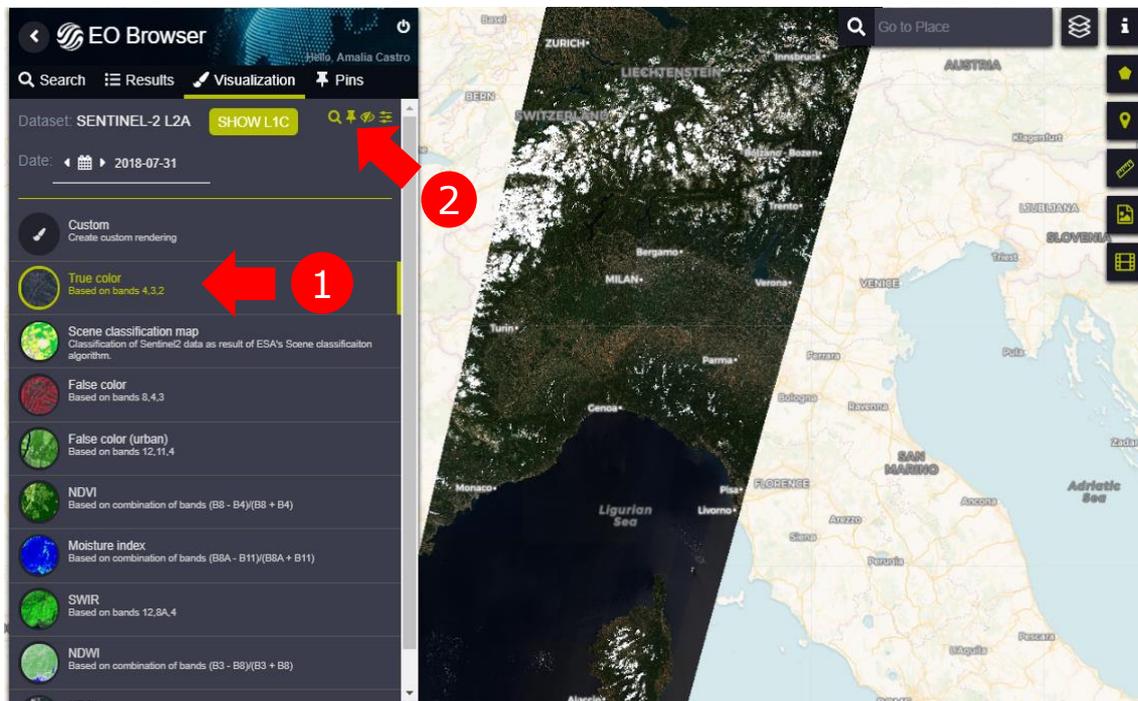


The screenshot shows the EO Browser interface with a search results panel on the left and a map on the right. The search results panel displays four Sentinel-2 L2A results. The first result is highlighted with a red arrow pointing to the 'Visualize' button. The map shows a satellite image of the Venetian region in Italy, with a blue grid overlay indicating the search area.

Result	Date	Time	Cloud Cover	Projection	Tile ID	Action
Sentinel-2 L2A	2018-07-31	10:27:01 UTC	3.79 %	EPSG:4326	32TMM	Visualize
Sentinel-2 L2A	2018-07-31	10:27:01 UTC	0 %	EPSG:4326	32TLL	Visualize
Sentinel-2 L2A	2018-07-31	10:27:01 UTC	0.2 %	EPSG:4326	32TML	Visualize
Sentinel-2 L2A	2018-07-31	10:27:01 UTC	6.65 %			

2.2. Context information with Sentinel-2

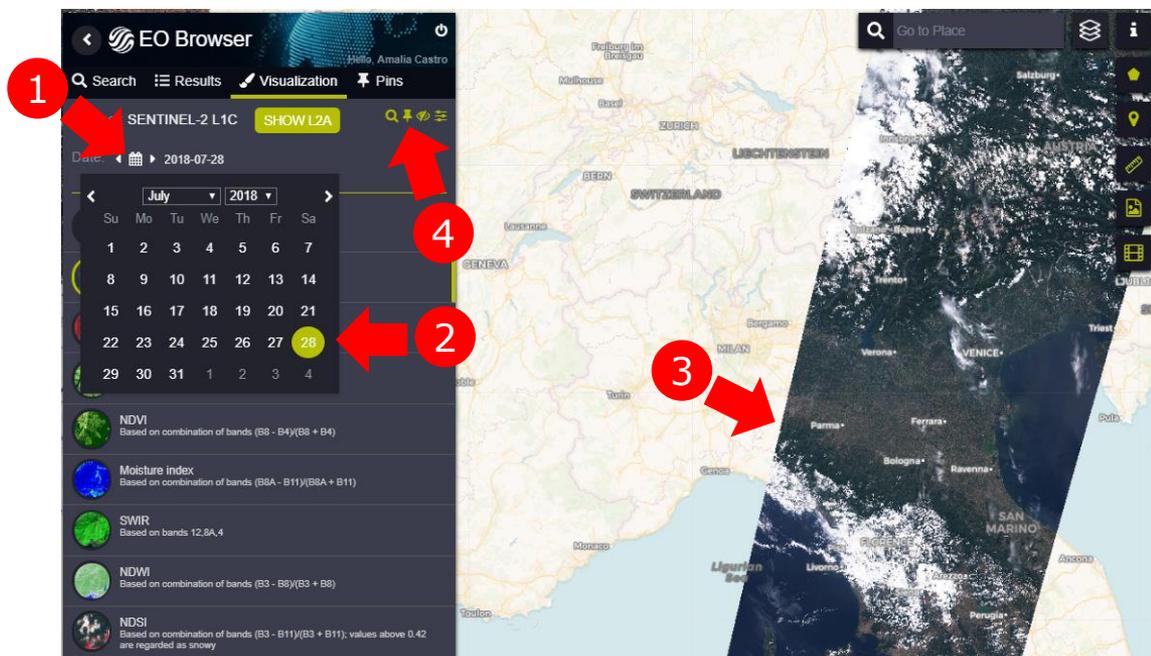
1. Then choose a **visualization**, for example **True Colour**
2. Next **pin the image**, in order to save it
3. Go back to the **Visualizations tab**



2.2. Context information with Sentinel-2

Let's find an image from **2018-07-28**. You could search from the Search tab, as you learned in the previous slides. Alternatively, here we show you a **shortcut**:

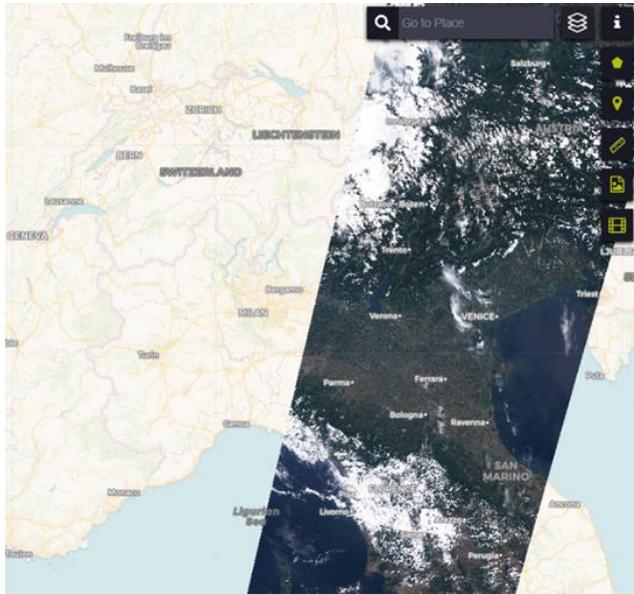
1. Always in the **Visualization tab**, click the **calendar icon**
2. Select **2018-07-28**
3. The display of the image will update
4. Pin the image to save it



2.2. Context information with Sentinel-2 – NOTE 2

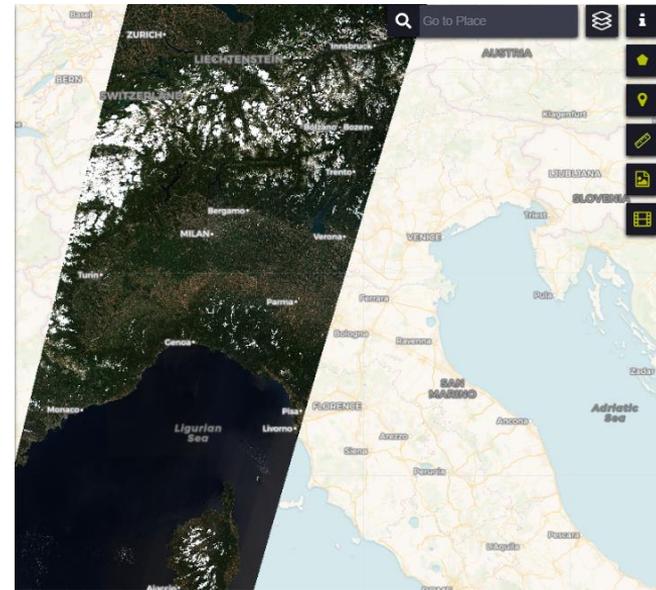
Did you notice how **the images Sentinel-2 acquires in a single day** look like, when put **all together**? They cover a different area each day.....

28-07-2018



WHY?

31-07-2018



2.2. Context information with Sentinel-2 – NOTE 2

Hint...

SENTINEL-2 GLOBAL COVERAGE



Watch in: 

[DOWNLOAD](#) **MP4** (3.73 MB)

[SOURCE](#) **MP4** (65.52 MB)

Embed Code

```
<iframe  
src="https://www.esa.int/spaceinvideos/content/view/embed/w/473937"  
width="640" height="360" frameborder="0"></iframe>
```

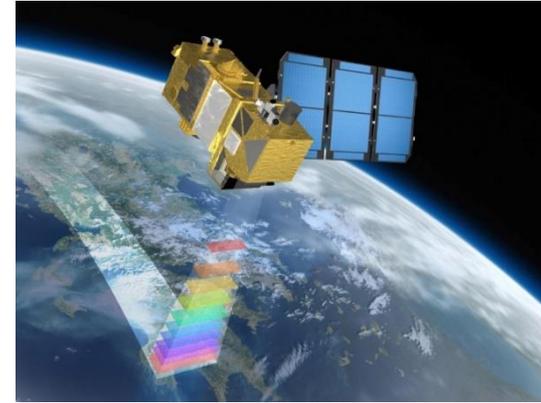
http://www.esa.int/spaceinvideos/Videos/2016/08/Sentinel-2_global_coverage?source=post_page

2.2. Context information with Sentinel-2 – NOTE 2

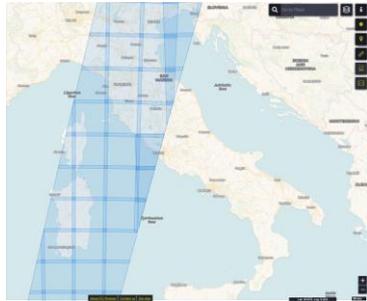
Answer: Satellites **follow an orbit around the Earth**, and can only “see” the part of the ground surface that is **under that orbit**.

What they see is called **swath**. The swath is in a **different location every day**, because the Earth rotates.

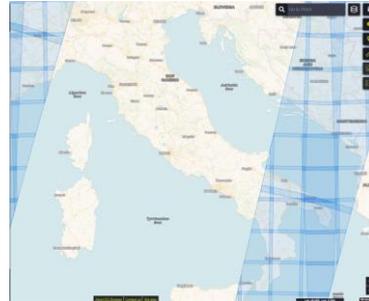
After some days, Sentinel-2 has imaged the whole Earth, and the cycle **starts again**.



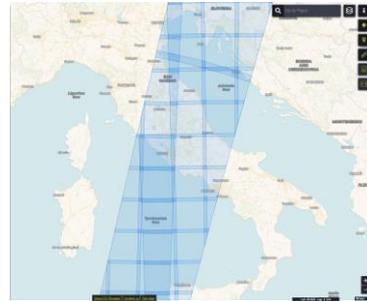
28-07-2018



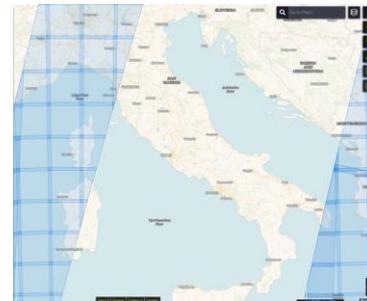
29-07-2018



30-07-2018



31-07-2018

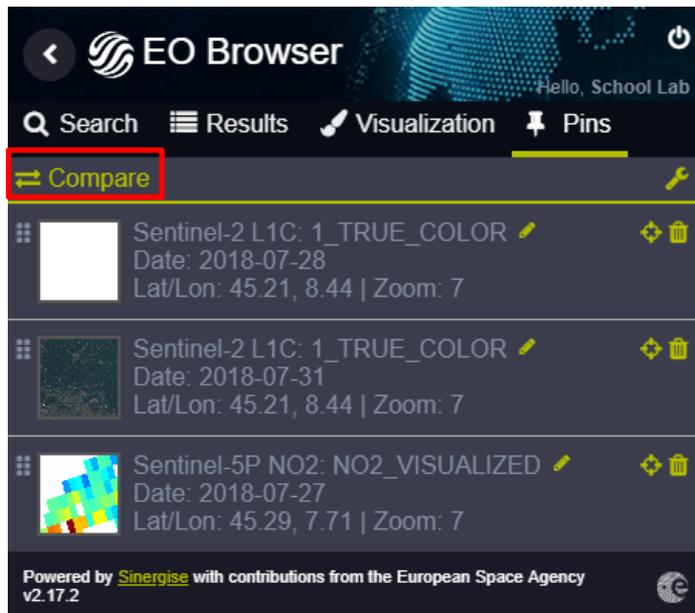


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2.3. Comparison of both sensors

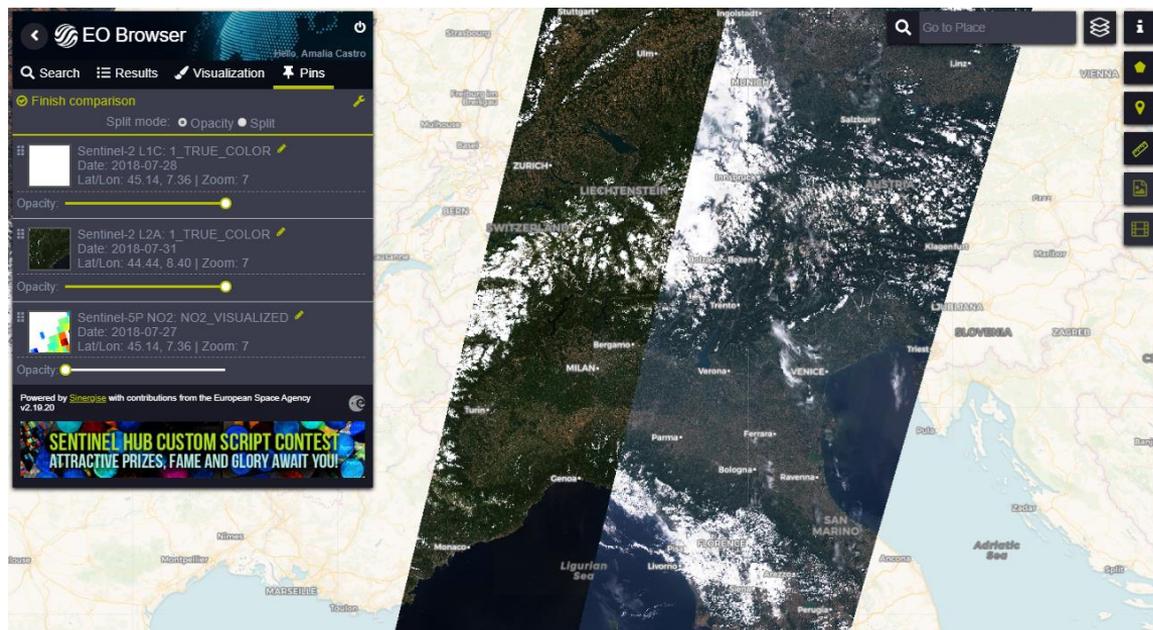
In your **Pins tab** you should have the following below.

Click **Compare** to start the comparison of the images. Opacity sliders will then be available.



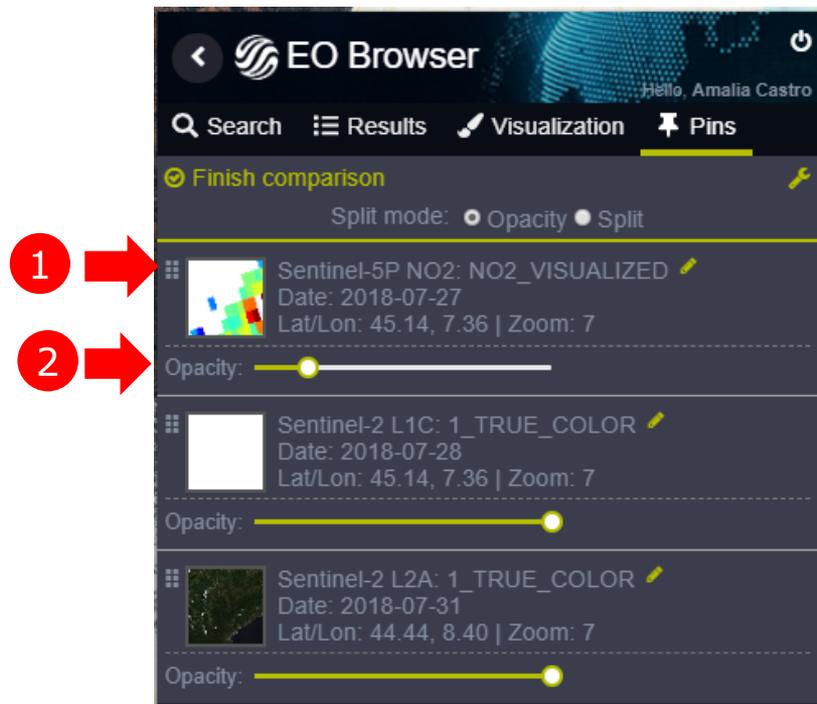
2.3. Comparison of both sensors

The Sentinel-5P image covers a **larger area than the Sentinel-2** image. Therefore we use **two Sentinel-2 images**, which overlap 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**.

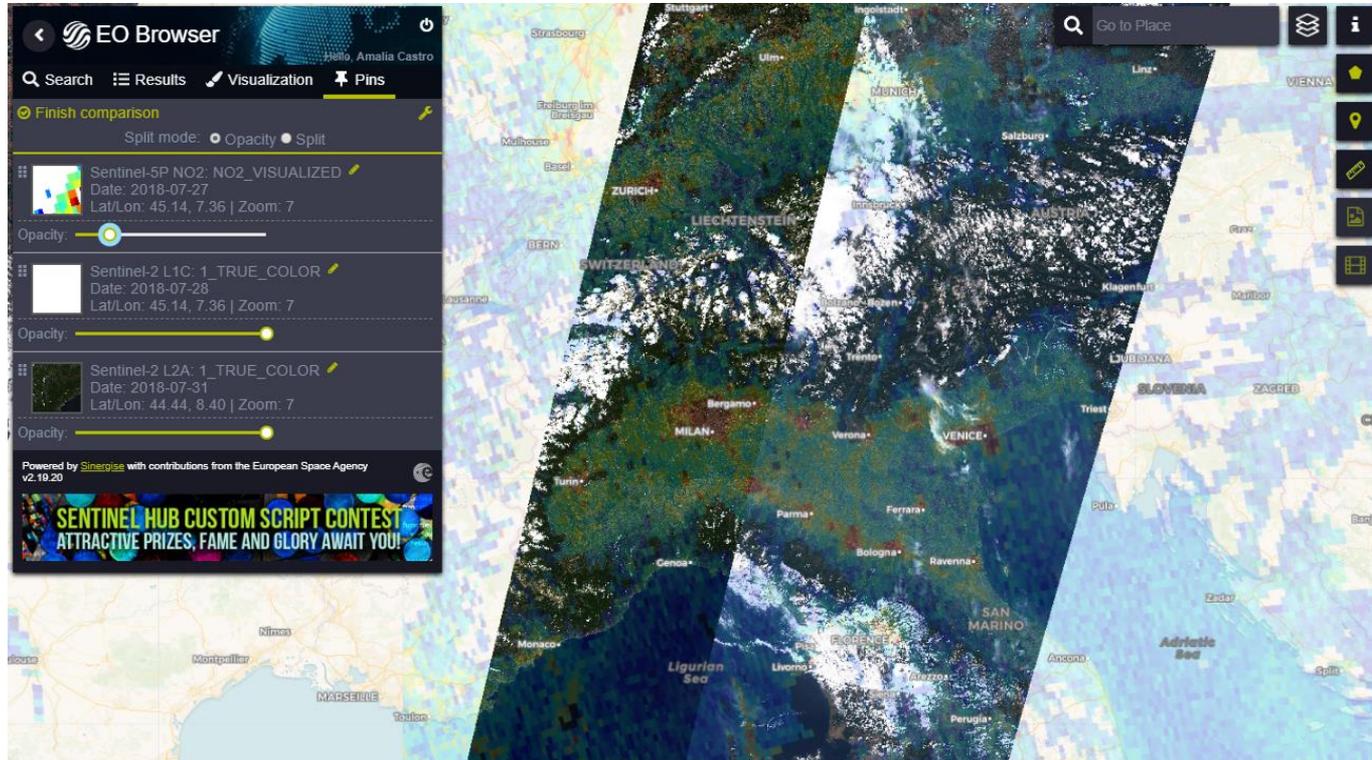


2.3. Comparison of both sensors

1. Use the  symbol to drag the **Sentinel-5P** image to the **top of the list**
2. Lower its **opacity**



2.3. Comparison of both sensors

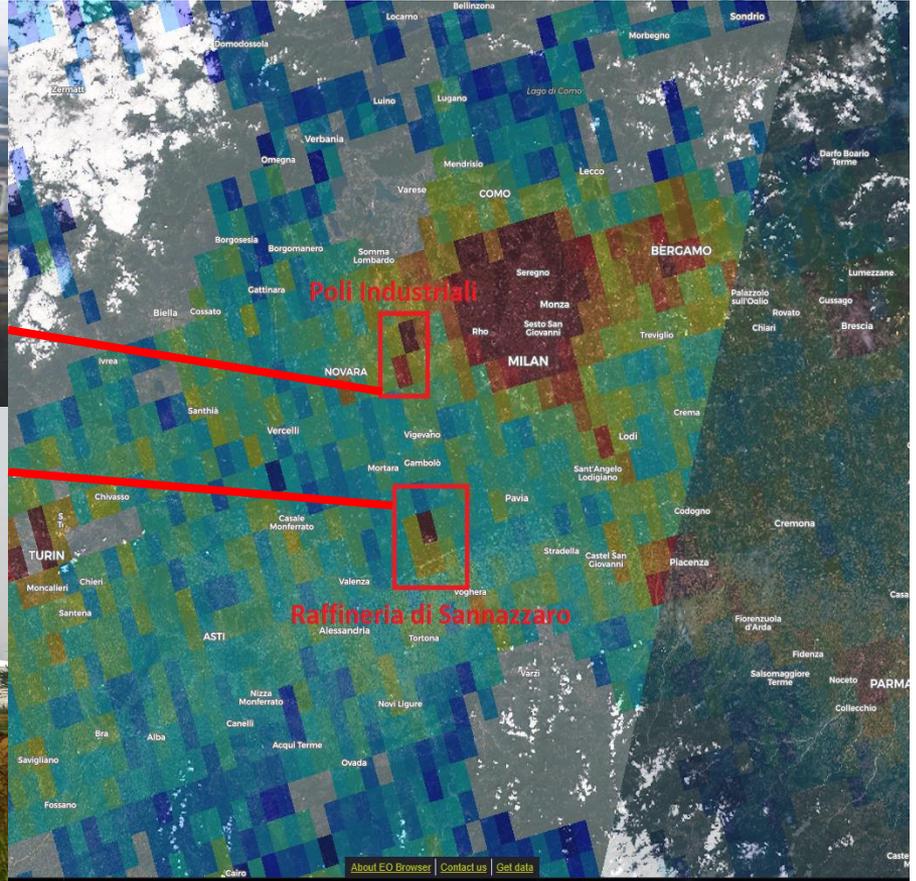


2.3. Comparison of both sensors

Zoom into the **Milan area** and investigate what can cause **high levels of NO₂**.

As expected, most **high NO₂** concentration occur in **large cities**. However, there are a few examples of high concentrations **outside of cities**. Two are shown in the next slide. Have a look at the Sentinel-5P image as it compares to the Sentinel-2 images. Can you make other interesting observations?

2.3. Comparison of both sensors



- ✓ Define suitable search criteria (time range, area, satellite, satellite product, visualization type) in EO Browser for a case study in air pollution
- ✓ Interpret Sentinel-5P NO₂ maps
- ✓ Understand the different levels of processing for Sentinel-2 products (L1C and L2A)
- ✓ Get basic introduction to the concepts of satellite revisit and coverage (including orbit, swath)
- ✓ Compare images from different sensors in EO Browser

Thank you for your attention!

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