

SPECIFIC PHYTOPLANKTON ABSORPTION VARIABILITY AND IMPLICATION FOR CHLOROPHYLL *a* RETRIEVAL IN BELGIAN WATERS (SOUTHERN NORTH SEA).

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ABSTRACT

Chlorophyll *a* retrieval from satellite is based on algorithms that convert the phytoplankton absorption into chlorophyll *a* by means of the specific-phytoplankton absorption. This factor has been found to be highly variable, spatially and seasonally.

The variability of the chlorophyll *a*-specific phytoplankton absorption in Belgian waters (Southern North Sea) was investigated to determine how it is affecting the chlorophyll *a* retrieval from satellite information. The Southern Bight of the North Sea is a very dynamic area influenced by river discharges and characterised by highly variable chlorophyll, suspended matter and coloured dissolved organic matter absorption.

The impact of using a mean value of specific-phytoplankton absorption as usually done instead of the real one in chlorophyll *a* retrieval was estimated and found to be significant (underestimation up to 70% at 665 nm).

1. INTRODUCTION

The Southern Bight of the North Sea is a shallow (<40m) region with strong (1 m/s) tidal currents which receives discharges from several rivers [1]. The spring bloom reaches high chlorophyll *a* (Chl-*a*) concentrations (e.g. >30 mg m⁻³). The rest of the year Chl-*a* values remain <10 mg m⁻³ in offshore areas and <30 mg m⁻³ in coastal stations [2]. High concentrations of suspended matter (e.g. 10-100 g m⁻³) result from resuspension of bottom sediments and river loads [3]. The latter causes also high (e.g. 0.7 m⁻¹ at 412 nm) coloured dissolved organic matter (CDOM) absorption [4].

From an optical point of view, these are highly scattering and absorbing case 2 waters, where the contribution of the main water components varies from one station to the other and seasonally [4].

For such waters, Chl-*a* can be estimated by algorithms based on the red absorption of chlorophyll (e.g. 665 nm), thus avoiding retrieval problems associated with CDOM and non-algae particle absorption in the blue

and green (e.g. 442 nm) [5]. Alternatively, a more complex method, the Neural Network which uses a number of reflectances and angles and retrieve the concentrations by multiple non-linear regression at 442 nm, is currently applied in the MERIS Chl-*a* retrieval [6].

Regardless of whether a red/near infrared or a Neural Network approach is used, all algorithms retrieve essentially the phytoplankton absorption coefficient which must then be converted to the geophysical parameter, Chl-*a*. Usually, algorithms consider a constant value for this conversion factor, the Chl-*a*-specific phytoplankton absorption (*a**). Therefore, any variability of *a** will affect the Chl-*a* retrieval.

In this study we explore how the observed variability of *a** in the Southern Bight of the North Sea is affecting the retrieval of Chl-*a*.

2. METHODS

Sampling was conducted at 15 stations in the Belgian and adjacent coastal waters during 5 campaigns between April 2004 and June 2005 (Fig. 1).



Figure 1: Location of sampling stations in the North Sea.

At all stations some 20 L seawater was sampled from surface for measurement of:

- Total particle absorption (phytoplankton and non-algal particles),
- HPLC Chl-*a*,
- Total suspended matter,
- salinity and
- CDOM absorption.

Methodology is described here for the two former measurements. A detailed description of the three later analyses can be found in [4].

2.1. Phytoplankton absorption

Seawater was filtered onto a 25 mm glass fiber filter (Whatman GF/F). The absorbance spectra of particles $OD_P(\lambda)$ and non-algal particles $OD_{NAP}(\lambda)$ retained on the filter was determined following the Transmittance-Reflectance (T-R) method [7]. Transmittance and reflectance were measured between 300 and 800 nm with a Uvikon 930 dual beam spectrophotometer equipped with a 6 cm-integrating sphere. Pathlength amplification was corrected using an algorithm which has been validated for several phytoplankton species and detrital particles [8]. The filter was bleached with a solution of sodium hypochlorite (0.13% active chlorine) to obtain the absorbance spectrum of NAP, $OD_{NAP}(\lambda)$ which includes de-pigmented algal cells retained on the filter [9]. Absorbance values at each wavelength were converted into absorption coefficients as:

$$a_{P/NAP}(\lambda) = 2.303 \times \frac{OD_{P/NAP}(\lambda)}{X} \quad (1)$$

where X is the ratio of filtered volume to the filter clearance area.

No correction to absorption for scattering in the NIR was performed since the T-R method has been proven to correct for scattering and because there is evidence that some mineral particles absorb in the NIR region [10].

The phytoplankton absorption coefficient $a_{ph}(\lambda)$ was obtained from:

$$a_{ph}(\lambda) = a_P(\lambda) - a_{NAP}(\lambda) \quad (2)$$

The Chl-*a*-specific phytoplankton absorption coefficient $a^*(\lambda)$ was obtained from:

$$a^*(\lambda) = \frac{a_{ph}(\lambda)}{Chl-a} \quad (3)$$

2.2. HPLC Chl-*a*

Between 0.05 and 1 L of seawater were filtered onto 25 mm glass fiber filters (Whatman GF/F) for HPLC Chl-*a* determination. The filters were kept in liquid nitrogen on board and then stored at -80°C in the laboratory until

analysis. HPLC Chl-*a* concentration (mg/m^3) was detected by absorption at 436 nm and identified based on comparison of the retention time and spectra with standards [11].

3. RESULTS

3.1. Specific absorption variability

The high variability of a^* in the area is shown in Fig. 2. Except for one extreme spectrum most values range from 0.013 to 0.11 $\text{m}^2 \text{mg Chl-}a^{-1}$ at 442 nm and from 0.006-0.034 $\text{m}^2 \text{mg Chl-}a^{-1}$ at 665 nm.

Mean values (thick black line) are: $0.039 \pm 0.054 \text{ m}^2 \text{mg Chl-}a^{-1}$ at 442 nm and $0.016 \pm 0.015 \text{ m}^2 \text{mg Chl-}a^{-1}$ at 665 nm.

The latter agrees perfectly well with that of Gons [12] ($0.016 \text{ m}^2 \text{mg Chl-}a^{-1}$) determined as an average for Dutch inland waters.

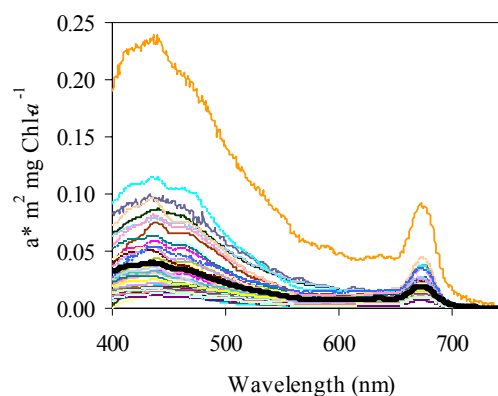


Figure 2: a^* spectra measured at different stations and seasons in the Belgian waters.

Fig.3 shows that $a^*(442)$ and $a^*(665)$ are inversely correlated to Chl-*a* concentrations. The relations are defined by a power function, whose slope is higher compared to those established by Bricaud et al. [13] for Chl-*a* concentrations between 0.02 and 25 mg m^{-3} . Our data show also a higher dispersion. At 442 nm, the scatter in the data decrease with increasing Chl-*a* and at concentrations $>10 \text{ mg m}^{-3}$ the power function is similar to that found by Bricaud et al. [13]. At 665 nm the dispersion of the data does not vary with Chl-*a* concentration. The power functions from our data intercept that of Bricaud et al. around 10 mg m^{-3} .

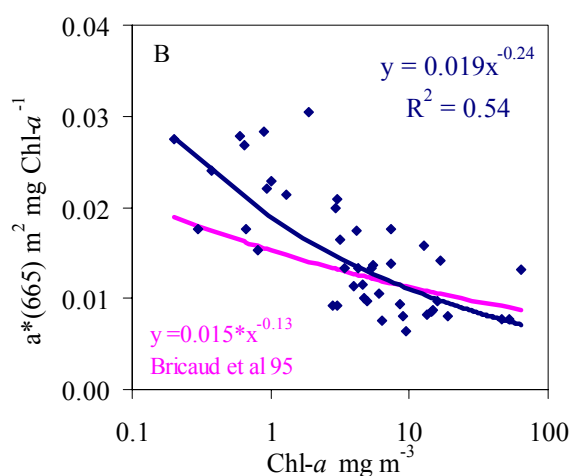
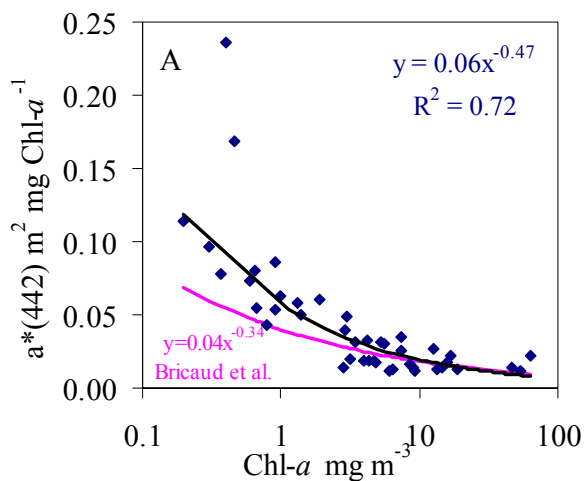


Figure 3: Relation between A: $a^*(442)$ and Chl- a and B: $a^*(665)$ and Chl- a concentration.

Reason for the high scattering of our data is unclear. Indeed no correlation exists between a^* and the main components of the water: Chl- a , total suspended matter, non-algal particles, phytoplankton absorption, a^* , salinity and CDOM absorption. This suggests that none of these variables alone can explain the scattering of the data. The latter may result from the fact that the contribution of the components is highly variable in the region. Other factors might have an influence like package effect or cell size structure.

The mean value of $a^*(665)$ calculated for each cruise is highly variable with summer values significantly higher than those of spring (Fig. 4). The spatial variability of $a^*(665)$, expressed here as standard deviation, amounts to $0.006 \text{ m}^2 \text{ mg Chl-}a^{-1}$ and is similar along the year.

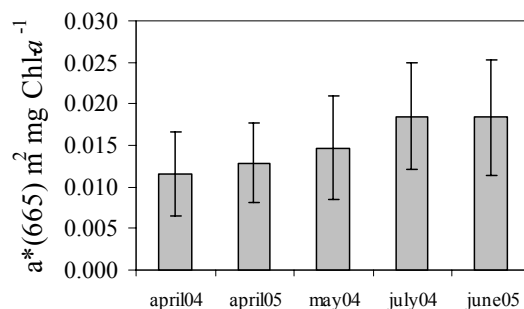


Figure 4: Mean $a^*(665)$ and standard deviation calculated for each cruise.

3.2. Chl- a retrieval simulation

A simulation was made to determine the impact obtained when using a mean value of $a^*(665)$ instead of the real one in the retrieval of Chl- a (Fig.5). For this, the algorithm proposed by Gons et al. [14], based in the ratio of two near infrared wavelengths, was used.

When using the mean $a^*(665)$ value found in this study ($0.016 \text{ m}^2 \text{ mg Chl-}a^{-1}$), the final Chl- a concentration can decrease up to 70%.

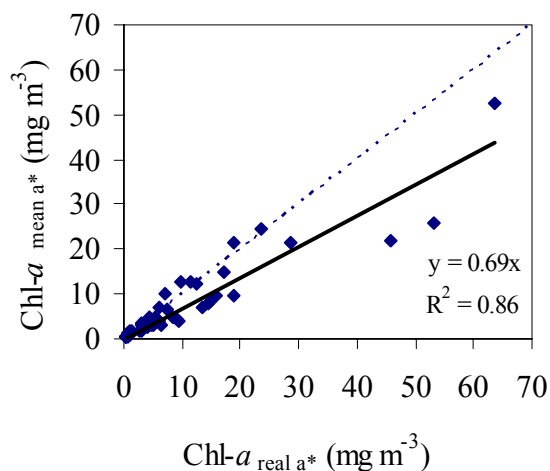


Figure 5: Chl- a calculated with real $a^*(665)$ versus Chl- a calculated with mean $a^*(665)$.

3.3. Inversion of Chl-*a* from $a_{ph}(442)$

The relation between $a_{ph}(442)$ and Chl-*a* is represented by a power function (shown in black). Also shown (in pink) is the relation found off Helgoland in the German Bight area of the North Sea [6] (Fig.6).

The intercept is twice higher than that from the Helgoland dataset, but the slope is similar. In general, for the same $a_{ph}(442)$ value our estimated Chl-*a* concentration is higher than when estimated with the Helgoland function.

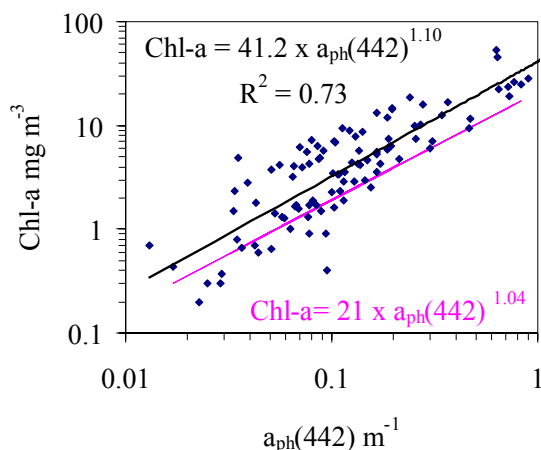


Figure 6: Relation between $a_{ph}(442)$ and Chl-*a* concentration for Belgian waters (blue) and comparison with the Helgoland dataset (pink).

4. DISCUSSION AND PERSPECTIVES

The Chl-*a*-specific phytoplankton absorption a^* at both 665 nm and 442 nm is highly variable in Belgian waters. This variability covers a Chl-*a* range of 3 orders of magnitude and is seasonal and geographical. The high dispersion found in the data cannot be explained by other components of the water column alone. One possible additional explanation is that this scattering is influenced by the package effect or/and the size structure of the populations [13].

The inversion of Chl-*a* from $a_{ph}(442)$ produce different coefficients compared to those used for Chl-*a* retrieval in the MERIS neural network algorithm. This will have an impact in the retrieval of Chl-*a* using the Neural Network algorithm in the Belgian coastal zone if those differences are not taken into account. The use of regional relations in those cases where the general relation is significantly different to the local one, could improve the Chl-*a* retrieval from satellite information.

Care must be taken when using an average value of a^* in Chl-*a* retrieval since it is shown that the retrieved Chl-*a* could lead up to 70% difference when compared to the measured Chl-*a*. Understanding of the main causes of a^* variability in this region still needs further research. The characterisation of this variability will give us a chance to improve the algorithms for Chl-*a* retrieval.

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