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Optical proxy for phytoplankton biomass in the absence of photophysiology: Rethinking the absorption line height

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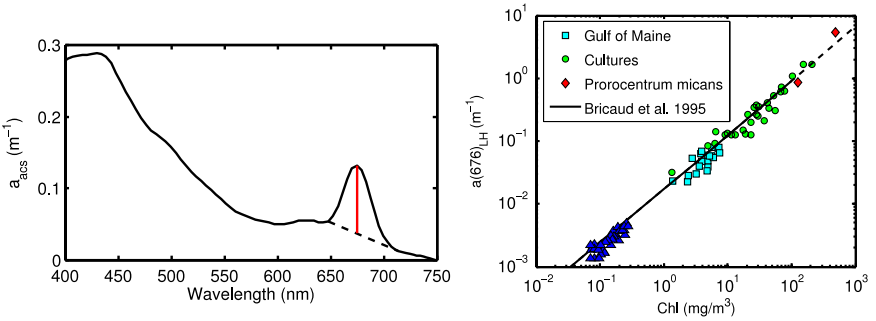
GRAPHICAL ABSTRACT



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ABSTRACT

The pigment absorption peak in the red waveband observed in phytoplankton and particulate absorption spectra is primarily associated with chlorophyll-*a* and exhibits much lower pigment packaging compared to the blue peak. The minor contributions to the signature by accessory pigments can be largely removed

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by computing the line height absorption at 676 nm above a linear background between approximately 650 nm and 715 nm. The line height determination is also effective in removing the contributions to total or particulate absorption by colored dissolved organic matter and non-algal particles, and is relatively independent of the effects of biofouling. The line height absorption is shown to be significantly related to the extracted chlorophyll concentration over a large range of natural optical regimes and diverse phytoplankton cultures. Unlike the *in situ* fluorometric method for estimating chlorophyll, the absorption line height is not sensitive to incident irradiance, in particular non-photochemical quenching. The combination of the two methods provides a combination of robust phytoplankton biomass estimates, pigment based taxonomic information and a means to estimate the photosynthetic parameter, E_K, the irradiance at which photosynthesis transitions from light limitation to light saturation.

1. Introduction

1.1. Historical perspective on optical sensing of chlorophyll-a absorption

Nearly two decades ago WET Labs released a small CHLorophyll Absorption Meter (CHLAM) which consisted of three wavelengths for absorption determination. The theory behind the instrument was that the red peak of phytoplankton absorption at 676 nm was primarily determined by Q-band chlorophyll absorption. By calculating the height of the peak absorption above the baseline absorption between 650 nm and 715 nm, most of the contribution by interfering particles and dissolved matter could be removed. An early version of the sensor, a three-wavelength absorption and attenuation (ac) meter, was deployed in the Bering Sea for six months (Davis et al., 1997). Davis and colleagues introduced the baseline correction as a means to remove biofouling from the signal. This approach compared favorably to that derived from sensors that employed chemical anti-biofouling features. However, the CHLAM sensor was not widely adopted by the optics research community, perhaps because *in situ* absorption technology was not as familiar as fluorescence and the slightly more complicated technical details required for use.

Over the past decade the user community has gained more experience with absorption meters such as the WET Labs ac9 and acs. As greater opportunities for deploying optical sensors on remote platforms arises (Dickey et al., 2008), uncertainties in the estimation of chlorophyll concentration from fluorescence suggest that the time may have come for a revival of the chlorophyll absorption meter. In this paper we present an analysis of the absorption line height as an *in situ* proxy for chlorophyll absorption and hence chlorophyll concentration. We compare and contrast this approach to standard *in situ* fluorometry, quantifying the strengths and weakness of each approach. Our hypothesis in setting out this analysis is that absorption and fluorescence target different characteristics of the chlorophyll molecule specifically, but more generally of phytoplankton ecology and physiology. Thus, while each is a robust proxy for concentration under certain conditions, each provides additional information such that the combination of approaches is more than the sum of the parts.

1.2. Variability in Fluorescence yield and absorption yield per chlorophyll a

The use of simple *in situ* fluorometers to obtain a proxy for chlorophyll concentration is one of the most common aquatic biological measurements. These devices rely on excitation of the chlorophyll-*a* molecule using a blue light source, and measuring the re-emission of photons of red light in the