



FRM4DRONES
fiducial reference
measurements
for water using
drones



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

Liesbeth De Keukelaere, Robrecht Moelans



Drone data acquisition and processing

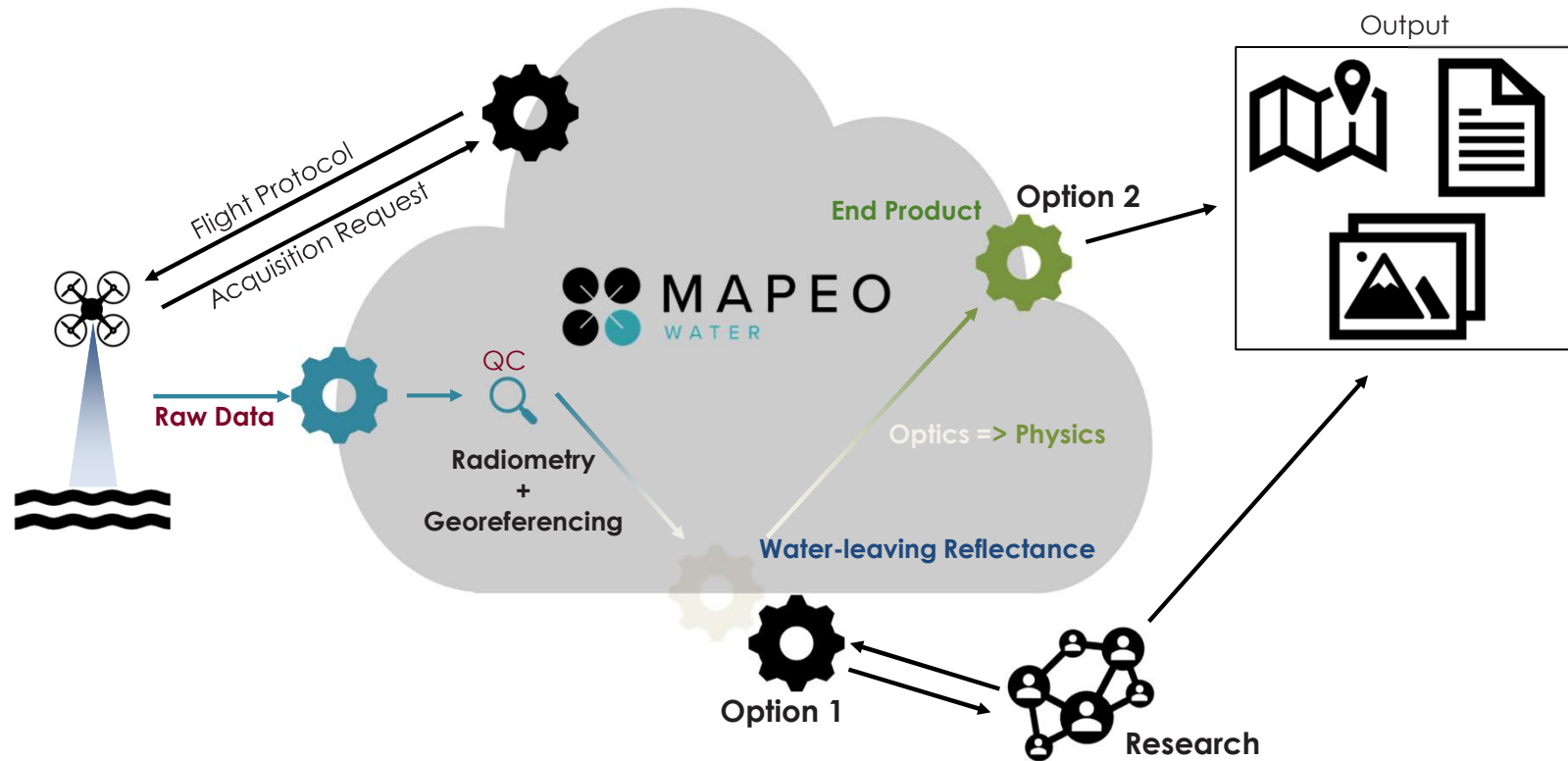
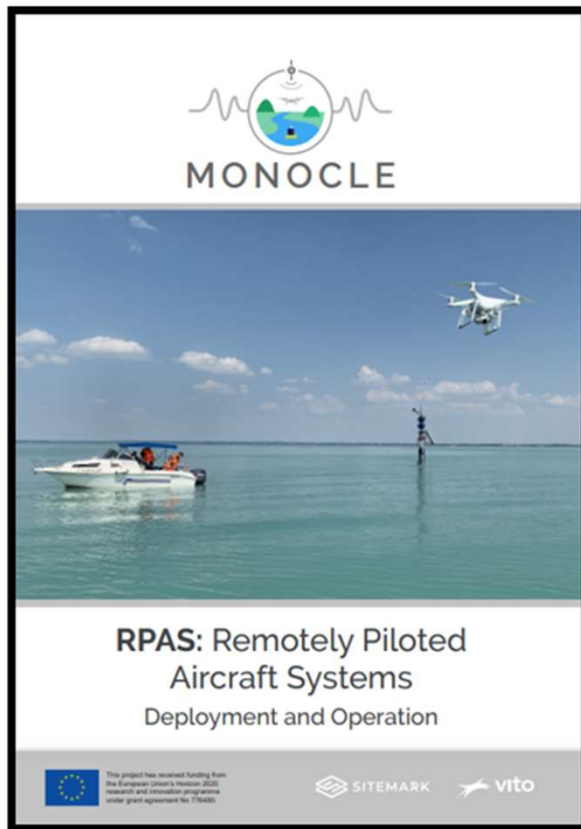
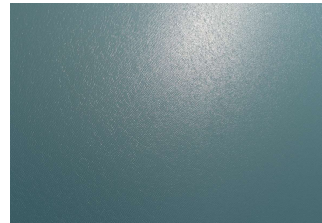




Image acquisition - Flight protocols



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



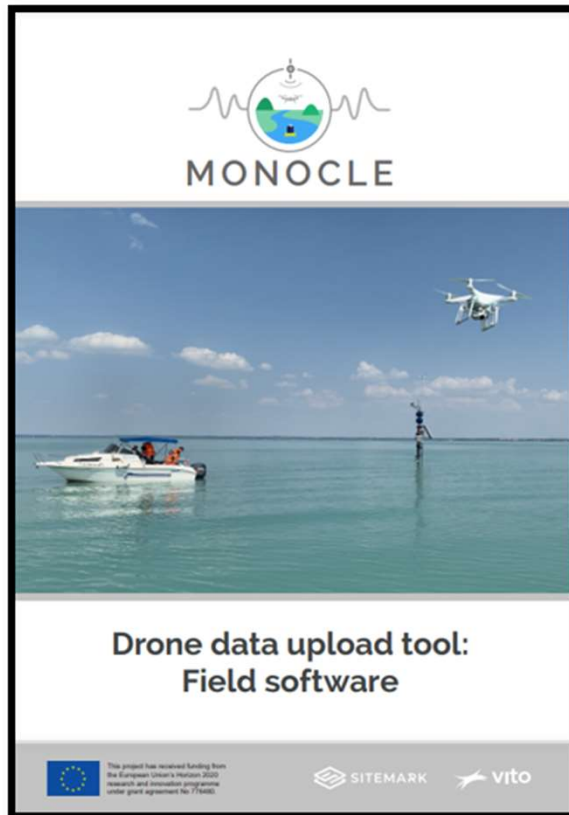
2. Include calibration panels in absence of irradiance sensor (DLS)
3. Collect RAW data



<https://zenodo.org/records/7461923>



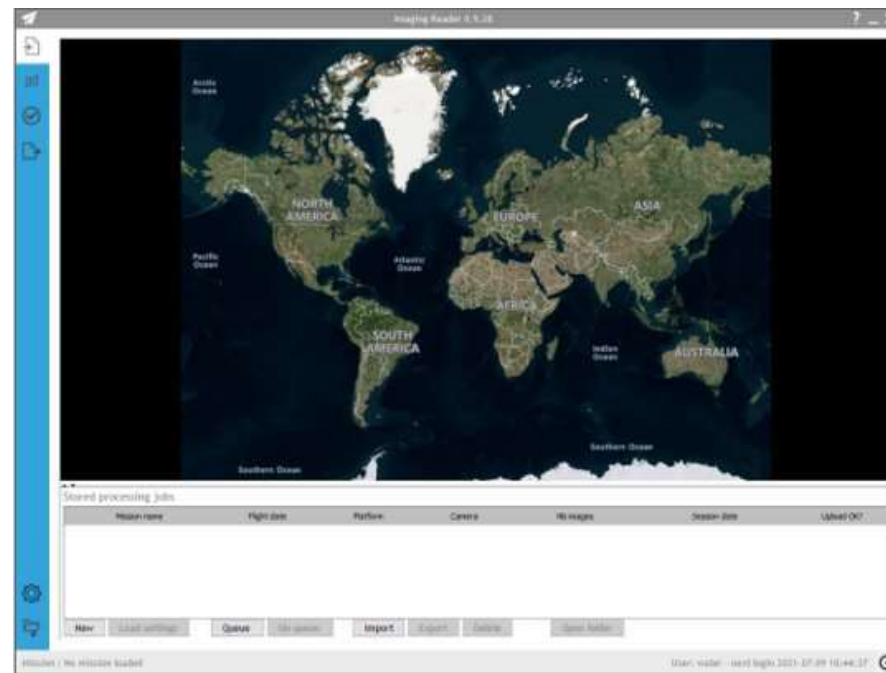
Data upload tool – Metadata



Location, name, ..

Sensor(s)

Relative height difference between take-off location and water level.

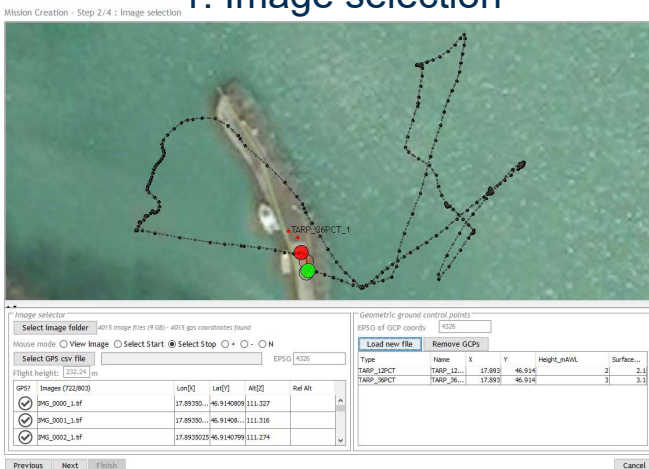




Data upload tool – Metadata



1. Image selection



2. Flight description

Imaging Reader 0.9.26

Mission Creation - Step 3/4 : Flight description

Flight

Date (yyyy/mm/dd) (*) 2019/07/03

Time (hh:mm) (*) 12:00:08

Location Balaton

Flight nb 4

Altitude Water level 109

Altitude take-off location 111

Flight description Some extra info about mission

Operator

Name op1

Email dominique.demundt@vito.be

Camera

INS type MICA

Camera type MSREM

Camera offset x (cm) 0

Camera offset y (cm) 0

Camera offset z (cm) 0

Camera angle x (°) 0

Camera angle y (°) 15

Camera angle z (°) 0

Irradiance sensor

Irradiance sensor type DLS-1

Irr. sensor vector coord x 0

Irr. sensor vector coord y 0

Irr. sensor vector coord z -1

Model (*) RedEdge-M

Serial

Serial Lens (*) RMD1-1817119-SC

Previous Next Finish

3. Product and processing options

Imaging Reader 0.9.26

Mission Creation - Step 4/4 : Product and processing options

Workflow type ☐ Predefined ☒ Remote config ☐ Local config file

Processing config: configBase.py

configBase.py

configNoEndProduct.py

Quality checks

Imaging Reader 0.9.26

Quality checks

All images have valid long/lat/alt coordinates? ☒

All images have non zero size? ☒

All images are taken within 1.0 hour? ☒

Processing It height remains constant within a range of 10.0 m? ☒ Min. altitude: 109.05m, Max. altitude: 238.3

All images have a valid shutter speed? ☒

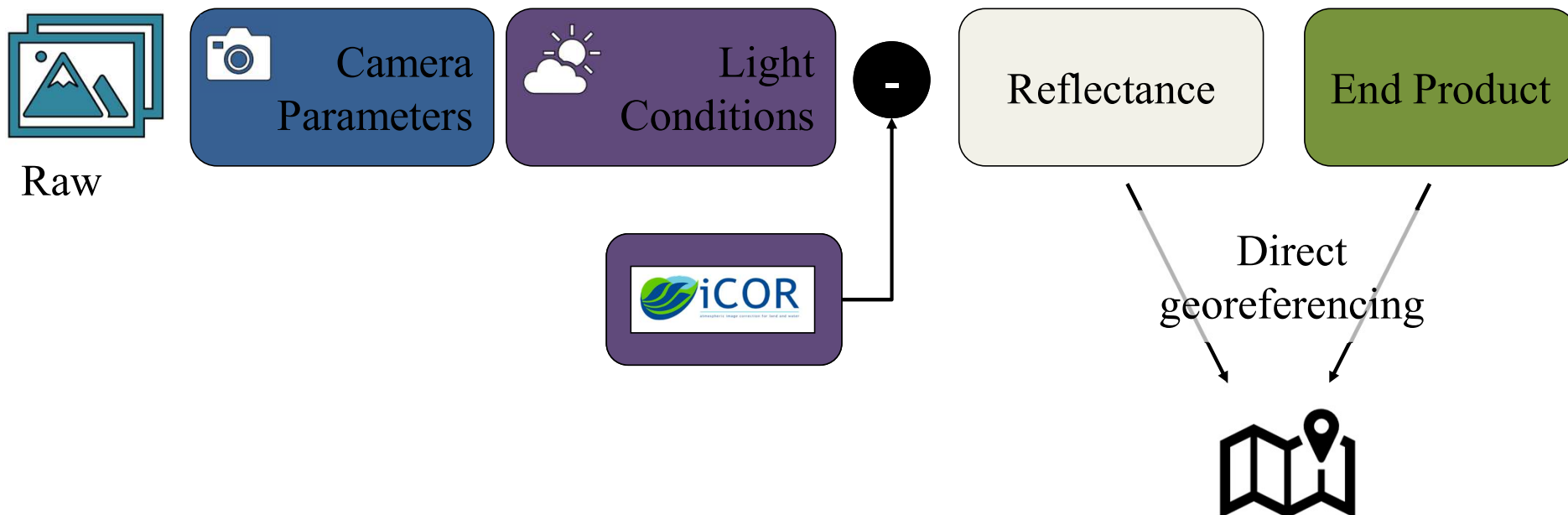
All images have a valid ISO? ☒

Nb of images with calibration panels: 0 ☒





Data Processing





Data Processing



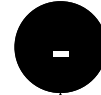
Raw



Camera
Parameters



Light
Conditions



Reflectance

End Product



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

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

Direct
georeferencing





Data Processing



Raw

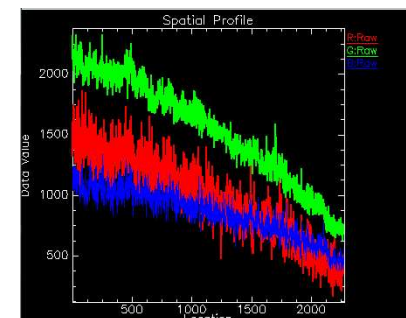


Camera
Parameters

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

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

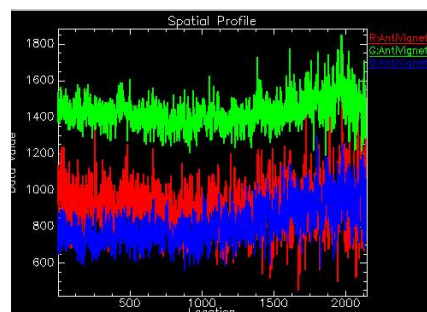
Uncorrected



Spectralon



Corrected





Data Processing

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



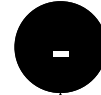
Raw



Camera
Parameters



Light
Conditions



Reflectance

End Product

Direct
georeferencing

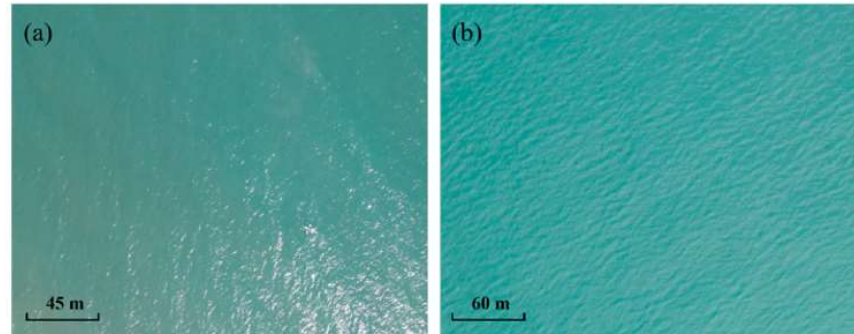
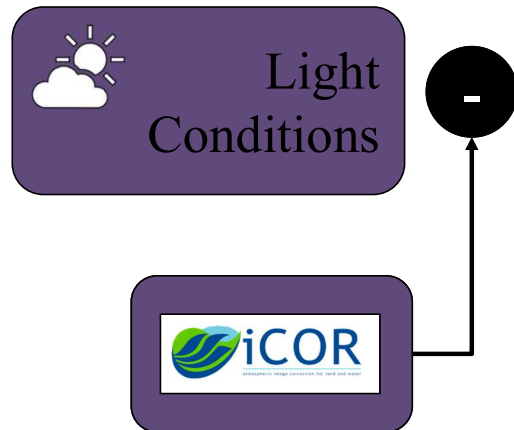




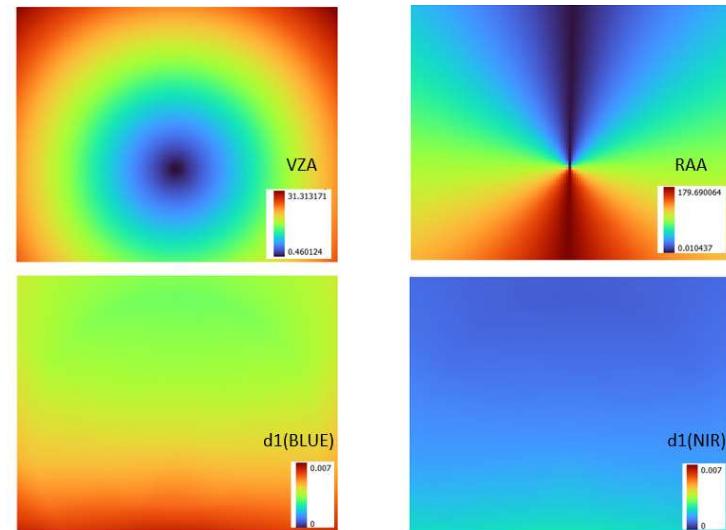
Data Processing

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]

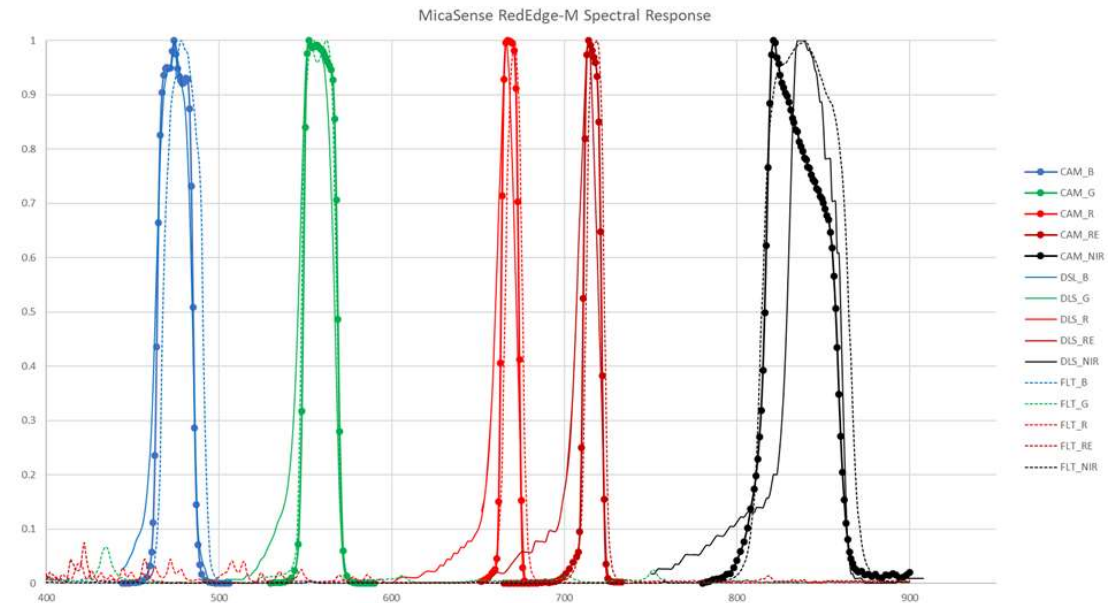
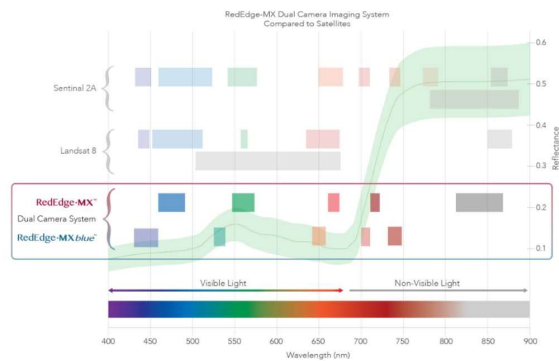


Sky glint correction with MAPEO-Water: View Zenith Angle (VZA), Relative Azimuth Angle (RAA).



Data processing

Spectral response curves



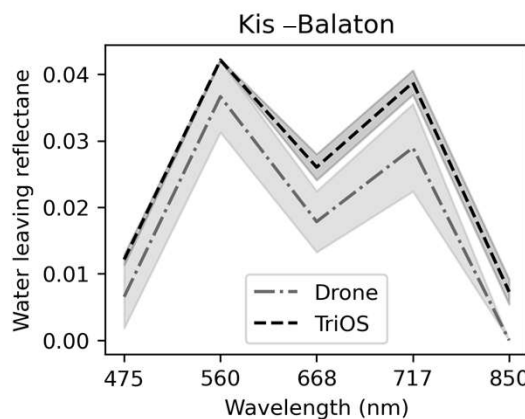
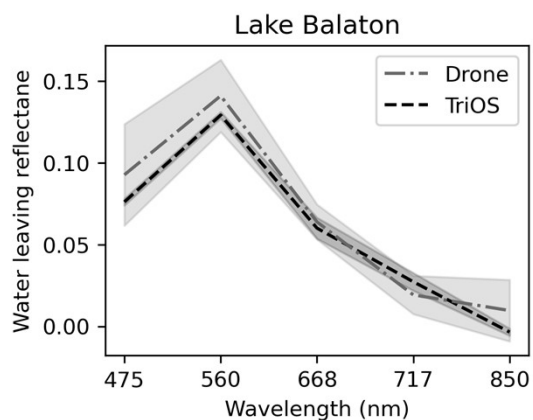
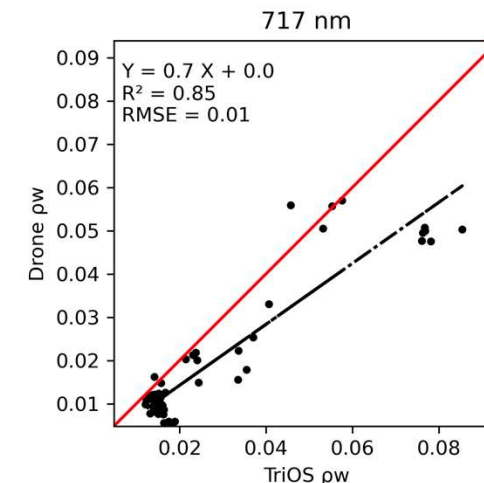
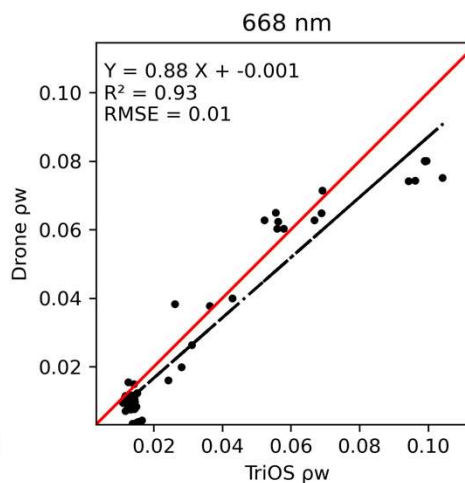
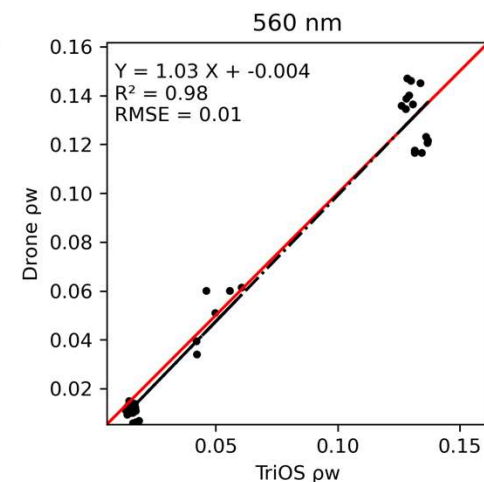
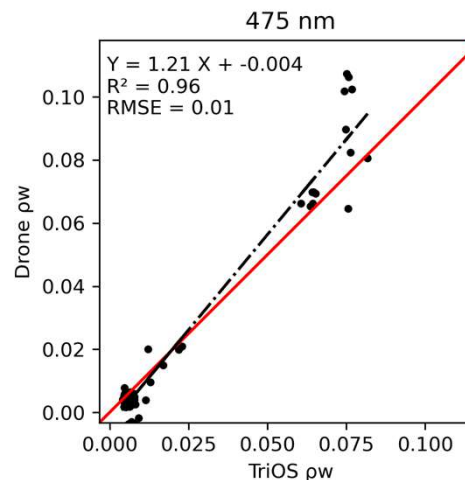
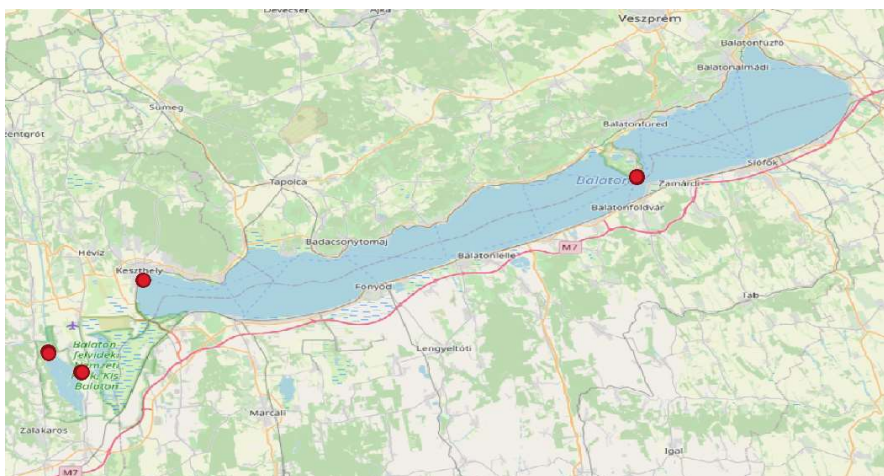
Characterization of the spectral response curves at NERC-FSF, 2018

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





Validation – Water-Leaving Reflectance





Data aggregation – Turbidity

Turbidity Mean

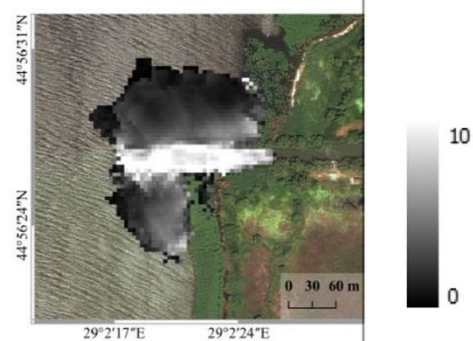
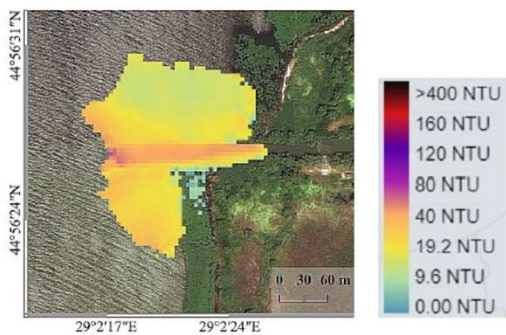
Turbidity Std

Rupelmondse Creek (BE)

Lake Marathon (GR)

Rupelmondse Creek (BE)

Lake Marathon (GR)

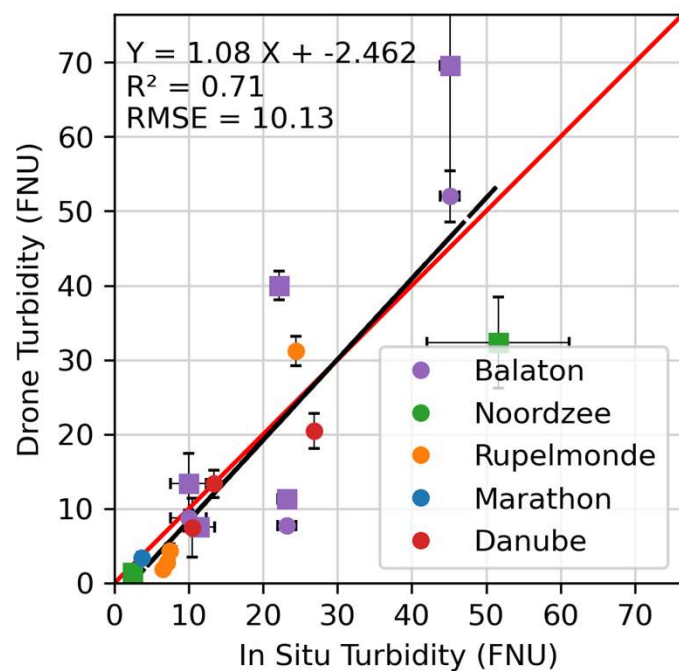


Danube Delta (RO)

Danube Delta (RO)

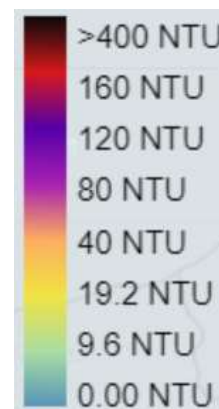
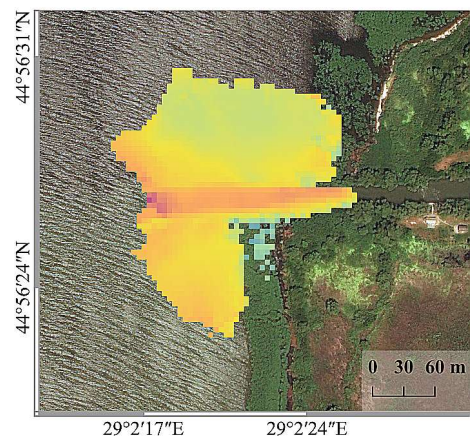
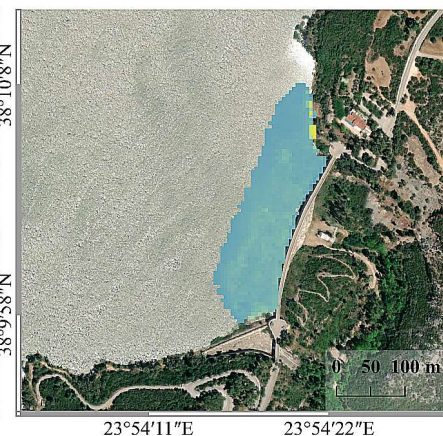
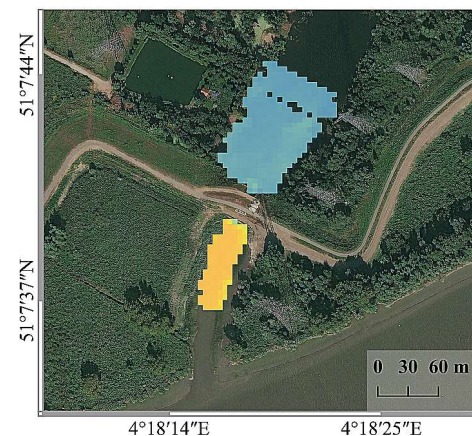


Validation – Turbidity



Rupelmondse Creek (BE)

Lake Marathon (GR)



Danube Delta (RO)





FAIR data & Metadata

GEOSJSON metadata standards

- Geometry info
- Data acquisition
- Data processing
- Processing workflow
- Platform
- Sensor

```
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  "type": "Feature",
  "id": "urn:eop:VITO:MONOCLE:20190703_Balaton_F01_MSREM_RGB_sub",
  "geometry": {
    "type": "Polygon",
    "coordinates": [
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          17.8904384133030270,
          46.8884476307194618
        ],
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          46.8890657799454544
        ],
        [
          17.8918135550530621,
          46.8884476307194618
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  },
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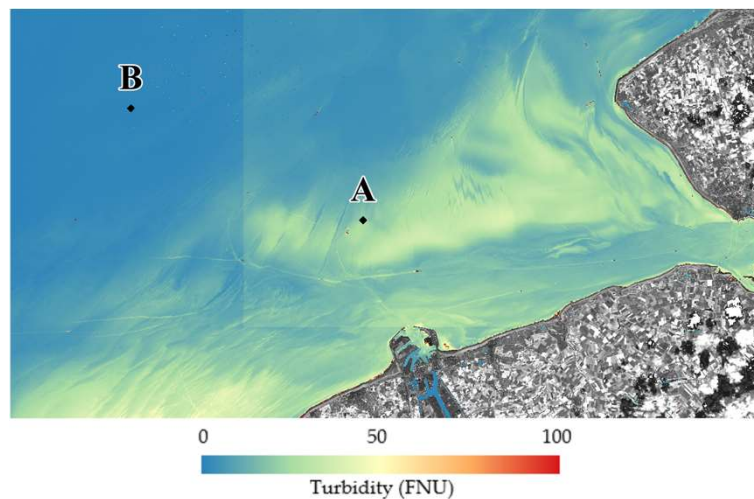
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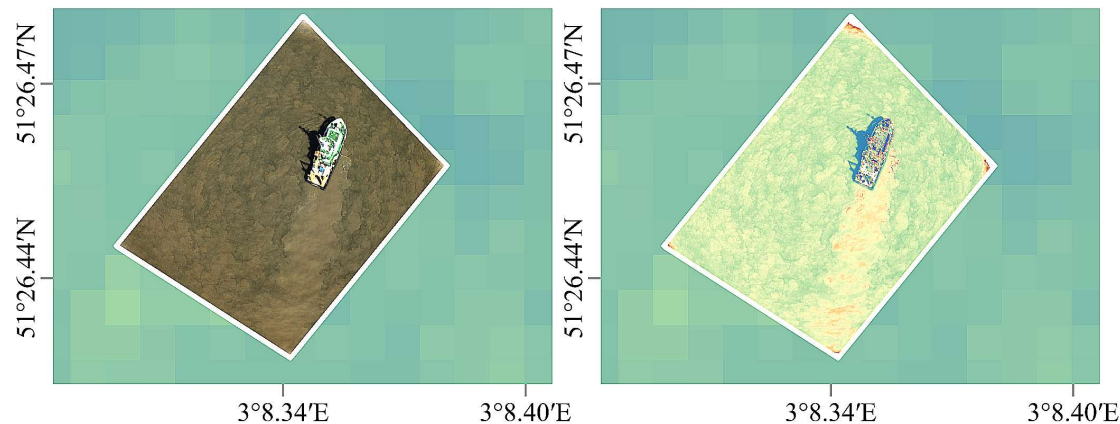
Drone data complementary to in situ data

10:59 UTC

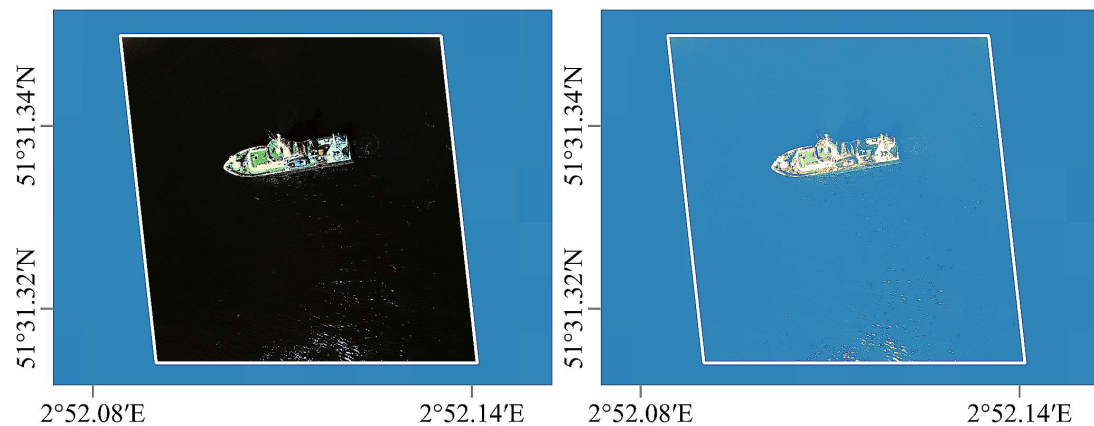


	Tur (FNU) - A	Tur (FNU) - B
S2	19–21	1.5
Drone	Plume: 40–60 Backgr: 30–40	0.5 – 5
IS	51.6 (40.7 – 58.6)	2.5

Location A - 10:05 UTC



Location B - 12:32 UTC





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Thank you

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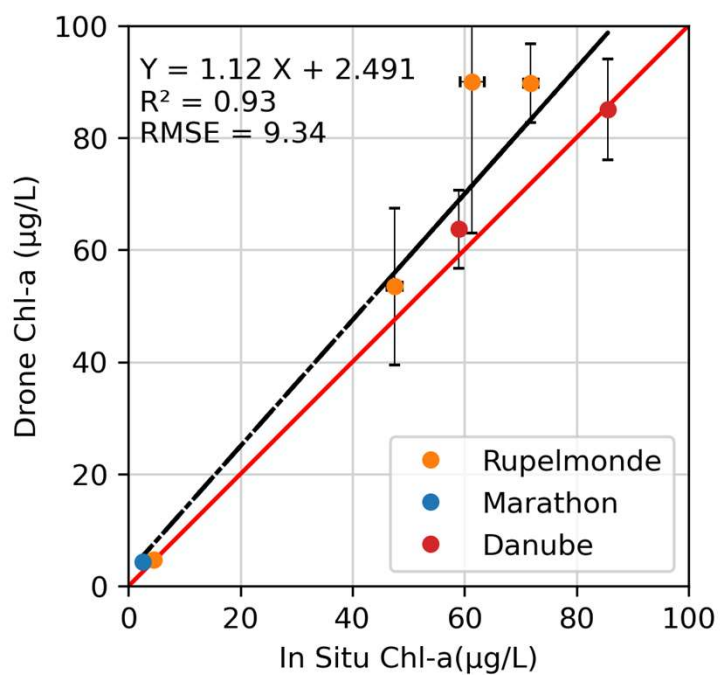


Challenges

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

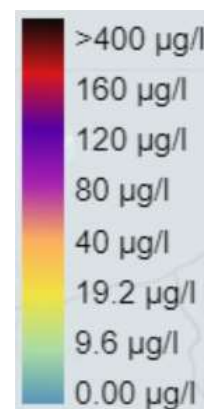
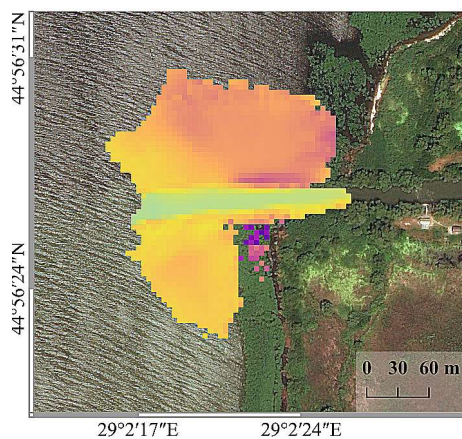
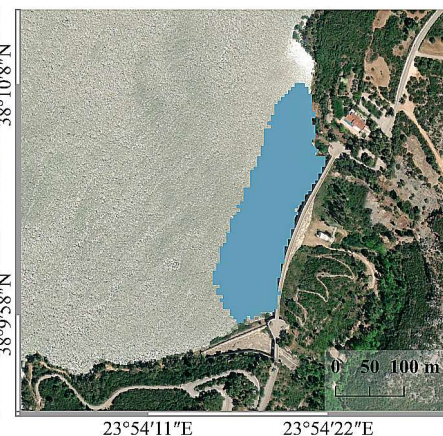
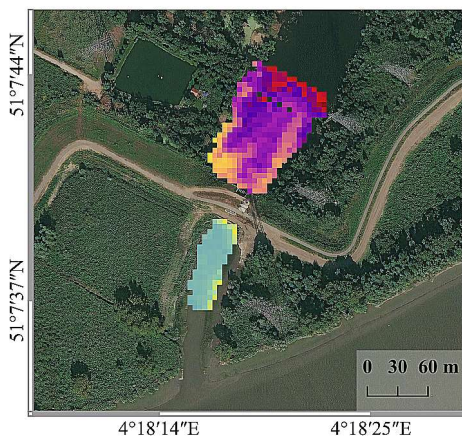


Validation – Chl-a



Rupelmondse Creek (BE)

Lake Marathon (GR)



Danube Delta (RO)



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.

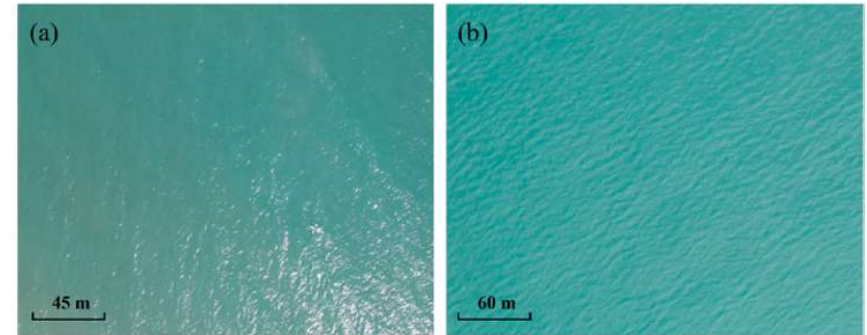


Figure 16. Figure illustrating difference between sun (a) and sky (b) glint in UAV images (source: Lee et al., 2025) [48]

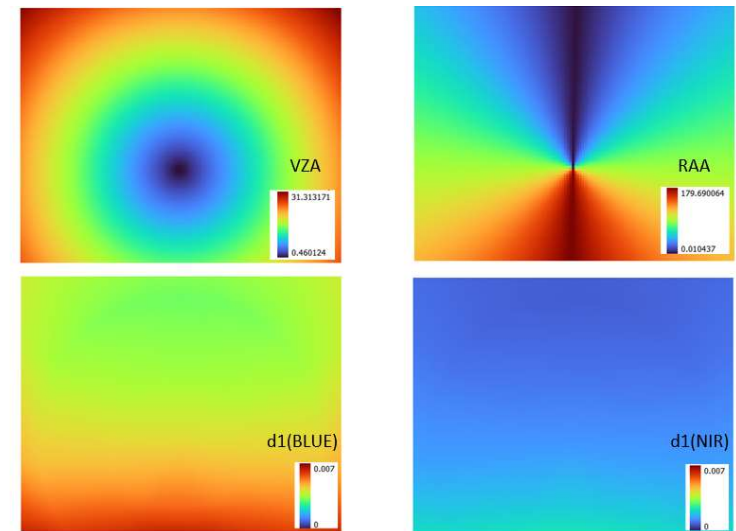


Figure 14. Sky glint correction with MAPEO-Water: View Zenith Angle (VZA); Relative Azimuth Angle (RAA); d1 for BLUE band with $d1 = \frac{\rho_{sky} L_{sky}(\lambda)}{E_d(\lambda)}$; d1 for NIR band