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Research papers

Particle characterization and composition in the NE Aegean Sea: Combining optical methods and biogeochemical parameters

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ABSTRACT

The NE Aegean Sea constitutes a challenging sector of the world's ocean in studying optical and biogeochemical properties and processes due to a dynamic frontal regime resulting from the continuous mixing of Black Sea waters (BSW) and waters of Levantine origin (LW), which are characterized by substantially different physical, chemical and biological properties. In the framework of the Perseus and AegeanMarTech projects, inherent optical properties (IOPs; beam attenuation, optical backscattering, chlorophyll-α fluorescence), particle size, and discrete bottle data (particulate matter, particulate organic carbon, and chlorophyll-α concentrations) were measured during October 2013, March 2014, and July 2014. Black Sea water enters into the Aegean Sea through the Dardanelles Straits and disperses to the west-northwest, as traced by characteristic salinity minima. The core of the BSW to the east of Lemnos Island was occasionally particle-enriched, showing maxima in c_p, b_{bp}, D_{50}, PMC, POC, and TChl-α, the latter, however, detected primarily at sub-surface layers. Particle composition was chiefly organic, associated with phytoplanktonic communities (BSW and LW), heterotrophic planktonic organisms and detrital organic matter primarily originating in the BSW and forming aggregates often > 100 μm in diameter. A discrepancy between particle and TChl-α abundance was observed, with c_p local maxima occurring in surface waters (BSW) and TChl-α maxima in mid-waters (LW). This pattern was attributed to phytoplankton photo- acclimation with depth leading to increased cell- chlorophyll content deeper, not necessarily matched by a similar biomass increase, thus, using TChl-α as an absolute proxy for phytoplankton biomass may not be appropriate, when considering water bodies encompassing the entire euphotic zone. Primarily in surface waters, the *in situ* optically measured median particle diameter corresponds to large particles/aggregates, contrary to findings obtained by laboratory analysis of cell counts in discrete water samples; this inconsistency was attributed to the fragile nature of aggregates that usually break up during sample processing and other methodological issues. The particulate backscattering ratio, as well as the estimated bulk particulate index of refraction, revealed a 2-layer structure, with biogenic particles and organic detritus occupying the upper ~65 m of the water column, whereas deeper waters were enriched in lithogenic/ organic particles resuspended from the seabed. Overall, the NE Aegean Sea is characterized by low particulate matter concentrations and low chlorophyll biomass during the sampling periods, exhibiting rather open-sea characteristics, reflected in all optical properties studied, as evidenced by their very low values and also by the POC:c_p regression parameters. The present work contributes to a better understanding of bio-optical properties of the Aegean Sea, which by extension may improve regional satellite algorithms applied to retrieve chlorophyll-α concentration from space.

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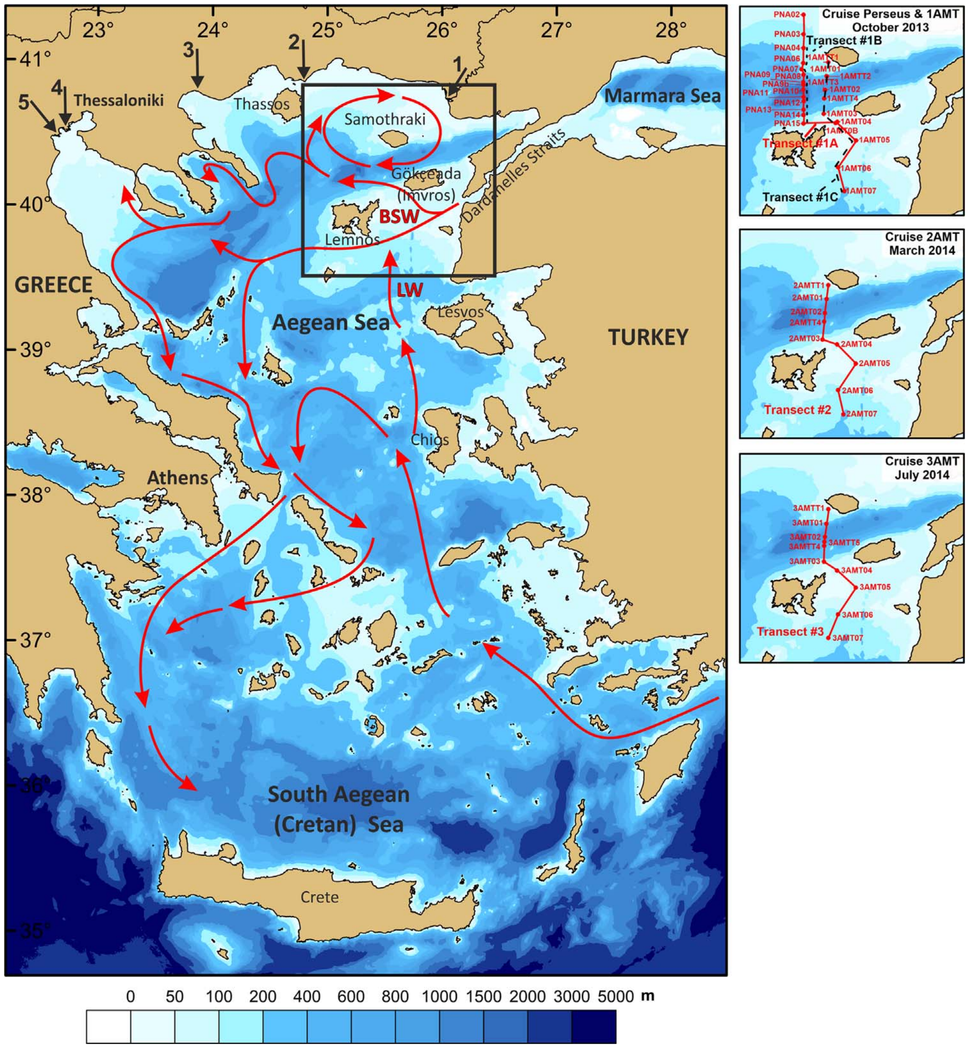

Fig. 1. Bathymetric map of the Aegean Sea and main surface circulation patterns (simplified after Olson et al., 2007). BSW: Black Sea Water, LW: Levantine Water. Numbers next to arrows indicate the main rivers flowing into the North Aegean Sea; 1: Evros, 2: Nestos, 3: Strymon, 4: Axios, 5: Aliakmon. Sampling stations and transects mentioned in text are illustrated in the three maps on the right panel for the cruises Perseus & 1AMT, 2AMT, and 3AMT, respectively.

1. Introduction

In the context of the study of ecosystem dynamics and biogeochemical processes, the evolution of commercial sensors measuring the inherent optical properties (IOPs) of seawater has offered great advancements over past decades towards the increase of high-quality data acquisition both in time and space scales, while on the other hand it has supported the development of a number of remote sensing products of primary importance such as ocean colour. The IOPs depend solely on the aquatic medium itself (water, particles and dissolved substances) and are independent of the light field and its geometrical distribution (Preisendorfer, 1961; Chang and Dickey, 2008). According to Morel (2008), the minimal set of independent IOPs comprises the index of refraction, the absorption coefficients, the volume scattering function and the source function.

A proxy commonly used among IOPs is the spectral beam attenuation coefficient $c(\lambda)$ (expressed as the sum of total absorption, $a(\lambda)$, and total scattering, $b(\lambda)$, at a certain wavelength (λ), i.e., $c(\lambda) = a(\lambda)+b(\lambda)$). Beam $c(\lambda)$, and its component beam $c_p(\lambda)$, the attenuation coefficient due to particles, is one of the first IOPs measured in oceanographic research by commercial transmissometers and is a reliable proxy for particulate matter concentration (PMC) as well as particulate organic carbon concentration (POC). Over past decades it has been applied to describe particle distribution patterns, to study its relationship with POC or even phytoplankton carbon (Eittreim et al., 1976; Biscaye and Eittreim, 1977; Gardner et al., 1985, 1993, 1995, 2003; Gardner, 1989; Durrieu de Madron et al., 1992; Bishop, 1999; McCave et al., 2001; Behrenfeld and Boss, 2006; Karageorgis et al., 2008).

Total scattering, $b(\lambda)$, backscattering coefficient, $b_b(\lambda)$, and particulate backscattering coefficient, $b_{bp}(\lambda)$ are IOPs carrying information about seawater constituents that scatter light. They are, to first order, proportional to the particle load and, to second order, to the size distribution, refractive index, composition, structure, and mean shape of the particle assemblage (Loisel et al., 2007; Huot et al., 2008), but most importantly, measurements and fundamental understanding of b_b and b_{bp} are required to assess and improve applications of remotely sensed ocean colour (Boss et al., 2004). An extensive review by Stramski et al. (2004) highlights the importance of understanding *'how different constituents of water contribute to absorption and backscattering of light, in order to deduce from ocean colour what substances are present in the water, and in what concentrations'.*

According to Mie-theory simulations for homogeneous spheres as well as *in situ* measurements, $c_p(\lambda)$ and $b_{bp}(\lambda)$ are influenced in a variable way by different particle-size populations (Boss et al., 2001; Morel and Ahn, 1991; Stramski and Kiefer, 1991): (i) particles in the size range 0.5–20 µm dominate $c_p(\lambda)$ in the open ocean; (ii) particles < 10 µm dominate total scattering ($b_p(\lambda)$) and particles < 1 µm dominate backscattering; (iii) microorganisms contribute little to $b_{bp}(\lambda)$