Phytoplankton Group Identification Using Simulated and In-situ Hyperspectral Remote Sensing Reflectance

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EnMAP Hyperspectral Imager

Background

Given that the commonly used parameter obtained directly from hyperspectral earth observation sensors is the **remote sensing reflectance (*R_{rs}*)**, we focused on identification of dominant phytoplankton groups by using R_{rs} spectra directly. Based on five standard absorption spectra representing five different phytoplankton spectral groups, a simulated database of R_{rs} (**C2X database**, compiled within the ESA SEOM C2X Project) that includes 10^5 different water optical conditions was built with HydroLight. In our previous study we have proposed an identification approach to determine phytoplankton groups with the use of simulated C2X data, and the skill of the identification were also tested by investigating how and to what extend water optical constituents (Chl, NAP, and CDOM) impact the accuracy of this identification (Xi et al. 2017). **To furthermore test whether the approach is applicable in various natural waters, we have collected a large set of in situ data from waters with different optical types, including coastal waters such as the German Bight and British coastal waters, and inland waters such as Elbe River and several lakes in Germany. Both in situ R_{rs} and absorption spectra (a_p) are used to identify the dominating phytoplankton group in these waters. Identification results from both approaches are compared, and the identification performance of the R_{rs}-based approach can therefore be evaluated for natural water applications.**

Data and methods

- **Datasets:**
  - In situ $R_{rs}(\lambda)$ spectra from underwater Trios-RMSES
  - Absorption measurements $a_p(\lambda)$ from campaigns and from 128 cultures
- **Methods:**
  - $R_{rs}(\lambda)$: previously proposed identification approach in Xi et al. (2017)
  - $a_p(\lambda)$: derivatives of $a_p(\lambda)$ from campaigns are compared with that of cultures from 5 phytoplankton groups by using similarity index

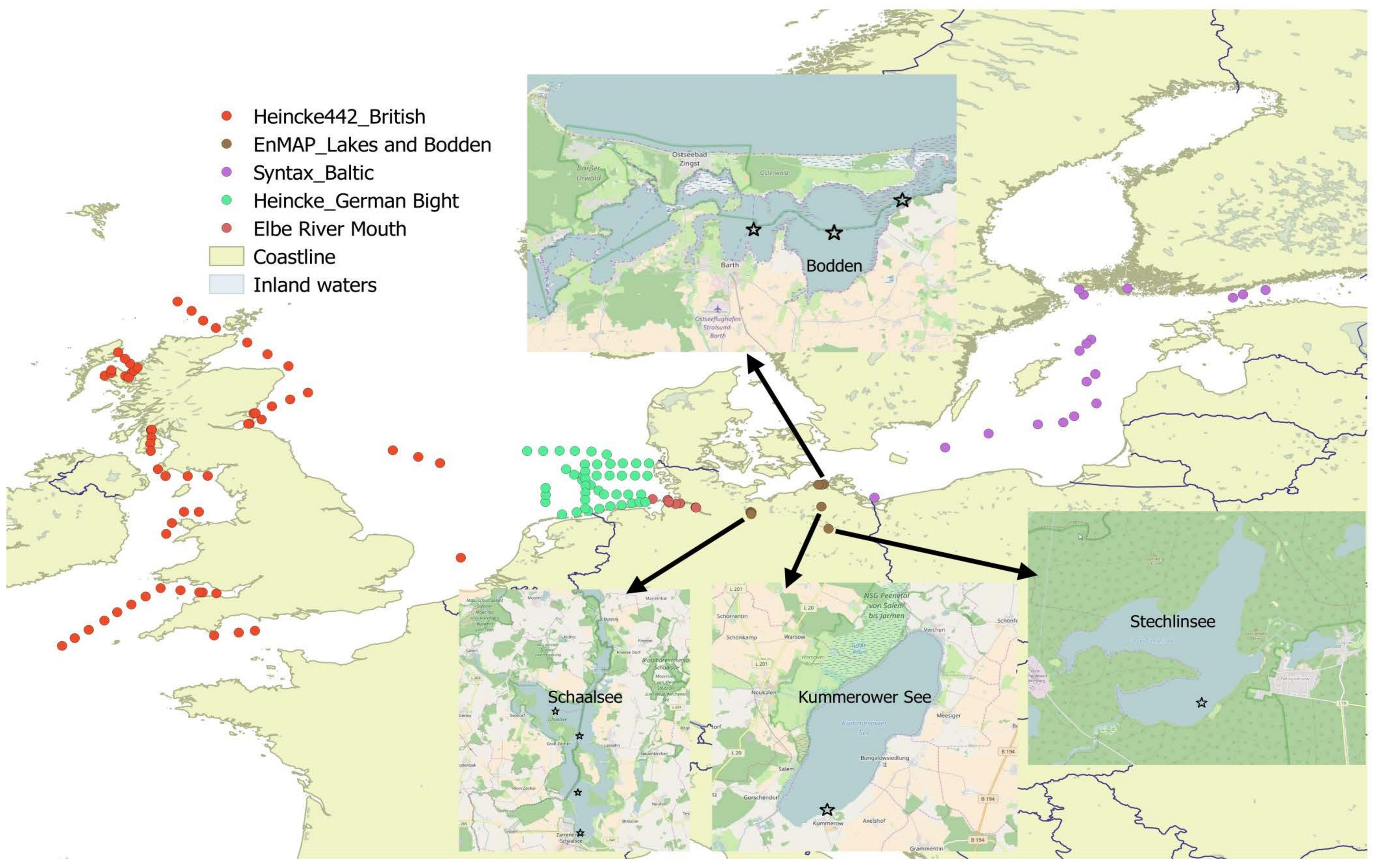


Figure 1: Locations and stations of the selected campaigns.

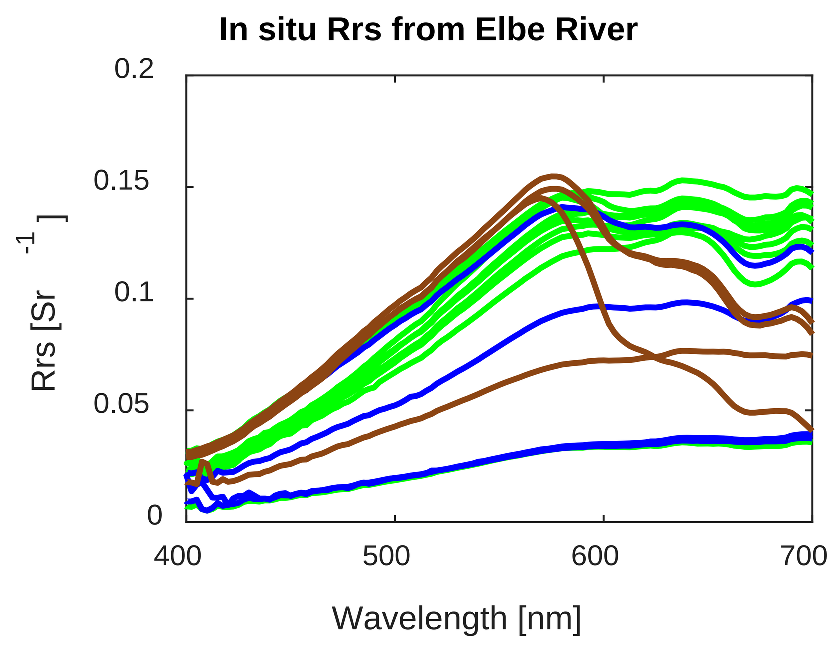
Table 1: Infos on in situ datasets and results of identified phytoplankton groups by the proposed R_{rs}-based approach, with comparison to the absorption-based identification results in (red brackets).

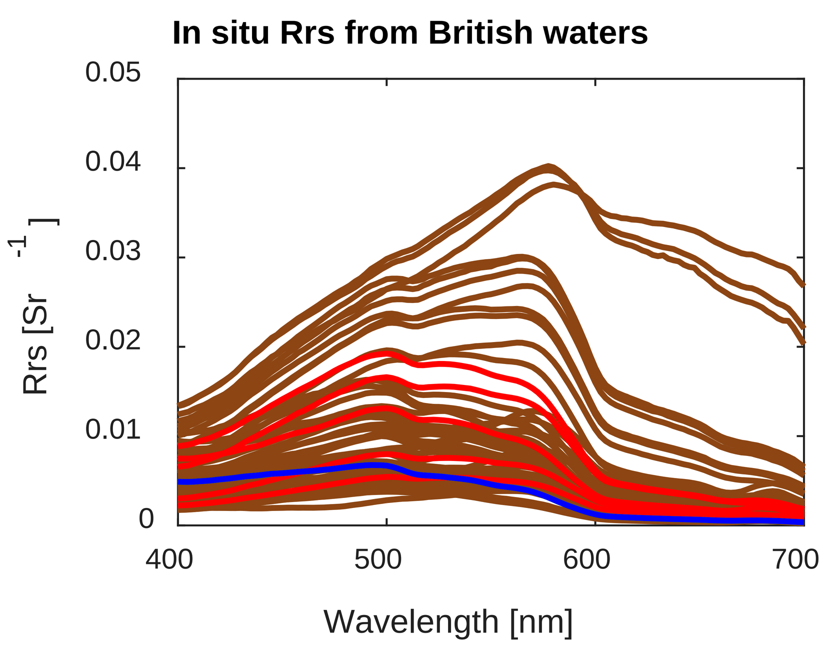
Campaigns	Location	Year	Period	Stations	R_{rs}	a_p by PSICAM	a_p by spectro-photometer	Number of stations under each identified group				
								Brown algae	Green algae	Red algae	Blue Cyano.	Red Cyano.
Prandtl_Elbe	Elbe River Mouth	2007	3-5 Jul.	16	X	X		5 (16)	8		2	
Heincke 287	German Bight	2008	29 Apr.-07 May	45	X	X		43 (45)			2	
Heincke 303	German Bight	2009	16-23 May	24	X	X		18 (24)		5	1	
Syntax	Baltic Sea	2010	19-30 Jul.	17	X	X		(2)	3 (2)		8 (7)	6 (6)
Heincke 353	German Bight	2011	6-11 Apr.	18	X	X		14 (18)		1	3	
Heincke 359	German Bight	2011	16-22 Jun.	25	X	X		24 (25)	1			
EnMAP n12	Bodden	2012	15 Aug.	3	X		X		1		2 (3)	
EnMAP n18	Schaalsee	2014	30 Apr.	4	X		X	(4)	4			
EnMAP n19	Schaalsee	2014	1 Jul.	1	X		X				1 (1)	
EnMAP n20	Schaalsee	2014	6 Aug.	4	X		X				4 (4)	
EnMAP n21	Schaalsee	2014	28 Aug.	4	X		X	(4)			4	
Heincke 442	British waters	2015	4-21 Apr.	60	X	X		53 (53)	1 (3)	5	1 (4)	
Stechlinsee	Stechlinsee	2015	2 Jul.	9	X	X		(3)	1 (5)	4	4 (1)	
Neustrelitz	Stechlinsee, Kummerower See	2016	30 May - 1 Jun.	3	X	X		(1)	1		2 (2)	

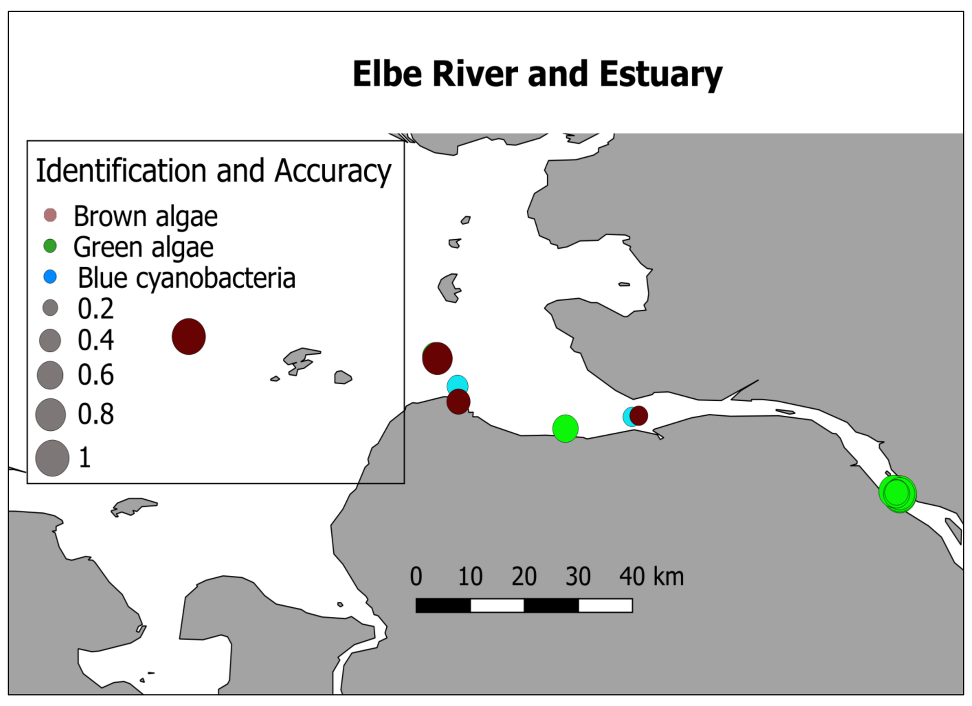
Comparison between R_{rs}-based and absorption-based approaches

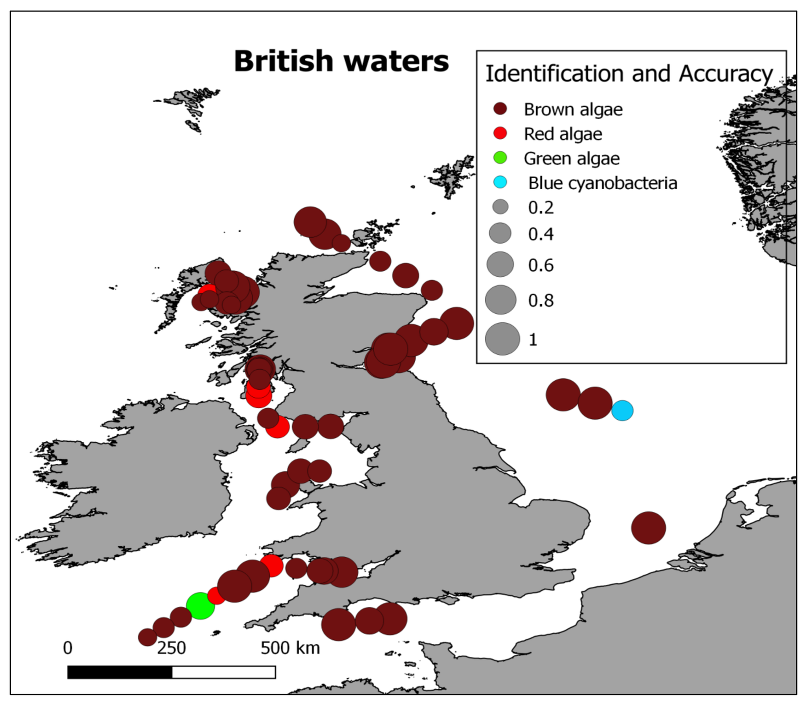
- North Sea: Absorption approach has identified all stations in Heincke campaigns as brown algae dominated, while the R_{rs} approach show a few stations with other groups dominated but with low identification accuracy. There is also a general agreement for British waters.
- Elbe River and lakes: Disagreements for the Eble River where NAP dominates and much discrepancy in lakes.
- Baltic Sea: Overall cyanobacteria dominated, a few points with disagreement.

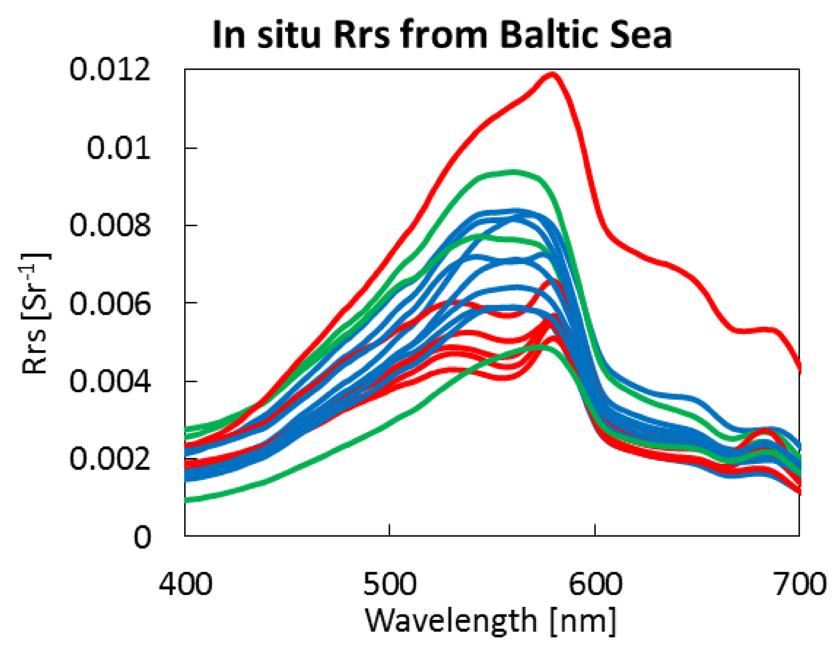
Results











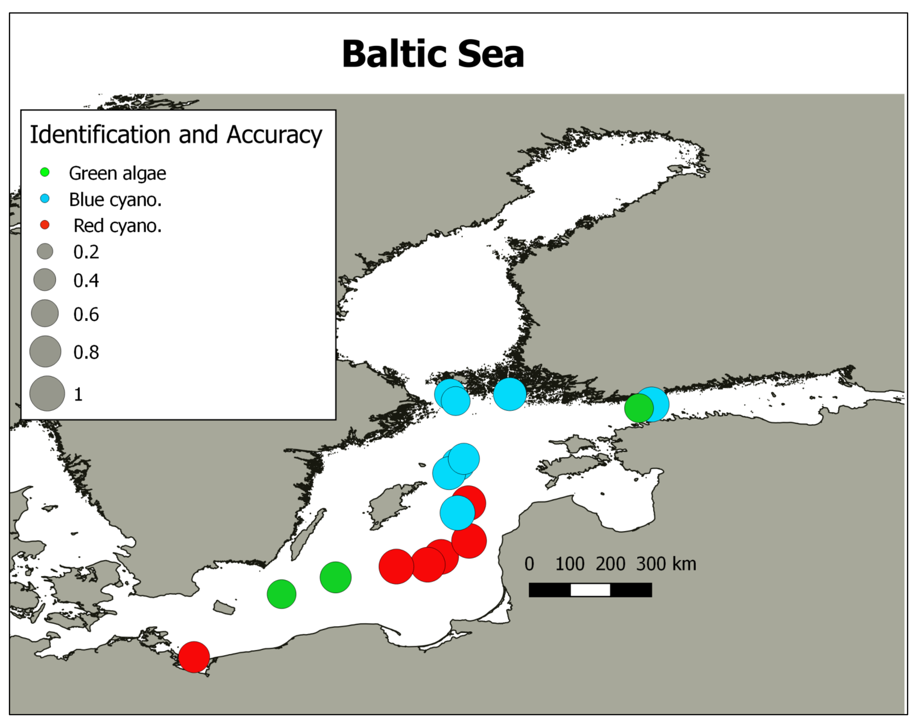


Figure 2: In situ R_{rs} spectra and the identified phytoplankton groups in the Elbe River Mouth, British coastal waters, and the Baltic Sea by using R_{rs}.

Conclusions

- Brown algae are the dominating group in the North Sea – German Bight and British waters. Cyanobacteria are dominating in the Baltic Sea. While in inland waters, normally there are more than one group and most of the time a few groups are coexisting. The dominating group in lakes may also vary with seasons and locations.
- Both approaches perform generally in consistence for phytoplankton identification in coastal waters and the Baltic Sea, but show disagreements for lakes and the Elbe River, due to much more complex optical properties in such water bodies.
- It is still a challenge to the proposed identification approach using R_{rs} when applied to waters where there are coexisting groups without a single outstandingly dominant group or highly sediment loaded waters such as Elbe River.
- More efforts will be put forward in the future on data quality check to understand the disagreements, and taking into account the in-situ data of pigments from HPLC measurements to get more accurate infos on the phytoplankton types.

Acknowledgements: This work was made possible with the support of the EnMAP project. We thank Stephen Gehnke for measuring absorption spectra of various cultures, Wolfgang Schonfeld, Kerstin Heymann and Christian Utschig for all the relevant measurements from the past cruises. Martin Hieronymi (MH) was supported by ESA through a Living Planet Fellowship (project LowSun-OC). The C2X database was established by MH in the ESA SEOM C2X project (ESA ESRIN/ C-No. 4000113691/15/I-LG). We thank the crew of all the campaigns for their contribution to the in situ datasets.

Reference: Xi H, Hieronymi M, Krasemann H and Röttgers R (2017). Phytoplankton Group Identification Using Simulated and In situ Hyperspectral Remote Sensing Reflectance. Front. Mar. Sci. 4:272. doi: 10.3389/fmars.2017.00272