SWAHILI

Satellite-based Water Assessment for Holistic Integrated Lake Information

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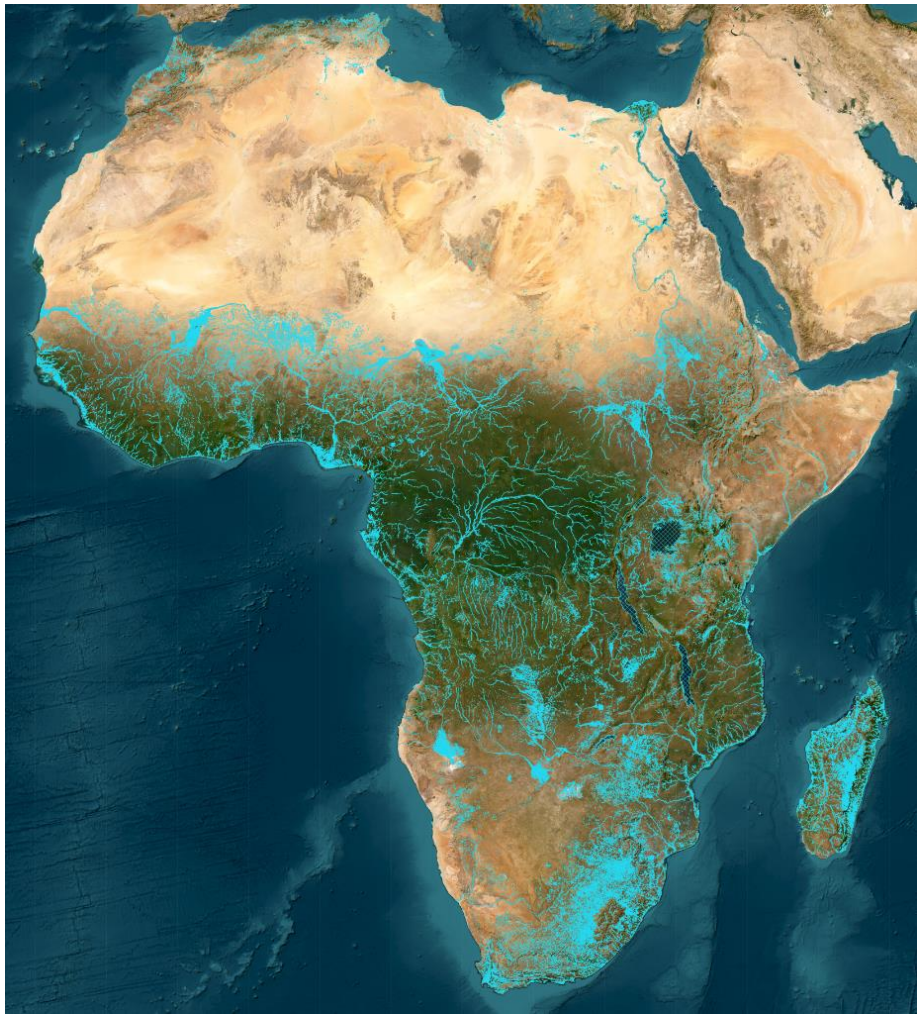
Outline

- Motivation : African Surface Water Systems Under Pressure
- Why SWAHILI?
- Monitoring Water Bodies from Space
- SWAHILI Lake Mapping Workflow
- Field Campaign and Water Quality Measurements
- Water Quality Retrieval from Satellite Data
- Next Steps

Part 1 :Motivation & Introduction to SWAHILI

Shagun Garg

African Surface Water under Increasing Pressure



Africa Waterbodies (Source : Digital Earth)

- Flood & drought buffering
- Pollution
- Encroachment
- Restoration
- Water security
- Climate impacts
- Transboundary systems

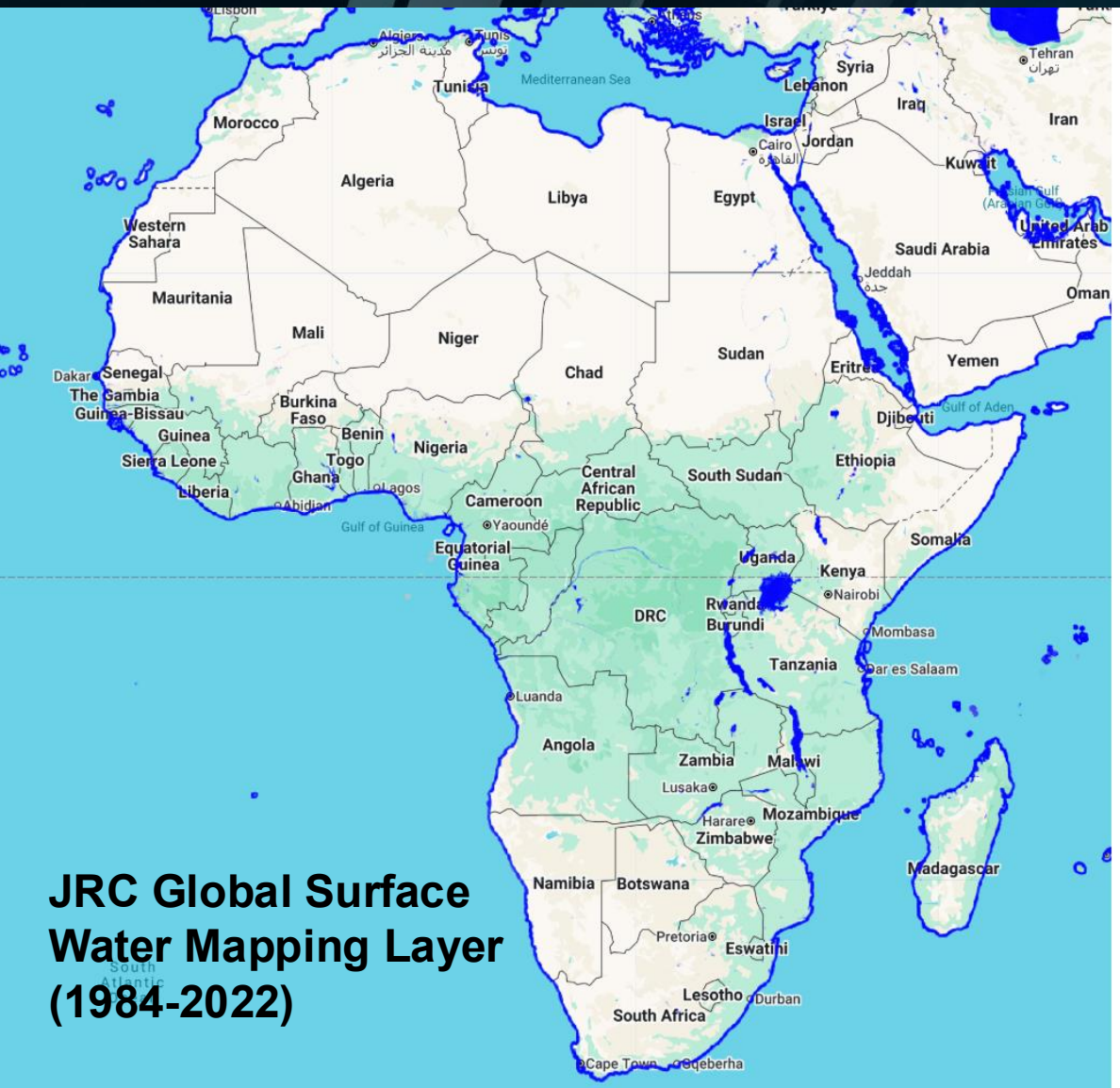
Monitoring African Surface Water : In-situ measurements

Water level Gauge

Total Station

Water Quality Measurement

Satellite-based Surface Water Information

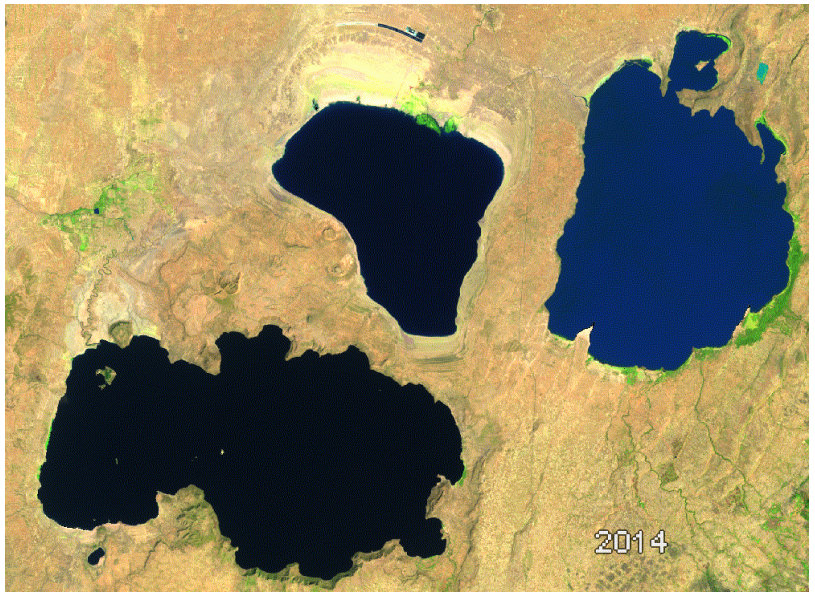


JRC Global Surface Water Mapping Layer (1984-2022)

- Other Surface Water products
  - SARL
  - DW_Water
  - ESA LandCover
  - Global Lakes and Wetlands Database

- Not dynamic (availability until 2022)
- Update frequency (every few years)
- Miss small water bodies (limited resolution
- Only extent

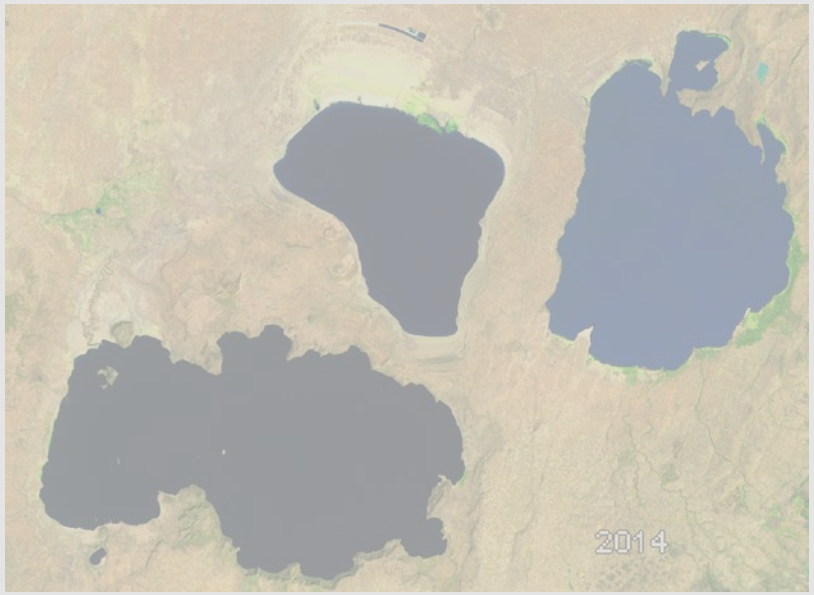
Water Extent



Euthopian lakes : Shalla (left), Abiyata (center), and Langano (right). Source CGIAR and Landsat

Satellite-based Surface Water Information

Water Extent



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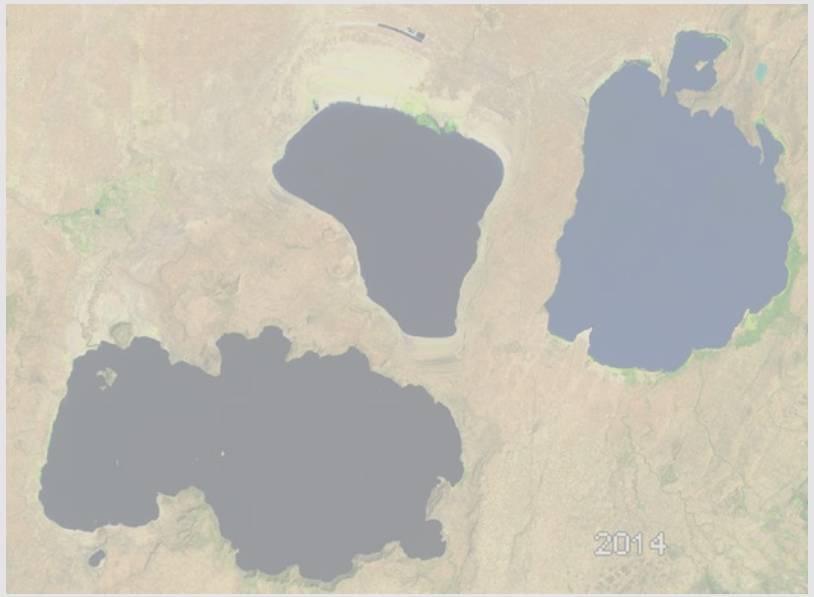
Water Quality

Lake Valencia, Venezuela [August 12, 2022. Source PlanetScope

Satellite-based Surface Water Information

Water Extent

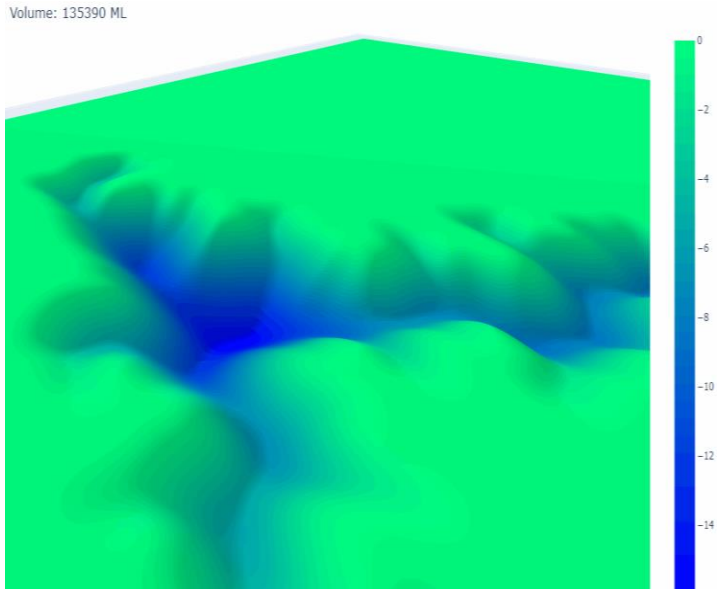


Euthopian lakes : Shalla (left), Abiyata (center), and Langano (right). Source CGIAR and Landsat

Water Quality

Lake Valencia, Venezuela [August 12, 2022. Source PlanetScope

Water Depth



Lake Bhavani Sagar, Tamil Nadu, India, Source Kavyajeet Bora (Medium)

Satellite-based Surface Water Information : SWAHILI

SWAHILI Aims to :

- Fully remote
- Automatic
- Transferable
- Including small lakes
- Water Quality (TSS, Chlorophyll),
- Water depth
- Reliable and accurate
- Sub-monthly frequency
- Any Lake in Africa (and worldwide)

Satellite-based Surface Water Information : SWAHILI

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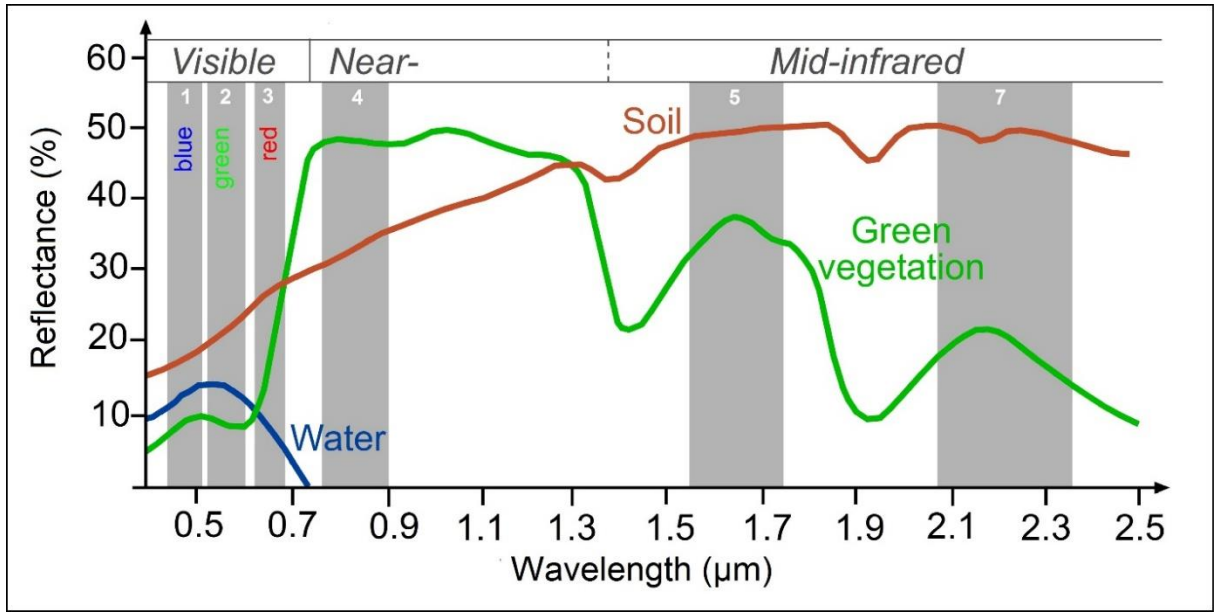
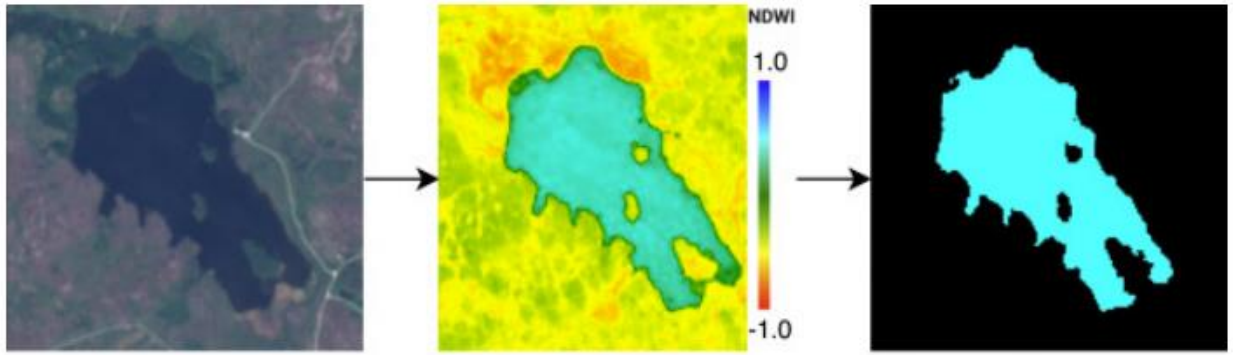
Part 2 :Surface Water Extent

Shagun Garg

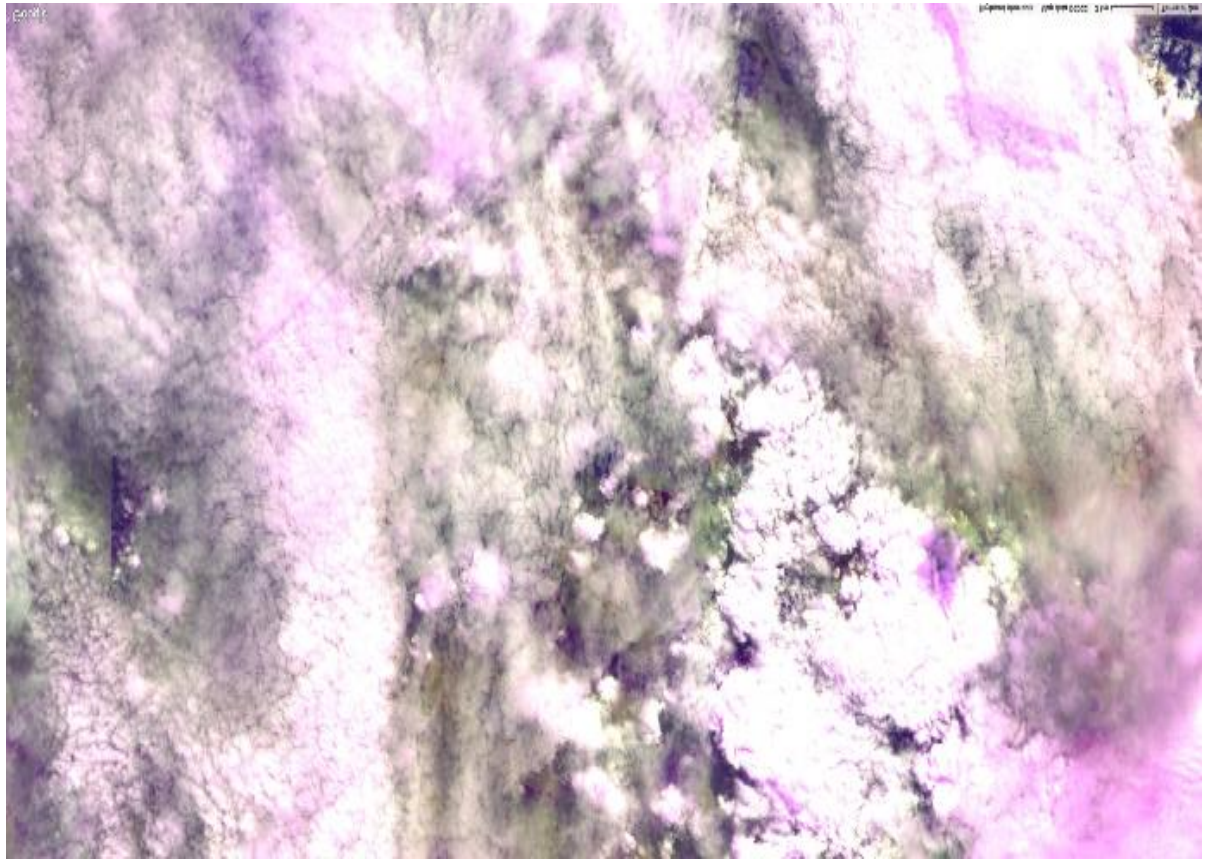
Spectral Signature in Multispectral Satellite Image





Major Challenge in Optical : Clouds

Optical/ Multispectral Image



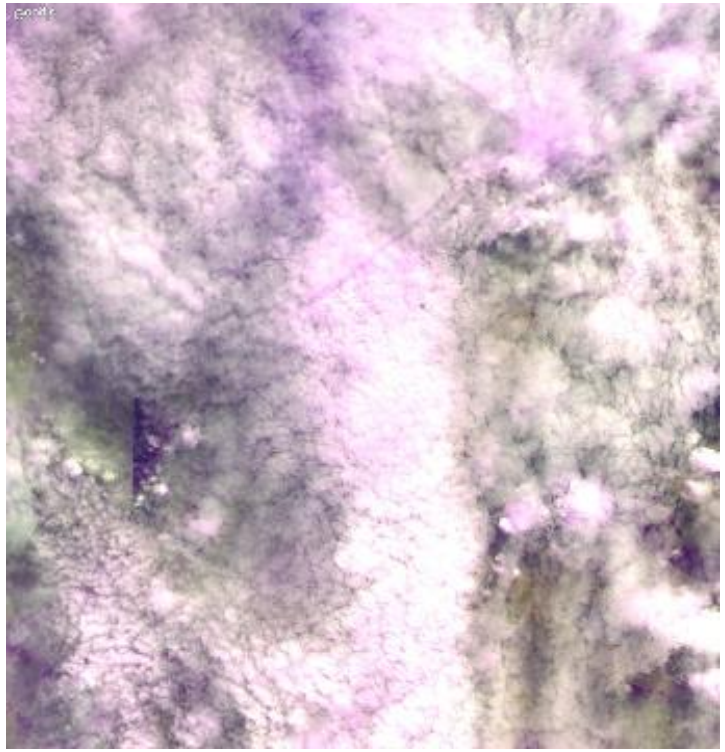
Cloud Problem

RADAR Image for Surface Water Mapping

Optical/ Multispectral Image

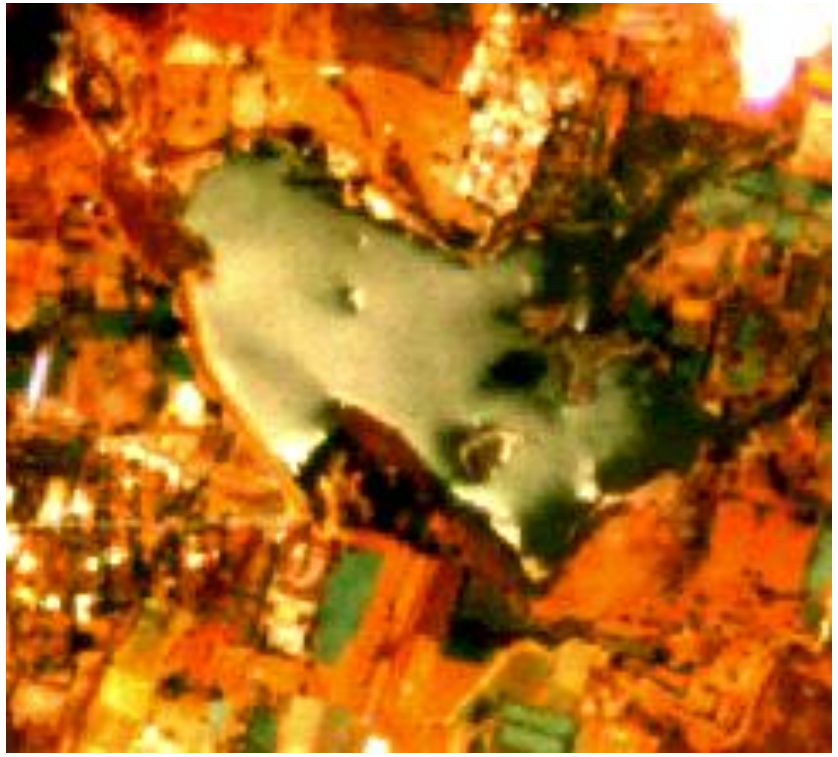
Synthetic Aperture Radar (SAR) Image

Challenges in Surface Water Mapping (Optical)



Cloud Cover

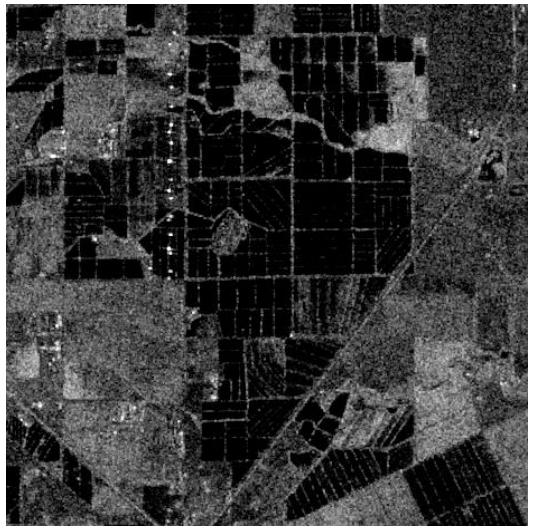
Muddy Water (in Arid regions and flooding)



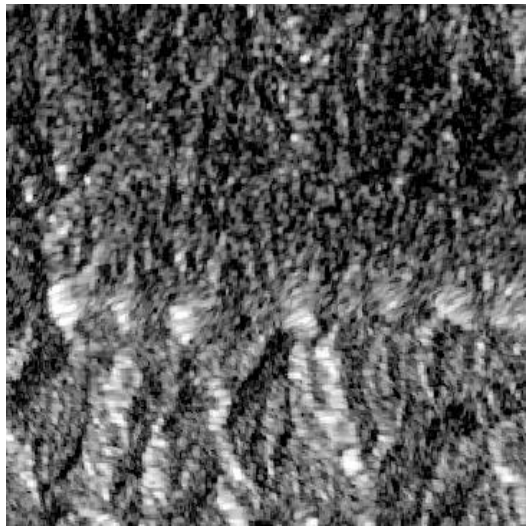
Sun Glint

Challenges in Surface Water Mapping (RADAR)

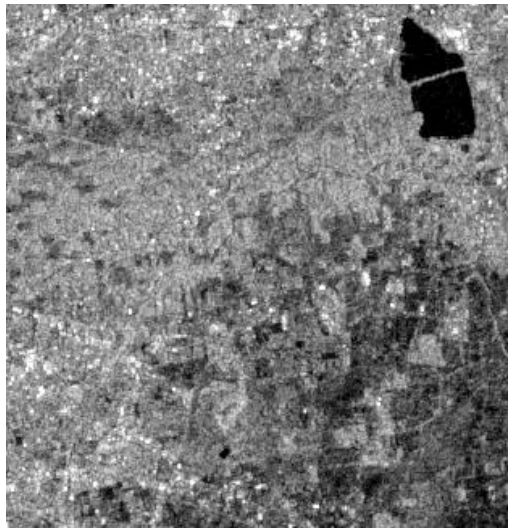
Irrigated Fields



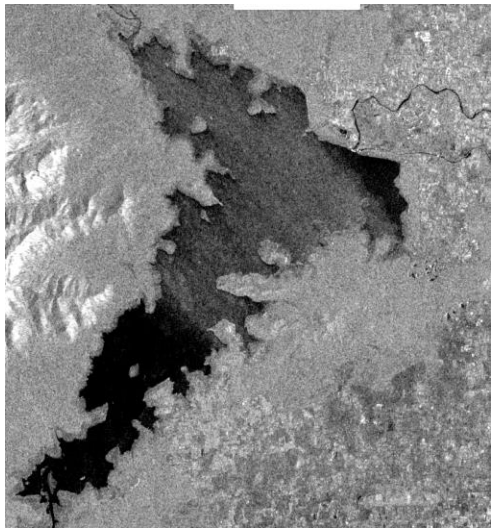
RADAR Shadows

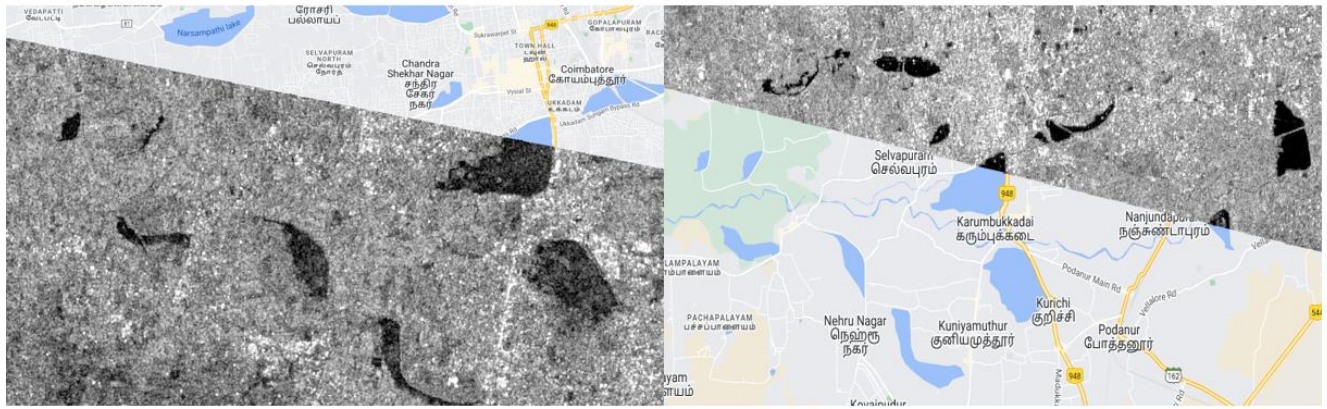


Barren Land



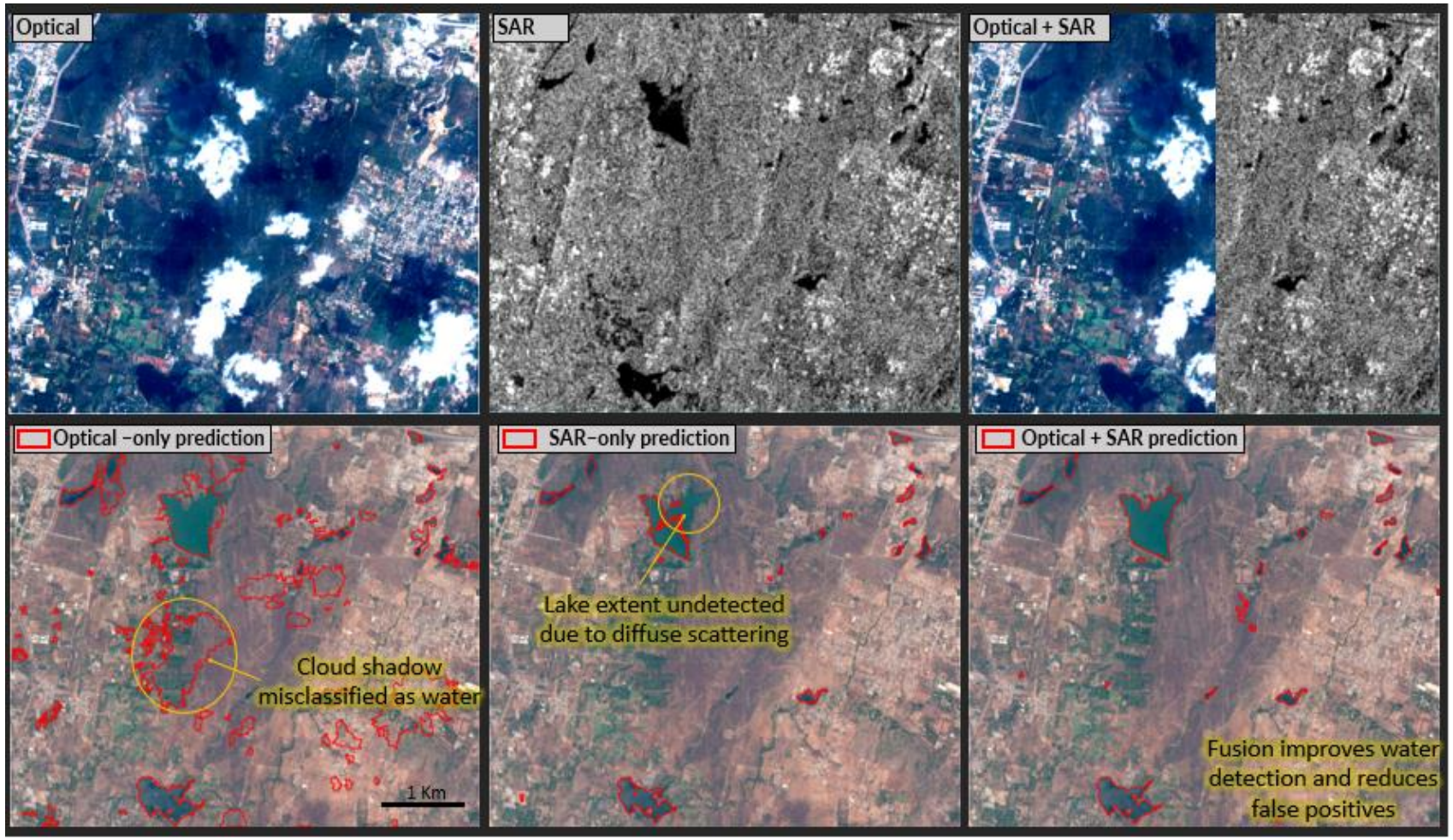
Wind Streaks

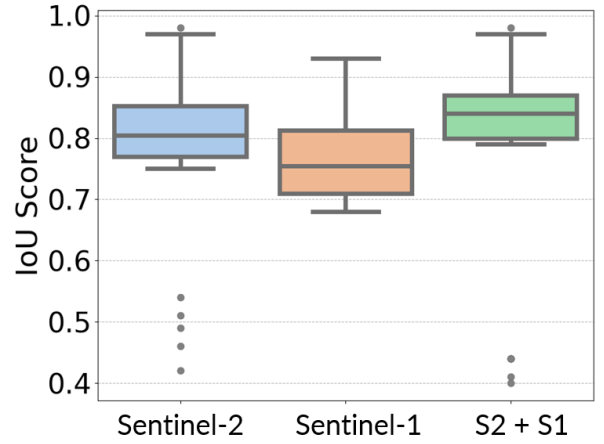


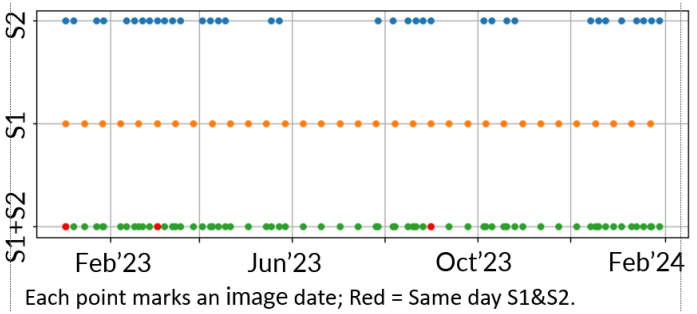


Data Gaps

Does Optical & RADAR fusion improve Surface Mapping ?



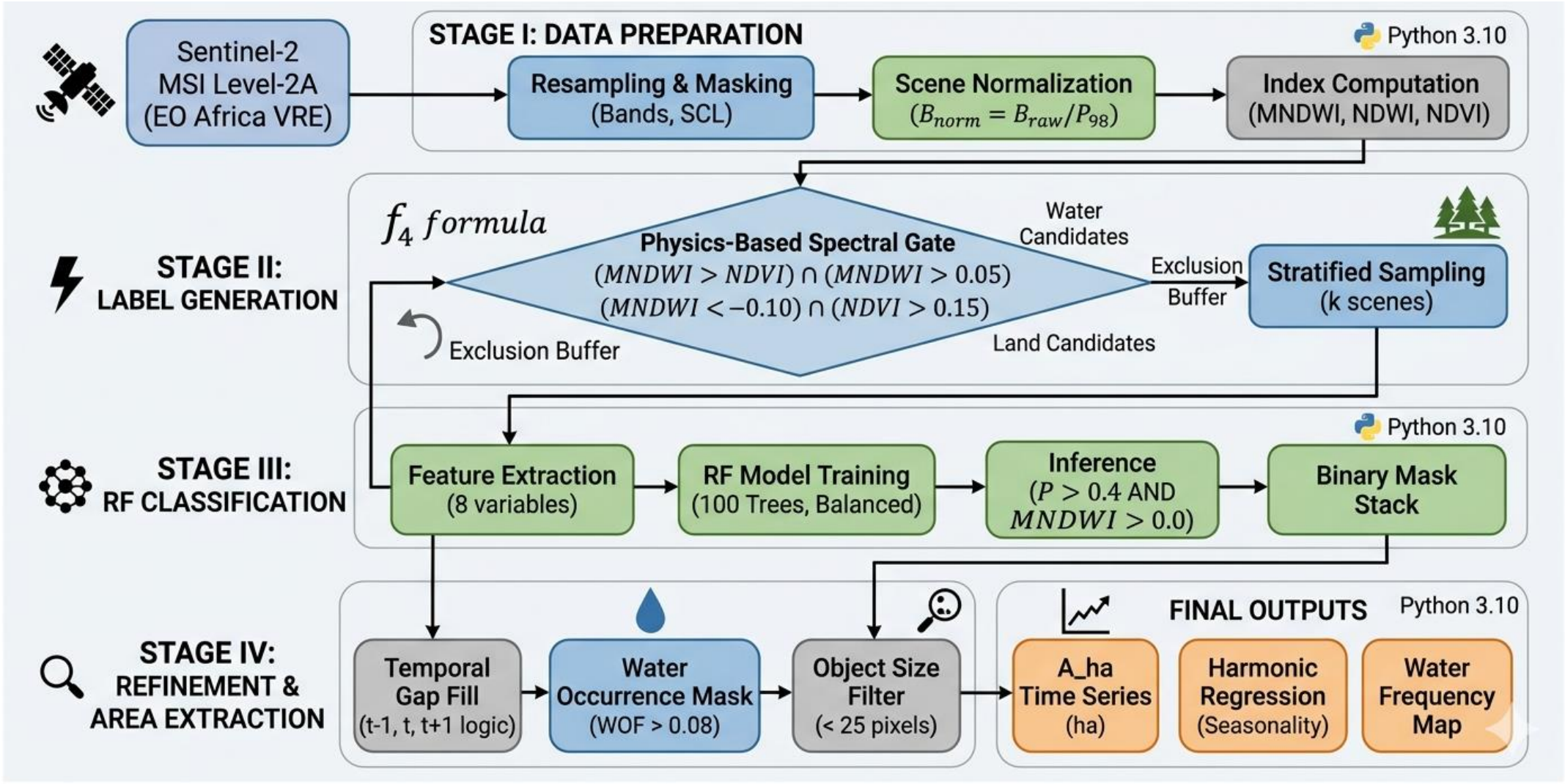




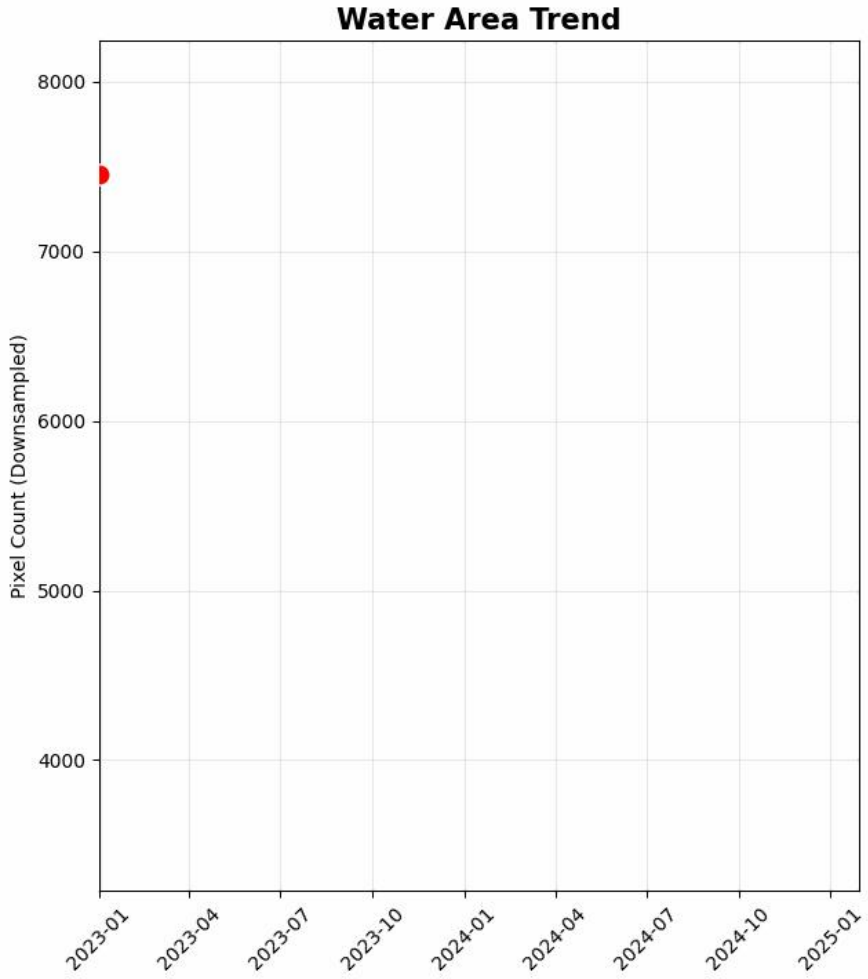
Each point marks an image date; Red = Same day S1&S2.

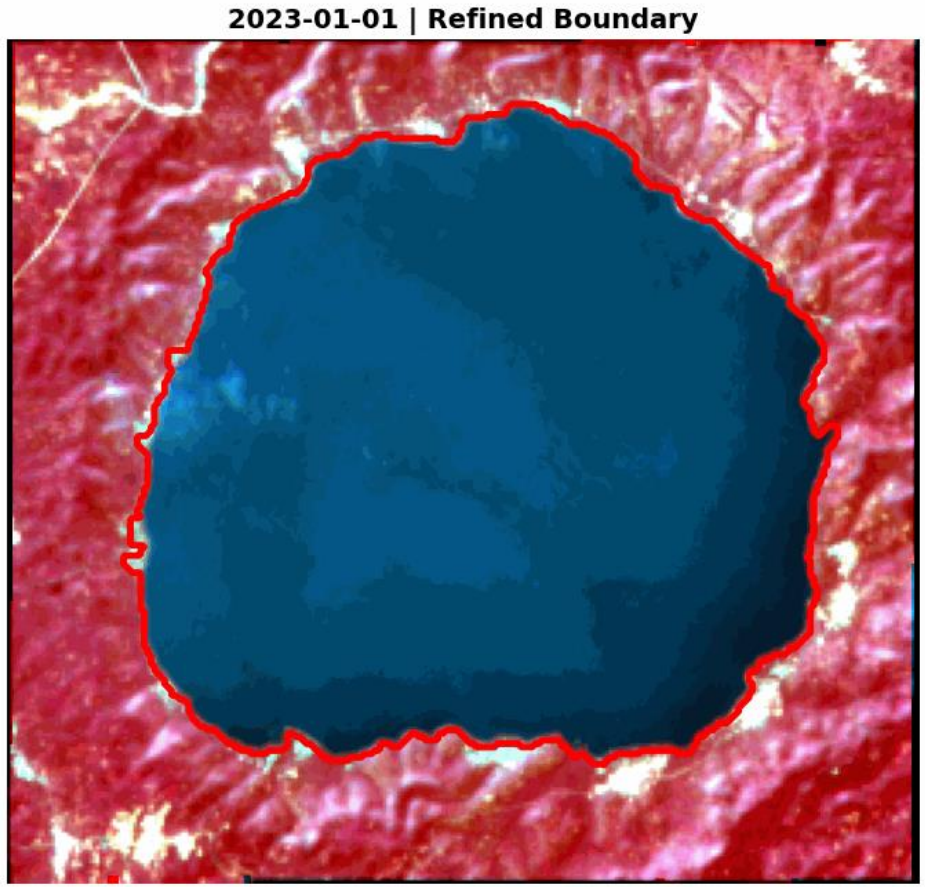
Garg, S., Borgomeo, E., Motagh, M., Selvakumaran, S. (2025): Multi-sensor Integration of SAR and Optical Data for Robust Surface Water Mapping. - Talk presented at the ESA Living Planet Symposium 2025 (Vienna, Austria 2025)

Fully Automatic Multi-temporal Water Surface Monitoring

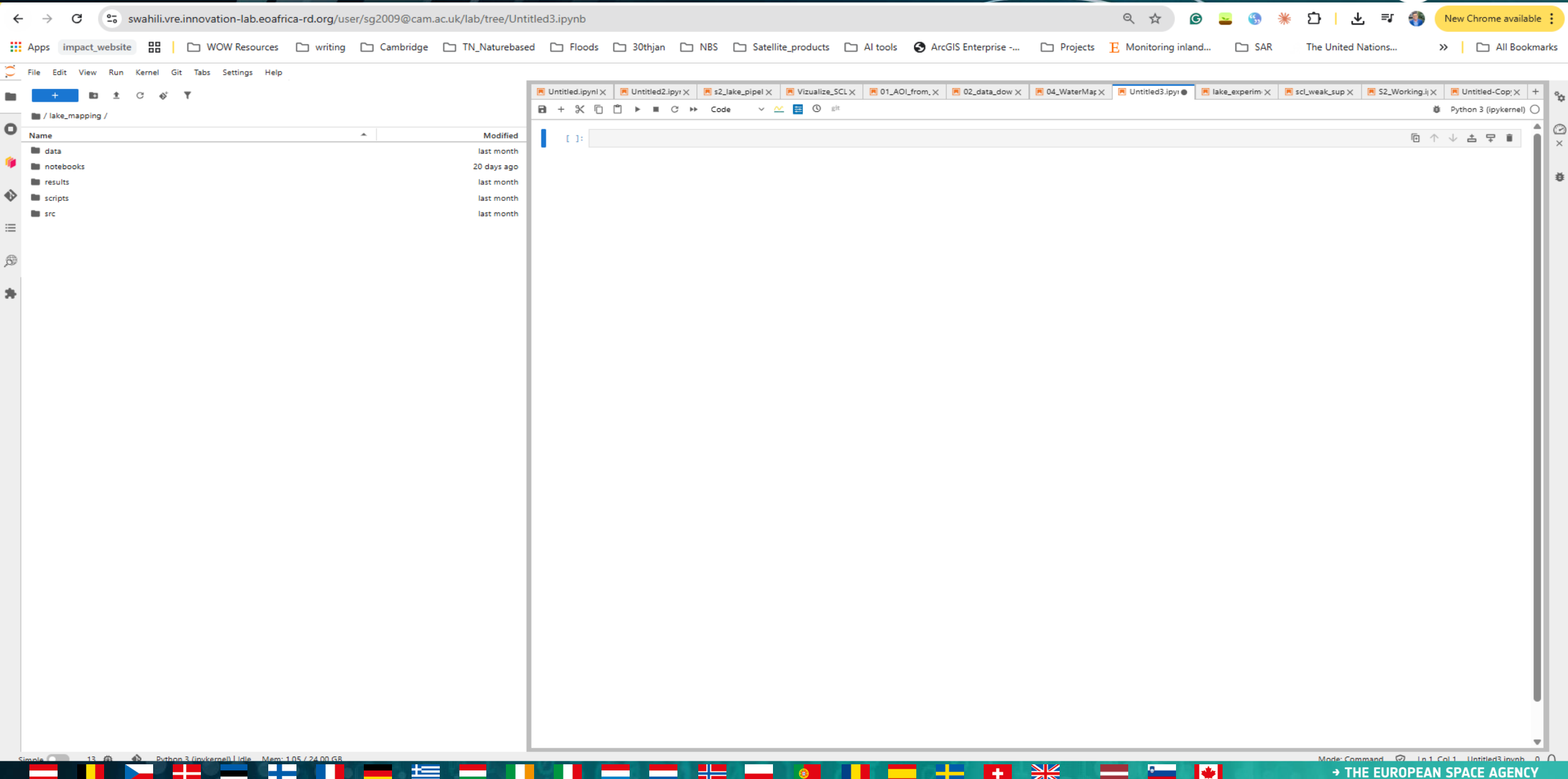


Results : Water Extent End-to-End Pipeline





Python Package : SWAHILI Lake Mapping



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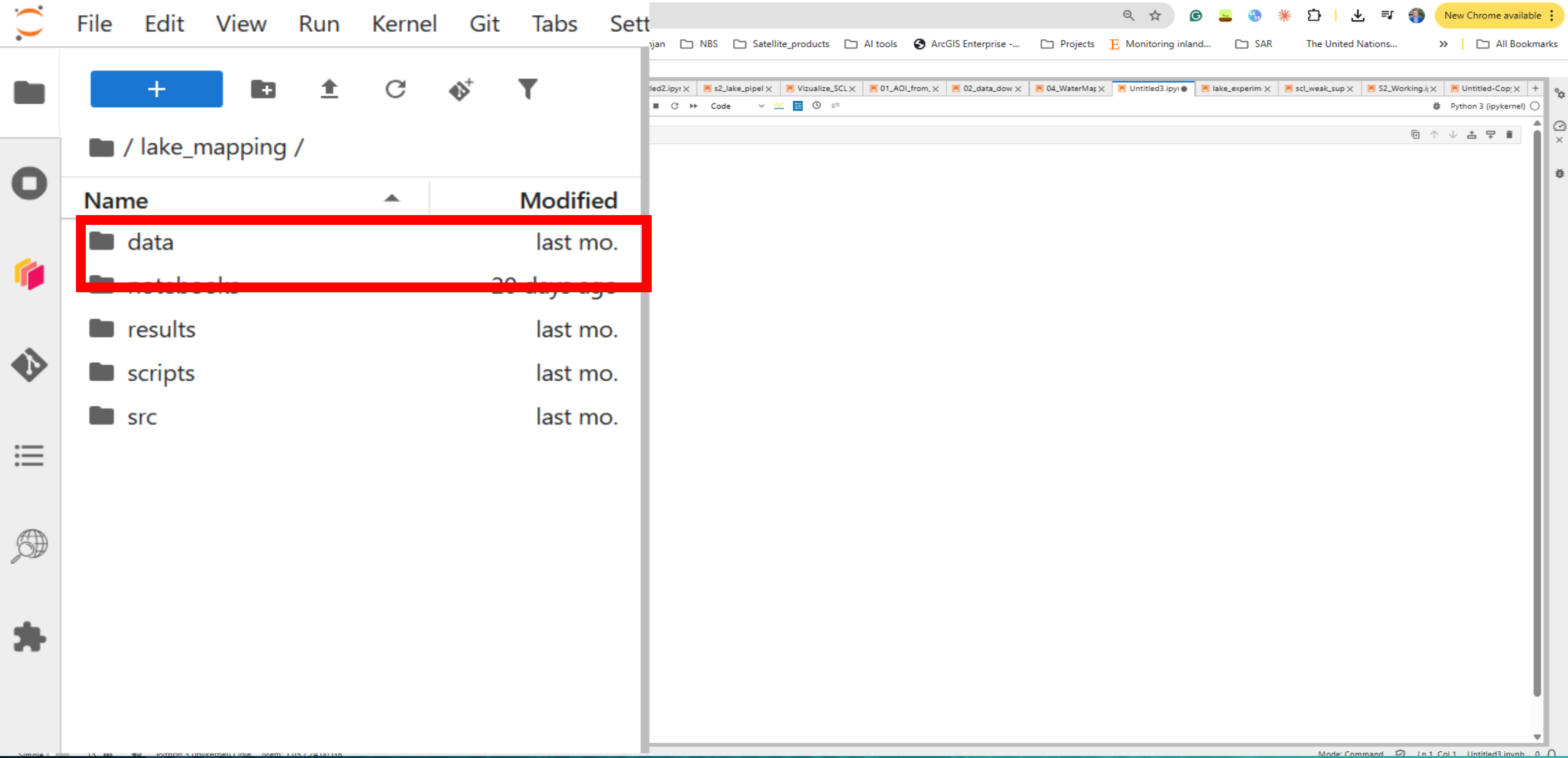


Python Package : SWAHILI Lake Mapping

File Edit View Run Kernel Git Tabs Settings Help

/ lake_mapping / notebooks /

Name	Modified
01_AOI_from_map.ipynb	1 sec. ago
02_data_download.ipynb	last mo
03_viz_data_and_preproce...	last mo.
04_WaterMapper.ipynb	20 days ago
Untitled.ipynb	20 days ago

Untitled.ip | Untitled2.i | s2_lake_pi | Vizualize_S | 01_AOI_frc | 02_data_d | 04_WaterM | Untitled3.i | lake_exper | scl_weak_s | S2_Workin | Untitled-C

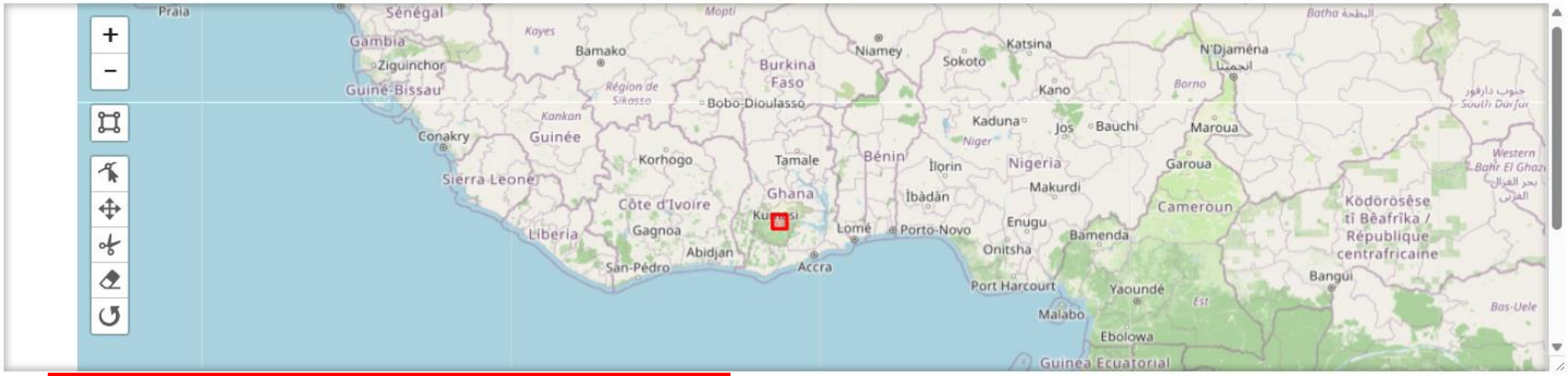
Markdown | Python 3 (ipykernel)

Downloading the Data

AOI using an interactive map

[1]:
```
import sys
import ipywidgets as widgets
widgets.IntSlider()
sys.path.insert(0, '/home/eoafrica/lake_mapping/src/')  # adjust if needed
```

[2]:
```
from lake_mapping.aoi import get_aoi_from_map
state = get_aoi_from_map(center=(28.6, 77.2), zoom=5)
```

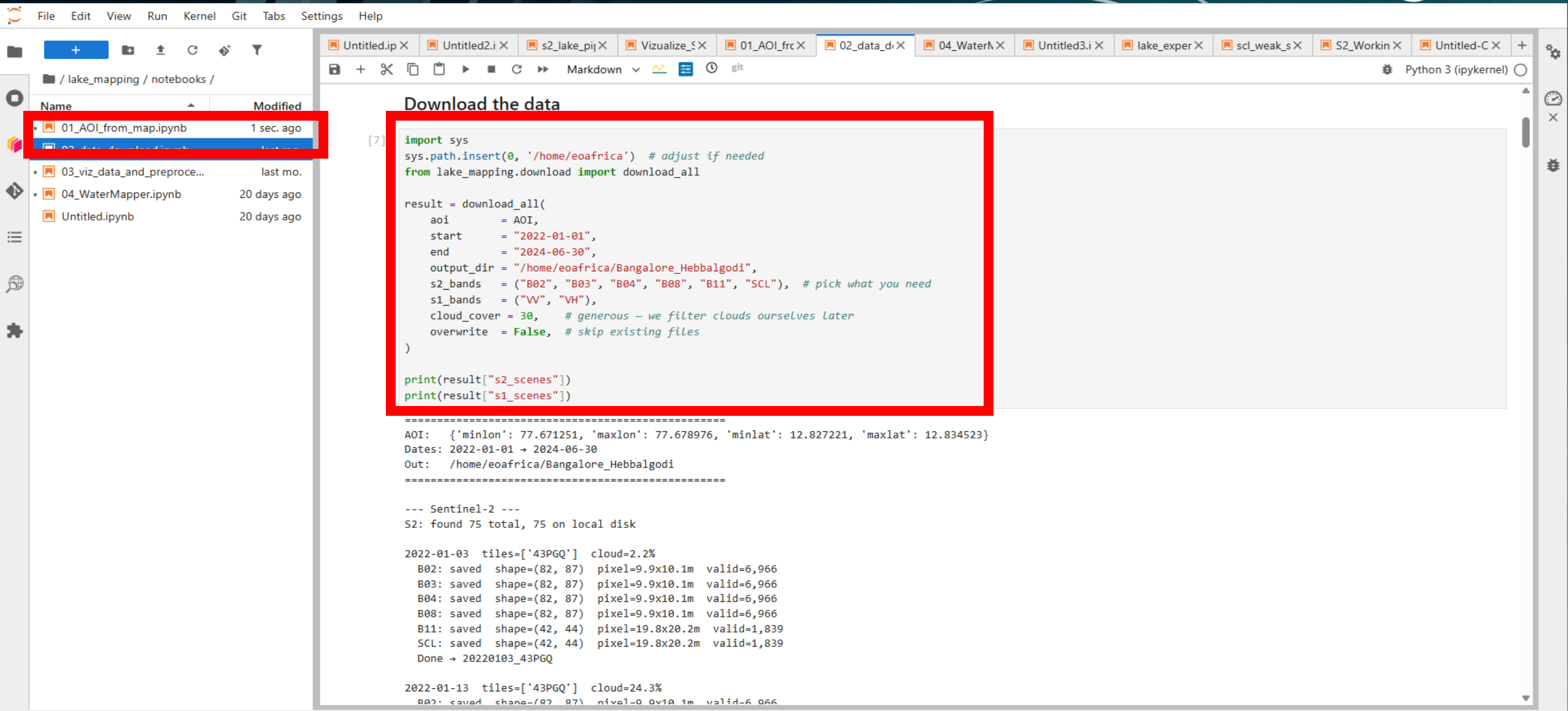


[22]:
```
AOI = state["bounds"]
print(AOI)
```

```
{'bounds': [50.537334, 28.071677, 56.029639, 30.90193], 'aoi': None}
[50.537334, 28.071677, 56.029639, 30.90193]
```

Simple 13 Python 3 (ipykernel) | Idle Mem: 1.07 / 24.00 GB Mode: Command Ln 1, Col 1 01_AOI_from_map.ipynb 0

Python Package : SWAHILI Lake Mapping



Python Package : SWAHILI Lake Mapping

File Edit View Run Kernel Git Tabs Settings Help

/ lake_mapping / notebooks /

Name	Modified
01_AOI_from_map.ipynb	1 sec. ago
02_data_download.ipynb	last mo.
03_viz_data_and_preproce...	last mo.
04_WaterMapper.ipynb	20 days ago
Untitled.ipynb	20 days ago

Untitled.i | Untitled2 | s2_lake_p | Vizualize | 01_AOI_f | 02_data_ | 03_viz_da | 04_Water | Untitled3 | lake_expe | scl_weak | S2_Worki | Untitled-

Code | git | Python 3 (ipykernel)

[1]:
```
import sys
import ipywidgets as widgets
widgets.IntSlider()
sys.path.insert(0, '/home/eoafrica/lake_mapping/src/')  # adjust if needed
```

[2]:
```
from lake_mapping.water_processor import WaterMapper
import matplotlib.pyplot as plt
```

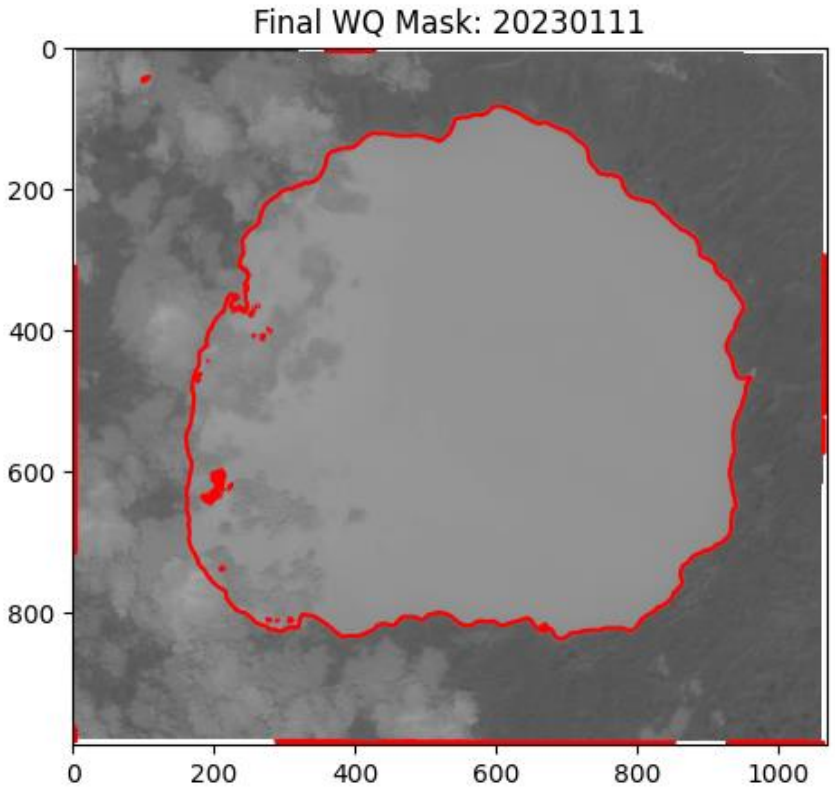
[3]:
```
# 1. Initialize Module
mapper = WaterMapper(
    region_name="/home/eoafrica/Ghana/",
    s2_dir="/home/eoafrica/Ghana/S2",
    output_dir="/home/eoafrica/Ghana/outputs_check"
)
```

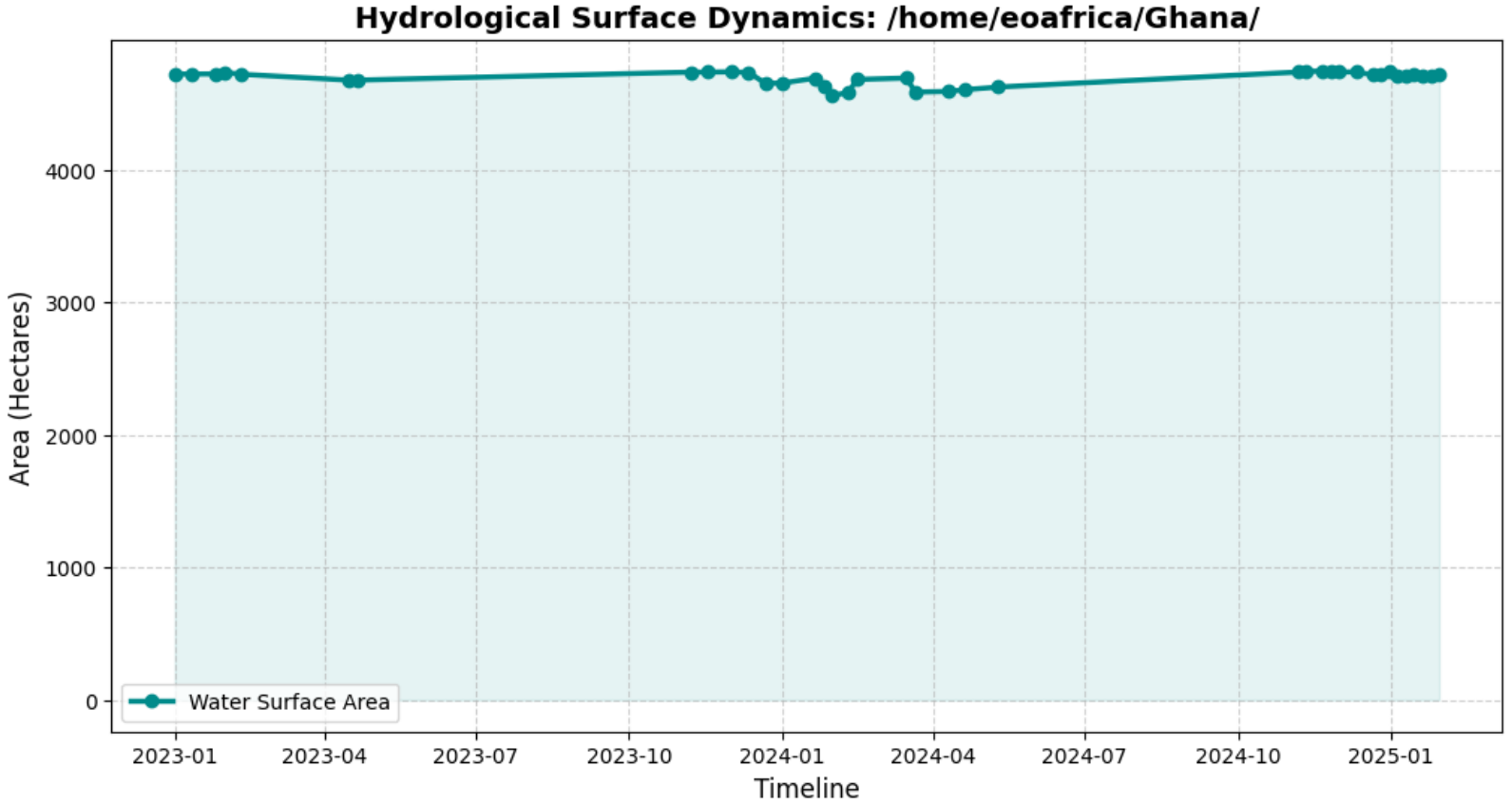
[4]:
```
# 2. Run the Workflow
mapper.train_master_rf(sampling_rate=12)
mapper.run_temporal_stack(prob_thresh=0.4, mndwi_thresh=0.0)
mapper.apply_temporal_filter(occurrence_thresh=0.08)

# 3. Analyze a specific date
sample_idx = 1
final_mask = mapper.get_final_mask(sample_idx)
meta = mapper.meta_list[sample_idx]

# 4. Quick Viz
plt.figure(figsize=(10,5))
plt.imshow(meta['mndwi'], cmap='gray')
plt.contour(final_mask, colors='red', levels=[0.5])
plt.title(f"Final WQ Mask: {meta['date']}")
plt.show()
```

```
--- Training Master RF for /home/eoafrica/Ghana/ ---
Master RF Trained Successfully.
--- Building Temporal Stack ---
Initializing Master Shape...
```

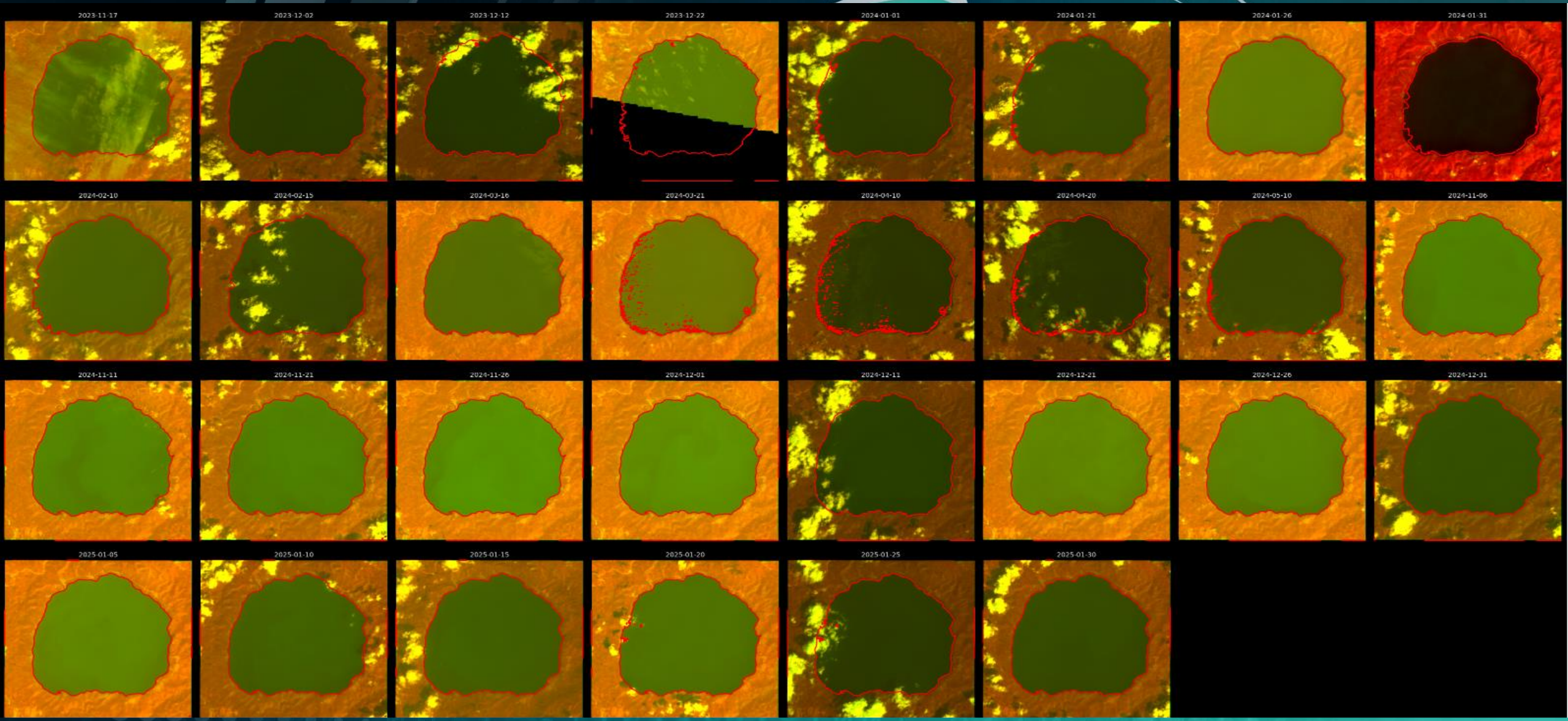
Simple 13 Python 3 (ipykernel) | Idle Mem: 1.78 / 24.00 GB Mode: Command Ln 1, Col 1 04_WaterMapper.ipynb 0

Dynamic Water Extent (Automatic)





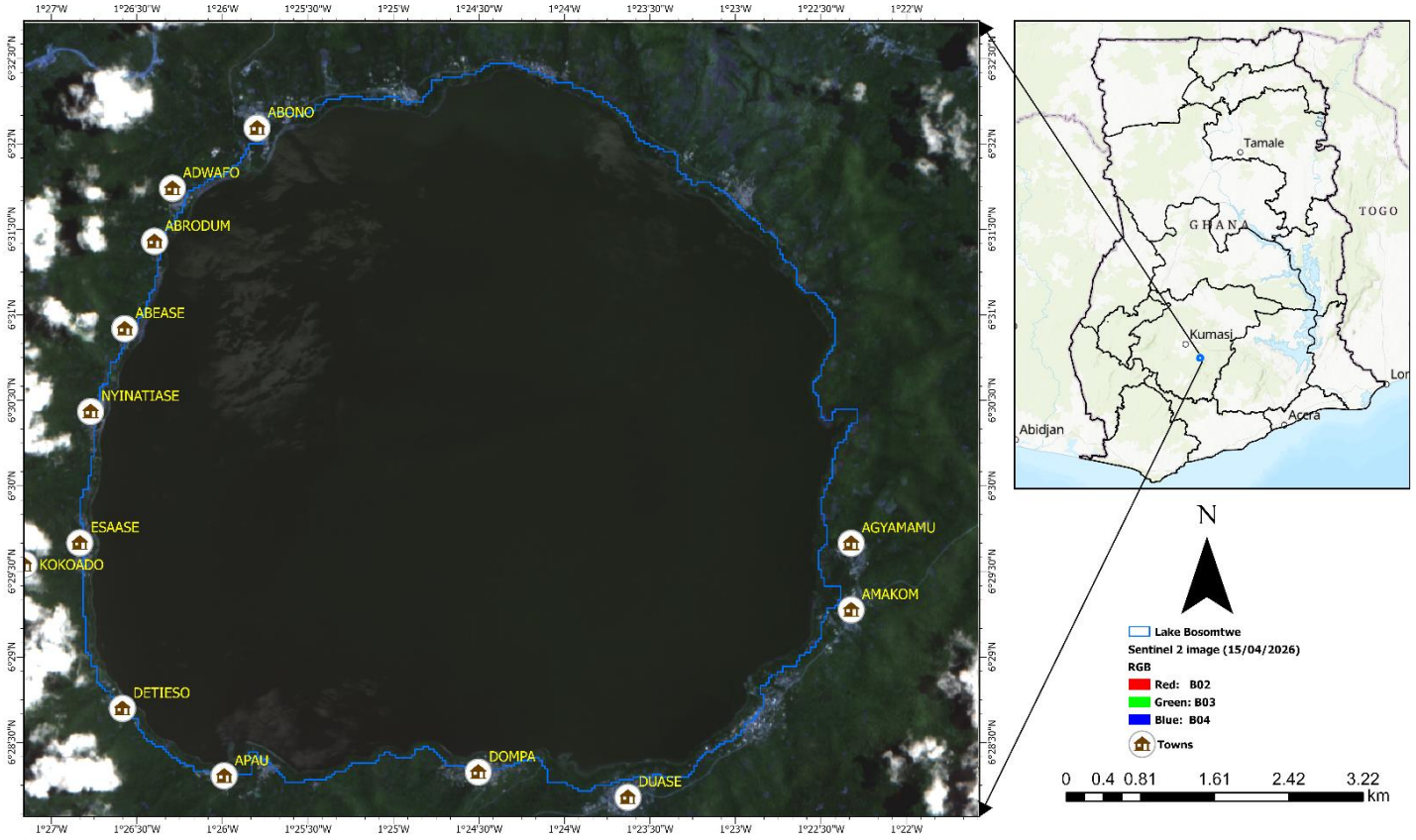
Reliability and Visual Assessment



Part 3 : Water Quality (Field and in-situ collection)

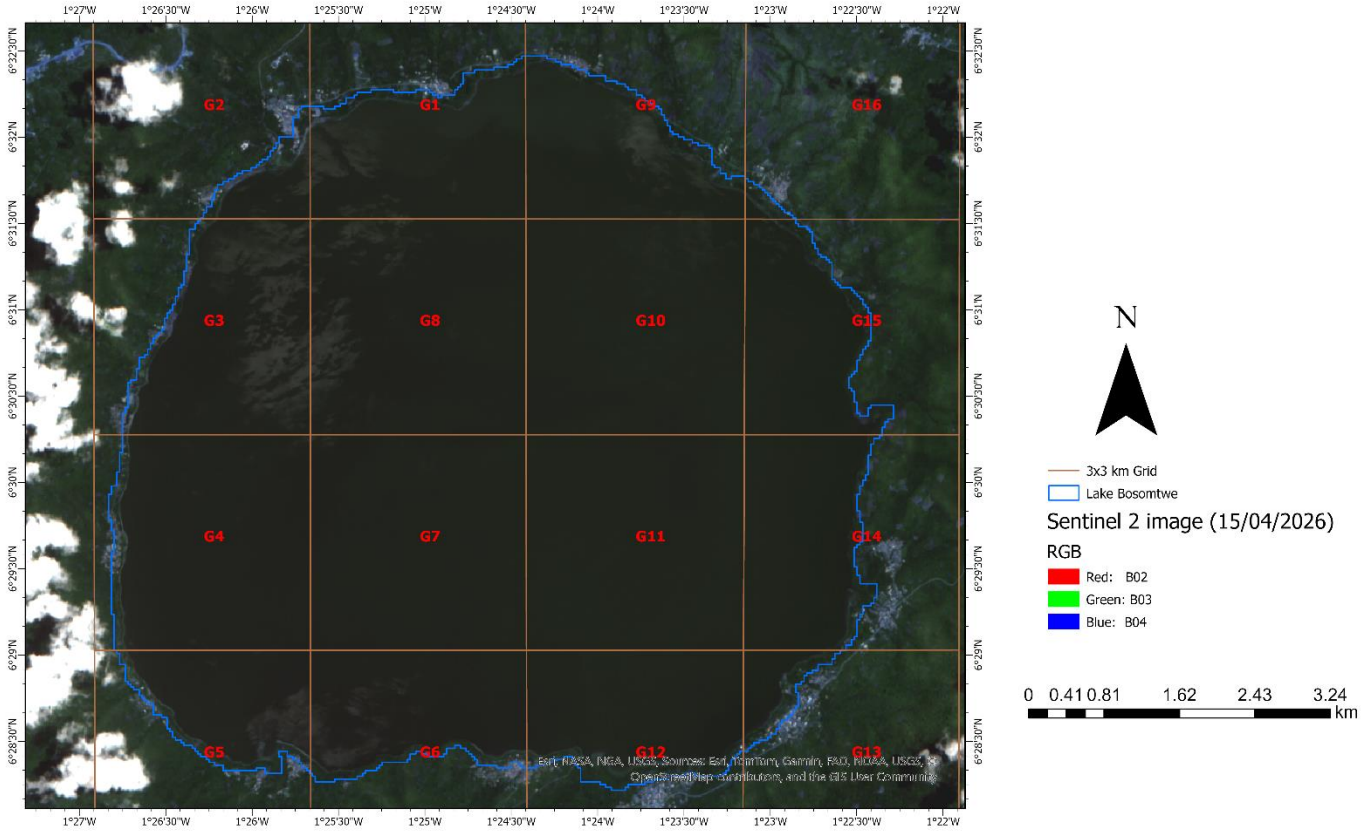
Ebenezer Saibi

Study Area : Lake Bosomtwe



- The lake Bosomtwe is geographically located in the Ashanti Region in the south-central part of Ghana (Sanful et al., 2017)
- Lies within the semi-deciduous forest ecological zone of West Africa (Hall and Swaine, 1981)
- It is the only naturally occurring lake in sub-Saharan West Africa
- The lake is within a one-million-year-old meteorite impact crater (Koeberl et al., 1997)
- Inputs of water are from rainfall falling directly on the lake surface area (80%) and watershed run-off
- while water losses are mainly due to evapotranspiration (Turner et al., 1996).

Workflow

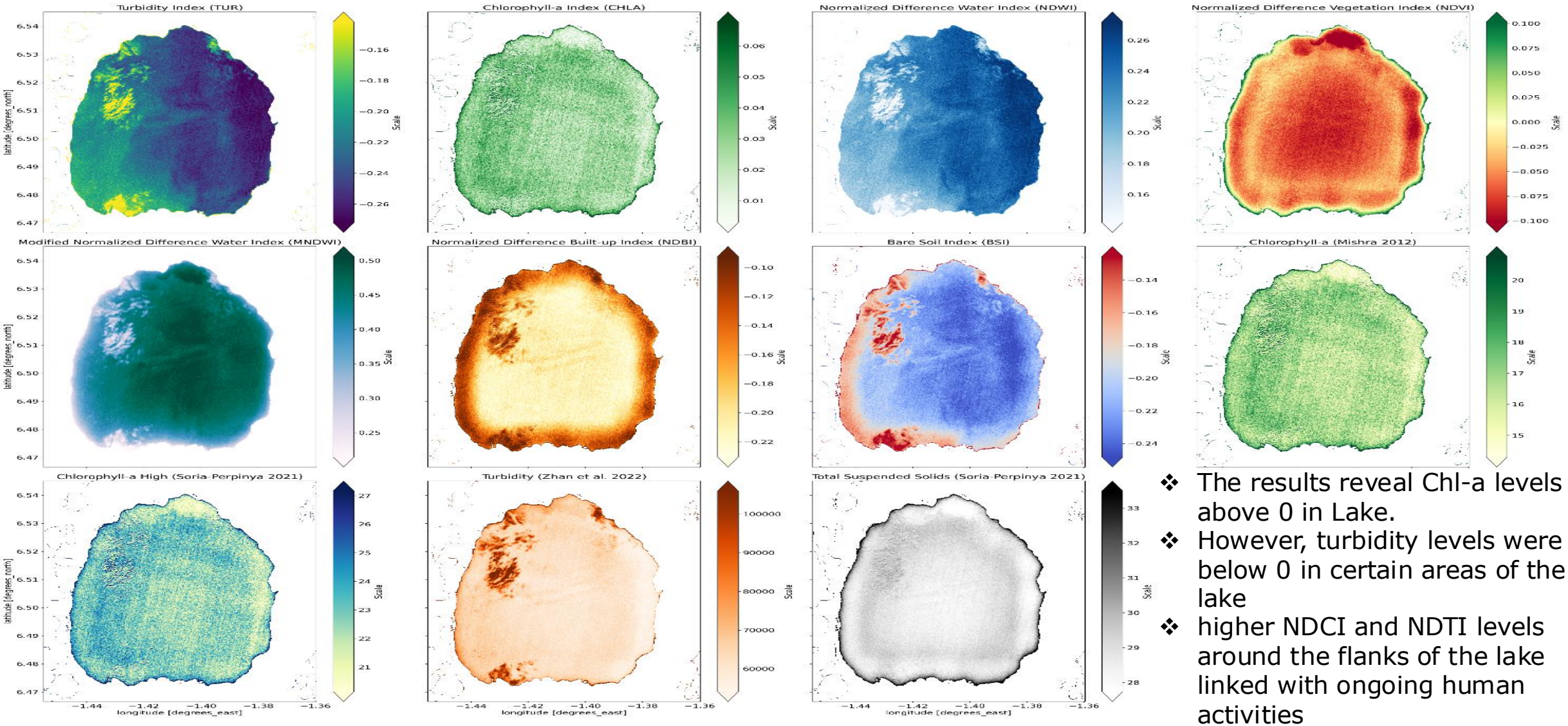


- Satellite data acquisition based on satellite overpass
- Data preprocessing and quality assurance (e.g. cloud contaminated sample points)
- Data sources (Insitu and satellite derived indices @ overpass)
- Empirical algorithm development (Water leaving reflectance, Turbidiy (NDTI), Chlorophyll-a (NDCI), TSS)
- Comparison with in-situ and other methods such as NDCI by Mishra 2012 and Soria-Perpinya 2021; NDTI by Zhan et al. 2022 and TSS by Soria-Perpinya 2021
- Human activities impact (BSI, NDBI, NDVI)
- Impact assessment

Field Data Collection

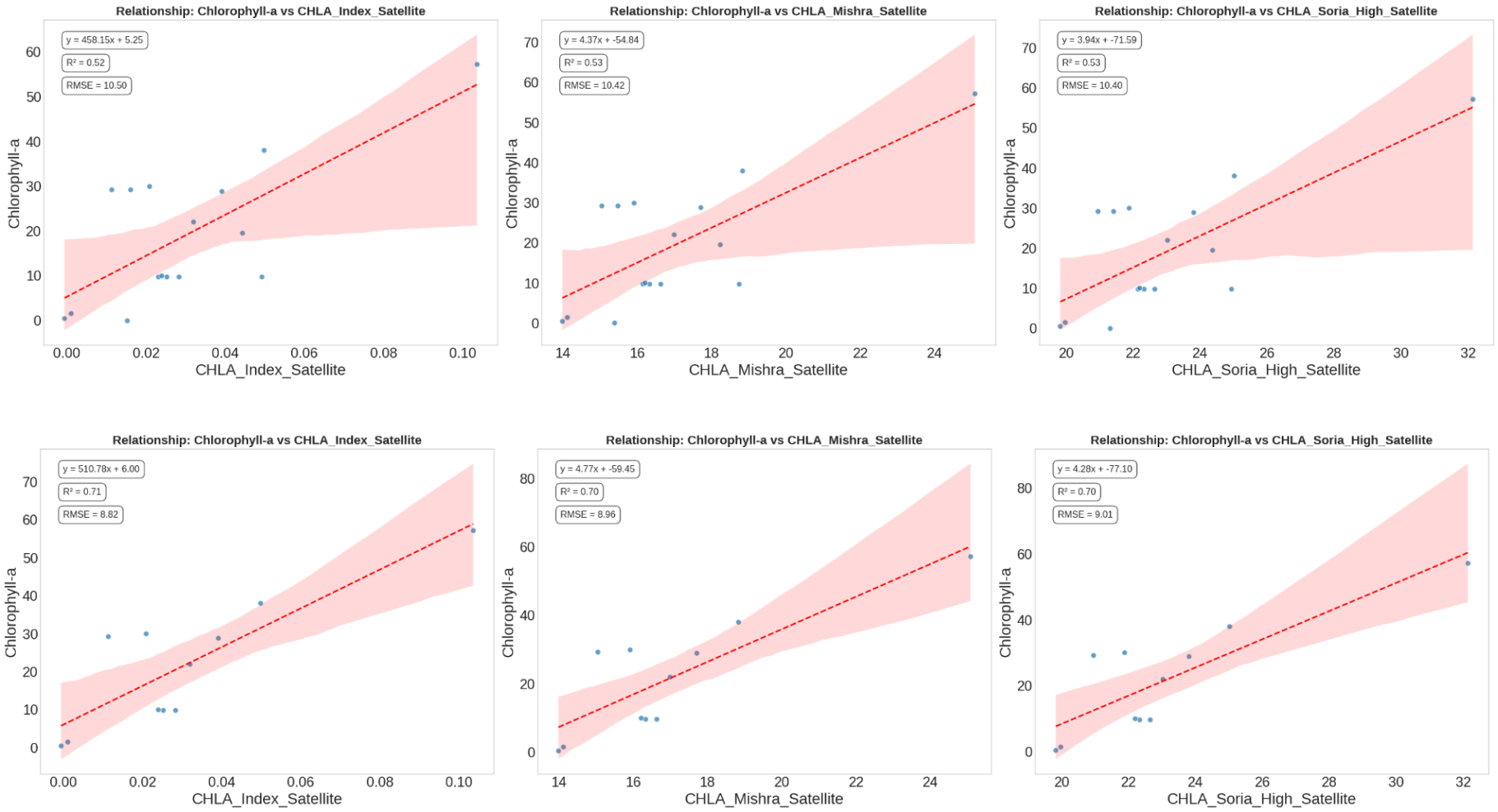
Images from Fieldwork

Results -Water Quality Assessment from EO Data



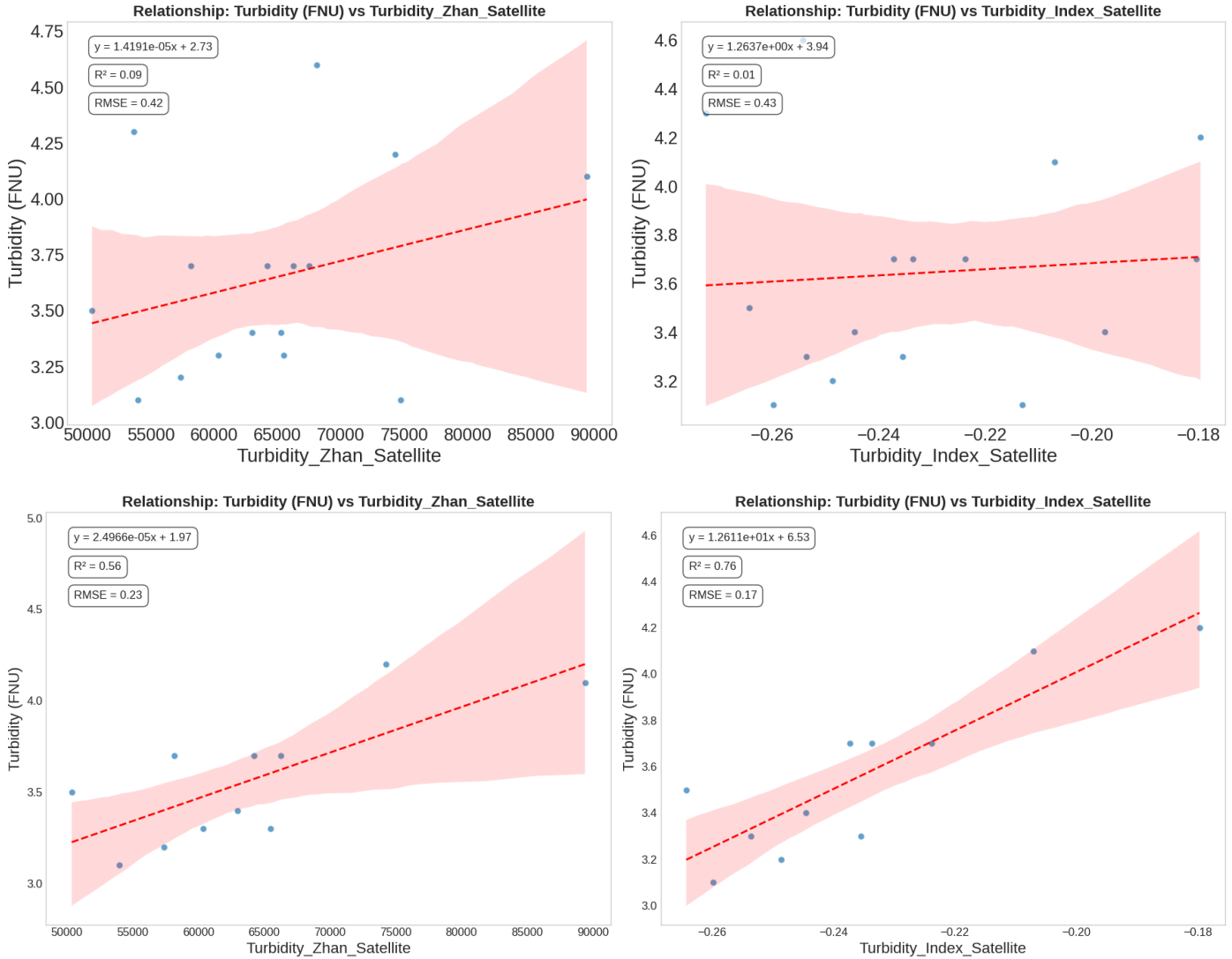
- The results reveal Chl-a levels above 0 in Lake.
- However, turbidity levels were below 0 in certain areas of the lake
- higher NDCI and NDTI levels around the flanks of the lake linked with ongoing human activities

Results -Regression Analysis (In-Situ Data and EO Estimates)



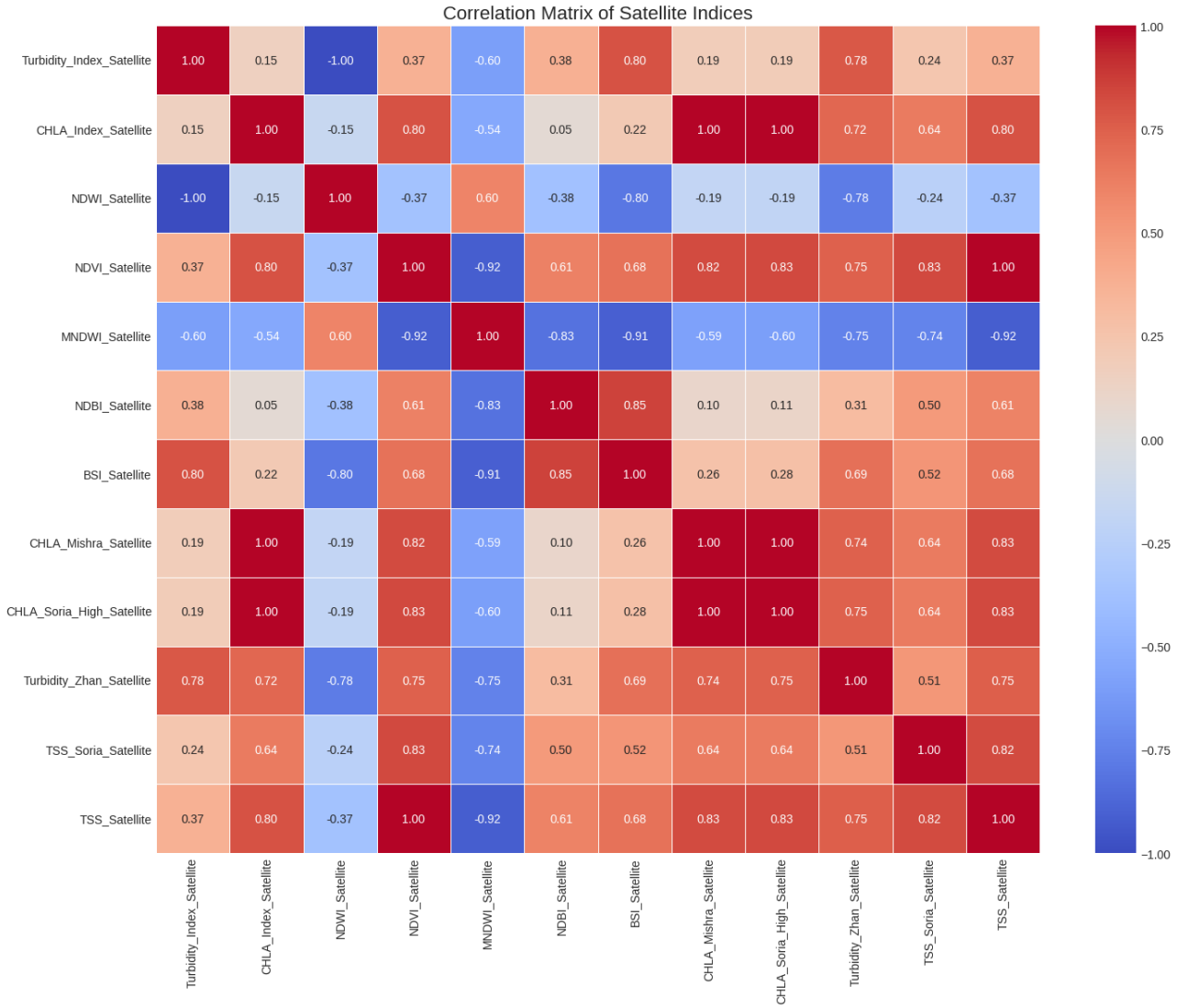
- Regression analysis of Chl-a before (Top figure) and after (Bottom figure) removing cloud contaminated samples
- The regression model revealed R^2 of 52 %, 53% and 53% for in-situ data and NDCI (Chl-a index), Chl-a by Mishra 2012 and Soria-Perpinya 2021 respectively before removing cloud sample points
- The regression model revealed R^2 of 71%, 70% and 70% for in-situ data and NDCI (Chl-a index), Chl-a by Mishra (2012) and Soria-Perpinya (2021) respectively
- Performance of the model improved after removing cloud samples.

Results -Regression Analysis (In-Situ Data and EO Estimates)



- Regression analysis of turbidity before (Top figure) and after (Bottom figure) removing cloud contaminated samples
- The regression model revealed R^2 of 9 % and 1% for in-situ data and turbidity by by Zhan et al. 2022 and NDTI (Turbidity index) respectively before removing cloud sample points
- The regression model revealed R^2 of 56% and 76% for in-situ data and turbidity by Zhan et al. 2022 and NDCI (Chl-a index) respectively

Results -Regression Analysis (In-Situ Data and EO Estimates)



- The correlation analysis as showed strong relationship between BSI
- and NDTI as well as NDBI with Pearson's Correlation coefficient (r) of 0.80 and 0.85 respectively.

- Indicating that increase in BSI will lead to increase in NDTI and NDBI

References

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