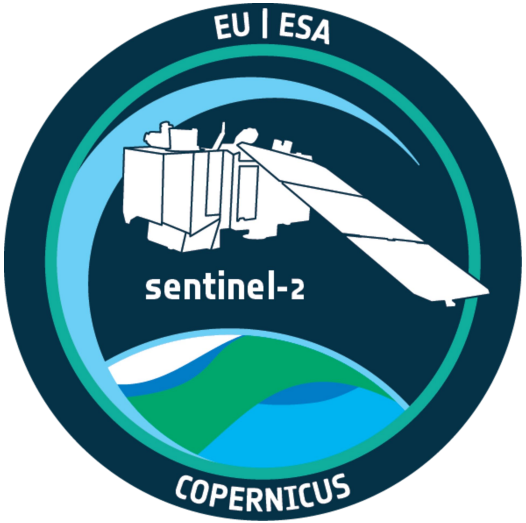



# Sentinel-2 Compositing Tool

GEOM4009 Final Project

Adriana, Christian, and Muhammad

# Our Client (Dr. Anders)

Chair, Department of Geography, Environment and Geomatics, University of Ottawa.

Involved in the Shallow Water Earth Observation Lab, specializing in Satellite-Derived Bathymetry (SDB).

Develop a compositing tool that filters out unusable pixels, enhances data quality, and improves the accuracy of satellite-derived bathymetry estimates.

**Communication** : Initial Zoom meeting to define project scope and familiarize ourselves with the project, with occasional email check-ins for feedback and troubleshooting.

# Purpose + Scope

## Purpose

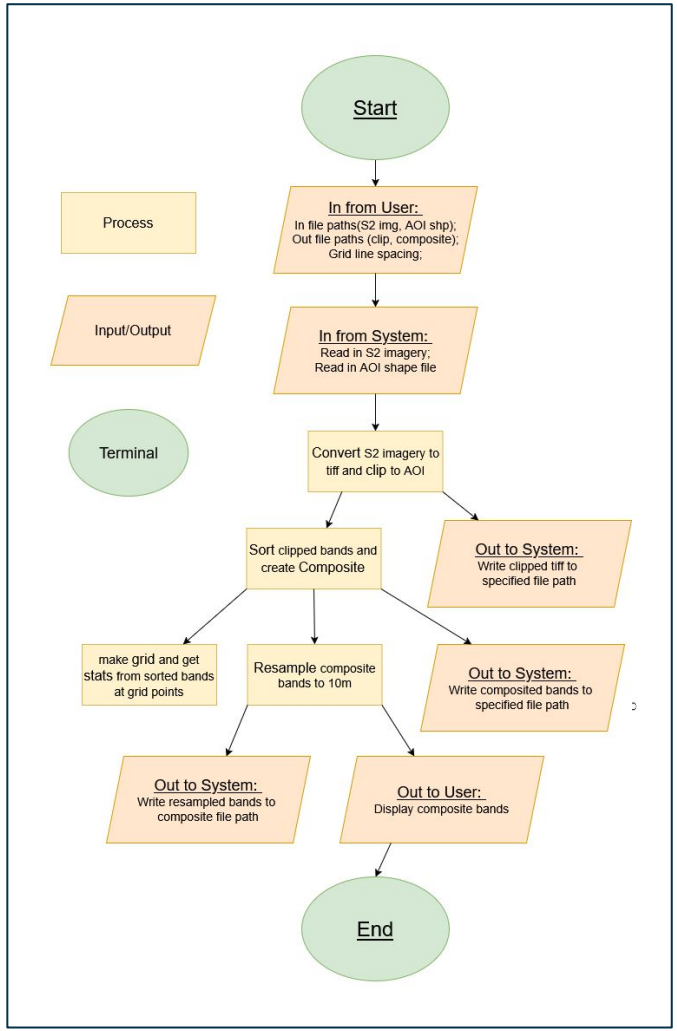
- Process series of S2 images of an area
- Use med comp to approach true values
- Extract data

## Scope

- Clip image to AOI and convert to TIFF
- Create Median composites
- Resample image to 10m
- Record descriptive stats from bands
- Display results

# Workflow

1. Get FIle Paths and other user input
2. Read in Data
3. Convert & Clip
4. Sort & Compose
5. Resample
6. Get Stats
7. Display



# Documentation - Dependencies


1. Clone GitHub repository

   `GEOM4009/`**`W25Project_Compositing`**

2. Download and install Anaconda
3. Create conda environment

   `conda env create -f` **`s2compo_env.yml`**

4. Activate conda environment

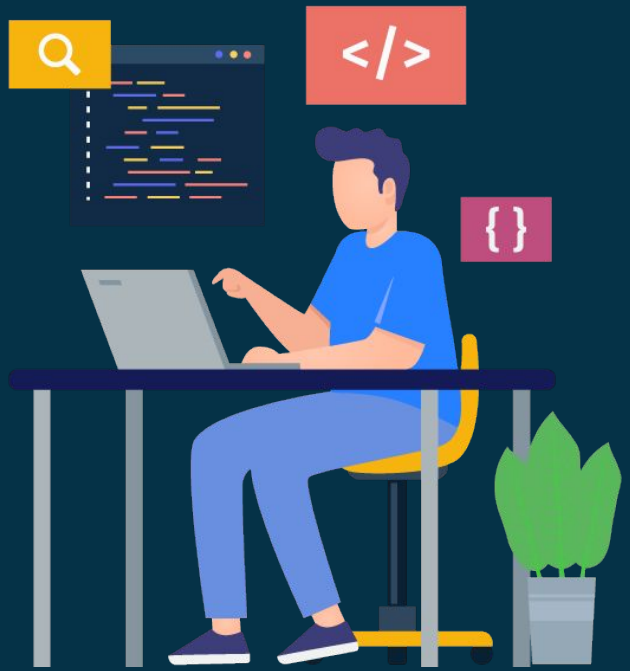
   `conda activate` **`s2compo`**

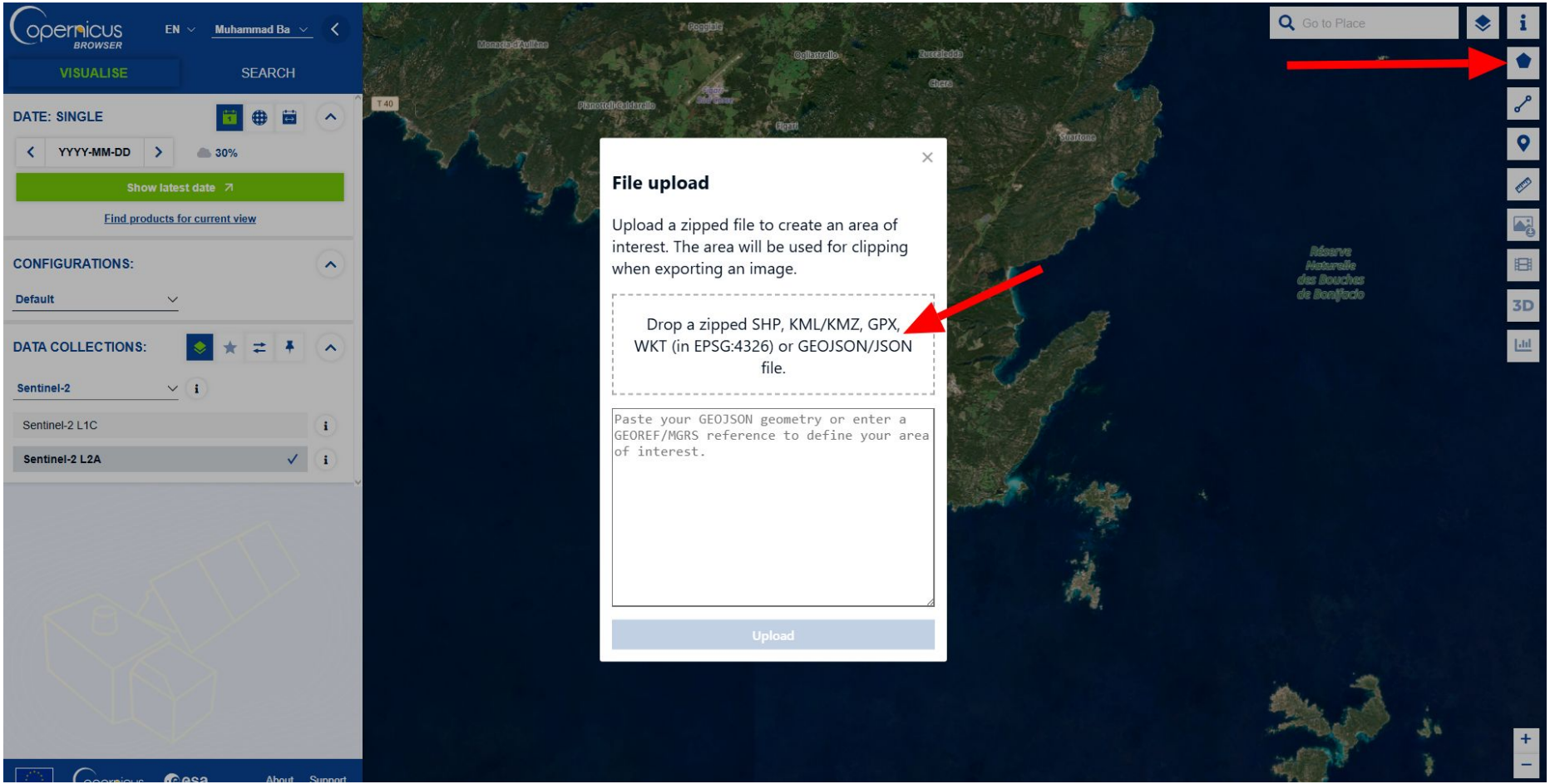
# Documentation - Demonstration

| | |
|---|---|
| Download Imagery / Demo Data | Use Copernicus Browser to select and download Sentinel-2 data. |
| **Folders** | Define folders for input data, clipped files, and output in the notebook. |
| Run The Tool | Activate the Conda environment and open the tool in Jupyter Notebook. |
| Preprocessing | **Clips Sentinel-2 data to theAOI and converts to TIFF.** |
| Create Composites & Generate stats | Generate and resample median value composites to 10m. |
| Visualise RGB and bands of interest for extra analyzation | Combine (Red, Green and Blue) into an RGB composite or visualize band of interest |

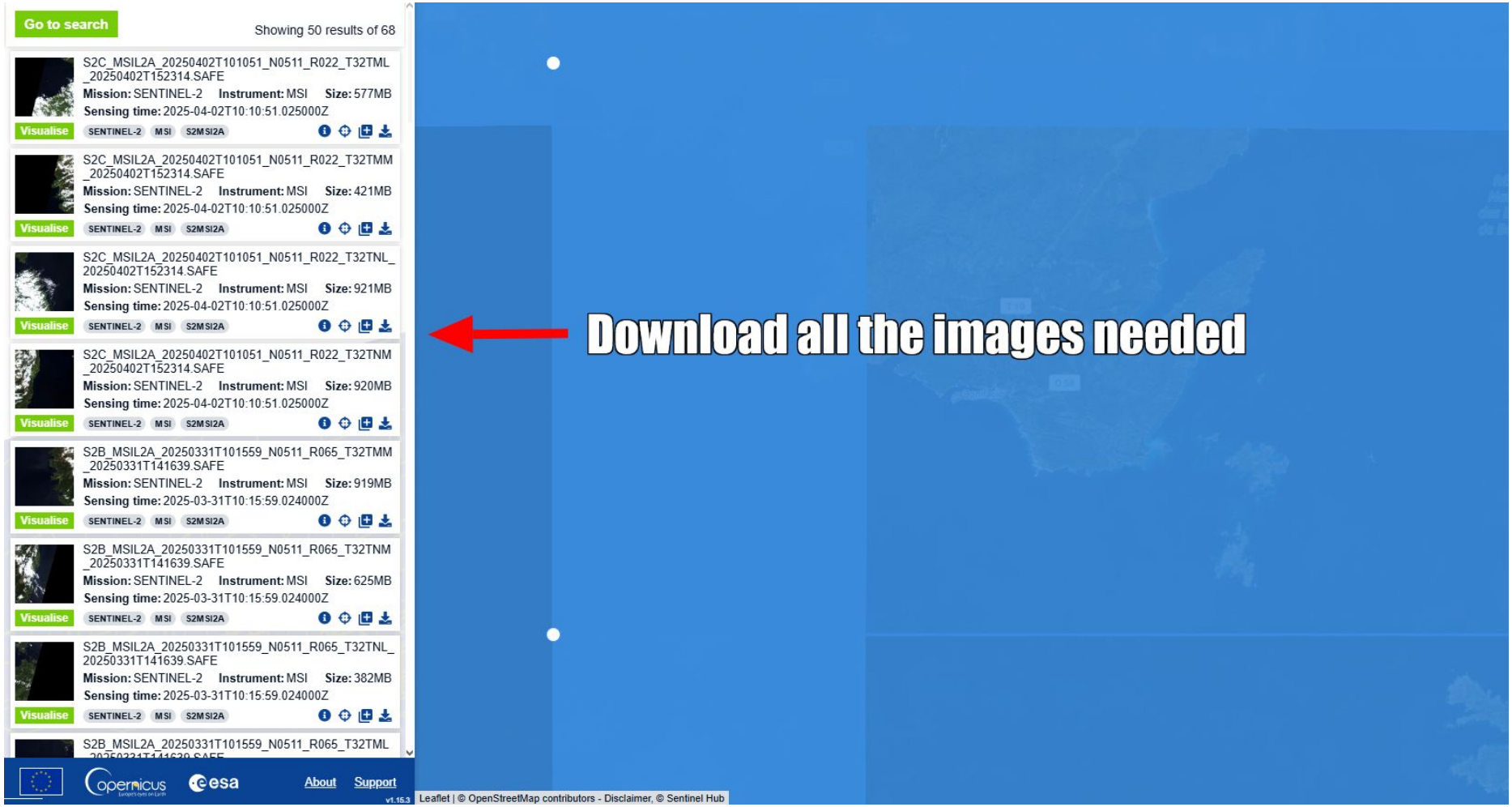
# Demonstration

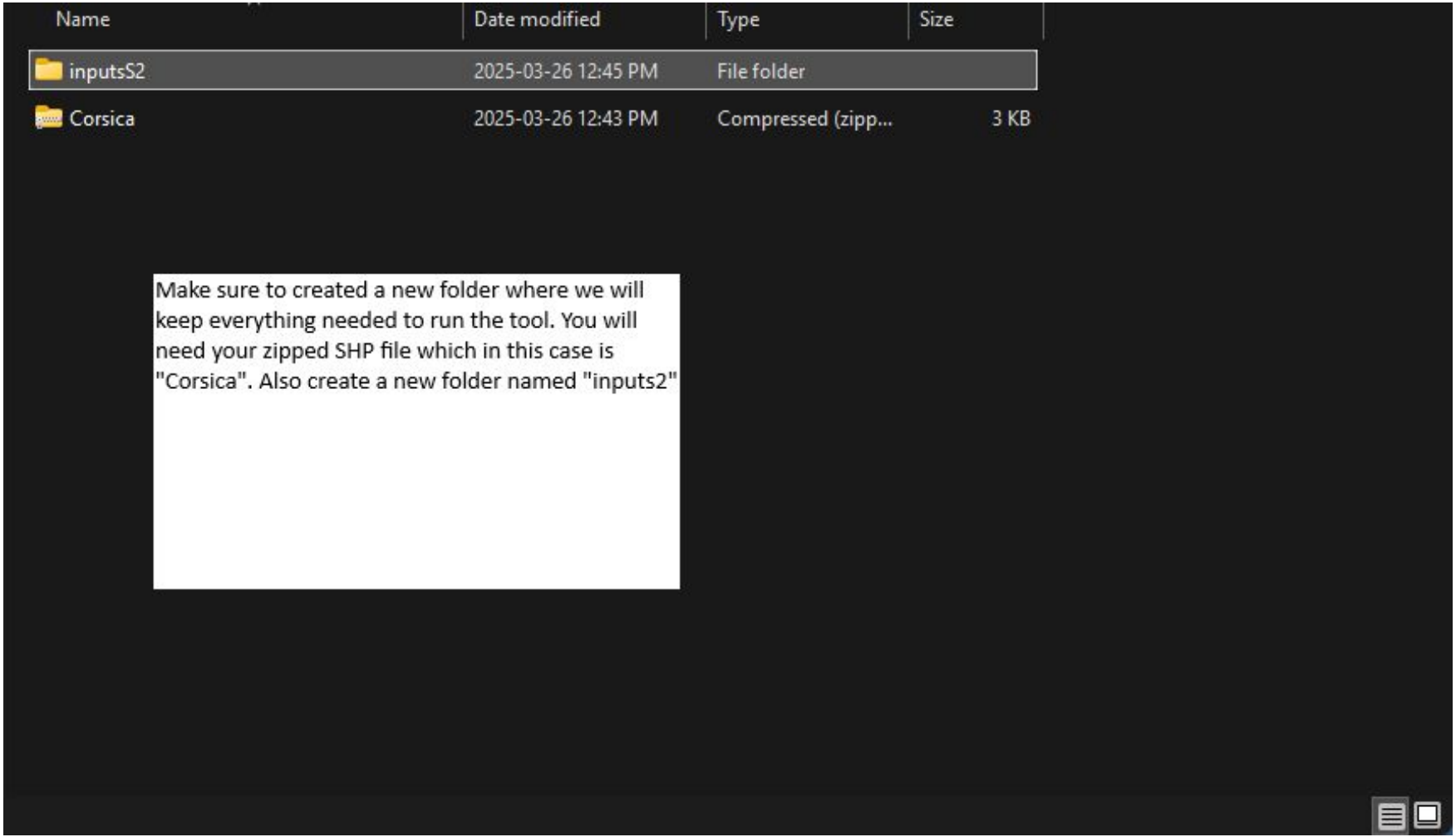
Screenshots

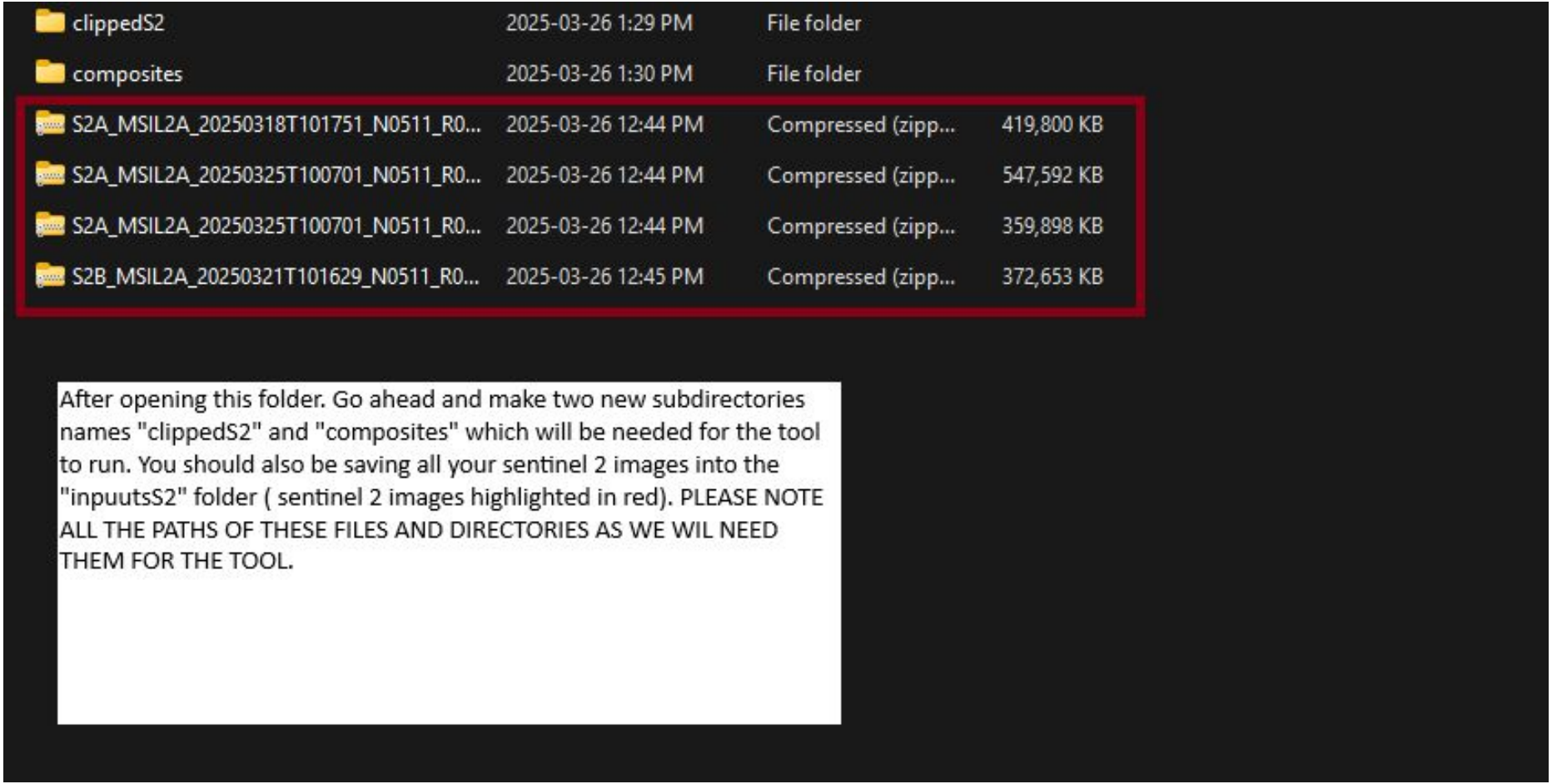



Copernicus BROWSER
EN
Muhammad Ba
VISUALISE
SEARCH
DATE: SINGLE
YYYY-MM-DD
30%
Show latest date
Find products for current view
CONFIGURATIONS:
Default
DATA COLLECTIONS:
Sentinel-2
Sentinel-2 L1C
Sentinel-2 L2A
About
Support
Go to Place
3D
File upload
Upload a zipped file to create an area of interest. The area will be used for clipping when exporting an image.
Drop a zipped SHP, KML/KMZ, GPX, WKT (in EPSG:4326) or GEOJSON/JSON file.
Paste your GEOJSON geometry or enter a GEOREF/MGRS reference to define your area of interest.
Upload


Copernicus BROWSER
EN
Muhammad Ba
VISUALISE
SEARCH
SEARCH CRITERIA:
Product name
To apply a location filter, please define an AOI/a POI
DATA SOURCES:
SENTINEL-1 Filters
SENTINEL-2 Filters
SENTINEL-3 Filters
SENTINEL-5P Filters
SENTINEL-6 Filters
CCM Optical Filters
CCM DEM Filters
CCM SAR Filters
GLOBAL-MOSAICS Filters
TIME RANGE:
From:
2025-03-02
hh 00 : mm 00
Until:
2025-04-02
hh 23 : mm 59
Filter by months
Search
About Support
Go to Place
596.03 km²
Réserve Naturelle des Bouches de Bonifacio
Make sure to select a time range
Leaflet | © OpenStreetMap contributors - Disclaimer, © Sentinel Hub
Lat: 41.5279, Lng: 9.1753
2 km


Go to search
Showing 50 results of 68
S2C_MSIL2A_20250402T101051_N0511_R022_T32TML_20250402T152314.SAFE
Mission: SENTINEL-2 Instrument: MSI Size: 577MB
Sensing time: 2025-04-02T10:10:51.025000Z
Visualise SENTINEL-2 MSI S2MSI2A
S2C_MSIL2A_20250402T101051_N0511_R022_T32TMM_20250402T152314.SAFE
Mission: SENTINEL-2 Instrument: MSI Size: 421MB
Sensing time: 2025-04-02T10:10:51.025000Z
Visualise SENTINEL-2 MSI S2MSI2A
S2C_MSIL2A_20250402T101051_N0511_R022_T32TNL_20250402T152314.SAFE
Mission: SENTINEL-2 Instrument: MSI Size: 921MB
Sensing time: 2025-04-02T10:10:51.025000Z
Visualise SENTINEL-2 MSI S2MSI2A
S2C_MSIL2A_20250402T101051_N0511_R022_T32TNM_20250402T152314.SAFE
Mission: SENTINEL-2 Instrument: MSI Size: 920MB
Sensing time: 2025-04-02T10:10:51.025000Z
Visualise SENTINEL-2 MSI S2MSI2A
S2B_MSIL2A_20250331T101559_N0511_R065_T32TMM_20250331T141639.SAFE
Mission: SENTINEL-2 Instrument: MSI Size: 919MB
Sensing time: 2025-03-31T10:15:59.024000Z
Visualise SENTINEL-2 MSI S2MSI2A
S2B_MSIL2A_20250331T101559_N0511_R065_T32TNM_20250331T141639.SAFE
Mission: SENTINEL-2 Instrument: MSI Size: 625MB
Sensing time: 2025-03-31T10:15:59.024000Z
Visualise SENTINEL-2 MSI S2MSI2A
S2B_MSIL2A_20250331T101559_N0511_R065_T32TNL_20250331T141639.SAFE
Mission: SENTINEL-2 Instrument: MSI Size: 382MB
Sensing time: 2025-03-31T10:15:59.024000Z
Visualise SENTINEL-2 MSI S2MSI2A
S2B_MSIL2A_20250331T101559_N0511_R065_T32TML
Download all the images needed
Copernicus
esa
About
Support
v1.15.3
Leaflet | © OpenStreetMap contributors - Disclaimer, © Sentinel Hub


Name
Date modified
Type
Size
inputsS2
2025-03-26 12:45 PM
File folder
Corsica
2025-03-26 12:43 PM
Compressed (zipp...
3 KB
Make sure to created a new folder where we will keep everything needed to run the tool. You will need your zipped SHP file which in this case is "Corsica". Also create a new folder named "inputs2"


clippedS2 2025-03-26 1:29 PM File folder
composites 2025-03-26 1:30 PM File folder
S2A_MSIL2A_20250318T101751_N0511_R0... 2025-03-26 12:44 PM Compressed (zipp... 419,800 KB
S2A_MSIL2A_20250325T100701_N0511_R0... 2025-03-26 12:44 PM Compressed (zipp... 547,592 KB
S2A_MSIL2A_20250325T100701_N0511_R0... 2025-03-26 12:44 PM Compressed (zipp... 359,898 KB
S2B_MSIL2A_20250321T101629_N0511_R0... 2025-03-26 12:45 PM Compressed (zipp... 372,653 KB
After opening this folder. Go ahead and make two new subdirectories names "clippedS2" and "composites" which will be needed for the tool to run. You should also be saving all your sentinel 2 images into the "inpuutsS2" folder ( sentinel 2 images highlighted in red). PLEASE NOTE ALL THE PATHS OF THESE FILES AND DIRECTORIES AS WE WIL NEED THEM FOR THE TOOL.

# Sentinel-2 Compositing Tool

Created by Adriana Caswell, Christian Devey, and Muhammad Ba

This tool creates median value composites for Sentinel-2 bands, resamples them to 10 m, and provides statistics about the composite. For more details, view the documentation.

[ ]:
```
import s2composite as s2
import rasterio as rio
from rasterio.plot import show
```

## User inputs

Access the tool using jupyter labs.

Source Sentinel-2 imagery for your area of interest from the Copernicus Browser and define the following variables:

- **inputS2**: Path to the directory where zipped Sentinel-2 SAFE files are saved
- **clippedS2**: Path to directory where clipped TIFF files will be saved after preprocessing
- **composites**: Path to directory where the median composites and resampled composites will be saved
- **aoiShp**: Path to the shapefile representing your area of interest (AOI) which will be used to clip the Sentinel-2 files
- **lineSpacing**: Spacing for grid statistics (in meters). This will help in calculating statistics like mean, variance, etc., over a grid defined by this spacing.

[ ]:
```
inputS2 = "demo//S2"
clippedS2 = "demo//S2//clipped"
compS2 = "demo//S2//composites"
aoiShp = "demo//StudyArea//StudyArea.shp"
lineSpacing = 5000
```

Change the paths depending on your computer and folder structure.

Once variables have been defined, you can *Run All Cells* or go through the workflow cell-by-cell below.

## Create composites

+ 5 cells hidden

## Composite statistics

+ 1 cell hidden

## Display composites

Clip the Sentinel-2 SAFE files to your area of interest and output TIFF files.

```
s2.prepS2(inputS2, aoiShp, clippedS2)
```

```
Clipping and converting 4 Sentinel-2 images...
Clipping and conversion complete.
```

Optional: Perform cloud masking or remove images with excessive cloud cover to improve the compositing results.

Run the following code block to create median value composites for each band and resample the composites to 10 m.

```
bands, meta10m, meta20m, meta60m = s2.sortBands(clippedS2)
s2.compositeBands(bands, meta10m, meta20m, meta60m, compS2)
composites = s2.resampleBandsTo10m(compS2, overwrite = False)
```

```
Sorting images by band...
Sort complete.
Compositing bands...
B01 median composite created.
B02 median composite created.
B03 median composite created.
B04 median composite created.
B05 median composite created.
B08 median composite created.
B11 median composite created.
B12 median composite created.
Compositing complete.
Resampling 8 bands to 10m resolution using bilinear...
Resampled: C:\School\GIS\Project\tool\inputsS2\composites\B01_resampled_10m.tif
Resampled: C:\School\GIS\Project\tool\inputsS2\composites\B02_resampled_10m.tif
Resampled: C:\School\GIS\Project\tool\inputsS2\composites\B03_resampled_10m.tif
Resampled: C:\School\GIS\Project\tool\inputsS2\composites\B04_resampled_10m.tif
Resampled: C:\School\GIS\Project\tool\inputsS2\composites\B05_resampled_10m.tif
Resampled: C:\School\GIS\Project\tool\inputsS2\composites\B08_resampled_10m.tif
Resampled: C:\School\GIS\Project\tool\inputsS2\composites\B11_resampled_10m.tif
Resampled: C:\School\GIS\Project\tool\inputsS2\composites\B12_resampled_10m.tif
```

After running the tool, the images should start to process and follow the steps. It will first create composites and display these files in the folders we created not too long ago. If there is no out put, please make sure to verify the file paths and also decompress the SHP file before using it.

[ ]:
```
stats = s2.gridStats(bands, lineSpacing)
```

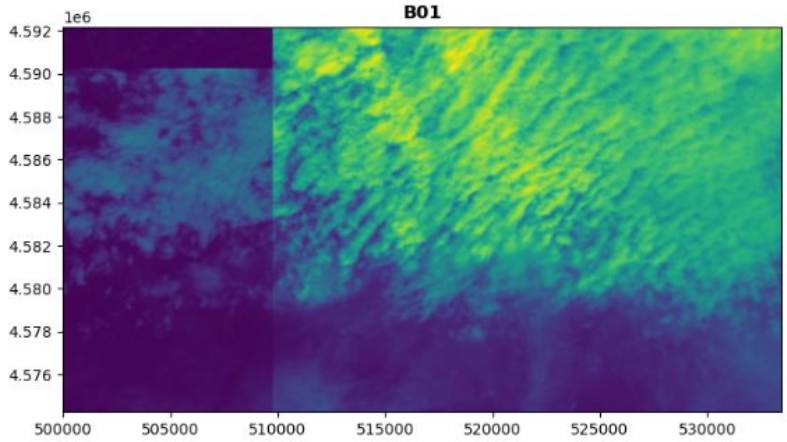
## Display composites

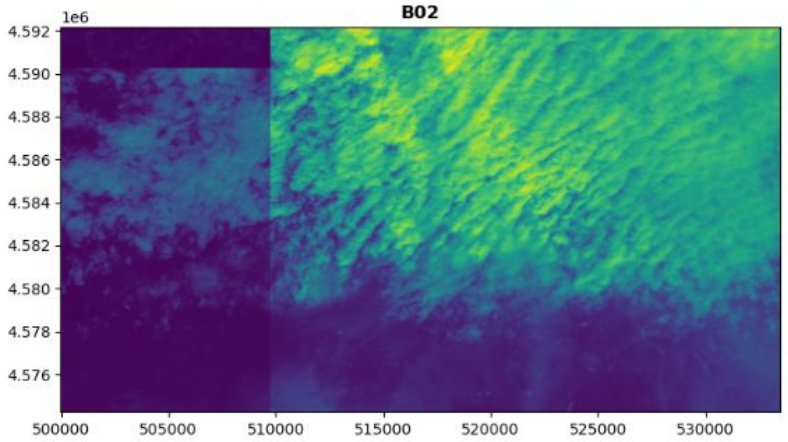
Run the following code bloacks to:

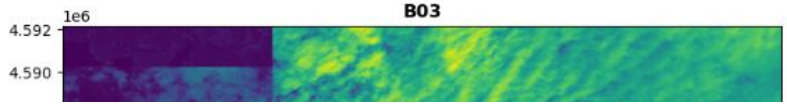
- Display the composite for each band of interest
- Display an RGB composite of the composites created
- Display the composite for a single band of interest

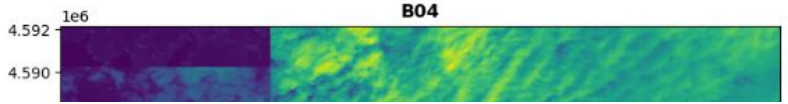
Further down in the tool, it will then get the composite statistics and also display these composites as you can see below

[8]:
```
# display composite for each band of interest
s2.showBands(composites)
```



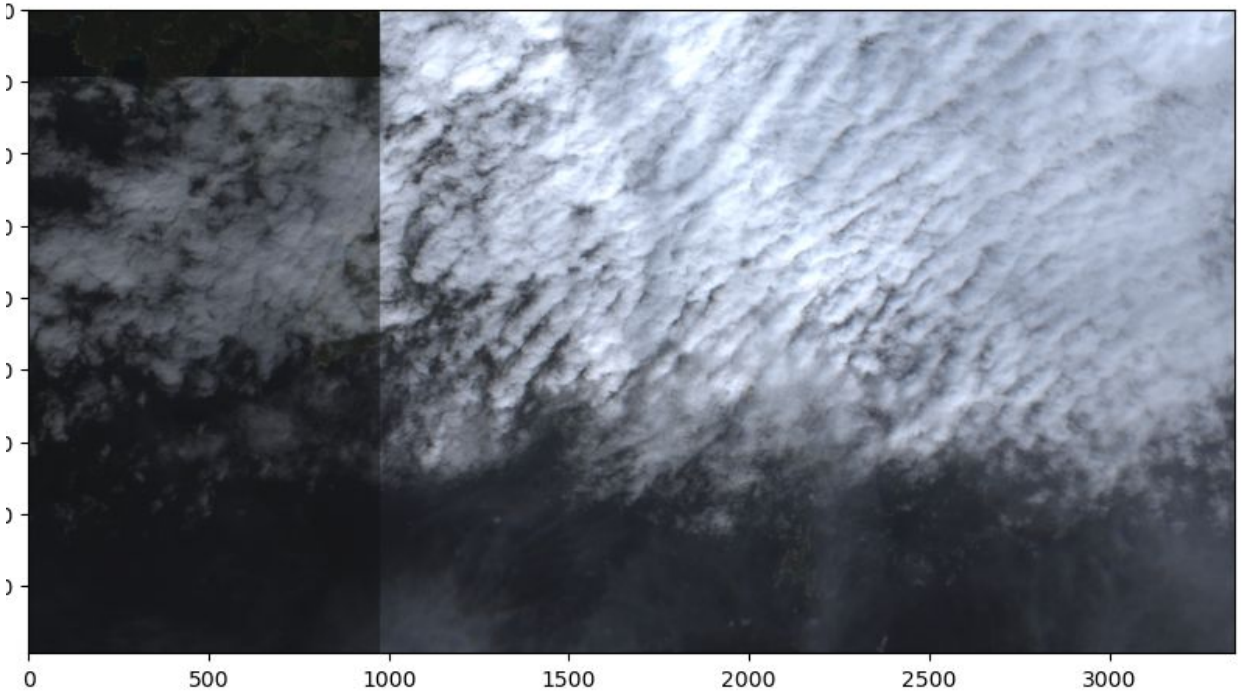



```
play RGB composite
"C:\School\GIS\Project\tool\inputsS2\composites\B04_resampled_10m.tif"
"C:\School\GIS\Project\tool\inputsS2\composites\B03_resampled_10m.tif"
"C:\School\GIS\Project\tool\inputsS2\composites\B02_resampled_10m.tif"

owRGB(R, G, B)
```

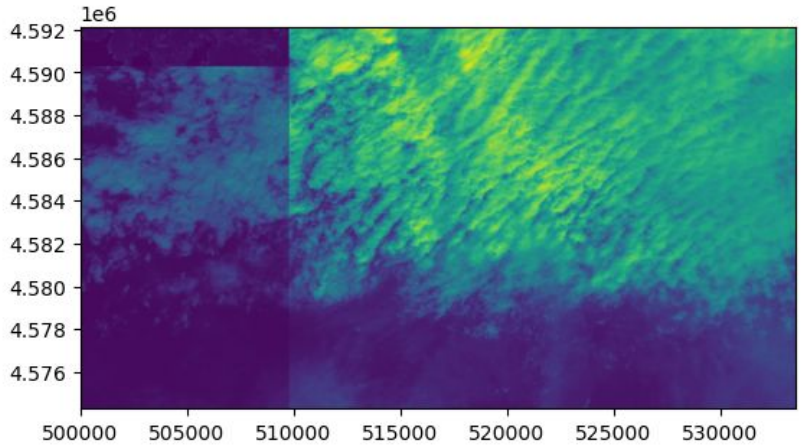
File paths can be inputted here which would then display the RGB composite




After all these steps are achieved, the major part of the tool is now completed and for further analyzation you can display the RGB composite. For this step you will have to head into the "inputsS2" then into the "composites" subdirectory where you can find the bands needed which are (B04, B03 and B02). Make sure to have the file paths of the bands needed.

[15]:
```
# display a single band of interest
boi = r"C:\School\GIS\Project\tool\inputsS2\composites\B04_resampled_10m.tif"

with rio.open(boi) as src:
    show(src)
```




Furthermore, if you would like to only have a look at a certain band for analyzing, you can follow the same steps and change the path to the band of interest which would then be displayed

# Documentation - Troubleshooting

**Check error messages**

| | |
|---|---|
| **File Paths** | Check that all file paths are correct |
| **Data types** | Ensure input paths are pointing to the correct data (.SAFE.zip, .shp) |
| **Storage** | Ensure your hard drive has adequate storage to output TIFF files |
| **Dependencies** | Ensure the tool is being used in the s2compo conda environment |

**Do not modify repo folder structure or Sentinel-2 SAFE files**

# Challenges


Challenge: Size of Sentinel-2 imagery

Solution: Clip to AOI

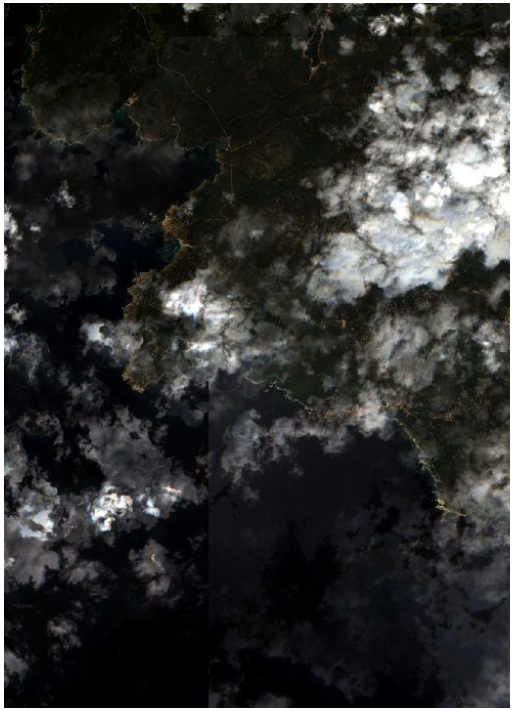
Challenge: Arrays from clipped imagery had different dimensions

Solution: Clip using GDAL

Challenge: NoData values affecting composite and stats output

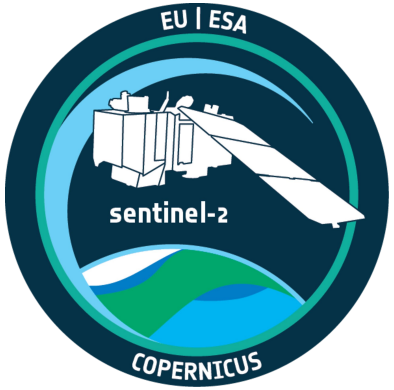
Solution: Use NumPy masked arrays

| Limitations | Future Work |
| --- | --- |
| Impact of clouds on composite quality | Add **cloud masking** into the workflow |
| Downloading S2 imagery from Copernicus Hub | Incorporating the **Sentinel-2 API** |
| Interpretation of output statistics | Create rasters containing **output statistics** |
| Median value compositing only | Adding **more composting methods** |



Example of clouds impacting the quality of the composite

# Conclusion




- S2B_MSIL2A_2022122...40806T072335.SAFE.zip
- S2B_MSIL2A_2025021...50219T142054.SAFE.zip
- S2C_MSIL2A_20250211...0211T142256.SAFE.zip
- S2C_MSIL2A_2025022...50221T174112.SAFE.zip

GitHub MIT

**Sentinel-2 Compositing Tool**

jupyter

- B01_composite.tif
- B01_resampled_10m.tif
- B02_composite.tif
- B02_resampled_10m.tif
- B03_composite.tif
- B03_resampled_10m.tif
- B04_composite.tif
- B04_resampled_10m.tif
- B05_composite.tif
- B05_resampled_10m.tif
- B08_composite.tif
- B08_resampled_10m.tif
- B11_composite.tif
- B11_resampled_10m.tif
- B12_composite.tif
- B12_resampled_10m.tif

**+ Statistics**

# Acknowledgements

**Thank you to Dr. Derek Mueller and Dr. Anders Knudby for initiating the project and providing guidance throughout its development.**

- ★ Inspiration for median value composite methods: ahmad-geo-edu/median-composite and Dimo Dimov
- ★ Clipping using GDAL: Geospatial Linux documentation by University of Edinburgh and LTS International
- ★ Documentation from GDAL, Rasterio, Matplotlib, and NumPy
- ★ ChatGPT