A Bird's Eye View On Multispectral Satellite Imagery

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SUMMARY

Data

Synthetic Aperture Radar (SAR)

Multi Spectral Images (MSI)

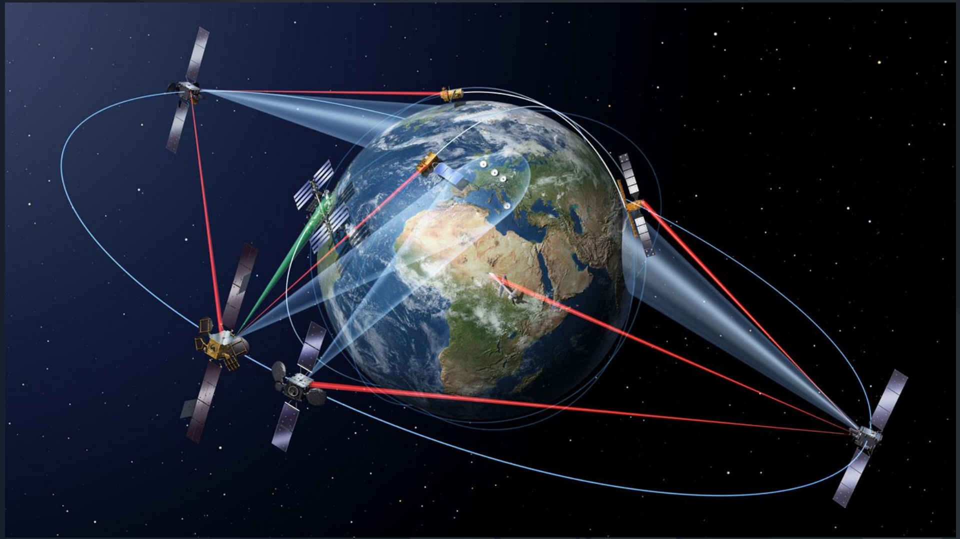
Data sources

ML & AI

Data preparation

Training

Real world applications



REMOTE SENSING THROUGH SATELLITES

TYPES OF SATELLITE DATA

MULTI SPECTRAL IMAGES (MSI):
Passive sensors

(E.g. ESA Sentinel 2 & 3, NASA Landsat 7 & 8)

SYNTHETIC APERTURE RADAR (SAR):
Active sensors

(E.g. ESA Sentinel 1)

SAR DATA

Pro:

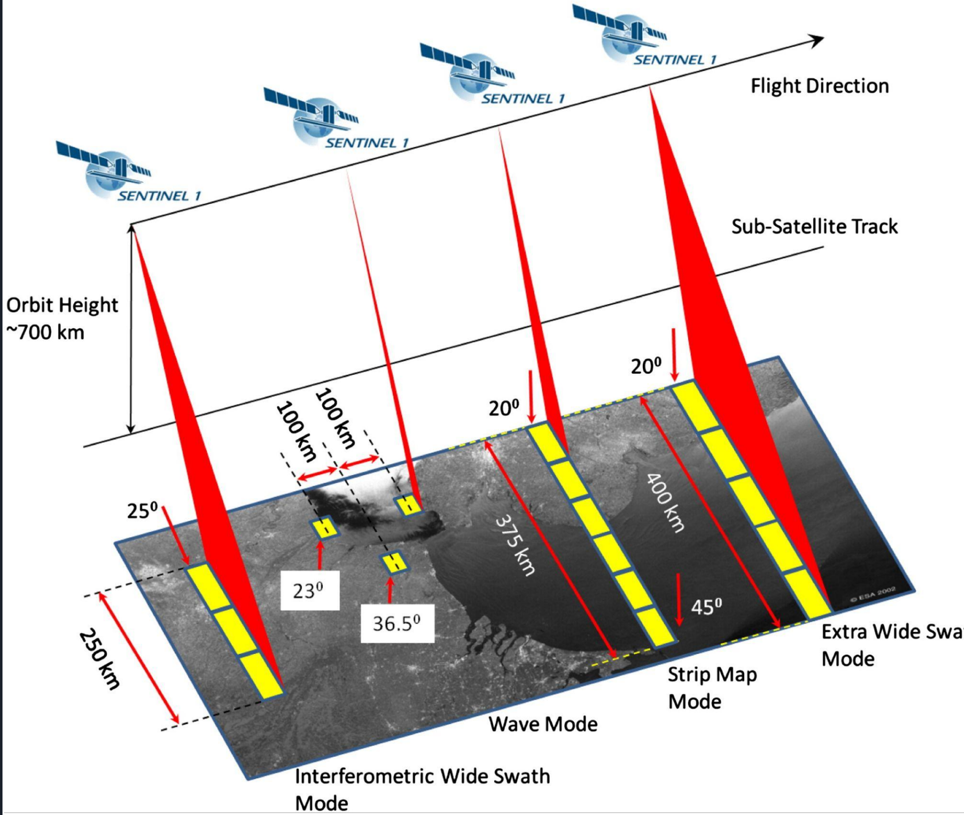
Weather-free measurements

Signal processing through time allows to detect cm-scale variations

Contra:

No true color information (false color with polarization)

Post processing is complex



SAR image of the Bosphorous Strait

MSI DATA

Pro:

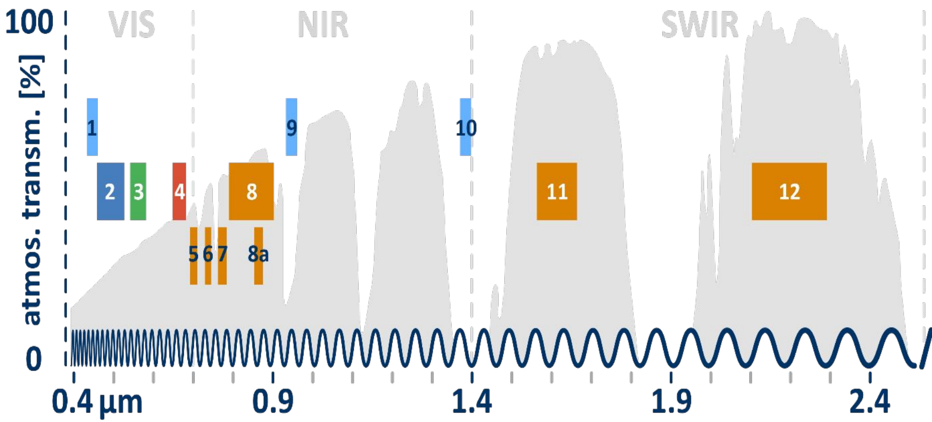
Directly understandable (**RGB**)

Many different wavelengths (Visible, Near Infra Red, Short Wave Infra Red)

Contra:

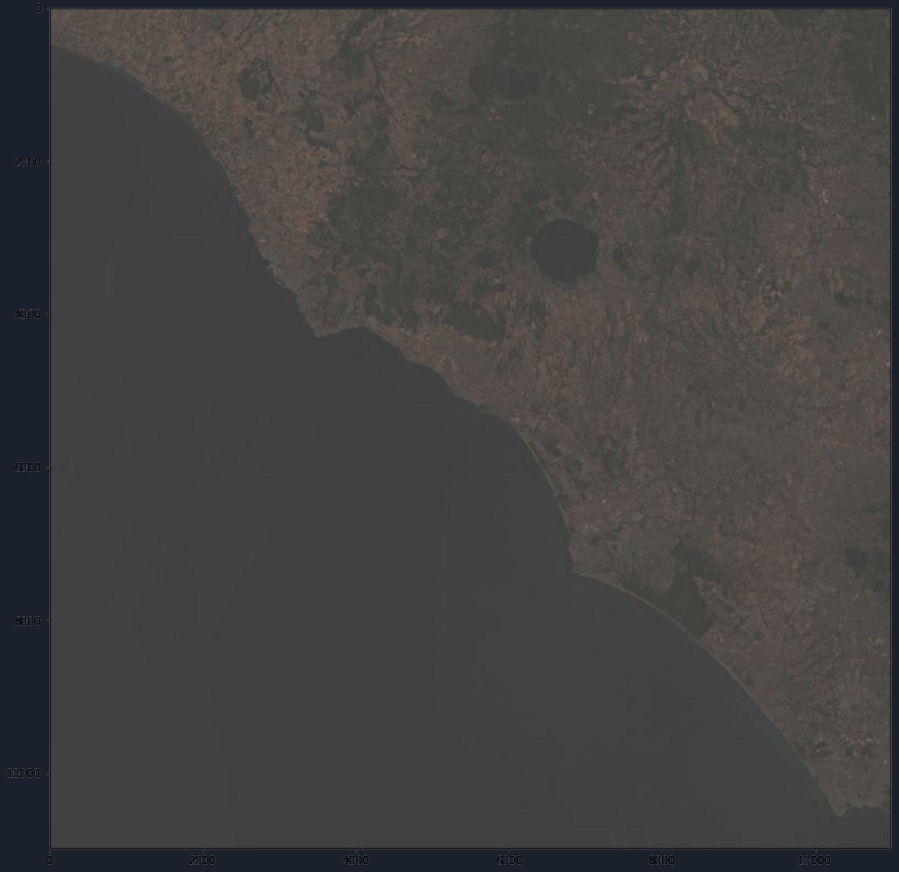
Atmospheric corrections

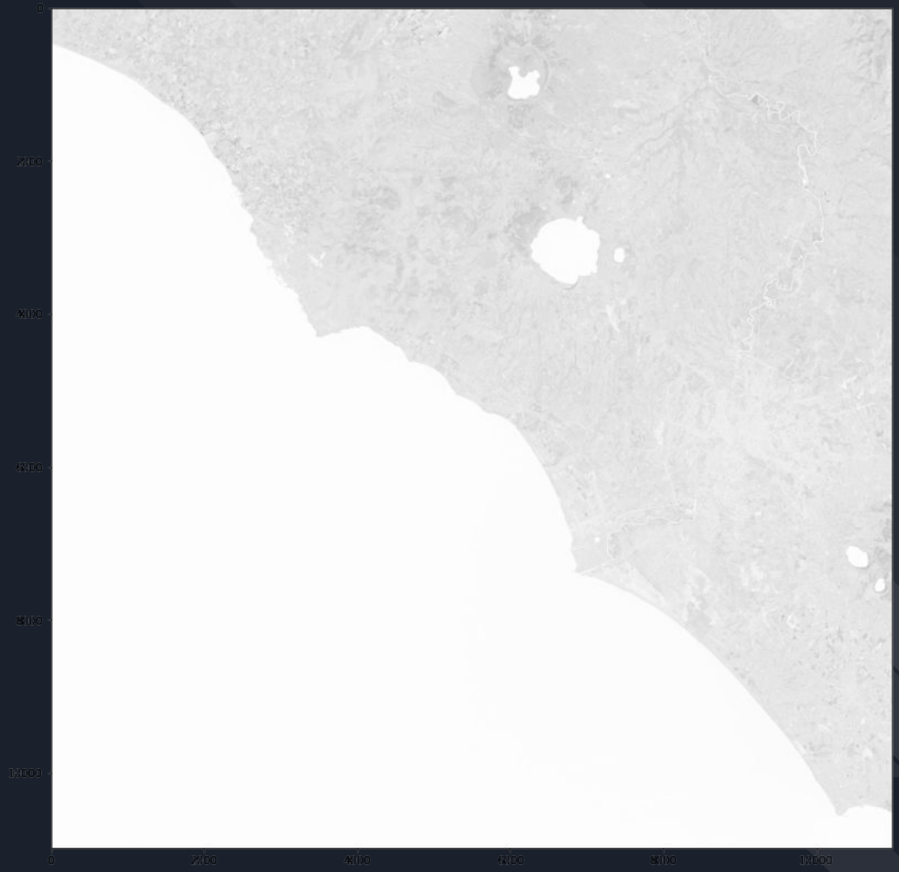
Clouds



BAND	SPECTRAL	WAVELEN. [µm]	GEOM. [m]	SENSOR
1	aerosols	0.429 – 0.457	60	MSI
2	blue	0.451 – 0.539	10	MSI
3	green	0.538 – 0.585	10	MSI
4	red	0.641 – 0.689	10	MSI
5	red edge	0.695 – 0.715	20	MSI
6	red edge	0.731 – 0.749	20	MSI
7	red edge	0.769 – 0.797	20	MSI
8	NIR	0.784 – 0.900	10	MSI
8a	narrow NIR	0.855 – 0.875	20	MSI
9	water vapour	0.935 – 0.955	60	MSI
10	SWIR cirrus	1.365 – 1.385	60	MSI
11	SWIR	1.565 – 1.655	20	MSI
12	SWIR	2.100 – 2.280	20	MSI

MSI IMAGES: RGB & NIR OF ROME AREA





ESA SATELLITE MISSIONS

Sentinel-1

- SAR data
- Two satellites (S1A & S1B), orbit period of 12 days
- 5m of spatial resolution

Sentinel-2

- MSI data (12 bands, from UltraViolet to Short Wave Infra Red)
- Two satellites (S2A, S2B), orbit period of 10 days
- Spatial resolution 10m (R, G, B, NIR) to 20m and 60m

Sentinel-3

- MSI mission for environmental monitoring
- 4 instruments on board, from 250m to 1km spatial resolution
- Orbital period: 27 days

HOW TO ACCESS THE DATA

Copernicus Open Access Hub

https://scihub.copernicus.eu/ (Sentinel 1, 2, 3)

Free access with API registration

Google Earth Engine

gs://gcp-public-data-sentinel-2 (Sentinel 2)

Free access with API registration

Sentinel Hub

https://www.sentinel-hub.com/ (Sentinel, Landsat, Airbus ...)

Free trial access

DIRECT APPLICATION: SPECTRAL INDICES

Using a direct algebraic combination of the bands we can highlight some properties of the terrain:

NDVI: Normalized Difference Vegetation Index

NDVI = (NIR - RED) / (RED + NIR)

NDWI: Normalized Difference Water Index

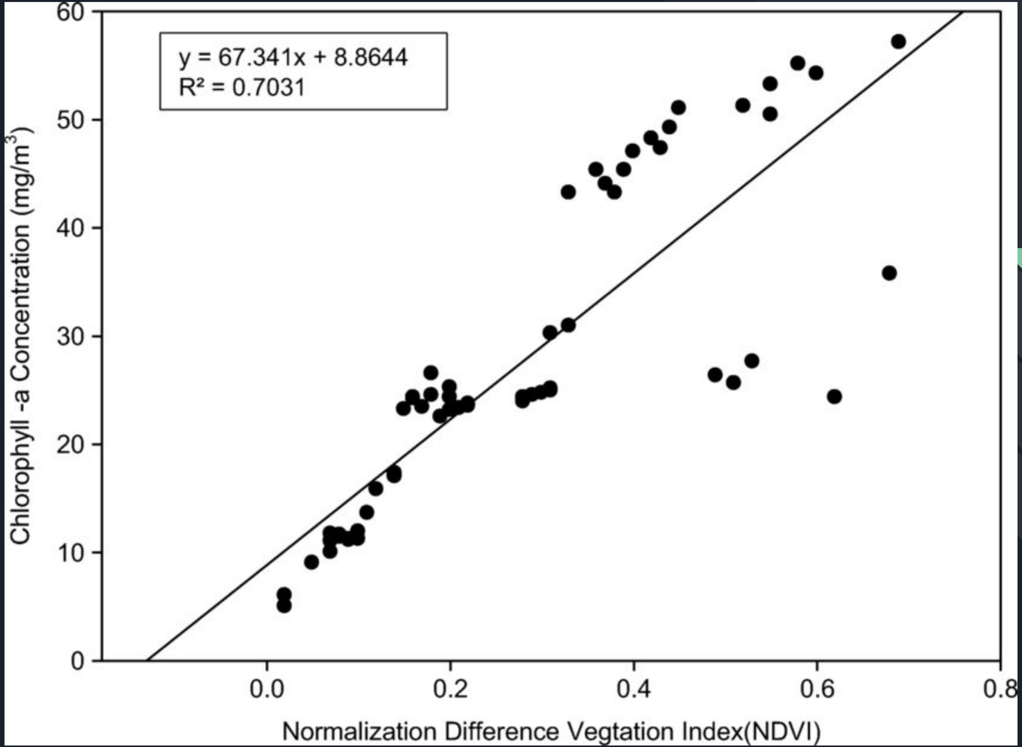
NDWI = (GREEN - NIR) / (GREEN + NIR)

NBR: Normalized Burned Ratio

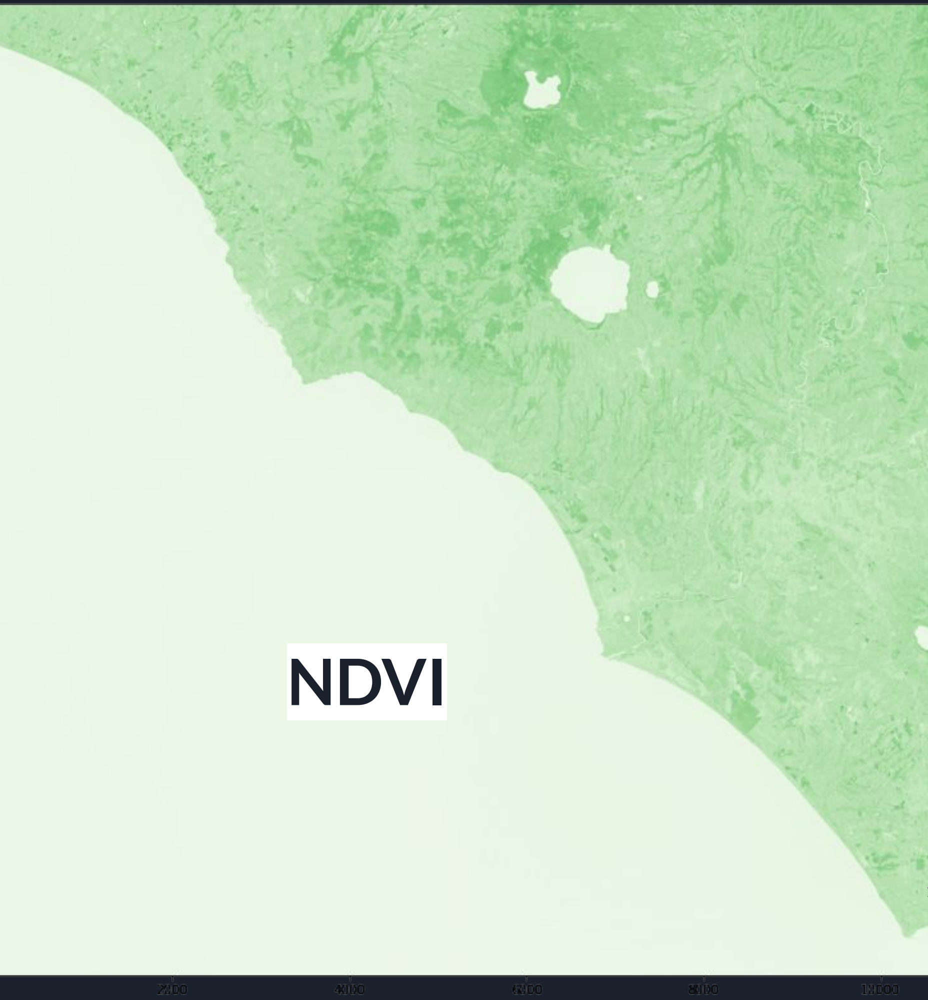
NBR: (NIR - SWIR) / (SWIR + NIR)

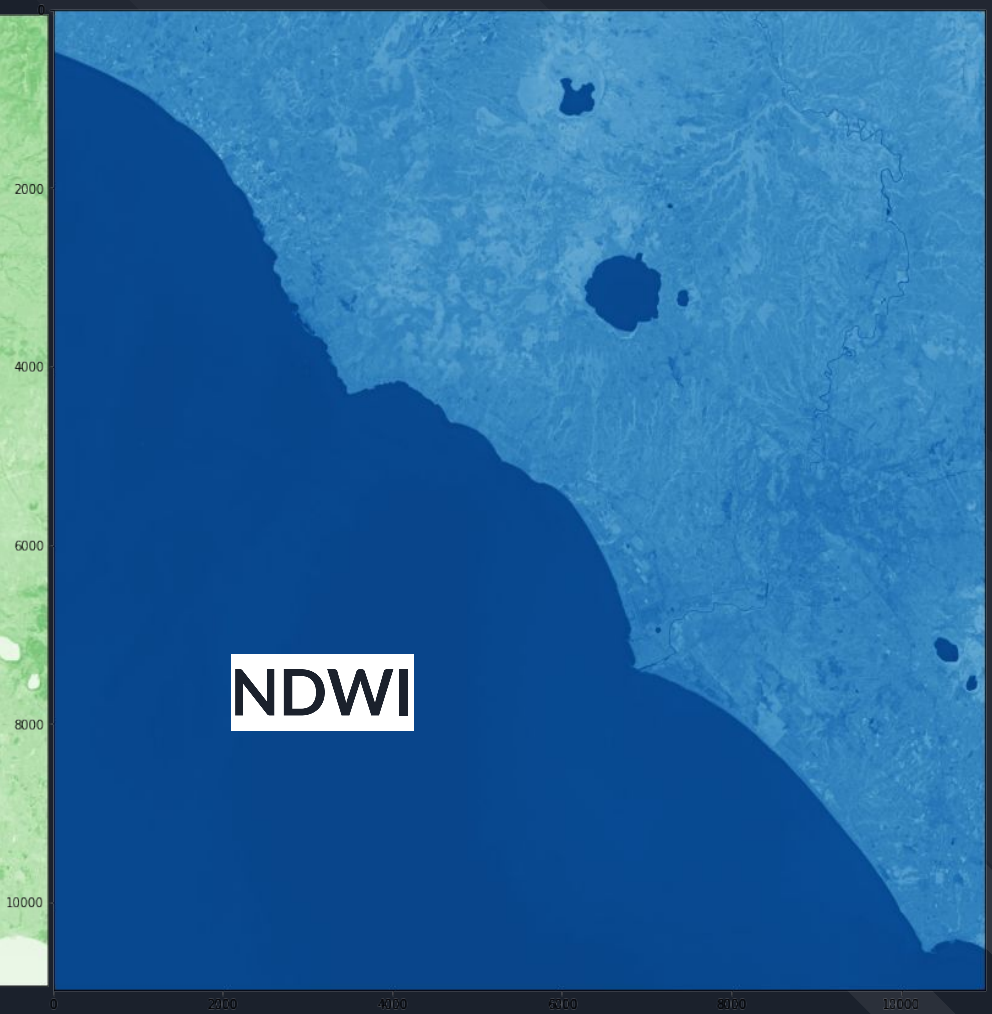
More custom indices: https://custom-scripts.sentinel-hub.com/custom-scripts/sentinel/

NDVI IS A GOOD PROXY FOR CHLOROPHYLL



Choon et. al (2018) https://www.x-mol.net/paper/article/1213013456713879559


NDVI
2000
4000
6000
8000
10000


NDWI
0
2000
4000
6000
8000
10000

ML & AI APPLICATIONS

Urban Trend (app within the **DataFactor** project, funded by Italian **MISE**):

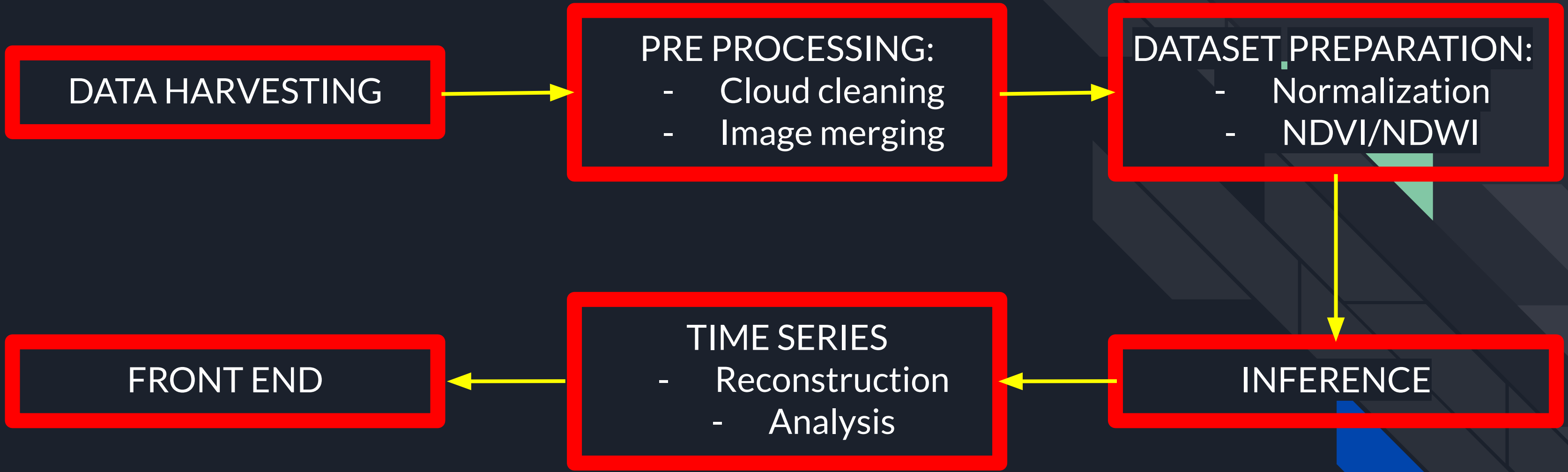
- Use open data
- Identify in land use (buildings, trees etc.)
- Seasonality, trends forecasts
- Works with very different kinds of terrains, time, light

AI / ML TOOLS:
Classic ML, pixel-based algorithms:

- Random Forest
- SVM
- Gradient boosting

Deep learning: CNN and U-Net for semantic segmentation

SYSTEM PIPELINE AND ARCHITECTURE (deployed on prem with Valohai MLOps orchestrator)

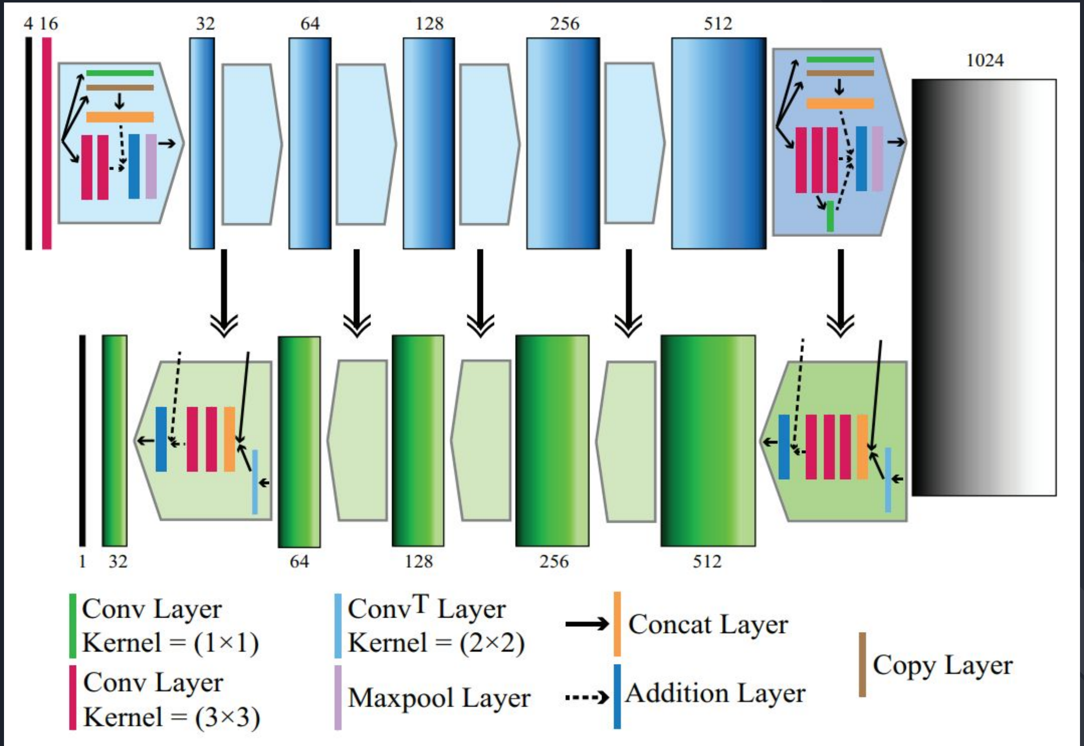


CLOUD SEGMENTATION

Cloud-Net:
U-Net [1], trained on Landsat 8, 4-band images (RGB + NIR)

Transfer learning:
Using S2 cloud dataset [2]

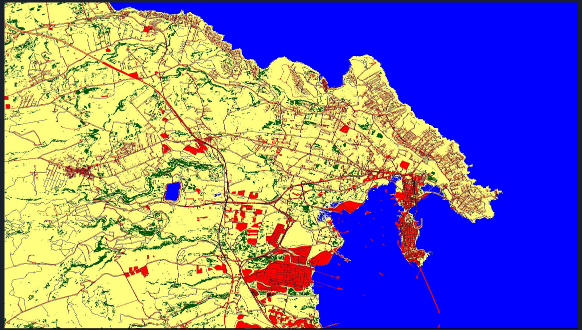
Stacking and merging:
Collect cleaned images over 30 days windows

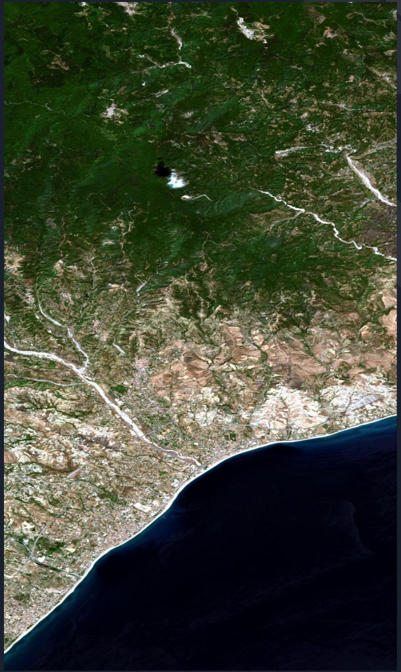


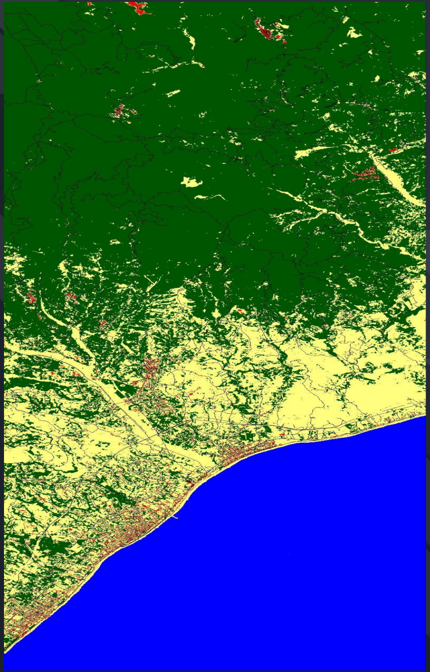
[1] Mohajerani, Saeedi (2019) https://arxiv.org/abs/1901.10077v1
[2] Sentinel 2 Cloud Segmentation Dataset (2020) https://mlhub.earth/10.34911/rdnt.hfq6m7

IMAGE SEGMENTATION TRAINING SET

150 cloud free (mostly) images, 4 bands, varying size 1024x512 to 3984x2048



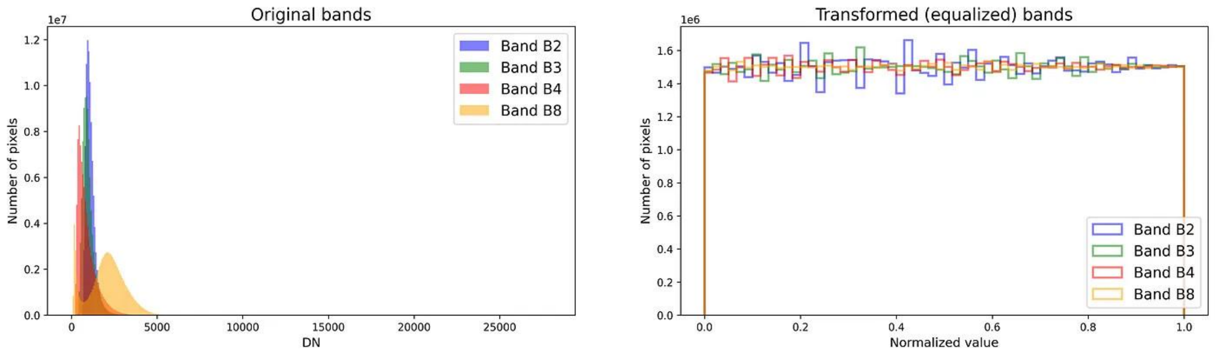




DATA PREPARATION PIPELINE

Custom labeling on 4 classes: water, trees, terrain, building

Image normalization: Histogram Normalization [1] & K-Means for the ground truth values:



Patchification and augmentation: extract NxN patches, rotate and zoom in

[1] Kadunc et al. (2022) https://medium.com/sentinel-hub/how-to-normalize-satellite-images-for-deep-learning

TERRAIN SEGMENTATION: U-NET ARCHITECTURE

Cannot use pre-trained models (e.g. Imagenet) due to Nchannels

Base Architecture: UNet/CloudNet with bridge 1024/2048

Multiclass: Water, Terrain, Trees, Buildings (ESRI classification, works better under different geo & weather conditions)

Input channels: R, G, B, NIR, NDVI, NDWI

Tensor shape = (Nchannels, Xpatch, Ypatch)

Nchannels = 4, 5, 6

X/Ypatch = 64, 96, 128, 256, 384

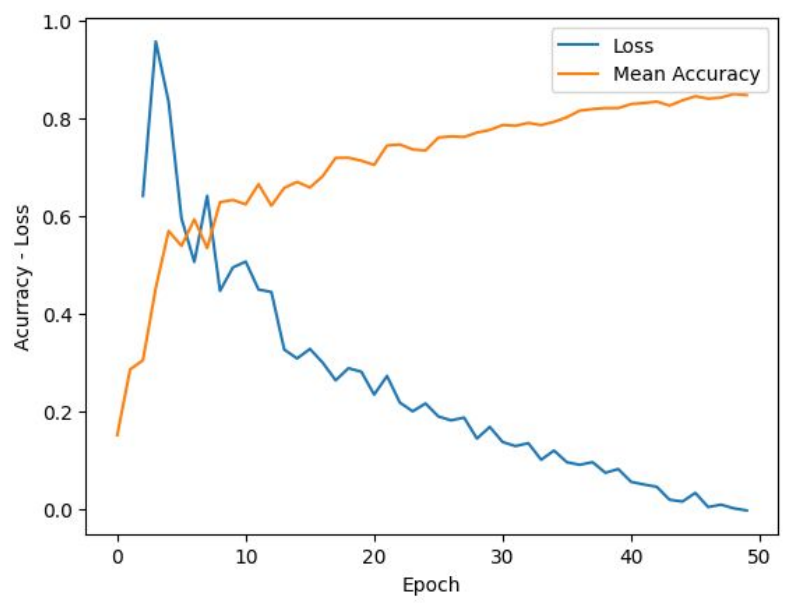
U-NET TRAINING STRATEGY

Loss Function: Weighted cross entropy

$$\ell(x, y) = L = \{l_1, \ldots, l_N\}^\top, \quad l_n = -w_{y_n} \log \frac{\exp(x_{n,y_n})}{\sum_{c=1}^{C} \exp(x_{n,c})}$$

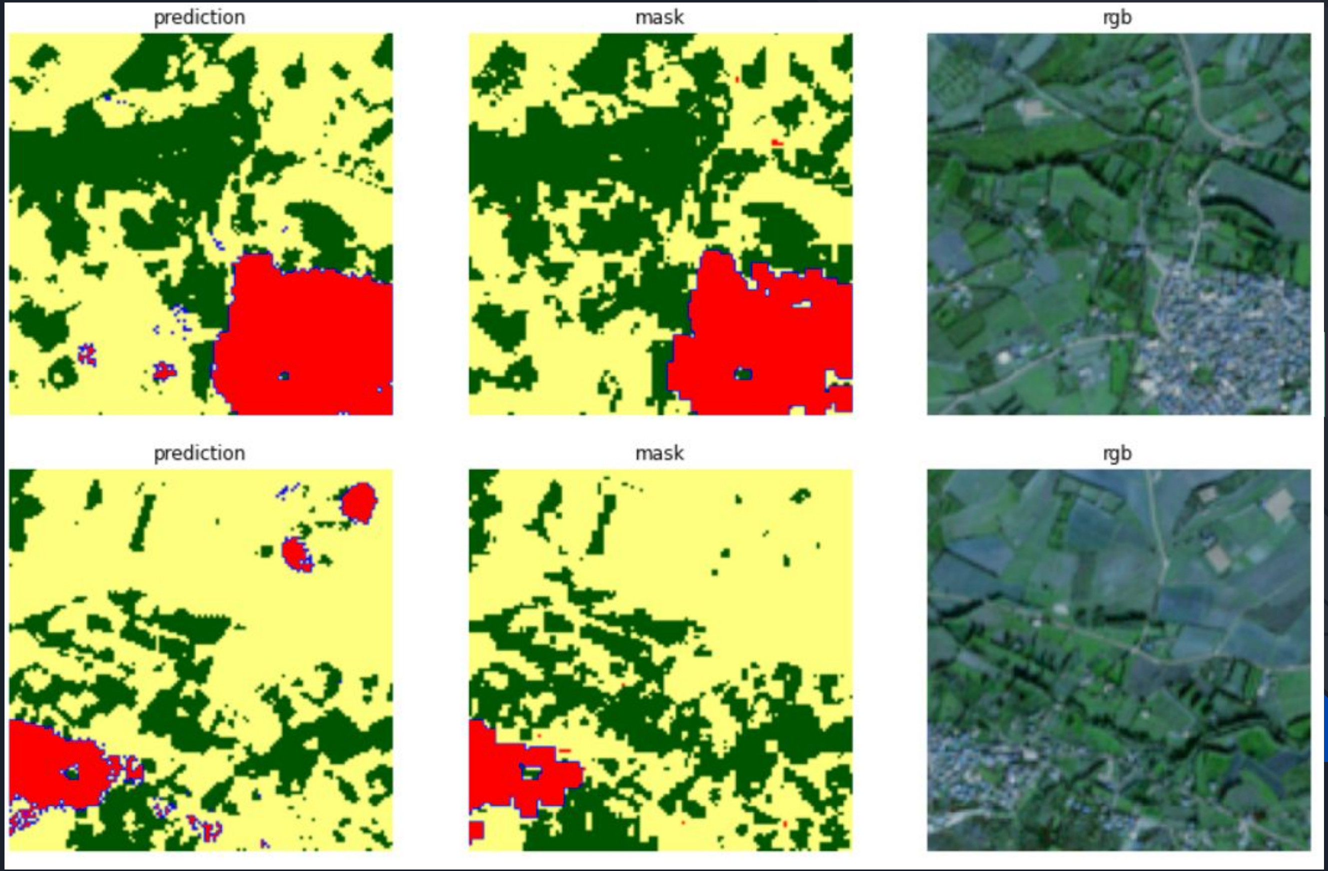
Relevant metrics:
Mean accuracy (per-class)

Hardware:
NVIDIA A6000 (48 GB),
NVIDIA Quadro RTX 6000 (24GB)




```
0) Correct pixels: 405260/449951, 0.9006758513704826
1) Correct pixels: 2046548/3099872, 0.6602040342310909
2) Correct pixels: 13863621/15315429, 0.905206181295999
3) Correct pixels: 8016909/9073564, 0.883545759968189
        Mean : 0.8374079567164403
```

U-NET APPLICATION



U-NET APPLICATION

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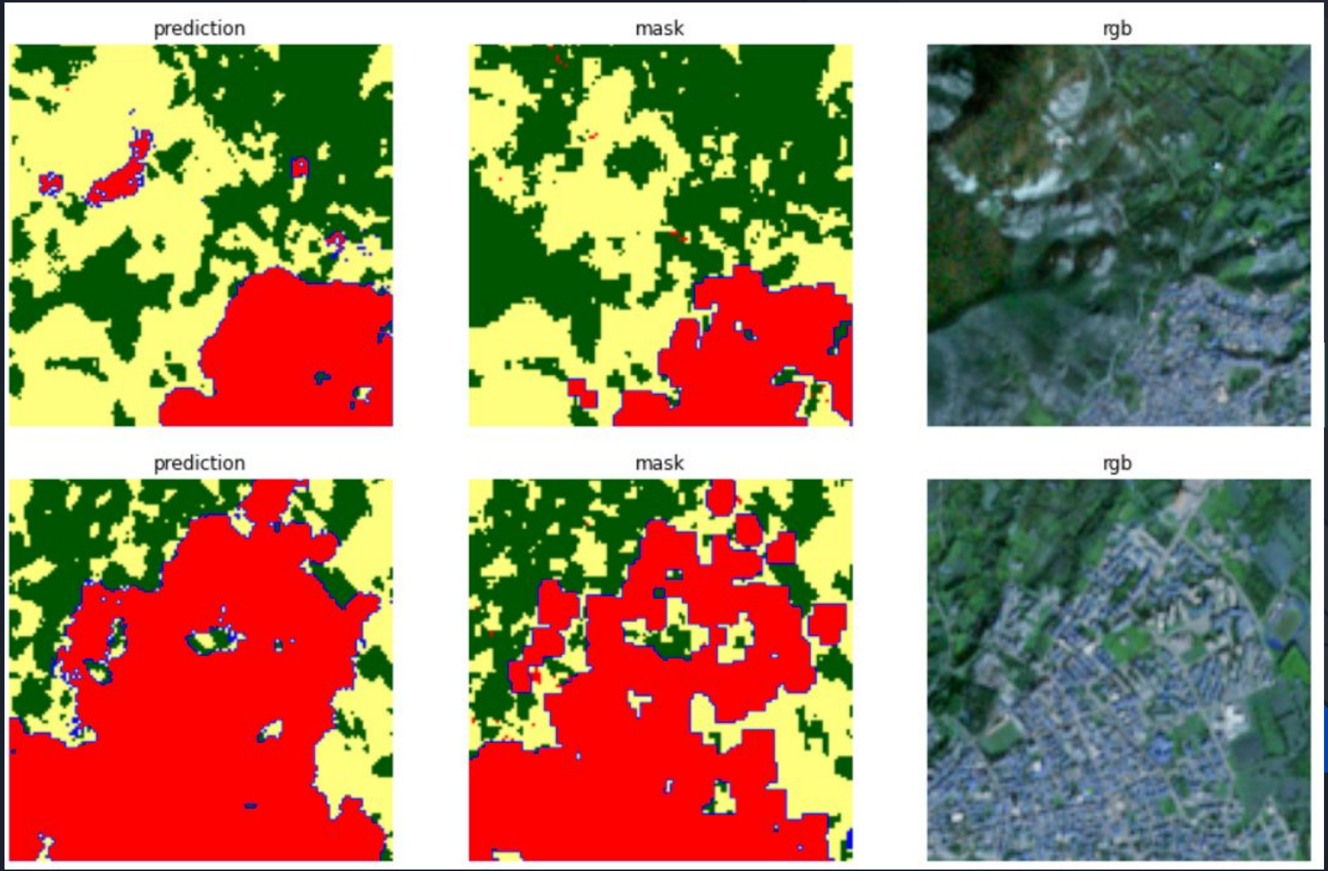
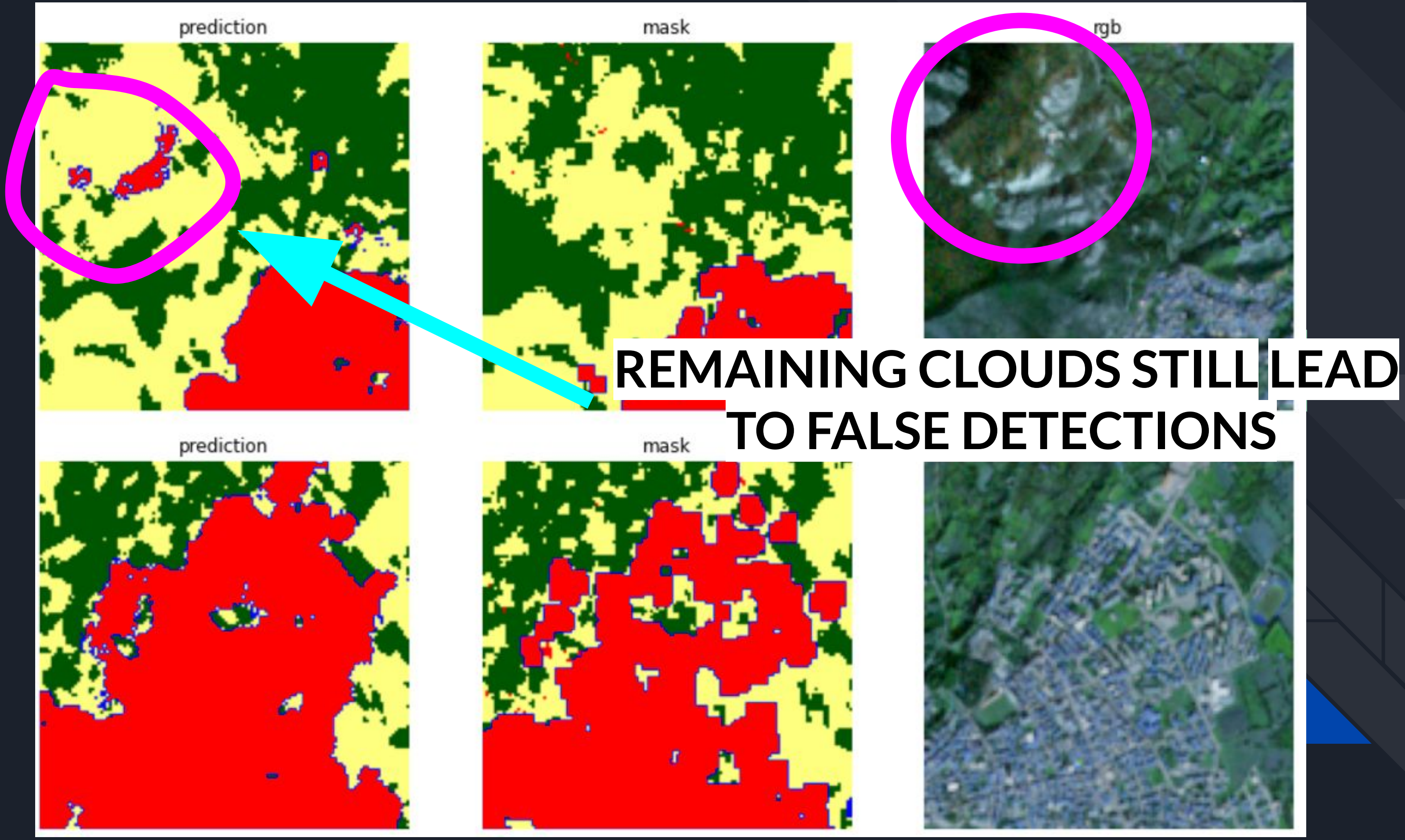
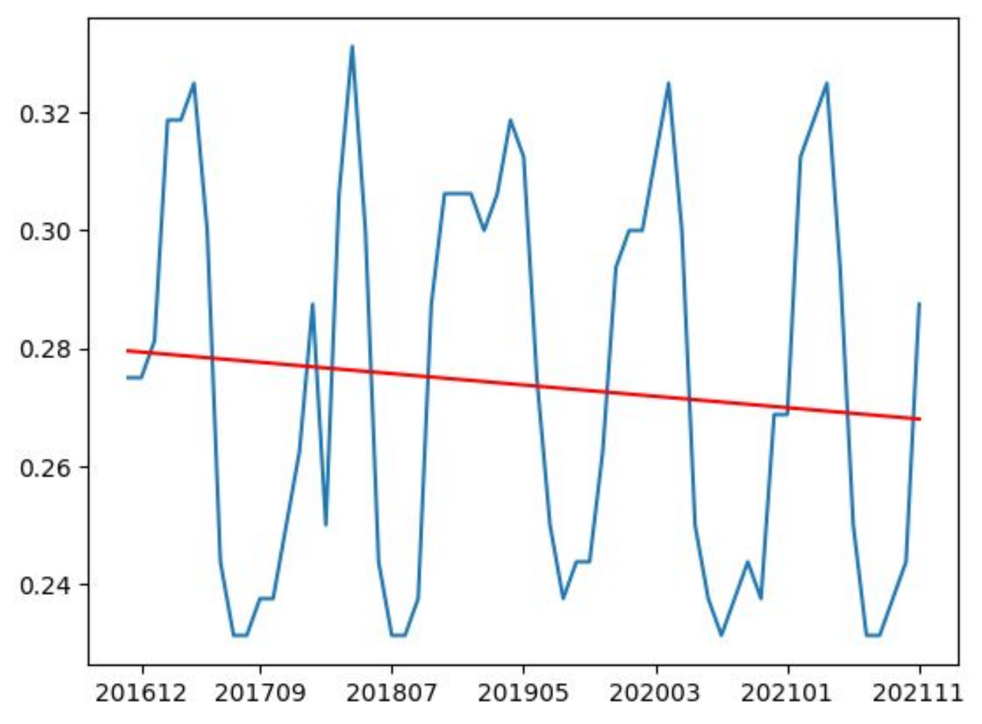


U-NET APPLICATION



FOREST AREA TIME SERIES APPLICATION

Municipality of Comitini (Agrigento), Sicily



CONCLUSION

SATELLITE IMAGERY IS ABUNDANT, FREE AND POWERFUL

HAVE FUN WITH IT!