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Bio-optical properties of coastal waters in the Eastern English Channel

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Abstract

Strong tidal currents, shallow water and numerous freshwater inputs characterize the coastal waters of the eastern English Channel. These case 2 waters were investigated through an intensive sampling effort in 2000 aiming to study the distribution and variability of the Chromophoric Dissolved Organic Matter (CDOM), Non-Algal Particles (NAP) and phytoplankton absorption at the mesoscale. Four cruises were carried out in February, March, May and July and more than 80 stations each cruise were sampled for hydrographical, chemical and bio-optical analyses. Results showed two distinct situations, the winter period characterized by the strong dominance of CDOM absorption over the particulate matter, and the spring−summer period when phytoplankton and CDOM represented the same contribution. Meteorology was the main factor driving the bio-optical properties of the water column in winter whereas in spring−summer the biological activity seemed to be the more active driving force. The algal community composition in term of dominant cell size and, therefore, pigment packaging, is the main factor driving the phytoplankton specific absorption in the water column. Photoprotective pigments did not significantly influence algal absorption, due to turbid and highly mixed water masses. This feature also explained the bio-optical homogeneity found along the water column. On the mesoscale, distinct bio-optical provinces were defined in relation with the observed bio-hydrographical variability.

Keywords: light absorption; coastal waters; CDOM; NAP; phytoplankton; pigments; eastern English Channel

1. Introduction

The application of the ocean color remote sensing technique in coastal areas still needs to be validated and calibrated and requires the study of inherent optical properties (IOPs) at regional scale (IOCCG, 2000; Babin et al., 2003). This is of considerable significance for oceanographers since coastal ecosystems are among the most productive and rich in biodiversity of marine systems. However, they represent complex systems at ecological and optical levels, in relation with high frequency variability in time and space due to hydrodynamics (e.g. tidal currents, coastal fronts, turbulence) and freshwater input fluctuations. From an optical point of view, these ecosystems correspond mostly to case 2 waters (Morel and Prieur, 1977) where the lack of direct relationship between the absorption of non-chlorophyllous components and phytoplankton makes difficult general parameterization of their optical properties on the contrary to the case 1 oceanic waters (Bricaud et al., 1995; Cleveland, 1995; Bricaud et al., 1998). Recently, coastal ocean optics have been the topic of numerous studies (e.g. Babin et al., 2003; Gallegos et al., 2005; Simis et al., 2005; Tilstone et al., 2005), highlighting the necessity of bio-optical measurements at regional scale, which is a crucial step in improving the accuracy of coastal bio-optical algorithms.

Freshwater inputs are assumed to be the major source of Chromophoric Dissolved Organic Matter (CDOM) in coastal

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waters (Siegel et al., 2002) even though biological sources (e.g. from phytoplankton and/or bacterioplankton) cannot be neglected (Nelson et al., 1998; Rochelle-Newall and Fisher, 2002; Gallegos et al., 2005). The CDOM absorption and spectral signature can change over time and space, in relationship with its composition and origin (Carder et al., 1989), and, for instance, with processes such as bacterial degradation, photodegradation, coagulation or selective sedimentation (Carder et al., 1989; Gao and Zepp, 1998). In contrast to CDOM, variations in the absorption coefficient of Non-Algal Particles (NAP) in coastal waters are less well described (e.g. Sydor and Arnone, 1997; Gallegos and Neale, 2002; Babin et al., 2003; Bowers and Binding, 2006). However, absorption of NAP seems to depend on particle size and composition, which vary from site to site and on a seasonal scale (e.g. Ferrari et al., 2003; Gallegos et al., 2005). In certain cases, phytoplankton may also represent the main contributor to the overall absorption in coastal waters, even though it is not a general rule (Schofield et al., 2004). Indeed, it depends on the high variability in space and time of the algal growth and dynamics, which is the result of the interactions between abiotic (nutrients, light) and biotic (grazing) factors depending on physical and climatic events. The absorption properties of phytoplankton mainly rely on the pigment composition, which is a function of community composition and physiological state, and on the packaging effect (Hoepffner and Sathyendranath, 1991; Bricaud et al., 1995; Sosik and Mitchell, 1995). Recent works by Ciotti et al. (2002) and Bricaud et al. (2004) showed that changes in the dominant cell size of the algal community, and subsequent changes in pigment packaging, can explain a major part of the natural variability observed in the spectral shape of algal absorption.

The general aim of this study is to quantify the contribution of the three main absorption components of seawater, and its variability on seasonal (winter, spring and summer periods), meso- and vertical scale in the eastern English Channel. Strong tidal currents, numerous freshwater inputs and shallow water masses characterize this highly productive coastal sea. The biological and environmental variability is further increased by the distinction of two ecosystems, located south and north of the region (e.g. Brunet et al., 1996) and by the development of a non-permanent tidal front separating the coastal and offshore waters (Brylinski et al., 1996). All these features make this area an interesting test site for studies dealing with relationships between bio-optical properties and environmental (biotic and/or abiotic) forcing.

2. Materials and methods

2.1. Sampling and hydrology

Four cruises were carried out in February, March, May and July 2000 from the Bay of Seine to the North of Boulogne sur mer (Table 1, Fig. 1). The sampling grid, consisted of 82 stations distributed along 18 coastal-offshore transects, and covered the different water masses present in the area, from estuarine (in relationship with the Seine and Somme rivers) to the coastal and offshore waters. In February, the number of stations sampled was of 26 (southern part of the sampling grid) due to the occurrence of bad meteorological conditions.

Table 1
Periods of sampling and number of stations and samples analyzed for CDOM, particulate (NAP and phytoplankton) absorption and ancillary parameters ("Ancil. Param.": pigments, nutrients, flow cytometry, particulate carbon)

Cruise	Period	Ancil. Param.	CDOM	Particulate	Stations
Bioptel 1	14–18 February	50	12	50	26
Bioptel 2	30–31 March	125	53	125	82
Bioptel 3	29–31 May	115	46	115	82
Bioptel 4	29 June–01 July	142	58	142	82

At each sampling station, profiles of salinity, temperature and density were recorded with a CTD (Seabird 25) equipped with a PAR quantameter (Li-Cor, LI-193SA), a fluorometer (WetLabs – Wetstar) and a transmissiometer (WETLabs) measuring light, chlorophyll *a* fluorescence and turbidity, respectively. Density profiles were used to estimate the Brunt-Väisälä frequency (N^2 in s^{-2}) used as an index of water mass vertical stability:

$$N^2 = (g/\sigma)(\Delta\sigma/\Delta z) \quad (1)$$

where, g is the acceleration due to gravity ($m\ s^{-2}$), σ the mean density of the water column ($kg\ m^{-3}$) and $\Delta\sigma$ the difference of density between surface and bottom (Δz, m).

Water samples were collected at two depths, 2 m below the surface and 2 m above the bottom, using 5 liters Niskin bottles for chemical, biological and bio-optical measurements (Table 1).

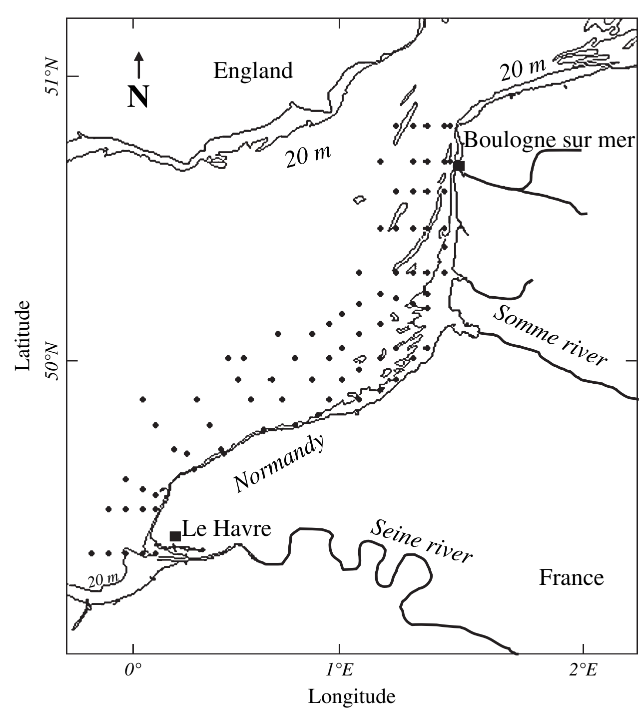

Fig. 1. Location of the stations sampled during the 4 cruises. In February, only the six more south transects has been sampled (see also Table 1).