Deriving space-time information of the organic fraction of suspended particular matter in a coastal environment

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This study introduces a method to estimate the temporal/spatial variability of total and organic suspended particulate matter (TSM, POM) in coastal seas based on a combination of water sampling analysis and satellite remote sensing products of surface concentrations of TSM (TSMC). Lab analysis of several thousand water samples indicates a general seasonally modulated link between TSMC and its organic fraction. This relationship can be well described by an analytical model. Applying this model to satellite TSM products yields images of the surface distributions of the suspended POM as a derived product. The model allows also for a separation between lithogenic and freshly produced pelagic components of the POM. The method was applied for the German Bight, North Sea, including its coastal fringe, the Wadden Sea, taking MERIS/ENVISAT products for case 2 coastal waters. The procedure resolves a transition zone between the Wadden Sea and the more open German Bight, where "fresh" and lithogenic organic material are of comparable magnitude. The transition zone is indicative of a belt of effective particle interaction where pelagic "fresh" POM is likely exported from the water column to the bed sediments.

Introduction

The exchange of particulate matter between the German Bight (North Sea) and its intertidal fringe, the Wadden Sea, is a critical and yet unresolved issue (Burchard *et al.*, 2008). The German Bight represents a coastal water mixing zone between riverine fresh water and oceanic waters of the shelf sea. It also corresponds to an environmental problem zone because of high nutrients and pollutants loading from land. At the same time, the Wadden Sea owes its high productivity the sustained import of POM from the German Bight (van Beusekom *et al.*, 2012). The mass flux estimations in coastal oceanography deal with variations in TSM, but their temporal/spatial patterns, and in particular the organic and inorganic components, are often insufficiently resolved. The study's central idea is to look beyond the spatial/temporal variations of bulk TSMC derived from ocean colour satellite products. We take advantage of a large set of TSMC and Loss-on-Ignition (LoI) water sample data. These data are assimilated into a model that parameterises the separation between mineral and organic fractions of TSM after which it is combined with satellite products of surface TSMC.

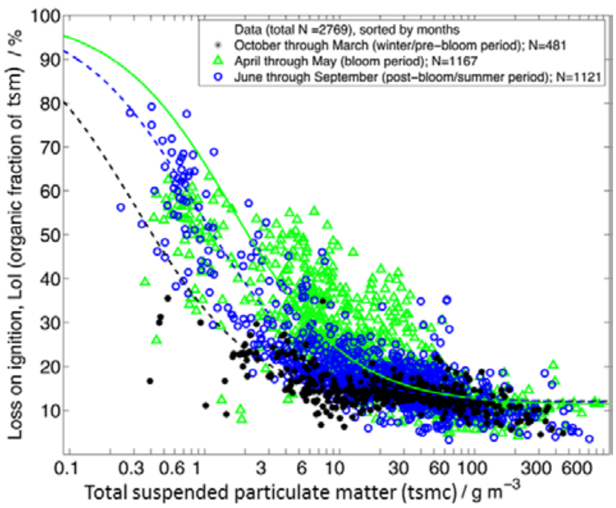

Fig. 1. Loss-on-Ignition versus TSMC. Symbols represent sample data, the lines the fitted functions due to eq. (1). The different colours indicate the seasons.

Methods

Nearly three thousand water samples were collected between 2000 and 2013 in the framework of numerous field surveys in the German Wadden Sea and the German Bight. Filtration, weighing and combustion of the filtered material followed the same procedures each year. LoI was used as proxy for the fraction of organic matter in the filtered material.

Satellite products of surface TSMC for the German Bight and the Wadden Sea were taken from ENVISAT/MERIS ocean colour images applying the MERIS operational processor for case 2 coastal waters. The processor delivers the scattering length at 440nm (b_{440}) that was shown to be proportional to TSMC at concentrations typical for the North Sea (Doerffer and Schiller, 2007; Sørensen *et al.*, 2007). For the higher TSMC prevailing in the Wadden Sea (>20gm^{-3}) the relationship between b_{440} and TSMC follows a power law with the exponent greater than one (Riethmüller *et al.*, in prep.).

Results

As Fig. 1 shows, LoI is decreasing with TSMC from about 70% at $0.6 gm^{-3}$ to some 15% at $60 gm^{-3}$ and then remaining constant at this value for higher TSMC. The data show a slight seasonal modulation with higher LoI during phytoplankton spring bloom and lower values in winter. This general behaviour can be well described by an analytical model that assumes that the organic fraction of TSM consists of living and non-living "fresh" particulate organic matter POM_f and POM chemically bound to the lithogenic part of the sediments (POM_s) in a fraction s_{POM} assumed to be constant over the whole range of TSMC. Hence $POM = POM_f + s_{POM} \cdot SLM$, SLM being the suspended lithogenic matter. Defining K_{POM} as the concentration of POM where the POM_f-to-SLM ratio becomes one, one can finally express LoI as a function of TSM and two free parameters s_{POM} and K_{POM}

$$LoI = \frac{\left(\frac{K_{POM}}{TSM}\right)}{\left(\frac{K_{POM}}{TSM}+1\right)\cdot(s_{POM}+1)} + \frac{s_{POM}}{(s_{POM}+1)} \qquad (1)$$

s_{POM} was found to be nearly constant (0.128 to 0.138), whereas K_{POM} varies by a factor of five (0.31 in winter, 1.63 in spring and 0.89 in summer). Knowing s_{POM} and K_{POM} also allows for the computation of POM_f and POM_s for any given TSMC.

If we apply the function (1) to the MERIS-TSM-products according to the respective season of observation, further satellite images of both the "fresh" and lithogenic component of POM may be generated. As an example the July 2010 result is shown in Fig. 2. One observes the typical situation of high TSMC in the Wadden Sea with a sharp decrease off the barrier islands (left panel). At the same time the percentage of POM increases (middle panel). Directly in front of the barrier islands a narrow band indicates a comparable magnitude of "fresh" and lithogenic POM resulting from resuspension and advection. These yellow areas mark regions where effective particle aggregation may enhance export of "fresh" material to the sediments. Their distances to the coast and spatial extensions vary with the season with the largest extension occurring during winter.

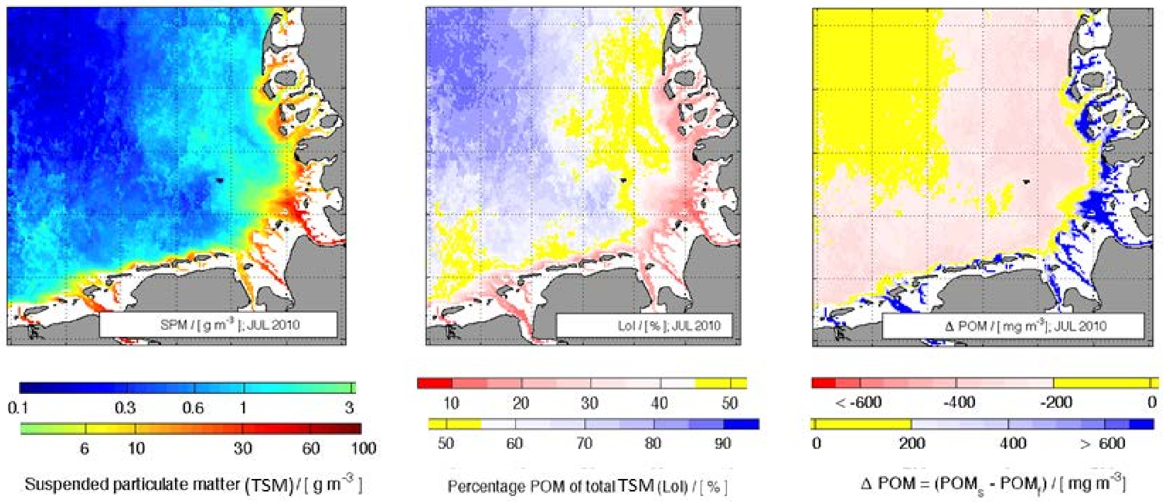

Fig. 2. July 2010 monthly averages for MERIS-TSM (left panel), LoI using eq. (1) (middle panel) and the difference between "fresh" POM_f and lithogenic POM_s (right panel).

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