Phytoplankton Groups from Space using PhytoDOAS: Improvements by Multi-target Fitting, Yearly Data Set, Validation and First Application

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ABSTRACT

Simultaneously derived global information on the quantitative distribution of major functional phytoplankton types (PFTs) of the world ocean improves the understanding of the role of marine phytoplankton's role in the global marine ecosystem and biogeochemical cycles. Global biomass distributions from 2008 of different dominant PFTs (diatoms, cyanobacteria, coccolithophores, Phaeocystis-type-haptophytes) are derived with PhytoDOAS, a method of Differential Optical Absorption Spectroscopy (DOAS) currently specialized for deriving chl-a of PFTs by Bracher et al. (2009) from satellite data of SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Cartography) on ENVISAT. The method has been improved by simultaneous fitting of the various PFTs. Results of the global maps of PFT distribution are validated with collocated pigment water samples analyzed via HPLC from various trans-Atlantic cruises. Phytoplankton groups are calculated from pigments by applying the CHEMTAX program (Mackey et al. 1996) and compared with satellite retrievals. These global PFT satellite data sets is used as input data for global ecosystem models and a first application of this approach is presented.

INTRODUCTION

To understand the marine phytoplankton's role in the global marine ecosystem and biogeochemical cycles it is necessary to derive global information on the distribution of its biomass and primary production, in particular the distribution of major functional phytoplankton types (PFT) in the world oceans. Using common ocean color sensors like SeaWiFS or MERIS, from the few broad bands only the overall phytoplankton biomass or the dominant phytoplankton group can be derived (e.g. Alvain et al. 2008). In order to get a global quantitative estimate of different PFT in the oceans, the Differential Optical Absorption Spectroscopy (DOAS), a technique established for extraction of atmospheric components from high spectrally resolved UV-VIS data, was adapted to the retrieval of the absorption and biomass of two major phytoplankton groups (PhytoDOAS) from data of the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) satellite sensor (Bracher et al. 2009). Within this method, hyperspectral information of SCIAMACHY is used to obtain the distinctive absorption characteristics from the different phytoplankton groups. In the presented study the method has been improved by simultaneous fitting of several phytoplankton types within DOAS. We have extracted the quantitative phytoplankton group information for one year (2008) from SCIAMACHY. The data set was validated against in-situ data and used for first applications in a biogeochemical model study.

MATERIAL AND METHOD

PhytoDOAS (Bracher et al. 2009, Vountas et al. 2007) is an extension of DOAS to extract information about oceanic phytoplankton biomass from hyperspectral satellite data. DOAS (Differential Optical Absorption Spectroscopy) itself is a classical method (Perner and Platt 1979) to retrieve atmospheric trace gases using highly varying parts of their absorption spectra, called differential absorption. The DOAS equation is an extension of Lambert-Beer equation, including all absorption and scattering signatures within the fit window of interest. Low varying features (including Rayleigh and Mie scattering) are approximated by a low-order polynomial together with other fit factors (slant column densities for different targets) through the least-square fitting.
In order to find optimized fit-windows, the fourth derivative spectra of the different PFT absorption spectra were investigated. With the optimized fit-window we use PhytoDOAS for simultaneous fitting. Fourth derivative analysis is being used to distinguish more precisely spectral behavior of given absorption spectra. Peak positions of 4^{th} derivative spectrum are indicators of maximum absorption of PFTs containing pigments. Using 4^{th} derivative analysis initial absorption spectrum can be decomposed by specific Gaussian peaks a combination of which could be used as input spectrum for PhytoDOAS fitting.

RESULTS

Results from PhytoDOAS clearly show the absorption inprints from different phytoplankton groups in the SCIAMACHY data (see Fig. 3 in Bracher et al. 2009). The conversion of these differential absorptions by including the information of the light penetration depth, according to Vountas et al. (2007), leads to globally distributed biomass concentrations for these characteristic phytoplankton groups (corresponding to chl a). Monthly averages for the global biomass concentrations of the three phytoplankton groups for the year 2008 have been retrieved. These global maps of phytoplankton distribution were validated with collocated in-situ data from various Atlantic cruises in 2008 determined via HPLC pigment analysis and applying the CHEMTAX program (Mackey et al. 1996). Fig. 1 shows the global diatom biomass distributions for monthly means (Feb, Mai, Aug, Nov) of 2008 retrieved with PhytoDOAS from SCIAMACHY data. Yearly data sets of Globcolour data (merged SeaWiFS /MODIS/MERIS chl-a product) and PhytoDOAS phycoerythrine-containing phytoplankton biomass distributions have been used as initial conditions to constrain a 1-dim model of Fe speciation and biogeochemistry, coupled with the General Ocean Turbulence Model (GOTM) and a nutrient-phytoplankton-zooplankton-detritus(NPZD)-type ecosystem model which has been applied for the Tropical Eastern North Atlantic Time-Series Observatory (TENATSO; model details in Ye et al. 2009). The yearly data set of PhytoDOAS total cyanobacteria chl-a has been used to validate the performance of the model for year round dynamics of cyanobateria at the model site.

CONCLUSIONS

The PhytoDOAS method applied to SCIAMACHY satellite measurements enables for the first time to establish a global data set on quantitative distribution of different phytoplankton groups. As first applications has shown this data base can be used by a wider community for the purposes of optical and ecosystem modeling.

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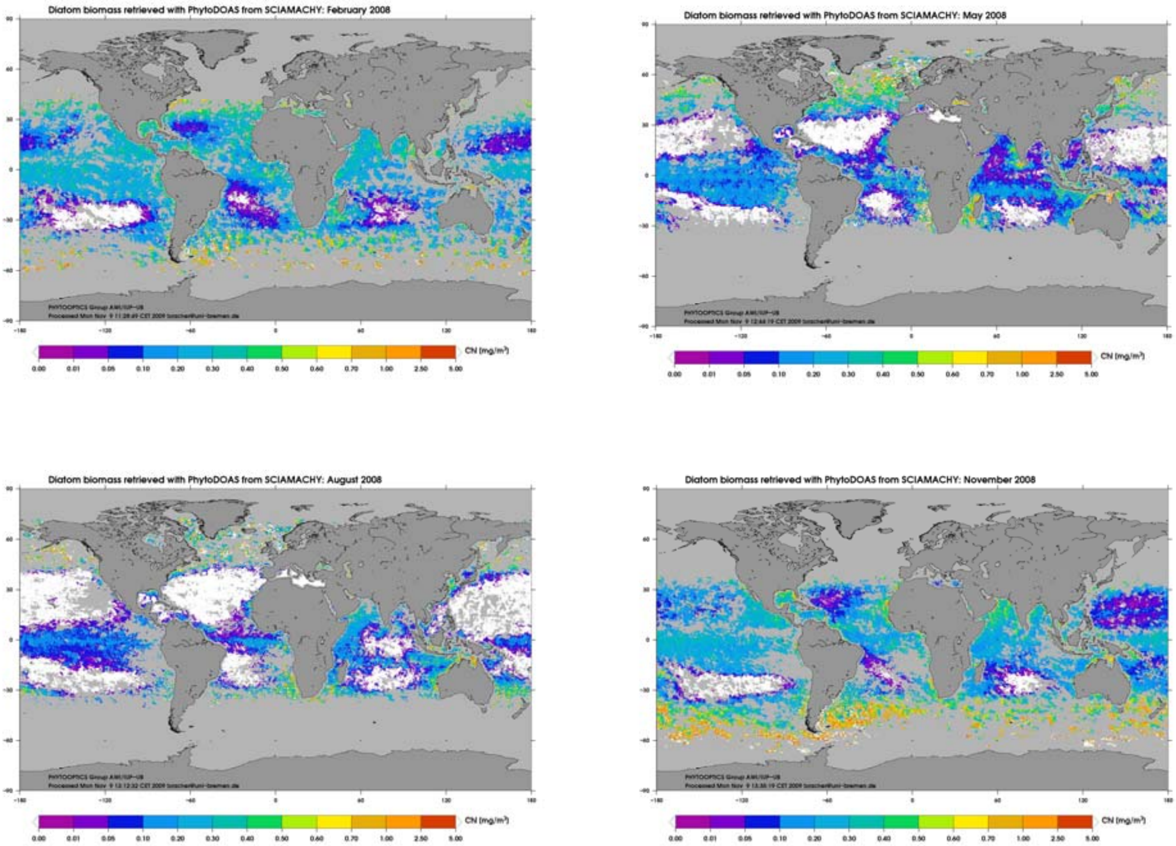

Figure 1. Monthly averages of global diatom biomass (chl-a) determined by using PhytoDOAS with SCIAMACHY data. At grey areas no SCIAMACHY data were available, at white areas no diatom absorption has been detected.

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