Papers

Simple statistical formulas for estimating biogeochemical properties of suspended particulate matter in the southern Baltic Sea potentially useful for optical remote sensing applications*

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Abstract

Simple statistical formulas for estimating various biogeochemical properties of suspended particulate matter in the southern Baltic Sea are presented in this paper. These include formulas for estimating mass concentrations of suspended particulate matter (SPM), particulate organic matter (POM), particulate organic carbon (POC) and total chlorophyll *a* (Chl *a*). Two different approaches have been adopted. The first approach was to use the available empirical material (the results of field measurements and laboratory analyses of discrete water samples) and find statistical formulas for estimating the biogeochemical properties of suspended particulate matter from those of inherent optical properties (IOPs), which are

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potentially retrievable from remote sensing measurements. The second approach was to find formulas that would enable biogeochemical properties of suspended particulate matter to be estimated directly from spectral values of the remote-sensing reflectance R_{rs}. The latter was based on statistical analyses of a synthetic data set of R_{rs} obtained from numerical simulations of radiative transfer for which the available empirical material on seawater IOPs and biogeochemistry served as input data. Among the empirical formulas based on seawater IOPs that could be used as a step in two-stage remote sensing algorithms (the other step is estimating certain IOPs from reflectance), the best error statistics are found for estimates of SPM and POM from the particulate backscattering coefficient b_{bp} in the blue region of light wavelengths (443 nm), and for estimates of POC and Chl a from the coefficient of light absorption by the sum of all non-water (i.e. suspended and dissolved) constituents of seawater a_n, in the blue (443 nm) and green (555 nm) parts of the spectrum respectively. For the semi-empirical formulas under consideration, which could serve as starting points in the development of local one-stage (direct) remote sensing algorithms, the best error statistics are found when SPM, POM and POC are estimated from the same blue-to-red band reflectance ratio ($R_{rs}(490)/R_{rs}(645)$) (with estimated SPM reaching a better precision than estimated POM and POC), and when Chl a is estimated from the green-to-red band ratio ($R_{rs}(555)/R_{rs}(645)$).

1. Introduction

As a result of the enormous technological advances of recent decades, remote observations of ocean colour have become an extensively used research tool in contemporary oceanography. By ocean colour we mean spectra of the optical quantity known as remote-sensing reflectance (for definitions of this and other optical quantities used here, see e.g. Mobley (1994)). Observations of ocean colour (remote-sensing reflectance spectrum) can be made from a number of satellites orbiting the Earth (detailed information on the development of optical remote methods for marine exploration can be found, for instance, in a series of reports by the International Ocean-Colour Coordinating Group (see IOCCG (2012)) or earlier reports cited there). Under favourable meteorological conditions (clear skies), satellite measurements allow scientists to obtain very large spatial and temporal scales of observations. This was not achievable with the traditional direct oceanographic methods of investigations conducted either by means of in situ measurements of the physical and chemical properties of seawater or by laboratory analyses of discrete water samples. But the ability to fully utilize the results of remote observations in routine environmental monitoring requires a profound understanding of a chain of complicated relations. Firstly, we need to know how the presence of dissolved and suspended constituents of seawater, possessing different properties and occurring in different concentrations, influences its inherent