Digital Earth: Big Data Concepts – Exercise 5 (Assignment)

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For each section of this Assignment/Exercise, screenshots, explanations, and additional information will be provided.

1. Introduction

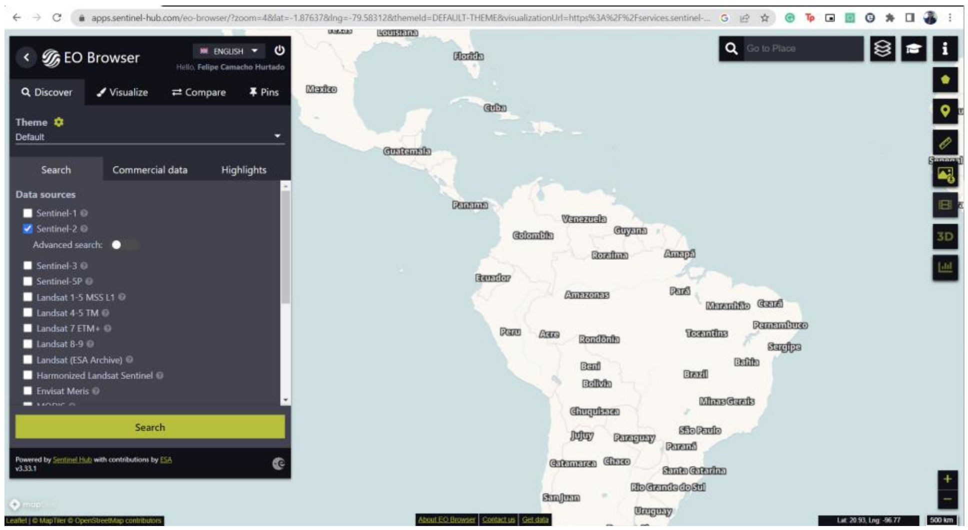

Figure 1. *EO Browser - Graphical User Interface (GUI).*

2. Graphical User Interface

- *Navigate to the Grossglockner (47.074184, 12.694290)*

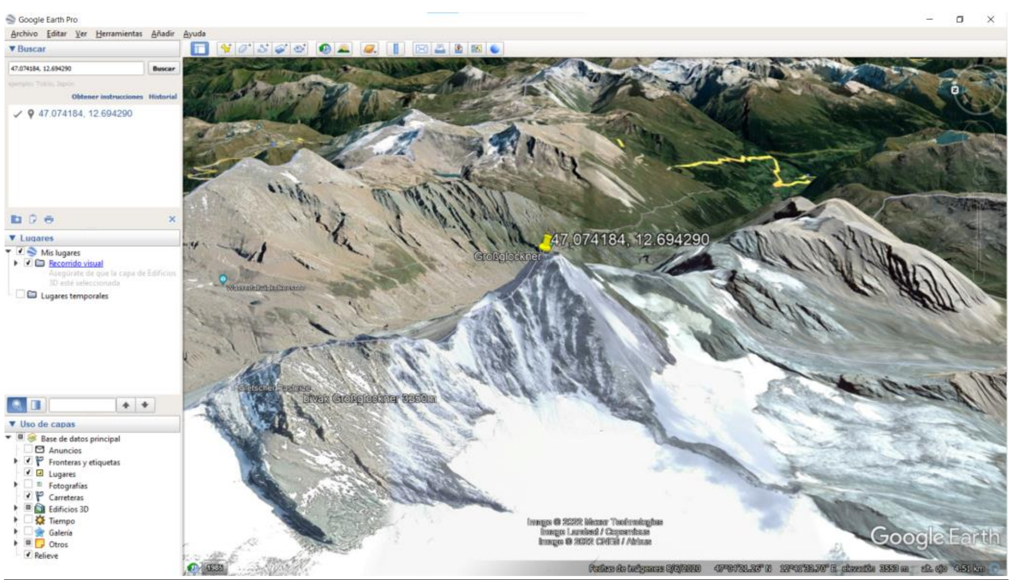

Figure 2. *Google Earth Pro – Validation of the Coordinates (47.074184, 12.694290).*

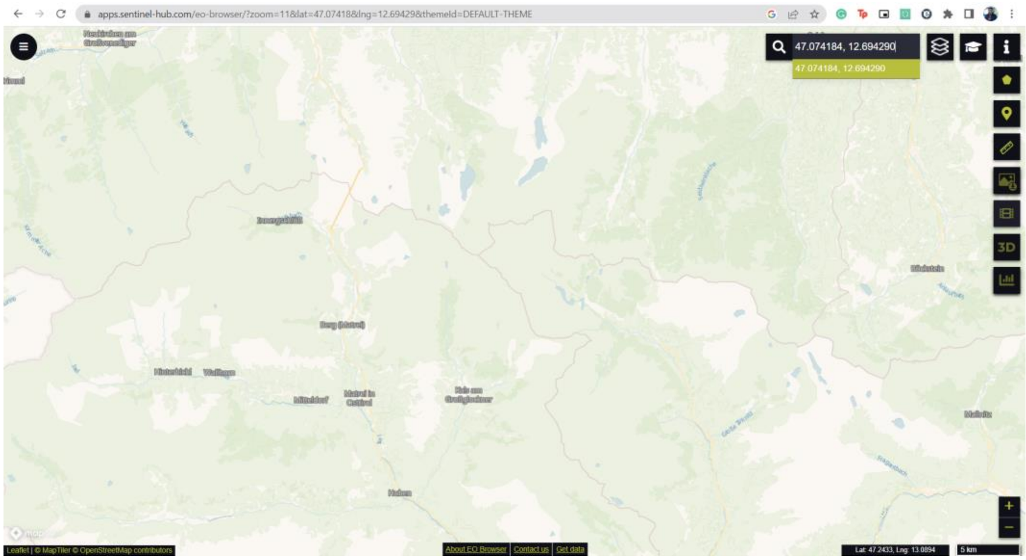

Figure 3. *EO Browser – Grossglockner (47.074184, 12.694290).*

- *<u>Select an area that covers approximately the mountain itself and important surrounding glaciers and lakes.</u>*

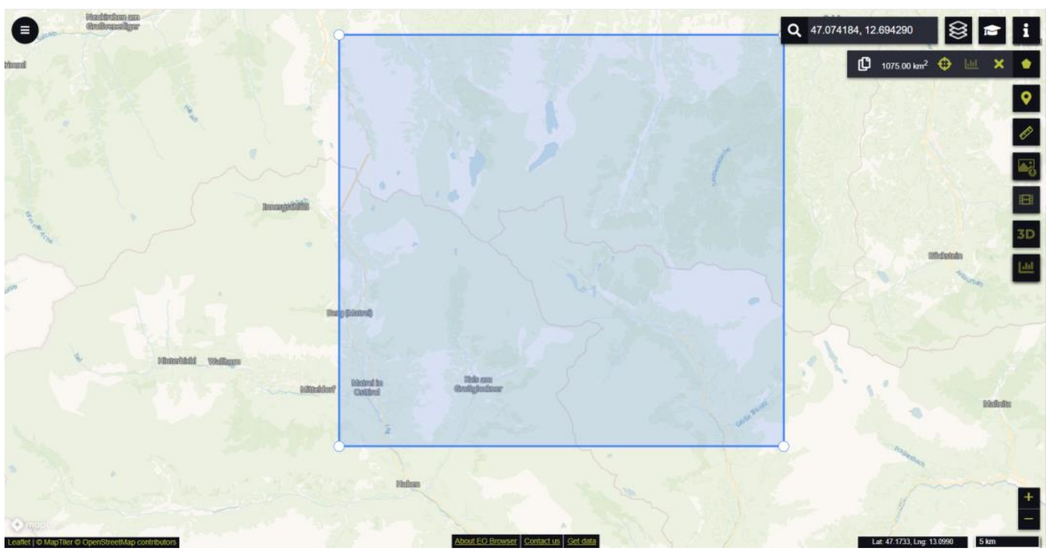

Figure 4. *EO Browser – Area of interest including the Grossglockner Mountain.*

3. Applying Search Filters

- *Navigate to the search interface on the left side*

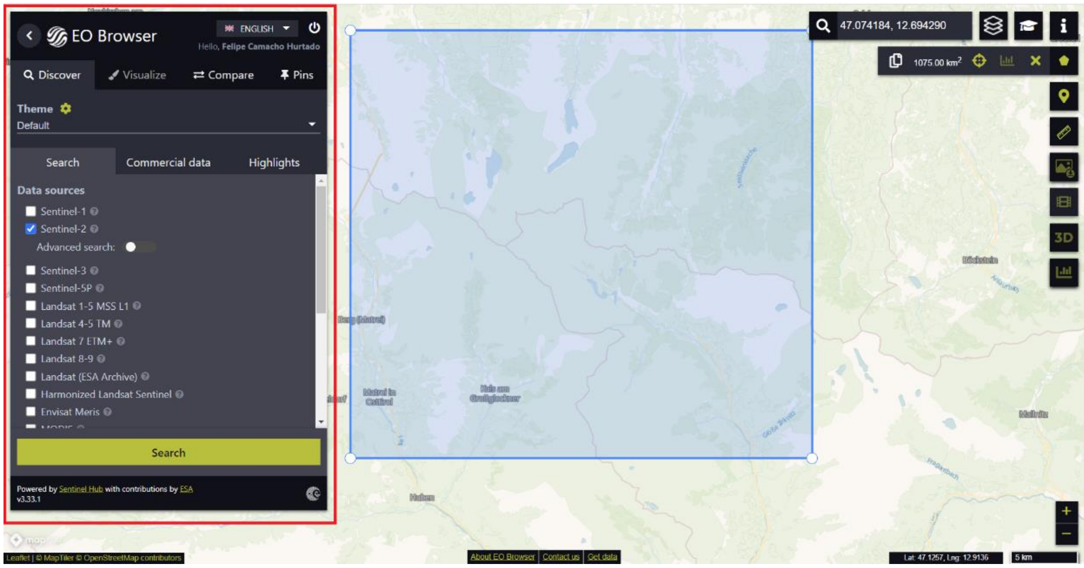

Figure 5. *EO Browser – Search Interface V3.33.1*

- *Set the filter to retrieve Sentinel-2 Level-1C images*

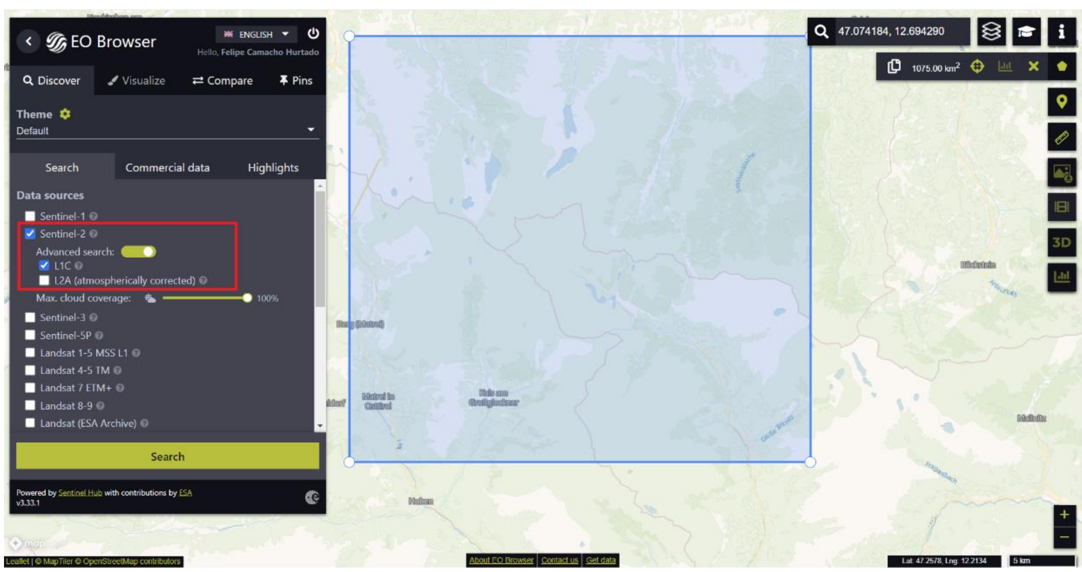

Figure 6. *EO Browser – Sentinel-2 Level-1C Filter.*

- *Set the filter to retrieve images with less than 40% cloud cover*

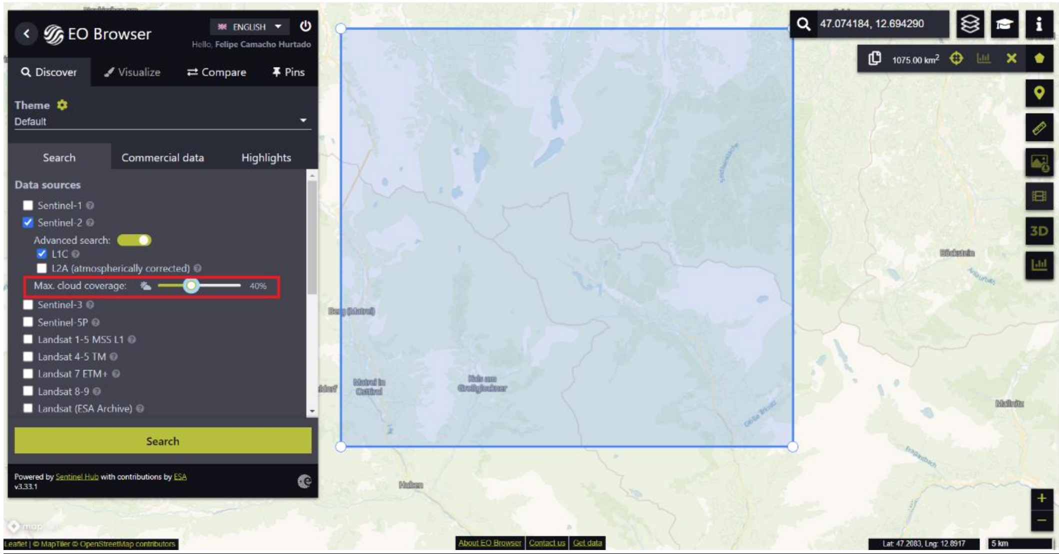

Figure 7. *EO Browser – 40% Cloud Cover Filter.*

- *Set the filter to retrieve images during the vegetation period (July-October) 2019, 2020, or 2021.*

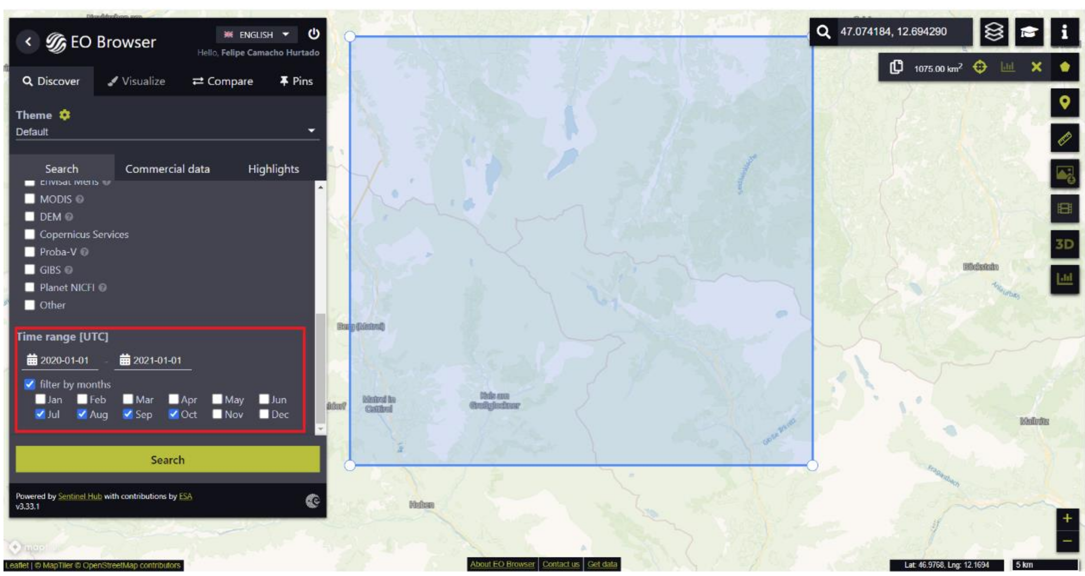

Figure 8. *EO Browser – 2020 July-October Filter.*

- *Click on the "Search" button to make the query.*

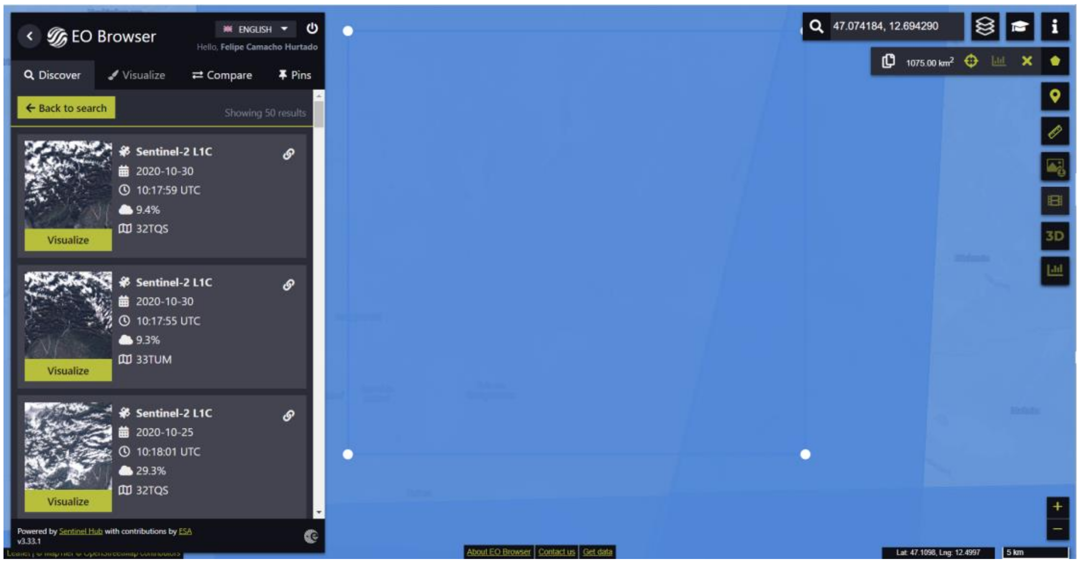

Figure 9. *EO Browser – Query results.*

4. Browsing Through Results

- *Get an overview over the result of your search. If you detect unexpected result set, go back and check your filter criteria.*

After checking the results, it was confirmed that the filters were applied properly and as result, 93 images were returned by the EO Browser.

- *Make yourself familiar with the images in the result list and their metadata*

While getting familiarized with the resulting images through the metadata, some observations were made. First, the maximum cloud coverage register was 39.4% and corresponds to an image captured in 2020-10-10 graticule 33TUN. On the other hand, the minimum cloud coverage (for a complete graticule) was 0.0 and corresponds to an image captured in 2020-09-15 graticule 33TUN.

5. Web-based image visualization.

- *Select an image footprint by clicking on a blue polygon (Try to find one with few cloud contamination).*

The image (Figure 10) taken on 2020-09-15/10:17:43 UTC graticule 33TUN with a cloud coverage of 0.0% was selected.

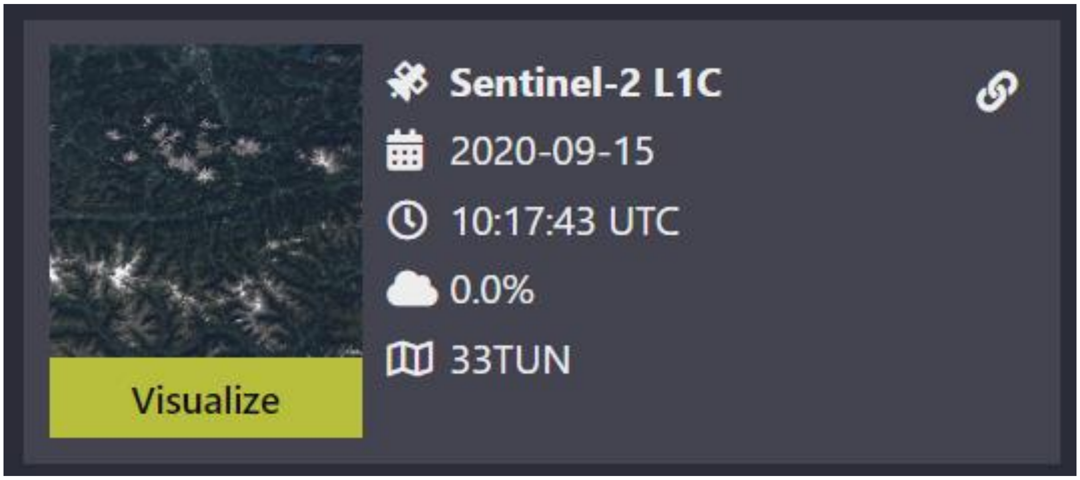

Figure 10. *EO Browser – Image taken on 2020-09-15 graticule 33TUN.*

- *In the window showing the thumbnail and the metadata information click on "visualize".*

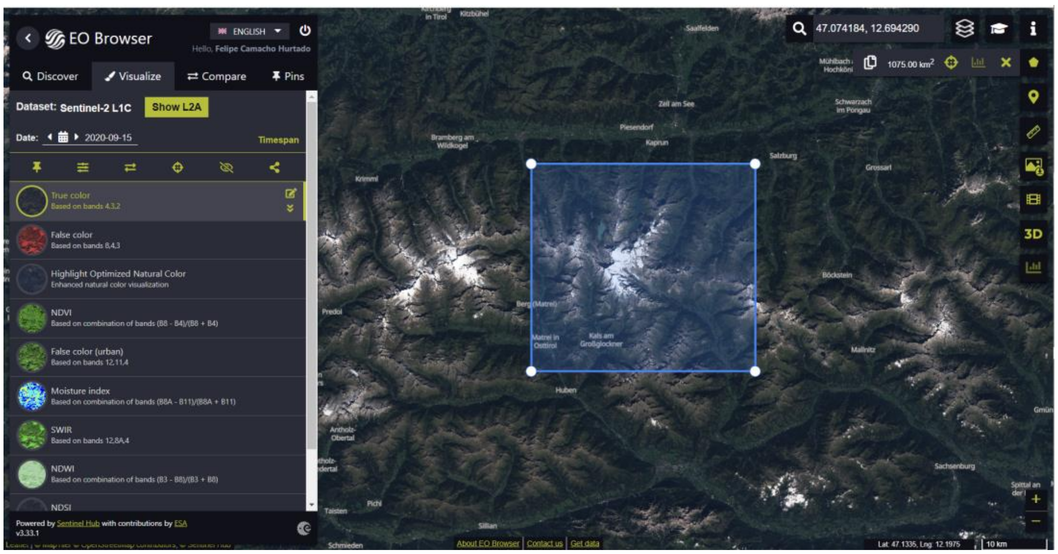

Figure 11. *EO Browser – Image taken on 2020-09-15 graticule 33TUN visualized.*

- *Try some pre-defined band combinations, especially "False Colour" and "NDVI". If you don't know these band combinations, have a look at resources in the Internet, e.g.: https://en.wikipedia.org/wiki/Normalized_difference_vegetation_index and https://en.wikipedia.org/wiki/False_color#False_color*

FALSE COLOR COMPOSITE

The False Color composite (Figure 12) was generated using band 8 (Visible and Near Infrared – 865nm) for the red channel, band 4 (Red - 665nm) for the green channel, and band 3 (Green – 560nm) for the blue channel. In this combination plants reflect near-infrared and green light while absorbing red, as a result, the false-color composite is dominated by the plant-covered land in deep red. This band combination is commonly used for assessing plant density and health. Other land coverages can be distinguished as cities/ ground in gray or tan colors and water in blue or dark.

Specifically for Grossglockner Mountain and its surroundings, plant, water, and city coverages can be distinguished. As mentioned previously, the deep red color it's associated with plant-covered land while darker red colors with denser plant growth. In this case, denser plant growth can be observed in the valleys and general plant-covered land along the valleys but mostly at high altitudes (mountain peaks).

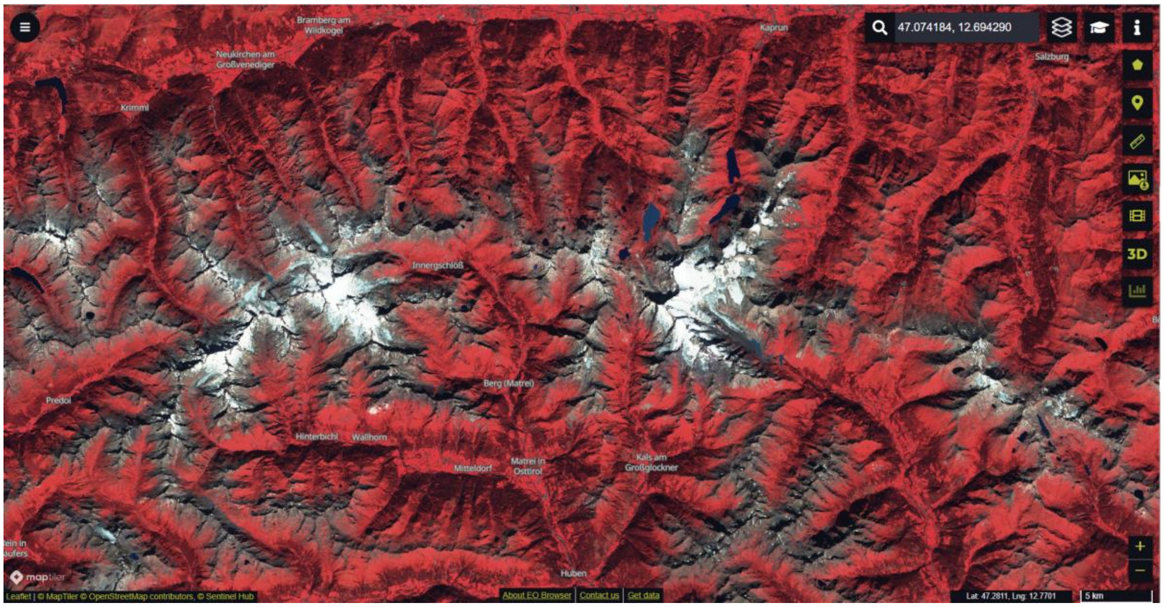

Figure 12. *EO Browser – False Color Composite.*

NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

The Normalized Difference Vegetation Index (NDVI – Figure 13) was generated. This index results from calculating the difference between two bands, visible red and near-infrared, and it's used to measure the state of plant health based on how the plant reflects light at certain frequencies. NDVI is one the most common remote sensing index, used for diverse purposes like quantifying forest supply, drought indicators, forecasting fire zones, and desert offensive maps.

$$NDVI := \mathtt{Index}(B8, B4) = \frac{B8 - B4}{B8 + B4}.$$

Figure 13. *NDVI Index Formula.*

The NDVI index is based on the scientific fact that Chlorophyll (a health indicator pigment) strongly absorbs visible light, and the cellular structure of the leaves reflects near-infrared light. Consequently, sick, or dehydrated plants will start to absorb more of the near-infrared light, rather than reflect it. This change can be measured using this remote index.

NDVI define values from -1.0 to 1.0, where negative values approaching to -1 corresponds to water, values close to zero from -0.1 to 0.1 are mainly associated with clouds, water and snow, and values close to zero are mainly rocks and bare soil. Moderate values from 0.2 to 0.3 usually represent shrubs and meadows, while the larges values from 0.6 to 0.8 indicates temperate and tropical forests.

Specifically for Grossglockner Mountain and its surroundings, snow, plants, rocks, bare soil, and water coverages can be observed. Water features are represented as black (values from -1 to -0.5). Snow features are represented with white and grey colors (values from -0.2 to -0.1). Bare soil and shadows are represented as grey (values from -0.2 to -0.1). And finally, plant coverages show values from 0.2 to 1. In this usage example, the NDVI index (Figure 14) accomplish its purpose of showing the areas where plants are concentrated and their health status, additionally, the water coverages are correctly identified. However, regarding the snow, soil coverage, and mountain shadow coverage, it tends to mix them into a single class which may lead to incorrect interpretations.

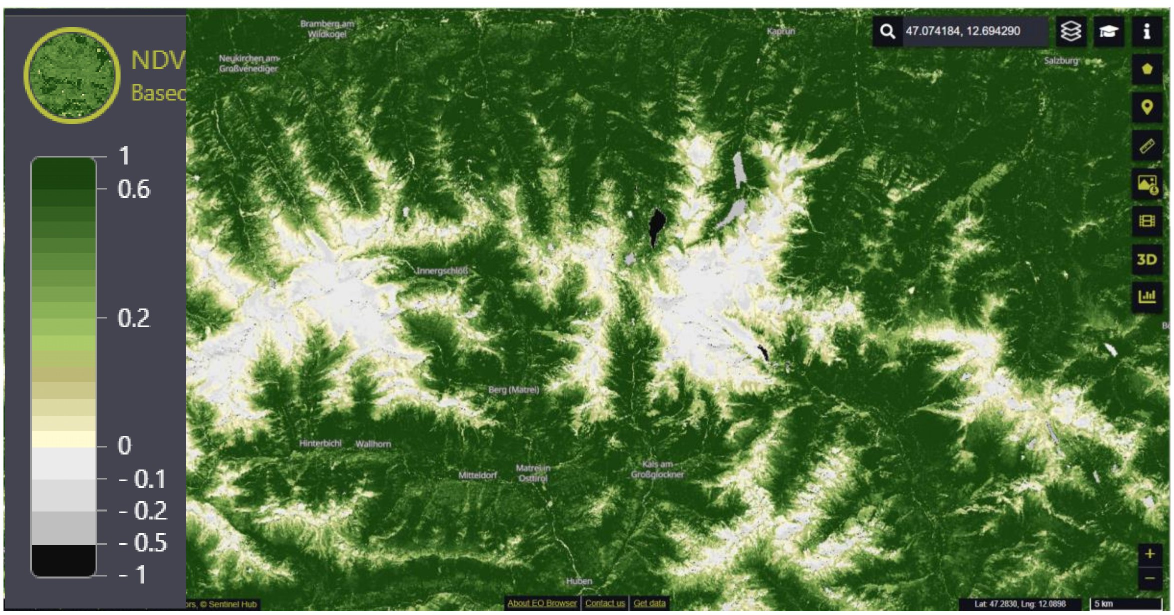

Figure 14. *EO Browser – NDVI Index Image.*

SHORT WAVE INFRARED COMPOSITE (SWIR)

Finally, the Short wave infrared (SWIR) composite (Figure 15) was generated using band 12 (Short Wave Infrared – 2190nm) for the red channel, band 8A (Narrow NIR – 865nm) for the green channel, and band 4 (Red – 665nm) for the blue channel. This composite is used by scientists to estimate how much water is present in plants and soils as water absorbs SWIR wavelengths. Additionally, Short wave infrared bands are also useful for cloud types, snow, and ice characterization. In this composite vegetation appears in shaded green, soils in various shades of brown, and water appear black. Moreover, this band combination is useful for geology mapping as each rock type reflects shortwave infrared light differently.

Specifically for Grossglockner Mountain and its surroundings, vegetation, rock types, and snow coverages can be observed. Even though the different vegetation coverage can be estimated, the most outstanding features are the snow and rock types coverages. Compared to the previous indexes and Composites, the SWIR has been the only one to correctly delineate the snow areas (cyan blue).

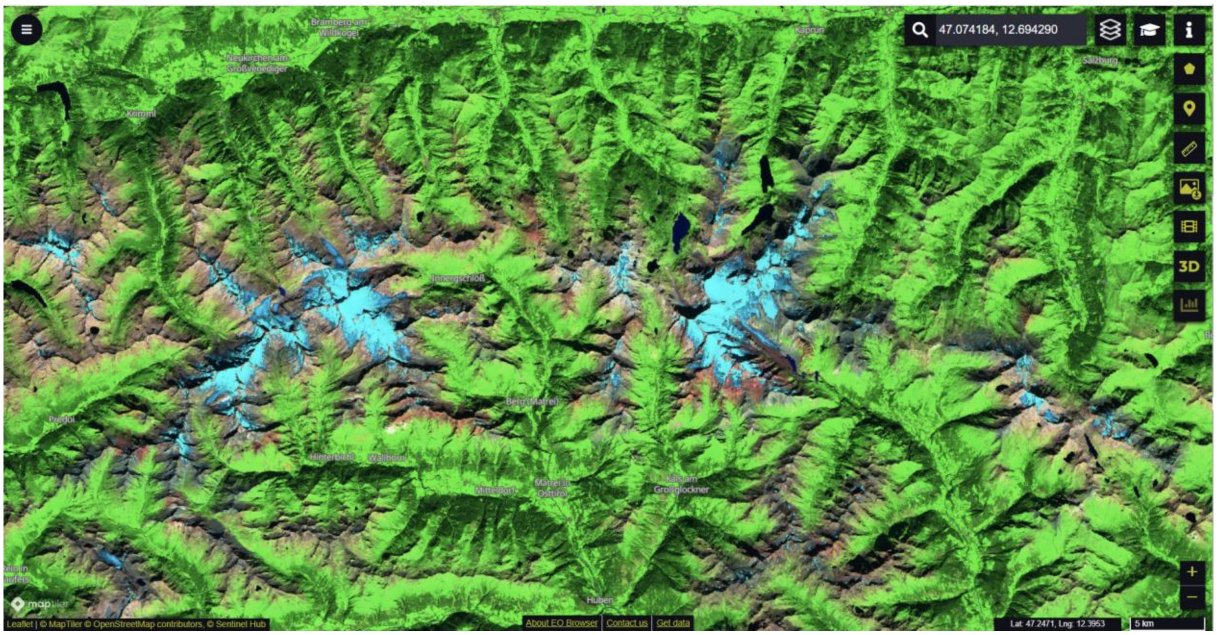

Figure 15. *EO Browser – SWIR Index.*

- *<u>Try some custom band combinations and observe and try to interpret the result. The following figure with the band numbers and this description https://en.wikipedia.org/wiki/Sentinel-2#Instruments might help you:</u>*

FALSE COLOR COMPOSITE (12, 10, 11)

To provide better visualization of the possible usages for this composite, a new area will be displayed. Instead of using the Grossglockner Mountain area, an overview of Romania (Figure 16) will be visualized using an image taken on 2020-10-25/33TUM with 38.4% for Cloud Coverage.

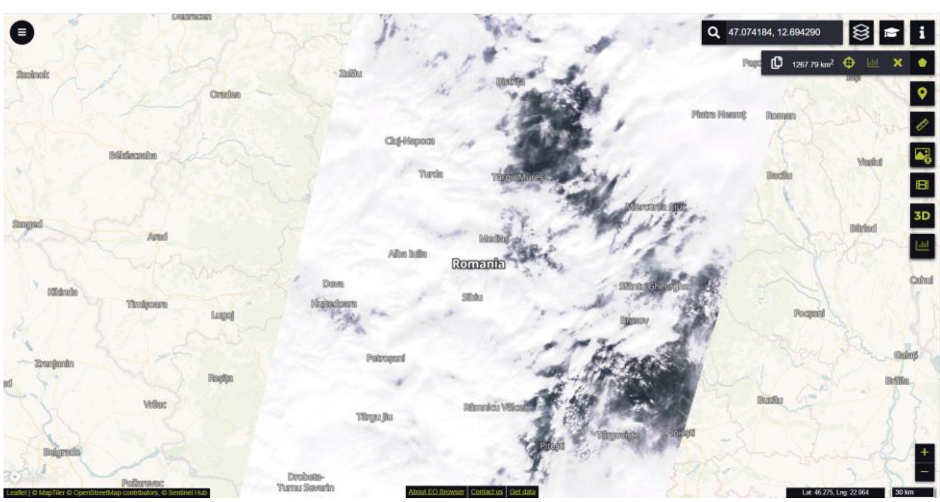

Figure 16. *EO Browser – True Color Composite for Romania.*

This False Color Composite was created using band 12 (Short Wave Infrared – 2190nm) for the red channel, band 10 (Short Wave Infrared – 1375nm) for the green channel, and band 11 (Short Wave Infrared – 1610nm) for blue channel. Bands 12 and 11 are commonly used for measuring the moisture content of soil and vegetation but also it helps differentiate between snow and clouds, even though they have limited cloud penetration. Regarding Band 10, its used for cirrus cloud detection.

As result, in the 12,10,11 False Color Composite (Figure 17), the high reflectance values in the red and blue bands generate the purple color, which based on the True Color image and band's purpose, can be associated with Cloud coverage. Additionally, the green colors are the result of the reflectance values in the green channel for the Cirrus band which can be associated with cirrus clouds (formed from the tops of thunderstorms and tropical cyclones) In overall, this bands composite can be a valid alternative to cloud detection in snow-free areas, as it tends to classify snow as part of the cloud coverages.

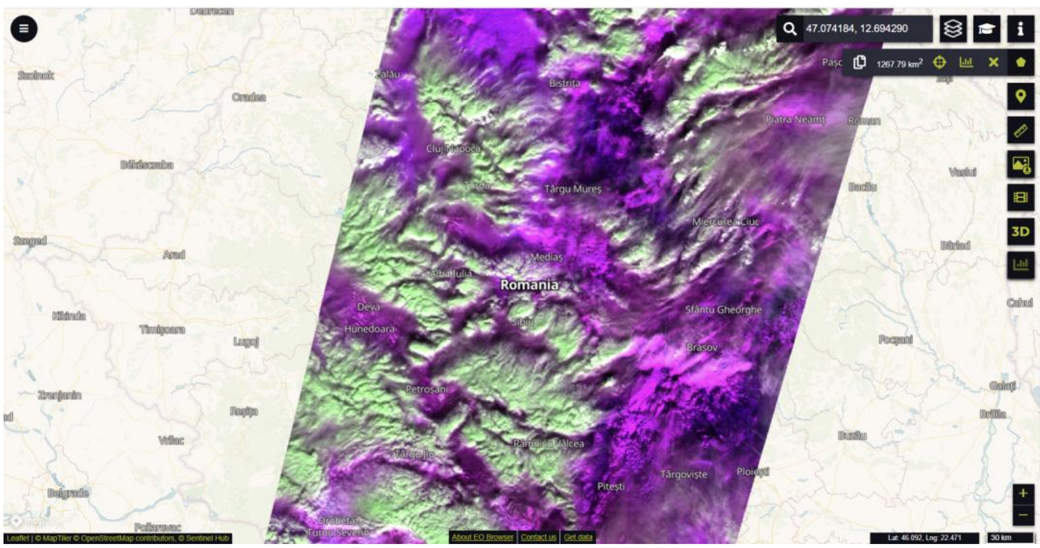

Figure 17. *EO Browser – False Color Composite (12, 10, 11) for Romania.*

FALSE COLOR COMPOSITE (8, 3, 6)

To provide better visualization of the possible usages for this composite, a new area (Figure 18) will be displayed. Instead of using the Grossglockner Mountain area, an overview of Italy will be visualized (focusing on Venice coast) using the same image as for the Grossglockner Mountain exercise (33TUN).

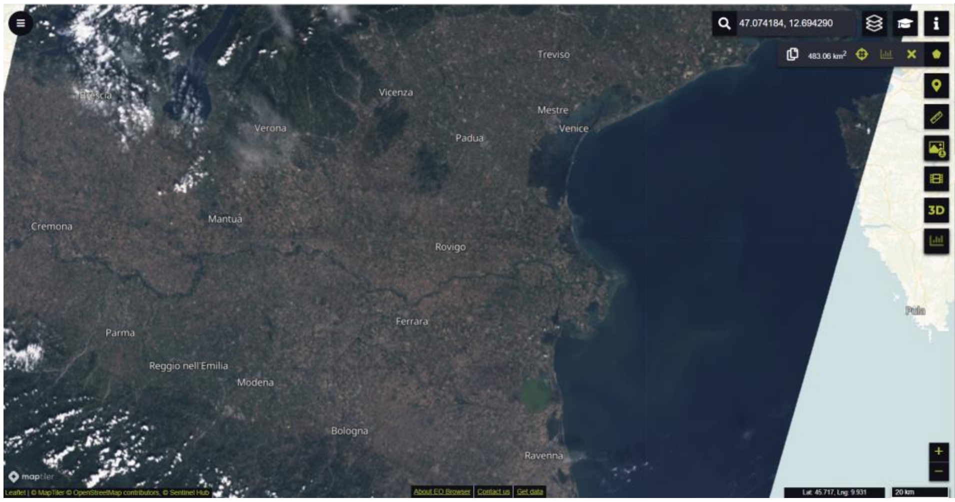

Figure 18. *EO Browser – True Color Composite for Italy (Venice)*

This False Color Composite was created using band 8 (Visible and Near Infrared – 842nm) for the red channel, band 3 (Green – 560nm) for the green channel, and band 6 (Visible and Near Infrared – 740nm) for the blue channel. Band 8 is used or mapping shorelines and biomass content, as well as for detecting and analyzing vegetation. Band 3 gives excellent contrast between clear and turbid (muddy) water. Finally, Band 6 is commonly used for classifying vegetation.

As result, in the 8, 3, and 6 False Color Composite (Figure 19), the high reflectance values in the red and blue bands generate the purple color, which based on the True Color image and band's purpose, can be associated with Forest biomass and the coast shore. The deep purple colors would correspond to high biomass forests which can be for example a good indicator for carbon monitoring. Regarding the green colors, they are the result of the reflectance values in the green channel for the green band which effectively differentiates turbid water on Venice's coast. Overall, this band's composite can be used for forestry assessment and water turbidity levels characterization. However, in agriculture areas, some parcels may be identified by band 6 as vegetation, resulting in forest characterization overestimation.

Figure 19. *EO Browser – False Color Composite (8, 3, 6) for Italy (Venice)*

- *<u>Switch to the programming interface.</u>*

Switched to the programming interface using the “show evalscript” button (Figure 20).

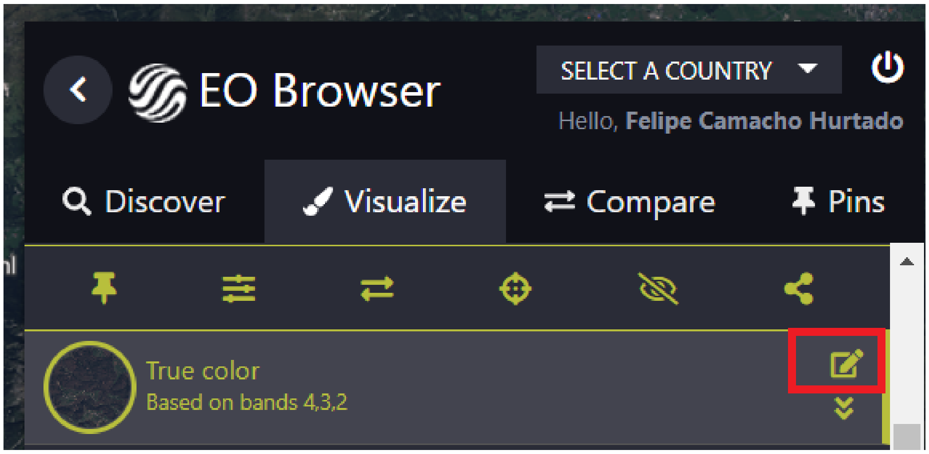

Figure 20. *EO Browser – Accessing Programming Interface.*

- *<u>The default script is quite simple: it returns the values of the three bands red, green, and blue as an array. The result values are depending on the pixel value. Make yourself familiar with this and try to understand what happens if you change the numbers.</u>*

As it’s mentioned in the enunciate, the default script (Figure 21) returns the values of the red, green, and blue bands, with a transparency band (dataMask).

```
//VERSION=3
let minVal = 0.0;
let maxVal = 0.4;

let viz = new HighlightCompressVisualizer(minVal, maxVal);

function setup() {
  return {
    input: ["B04", "B03", "B02","dataMask"],
    output: { bands: 4 }
  };
}

function evaluatePixel(samples) {
    let val = [samples.B04, samples.B03, samples.B02,samples.dataMask];
    return viz.processList(val);
}
```

Figure 21. *EO Browser – Default “True Color” Composite Script.*

If the band's numbers ("B04", "B03", "B02") are changed, the bands used for the composite will honor the new band's numbers. Moreover, a multiplication factor for each band (including the transparency band), can be applied to increase its brightness and transparency respectively. In the image below (Figure 22) a multiplication factor of 2.5 was applied to the red, green, and blue bands. Additionally, a factor of 0.1 was applied to the transparency band. As result, a brighter image should be displayed but in this case, the transparency of 90% reduces drastically the visualization.

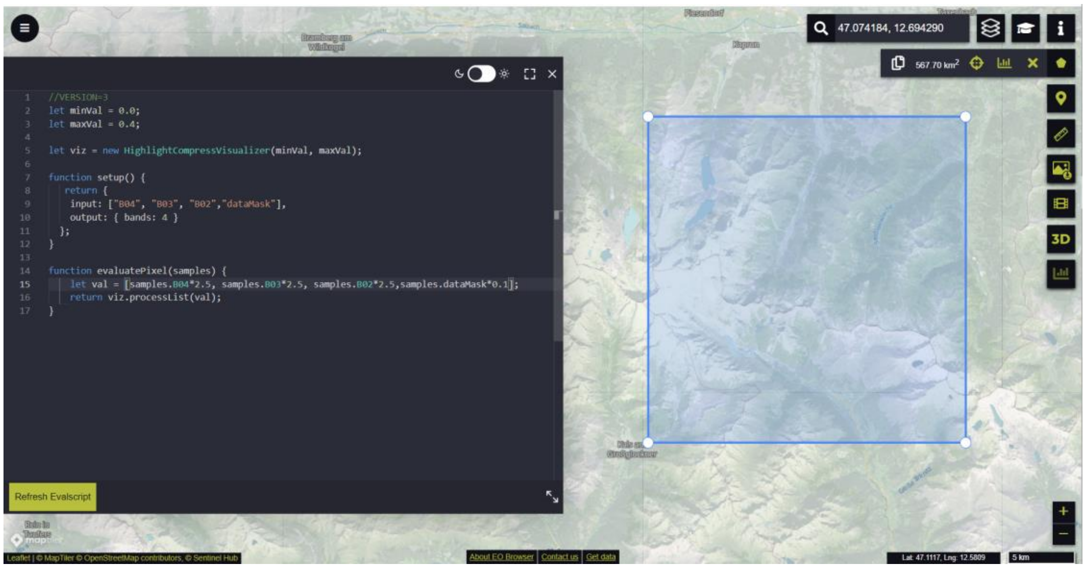

Figure 22. *EO Browser – Custom Script.*

- <u>*Zoom / pan to an urban area and post the code from code-block 1 in the script field. It enhances the visualization that allows a better distinction of urban structures.*</u>

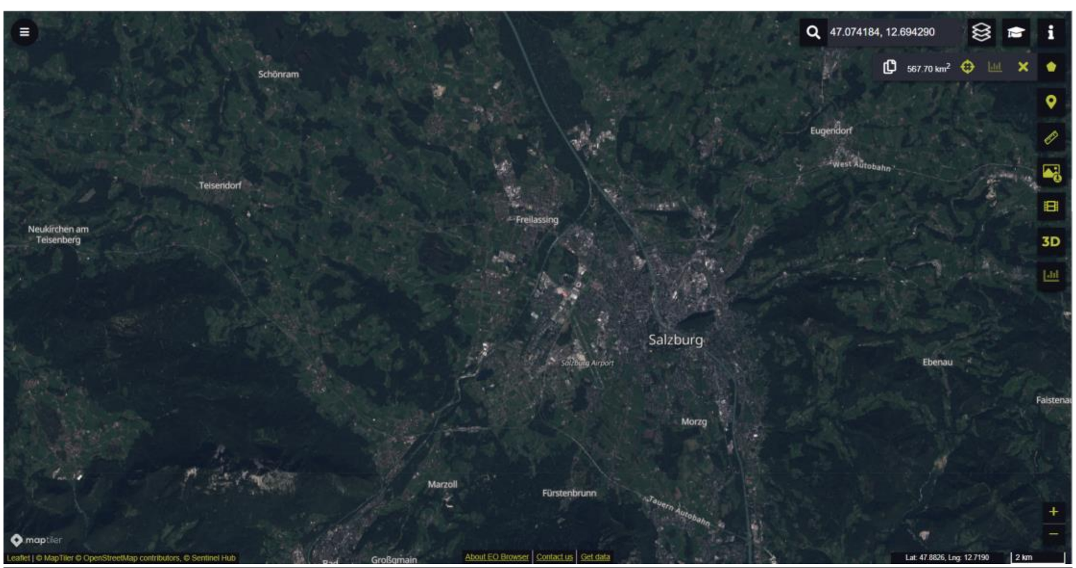

Figure 23. *EO Browser – Salzburg Urban Structures.*

Figure 24. *EO Browser – Salzburg Urban Structures (Enhanced Image).*

- *Zoom / pan to a high-altitude area that contains snow. Post the code from code-block 2in the script field. The script identifies snow based on the spectral values.*

Figure 25. *EO Browser – Grossglockner Mountain.*

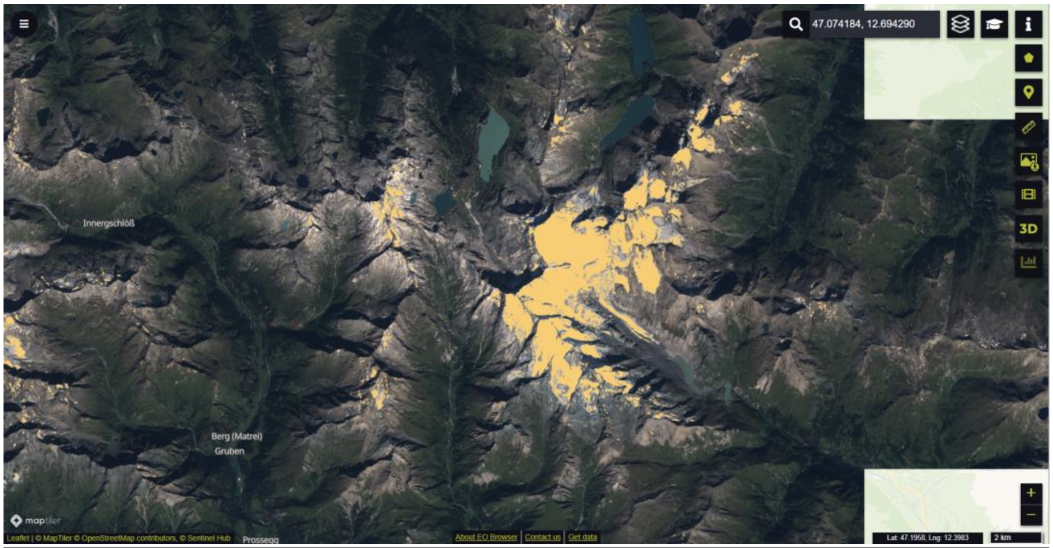

Figure 26. *EO Browser – Grossglockner Mountain (Custom Script Applied).*

- *Go to the script repository, select one script:* https://github.com/sentinel-hub/custom-scripts

The "city_highlights" script for Sentinel-2 was applied.

```
/*
Author of the script: Thales Sehn Koerting
*/

// detection of vegetation
NDVI_RedEdge = (B08 - B05)/(B08 + B05)
threshold_vegetation = 0.45
Vegetation = NDVI_RedEdge > threshold_vegetation

// ceramic rooftop detection
RATIO_Red = B04/[B01+B02+B03+B04+B05+B06+B07]
NDBI = (B11 - B08)/(B11 + B08)
threshold_rooftop = 0.14
Rooftop = (RATIO_Red > threshold_rooftop) && (NDBI > threshold_rooftop)

// water detection
NDWI = (B03 - B08)/(B03 + B08)
threshold_water = 0.2
Water = NDWI > threshold_water

// gain to obtain smooth visualization
gain = 0.7
return [gain*Rooftop, gain*Vegetation, gain*Water]
```

Figure 27. *GitHub – City_Highlights Custom Script.*

- <u>*Make yourself familiar with them and apply it at the region of Salzburg.*</u>

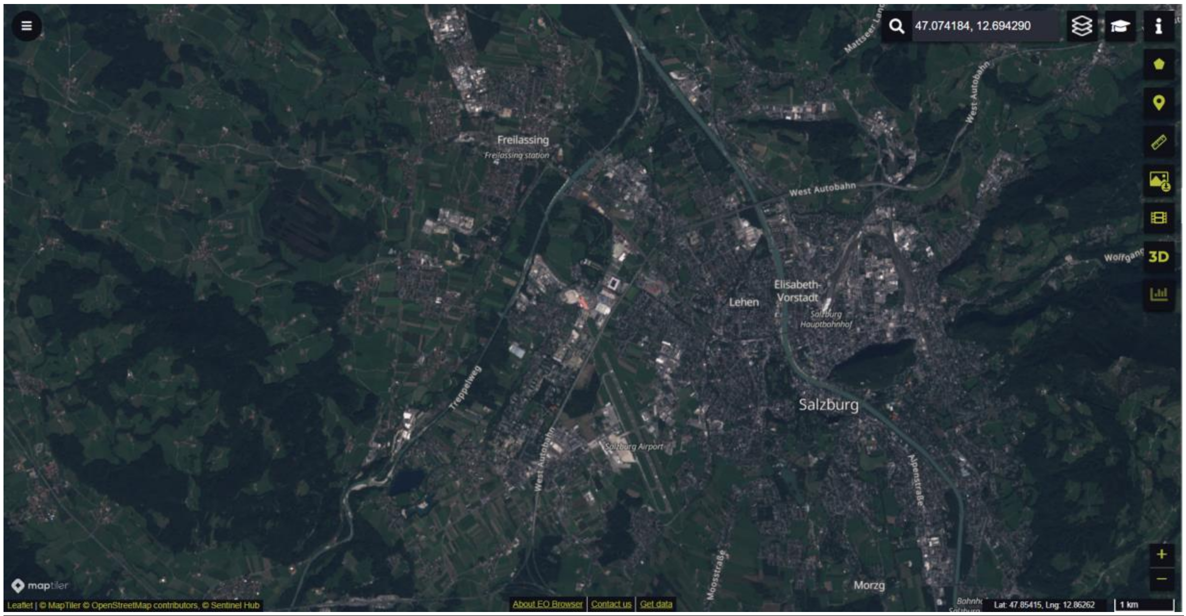

Figure 28. *EO Browser – Salzburg and Freilassing.*

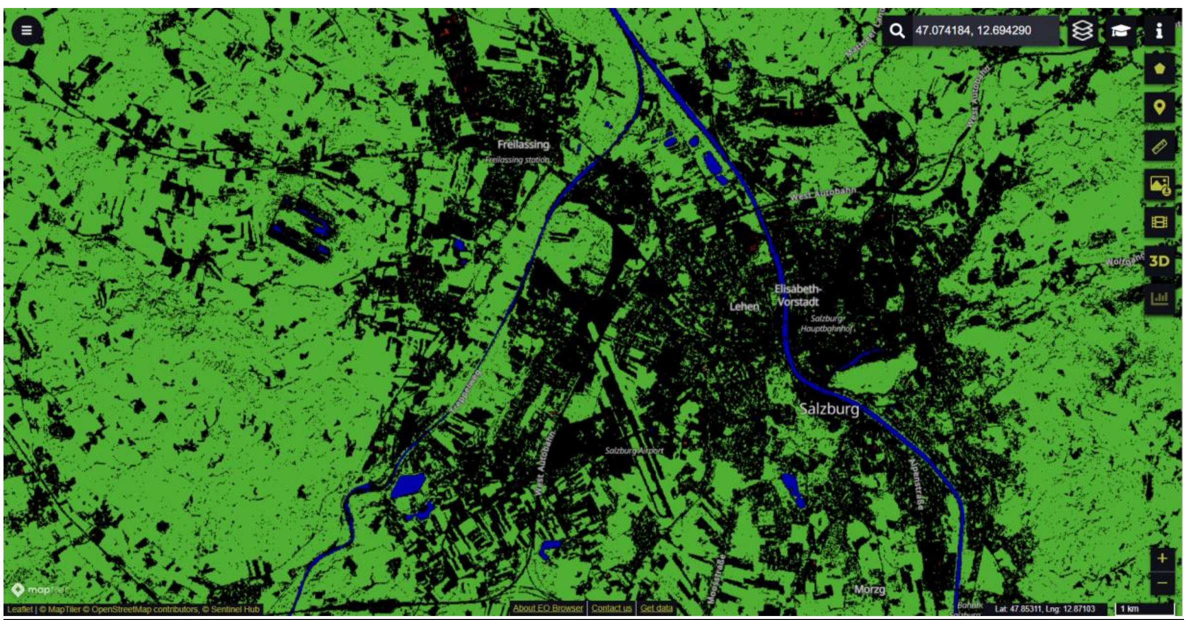

Figure 29. *EO Browser – Salzburg and Freilassing ("city_highlights" Script Applied).*

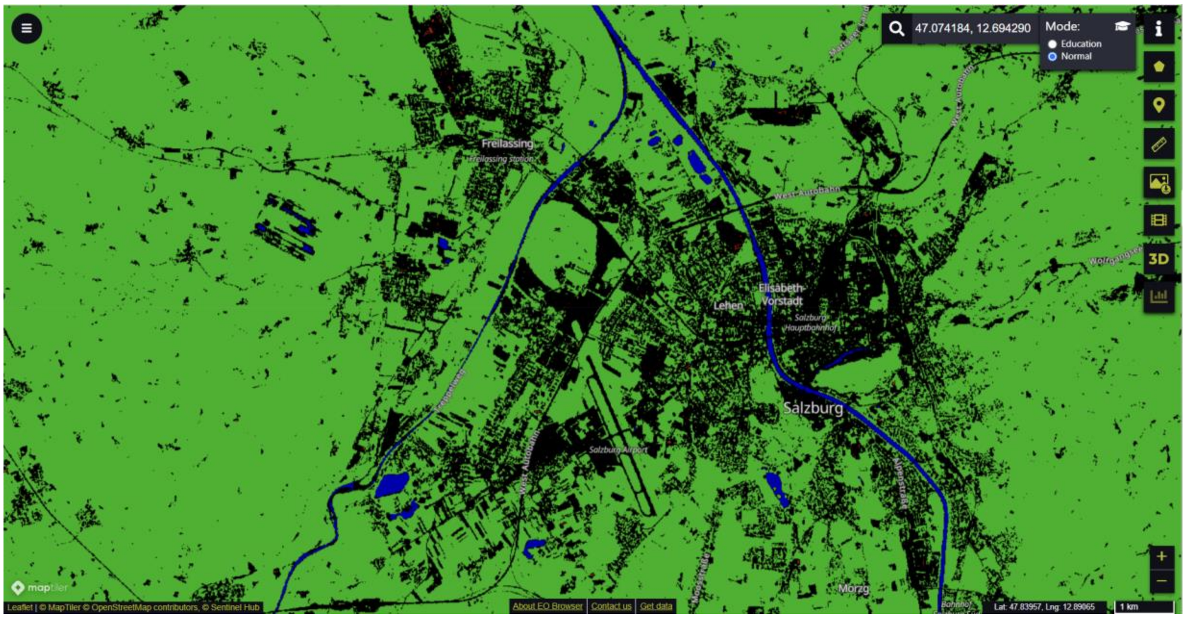

Figure 30. *EO Browser – Salzburg and Freilassing ("city_highlights" Script Applied – Using B04 for the NDVI Index).*

- *<u>Create a document that explains what the script does in your own words and screenshots that shows how you applied it.</u>*

Before explaining in detail how the script works and the results evidenced in the study area (Figure 28), let's understand the different indices and band ratios used by the algorithm. The "city_highlights" algorithm aims to categorize where the cities are and their relationship with water bodies and vegetation areas. Moreover, it identifies rooftops. For that purpose, it uses three different indices.

First, the Normalized Difference Red Edge Index (NDRE – Figure 31) is used for estimating vegetation health using the red-edge (Band 5 – 705nm) and Visible and Near Infrared (Band 8 – 842nm) bands.

$$\mathrm{NDRE} = \frac{(\mathrm{NIR} - \mathrm{RE})}{(\mathrm{NIR} + \mathrm{RE})}$$

Figure 31. *NDRE Index.*

Even though in the algorithm's documentation it's established that they calculated the NDVI index, by checking the code it can be observed that they didn't use band 4 (Red Band) but band 5, which is the NDRE index. Furthermore, the results using the NDVI index are presented (Figure 30).

Secondly, the Normalized Difference Built-up Index (NDBI – Figure 32) is calculated to emphasize manufactured built-up areas using the Visible and Near Infrared (Band 8 - 842nm) and Short Wave Infrared (Band 11 – 1610nm) bands.

$$NDBI = \frac{SWIR1 - NIR}{SWIR1 + NIR}$$

Figure 32. *NDBI Index.*

The NDBI index mitigates the effects of terrain illumination differences as well as atmospheric effects.

Third, the Normalized Difference Water Index (NDWI – Figure 33) is calculated to highlight the among of water in water bodies, using the Green (Band 3 – 560nm) and Visible and Near Infrared (Band 8 – 842nm) bands.

$$\mathrm{NDWI} = \frac{\mathrm{Green} - \mathrm{NIR}}{\mathrm{Green} + \mathrm{NIR}}$$

Figure 33. *NDWI Index.*

Finally, the ratio between the band 4 and bands (1-7) is calculated to enhance the spectral differences for the band 4.

Regarding the algorithm itself, for the detection of vegetation, it calculates first the NDRE index and set a threshold for the vegetation coverage of 0.45. Then, it assigns the “Vegetation” classification for the NDRE pixels with values bigger than 0.45. For the ceramic rooftop detection, the previously mentioned ratio (“RATIO_Red) between band 4 and bands 1-7 and the NDBI index are calculated. Then, a threshold of 0.14 for the rooftop features is set up and the “Rooftop” classification is assigned if the NDBI and “RATIO_Red” resulting pixels are bigger than 0.14. Finally, the NDWI index is calculated and a threshold of 0.2 is set up, assigning the “Water” classification for the NDWI pixels bigger than 0.2.

As the last step, the “Rooftop” values are returned in the red channel, the “Vegetation” values in the green channel, and the “Water” values in the blue channel. All of the channel’s values are multiplied by a gain factor of 0.7 to decrease the brightness.

As result, after applying the “city_highlights” algorithm in the areas of Salzburg and Freilassing (Figure 29), the water (Blue), vegetation (Green) and ceramic rooftops (Red) features can be distinguished, and by comparing it with a True Color composite, the classification reliability can be confirmed.

6. Timelapse Animations

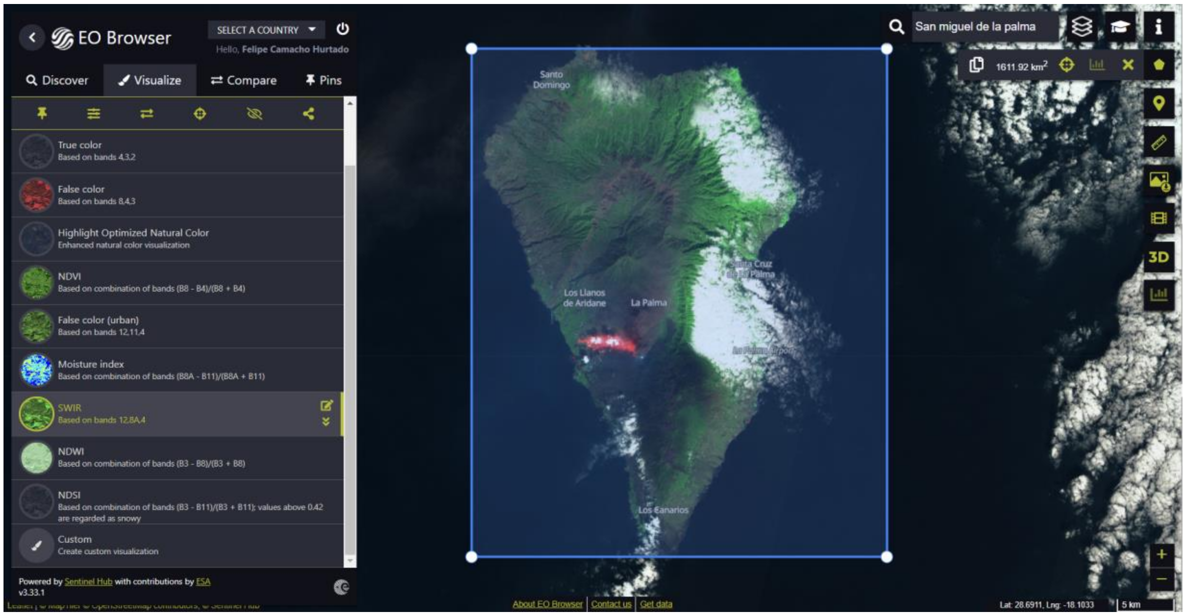

Figure 34. *Volcan La Palma – Timelapse Preparation*

Please, check the .GIF attached.

7. References

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