Particle distribution and composition in the NE Aegean Sea based on transmissometry, optical backscattering and size measurements

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Abstract

The complex optical properties of NE Aegean Sea particles were studied in the framework of Perseus and AegeanMarTech projects. Inherent optical properties (IOPs; beam attenuation, optical backscattering, fluorescence) and discrete bottle data (PMC, POC, TChl-a) were measured during October 2013. Black Sea water (BSW) enters into the Aegean Sea from the Dardanelles and disperses to the west-northwest, as traced by characteristic salinity minima. The core of the BSW to the east of Limnos Island was relatively particle-enriched, showing maxima in beam c_p, b_{bp}, fluorescence, D_{50}, PMC, POC, and TChl-a. Organic particles dominated in the upper water column, whereas resuspension of surface sediments was detected.

Keywords: IOP, scattering, particulate matter, particle size, NE Aegean Sea

1. Introduction

The hydrology of the NE Aegean Sea is characterized by the outflow of low-salinity waters from the Dardanelles Straits, i.e. Black Sea water (BSW), which overlies high salinity Levantine intermediate water (LIW) originating in the south Aegean Sea. Spreading of BSW to the west is followed by a bifurcation around Limnos Island, with one branch directed to the NW and another to the SW (Olson et al., 2007). BSW is generally cooler and enriched in nutrients, in contrast to the oligotrophic character of the Aegean Sea (Siokou-Frangou et al., 2002), with low particulate matter concentrations, below 0.5 mg/l (Karageorgis et al., 2003; Lykousis et al., 2002).

This work aims at gaining new insights on the complex optical properties of the NE Aegean seawater, combining measurements of bulk inherent optical properties and discrete bottle data, obtained during October 2013 in the framework of the projects Perseus and AegeanMarTech.

2. Materials and methods

Perseus cruise took place between 4 and 9 October 2013 and was followed by the AegeanMarTech cruise (9-12 October 2013), aboard the R/V Aegaeo. A total of 27 stations were occupied, at water depths varying between 60 and 1596 m (Fig. 1). Conductivity-temperature-depth (CTD) profiles were collected at all stations, accompanied by light transmission (WET Labs C-Star, 660 nm), chlorophyll fluorescence (Chelsea AQUA*tracka* III; excitation: 430 nm, emission: 685 nm), cdom fluorescence (WET Labs ECO FL; excitation: 370 nm, emission: 460 nm), particle volume concentration and particle size distributions (LISST-Deep) (for details see Karageorgis et al., 2008, 2012). In addition, the total backscattering coefficient b_b was measured by a WET Labs ECO-BBFL Measurement Sensor at two wavelengths (532 and 660 nm, sampling rate 1 Hz), also equipped with a cdom fluorometer; due to some technical problems we report here only the $b_b(660)$ data.

Water samples from standard depths were filtered to determine the concentrations of particulate matter (PMC), particulate organic carbon (POC) and total Chl-a (TChl-a) (for details see Karageorgis *et*

al., 2014). Results presented hereafter include sections of N-S orientation, from northern Greece towards the east of Limnos Isl. (see Fig. 1 for location) and variable- variable scatter plots.

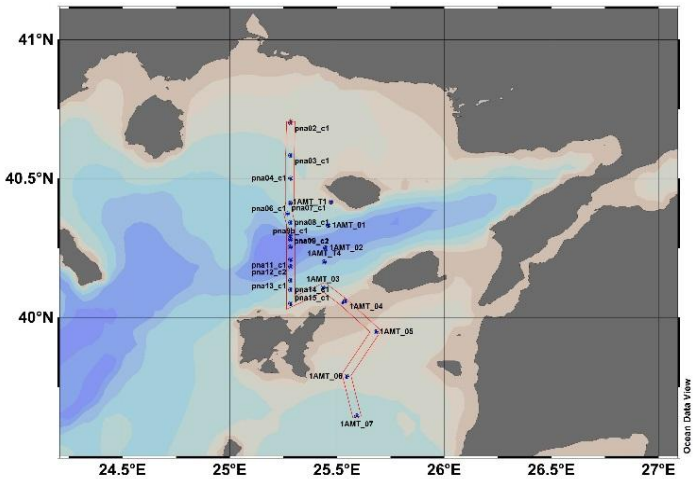

Fig. 1. Study area map and sampling stations. Red line: section location.

3. Results/Discussion

Temperature at the surface is high (max. 21.631 °C) and a strong thermocline is developed, typical for autumn period. Salinity at the surface is controlled by the BSW spreading and mixing. The low-salinity layer extends up to 50-m depth, with the lowest value of 31.41 recorded SE of Limnos Isl. (at Stn. 1AMT_06). The core of BSW is located to the east and north-northeast of Limnos Isl., suggesting that, at this time of the year, the main spreading direction is from the Dardanelles towards the west-northwest. Below 200-m depth, temperature decreases gradually (min. 13.664 °C) and salinity increases (range: 38.878-39.033).

A proxy commonly used among IOPs to describe particle distribution patterns is the beam attenuation coefficient c (is expressed as the sum of total absorption, a, and total scattering, b, i.e. $c = a + b$) and its component beam c_p, the attenuation coefficient due to particles (e.g. Karageorgis et al., 2008). Beam c_p in the study area varies between 0.014 and 0.425 m^{-1} (mean 0.045 m^{-1}, st. dev. 0.032 m^{-1}, n = 9065), which are very low values, corresponding to Case 1 waters and comparable to the open sea. Relatively high values are observed at surface waters (0-30 m depth) and particularly at the core of the BSW, east of Limnos Isl., followed by lower values within the lower part of the euphotic layer, to increase again near the bottom, around 100-m depth. The latter pattern is attributed to sediment resuspension due to current activity. The most striking pattern and also the highest c_p values are associated with the presence of an intense intermediate nepheloid layer (INL) spreading from the northern flank of Limnos basin towards the south, at water depths between 250 and 400 m over a distance of more than 25 km (data not shown). At continental shelves and slopes, such INLs are detaching from the seabed and are dispersed to the open ocean along isopycnals (Durrieu de Madron et al., 1999; Lorenzoni et al., 2009). INL presence could be attributed to internal wave activity, near-bottom currents, and also human-induced resuspension due to trawling.

The optical backscattering coefficient b_b carries information about seawater constituents that scatter light, but most importantly, measurements and fundamental understanding of b_b are required to assess and improve applications of remotely sensed ocean color (Boss et al., 2004). In the present study we focus on the particulate component, b_{bp}, which is very similar to the total backscattering, as backscattering due to seawater alone is lower by an order of magnitude.

The profiles of b_{bp} showed several spikes, which were attributed to the presence of large particles passing in front of the sensor, and thus were removed. Readings of b_{bp} varied between 0.707×10^{-3} m^{-1} and 3.76×10^{-3} m^{-1} (mean 1.15×10^{-3} m^{-1}, st. dev. 0.272×10^{-3} m^{-1}, n = 1875). The spatial distribution of

b_{bp} is fairly similar to beam c_p showing relatively higher values at surface waters and in particular within the BSW core, as well as near the seabed/resuspension areas.

Beam c_p and b_{bp} are positively correlated (r = 0.571, p = 0.01, n = 1875), suggesting that the NE Aegean Sea exhibits Case 1, thus open-sea characteristics, where scattering is phytoplankton-dominated. In resuspension zones lithogenic particles are more abundant and maybe locally characterized as Case 2 waters. However, both variables are uncorrelated to TChl-a indicating that other factors add to breaking up a quasi-linear relationship observed in the open ocean (Dall'Olmo et al., 2009). The main factor is most probably the variable composition of suspended particles, which have mean %POC >40% (%POC = 100 x POC/PMC) and variable particle-size distributions (PSD). Particle-size varies between 19.5 and 165 μm (mean 39 μm, st. dev. 36 μm, n = 2471), implying the presence of large aggregates in the water column and increased particle size in the BSW core, although there is some interference due to intense stratification and subsequently schlieren effects (Karageorgis et al., 2014).

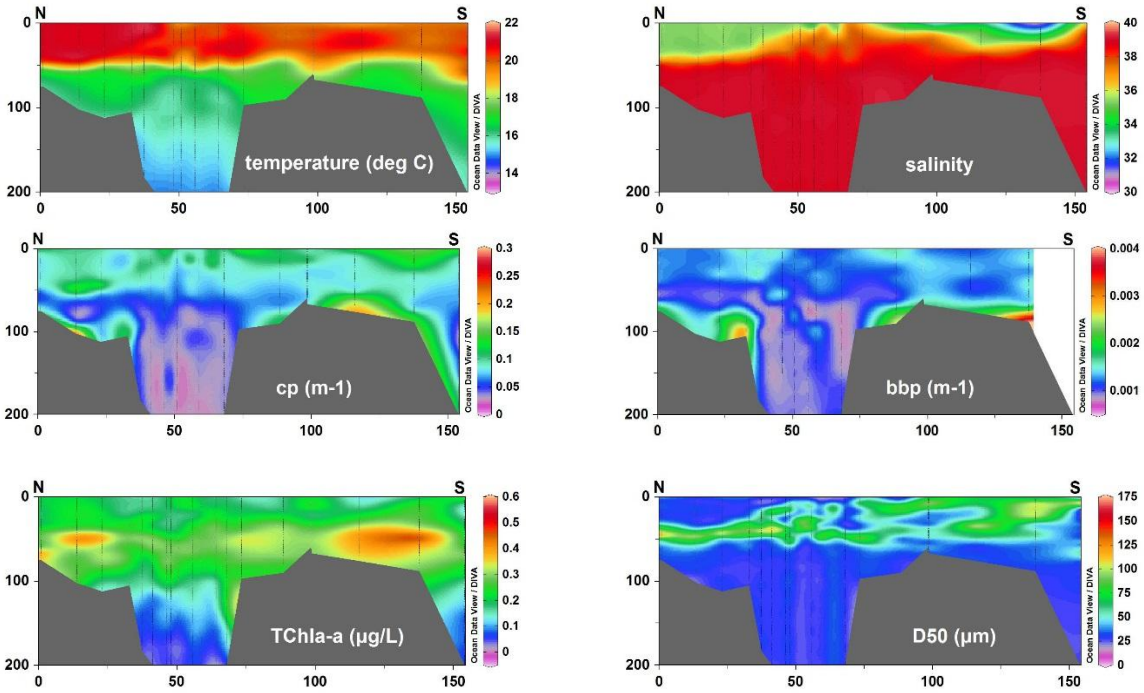

Fig. 2. Sections of temperature, salinity, beam c_p, particulate backscattering coefficient b_{bp}, TChl-a, and particle median diameter D_{50} in the NE Aegean Sea, October 2013. X-axis: Section distance (km); Y-axis: pressure (dbar). See Fig. 1 for section location.

4. Conclusions

- BSW in October 2013 was dispersed to the west-northwest, easily traced by salinity minima
- BSW was enriched in organic particles and aggregates >100 μm
- Particles' composition was variable, with organic particles predominating the upper water column and inorganic particles near the seabed
- First time measured IOPs c_p and b_{bp} were positively correlated
- Particles optical properties are complex due to co-existence of phytoplanktonic and lithogenic components

5. Acknowledgements

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