A Scattering-sensitivity Analysis Based on Radiative Transfer for Modelling the Optical Reflectance of Phytoplankton Groups

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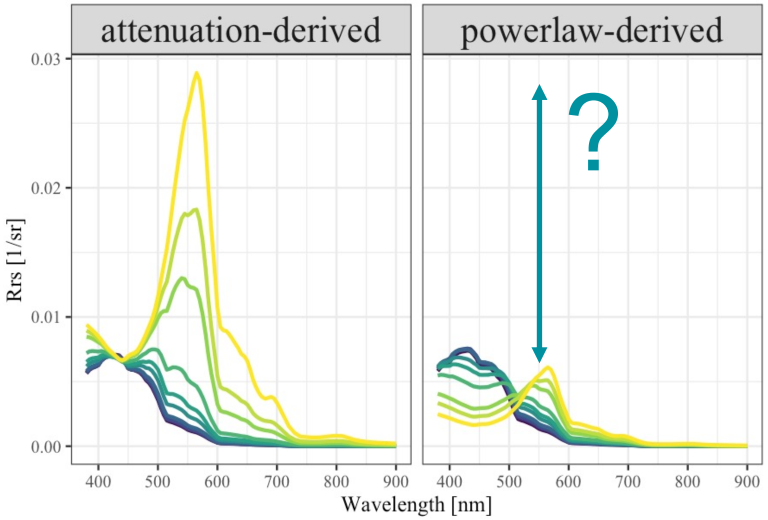

Fig.1 $R_{rs}(\lambda)$ difference between scattering modes of *Coccolithophores* colored by biomass. A huge "gap" was observed between different scattering modes.

Abstract

Phytoplankton plays a critical role in the global carbon cycle. The unequal inherent optical properties of different phytoplankton groups affect the performance of algorithms and bias global ocean colour products. In this study, we conduct a sensitivity analysis to evaluate the effect of different scattering models on ocean colour algorithms like ONNS[1] and OCI[2].

The widely used power-law function for the phytoplankton scattering coefficient[3] often oversimplifies scattering properties. For more turbid or productive waters, the scattering model has a considerable **effect on reflectance brightness but less on spectral shape** i.e. only slight effect on optical water type classification.

For Case-2 waters and higher chlorophyll concentrations, the attenuation-derived scattering yields more reliable reflectance spectra for all phytoplankton groups.

Methodology

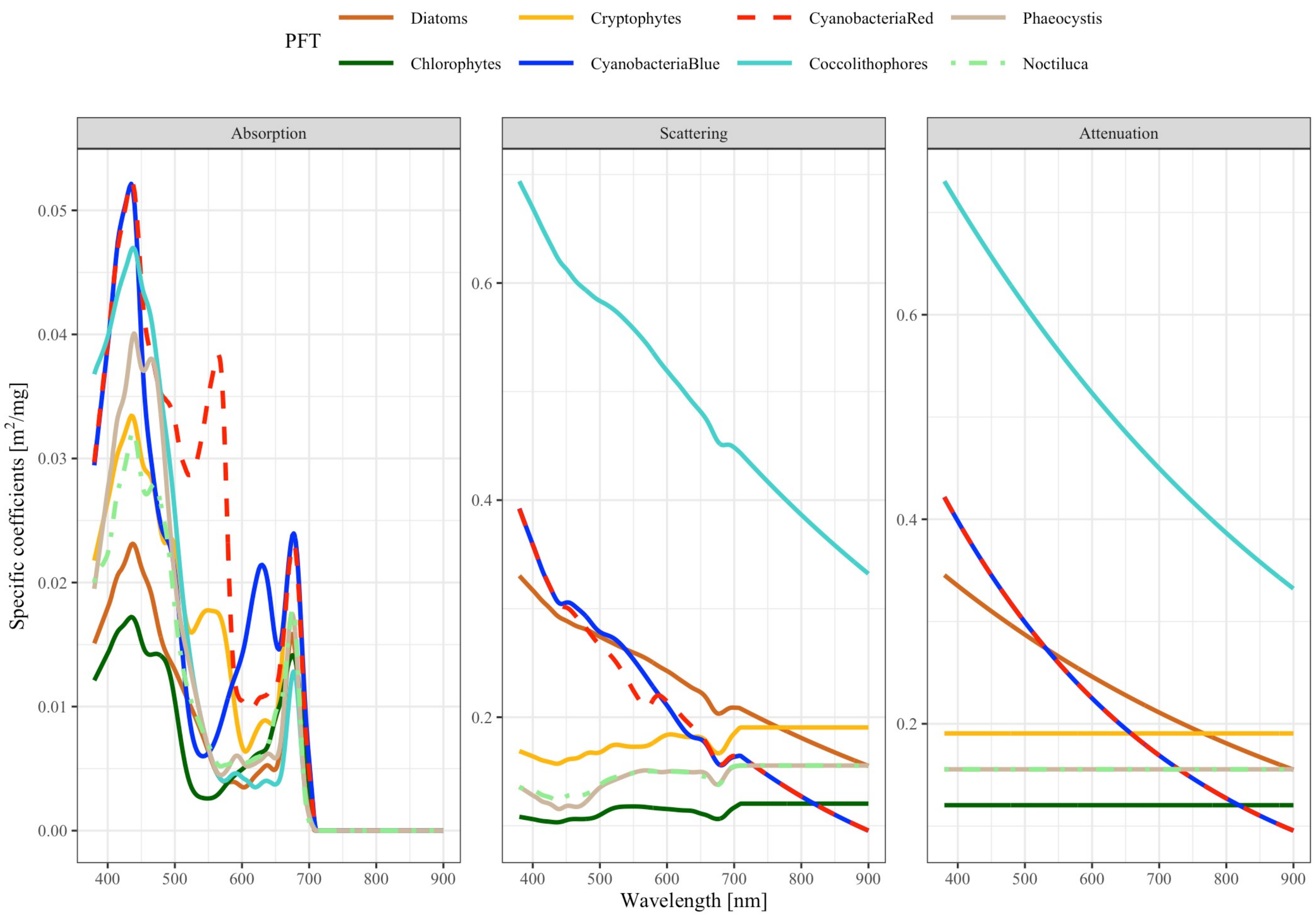

Fig 2. Specific absorption, scattering, and attenuation spectra for phytoplankton groups.

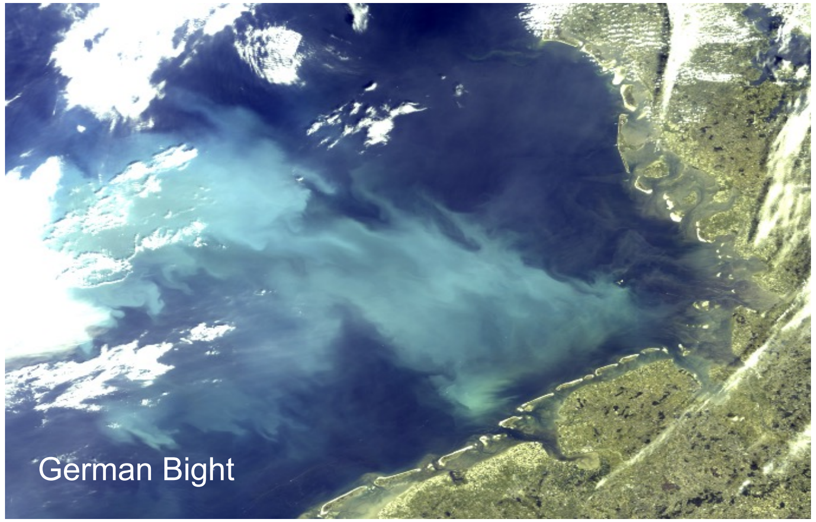

Fig 3. Satellite image during *E. huxleyi* blooms in bright milky turquoise color.

- Two scattering modes the power law function based on Chl concentration[3] and specific scattering by attenuation minus absorption[4] .
- Satellite observations (Fig. 3) illustrate the demand for choosing appropriate scatter for simulating phytoplankton reflectance.
- For simulating the different stages of *E. huxleyi* bloom, *Coccoliths* are assumed to have the same scattering of *Coccolithophores* but reduced absorption[5].

Results: effects on Remote Sensing reflectance $R_{rs}(\lambda)$

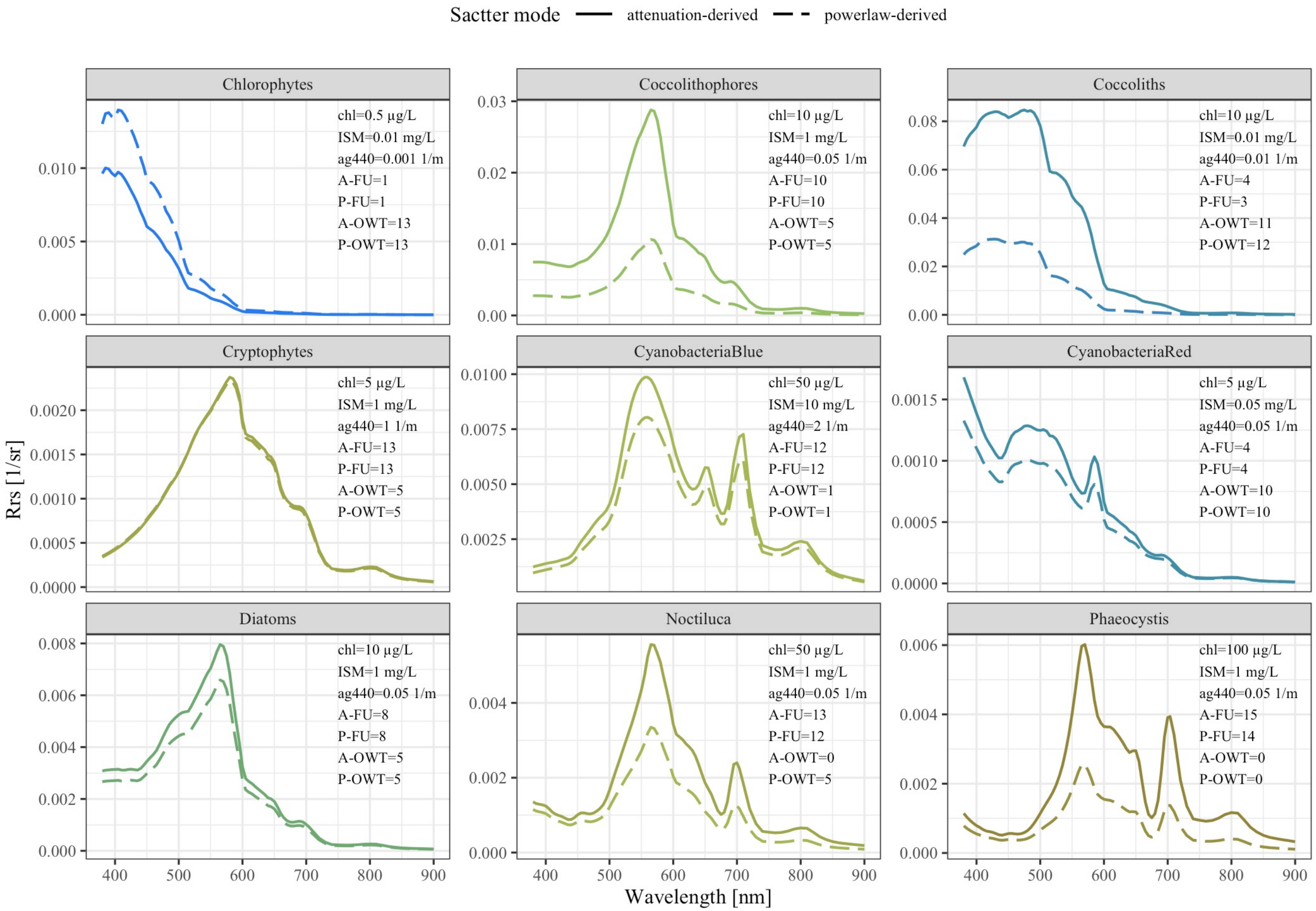

Fig. 4 Several cases of R_{rs} spectra based on attenuation-derived and power law-derived scattering. A and P denote attenuation-derived and power law-derived scattering, respectively.

- The attenuation-derived scatter results in higher reflectance at visible bands for productive waters in groups like *Coccolithophores*, *Cyanobacteria*, *Diatoms*, etc.. In the case of *Chlorophytes*, it also leads to decreased reflectance in clear waters.
- Non-algal components have the opposite effect on R_{rs} difference, implying that the phytoplankton scattering difference could be omitted in extreme high CDOM or sediments waters, such as river plume.
- *Coccolithophores* are most sensitive to the scattering mode of these groups. The simulated spectra match the bright milky turquoise observed from satellites and FU color scales.

Results: effects on optical classification and ocean color algorithm

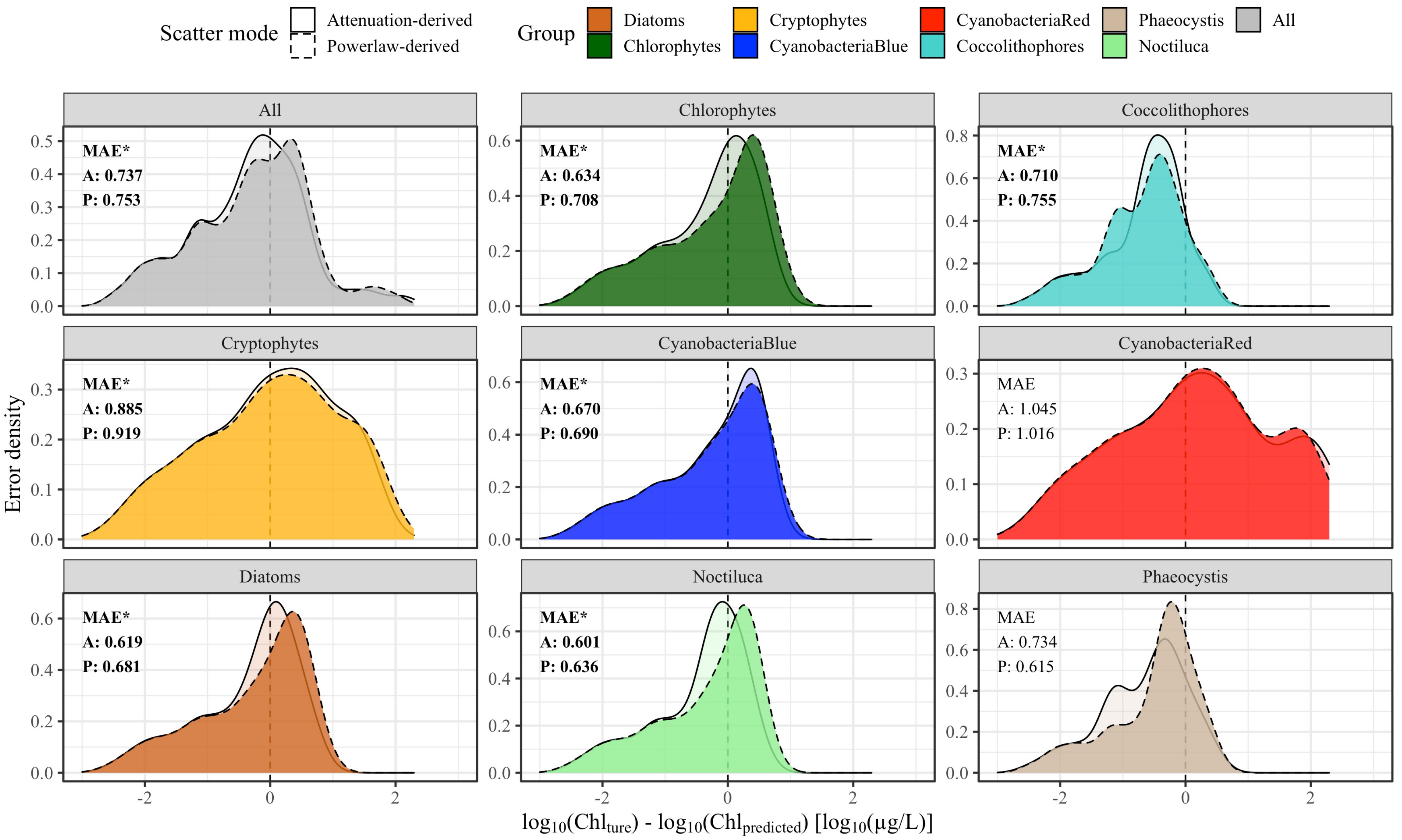

Fig. 5 Density plots of the log10-scaled *bias* of OCI algorithm[6] (for Chl > 0.05 µg/L).
A and P denote attenuation-derived and power law-derived scattering, respectively. Bold MAE (mean absolute error) tagged with * means attenuation-derived R_{rs} outperforms Chl prediction.

- The scattering model has a minor impact on ONNS optical water type classification (~6.4% changed).
- Attenuation-derived R_{rs} is more plausible for Case-2 waters, allowing a better differentiation of phytoplankton and sediments. The power law-derived scattering in the previous ONNS training has an under-estimate of reflectance brightness in Case-2 waters, although the effect diminishes in oceanic waters.
- The attenuation-derived R_{rs} has a better Chl prediction based on the OCI algorithm[2], showing the rationality of this scattering property.

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Knowledge gaps

- Our study uses phase function determined based on the reported backscattering ratio for the corresponding Fournier-Forand functions. However, there remain big unknowns regarding phytoplankton scattering properties like phase function, which has a considerable influence on R_{rs} simulation.

- Besides, variability of specific scattering within one phytoplankton group still exists due to different particle shapes and size distribution. Spectral properties of PFT like *Coccolithophores* may vary within the attributes of coccoliths.

Next steps

Short-term plan

- Optical closure tests based on the simulated reflectance data and *in situ* measurements are required to optimize the appropriate scattering to specific phytoplankton groups
- With the robust IOP settings for phytoplankton, we will re-build the database for the neural network training

Mid-term plan

- Given a better understanding of phytoplankton scattering properties, we can distinguish phytoplankton groups in ONNS (possibly only with hyperspectral data)

Long-term plan

- To better provide global products of the carbon-related parameters (like DOC, POC & PIC and primary production) with the improved IOP-based ONNS

References

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