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Particle dynamics in the Eastern Mediterranean Sea: A synthesis based on light transmission, PMC, and POC archives (1991–2001)

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Abstract

During the last two decades light transmission (LT) data have been collected routinely in the Eastern Mediterranean Sea, within the framework of several research projects. A procedure was developed to obtain beam attenuation coefficient due to particles (c_p) at 660–670 nm adjusted for variations in mid-depth 'clear' water and instrumental drifts. Data from 3146 stations occupied between 1991 and 2001 were converted to a common format for the analysis of particulate matter (PM) temporal and spatial distribution patterns. The data were separated into 'wet' (December–May) and 'dry' (June–November) periods. The horizontal distribution of beam c_p at various depths revealed clearly higher values in the surface nepheloid layer (SNL) in the vicinity of river mouths during the 'wet' period, whilst the increase was negligible during the 'dry' period. In contrast, the bottom nepheloid layer (BNL; 1–10 m above bottom) appeared to be turbid throughout the year, particularly on the continental shelves receiving riverine discharge. This feature is attributed to resuspension and advection of recently deposited bottom sediments due to waves and currents. However, the Eastern Mediterranean as a whole is impoverished in PM in the water column, particularly at depths >200 m. The behavior of surface-water c_p revealed a strong relationship to mesoscale dynamic features. Cyclonic eddies, which upwell nutrient-rich waters toward the surface, favor primary production, which was identified as elevated beam c_p values. Beam c_p was correlated with PM concentration (PMC) and particulate organic carbon (POC) concentration obtained by bottle sampling. Although there were regional differences in the correlations, no significant seasonal variations were observed. Two generic equations were generated that can be used for a first-order estimate of PMC and POC from historical LT measurements conducted in the area, provided that data are handled according to the proposed methodology.

Keywords: Light transmission; Beam attenuation; Particulate matter; Particulate organic carbon; Eastern Mediterranean Sea

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1. Introduction

Ever since the 1970s, numerous particulate matter (PM) studies have been undertaken over the world's oceans, providing on the temporal and spatial variations of the PM field, aimed at a better understanding of PM optical characteristics and its distribution patterns in the ocean (Eittreim et al., 1976; Biscaye and Eittreim, 1977; Spinrad et al., 1983; Gardner et al., 1985; Spinrad, 1986; Richardson, 1987), shelf/slope exchange processes (Biscaye et al., 1994; McCave et al., 2001; McCave and Hall, 2002), submarine canyon role and dynamics (Drake, 1971; Baker and Hickey, 1986; Hickey et al., 1986; Gardner, 1989a), sediment resuspension mechanisms (Moody et al., 1987; Gardner, 1989b), relation between hydrography and nepheloid layers (Cacchione and Drake, 1986; Durrieu de Madron et al., 1990; Palanques and Biscaye, 1992; Durrieu de Madron, 1994; Puig and Palanques, 1998; Castaing et al., 1999; Durand et al., 2002), and biogeochemical cycles (Monaco et al., 1990; Gardner et al., 1993, 1995).

The use of transmissometers and other types of optical instruments measuring light attenuation (scattering and absorption), light scattering, or optical backscatter in seawater greatly supported this research, obtaining data on vertical profiles or occasionally as time series. The inherent problem of such kinds of station-based measurements is relatively poor spatial coverage. In most cases, research projects aim to study specific processes in selected marine regions, whilst very few of them have covered adequately large sectors of the ocean, e.g. the entire Atlantic Ocean (Eittreim et al., 1976; Biscaye and Eittreim, 1977), the Goban Spur (McCave et al., 2001), the Pacific (Kawahata, 2002), and the Yellow Sea (Park et al., 2001).

Studies employing optical turbidity measurements in the Western Mediterranean Sea have provided comprehensive information on PM dynamics on the Spanish continental margin (Puig and Palanques, 1998; Puig et al., 2004) and in the Gulf of Lions (Durrieu de Madron et al., 1990; Monaco et al., 1990; Durrieu de Madron, 1994; Lapouyade and Durrieu De Madron, 2001; Frignani et al., 2002). In the Eastern Mediterranean, despite the collection of light transmission (LT) data since the early 1990s, an overall picture of PM distribution patterns is missing. However, results from several small-scale investigations have been published, usually covering coastal areas and regional seas (Durrieu de Madron et al., 1992; De Lazzari et al., 1999; Karageorgis et al., 2000, 2003; Karageorgis and Anagnostou, 2001, 2003; Karageorgis and Stavrakakis, 2005; Krasakopoulou and Karageorgis, 2005), where LT readings were collected routinely as part of CTD casts. Nevertheless, numerous LT data remain unused to date because of lack of expertise in studying such parameters in particular projects where, e.g. only temperature and salinity were required, but the importance of LT data was recognized.

This paper aims to compile all available LT measurements conducted in the Eastern Mediterranean at the Hellenic Center for Marine Research (HCMR) (Fig. 1), in order to assess general temporal and spatial distribution trends, as well as their relation to hydrographic features of the region. To accomplish this, a series of methodological steps used for data integration are presented. Apart from the painstaking, tedious task of data collection and handling, there is a specific issue addressed here that deserves particular attention: the merger of LT measurements obtained over a 11-year time span, while ensuring data comparability against instrument drift and any type of shifts or errors generated during sampling. Moreover, PM concentration (PMC) and particulate organic carbon (POC) concentration data have been collected in parallel. The latter parameters are physically linked to light attenuation and their relationships are documented.

2. Regional setting

2.1. Morphology of the Eastern Mediterranean

The Eastern Mediterranean Sea is a relict of the ancient Tethys Ocean, and its morphology has been formed by continuous geodynamic processes during $50–70 \times 10^6$ years, largely the subduction of the African tectonic plate under the Aegean microplate (Sakellariou et al., 2005). The seafloor morphology is extremely complex (Fig. 1). The North Aegean is one of the few areas where wide continental shelves have developed, dipping rapidly into deep (1400 m) basins and alternating with shallower plateaus toward the Central Aegean, which is dominated by the Cyclades Island arc. The South Aegean includes the Cretan Sea, where water depths up to 2500 m are found. The Ionian Sea in its northern sector is the continuation of the Adriatic Sea and is characterized by an extensive shelf, while its southern sector is very steep, characterized by deep canyons and basins more than 4000 m deep. Thirty miles off SW Peloponnisos one finds the deepest