RC2: 'Comment on essd-2025-443', Timothy Moore, 29 Dec 2025

Thank you very much for carefully reviewing our paper and for your helpful comments on how to improve it. Your contributions are very much appreciated. We will address all points below (our responses are highlighted in blue).

General comments

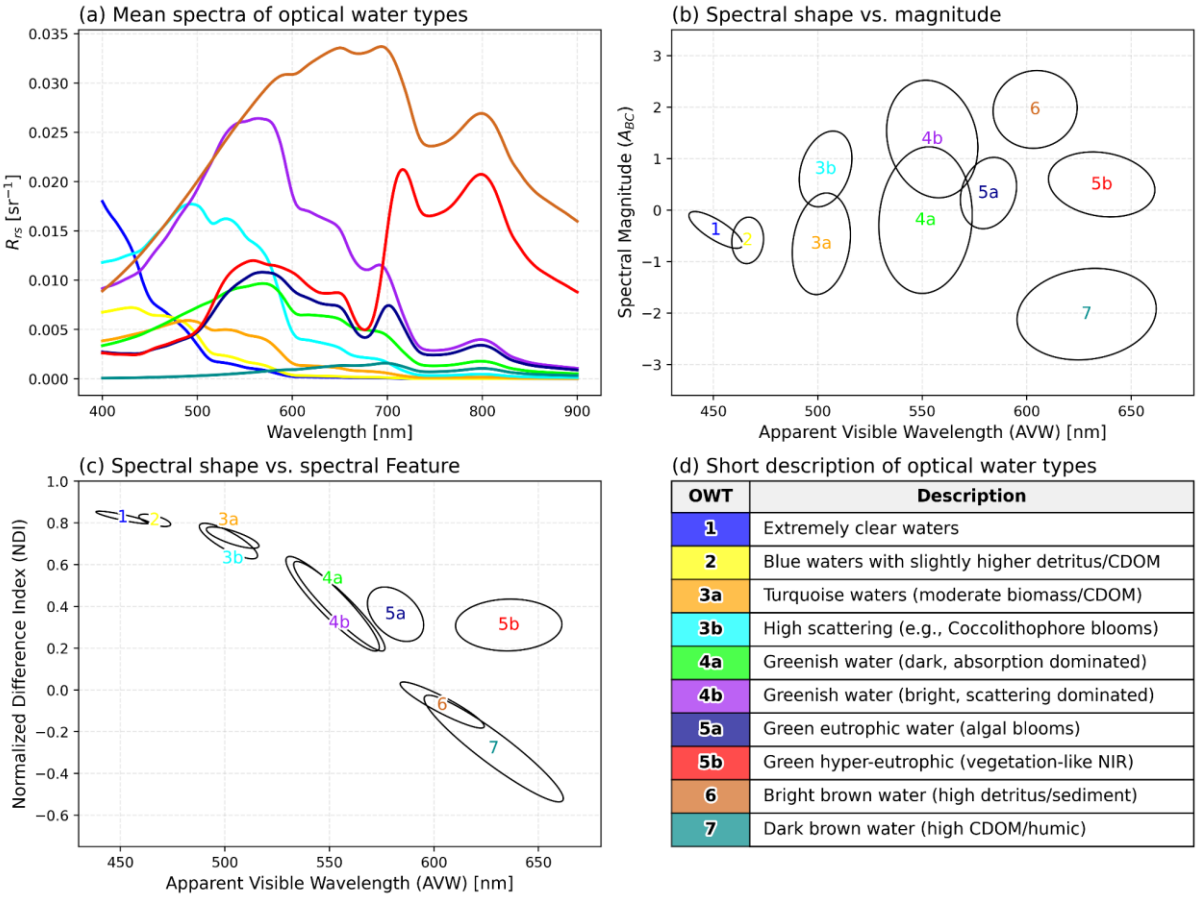
Overall: The present manuscript describes an end-to-end processing chain for generating regional ocean color products from a processing scheme that incorporates flexible choices for atmospheric correction and bio-optical algorithms through a classification scheme developed in a previous manuscript. This comprehensive approach is a realization of how optical water type classification schemes can be fully utilized in a processing chain, as both integrating intermediate products for blending, and as stand-alone products in of themselves. The developed scheme covers a wide variety of waters, from inland systems to coastal and open oceans of the Baltic/North Atlantic region. The developed scheme addresses problems of choosing algorithms across such diversity of systems.

Response: We appreciate your positive assessment of the benefits of this new technology.

The presentation of the overall manuscript is reasonable. However, notable omissions hinder important aspects of the manuscript. First, the OWT scheme, which is the central 'glue' to the processing chain, is not visualized and referenced in a previous manuscript. The OWTs are never shown or clearly explained as to what they represent. A new section should be devoted to this. What are the centroids and distributions of the 3 variables - this could be shown in 3-d space. What do the Rrs shapes look like, what are the spectral/optical characteristics, why are there 'a' and 'b' subdivisions - are these variations? I think it is crucial for a table and/or figure showing the OWTs, as these are referenced throughout the paper.

Response: Thank you, it's a good recommendation for introducing the OWT framework even better.

Changes: We have written a separate chapter on the OWT system (new 2.4) and adapted previous information accordingly. We have also added an illustration of the mean spectra, the co-variances of the optical parameters and a brief description (new Fig. 4).



(d) Short description of optical water types

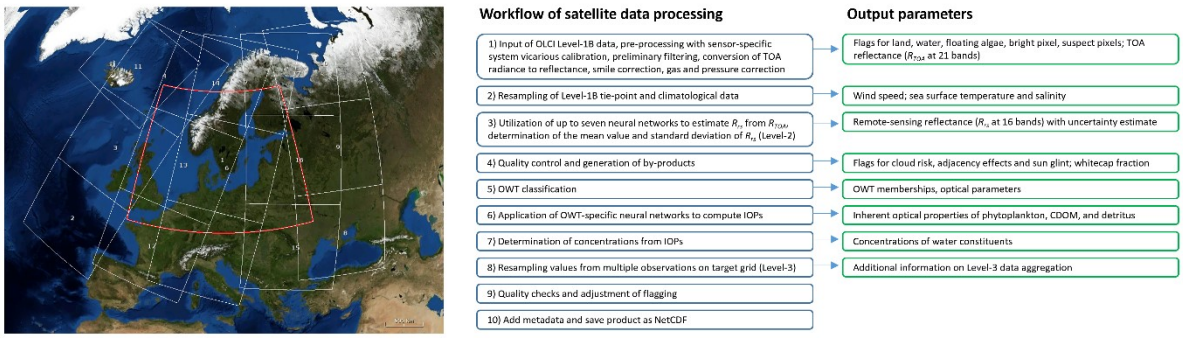
OWT	Description
1	Extremely clear waters
2	Blue waters with slightly higher detritus/CDOM
3a	Turquoise waters (moderate biomass/CDOM)
3b	High scattering (e.g., Coccolithophore blooms)
4a	Greenish water (dark, absorption dominated)
4b	Greenish water (bright, scattering dominated)
5a	Green eutrophic water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

Figure 4: Spectral characteristics and definitions of the Optical Water Types (OWTs) from Bi and Hieronymi (2024). (a) Mean remote-sensing reflectance (R_{rs}) spectra for each type. (b-c) Distribution of OWT clusters across the three optical classification variables: Apparent Visible Wavelength (*AVW*), Spectral Magnitude (A_{BC}), and Normalized Difference Index (*NDI*). (d) Descriptive summary of the ten water types.

Secondly, an overarching figure showing the scheme would also be very helpful. The 'algorithm' is really a fully developed scheme that incorporates A/C with classification and production of in-water properties as products. Using the term 'algorithm' to describe the full processing chain is somewhat mis-leading, as many readers may associate 'algorithm' with a formula for generating a specific bio-optical product from Rrs.

Response: A good suggestion to emphasise the complexity of the end-to-end processor more strongly.

Changes: We have expanded Fig. 2 and added the proposed workflow of the overall processing chain.



Lastly, the final optical products produced are not validated with any field data, but are qualitatively assessed. Operationally, extra processing effort (=time and computing power) is required for such a processing chain, which is justifiable if this leads to product improvement. This lack of verification without comparisons with 'validation' data leaves this question dangling. While this has been demonstrated in other earlier OWT-based studies, it is left unanswered here.

Response: Please refer to our detailed comments on validation in response to Reviewer #1. In summary: The validation of the 73 individual parameters in the dataset, including R_{rs}, IOPs, and concentrations of water constituents, is very complex and involves specific error assessments. In addition, we call for an OWT-specific evaluation of "algorithm" performance, as measurement methods are also not applicable to all water types. We would like to refer more prominently to earlier work and comparisons, especially for R_{rs}, which is the basis for OWT analysis. We are aware of the pressing issue of validation and want to address it more thoroughly, but not comprehensively in this article. We propose to address the validation issue using the one water parameter described, namely *POC*, where there is very little measurement data that matches the satellite data set. This comparison is only meaningful for one water class, not for the other nine defined OWTs. Our main focus is on demonstrating the fitness for purpose of the A4O atmospheric correction for this region, which includes all defined OWTs.

The goal of this development is to create a processing system that works quickly, efficiently, and provides reliable products, making it suitable for operational use. By using OWT-specific water algorithms, we want to improve water product quality (because we can reduce ambiguities and adjust the scope), but this requires additional computational effort. We are currently working on a more efficient solution and system integration; validation of the end-products will follow.

Changes: We complement the quantitative evaluation of the POC results with a comparison with in situ data from the Baltic Sea and July 2023. Moreover, we add discussion on a validation plan.

Specific Comments:

L29: PACE now expands wavelength range into the UV

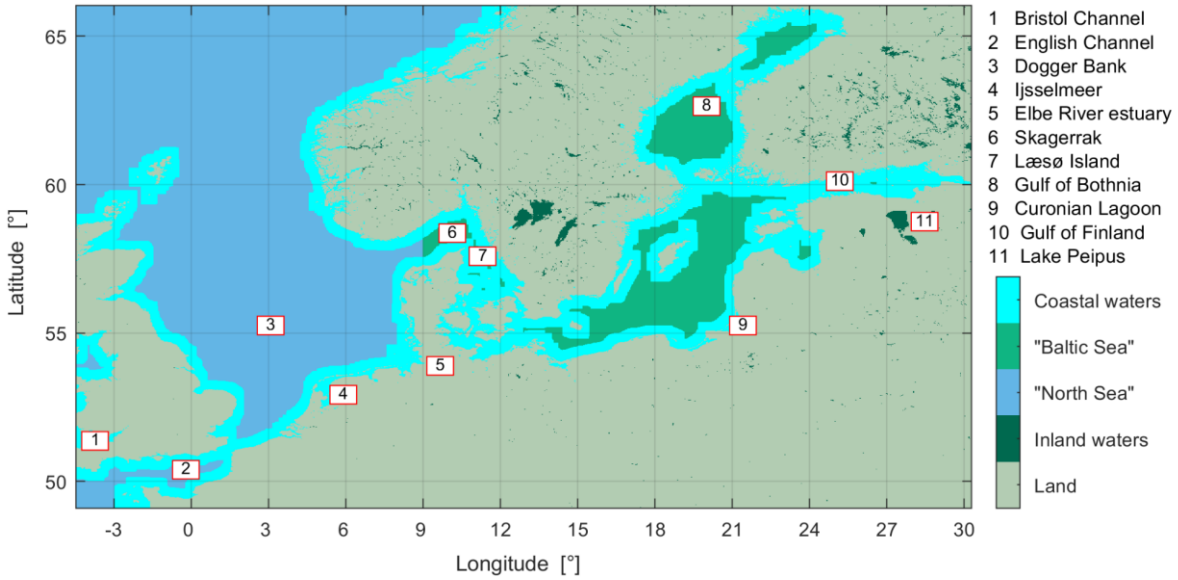
Changes: UV included.

L44: What is meant by the 'view'? Is this a geometric view from satellite, or a philosophical view of ocean color?

Changes: We reformulated the sentence to "Earth observation of large areas with different types of waters also poses significant challenges for analysing satellite images."

L98-104: Not familiar with the geographic landmarks mentioned and they are not indicated on the map.

Changes: The overview map (Fig. 1) has been modified accordingly and the waters mentioned in the text have been labelled.



L124: so, 4 months of image data used in total?

Changes: Yes, "four-month period" was included.

L134: What is meant by the 'algorithm'? It sounds like at least part inclusion of an atmospheric correction? Should this be the 'processing scheme' or 'algorithm scheme'? Also, The 'used' algorithm could be phrased better…the 'developed' algorithm or 'proposed algorithm'? A schematic figure showing the processing chain and/or evolution of the 'algorithm' would be a useful (critical!) figure for this section.

Response: Thanks for the hint to unclear wording. We will emphazise more the "processing scheme" or "end-to-end processor" in the manuscript.

Changes: We changed the wording and included a schematic figure illustrating the workflow.

L153: the 'used processing chain' is a bit awkward phrasing…alternative suggestions: the 'developed processing chain'…the 'implemented processing chain'…the 'presented'. This section is a bit confusing because now it appears that daily averaging is part of the 'algorithm', along with in-water production generation. I really think this needs to be clarified what components are involved in the 'algorithm' - A/C correction, water typing, averaging, product generation (a schematic would help here).

Changes: Thanks for the suggestions, we rephrased it accordingly.

L155-160: Unclear how many pixels were used for the developing the OWT scheme.

Response: We apply the OWT scheme developed by Bi and Hieronymi (2024) based on simulated R_{rs} data, which are based on state-of-the-art biogeo-optical modelling by Bi et al. (2023). Thus, the OWT scheme is independent of any actual satellite data but can be flexibly applied to atmospherically corrected scenes with many different band configurations, e.g. for

Sentinel-2 MSI, VIIRS, PACE etc.. A fundamental description of the OWT scheme has been included.

L165-238: Elements described here could be better visualized if included in an overarching schematic.

Changes: We included a schematic figure illustrating the workflow.

L252: 'already favoured'->'promoted' or 'advanced'?

Changes: We chose “promoted”.

L270: Comment: the OWT scheme is based on satellite data (it was unclear up to this point).

Response: No, actually not. Both independent OWT schemes, Hieronymi et al. (2017) and Bi and Hieronymi (2024), are based on radiative transfer simulations and resulting R_{rs}. The mentioned publication by Hieronymi et al. (2023) compared four different OWT schemes applied to atmospherically corrected OLCI scenes.

L275: This is an important section and its a bit unclear how or what the premise of the OWT scheme is. The statement that 'Rrs is not compared directly..' and '3 optical variables' is critical, but the 3 variables should immediately be listed as it wasn't totally clear what those were in the following sentences. Recommend listing them directly as 1), 2) and 3) here. It appears that its OWT_area, AVW, and the NDI? Its unclear how many OWTs there are, and what their characteristics are in terms of the 3 parameters. A figure or table would be helpful.

Response: Thanks for pointing this out.

Changes: We have written a separate chapter on the OWT system and adapted previous information accordingly. We have also added an illustration of the mean spectra, the co-variances of the optical parameters and a brief description (new Fig. 4).

L293: Need references for 'fuzzy logic approach' or more description of its use.

Changes: This is integrated into the new separate chapter.

L326: Its unclear what is meant by 'the variability is broad' - environmental, optical, both? This whole sentence is a bit ambigous and phrasing is unclear: the sentence continues with 'possible problems of the water algorithms used', which now switches topic from optical variability (leading to?) higher uncertainties in optical products from applied algorithms (that is how I interpret this, which could be wrong).

Changes: We rephrased this: “Coastal and inland waters vary more in colour and are often dominated by optical effects from high concentrations of sediments, CDOM, or phytoplankton. This wide range of concentrations may also exceed the validity range of applied satellite algorithms.”

L327: 'ambiguous variability' is ambiguous in itself. Do the authors mean, unpredictable Rrs shapes resulting from errors in atmospheric correction?

L328: '...with A4O having a possibly erroneous tendency towards more blue water (i.e. OWT 1)': this statement is unclear - I'm not sure what this means. Can you clarify and rephrase?

L329: ' The other AC methods would probably result...' - this sounds like conjecture - was this observed?

Changes: In response to the three points, we rephrased this section: “Hieronymi et al. (2023a) compared five atmospheric correction methods for OLCI and showed that, especially in the transition from coastal to clearer North Sea waters, the resulting R_{rs} can be fundamentally different. Here, the comparative uncertainties in the shape and magnitude of R_{rs} are particularly high, but also difficult to quantify. Comparison with in-situ data show a tendency for A4O to assess the water as clearer and bluer, i.e. to switch earlier than the other methods to maximum membership in OWT 1 during the transition to the open sea. Consequently, this means that absorption and scattering of water constituents are underestimated, and therefore the predicted concentrations are underestimated too.”

L337: What is the reason for ascribing OWTs labeled with 'a' and 'b'?

Response: The OWT framework is very flexible and applicable to many band configurations. It focuses on three RGB bands to realize this flexibility and uses R_{rs} shape and magnitude information. Of the ten defined classes, three of them have an additional label “a” or “b”. They have the same spectral shape but different magnitudes (brightness). In this way, it is possible to define a separate class for coccolithophores for example (OWT 3b), calcifying phytoplankton with crucial function in global biogeochemical cycling. The IOPs of that single-celled algae are significantly different than of other algae groups. The approach allows therefore application of dedicated water algorithms, e.g. to estimate the related particulate inorganic carbon (PIC) concentration.

Changes: The OWT framework is better introduced in a separate section.

L344: Use of the word 'visible' twice in the same sentence for different reasons is confusing - suggest rephrasing.

Changes: One replaced with “recognisable”.

L345: The underlying assumptions meaning that algorithms assume optically deep conditions?

Response: Yes, this is generally true for ocean/aquatic colour algorithms. Moreover, they expect moderate wind speed, certain sun height (if not at zenith), and a well-mixed upper layer without floating material.

Changes: Insert of clarifying words.

L347-348: By 'too blue', is the inference that pixels are erroneously classified? Its unclear what the OWTs are representing without a table, figure or other explanation.

Response: Within the new mentioned OWT section, we have included a figure that contains a table with OWT description.

L360: A frequency map of OWTs would illustrate the permanence or variability of areas in relation to OWTs (this could be a sub-figure to Fig. 10 or 11).

Response: This is an interesting point for future analysis, also the distribution of covarying class memberships. However, a frequency map of OWTs would be affected by inhomogeneous distributions of data gaps, which is the case because of diverse cloud cover (Fig. 3).

L383: 'not shown' implies this was tested, but the statement says '..it would be expected..' - this needs to be clarified as to whether in fact the authors did try this, or this is speculation or based on some other result which would need references in that case.

Response: The reviewer is right; the sentence is too speculative and is removed. The general behaviour was discussed in Hieronymi et al. (2023) and tested for the supporting information of Bi and Hieronymi (2024), but not specifically on the same period.

L390: Its not evident to the reader at this point what any OWTs look like or represent. This needs to be presented as a section devoted solely to the characteristics of the OWTs earlier in the manuscript.

Response: Within the new OWT section, we have included a figure that includes mean R_{rs}.

L396: This statement needs some references.

Changes: We added the following references: "(e.g., Nelson and Siegel 2013; Kutser et al., 2016; Spyrakos et al., 2018)".

L414-415: Are these global numbers or over the study area?

Response: This is unclear, as it says: "From global MODIS cloud observations, …".

Changes: We include "worldwide land surfaces" to emphasize that this is not only our region of interest. Moreover, we include a reference for the following sentence: (e.g. Schrum et al., 2003).

L435: What does 'guaranteed' mean? This is a strong statement, and would recommend to modify.

Changes: We change it to "is satisfied on average".

L430-437: not sure if anything new or relevant from this section

Response: This is maybe not visible on the first view but contains interesting questions on validation. Wind speed is one factor that influences measured R_{rs}. Available matchups are significantly reduced if one applies a wind speed threshold of e.g. 6 m/s. At higher wind speeds, we may have optical effects from suspended particles or air bubbles in water, even causing a change of OWT distribution. Thus, we keep the section for future reference.

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