DTU

Tracer test to investigate the dilution of a contaminant plume in Mølleåen at Raadvad

UAV Tracer Test

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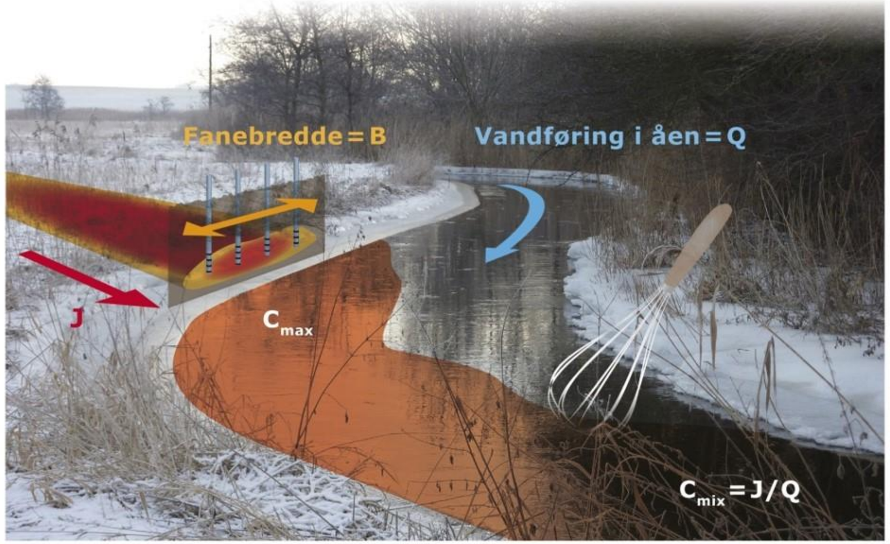
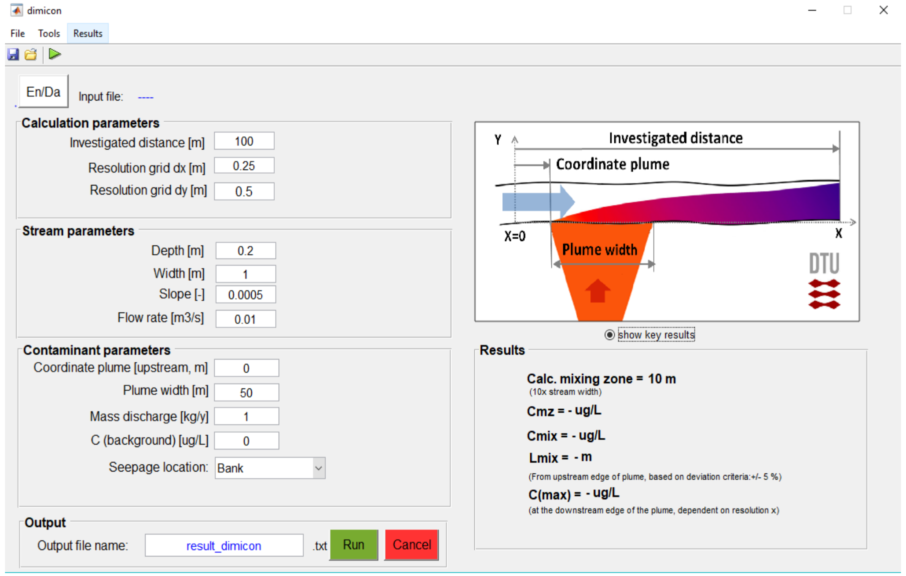
Importance of mixing in streams for contaminated sites



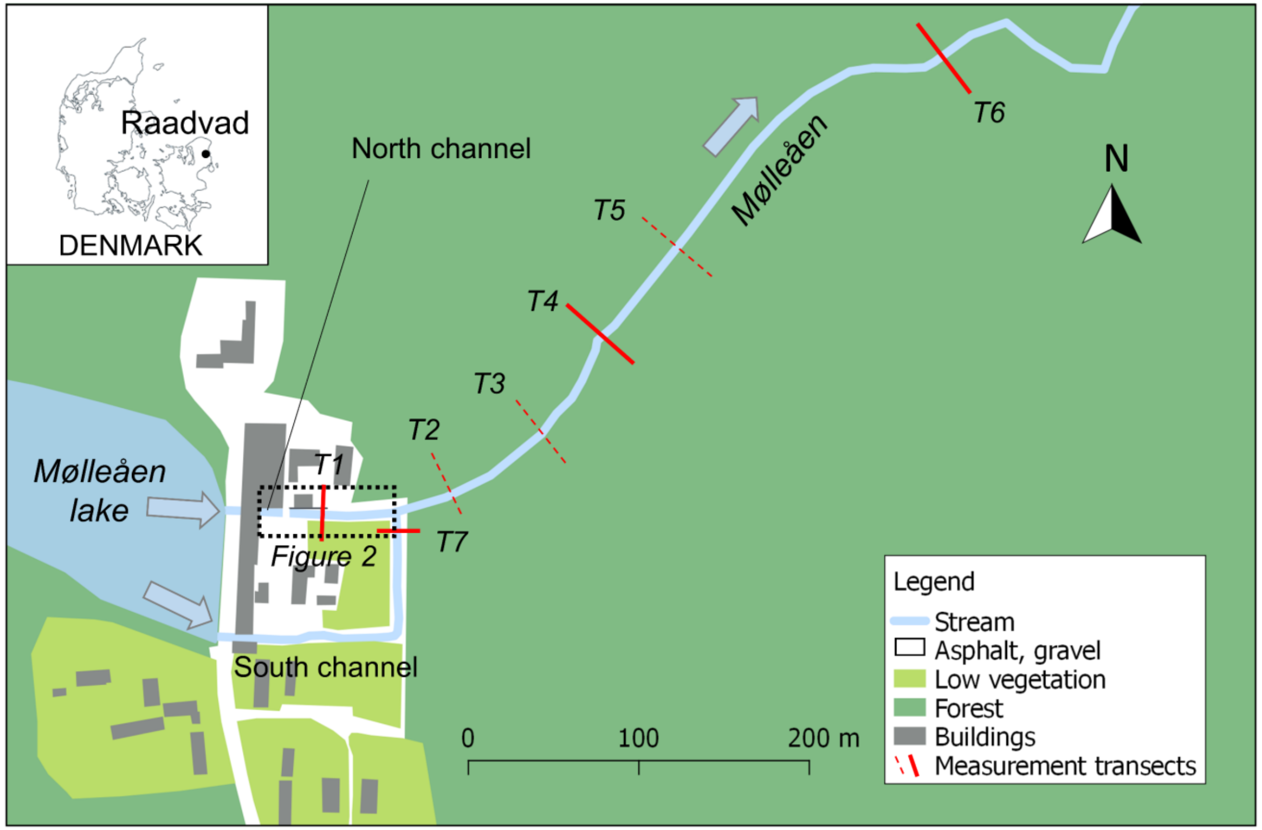
- Lateral mixing in streams is a key process determining dilution and impact of contaminants, e.g. contaminated groundwater seeping into streams
- It would be useful to directly observe lateral mixing in streams at sites of interest
- Idea: Inject a tracer with a distinct spectral fingerprint (Rhodamine WT) into the stream and observe the spreading/mixing with hyperspectral imagery from drones



- Novelty and impacts
  - Novel drone method
  - New knowledge about mixing processes in streams
  - Investigations at contaminated sites
  - Application of mixing models
  - Management of contaminated sites

Field Site

- Old Raadvad knife factory
- Pollution with:
  - chlorinated aliphatic hydrocarbons
  - petroleum hydrocarbons
  - heavy metals
  - Oil
- Complicated flow
- Injection of conservative tracer to simulate contaminant mixing



Lemaire, G.G., McKnight, U.S., Schulz, H., Roost, S., Bjerg, P.L., 2020. Evidence of Spatio-Temporal Variations in Contaminants Discharging to a Peri-Urban Stream. Groundw. Monit. Remediat. 40, 40–51.

Permission for using Tracer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Assessing the aquatic toxicity and environmental safety of tracer compounds Rhodamine B and Rhodamine WT

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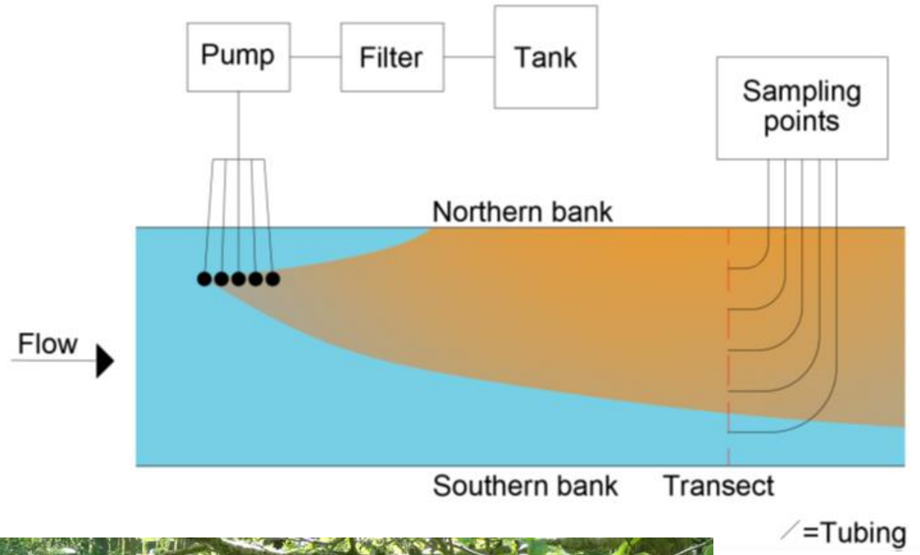
- Advantages of Rhodamine WT:
  - Conservative
  - Low Photolysis
  - Extensive use in literature
  - Assumed low eco-toxicity
  - Low concentrations highly visible
  - Fluorescence
- Problem: Eco-toxicity not documented in scientific literature, MST could not give permission
- Ecotox Tests on all trophic levels at DTU and Scientific Publication
- Rhodamine WT has a lower eco-toxicity than most common tracers
- For the future tracer injection permissions should be easy

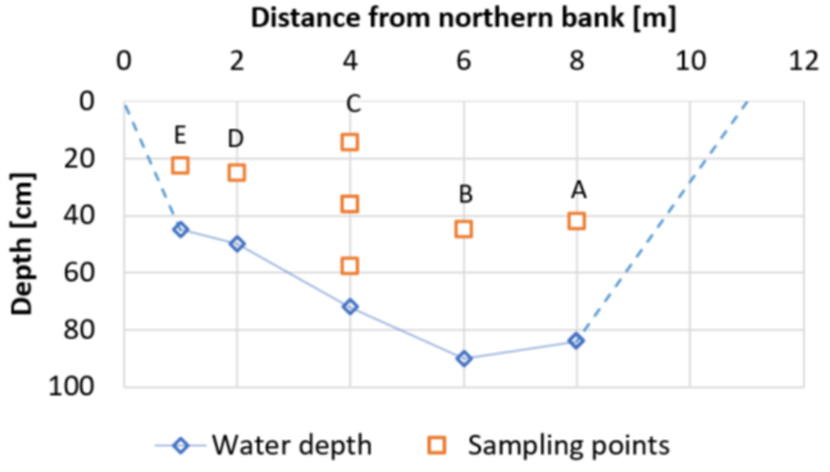
Experimental plan - Injection

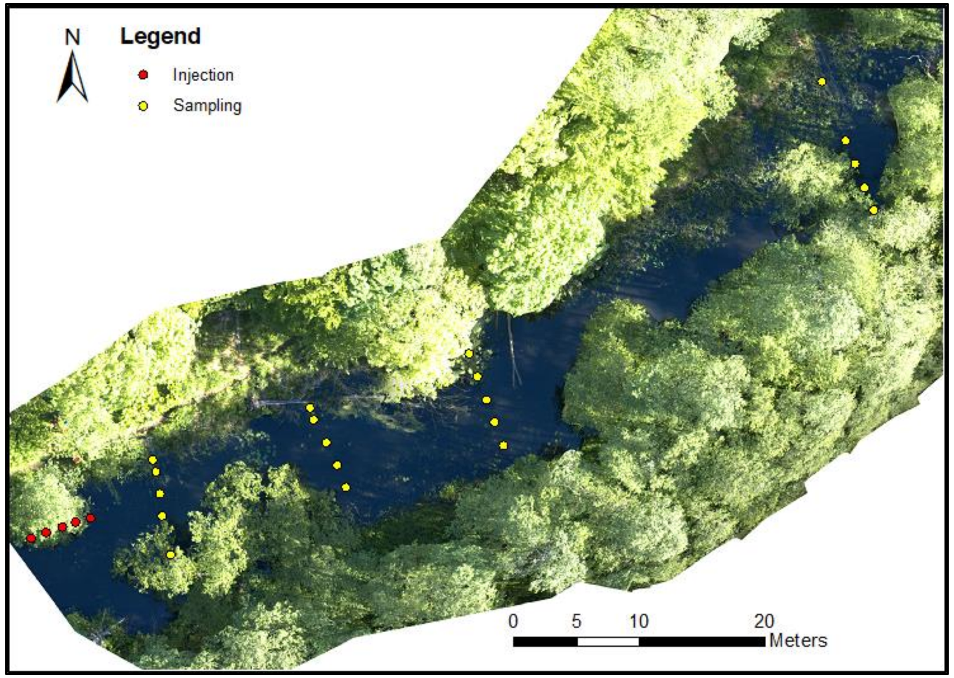
- 5 injection points
- Length 5m
- Aim: c steady state 5µg/L

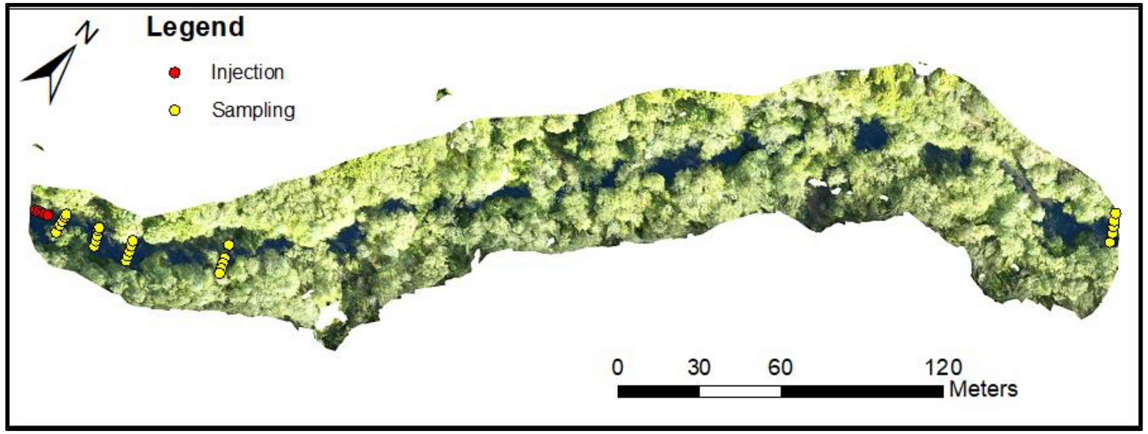


Experimental plan – in-situ measurements

- 5 cross sections
- 5 points per cross section
- 2 cross sections with additional vertical points
- 3 sampling rounds

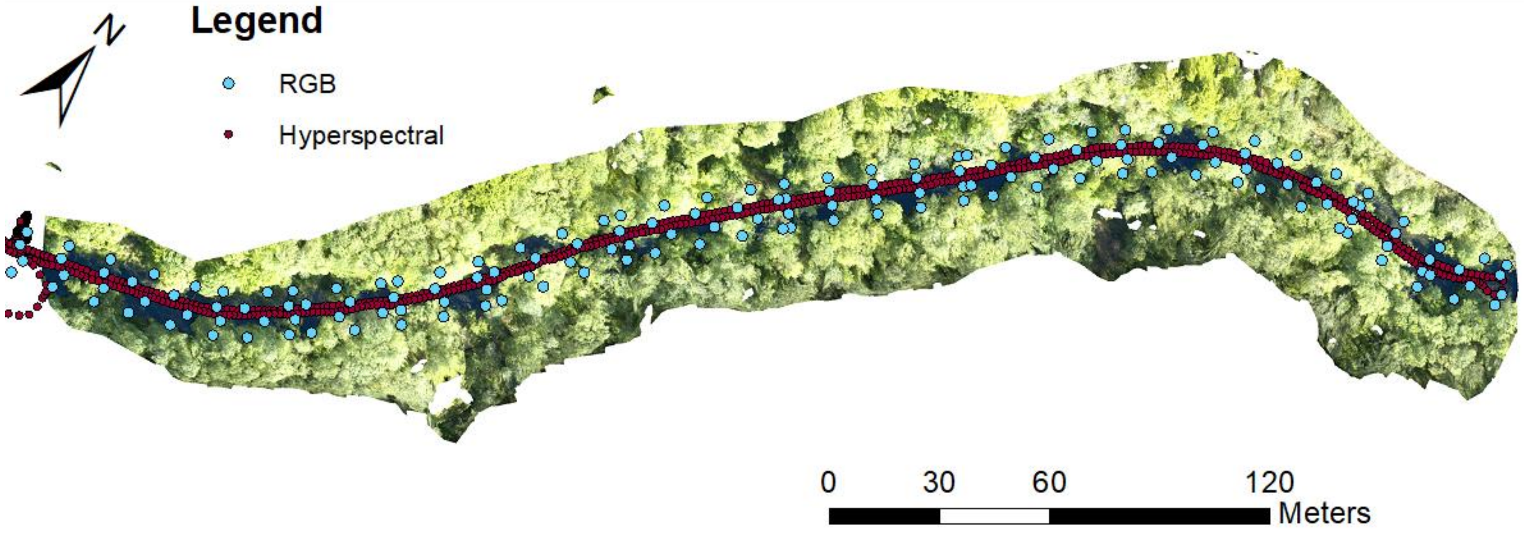


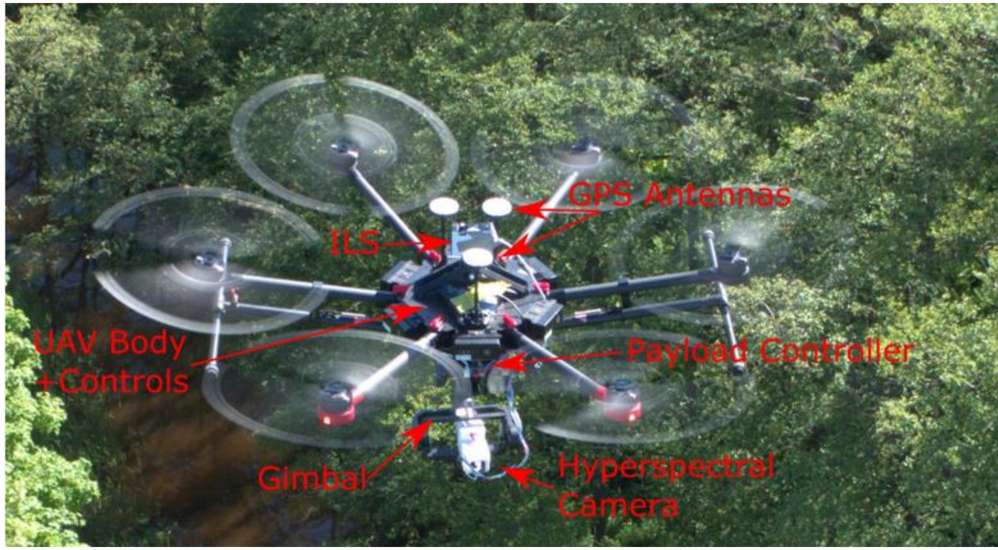




UAV flights

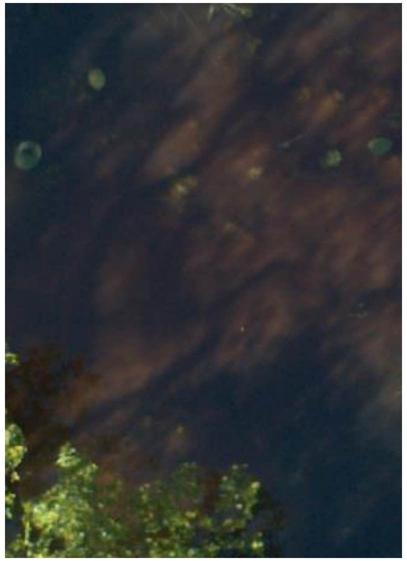
- Two different Drone set ups:
  - Simple consumer drone with photo camera
  - Commercial drone with calibrated hyperspectral camera and incoming light sensor

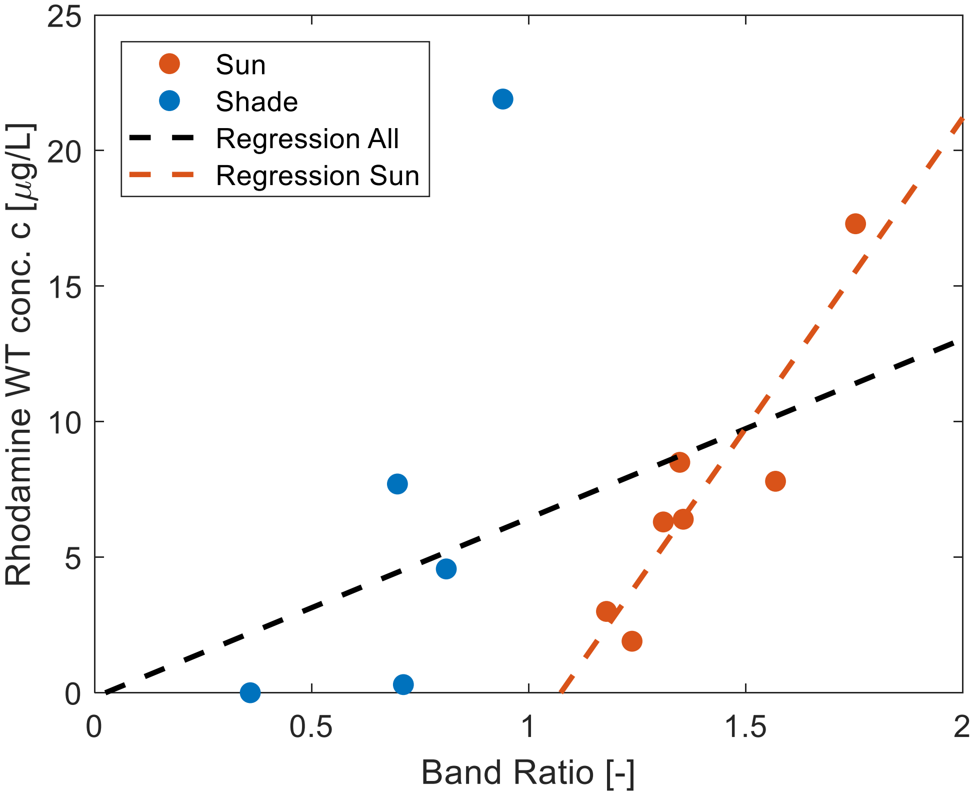




Rhodamine WT concentration from Photo Camera

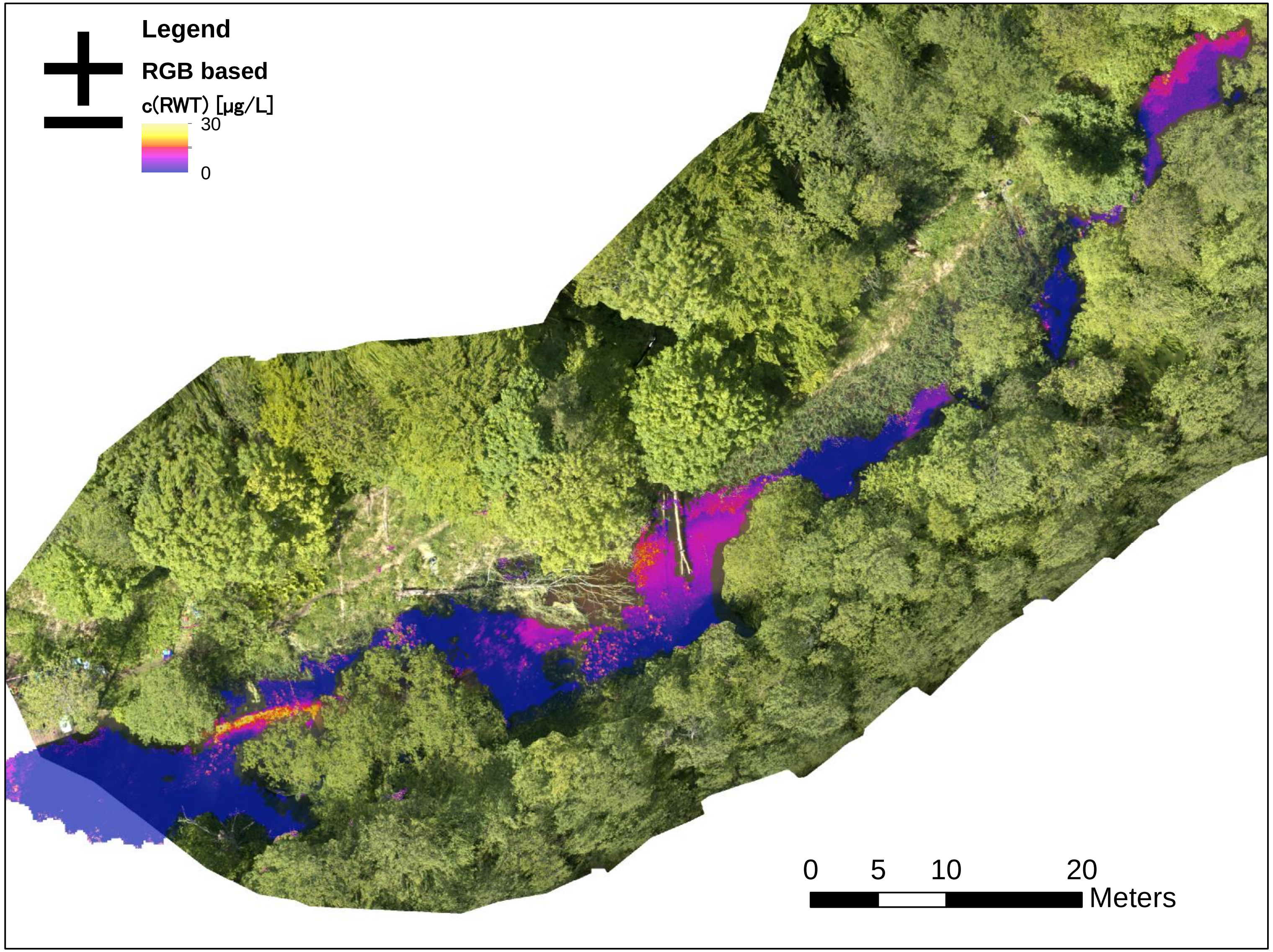
- Using band ratio: Red/Blue
- Calibration to in-situ points
- Only works in sunny conditions





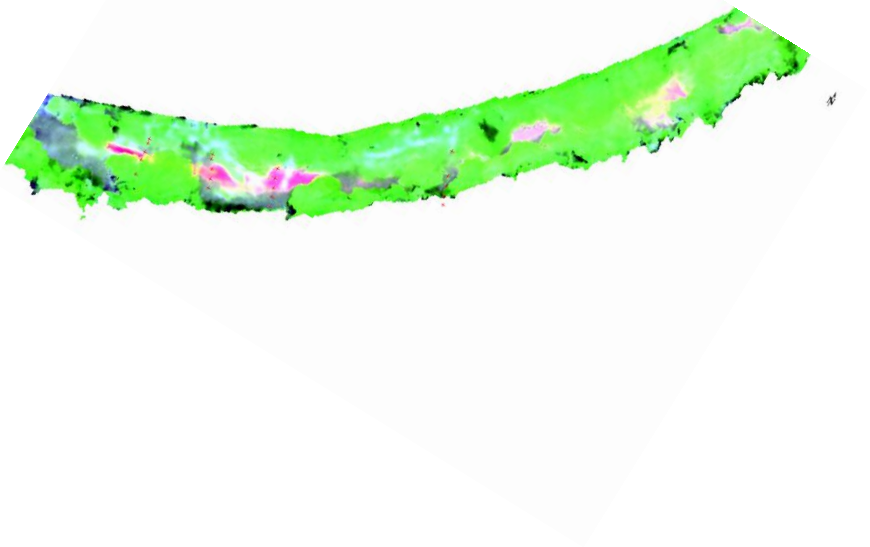
	nRMSE	RMSE	R^2
All points	28.7 %	6.3 μg/L	0.17
Sunny points	10.2 %	2.2 μg/L	0.83

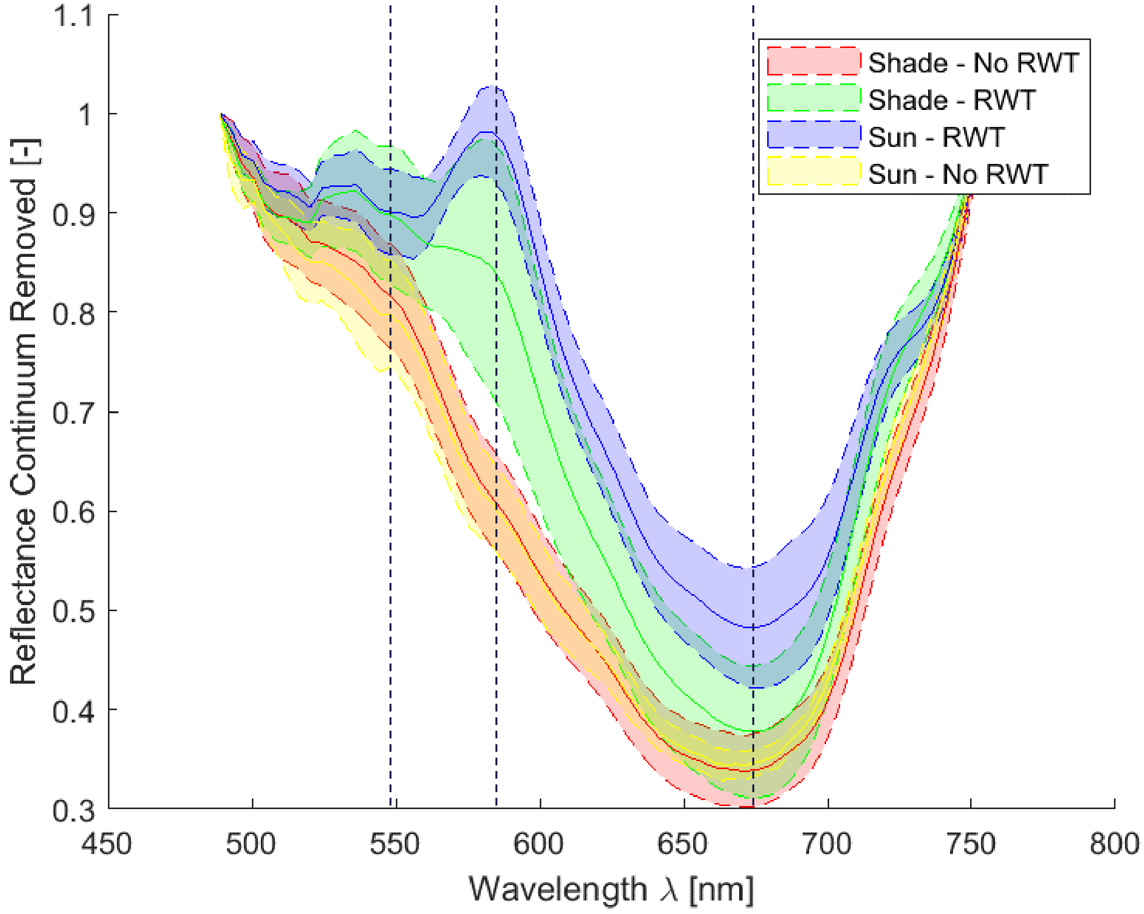
Rhodamine WT concentration from RGB



Rhodamine WT concentration from hyperspectral data

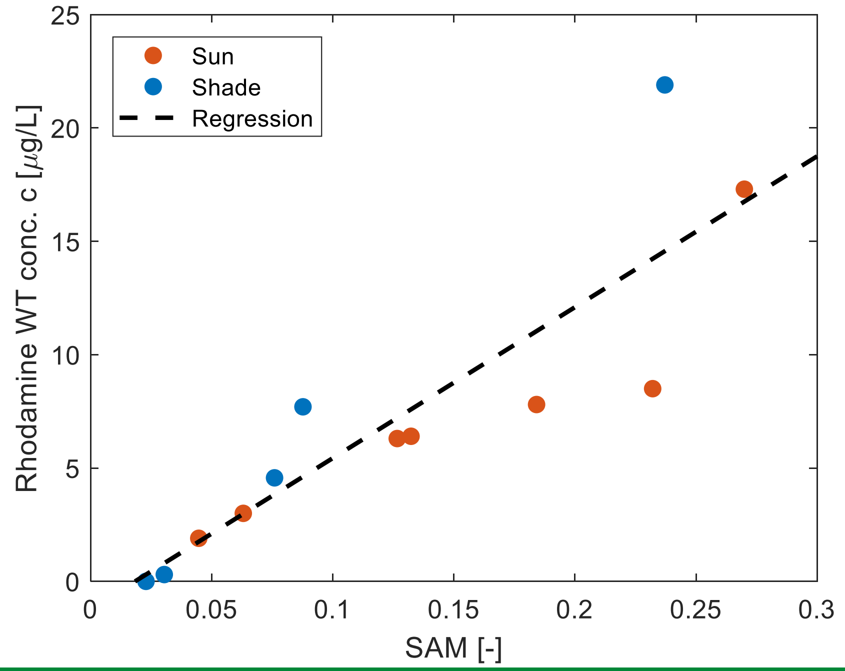
- Normalizing the data:
  – Using bands 10 – 80 (482 nm – 752 nm)
  – Continuum removal
- Characteristic wavelengths:
  – 548 nm; 587 nm; 680 nm



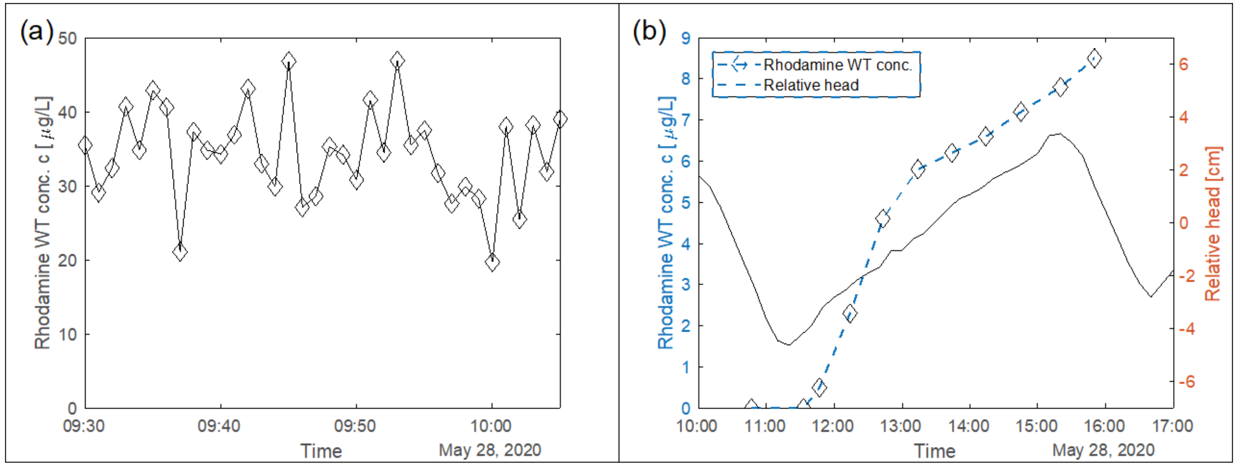


Spectral Angle Mapper (SAM) approach

- Choose relevant wavelengths
- Extract Spectrum of water – no RWT
- Calculate Spectral Angle of each pixel to reference
- Linear regression between angle and RWT conc.
- Some uncertainty caused by matching in-situ data to drone data



In-situ data: tracer concentration over time

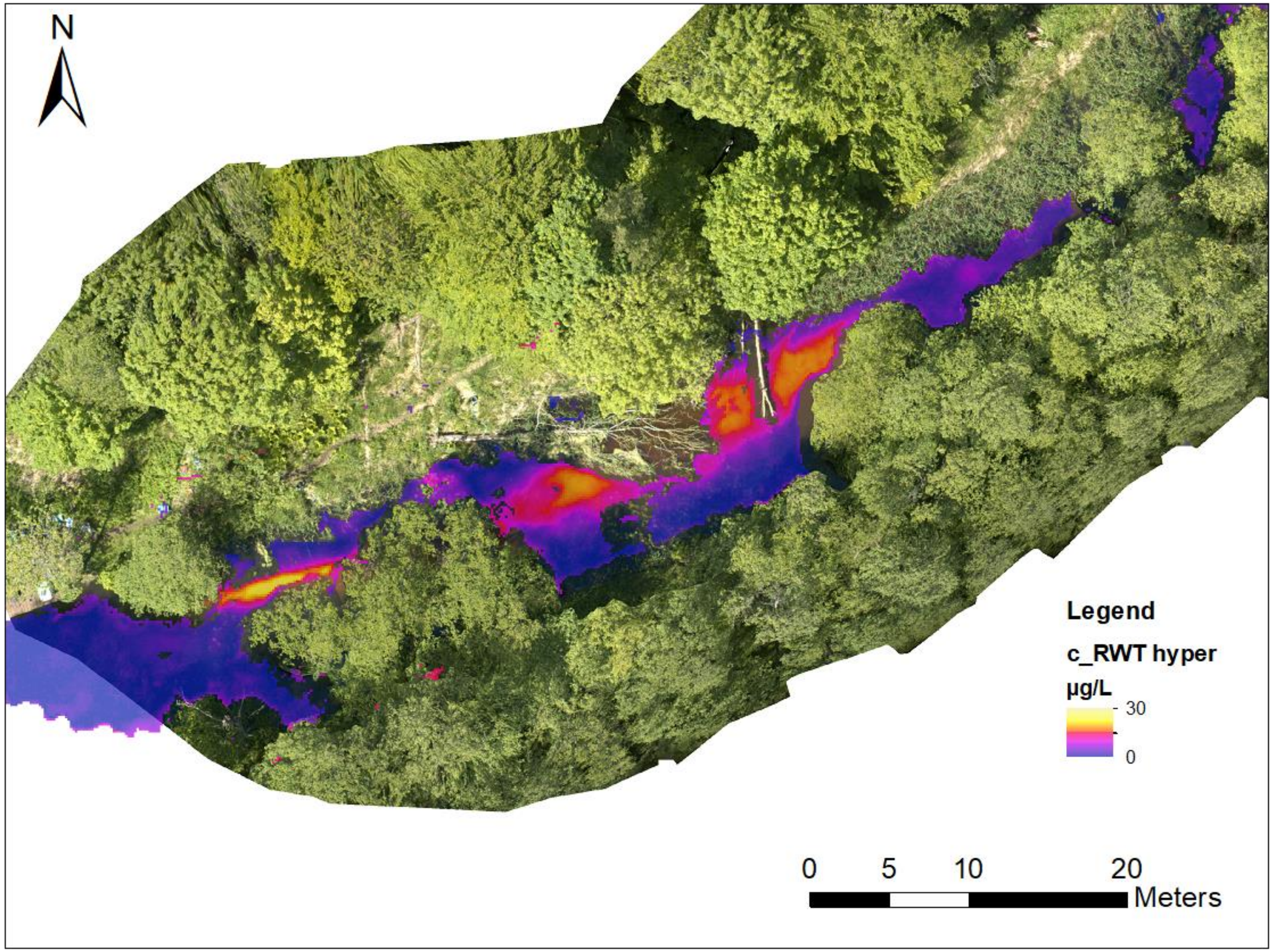


Close to injection

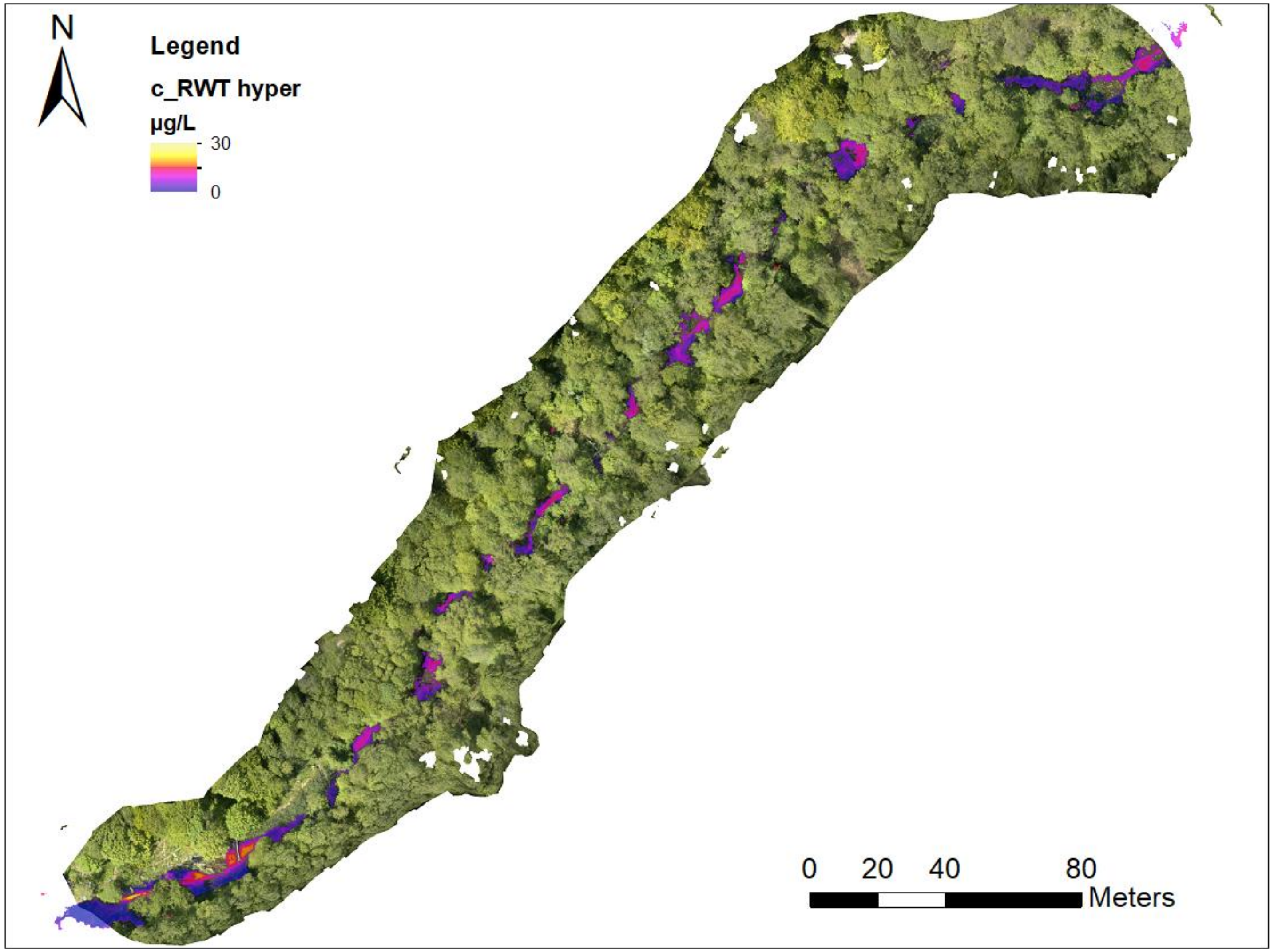
400 m downstream

	nRMSE	RMSE	R^2
All points	15.1 %	3.32 µg/L	0.76

Rhodamine WT concentration from Hyperspectral



Rhodamine WT concentration from Hyperspectral



RGB camera versus hyperspectral camera

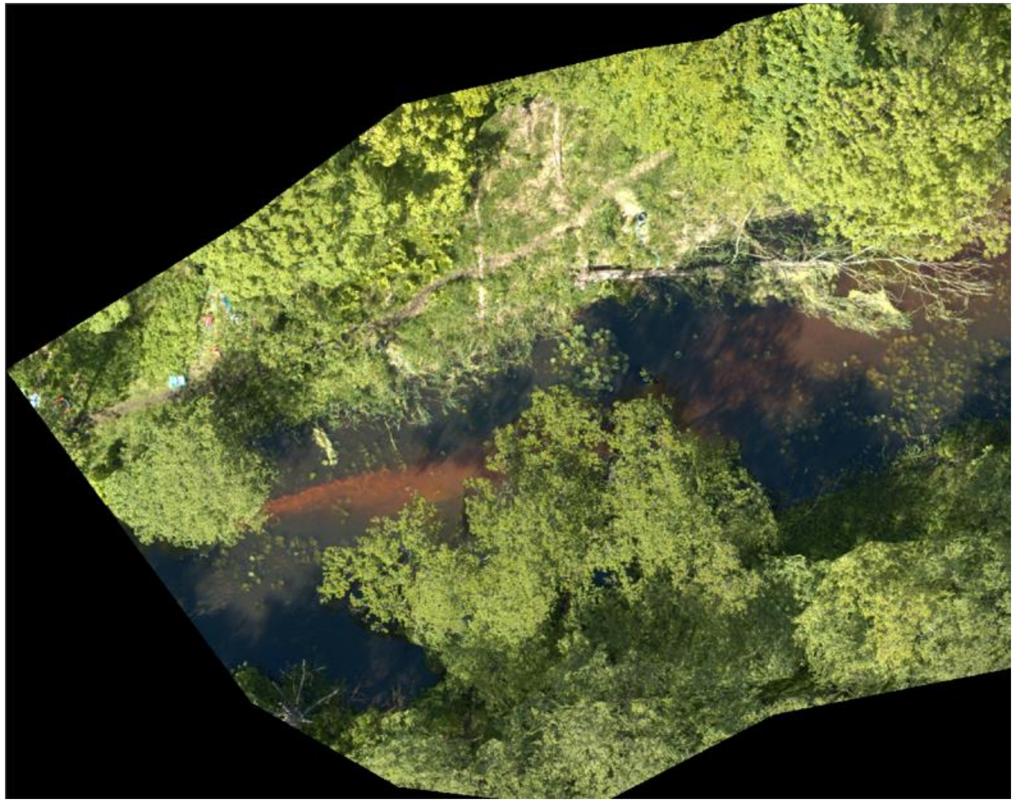
	RGB	Hyperspectral
Stream conditions	Sunny, no macrophytes	All conditions
Weather conditions	Constant sunny or constant cloudy, no rain	No rain
Price	Cheap (12 000 DKK)	Expensive (450 000 DKK)
Who can collect data (fly)	Anyone	Trained operator (e.g. Drone Systems, DTU)
Data processing	Commercial software (Agisoft + Gis software)	Commercial software + specialized computer scripts (DTU)
Ready to use	Off the shelve	After calibration in laboratory (manufacturer calibration available)

Conclusions

- Success in estimating Rhodamine WT concentration in streams from UAV
- Hyperspectral camera performs well under all conditions
- RGB camera cheap and easy
- Direct visualization and quantification of mixing processes
- Quantification requires in-situ measurements, Qualitative analysis can be done without
- Possible screening tool for key polluted sites (Investigation of complex mixing patterns)
- Enables validation/optimization of pollution transport models

”Removing trees” in RGB maps – taking advantage of large FOV and shifted flight lines

- Agisoft ortho-mosaic



- ”Trees removed” ortho-mosaic