OCOC-FROM OCEAN COLOUR TO ORGANIC CARBON

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ABSTRACT

Enhanced permafrost warming and increased arctic river discharges have heightened concern about the input of terrigenous matter into Arctic coastal waters. The IPY project 'OCoc- from Ocean Colour to Organic Carbon' (2008-2010) uses Ocean Colour data for synoptic monitoring of the input of organic matter – from both fluvial and coastal sources – into the Arctic coastal waters.
Initial results from the German-Russian Expedition Lena08 along the southeastern Laptev Sea Coast (Arctic Siberia, Russia) in August 2008 are presented. Preliminary investigations using the MERIS Case2Regional Processor (C2R) show that the inherent optical properties (IOP) parameter C2R-'total absorption' and the optical parameter C2R-'Z90' (equivalent to the first attenuation depth layer wherefrom 90 % of the water leaving signal originates) are of immediate value for synoptic and dynamic investigations of northeastern Siberian coastal waters that are influenced by organic-rich terrigenous input.

1. INTRODUCTION

The International Polar Year (IPY 2007-2008) [1] supports initiatives for assessing the current state of the sensitive and vulnerable arctic environment. Baseline studies are still needed to understand processes within these highly specific terrestrial and aquatic ecosystems driven by hard climatic conditions. Global warming is most rapid in the polar regions and considerable environmental changes are already obvious there. Specific to the Arctic, coastal erosion rates are often rapid compared to rates in temperate regions despite extremely shallow shoreface profiles and the short erosion season.
The 'OCoc-from Ocean Colour to Organic Carbon' project (IPY-project 1176), funded by the German Research Foundation (DFG), is an Ocean Colour study joined with the Arctic Circum-polar Coastal Observatory Network Acco-Net (ACCO-Net: IPY-project 90) [2] originating from the Arctic Coastal Dynamics ACD project [3]. Within this circum-arctic framework cruise archives will be searched for optically relevant parameters from arctic coastal waters, such as Dissolved Organic Carbon (DOC), Total Organic Carbon (TOC), Suspended Particulate Matter (SPM), coloured Dissolved Organic Matter (cDOM), chlorophyll-a, transparency, turbidity. Optical and geochemical characteristics of specific coastal water types will be investigated. An Ocean Colour satellite data base will be collected and archived with open access to the derived higher products.
Regional investigations will be carried out within the framework of German-Russian field expeditions along the arctic Siberian Coast. The first investigations have now been carried out during the German-Russian Expedition Lena08 in the southeastern Laptev Sea Coast: the Lena River Delta and the Buor-Khaya Bay (Fig.1).

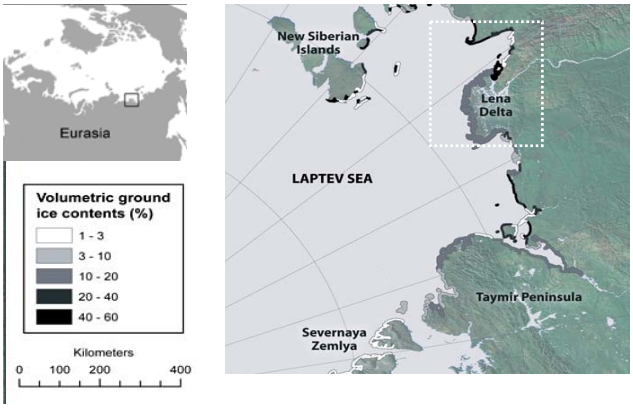

Figure 1. Arctic Siberia, study site Lena River Delta and Buor-Khaya Bay. Arctic Coastal Dynamics pan-Arctic GeoInformation System (ACD-GIS), online soon [3]).

The hydrodynamics of the arctic Laptev Sea Coast, and the carbon and sedimentary fluxes from the Lena River into the Arctic shelf sea are of high interest and have been investigated in Russian and joint international marine programs e.g., [4,5]. This presented study is a specifically regional based investigation within the circum-Arctic OCoc-approach that focus on near-shore data of a very specific Arctic surface water type: the northeastern Siberian Coast that is dominated by terrigenous matter input from coastal erosion of organic-rich and ice-rich coasts. The fluvial input is geochemically influenced by permafrost catchments. These fluvial and coastal waters are therefore loaded with organic-rich terrigenous input.

The term ‘terrigenous input’ incorporates a variety of operationally defined components, such as for the dissolved organic fraction the operational parameter ‘DOC’, and for the particulate fraction the operational parameter ‘SPM’. Operational ‘SPM’ includes organic and inorganic matter. In moderate and high latitudes, the fine-sized inorganic matter occurs coagulated with humic acids, i.e. with an organic-rich coating.

The coloured fraction of the DOC is represented by fulvic and humic acids in varying attributions that constitute the main part of the non-phytoplankton organic matter in natural waters. They are operationally summarized as chemico-optical group (named Gelbstoff, or yellow substance, or coloured Dissolved Organic Matter cDOM). Their strong, overlapping absorption bands lay in the blue spectral wavelength domain. The term ‘dissolved’ is defined operationally by the pore-size (0.2, a 0.45, or a 0.7 µm) of the chosen filtration. Therefore, organic colloids ranging up to sizes around 1 µm are operationally partly attributed to the SPM fraction.

Because we are interested in the organic-rich terrigenous matter input, our investigations focus on the parameters SPM, DOC and cDOM. The spectral characteristics of cDOM and SPM and the cDOM/ DOC ratios are to be exploited in different coastal water types. Initial results on transparency and cDOM-absorption from water samples of the Lena08-Expedition in August 2008 expedition are presented here.

2. STUDY AREA

The Laptev Sea is a very shallow epicontinental sea in the Russian Arctic and is bounded by the Taimyr Peninsula on the west and the New Siberian Islands on the east. Most of the shelf area has a water depth of less than 20 m. The Lena River Delta (Fig.1) is centrally situated at the Laptev Sea Coast, to the south-east opens the Buor Khaya Bay.

Large parts of the Central and Eastern Siberian coastline are characterized by highly erosive sedimentary ice-rich material. The sedimented material and genetic conditions steam from the extreme climatic conditions during the late Pleistocene where the large shallow northeastern Siberian shelves were exposed to continental climates and not glaciated at least in the last glacial period. This triggered the accumulation of the so called northern Siberian Ice-Complex (IC) and of fluvial sediments on the exposed shelves. The IC is a stratigraphic unit composed of very ice-rich (usually >80% by volume) and perennially frozen organic-rich deposits, penetrated by thick polygonal icewedge systems [6]. This ice-rich and organic-rich coast line of the permafrost landscape of the northeastern Siberian lowlands and islands is highly vulnerable to thermo-erosion and coastal wave-energies, and therefore subject to severe coastal erosion during the ice-free period [7].

The modern Lena River Delta is post-glacially created from one of the largest Eurasian rivers, the Lena River. Its southeastern part with modern floodplains is the active delta [8]. Southeast of the Lena River Delta, the coast and coastal islands are composed of organic and ice-rich Ice Complex sediments. The adjacent source rocks are black shales from the Kharaulakh mountain range. The bathymetry of the Buor Khaya bay is very shallow, with only up to 3 meter water depth for near-shore coastal waters and up to 10 to 15 m water depth for off-shore coastal waters.

3. DATA AND METHODS

4. Lena08-Expediton, Lena River Delta and Coastal Waters of Eastern Buor Khaya Bay (NE-Siberia)

The Lena08-expedition in August 2008 focused on coastal waters within the Lena region of freshwater influence and on the central Lena River Delta. The Lena Hydrobase small river-vessel “405” served as platform in the shallow coastal waters of southeastern Buor Khaya Bay. The river-vessel “RV Orlan” from the Lena Delta Natural Reserve served as platform for work in the Central Lena River Delta. The research cruises were dedicated to bathymetric investigations, deploying and recovering automated instruments, and investigation of coastal cliffs and waters. Hydrographical investigations included measurements for Secchi depth transparency, surface and bottom layer temperature, electrical conductivity and water sampling for Suspended Particulate Matter SPM (gravimetric method), Dissolved Organic Carbon DOC (high temperature catalytic oxidation method), coloured Dissolved Organic Matter cDOM (photometric method). The water samples were filtered and prepared at site. One liter was filtered through 0.45 µm-pore size pre-weighed cellulose-acetate (CA) filters for SPM and through 0.7 µm-pore size glass-fiber (GF)-filters for spectrometric measurements. Filtrates for DOC analyses were filtered through 0.7 µm GF-filters. For comparison with DOC concentrations we prepared cDOM filtrates where the subsamples were filtered through 0.7 µm-pore size GF-filters and 0.45 µm-pore size CA-filters either. cDOM spectra were directly measured after the LENA08-Expedition at the Russian-German Otto-Schmidt Laboratory in St. Petersburg (RU) using a Specord200 (Jena Analytik). Optical density OD spectra of the 0.45 µm and 0.7 µm filtrates was measured from 300 nm to 750 nm in 2 nm steps in 10-cm glass cuvettes according the recommendations of the Ocean Optic Protocols [9]. Absorption [m^{-1}] was calculated using $2.303 \times OD / 0.1$.

Preliminary spectro-radiometrical measurements were carried out using a HAMAMATSU mini-spectrometer (350 to 800 nm) for above-water for Lena River waters, and a RAMSES irradiance spectrometer (TRIOS) for in-water measurements. The downwelling irradiance above the water surface was measured directly before and after the in-water upwelling irradiance measurements using the same sensor. In the water column, the sensor measured in 0.5 m depth steps the upwelling in-water irradiance up to 0.5 m below Secchi depth.

5. MERIS RR Ocean Colour L2 Products

At this preliminary stage, MERIS Reduced Resolution (RR)-LIB data of the study site were acquired from the 08.,10.,11.,12.13.,15.,16. August 2008 and processed towards L2 parameters using Beam-Visat4.2© and the MERIS case2 regional processor for coastal application (C2R) [10]. C2R uses neural network procedures for the retrieval of water leaving reflectances from calculated top-of-atmosphere reflectances after ozone, water vapour and surface pressure correction, and neural network procedures to derive the inherent optical properties (IOPs) from the water leaving reflectances. C2R output parameters are IOPs (absorption and backscattering coefficients), apparent optical properties (AOPs) (water leaving radiance reflectance, attenuation coefficient 'k'), optical parameters such as the first attenuation depth ('Z90') and calculated concentrations of chlorophyll, total suspended matter (TSM), and yellow substance absorption (conversion by specified factors).

6. (PRELIMINARY) RESULTS

7. Coastal Water Types in Eastern Buor Khaya Bay (NE-Siberia)

We give a preliminary summary of the parameters measured in-situ in the Siberian coastal waters in August 2008. In all investigated near-shore and offshore (up to 70 km offshore) water types, the water surface layer and in mixed water columns up to 5 m water depth were fresh (70 to 3000 µS cm^{-1}). All waters were characterized by low Secchi depth transparencies. Lena river waters had extremely high turbidity, with estimated Secchi depths of less than 0.5 m. The estuarine waters were characterized by high turbidity and measured Secchi depth transparencies of 1 to 1.5 meters, onshore waters of the Buor Khaya Bay (2 to 5 m water depth, mixed conditions) were characterized by Secchi depths from 0.8 to 1.5 meters, offshore waters (> 5 m water depth, stratified) by Secchi depths from 1.5 to 2 meters. Waters close to the IC-coast showed a moderate turbidity, however low Secchi depths (0.5 to 0.8 m). Measured cDOM values are of high magnitudes, especially for the Ice-Complex influenced near shore waters.

Ranges for the absorption of DOM at 440 nm (0.45-filter) are: estuarine waters, a_{442}cDOM: 1.3-2 m^{-1}; onshore waters, a_{442}cDOM: 1-2.5 m^{-1}; offshore waters, a_{442}cDOM: 1-2 m^{-1}; coastal waters close to the IC-coast show considerable high a442cDOM values: 3-7 m^{-1}.

8. MERIS Synoptic Information

We give a preliminary summary of the first processed MERIS C2R L2 parameters from August 2008. Fig.2 gives an impression on value ranges of the calculated C2R attenuation depth, Z90, and the distribution of the LENA08-Expedition water sampling stations.

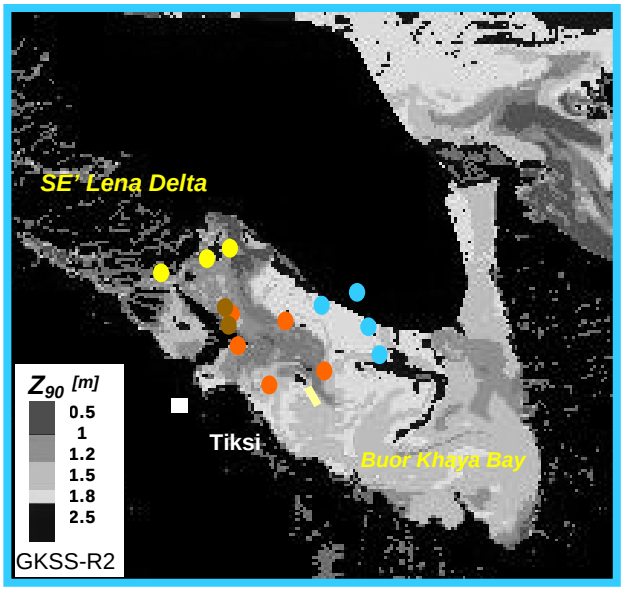

Figure 2. MERIS RR, 2008-13-08, 11:38 local time, MERIS C2R processor: 'attenuation depth, 'Z90', (thin clouds manually masked in black). Lena08-expediton stations: near-shore waters of Ice-Complex (brown), on-shore (orange), offshore (blue), estuarine waters (yellow).

Initial comparisons with Lena08-Expedition data (Secchi depths, cDOM) and water transparency data from former arctic cruises in Buor Khaya Bay show that the MERIS-C2R optical parameters 'total absorption' and the first attenuation depth, 'Z90', seem adequately to represent true conditions.

Whereas the derived concentration parameters MERIS-C2R-chlorophyll and MERIS-C2R-TSM seem to be overestimated by an order of magnitude. The main attribution from MERIS-C2R 'total absorption' goes to MERIS-C2R 'absorption by phytoplankton', so no partition is left for MERIS-C2R 'yellow substance' that is thereby underestimated by one to two orders of magnitude. This problem has to be solved before field investigations will provide the parameters for an optical model for northeastern Siberian coastal waters.

Comparison of the processed MERIS-C2R parameters for the August 2008 time series (2008-08-08,2008-10-

08,2008-13-08,2008-14-08,2008-16-08) shows the stable derivation of MERIS-C2R parameters in magnitude accounting for a well functioning atmospheric correction for this region. Fig. 3 shows the time series of the MERIS-C2R parameter 'total absorption' (thin-cloud contaminated areas are manually masked in black).

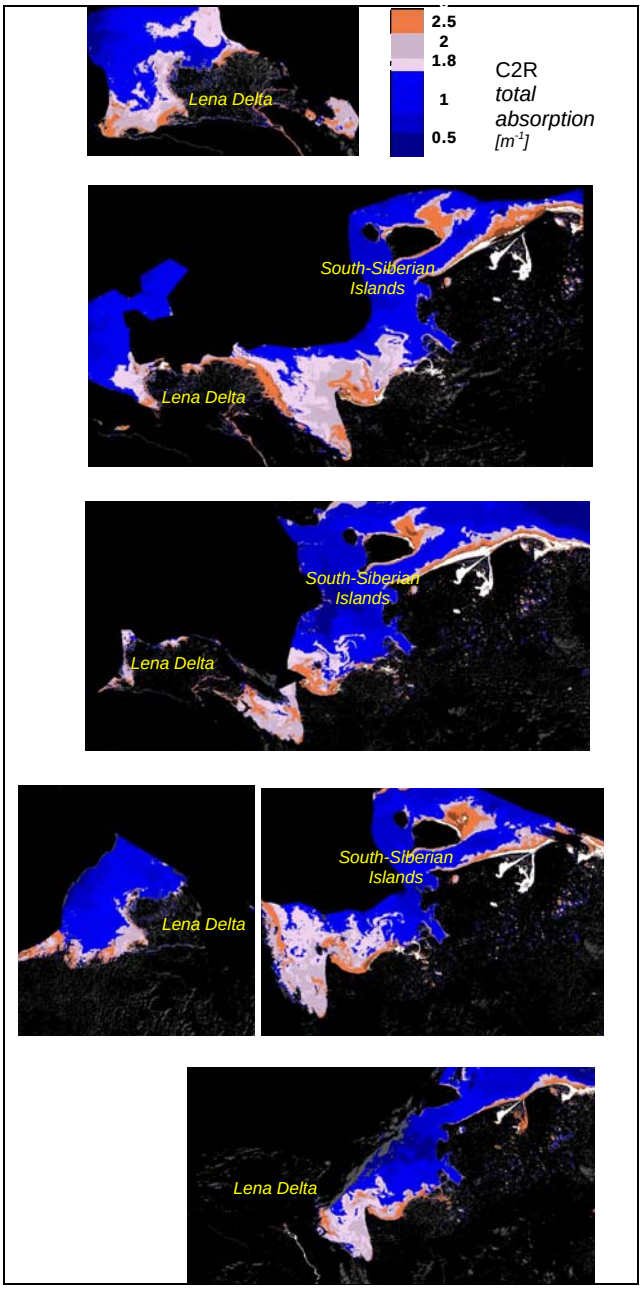

Figure 3. Time series of C2R ' total absorption' from top to bottom: 2008-08-08, 2008-10-08, 2008-13-08, 2008-14-08 (2), 2008-16-08 (thin clouds manually masked in black).

9. DISCUSSION

We conclude that the investigated northeastern Siberian arctic coastal waters are highly specific in terms of being influenced by organic-rich terrigenous input derived from warmed-up ice-rich, organic-rich sedimentary sources in summer months.

The preliminary investigations show that despite the low bathymetry of Buor Khaya Bay, the water leaving optical information will not be influenced by the optical bottom signal, due to the generally low transparencies.

Detailed optical, geochemical and biological investigation will have to be carried out in these specific water types before an optical model can be developed. cDOM and SPM in-situ data from the Lena08-Expedition and future arctic expeditions will provide the first parameters to link to C2R-concentrations. The synoptic information of the optical MERIS-C2R parameters 'total absorption' and 'Z90' offers an immediate wealth of information.

The investigations so far concentrated on geochemical parameters and do not provide chlorophyll in-situ data. Low phytoplankton concentrations are reported in estuarine and near-shore coastal waters in Buor-Khaya Bay, e.g. late-summer concentrations rich up to 2 µg l^{-1} Chl-a and phytoplankton blooming occurs farer off-shore near the ice margins. Initial investigations on the spectral shape of the field spectrometer measurements from the Lena08-expedition in stations in estuarine and coastal waters (indicated in Fig.2) and in the Lena River (not indicated in Fig.2) also do not indicate absorption bands from phytoplankton pigments. However, investigations of the biological component in these optically specific, highly absorbing waters will be of high value for research on arctic ecosystems.

The synoptic information of MERIS Ocean Colour products will provide valuable spatial and dynamical information on the Organic Carbon and sediment fluxes from the Siberian permafrost coast.

10. ACKNOWLEDGMENTS

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