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Cyanobacteria detection with Sentinel 2 MSI

How to use machine learning to detect cyanobacteria risks in inland waters

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Importance of Cyanobacteria Detection

- Potentially harmful cyanobacteria
  - Affect freshwater and coastal ecosystems
  - Health impact
  - Relevant for recreational activities
- Assessing and monitoring water quality
  - Monitoring of lakes for local authorities
  - Potential indicator for climate change

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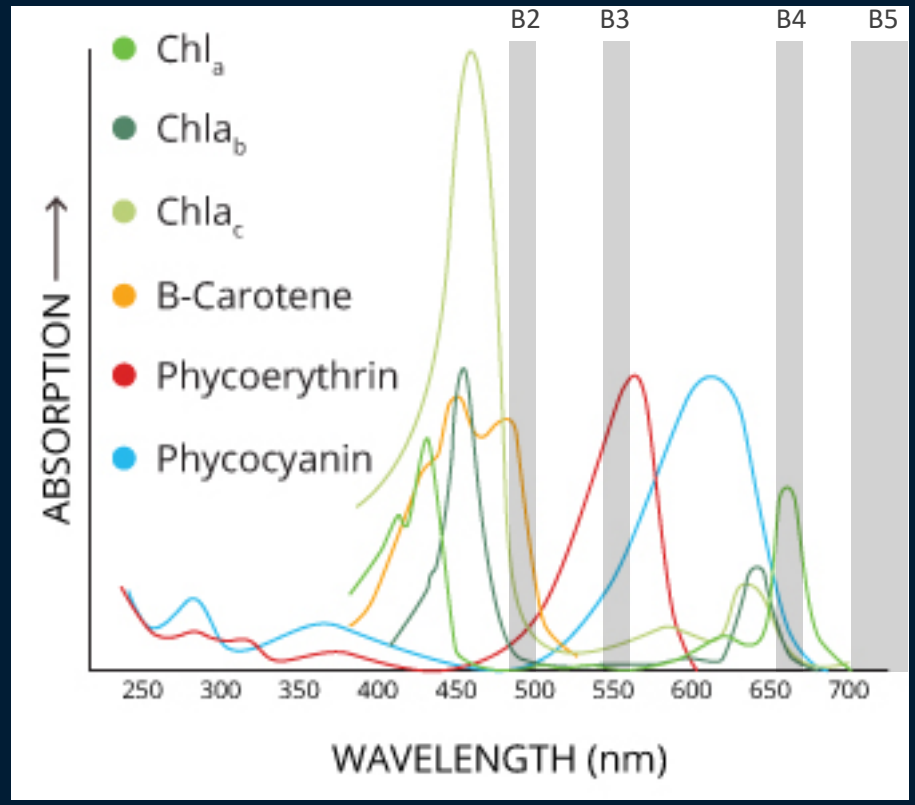
Earth Observation for Cyano Detection

- Various publications and algorithms address immersed and floating cyano detection[1]
  - Phycocyanin detection, cell counts, abundances
  - Based on water colour sensors with respective bands at absorption features
  - Spatial resolution of medium resolution water colour sensors not sufficient for small inland waters

- S2 MSI proven to be a valuable sensor for monitoring smaller inland waters bodies
  - cyano absorption features not covered with channels



[1] Kutser 2004,2009, Kahru et al. 2007, Simis et al. 2005, Alikas et al 2010, Matthews et al. 2012, Lunetta et al. 2014

Methodology

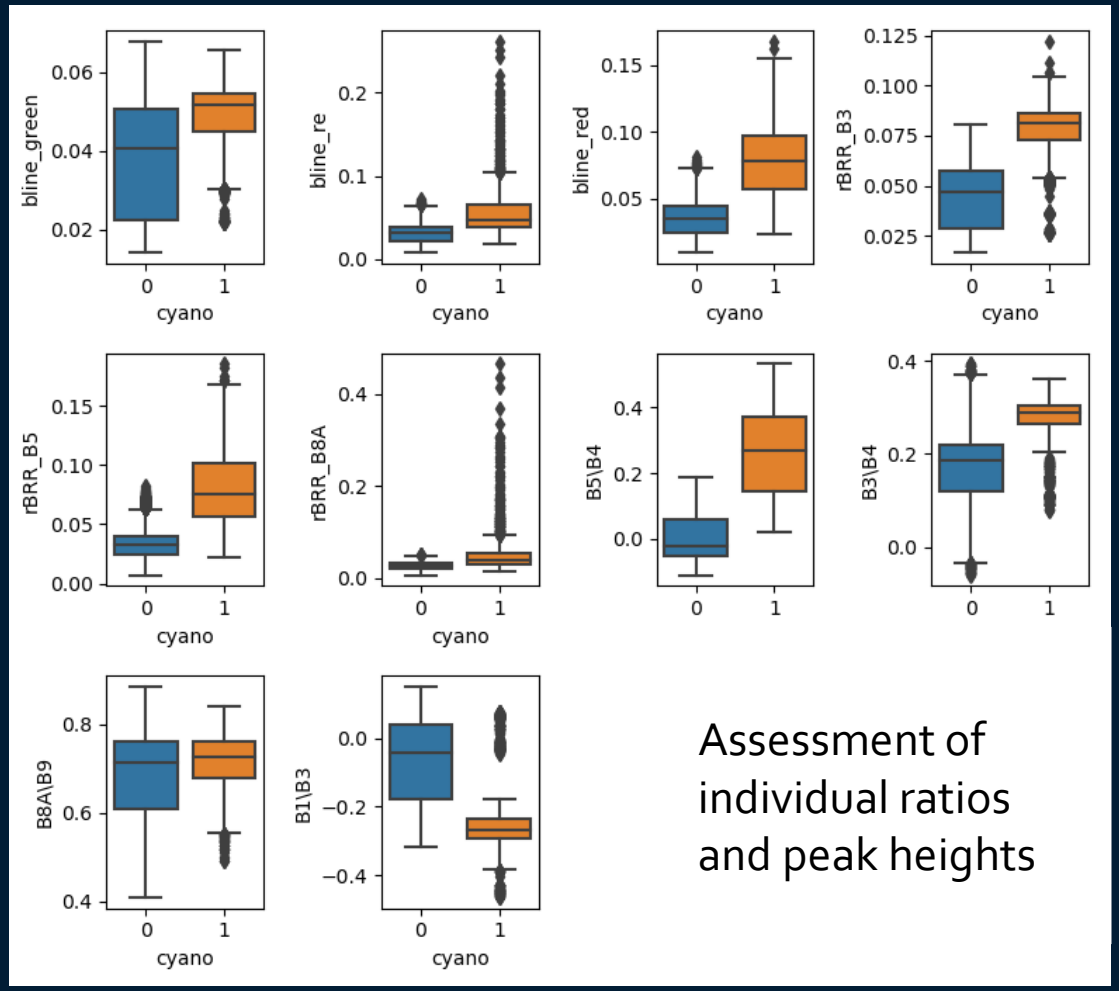
- Maximum Peak Height[1] (MPH) based for MERIS and OLCI
  - good results based on in-situ comparison
- Atmosphere
  - Rayleigh correction → BRR
- In-Water
  - S2 spectral band at 620nm is missing → MPH not applicable
  - Our approach:

Using a Random Forest Model to detect distinct spectral features of cyano blooms with S2.

[1] Matthews, M. W., & Odermatt, D. (2015).

Selection of Model Inputs

- manually selected dataset covering various water types:
  - Cyano blooms
  - high chlorophyll biomass blooms, springblooms
  - clear water cases
- Cyanobacteria blooms defined from in-situ data:
  - Biovolume of Cyano > 50% of total biovolume and a minimum CHL-a concentration of 10 µg/L
- Dataset taken in lakes in Germany and the US
- Analysis of indices and peak heights to distinguish cyanos from green algae blooms



Assessment of individual ratios and peak heights

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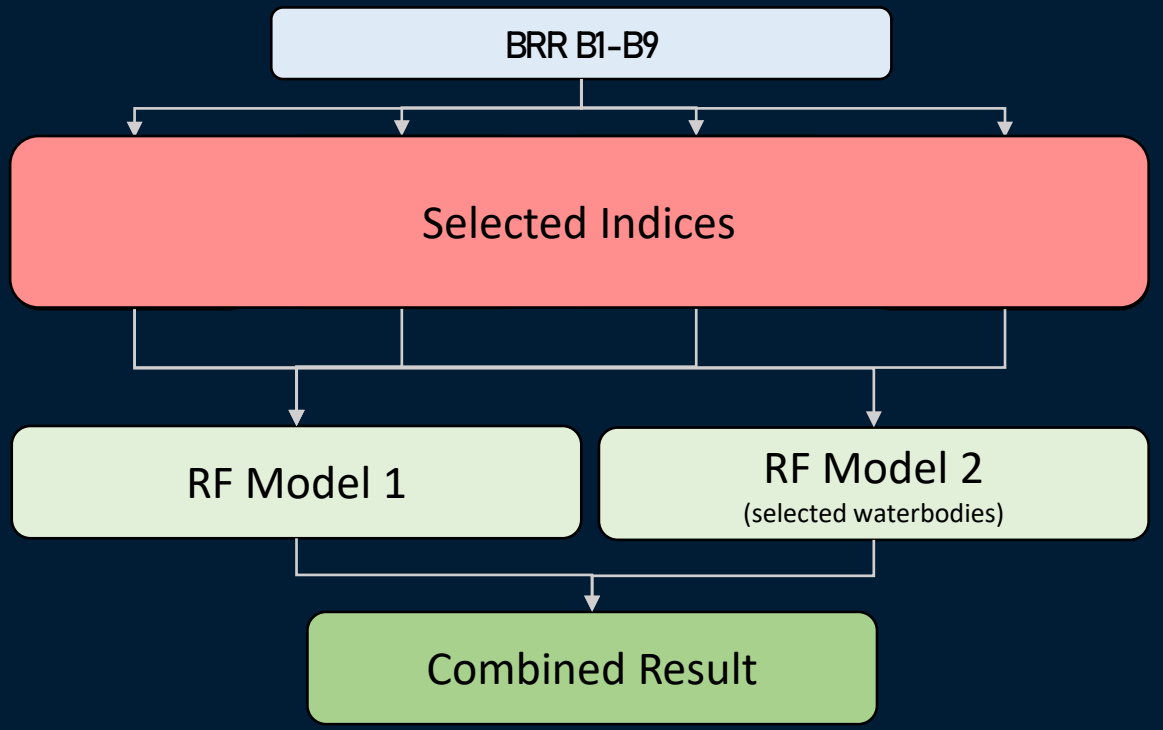
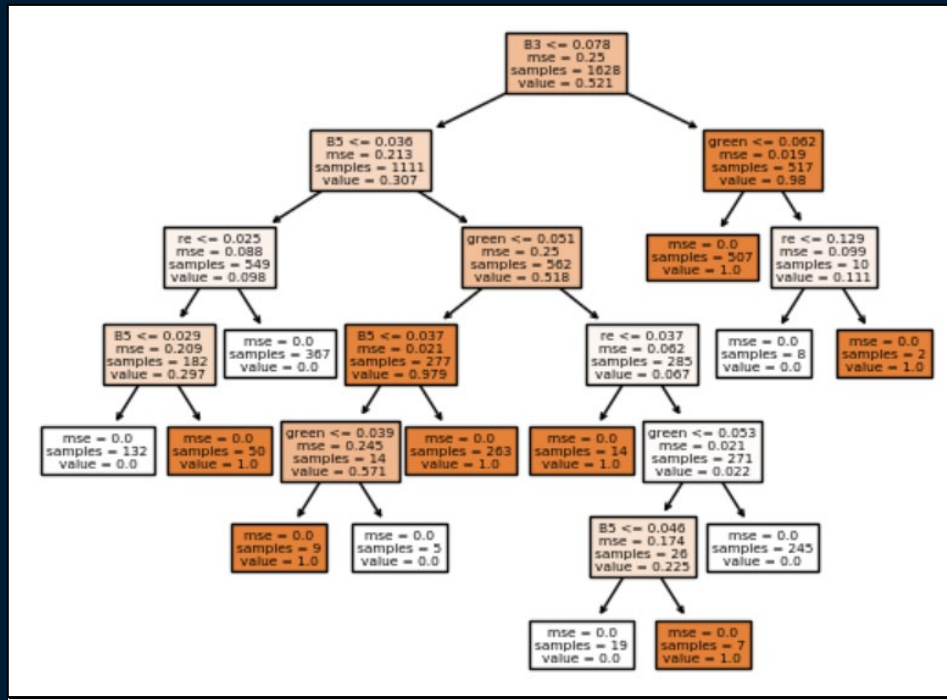
Model Configurations

- Selection of 4 indices based on BRR
- Identification of two Models
  - Model 1: covering various waterbodies
  - Model 2: covering cyano abundances in darker brown lakes
  - Combination of both model results



Random Forest

- Supervised machine learning algorithm
- Multiple decision trees, with each tree representing a class prediction
- Wisdom-of-crowds concept
  - ➢ class with the most votes becomes the model's prediction
- Easy and fast model training
- Full dataset split
  - 70% training data
  - 30% test data



Number of trees	Maximum depth
400	13

Testing of Model

- Test dataset showed very high accuracy
  - OAA > 95%
- Based on manually collected water pixels
  - Biased approach
- Unbiased validation necessary
  - Extensive in-situ dataset from German authorities

Model 1 — RF CB

True CB	Cyano	No Cyano	Sum	U A
Cyano	507	8	515	98.45
No Cyano	2	513	515	99.61
Sum	509	521		
P A	99.61	98.46		OAA: 99.03

Model 2 — RF CB

True CB	Cyano	No Cyano	Sum	U A
Cyano	36	4	40	90.00
No Cyano	2	191	193	98.96
Sum	38	195		
P A	94.74	97.95		OAA: 97.42

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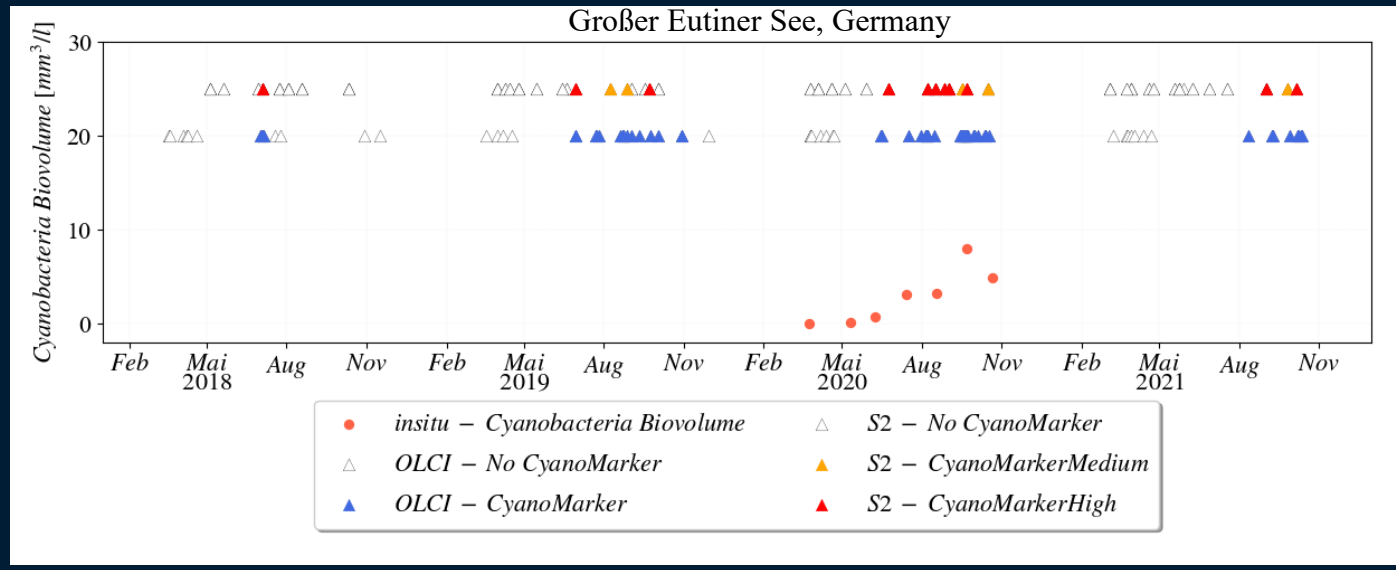
Validation of Model

- Validation of model based on:
  - In-situ measurements
    - Cyano Biovolume > 50% of total Biovolume
    - CHL-a > 10µg/L
    - Same day
  - OLCI MPH CyanoMarker
    - Time series of German lakes
    - Check periodic cyano abundance
- High confidence in cyano risk assessment with random forest model

Germany — RF CB

In-situ CB \ Class	Cyano	No Cyano	Sum	U A
Cyano	15	2	17	88.24
No Cyano	2	30	32	93.75
Sum	17	32	49	
P A	88.24	93.75		OAA: 91.84



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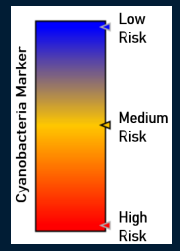
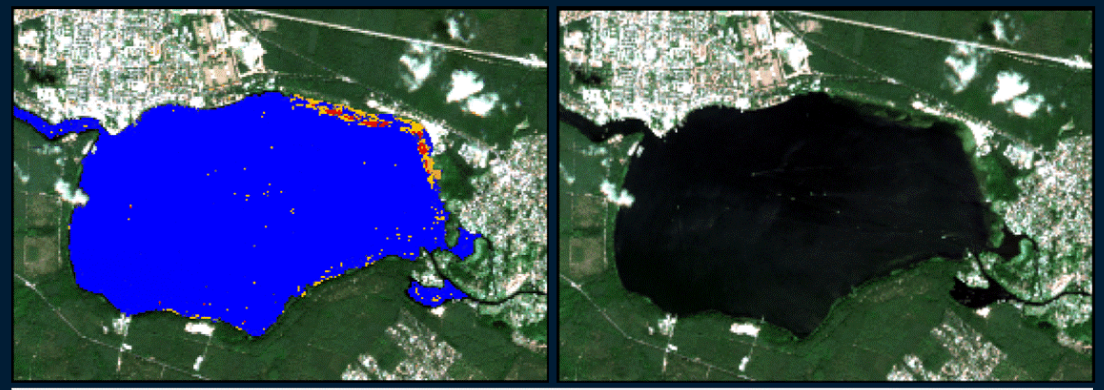
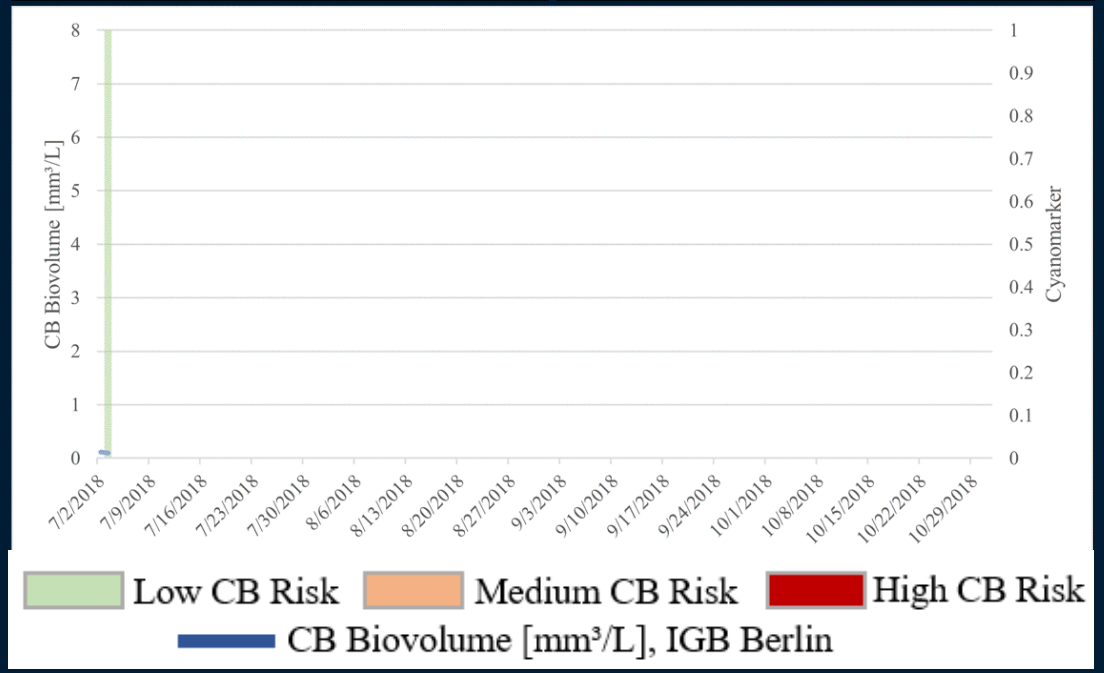
Case Study – Müggelsee

- Müggelsee (Berlin, GER)
  - Frequent cyano abundance
  - Monthly in-situ measurements
- S2 MSI cyano risk identifies cyano bloom in time and space
  - Spatial information cyano bloom crucial for public bathing places
  - Static in-situ measurements station not covering full spread of cyano bloom







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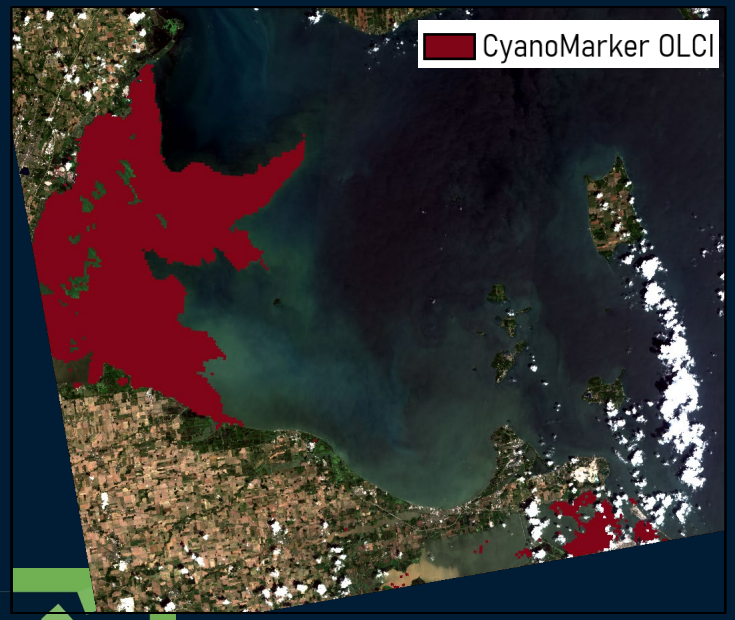
Validation with the CyanoTRACKER

- Using public monitoring programs to validate model
  - CyanoTRACKER (University of Georgia)

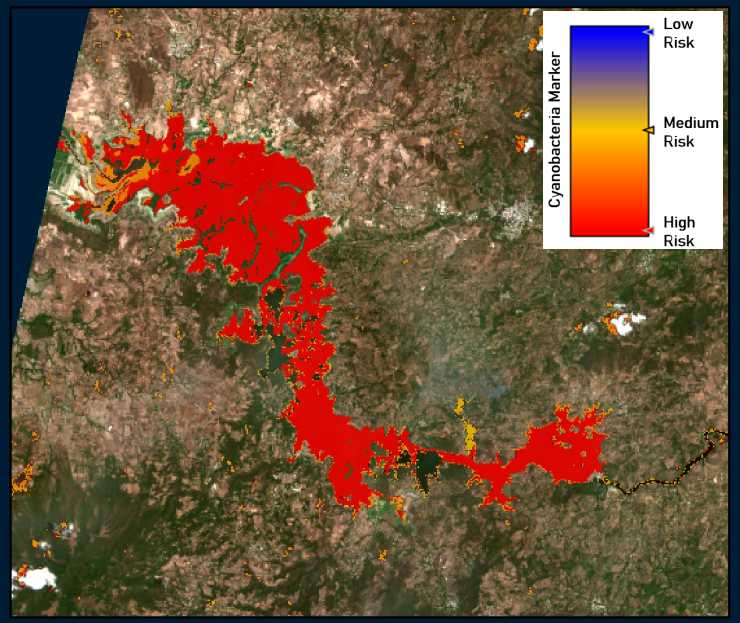
Lake Erie - USA

24.07.2019



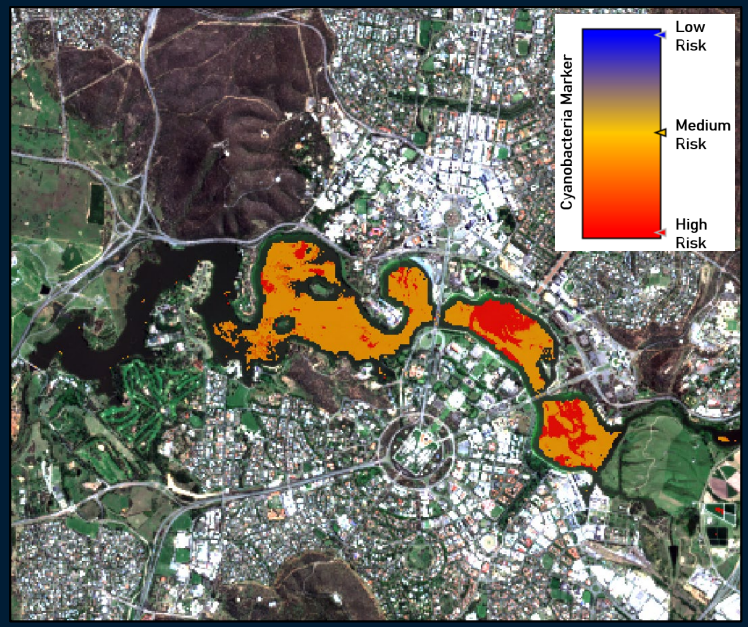
Embalse Cerrón Grande - El Salvador

22.04.2022



Lake Burley Griffin - Australia

28.02.2021



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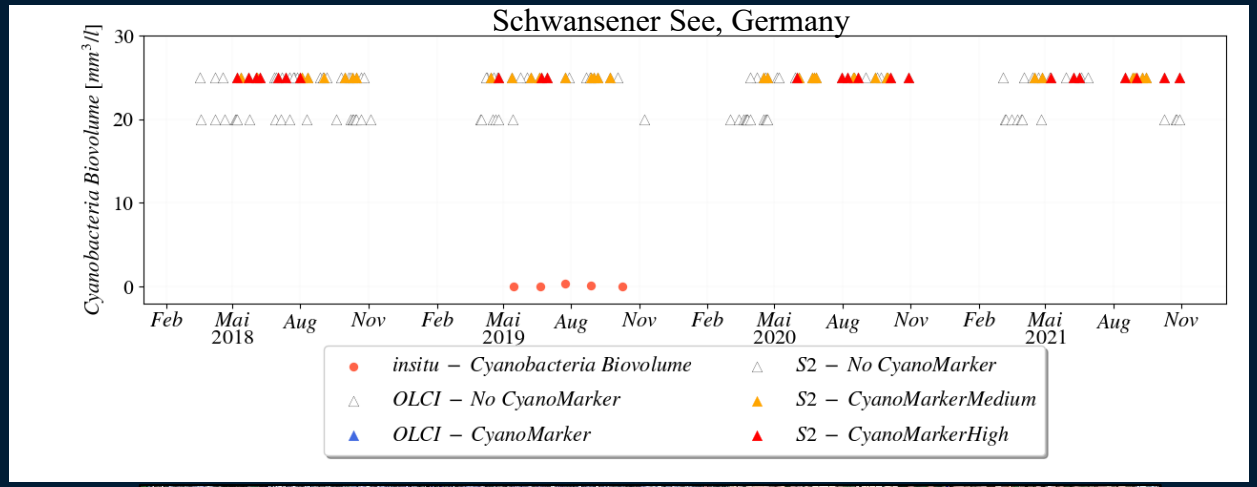
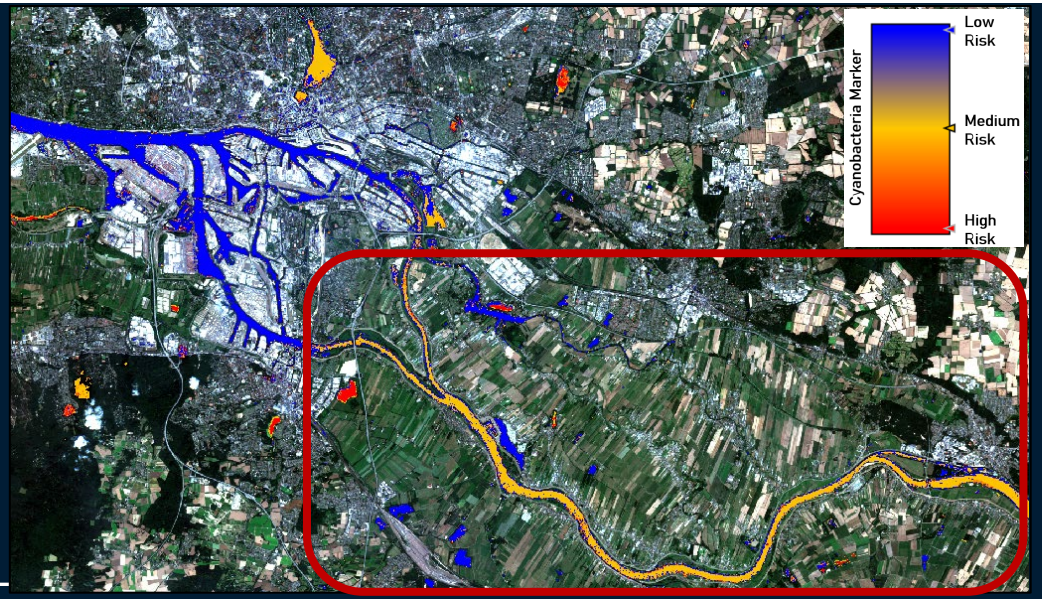
Limitation encounters

- Limitations for S2 MSI cyanobacteria risk assessment
  - High algae blooms with CHL-a concentrations > 100µg/L
  - Shallow waters/bottom reflection
  - Rivers with high CHL-a concentrations
- Risk assessment
  - No cyano biovolume
  - Low biomass cyano blooms undetected





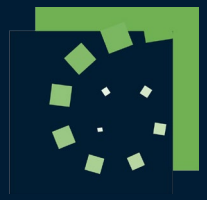
Improvements & Conclusion

Improvements

- Continuation of improving the model
  - Extension of training dataset
  - Extension with a third model
- Limitations for S2 MSI cyanobacteria detection
  - Phycocyanin absorptions wavelength 620nm not covered with S2 MSI
  - Upcoming high-resolution sensors may include bands covering these wavelengths

Conclusion

- Random Forest Model approach based on selected indices and a manually selected training dataset
- High confidence in cyanobacteria risk detection based on S2 for various lakes



Thank you!

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