Remote sensing-based Water Hyacinth monitoring using the novel Aquatic Macrophyte Index (AMI)

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Shades of water

Figure 1. The diversity of watercolors (Stevens et al. 2022).

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1. Remote Sensing sensor options

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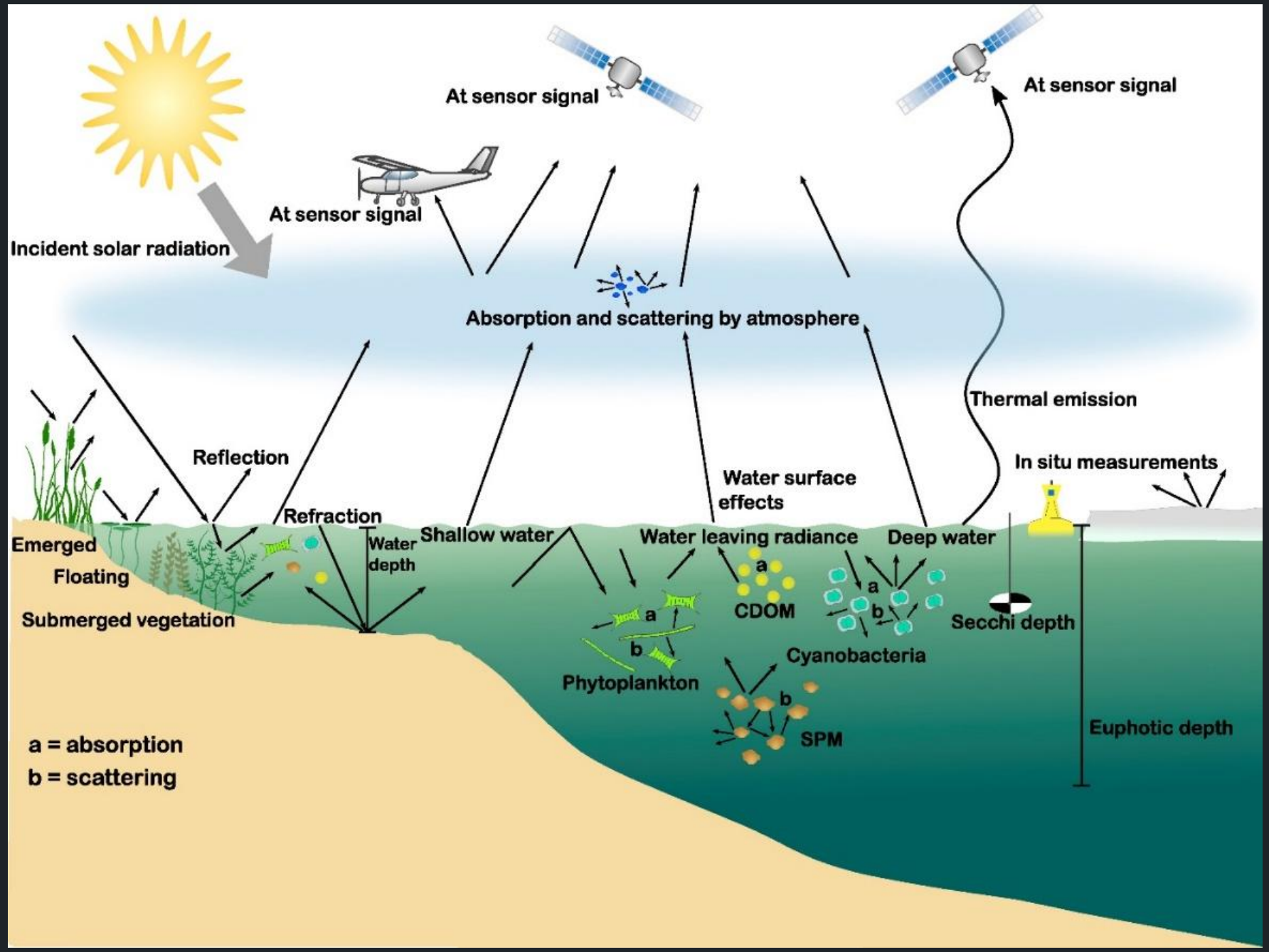

Figure 2. Absorption and scattering processes in the atmosphere and hydrosphere (Dörnhöfer & Oppelt, 2016).

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Active Remote Sensing

- Radar (Backscatter)

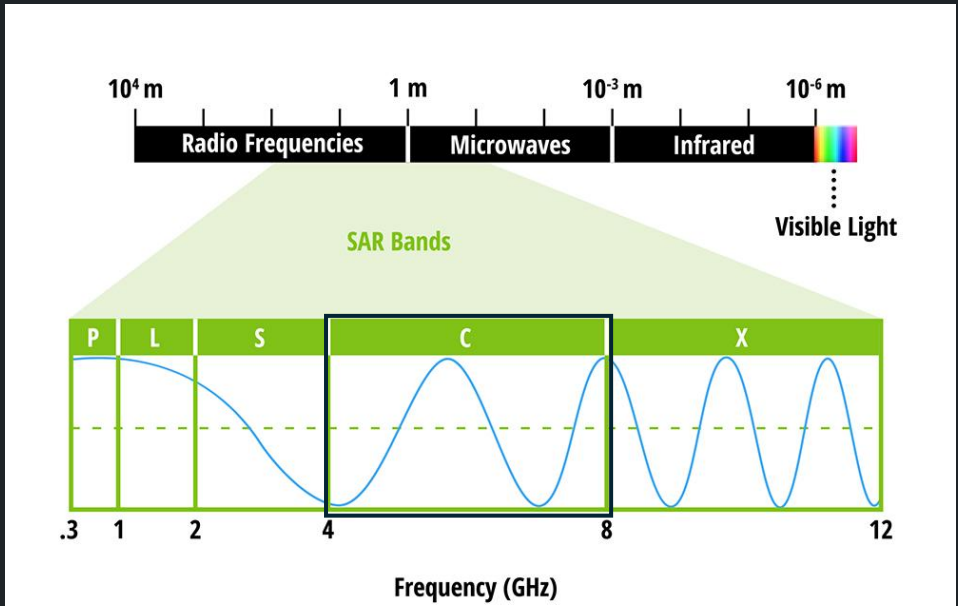

Figure 3. Sentinel-1 C-SAR band on the electromagnetic spectrum (NASA 2024).

Passive Remote Sensing

- Multispectral
  Visible & Infrared (Reflectance)
  in 12 spectral bands

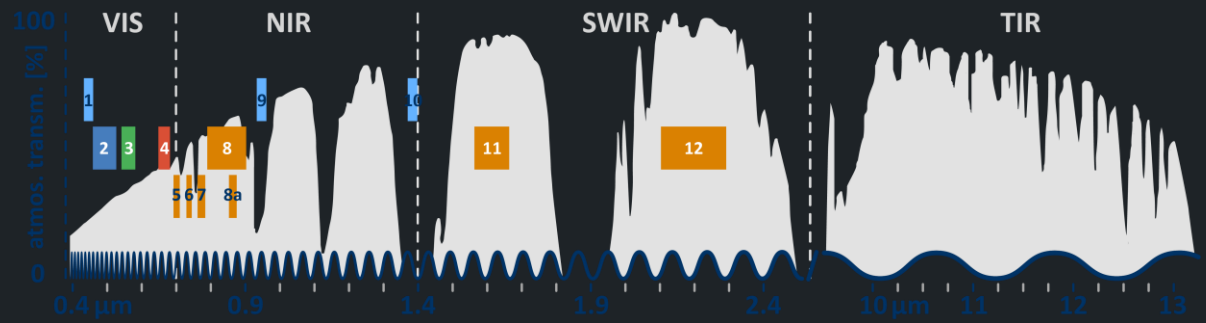

Figure 4. Sentinel-2 MSI bands on the electromagnetic spectrum (FU Berlin 2024).

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Passive Remote Sensing

- Hyperspectral
  Visible & Infrared (Reflectance)
  in 246 spectral bands
  VNIR: 8.1 +/- 1 nm
  SWIR: 12.5 +/- 1.5 nm

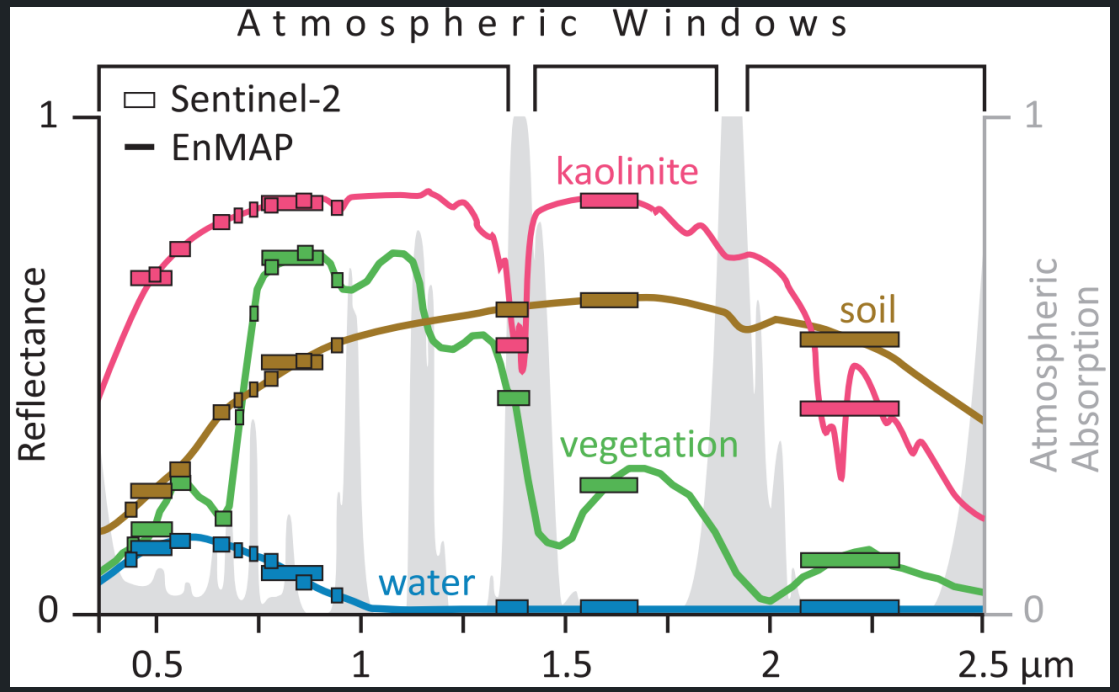

Figure 5. Sentinel-2 MSI & EnMAP bands on the electromagnetic spectrum (DLR et al. 2022).

Passive Remote Sensing

- Multispectral
  Visible & Infrared (Reflectance)
  in 12 spectral bands

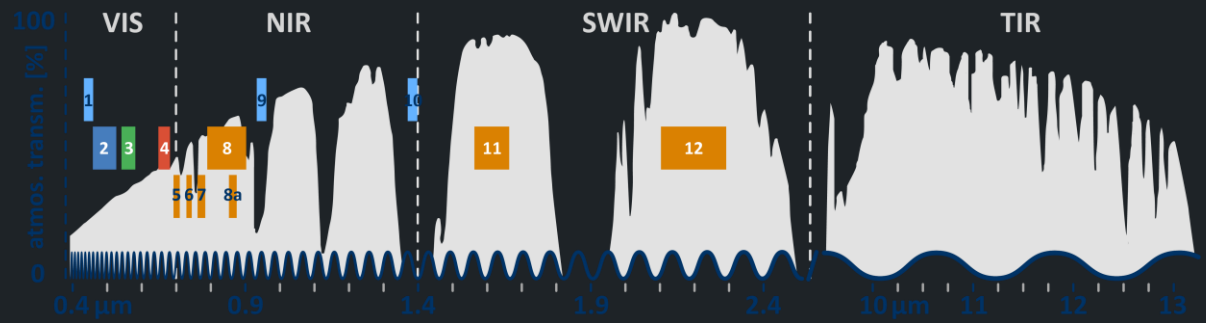

Figure 4. Sentinel-2 MSI bands on the electromagnetic spectrum (FU Berlin 2024).

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Optically active water components

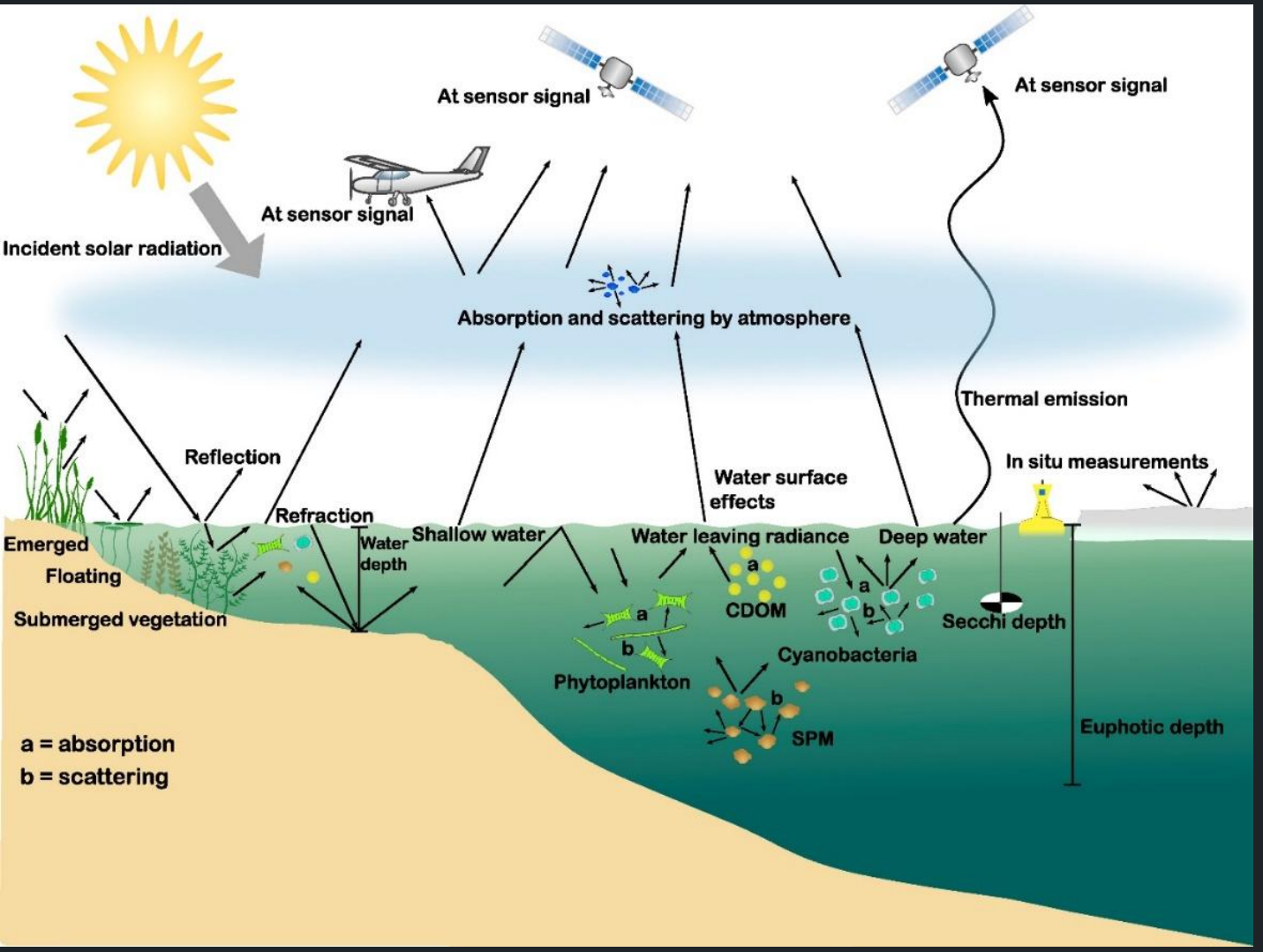


Figure 2. Absorption and scattering processes in the atmosphere and hydrosphere (Dörnhöfer & Oppelt, 2016).

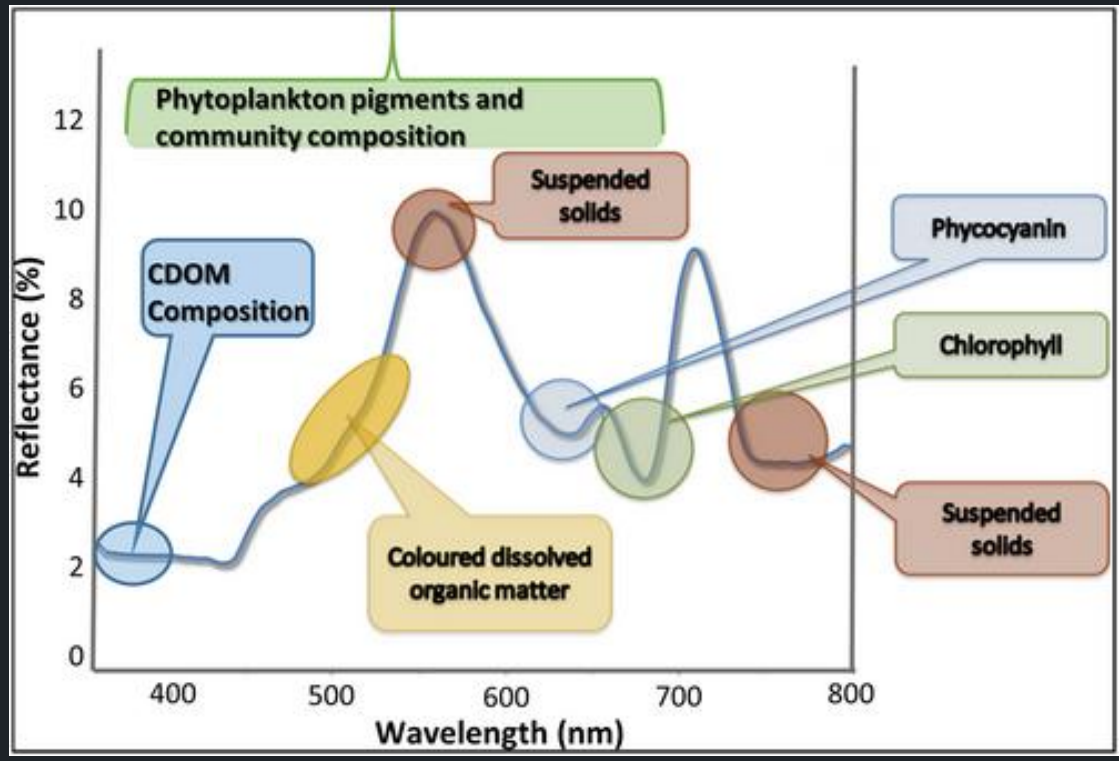
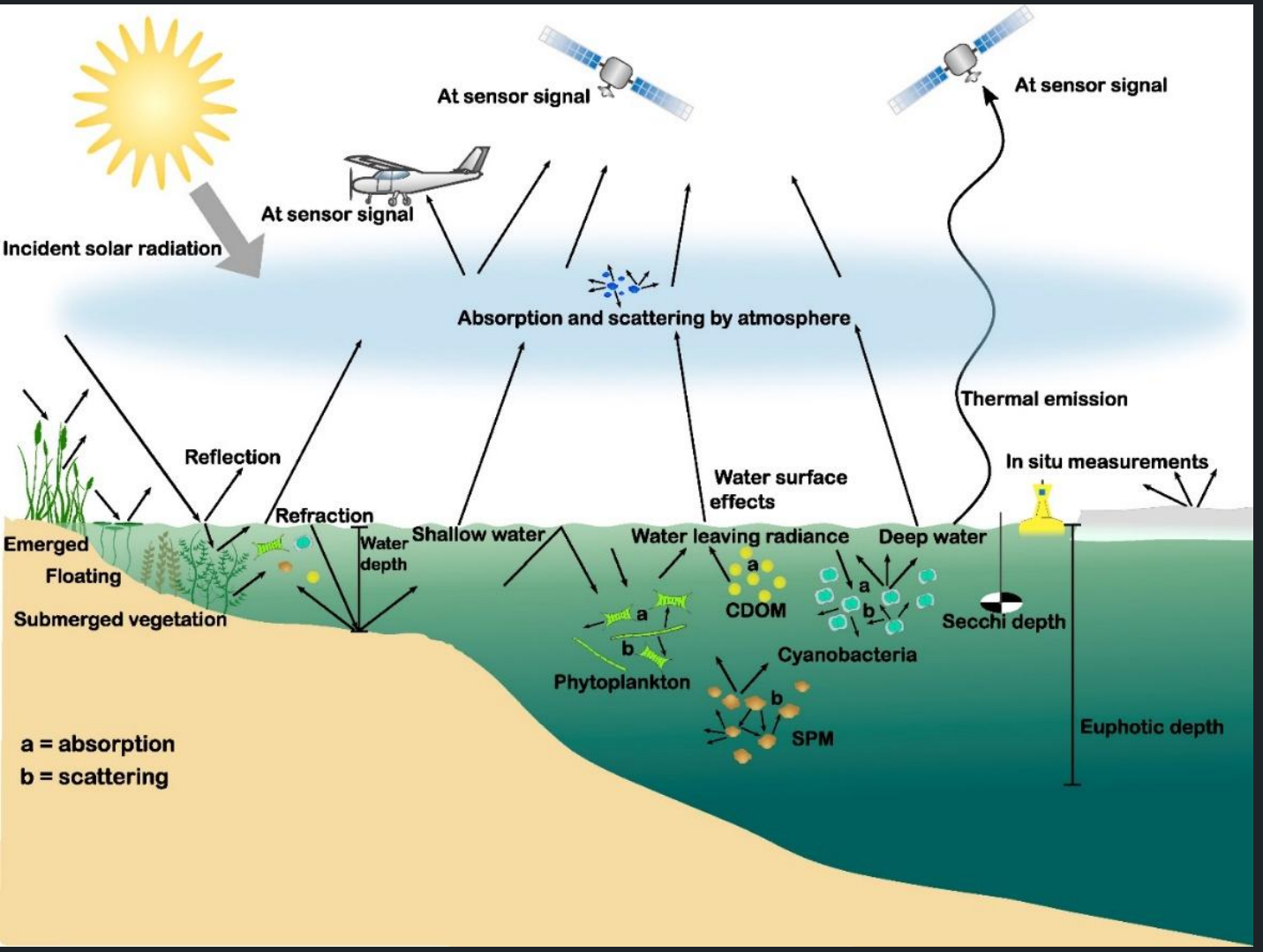


Figure 6. Inland water spectrum indicating spectral parts of interest for water quality parameter observation (Dierssen et al., 2023, p. 9).

Optically active water components



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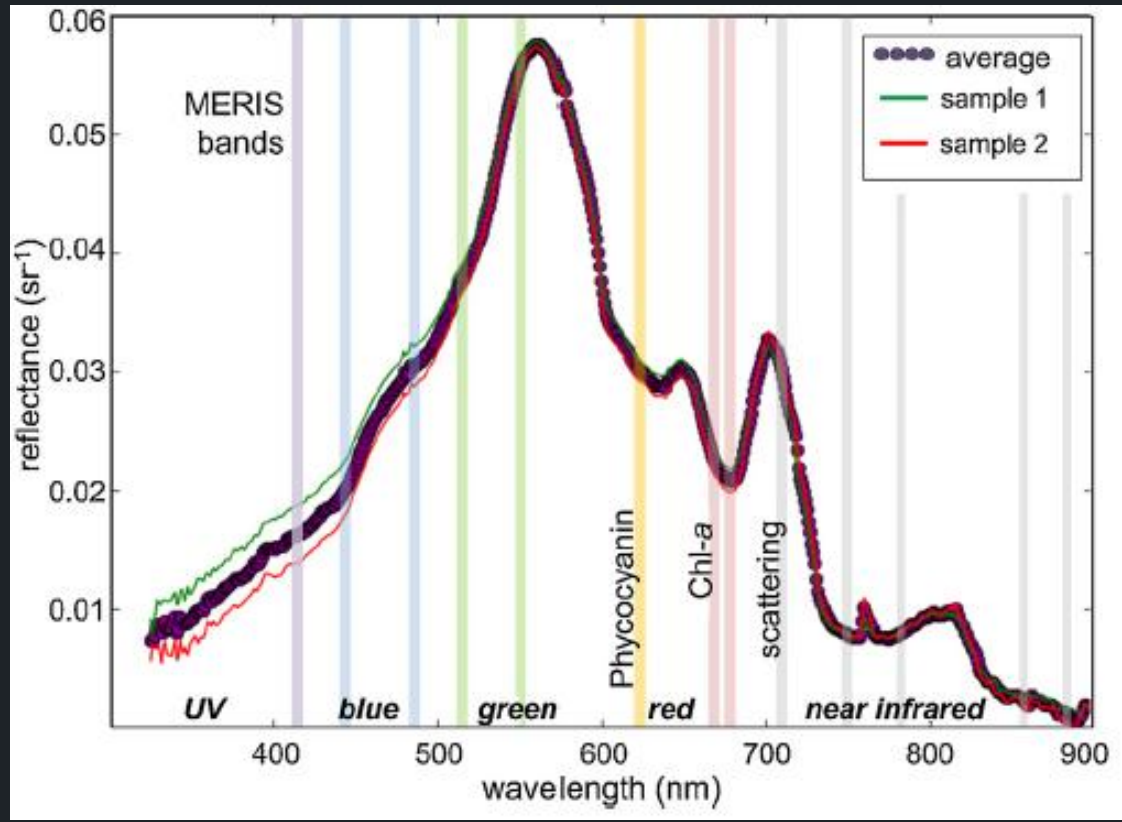

Figure 7. Spectrograph of cyanobacteria measured with the ASD FieldSpec spectroradiometer (Stumpf et al., 2016, p. 162).

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2. Detection of aquatic macrophytes and phytoplankton

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Active Remote Sensing

- Radar (Backscatter)

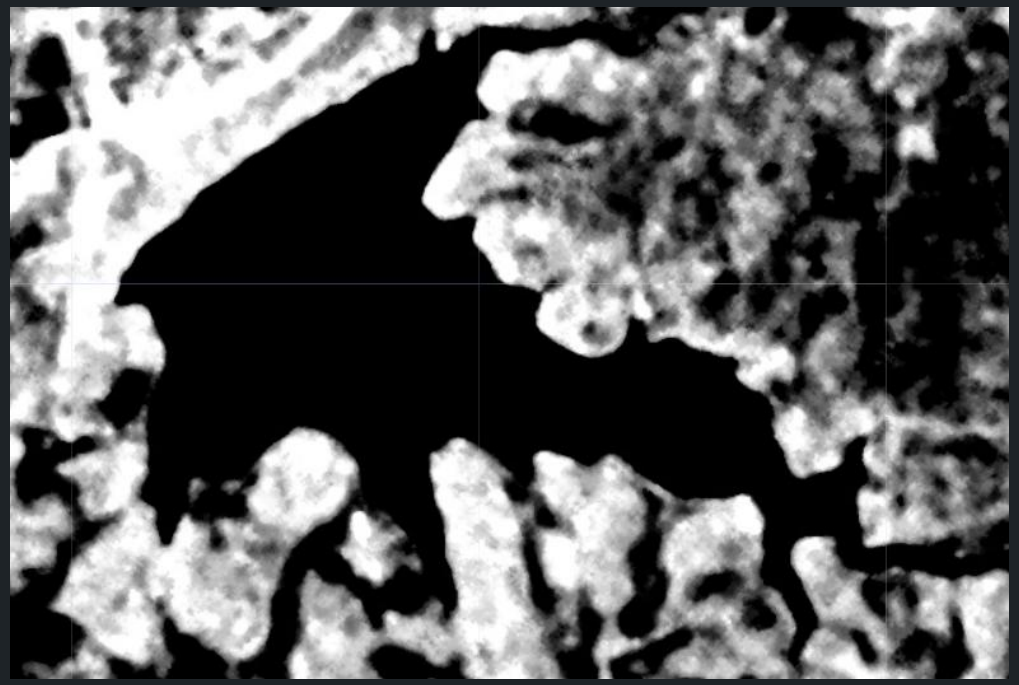

Figure 8. Lake Chivero backscatter captured by Sentinel-1 C-SAR (2021-06-05 16:23 GMT).

Passive Remote Sensing

- Visible & Infrared (Reflectance)

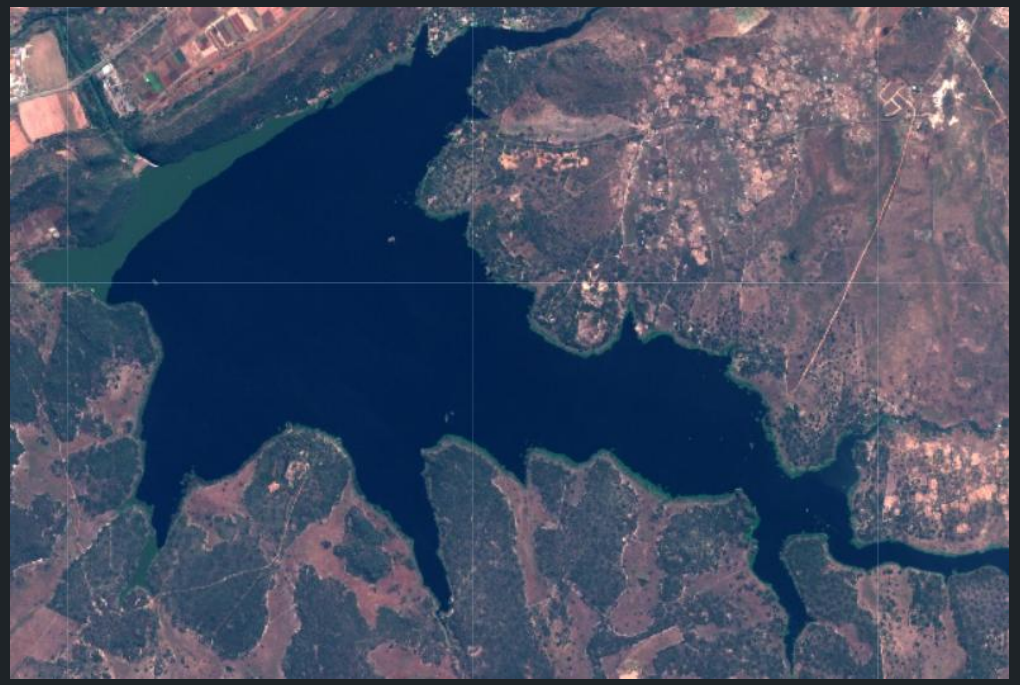

Figure 9. Lake Chivero multispectral reflectance captured by Sentinel-2 MSI (2021-06-05 08:15 GMT).

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Active Remote Sensing

- Radar (Backscatter)

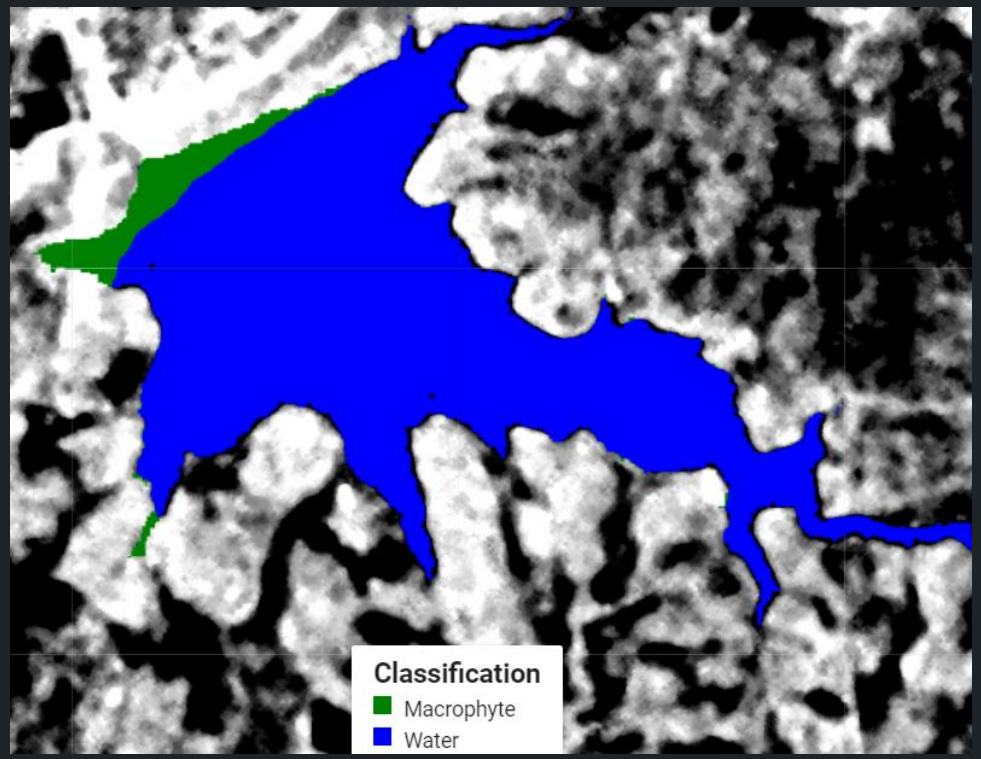

Figure 10. Thematic map of aquatic macrophyte and water based on Sentinel-1 C-SAR (2021-06-05 16:23 GMT)

Passive Remote Sensing

- Visible & Infrared (Reflectance)

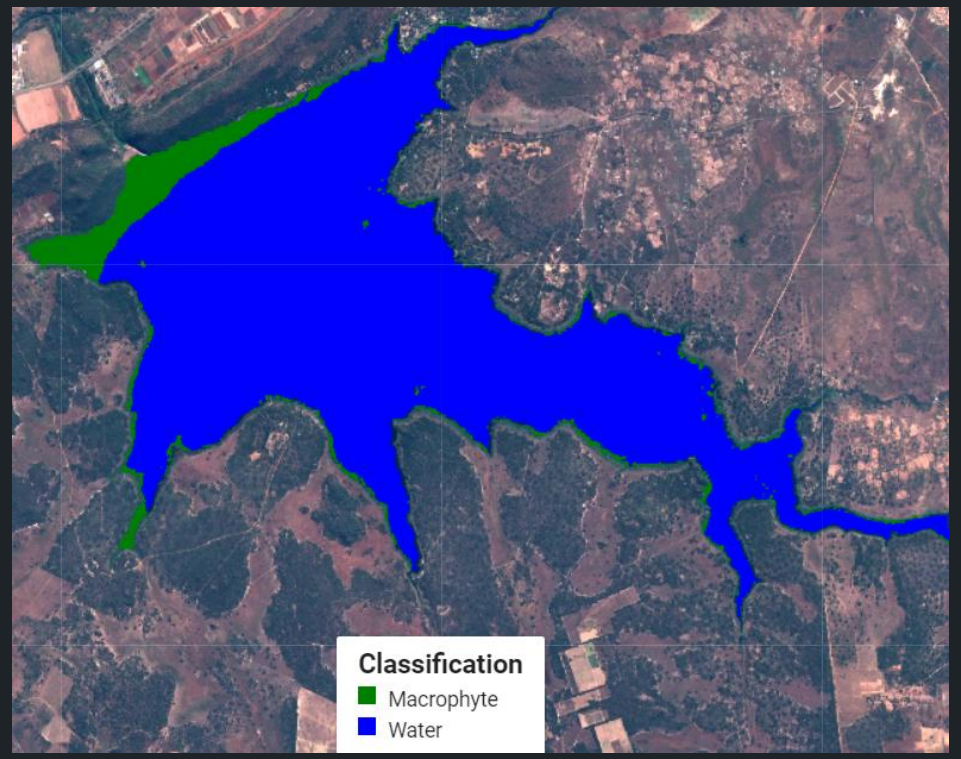

Figure 11. Thematic map of aquatic macrophyte and water based on Sentinel-2 MSI (2021-06-05 08:15 GMT)

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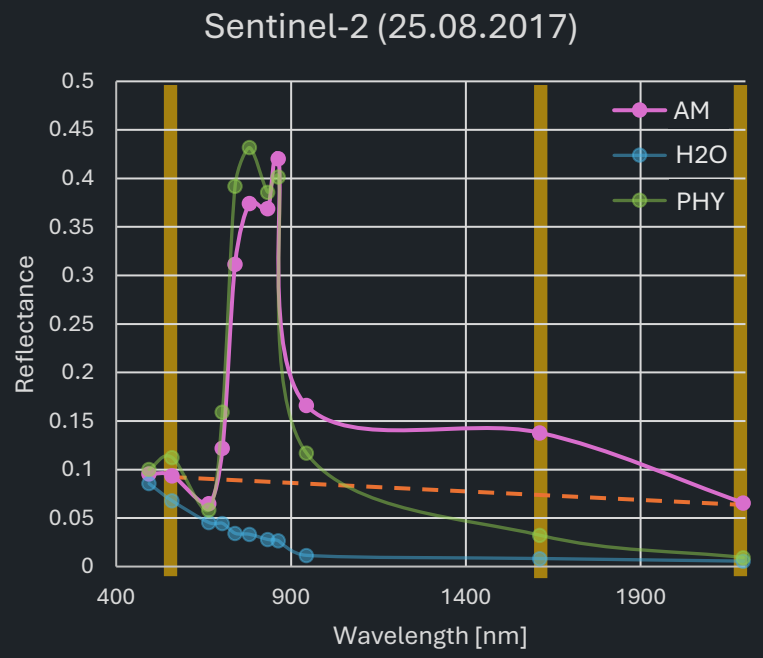
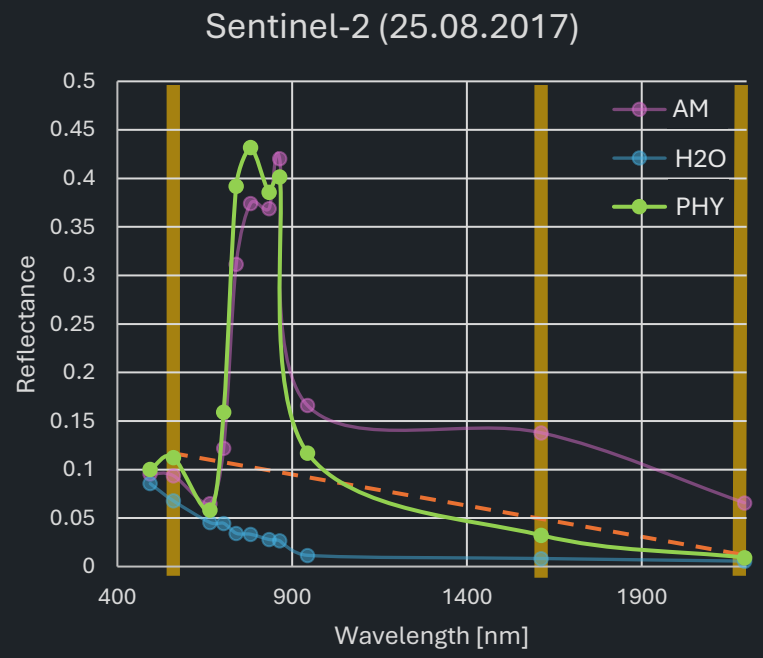
Aquatic Macrophyte Index (AMI)

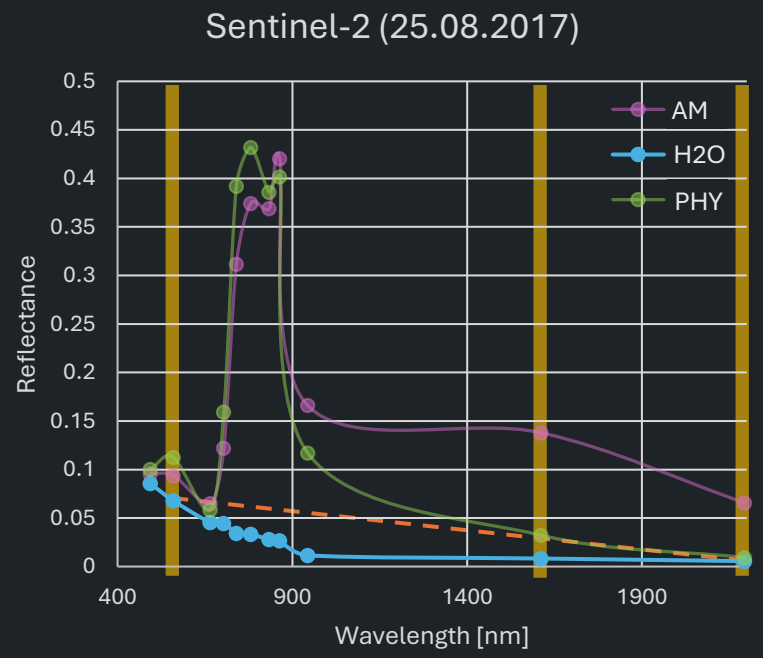
$$AMI = \rho_{SWIR1} - \left(\rho_{Green} + (\rho_{SWIR2} - \rho_{Green}) \times \left(\frac{\lambda_{SWIR1} - \lambda_{Green}}{\lambda_{SWIR2} - \lambda_{Green}} \right) \right)$$



AMI_AM = 0.062



AMI_PHY = -0.014



AMI_H2O = -0.021

Figure 12. Spectral signatures captured at Lake Chivero by Sentinel-2 MSI (2017-08-25). Where yellow vertical bars | indicate the spectral bands of interest for the AMI computation. Orange dashed lines --- illustrate the interpolation between the Green and SWIR2 band. AM = Aquatic Macrophyte, PHY = Phytoplankton, H2O = Water (Münch et al. in preparation).

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AMI & FAI application at Lake Chivero in June 2023

Figure 13. AMI & FAI based classification Sentinel-2 (2023-06-05).

AMI & FAI application at Lake Chivero in June 2023

Figure 13. AMI & FAI based classification Sentinel-2 (2023-06-05).

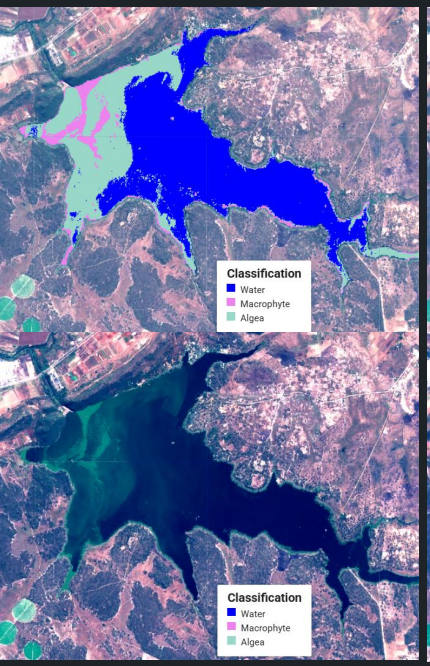


Figure 14. AMI & FAI based classification Sentinel-2 (2023-06-10).

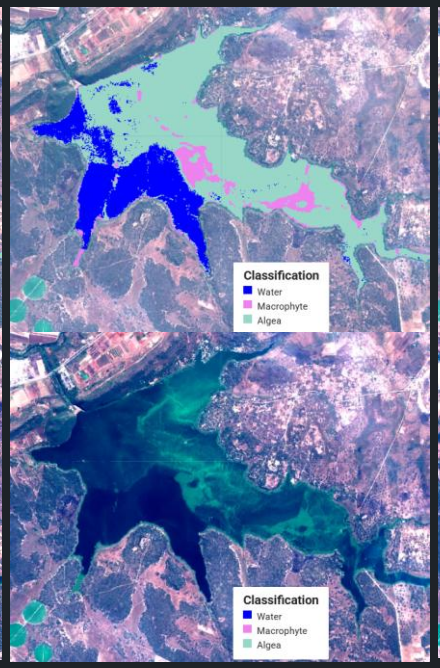


Figure 15. AMI & FAI based classification Sentinel-2 (2023-06-15)

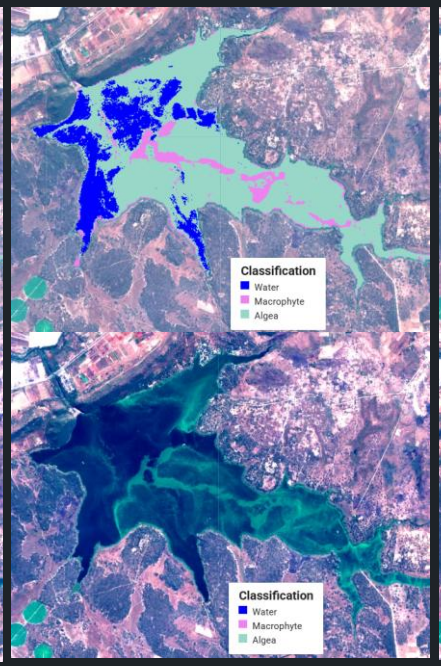


Figure 16. AMI & FAI based classification Sentinel-2 (2023-06-20)

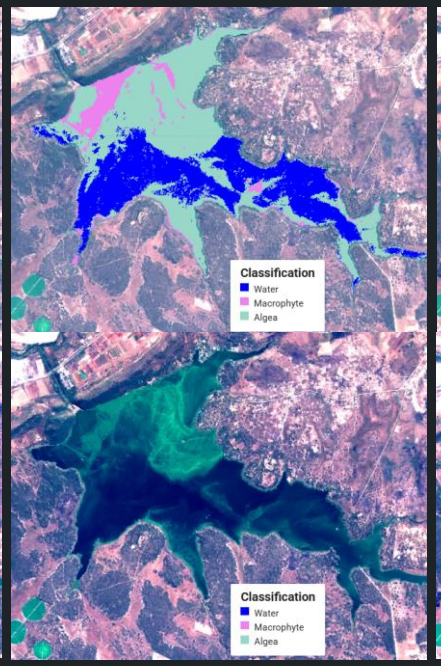


Figure 17. AMI & FAI based classification Sentinel-2 (2023-06-25)

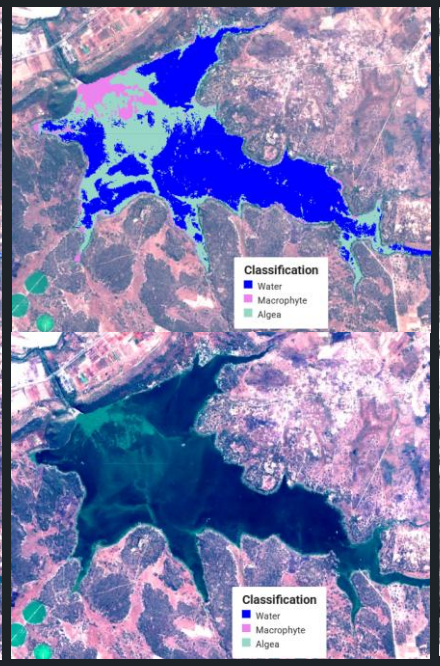
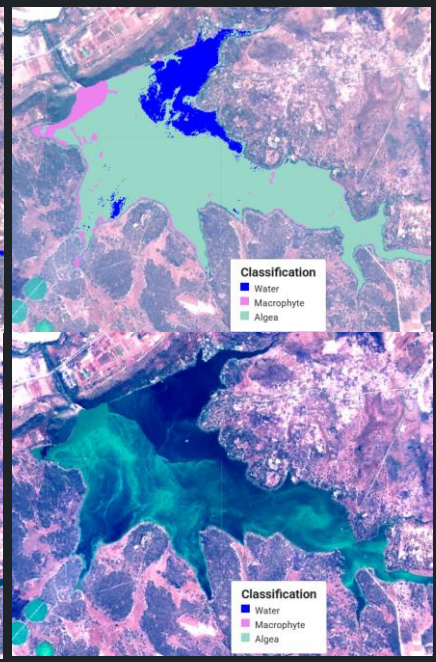


Figure 18. AMI & FAI based classification Sentinel-2 (2023-06-30)



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3. Field surveillance

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Uncrewed Aerial Vehicle (UAV)

DJI Mavic 3M

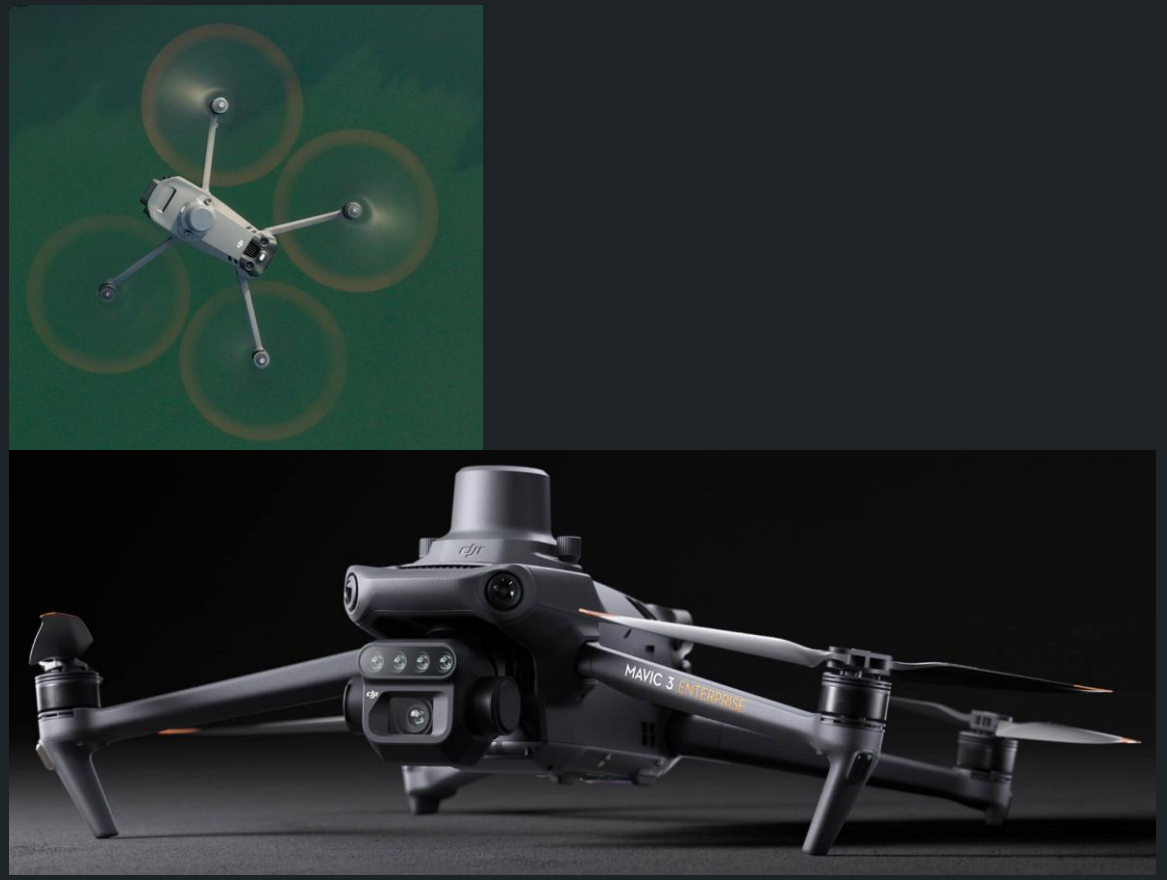

Figure 22. DJI Mavic 3M (DJI 2025) .

Spectral bands:

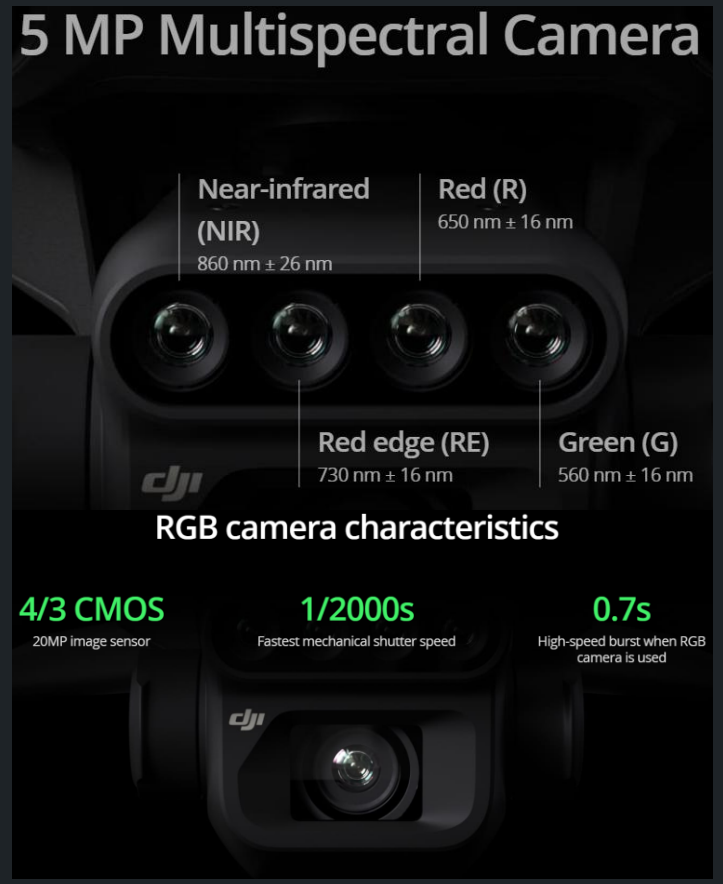

Figure 23. DJI Mavic 3M sensors (DJI 2025).

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Spectroradiometer

TriOS RAMSES

- 256 spectral channels
- Spectral range: 320 – 950 nm

Figure 19. TriOS RAMSES ARC VIS (TriOS Mess- und Datentechnik GmbH 2025)

ASD FieldSpec

- VIS (3 nm), IR (10 nm)
- Spectral range: 350 – 2500 nm

Figure 20. ASD FieldSpec 3 (ASD Inc. 2010).

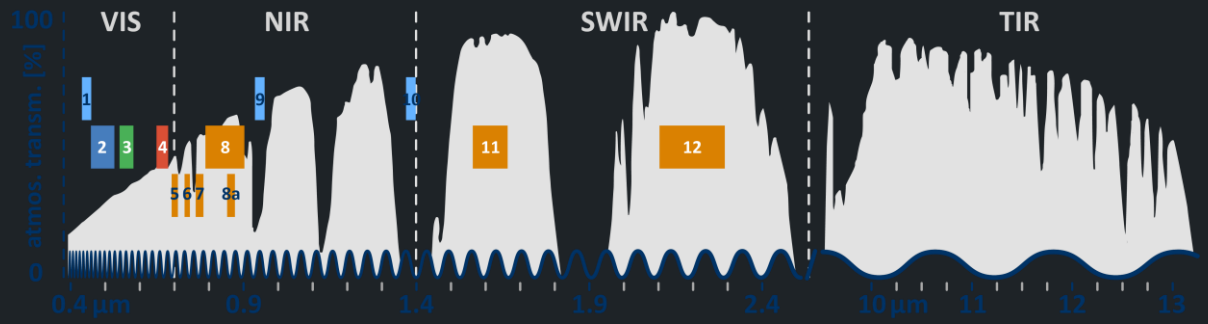

Figure 3. Sentinel-2 MSI bands on the electromagnetic spectrum (FU Berlin 2024).

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Fluorometer

bbe moldaenke FluoroProbe

Figure 21. Biological biophysical engineering (bbe) moldaenke FluoroProbe (bbe moldaenke GmbH 2025).

Measurands:

total **chlorophyll** [µg chl-a/l]
concentration of **green algae** [µg chl-a/l]
concentration of **cyanobacteria** [µg chl-a/l]
concentration of **diatoms/brown algae** [µg chl-a/l]
concentration of **cryptophytes** [µg chl-a/l]
fingerprints of classes/species, also user-defined (e.g. Planktothrix rubescens) [µg chl-a/l]
yellow substances (CDOM)
depth
temperature (optional)
transmission (optional)

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