Papers

Relationships between inherent optical properties in the Baltic Sea for application to the underwater imaging problem*

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Iosif Levin[2]
Mirosław Darecki[1]
Sławomir Sagan[1]
Tamara Radomyslskaya[2]

[1] Institute of Oceanology,
Polish Academy of Sciences,
Powstańców Warszawy 55, Sopot 81–712, Poland;

e-mail: darecki@iopan.gda.pl

[2] St. Petersburg Branch of the P. P. Shirshov Institute of Oceanology
of the Russian Academy of Sciences (IO RAS),
1 Linia 30, 199053, St. Petersburg, Russia;

e-mail: ocopt@yandex.ru

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Abstract

Statistical relationships between coefficients of light attenuation, scattering and backscattering at wavelength 550 nm derived from series of optical measurements

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performed in Baltic Sea waters are presented. The relationships were derived primarily to support data analysis from underwater imaging systems. Comparison of these relations with analogous empirical data from the Atlantic and Pacific Oceans shows that the two sets of relationships are similar, despite the different water types and the various experimental procedures and instrumentation applied. The apparently universal character of the relationships enables an approximate calculation of other optical properties and subsequently of the contrast, signal/noise ratio, visibility range and spatial resolution of underwater imaging systems based on attenuation coefficients at wavelength 550 nm only.

1. Introduction

Satellite, airborne and shipboard imaging, and lidar systems are valuable tools for investigating the World Ocean. They are used in underwater manned, remote-controlled and robotic vehicles in the search for minerals and sunken objects on the sea floor. In some applications, imaging systems are used to draw maps of distributions of vegetation and bottom sediments. In ecological and environmental studies imaging systems serve as a tool for detecting water pollution and bottom debris, for monitoring fish spawning regions, changes to the sea bed, beach destruction, the amount and type of suspended matter transported in river and current flows, and a multitude of other effects of man-made and natural processes (Dolin & Levin 1991, Fournier et al. 1993, Tang et al. 1998, Stemmann et al. 2000, Mayer et al. 2002, Dolin et al. 2006).

Modern theories of underwater imaging (Dolin & Levin 1991, 2004, Zege et al. 1991) and of imaging through a wave-roughened sea surface (Dolin et al. 2006), focusing as they do on optimizing imaging systems, show that the most important parameters determining visibility in the water (contrast, signal/noise ratio (SNR), visibility range and spatial resolution) depend on the inherent optical properties of water (IOP) to a greater extent than on the parameters of the imaging system itself and can be found if the coefficients of light scattering b, backscattering b_b and absorption a (or attenuation $c = a + b$) are known. All these IOPs depend strongly on wavelength λ. However, all imaging systems, including many of the laser-based systems, work in the spectral region close to 550 nm. As shown by Levin & Radomyslskaya (2007), the wavelength corresponding to the maximum water transparency and maximum visibility range when observations are made through a narrow spectral filter varies monotonically from 500 nm for the clearest ocean water to 590 nm for the most turbid coastal water, whereas the maximum visibility range, when observed by a receiver with a spectral sensitivity close to that of the human eye, is located for all waters in the spectral region of 530–550 nm with an accuracy of several per cent (see also Zaneveld & Pagau