FRM4DRONES
fiducial reference measurements for water using drones

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NPL

MAPEO-water
Cloud-based workflow for drone-derived aquatic reflectance and water quality parameters

Liesbeth De Keukelaere, Robrecht Moelans

Drone data acquisition and processing

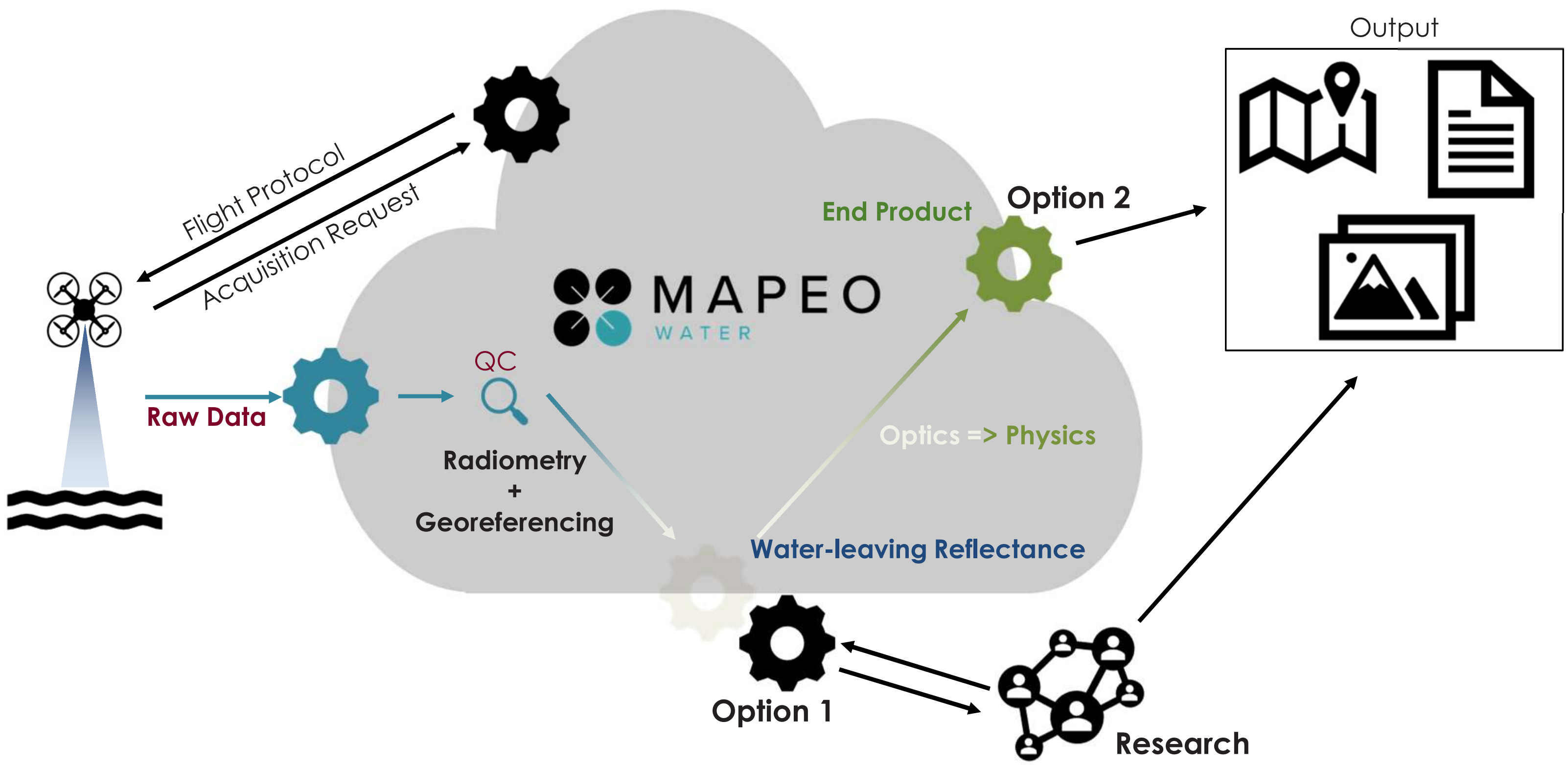
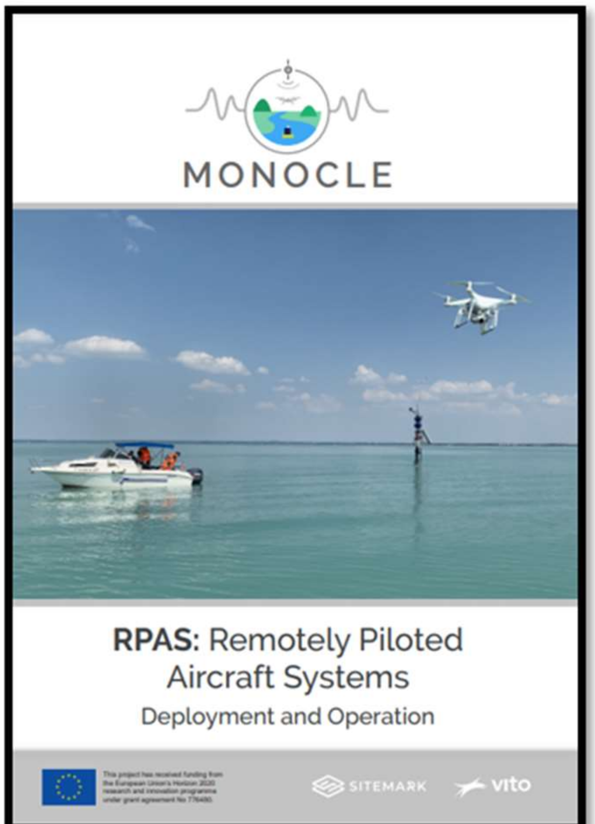


Image acquisition - Flight protocols

MAPEO WATER



1. Avoid sun glint:
   - Don't look nadir
   - Look away from the sun

2. Include calibration panels in absence of irradiance sensor (DLS)

3. Collect RAW data

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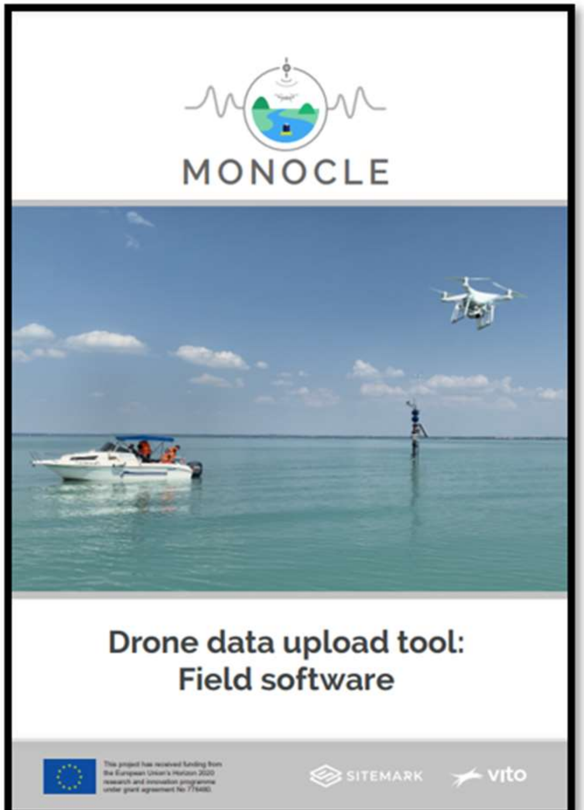
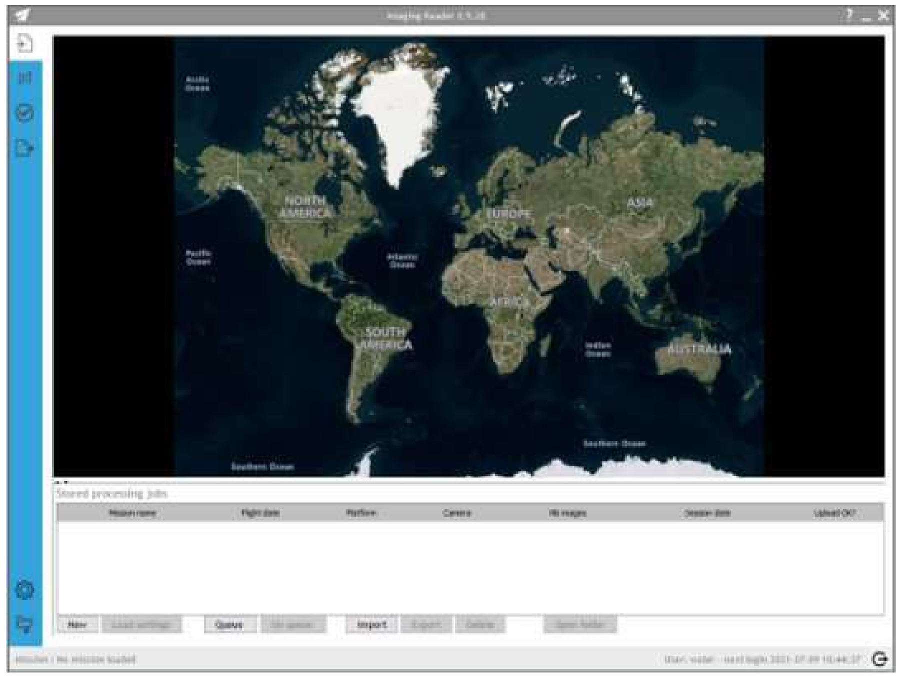
https://zenodo.org/records/7461923

Data upload tool – Metadata

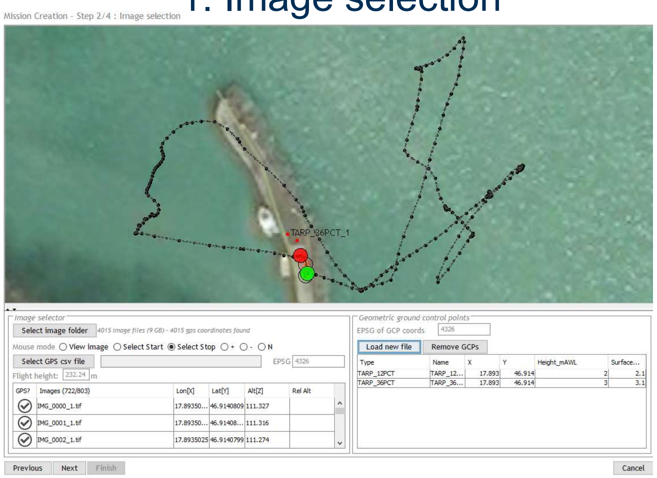
Location, name, ..
Sensor(s)
Relative height difference between take-off location and water level.



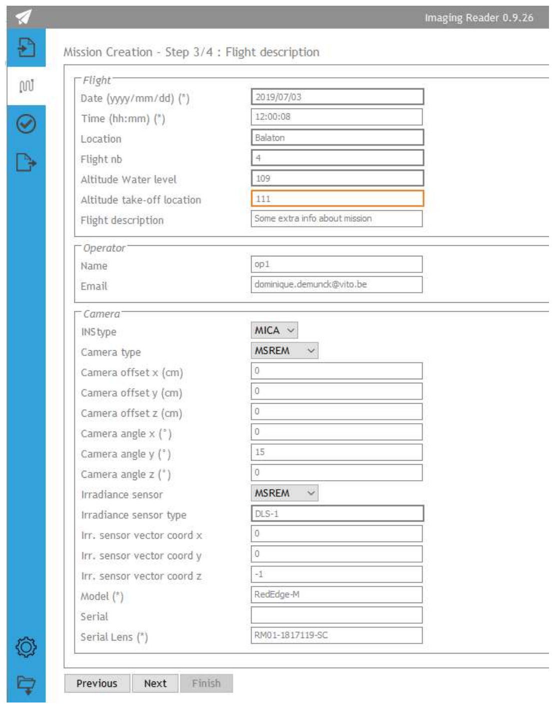


Data upload tool – Metadata

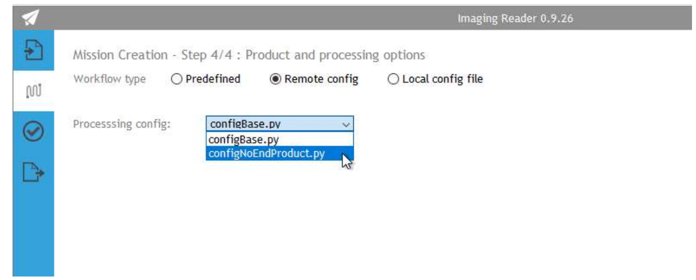
1. Image selection



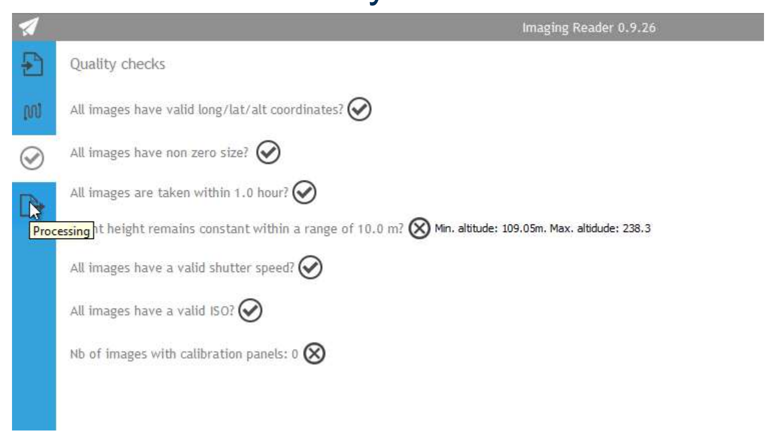
2. Flight description



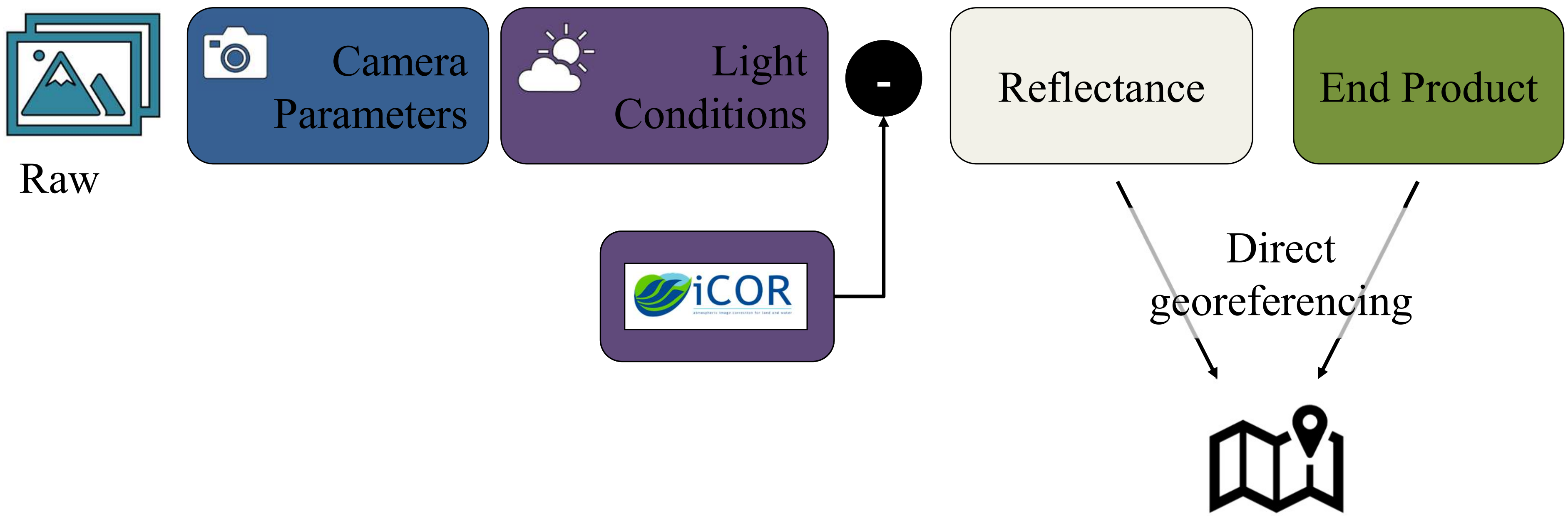
3. Product and processing options



Quality checks

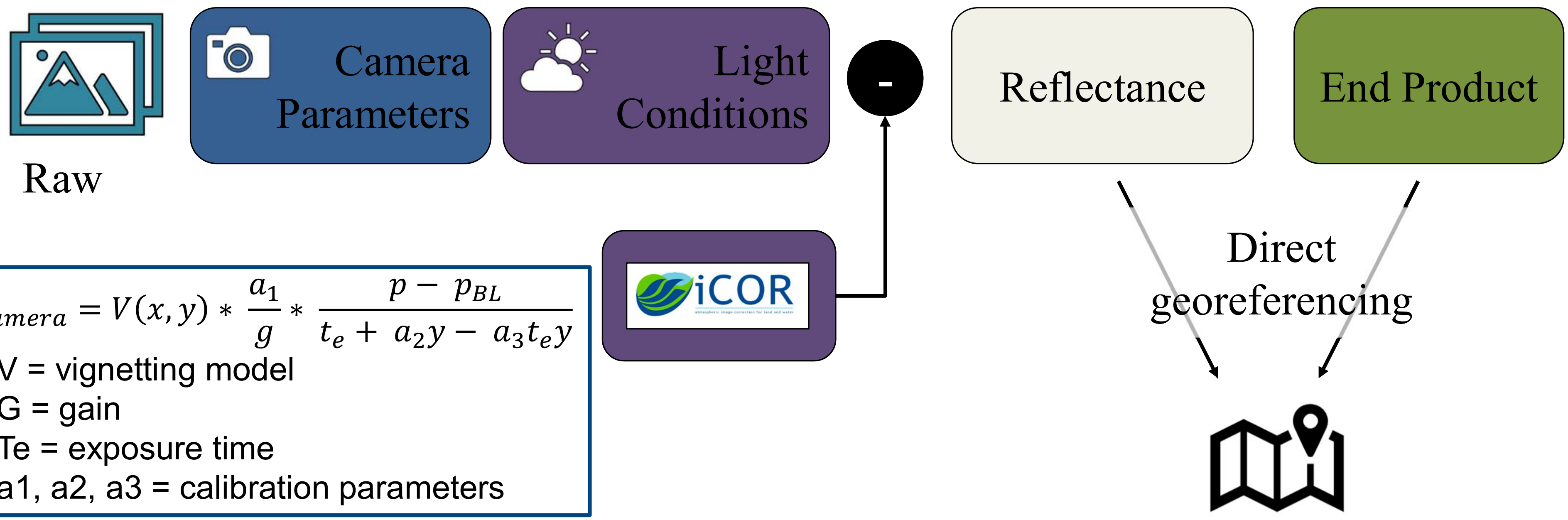


Data Processing



Data Processing

MAPEO WATER



$$L_{camera} = V(x,y) * \frac{a_1}{g} * \frac{p - p_{BL}}{t_e + a_2 y - a_3 t_e y}$$

- V = vignetting model
- G = gain
- Te = exposure time
- a1, a2, a3 = calibration parameters

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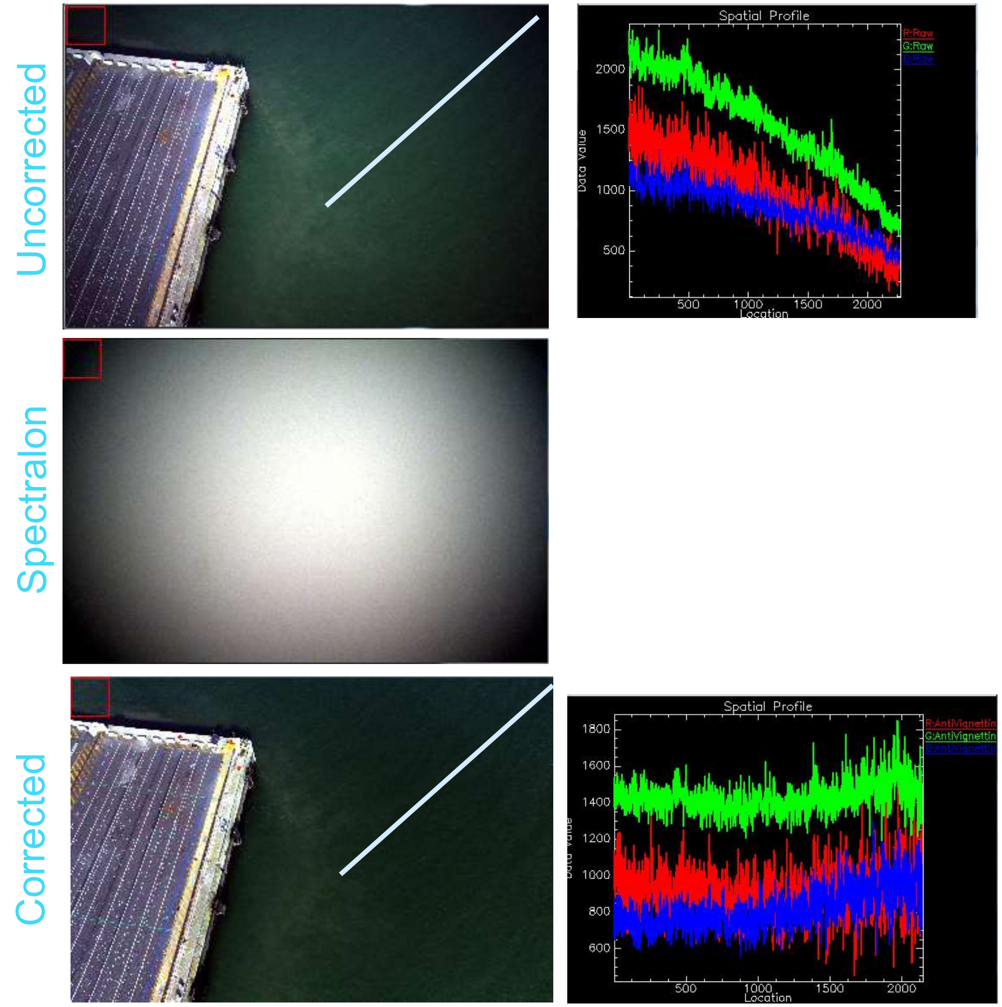
Data Processing

Raw

Camera Parameters

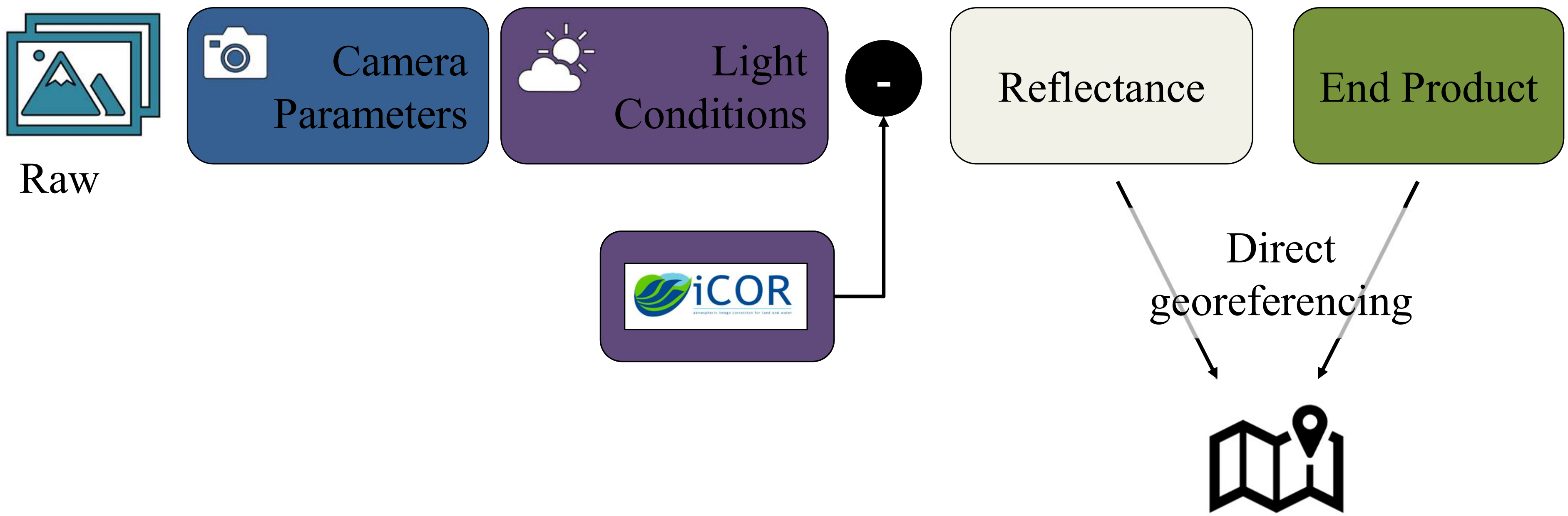
$$L_{camera} = V(x,y) * \frac{a_1}{g} * \frac{p - p_{BL}}{t_e + a_2 y - a_3 t_e y}$$

- V = vignetting model
- G = gain
- Te = exposure time
- a1, a2, a3 = calibration parameters



Data Processing

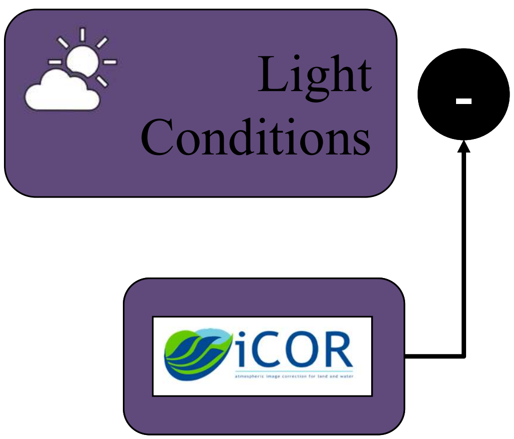
$$\rho_w = \frac{\pi \, L_{camera}}{E_d} - \frac{\pi \, r(\theta_v) L_{sky}(\theta_v, \varphi_v)}{E_d}$$

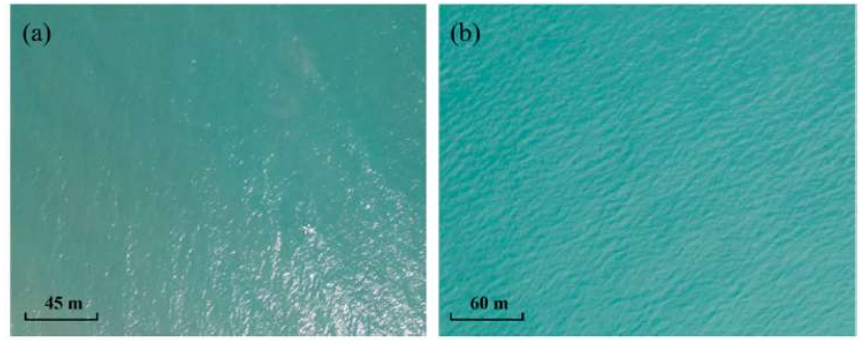


Data Processing

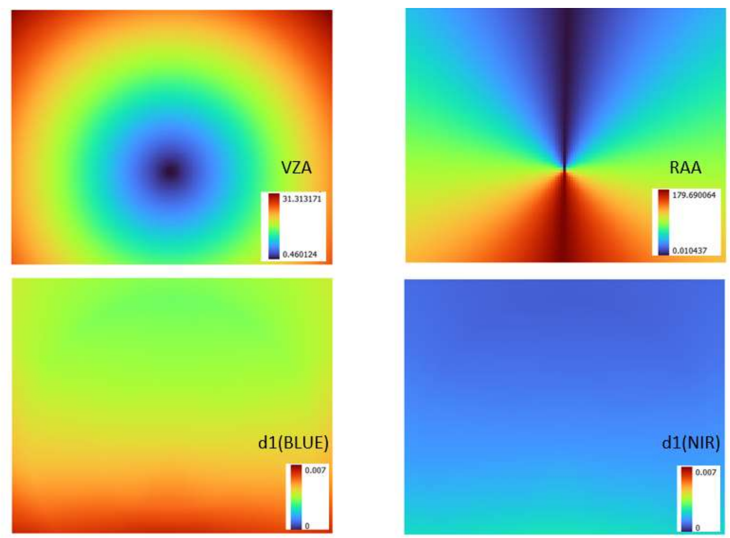
Sky glint: d1

$$\rho_w = \frac{\pi \, L_{camera}}{E_d} - \frac{\pi \, r(\theta_v) L_{sky}(\theta_v, \varphi_v)}{E_d}$$





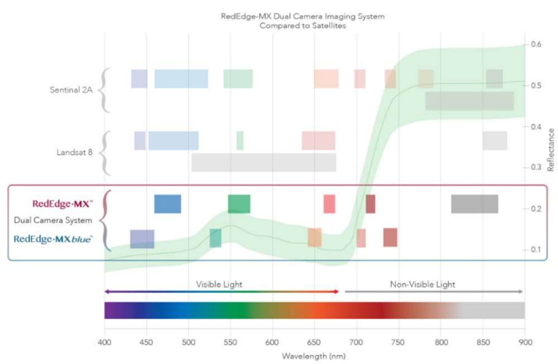
Difference between sun (a) and sky (b) glint in UAV image. [Lee et al., 2025]

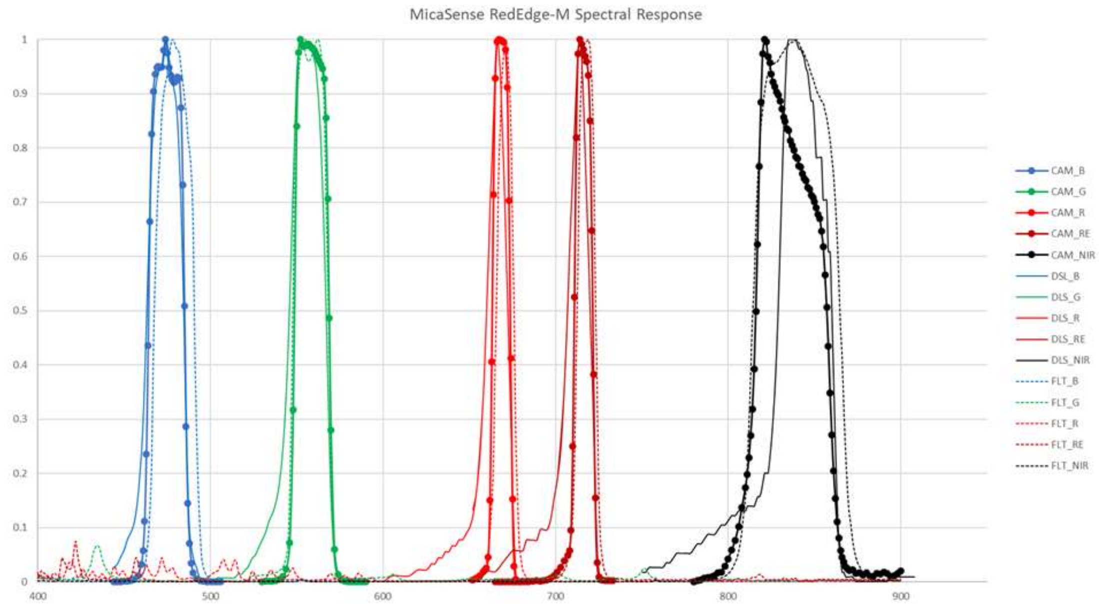


Sky glint correction with MAPEO-Water: View Zenith Angle (VZA), Relative Azimuth Angle (RAA).

Data processing

Spectral response curves

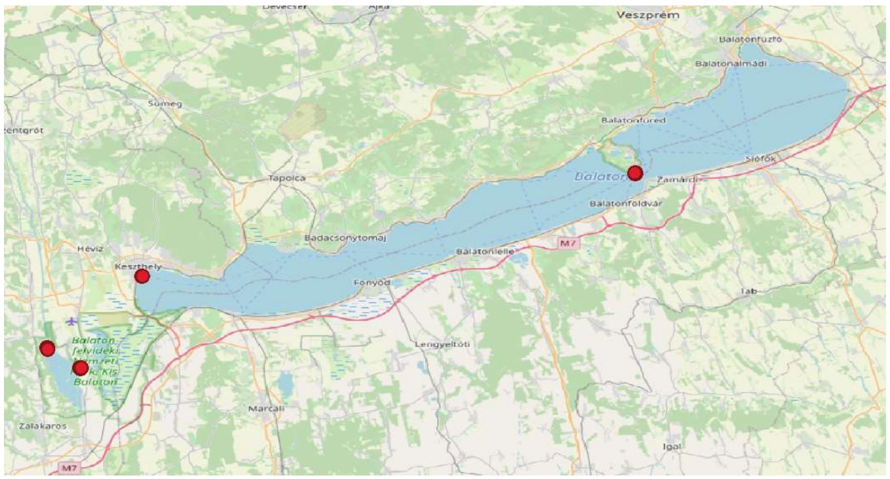


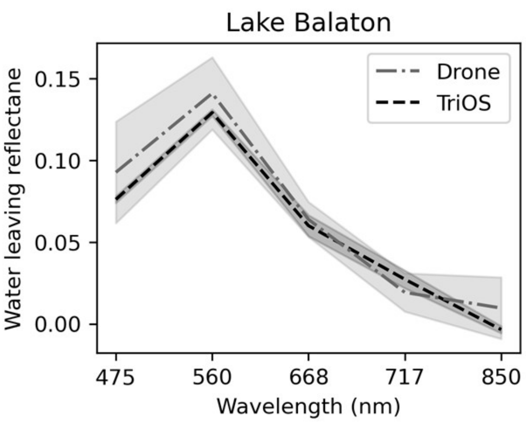


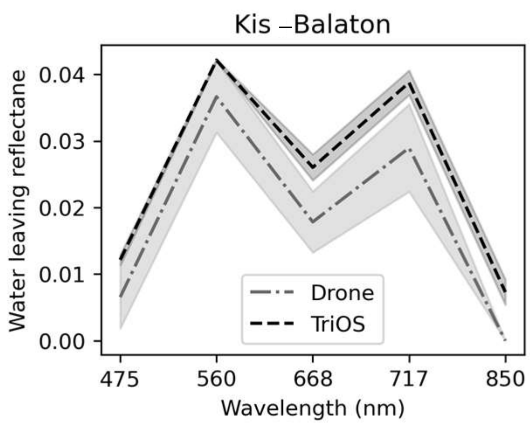
Characterization of the spectral response curves at NERC-FSF, 2018

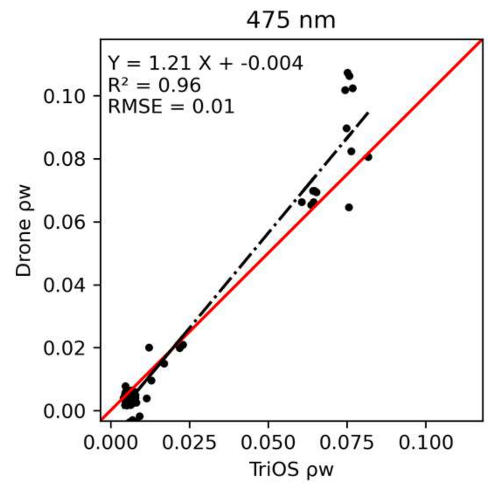
- Camera (solid line with dots)
- Irradiance sensor (solid line)
- Filter transmissivity, provided by MicaSense (dotted lines)

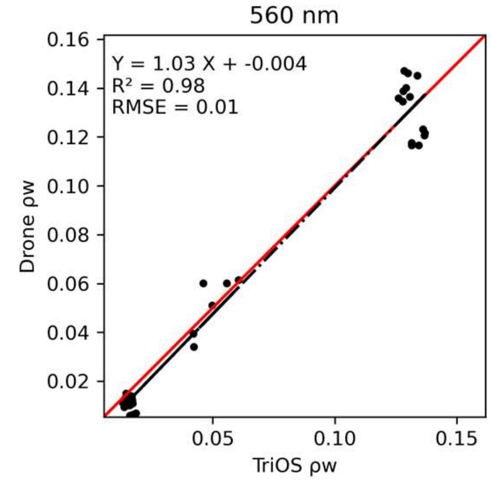
Validation – Water-Leaving Reflectance

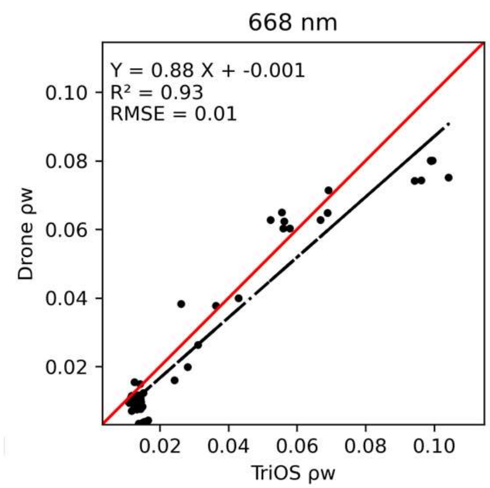


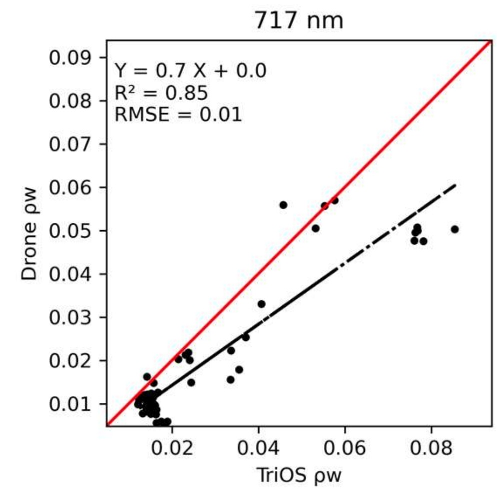




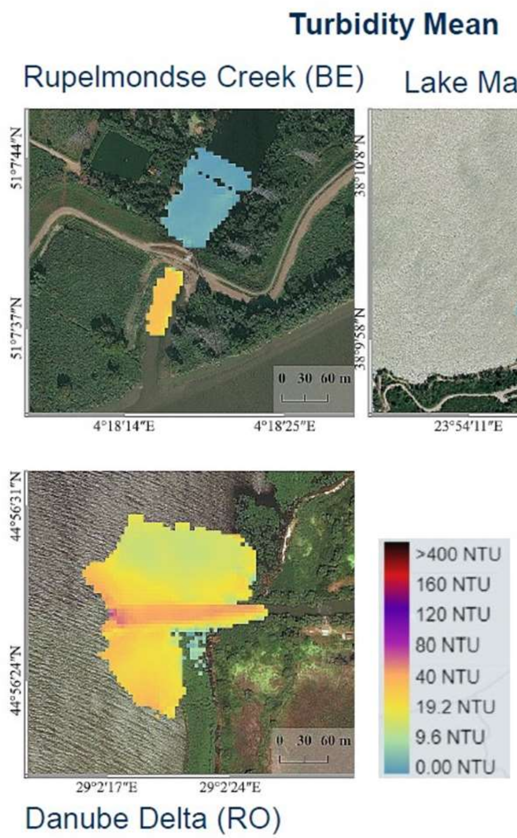


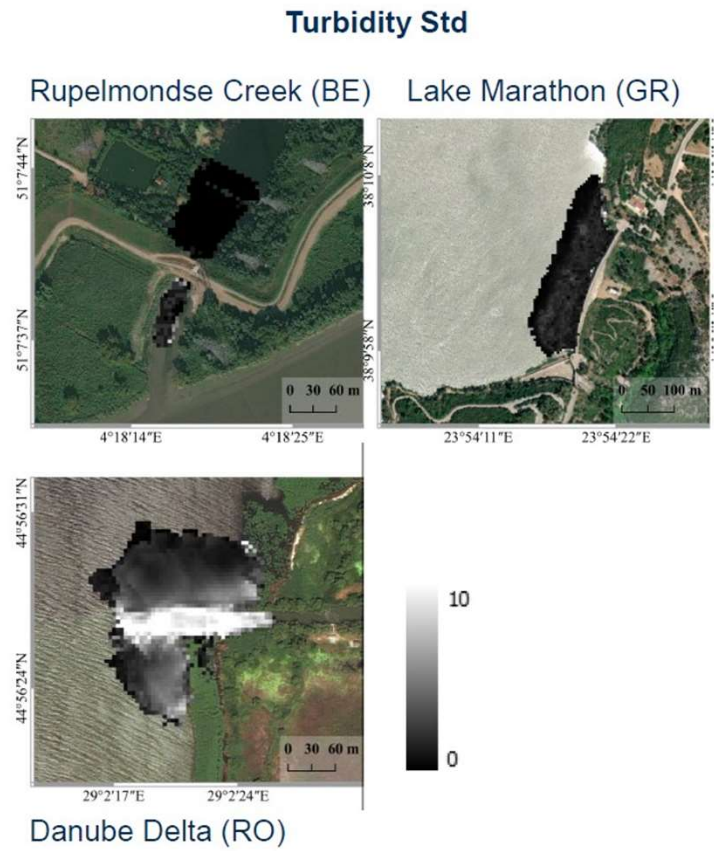






Data aggregation – Turbidity





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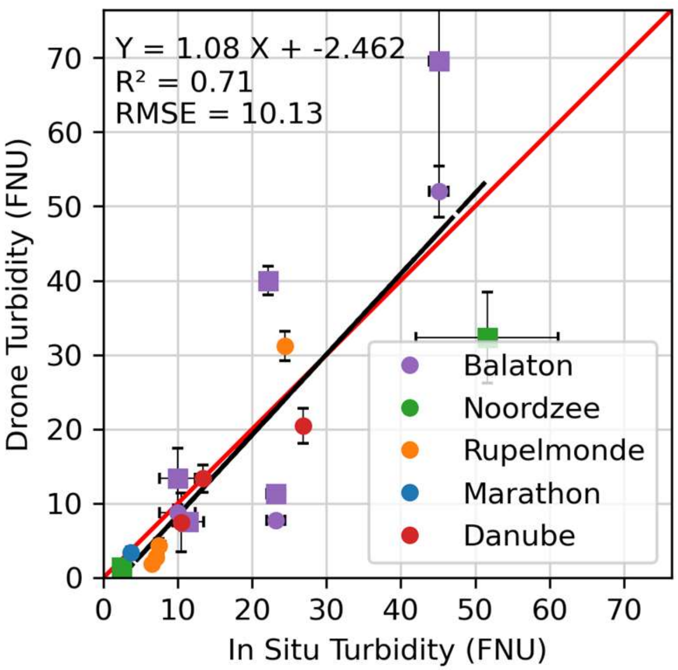
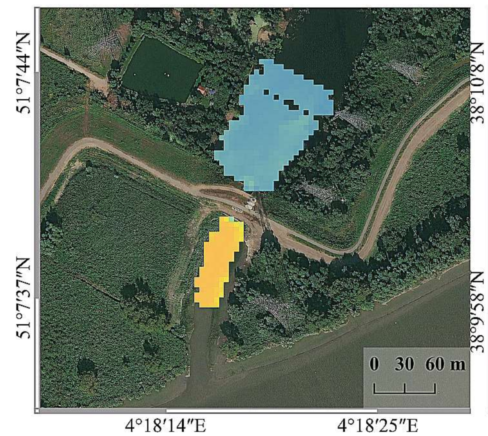
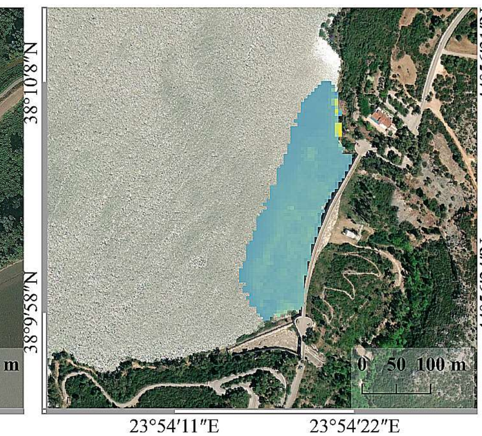
Validation – Turbidity

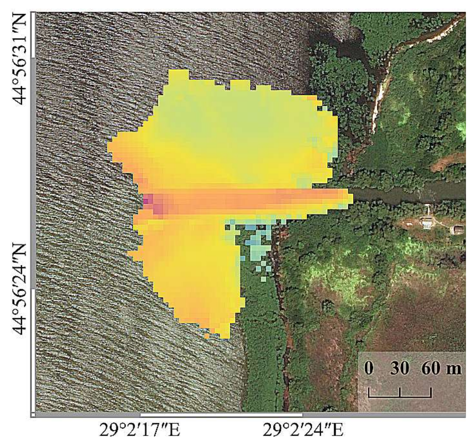


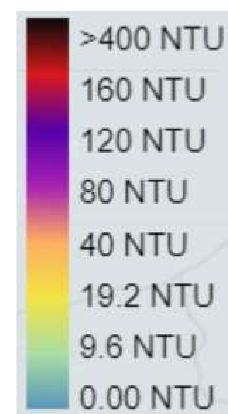
Rupelmondse Creek (BE)



Lake Marathon (GR)







Danube Delta (RO)

FAIR data & Metadata

GEOSJON metadata standards

- Geometry info
- Data acquisition
- Data processing
- Processing workflow
- Platform
- Sensor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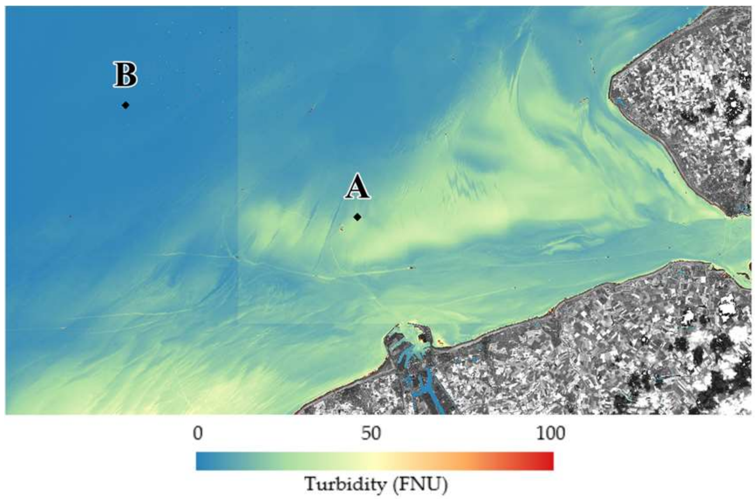
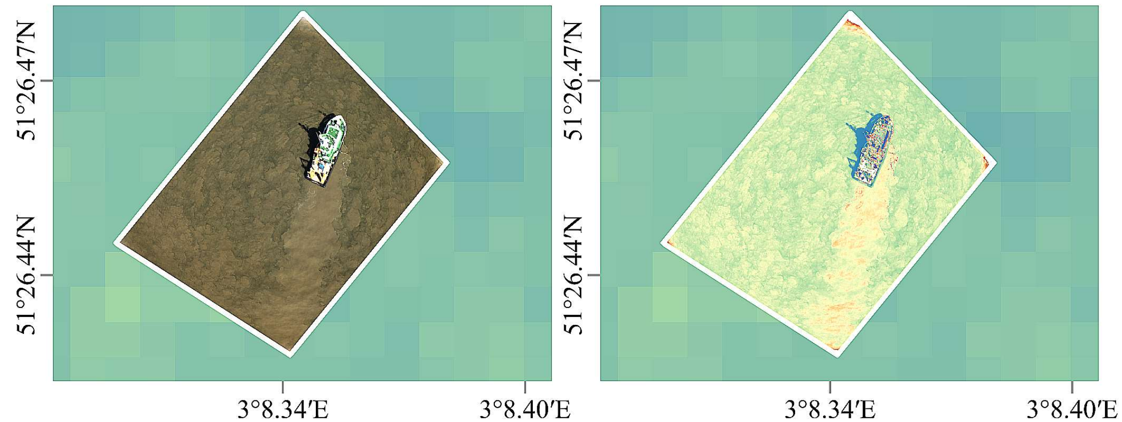
Drone data complementary to in situ data

10:59 UTC

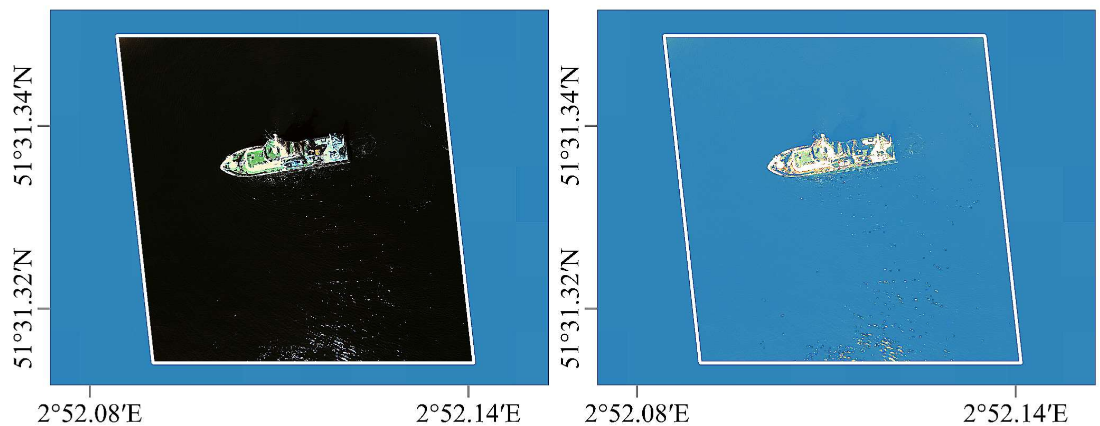


	Tur (FNU) - A	Tur (FNU) - B
S2	19–21	1.5
Drone	Plume: 40–60 Backgr: 30–40	0.5 – 5
IS	51.6 (40.7 – 58.6)	2.5

Location A - 10:05 UTC



Location B - 12:32 UTC

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Thank you
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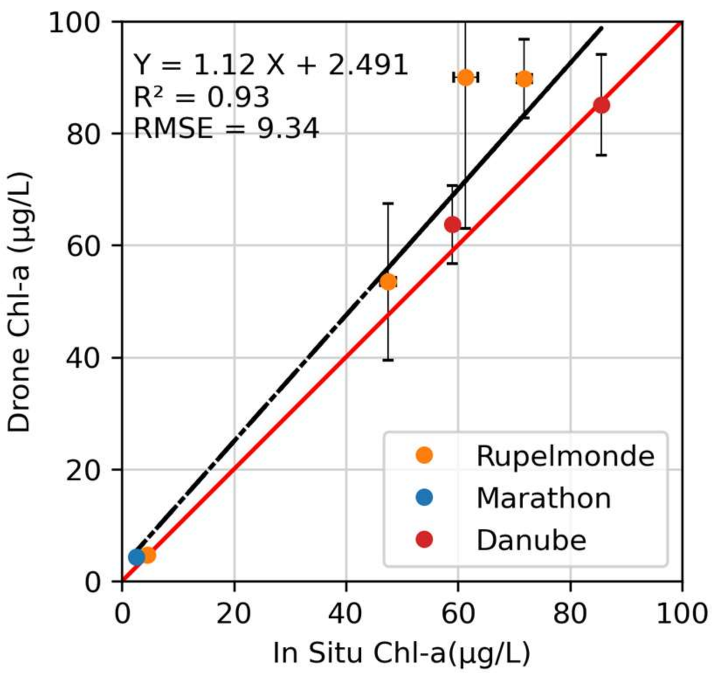
Challenges

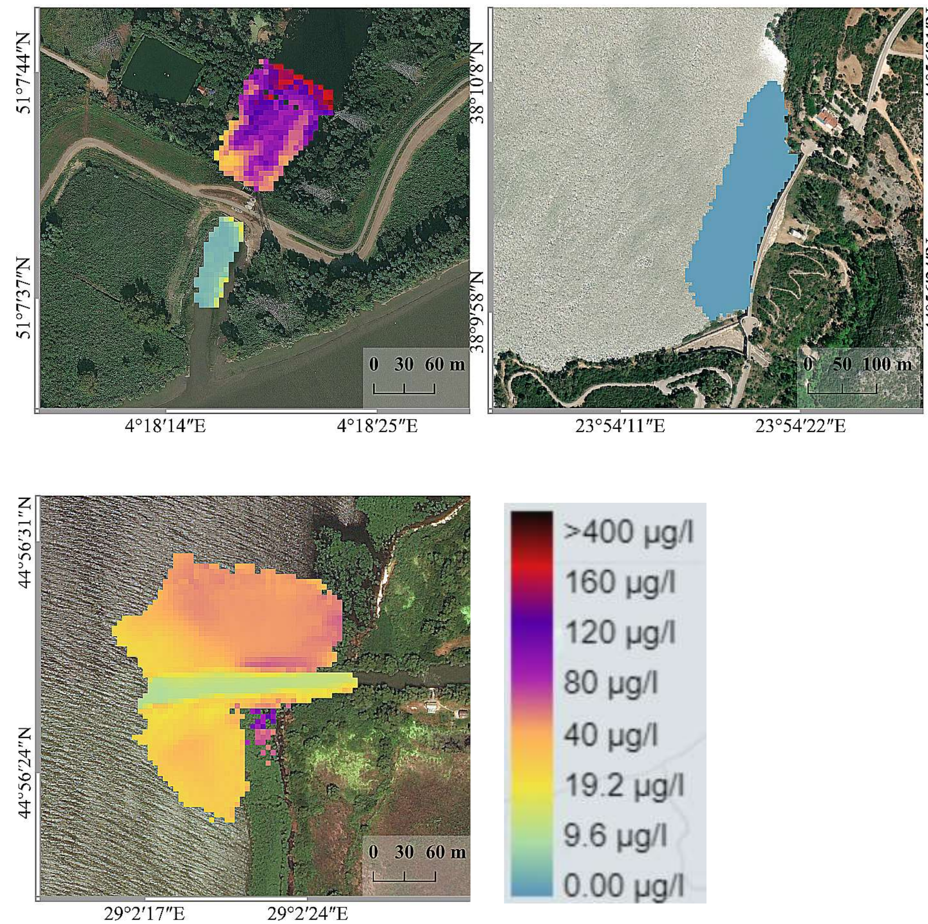
- Vignetting
- Sun glint
- Varying light
- White caps
- Bottom effects
- Dynamic
- Geolocation
- Low signal

Validation – Chl-a



Rupelmondse Creek (BE)

Lake Marathon (GR)



Danube Delta (RO)

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Data Processing

Sky glint – impossible to avoid

$$\rho_w = \frac{\pi \, L_{camera}}{E_d} -$$

- Sun glint:
  - Caused by direct sunlight reflecting off the water surface toward the sensor.
  - Highly dependent on sun-sensor geometry and water surface conditions.
  - Often appears as localized bright spots in images.

- Sky glint:
  - Originates from diffuse sky radiation reflecting off the sea surface.
  - Affects every pixel due to the hemispherical nature of skylight reflection.
  - Sky glint is unavoidable, while sun glint can be minimized by adjusting viewing geometry.
  - Diffuse sky radiance: Has a different spectral signature than direct sunlight. Is weaker in intensity but variable due to changing wave facet orientations.

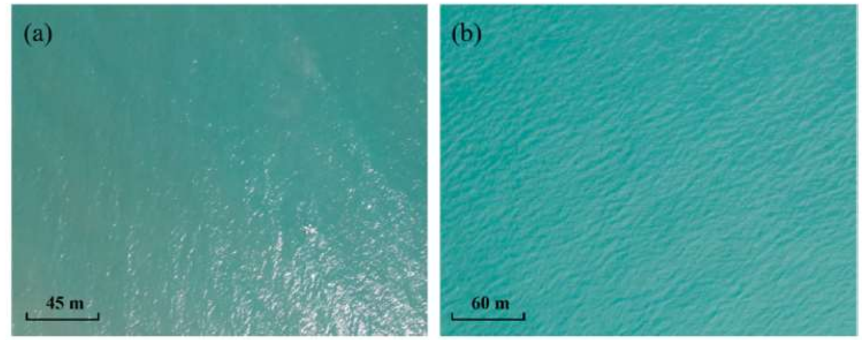

Figure 16. Figure illustrating difference between sun (a) and sky (b) glint in UAV images (source: Lee et al., 2025) [48]

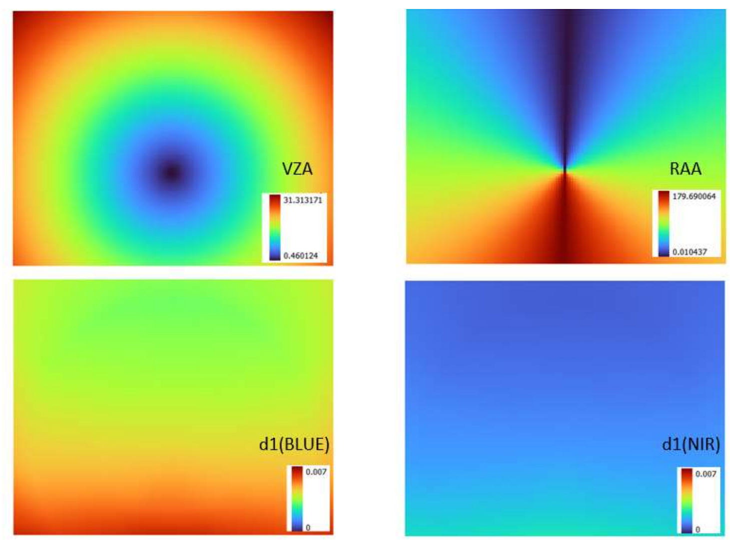

Figure 14. Sky glint correction with MAPEO-Water: View Zenith Angle (VZA); Relative Azimuth Angle (RAA); d1 for BLUE band with $d1 = \frac{\rho_{sky} L_{sky}(\lambda)}{E_d(\lambda)}$; d1 for NIR band