

# Validation of satellite data in context of optical water types

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# Announcement of a new paper 1



- Reference for C2RCC
- Background information
- Performance overview and outlook

<https://doi.org/10.3389/frsen.2026.1710758>

Müller, D., Hieronymi, M., Ruescas, A. B., Peters, M., Röttgers, R., König, M., Lebreton, C., Stelzer, K., Brockmann, C., & Doerffer, R. (2026): Case 2 Regional Coast Colour: A Neural Network-Based Framework for Atmospheric Correction and In-Water Retrievals Across Multiple Ocean Colour Satellite Sensors. *Frontiers in Remote Sensing*, 7, 1710758

The screenshot shows the front page of a paper on the Frontiers in Remote Sensing website. The page layout includes the journal logo and name at the top left, publication details at the top right, a 'Check for updates' button, and sections for 'OPEN ACCESS', 'EDITED BY', 'REVIEWED BY', '\*CORRESPONDENCE', 'RECEIVED', 'REVISED', 'ACCEPTED', 'PUBLISHED', 'CITATION', and a short introductory paragraph. The main title and authors are prominently displayed in the center-right.

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*Front. Remote Sens.* 7:1710758.  
doi: 10.3389/frsen.2026.1710758

## Case 2 Regional Coast Colour: a neural network-based framework for atmospheric correction and in-water retrievals across multiple ocean colour satellite sensors

Dagmar Müller<sup>1\*</sup>, Martin Hieronymi<sup>2</sup>, Ana B. Ruescas<sup>1,3\*</sup>, Marco Peters<sup>4</sup>, Rüdiger Röttgers<sup>2</sup>, Marcel König<sup>1</sup>, Carole Lebreton<sup>1</sup>, Kerstin Stelzer<sup>1</sup>, Carsten Brockmann<sup>1</sup> and Roland Doerffer<sup>1,2</sup>

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Since the 1990s, Doerffer and Schiller have been developing physics-based neural network algorithms for analyzing ocean colour in satellite imagery of optically complex coastal waters. At its core, the approach uses neural networks to solve the inversions in various aspects of solar radiative transfer in both the atmosphere and water, including atmospheric correction

# Announcement of a new paper 2

- Background information on A4O-ONNS processing
- Datasets for testing flags and validation

<https://doi.org/10.5194/essd-18-1307-2026>

Hieronymi, M., Behr, D., Bi, S., & Röttgers, R. (2026): Optical complexity of North Sea, Baltic Sea, and adjacent coastal and inland waters derived from Sentinel-3 OLCI satellite data. *Earth System Science Data*, 18(2), 1307-1329

Earth Syst. Sci. Data, 18, 1307–1329, 2026  
<https://doi.org/10.5194/essd-18-1307-2026>  
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Earth System  
**Science  
Data**

## Optical complexity of North Sea, Baltic Sea, and adjacent coastal and inland waters derived from Sentinel-3 OLCI satellite data

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<sup>1</sup>Department of Optical Oceanography, Institute of Carbon Cycles, Helmholtz-Zentrum Hereon, 21502 Geesthacht, Germany

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**Correspondence:** Martin Hieronymi (martin.hieronymi@hereon.de)

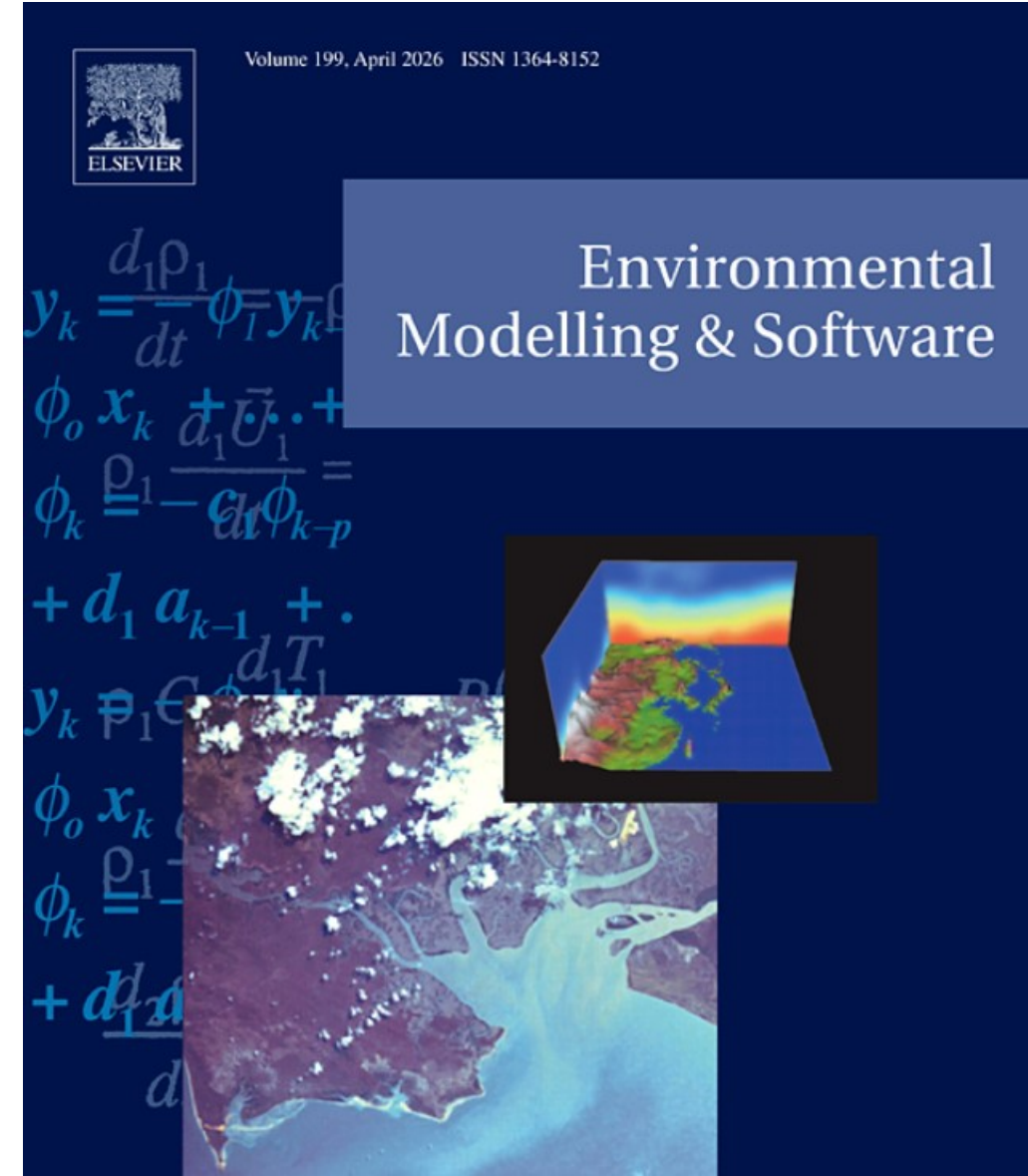
Received: 25 July 2025 – Discussion started: 8 August 2025

Revised: 22 January 2026 – Accepted: 7 February 2026 – Published: 19 February 2026

**Abstract.** Despite advances in remote sensing, consistent monitoring of water quality across freshwater-marine systems remains challenging due to methodological fragmentation. Here, we provide an overview of an exemplary dataset on water quality characteristics in inland waters, coasts, and the open sea estimated from optical satellite data ([https://doi.org/10.26050/WDC/AquaINFRA\\_Sentinel3\\_v2](https://doi.org/10.26050/WDC/AquaINFRA_Sentinel3_v2), Hieronymi et al., 2025). Specifically, this is Sentinel-3 OLCI (Ocean and Land Colour Instrument) data for the entire North Sea and Baltic Sea region for the period June to September 2023. The dataset includes daily aggregated observational data with a spatial resolution of approximately 300 m of reflectance at the top-of-atmosphere and for cloud-free water areas remote-sensing reflectance, inherent optical properties of the water, and an estimation of the concentrations of

# Announcement of a special issue

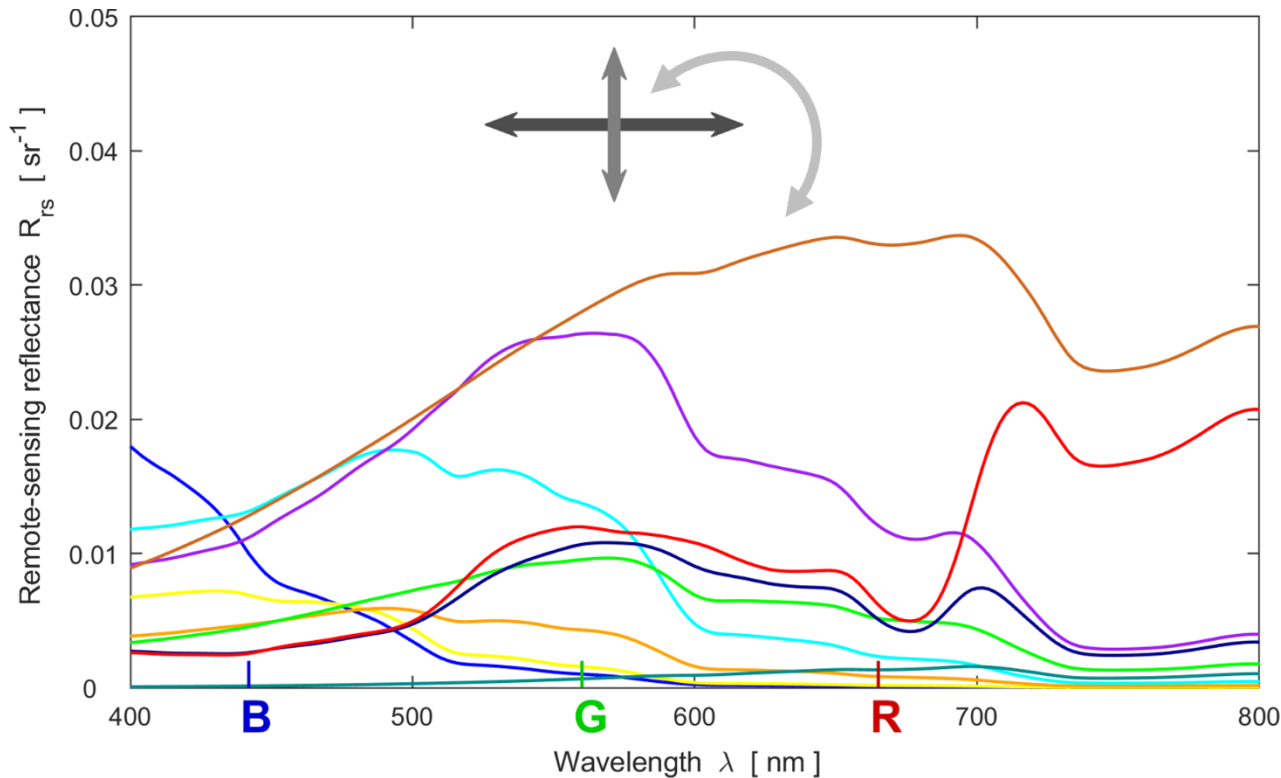
- Advancing integrated ocean, coastal and inland water research through open digital infrastructures
- Methodological papers on data workflows, software tools, and interoperability
- Journal: Environmental Modelling & Software (EM&S)
- Until March 2027



# Optical water type classification

- Enables
  - Qualitative characterisation of waters – clean, turbid, eutrophic
  - Quantitative characterisation of the ranges of water constituents
    - For selection of appropriate algorithms
  - Seamless transition of water quality products across gradients
  - Assessment of the validity of methods used
  - Class-based estimation of uncertainties
- Application of OWT framework of Bi & Hieronimi [2024] → OWC ([iop\\_lsd.nc](http://iop.lsd.nc)) not tested
  - Based on simulations of “all natural waters” [Bi et al., 2023]
  - Including different phytoplankton groups

# Spectral analysis based on three parameters

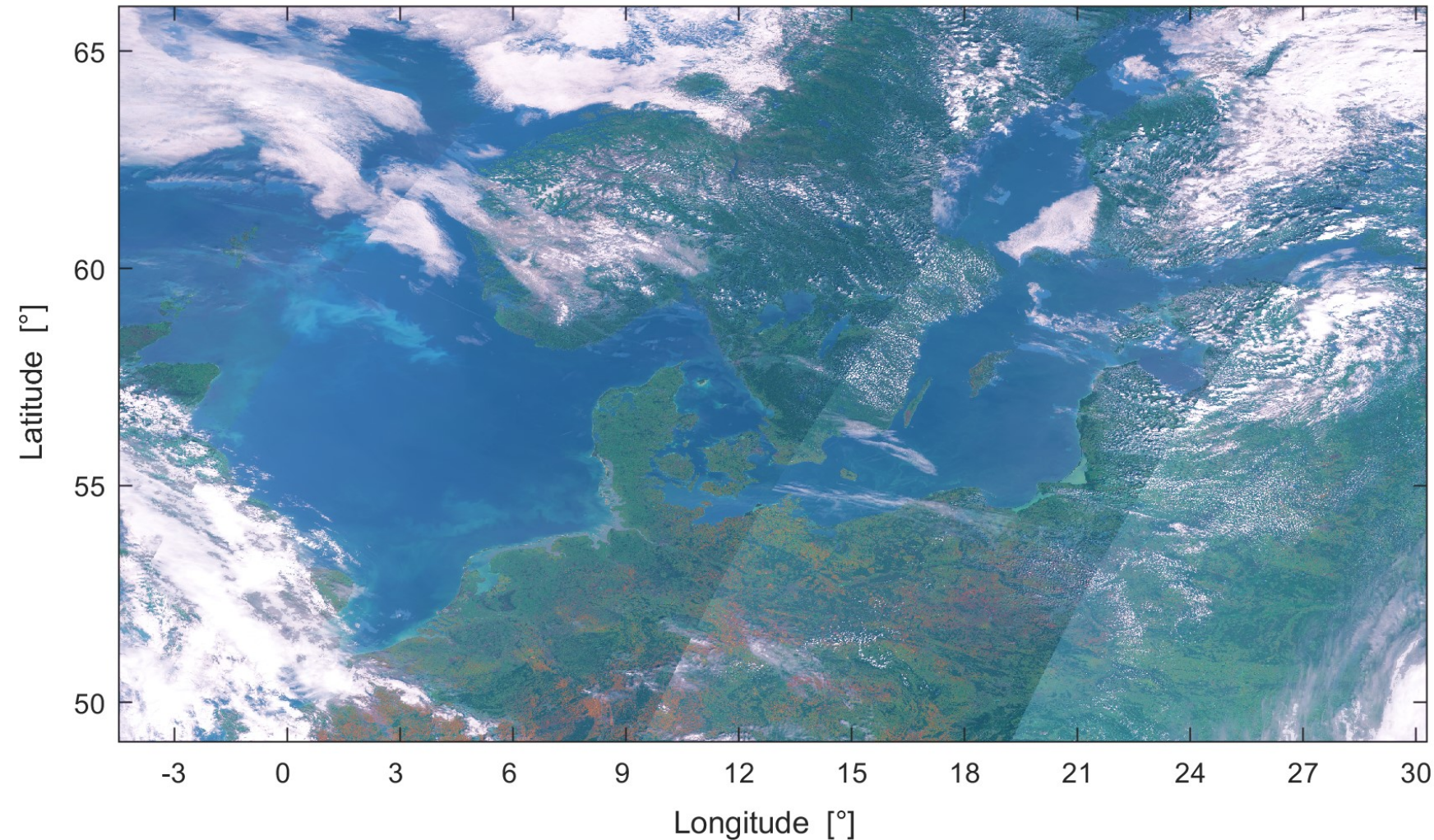


- Apparent Visible Wavelength (400-800 nm)
- (Box-Cox transformed) Area under RGB bands
- Normalized Difference Index at Green and Red

AVW → Robust classifiability (memberships)  
 $A_{BC}$  → Good transferability of spectral bands  
 NDI

OWT	Description
<b>1</b>	Extremely clear waters
<b>2</b>	Blue waters with slightly higher detritus/CDOM
<b>3a</b>	Turquoise waters (moderate biomass/CDOM)
<b>3b</b>	High scattering (e.g., Coccolithophore blooms)
<b>4a</b>	Greenish water (dark, absorption dominated)
<b>4b</b>	Greenish water (bright, scattering dominated)
<b>5a</b>	Green eutrophic water (algal blooms)
<b>5b</b>	Green hyper-eutrophic (vegetation-like NIR)
<b>6</b>	Bright brown water (high detritus/sediment)
<b>7</b>	Dark brown water (high CDOM/humic)

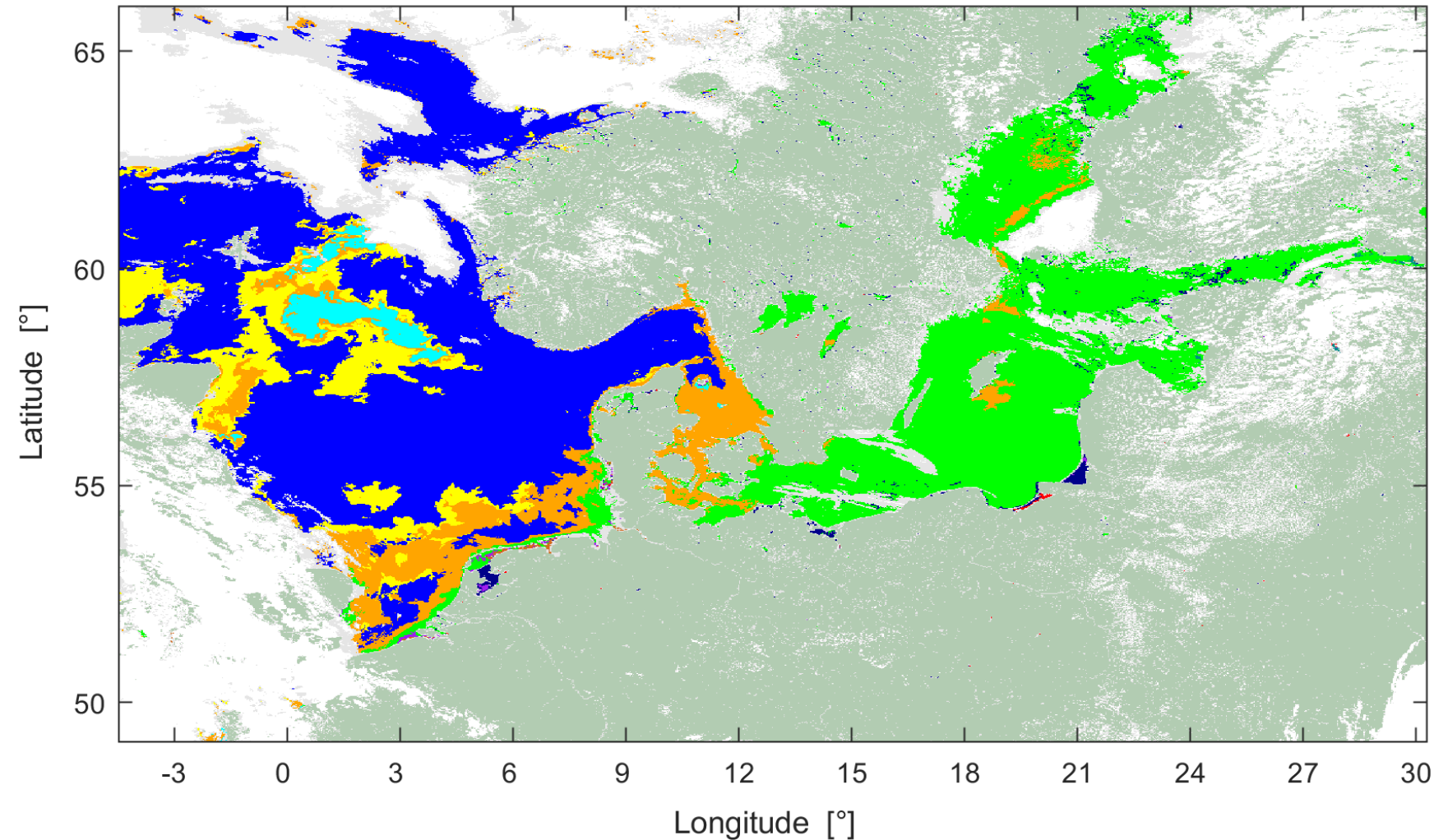
# Merged OLCI images at top-of-atmosphere



- North Sea – Baltic Sea region (8 June 2023)

Hieronymi, M., Behr, D., Bi, S., & Röttgers, R. (2025). Optical complexity of North Sea, Baltic Sea, and adjacent coastal and inland waters derived from satellite data. *Earth System Science Data Discussions*, 2025, 1-30.

# OWT distribution from S3-OLCI A40

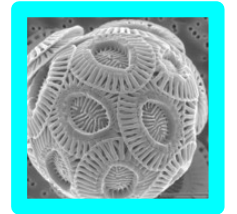


- Land
- Clouds
- Cloud risk

Optical Water  
Types

OWT [-]

- 7
- 6
- 5b
- 5a
- 4b
- 4a
- 3b
- 3a
- 2
- 1



*Emilia huxleyi* (Coccolithophores)



*Noctiluca sp.* (Dinoflagellate)

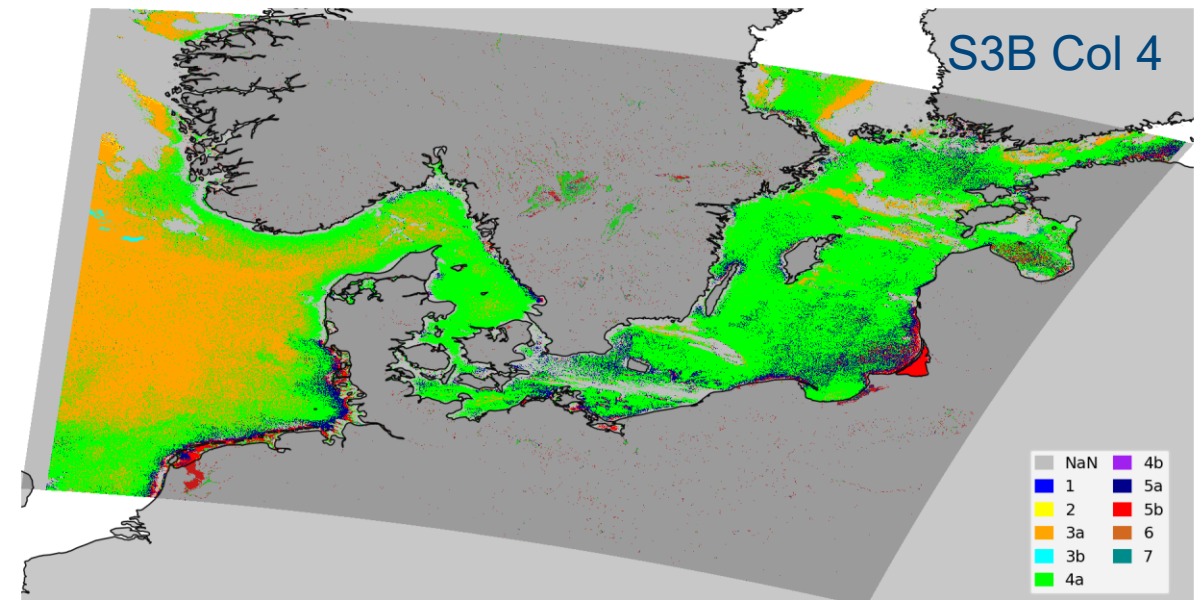
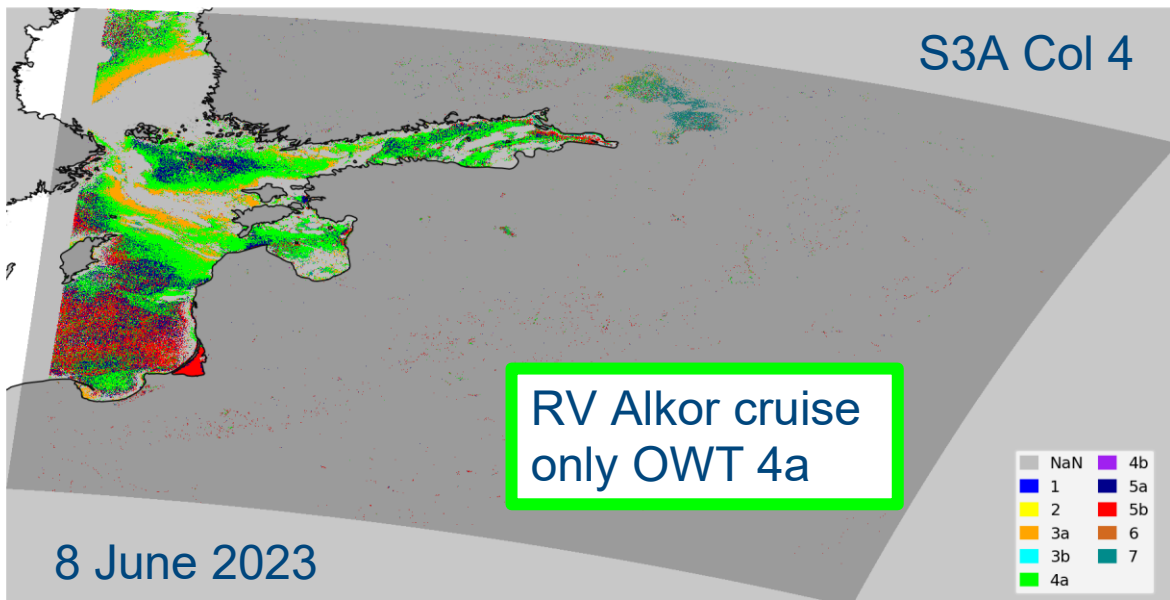
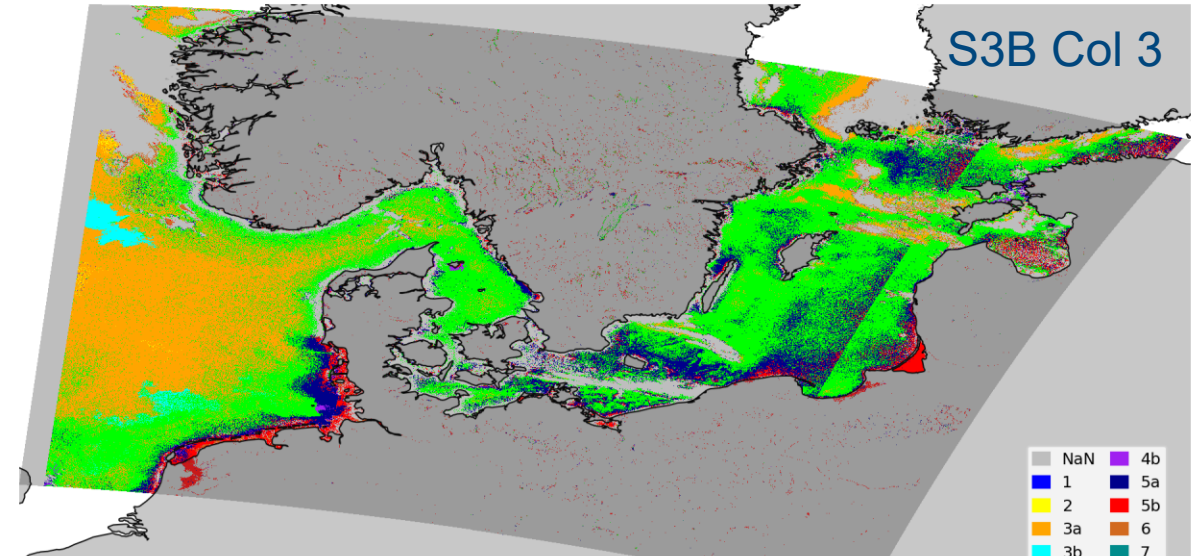
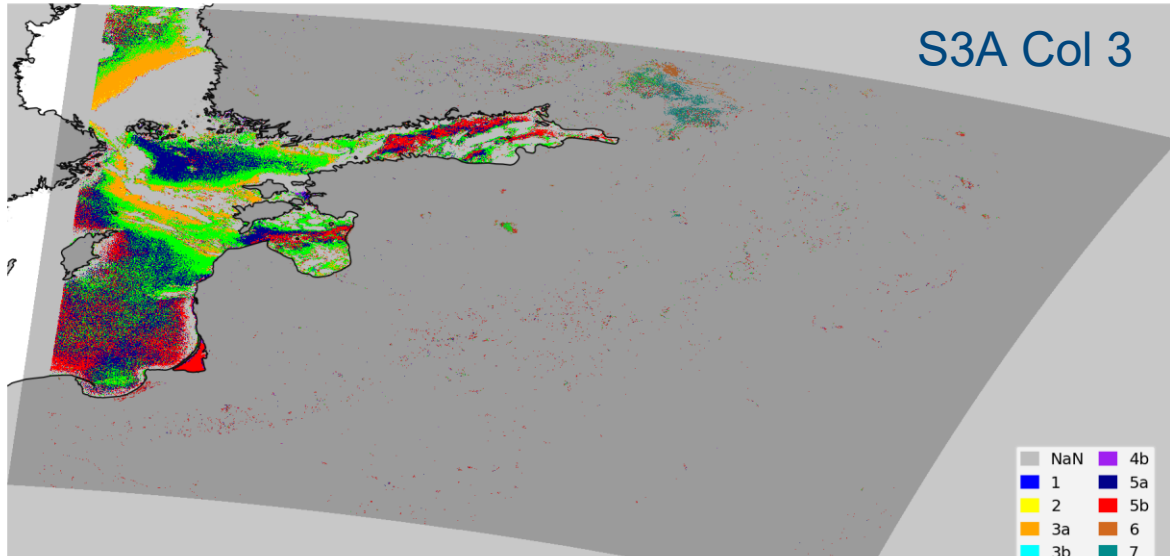


*Nodularia sp.* (Cyanobacteria)

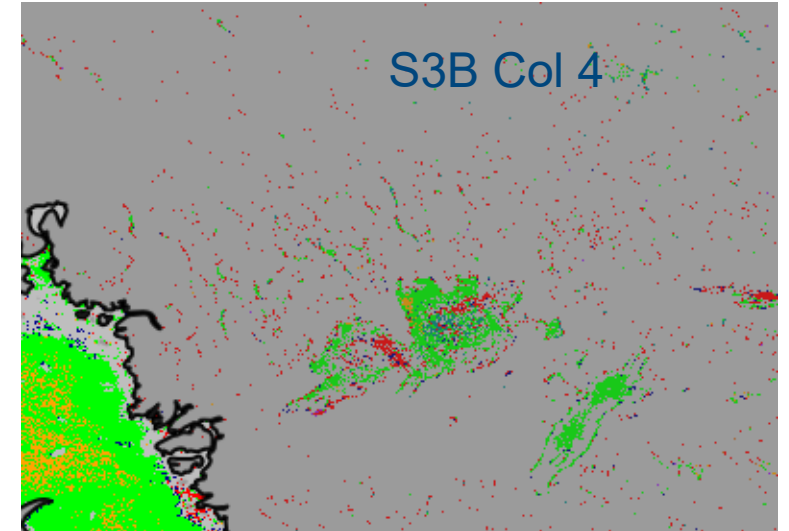
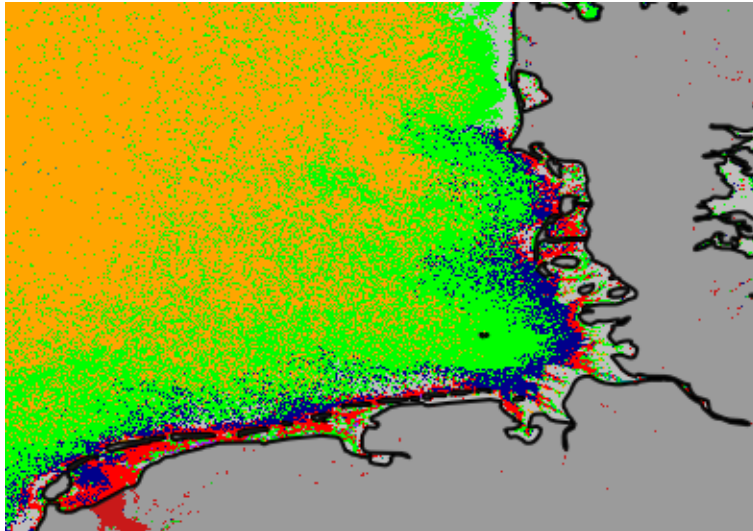
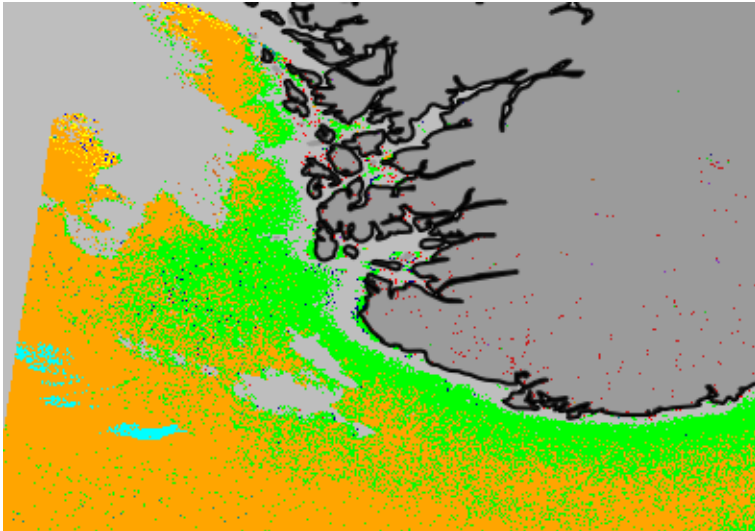
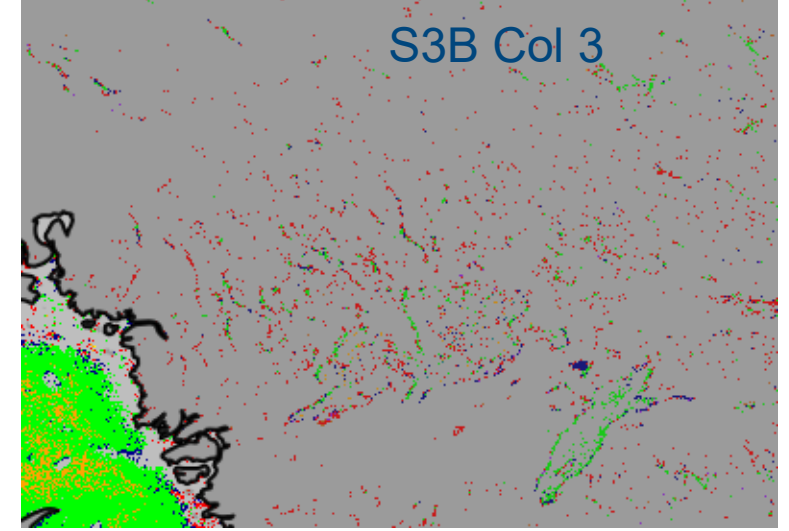
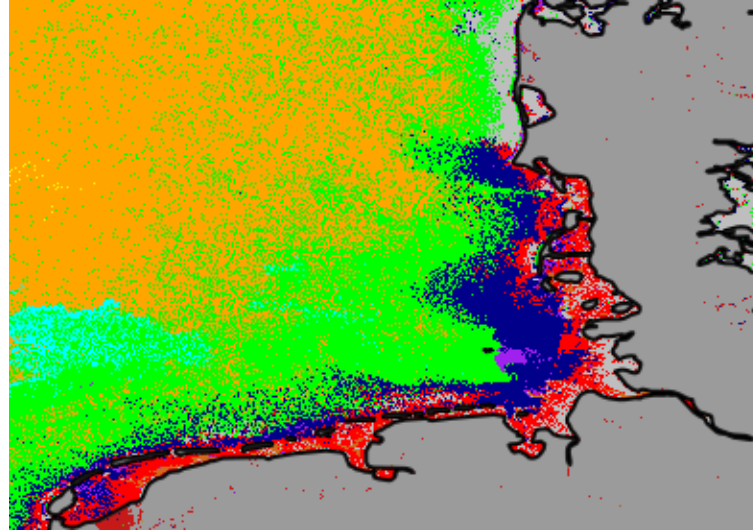
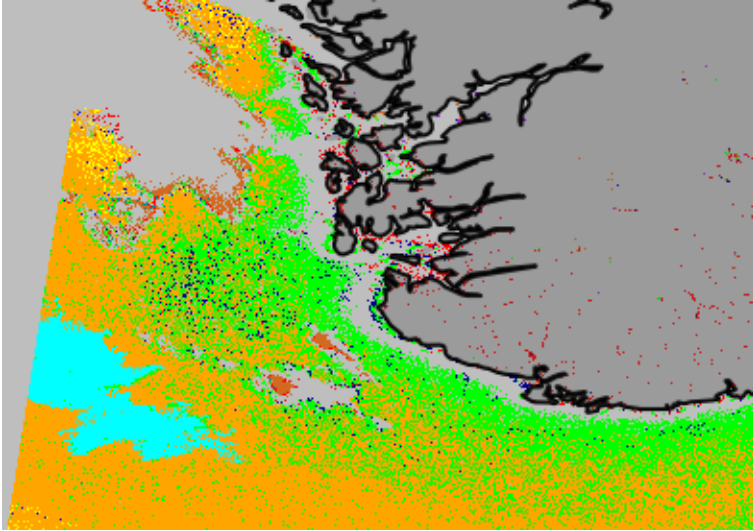
- North Sea – Baltic Sea region (8 June 2023)

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# OWT from OLCI A vs B, Collection 3 vs 4



# OWT from OLCI A vs B, Collection 3 vs 4

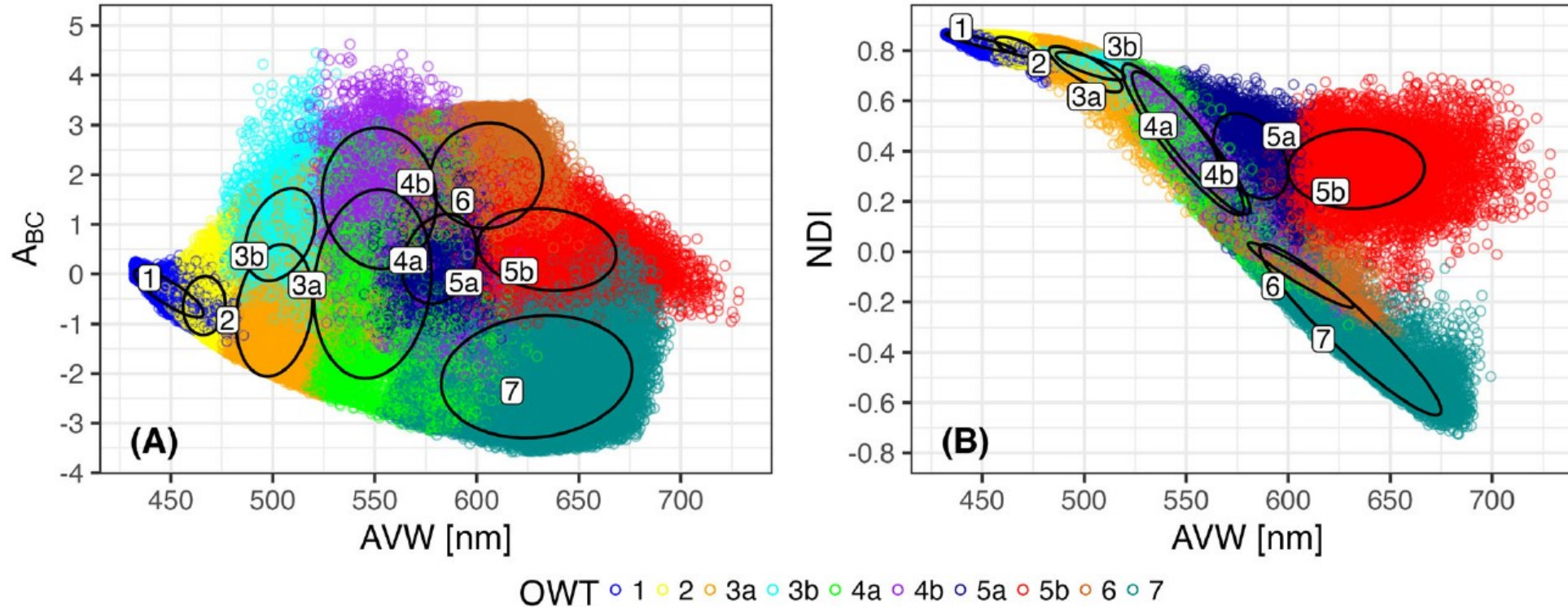


Norwegian Trench

German Bight

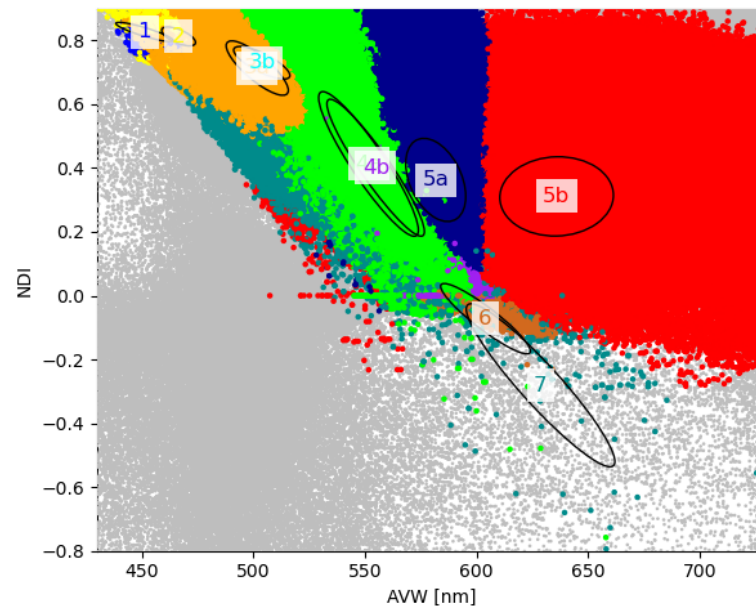
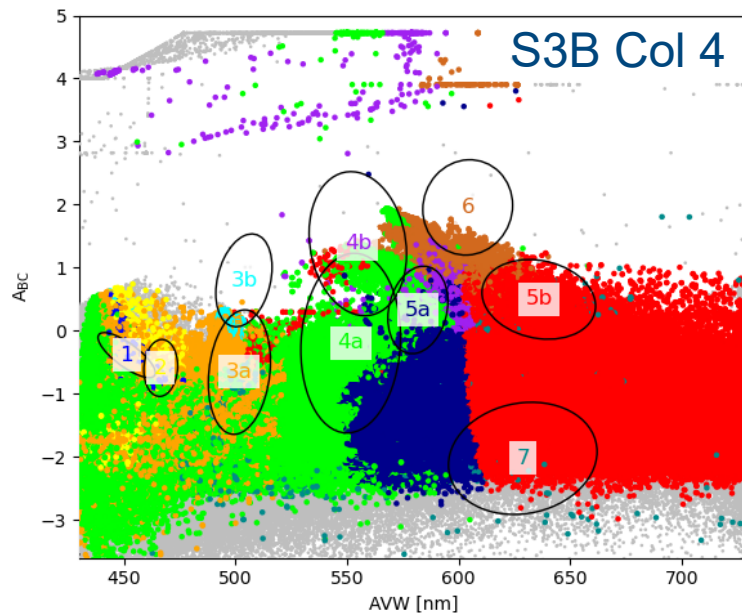
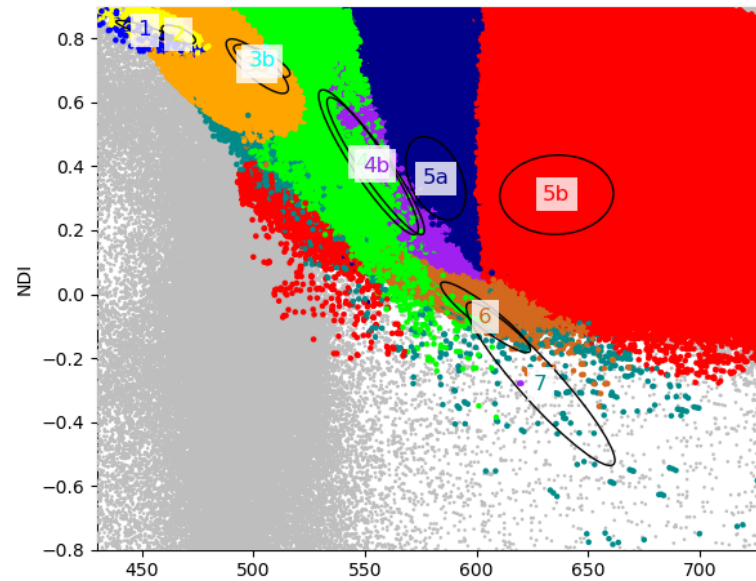
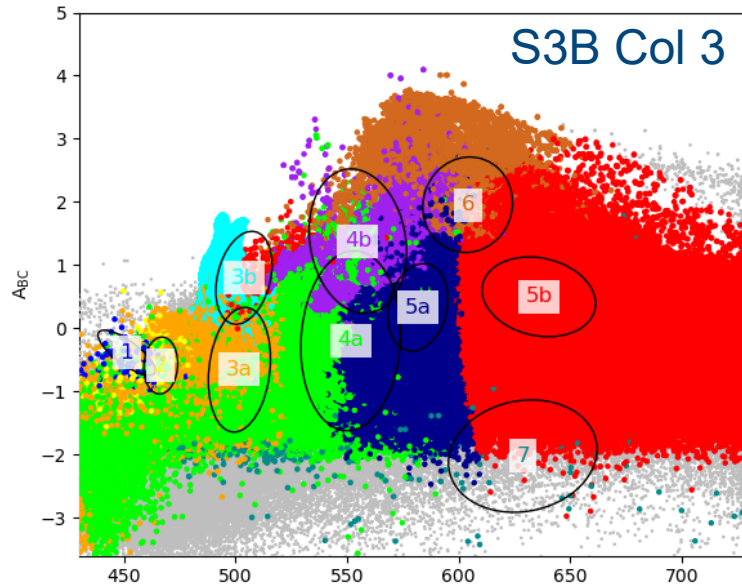
Lake Vänern

# Covariances of optical parameter



- OWT framework based on simulations – based on IOP & Rrs measurements
- Outside the coloured area is an indicator of issues – but possible
- If outside: 1) out of usual model assumptions, 2) higher single-scattering albedo, 3) AC issue (incl. negative reflectance)

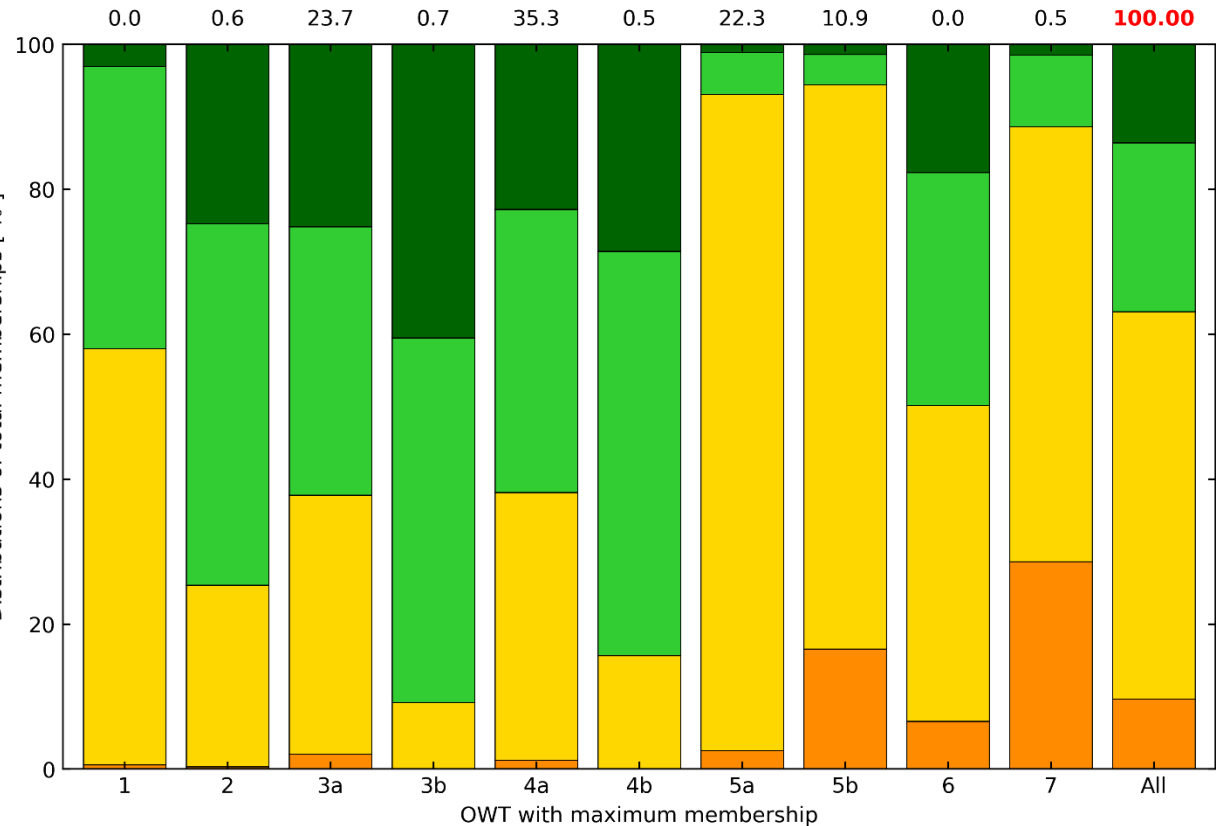
# Covariances of optical parameter Col 3 vs 4



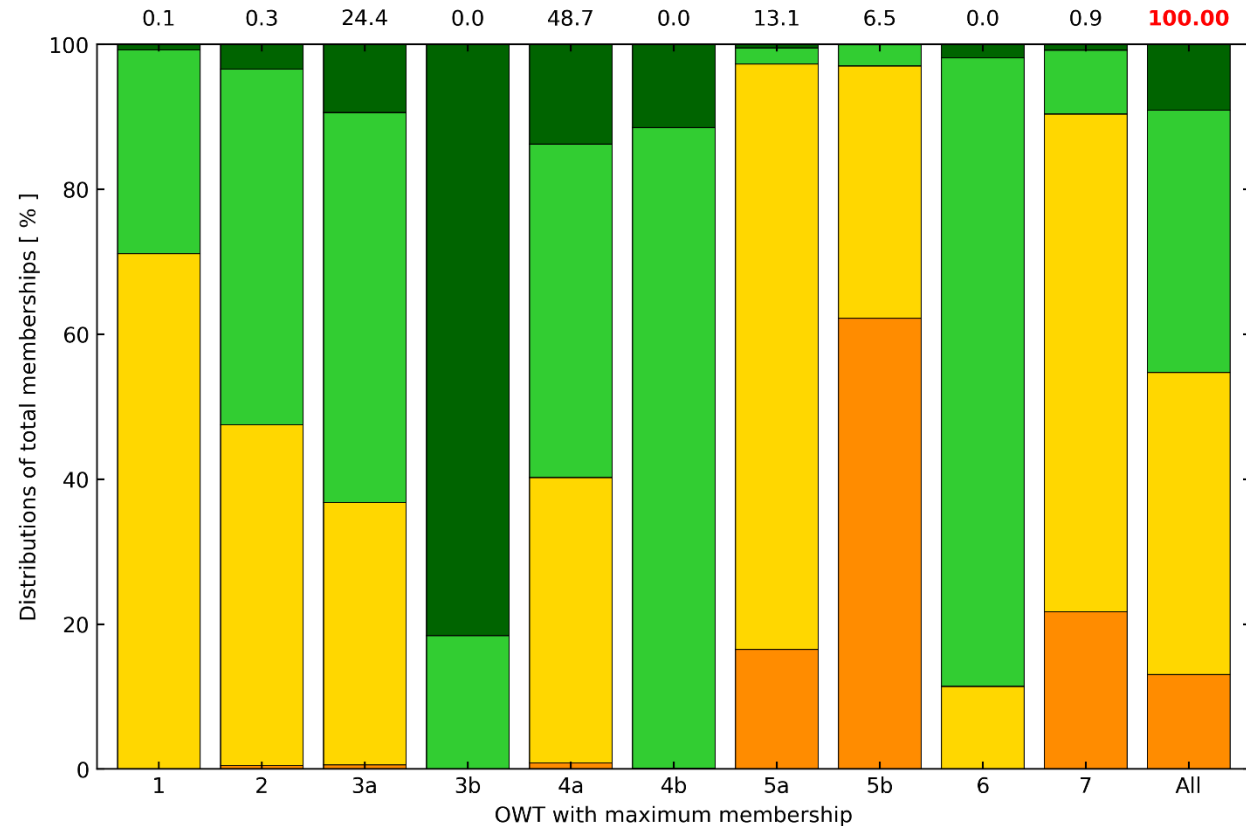
- This representation only shows the points, not the density
- There are still (too) many Rrs spectra with negative values  
→ recommendation to incorporate log-transform
- Thereby (too) many invalid pixel
- Significant shift in AVW and Area (possibly miss-assigned to OWT)
- Col 4 has fewer high spectra (possible effect of BRDF and normalisation – unknown effects on classification)
- Almost no coccolithophores are visible (OWT 3b)

# OLCI Col 3 vs 4 (Baltic Sea, June 2023)

Collection 3 | Percentage of classifiable pixels [ % ]



Collection 4 | Percentage of classifiable pixels [ % ]

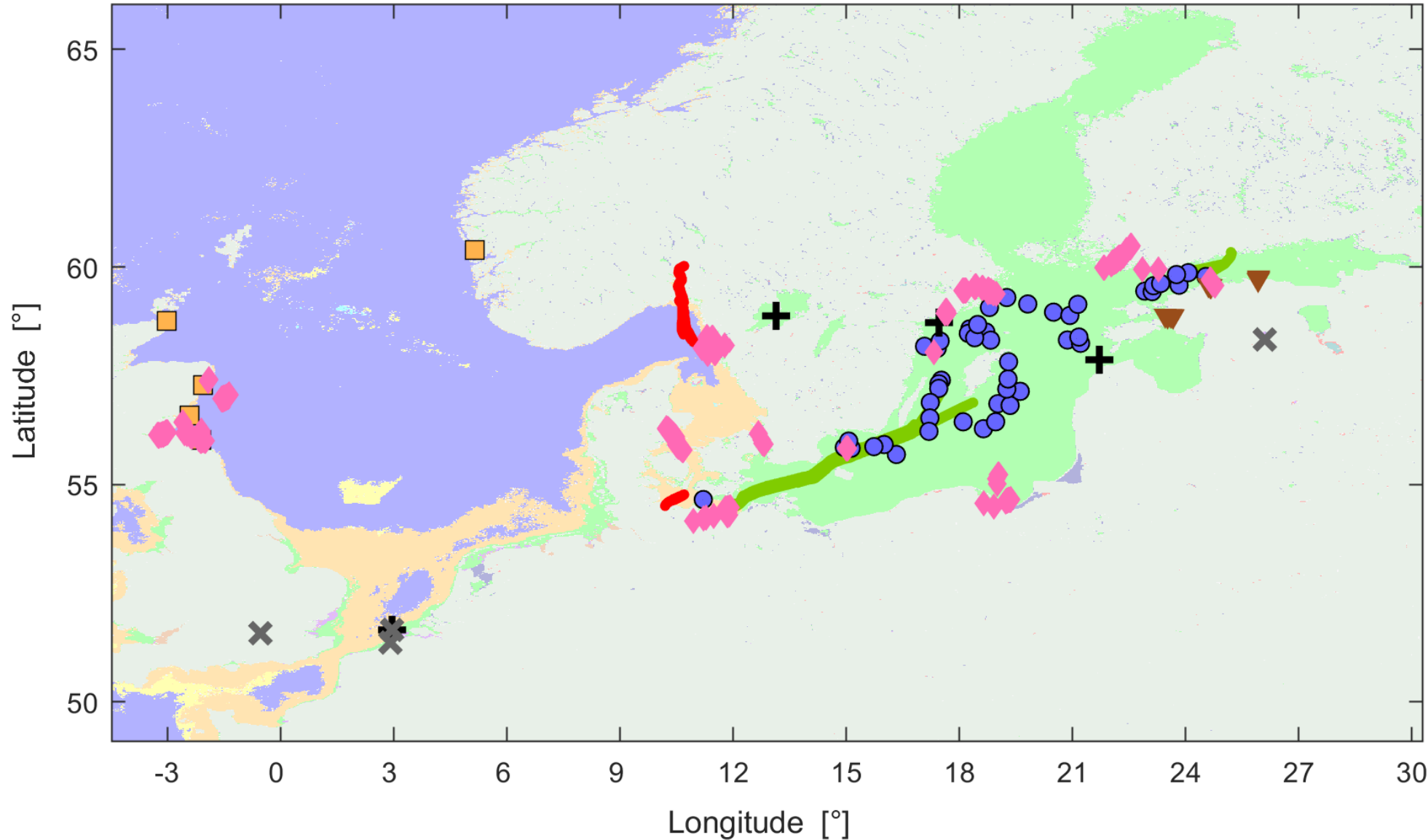


■ Below threshold  
■ Low  
■ Medium  
■ High

- Large-scale changes in the Rrs spectra – shifts in OWT distributions
- In Col 4: increase max. membership in 3a, 4a, 7; decrease in 2, 3b, 4b, 5a, 5b
- A few more spectra that cannot be sufficiently classified (~12%)

Total files processed: 31  
 Total valid pixel: 60 Mio

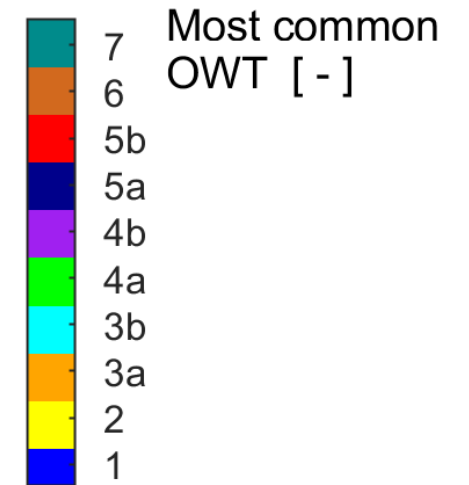
# Rrs validation data June to September 2023



Stationary networks:  
 + AERONET-OC  
 X WATERHYPERNET

Autonomous on ferry lines:  
 Oslo - Kiel  
 Helsinki - Travemünde

Campaigns:  
 AL597  
 TREC-TARA HyperOCR  
 TREC-TARA So-Rad  
 TREC-TARA Ramses



# Rrs validation data June to September 2023



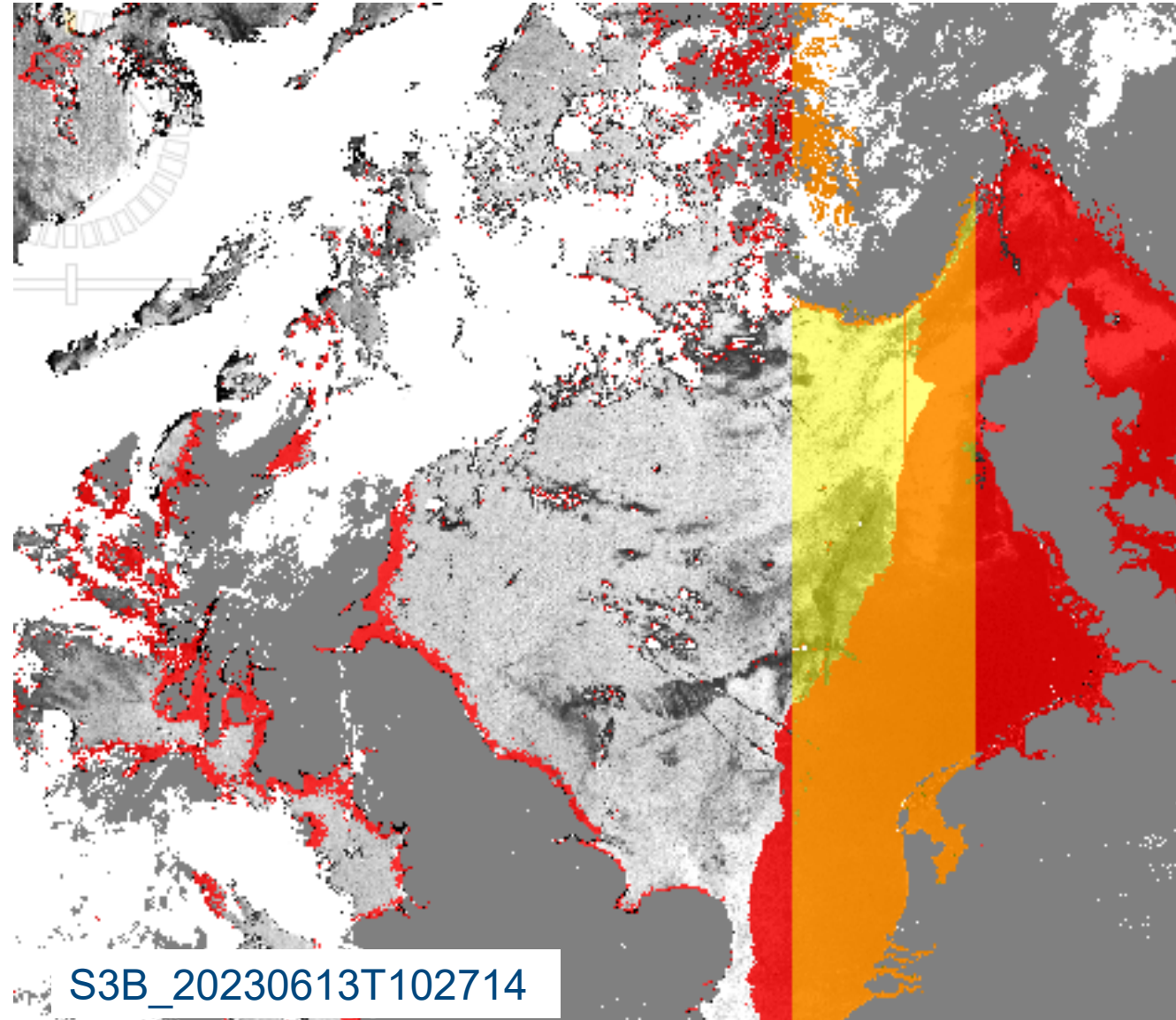
Framework	ID	Sensor	Data points	Derived OWT, numbers are percentage of cases with maximum membership, X is for contributing classes									
				1	2	3a	3b	4a	4b	5a	5b	6	7
AERONET-OC	Irbe Lighthouse	SeaPRISM	434			X	X	86	X	14	X		X
	Gustav Dalen Tower	SeaPRISM	1179			X	X	78	3	19	X		X
	Palgrunden	SeaPRISM	415			X		19	X	81	X		X
	Thornton C-power	SeaPRISM	22			X	X	73	27	X	X		X
WATER-HYPERNET	O1BE	PANTHYR (Ramses)	569			X		1	99	X	X	X	X
	WRUK	HYPSTAR	215			X		66	X	33	1		X
NIVA Ferry	Ferry Oslo-Kiel	Ramses	10223			15	X	75	<1	2	3	X	7
TREC-TARA	TARA	So-Rad (Ramses)	712		X	21	X	70	4	4	X		X
	Tara Europa 2023	HyperOCR	5			60	X	40	X	X			
	TREC Estonia	Ramses	20			X		36	8	46	X	X	10

# Criteria for valid match-ups

- We propose a relaxation of the match-up criteria to improve comparability in AC performance evaluation especially in under-represented OWT (3b, 4b, 5a, 5b, 6, 7)
- Do not consider spatial homogeneity criterion (but do document it)
  - Major influence on the exploitation of the valid match-ups
  - Cases with high biomass cannot be validated (partly also flagged in AERONET-OC L1.5 to L2)
- Flags
  - New CLOUD\_SHADOW useful
  - HIGHGLINT questionable

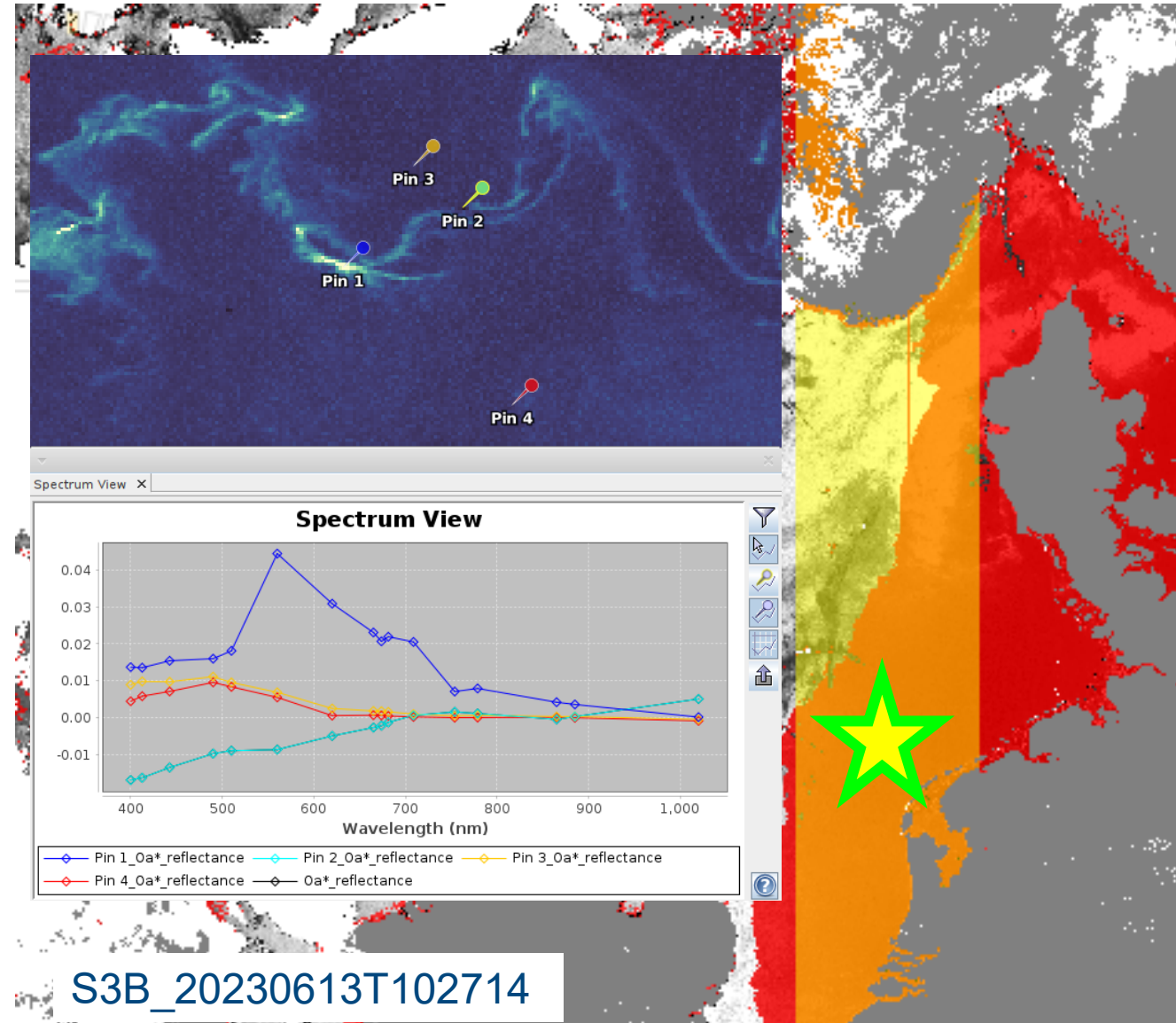
# FLEX-FLORIS synergy with Sentinel-3-OLCI

- FLORIS covers same area as OLCI's camera 4 with 6-15 seconds time difference
- For match-ups: invalid pixel expression includes high sun glint and negative reflectance at bands 2-8 (in addition criterion for spatial homogeneity)
- Entire area of camera 4 can be affected



# FLEX-FLORIS synergy with Sentinel-3-OLCI

- FLORIS covers same area as OLCI's camera 4 with 6-15 seconds time difference
- For match-ups: invalid pixel expression includes high sun glint and negative reflectance at bands 2-8 (in addition criterion for spatial homogeneity)
- Entire area of camera 4 can be affected
- Rrs spectra are generally usable even in high sun glint (not extensively tested)



# Conclusions



- OWT analysis assigns spectral shape and magnitude, enabling global comparability
  - AC over-correction (negative reflectance) can make it more difficult to assign
- Based on a few tests, first impressions of OLCI Collection 4:
  - Probably better consistency between cameras 3, 4 and 5
  - Some cases seem to make more sense, e.g. at clouds, in the German Bight, and cases that were previously unclassifiable
  - The differences in observation geometries should be compared in detail (S3A vs S3B)
  - Rrs is still very noisy
  - Rrs of Coccolithophores may be less well represented → check against the AERONET-OC data in Cazzaniga et al. 2021
- In general, in situ measuring stations cover relatively similar types of waters (OWT 4 a-b)
- More clear waters (OWT 1-3b) and phytoplankton-dominated classes (OWT 5a-b) would be desirable