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In-situ hyperspectral and fluorescence methods compared with remote sensing Sentinel-2 satellite data for mapping chlorophyll-a/cyanobacteria concentrations

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The INXCES Project

Climate change accentuates heat waves in The Netherlands. This, in combination with high nutrient concentrations in Dutch surface waters, is intensifying the proliferation of toxic blue-green algae (cyanobacteria), a threat for the health of the population and ecosystems. Lakes are resources for recreational activities, such as bathing, sailing and fishing. Dutch water managers struggle with lack of high spatial resolution information and updated/real-time alarm systems. Algal concentration data and its spatial distribution is important to support and calibrate (early warning) forecasting models.

This study focuses on collecting and comparing simultaneous in-situ and remote sensing data of chlorophyll-a and phycocyanin, and assessing the suitability of each method to characterize spatial (and with depth) variations of algae concentrations. The in-situ measurements were performed using a portable water quality spectrometer (WISP-3) and a hand-held fluorescence algae sensor (TriLux). Remote-sensing data was derived from Sentinel-2 multi-spectral earth observation satellite using existing algorithms (WISP-3 measurements were used to force atmospheric corrections). The data collection campaigns took place during overpasses of the satellite and when days were cloud-free, and between 10am and 15pm.The spatial variations of algal concentrations were investigated using autonomous unmanned vehicles equipped with the algae sensor to perform depth profiles and multiple transects along the canals and the lake. The study sites for this research were Lake Paterswoldsemeer and its main tributary channels. This region is managed by the Water Authority Noorderzijlvest that was also involved in this monitoring campaign.

The depth profiles measured with the algae sensor showed some variation, with the algal concentrations increasing with depth to a maximum value a few centimeters from the surface, and then decreasing to a stable concentration at higher water depths. Sentinel-2 data showed variations in the cross sections of the channels that were not detected by the in-situ methods. The deviating values near the margins indicate that surrounding land and trees/buildings influence pixel values. Finally, considering the different results obtained with different methods, additional laboratory validation measurements should be conducted for verification in future campaigns.

The collected data is now being incorporated in the calibration of algae forecasting models that are currently being developed and applied in this region and up-scaled to many projects in the world. Output from these models provides crucial information for decision-making on adequate measures and actions to address the problem of harmful algal blooms.

Acknowledgements: Funding: European Union's Horizon 2020 research and innovation programme (EOMORES, n°730066), Noorderzijlvest, and Interreg WaterCoG (water-Co-Governance) and JPI Water funded project INXCES

Comparing in-situ hyperspectral and fluorescence methods with remote sensing Sentinel-2 satellite data for mapping chlorophyll-a/cyanobacteria concentrations

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1. Introduction

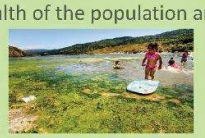
Lakes and canals in The Netherlands: resources for recreational activities, such as bathing, sailing and fishing.

Climate change: accentuation of heat waves

High nutrient concentrations in Dutch surface waters

Proliferation of toxic blue-green algae (cyanobacteria)

Threat for the health of the population and ecosystems.



Spatial distribution is important to support and calibrate (early warning) forecasting models:

- Accurate monitoring needed
- Strict regulations and standards to comply with (EWFD)
- Monitoring programs lack detailed spatial data
- Data needed to support early detection and quick action systems

2. Methodology

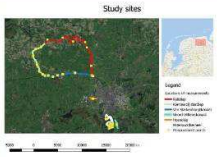
Simultaneous collection of in-situ and remote sensing data of chlorophyll-a and phycocyanin:

- Portable water quality spectrometer (WISP-3)
- Hand-held fluorescence algae sensor (TriLux)
- Remote-sensing data derived from Sentinel-2 multi-spectral earth observation satellite

The spatial variations of algal concentrations were also investigated in-situ using autonomous unmanned vehicles equipped with algae sensor, including depth profiles / transects along the canals and the lake.

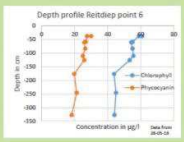
Data collection campaigns during overpasses of the satellite in cloud-free days.

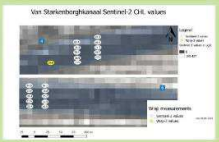
The study site for this research was the Lake Paterswoldsemeer and its main tributary channels.



3. Results

The depth profiles measured with the algae sensor equipped on an underwater drone showed that the top layer of a few centimetres show an increase of concentration, and then it decreases with depth to a stable algal concentration.





Sentinel-2 data showed variations in the cross sections of the channels that were not detected by the in-situ methods. The deviating values near the margins indicate that surrounding land and trees/buildings influence pixel values.

Table 2 CHL comparison channels

Parameter	Method	Reitdiep		Kommerzijlsterdiep		Van Starkenborghkanaal		Average
point		4	6	1	3	4	7	
CHL in µg/l	WISP-3	60.6	25.4	20.9	22.9	18.6	18.2	27.8
	Sentinel-2	30.7	21.7	28.9	28.8	17.5	14.3	23.7
	Algae sensor	151	46	42	51	30	27	67.7
Difference in %	Sentinel/ WISP	50.7	85.4	138.3	125.8	94.1	78.6	95.5
	Algae sensor/ WISP	249.2	177.2	201	222.7	161.3	148.4	193.3

Table 3 CPC comparison channels

Parameter	Method	Reitdiep		Kommerzijlsterdiep		Van Starkenborghkanaal		Average
point		4	6	1	2	4	7	
CPC in µg/l	WISP-3	65.8	47.6	43.8	43.4	58.8	62.7	53.9
	Algae sensor	62	20	29	25	10	10	24.6
Difference in %	Algae sensor/ WISP	94.2	42	45.7	57.6	16.7	15.9	45.4

Considering the different results obtained with different methods, additional laboratory validation measurements should be conducted for verification in future campaigns.

5. Follow-up research

- The collected data is now being incorporated in the calibration of algae forecasting models
- These models are being applied in the Netherlands and being up-scaled to many projects in the world.
- Output from these models provides crucial information for decision-making on adequate measures and actions to address the problem of harmful algal blooms.

Funding

EOMORES

European Union's Horizon 2020 research and innovation programme (EOMORES, n°730066),

Waterschap Noorderzijlvest

interreg North Sea Region WaterCoG

Water Insight

INNOVATIVE DYNAMIC MONITORING