Workshop 'Biogeochemical processes in the Lena Delta and Laptev Sea regions',

LenaDNM project

25-27 of June, 2016

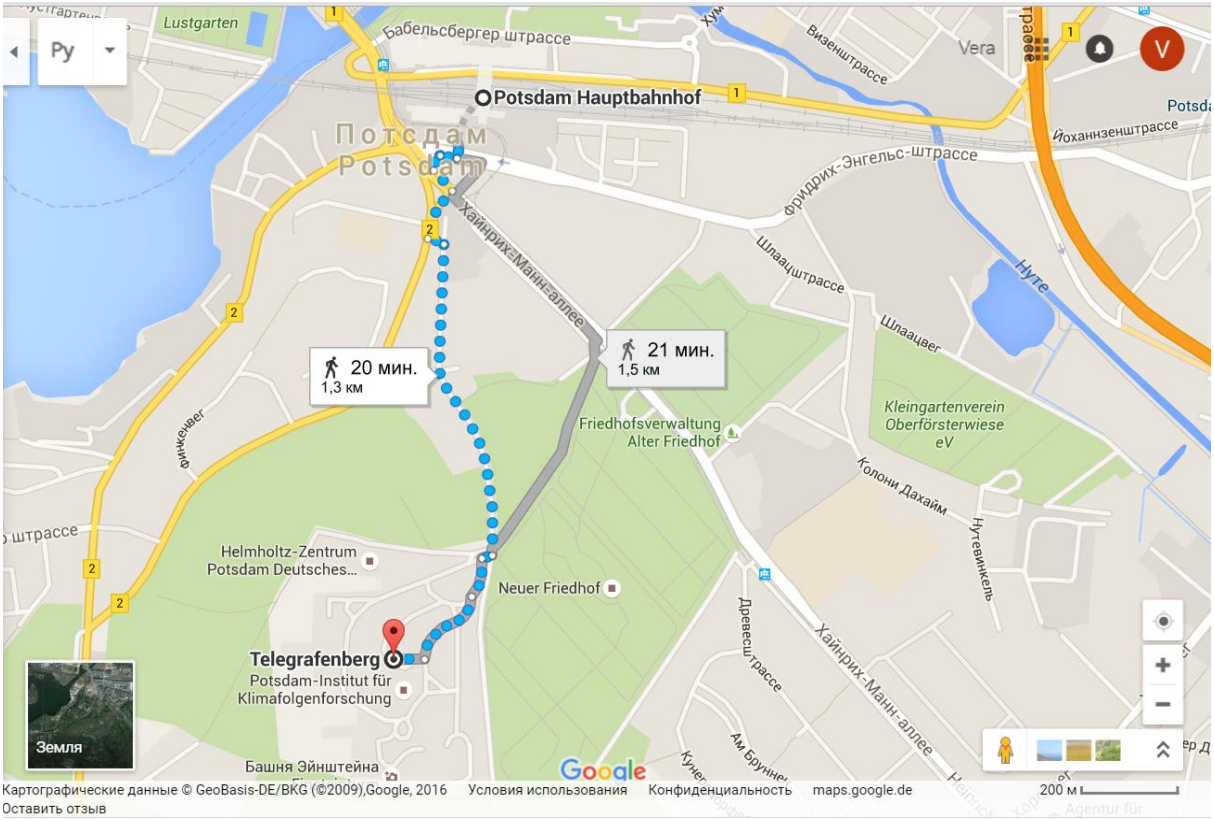
Tit-Ari Island

(http://dnevniki.ykt.ru/Aitalina_Efimova/555826?fromC=true)

Place&Date

25-26, AWI (Alfred-Wegener-Institute), Potsdam, Telegrafenberg A43, Hörsaal

27, AWI, Potsdam, Telegrafenberg A43, Konferenzraum



How to get to the Research Unit in Potsdam?

The AWI Research Unit Potsdam is located on the Telegrafenberg, the historic science campus ‘Albert Einstein’, South of Potsdam's city centre. From the railway station ‘Potsdam Hauptbahnhof’, a 20 minute walk takes you to the campus on the Telegrafenberg. Alternatively, a taxi takes less than 5 minutes and costs approximately 5 Euro. Local public transport in Potsdam (bus and tram), does not service the Telegrafenberg directly. There are two AWI buildings on the campus. The old one (A43) is located on the right-hand side, about 50 m from the entrance of the campus, and the new laboratory building (A45) is located about 100 m left of the campus' gateway.

https://www.awi.de/en/about-us/sites/potsdam.html

Participants

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Vibe Schourup-Kristensen, Alfred-Wegener-Institute

Program

Data/ Place	*Time*	*Presentation*	*Speaker*
25.06 AWI, Telegrafenberg A43, Hörsaal	14.00-14.20	coffee pause, time to hang the posters on the wall / board, presentation uploading	
	14.20-14.30	opening remarks	
	14.30-15.15	Pelagic ecosystems of the Lena-Laptev See-Region: current status and trends	Ekaterina Abramova, Lena-Delta Nature Reserve
	15.15-15.45	Microbial processes in the Laptev Sea pelagial	Nadezda Romanova, P.P. Shirshov Institute of Oceanology
	15.45-16.25	Zooplankton grazing in the Laptev Sea: influence of Lena discharge	Anna Pasternak, P.P. Shirshov Institute of Oceanology
	16.25-16.45	coffee pause	
	16.45-17.10	Phytoplankton data in the Lena Delta: where do we stand?	Alexandra Kraberg, AWI
	17.10-18.05	a) Sediment delivery towards the Lena River delta: quantification and environmental impact b)Recent trends in streamflow of the rivers in the Lena River basin	Nikita Tananaev, Igarka Geocryology Laboratory, Permafrost Institute
	18.05-18.40	Influence of the Lena runoff on hydrochemical structure of the central part of the Laptev Sea in autumn 2015	Alexander Polukhin, P.P. Shirshov Institute of Oceanology

Data/ Place	*Time*	*Presentation*	*Speaker*
26.06 AWI, Telegrafenberg A43, Hörsaal	9.00-9.15	coffee pause, presentation uploading	
	9.15-10.05	Dissolved organic matter in pore water of Arctic Ocean sediments: Environmental influence on molecular composition	Pamela Rossel, AWI
	10.05-10.35	Isotopic and compositional analyses of DOM and POM collected in the Lena Delta between May and August 2014	Gesina Mollenhauer, AWI
	10.35-10.50	coffee pause	
	10.50-11.35	Transport and Degradation of Dissolved Organic Matter and Associated Freshwater Pathways in the Laptev Sea	Jens Holemann, AWI
	11.35-12.05	Effects of source, degradation, and/or transport on the composition of particulate organic matter discharged by the Lena River	Maria Winterfeld , AWI
	12.05-12.30	Poster session announcement	
	12.30-13.30	Lunch	
	13.30-14.15	Poster session	
	14.15 - 14.50	Mathematical models of biogeodynamics: coexistence of species and cosymmetric approach	Tsibulin Viacheslav, Dept. Comput. Mathematics & Math. Physics, Southern Federal University
	14.50-15.45	Modeling efforts for the Lena Delta and Laptev Sea regions	Vera Fofonova, AWI
	15.45 - 16.10	A high resolution Pan Arctic biogeochemical model	Vibe Schourup-Kristensen, AWI
	16.10-16.30	coffee pause	
	16.30-18.00	Round table	
	19.00	Workshop dinner in the ' Lena's restaurant'	

Data/ Place	*Time*	*Presentation*	*Speaker*
27.06 Telegrafenberg A43, Konferenzraum	*9.00-14.00*	Informal program	

Poster session

We kindly ask those, who present posters during the workshop, to prepare 3 min announcement of your poster. You can also prepare 1-slide presentation to help yourself briefly introduce the topic. Please, send this slide to vera.fofonova@awi.de before workshop. The poster sizes are not fixed, posters will be hanging on the walls (arbitrary size is possible) and partly on the boards (A0 vertically oriented and smaller posters).

Round table

The round table is aimed to strengthen the existing modelling efforts for the Lena Delta region including biogeochemical component. For the passive tracers we need boundary and initial conditions. For any kind of mixture, organic and inorganic, the high quality input information is one of the key points of success. The question here is 'what can we do?' with existed database using numerical solutions.

Another broad topic is addition of active tracers and reproduction of the cycles (carbon, nitrogen ....). This topic contains both issues of the limited database and powerful numerical solutions for each type of active tracer for particular region.

Also we would like to discuss possible stochastic approaches based on what we have. The necessity of the stochastic approach is dictated by the large gap in observations and the complexity of the system.

Additional focus will be on bio-optical analysis via remote sensing, which can be a powerful instrument to get some initial data and verify the techniques.

You are very welcome with your ideas, with points like 'What I have, what can be a contribution', 'What do I want to get from the modeling approach', 'What are the main difficulties'.

Informal program

Informal program will be presented by discussion of the workshop results and possible ways of collaboration and planning of the common grant proposal.

Questions?

Please, write (vera.fofonova@awi.de) or call (+491773139758) to Vera Fofonova.

Workshop dinner

Workshop dinner will take place in the Lena's restaurant.

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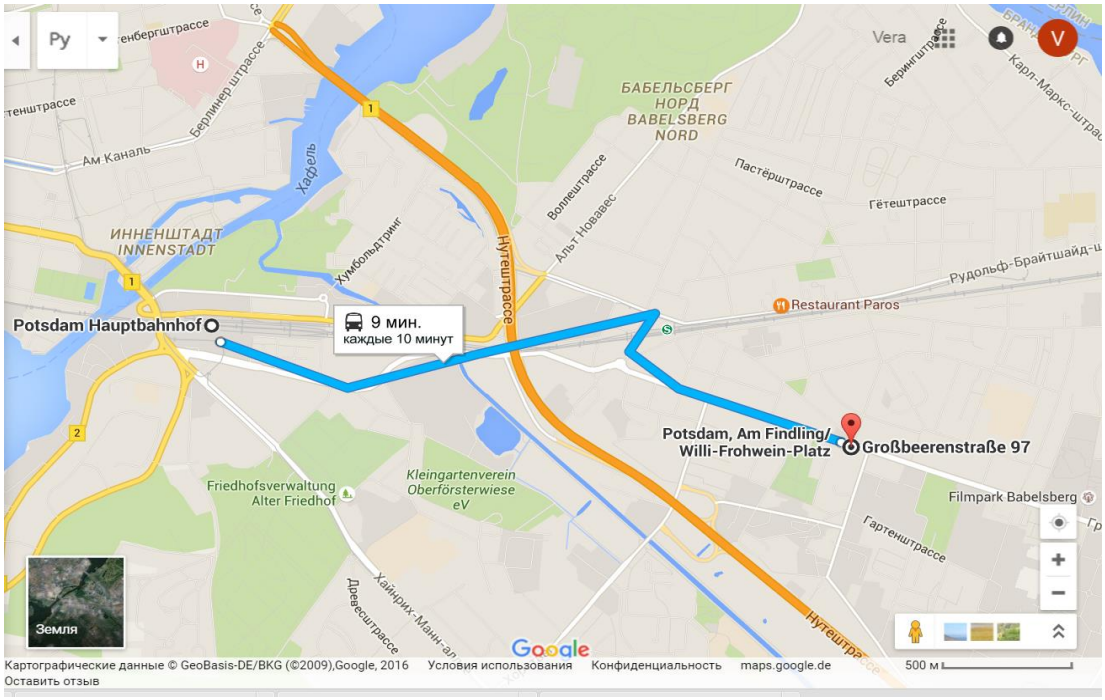

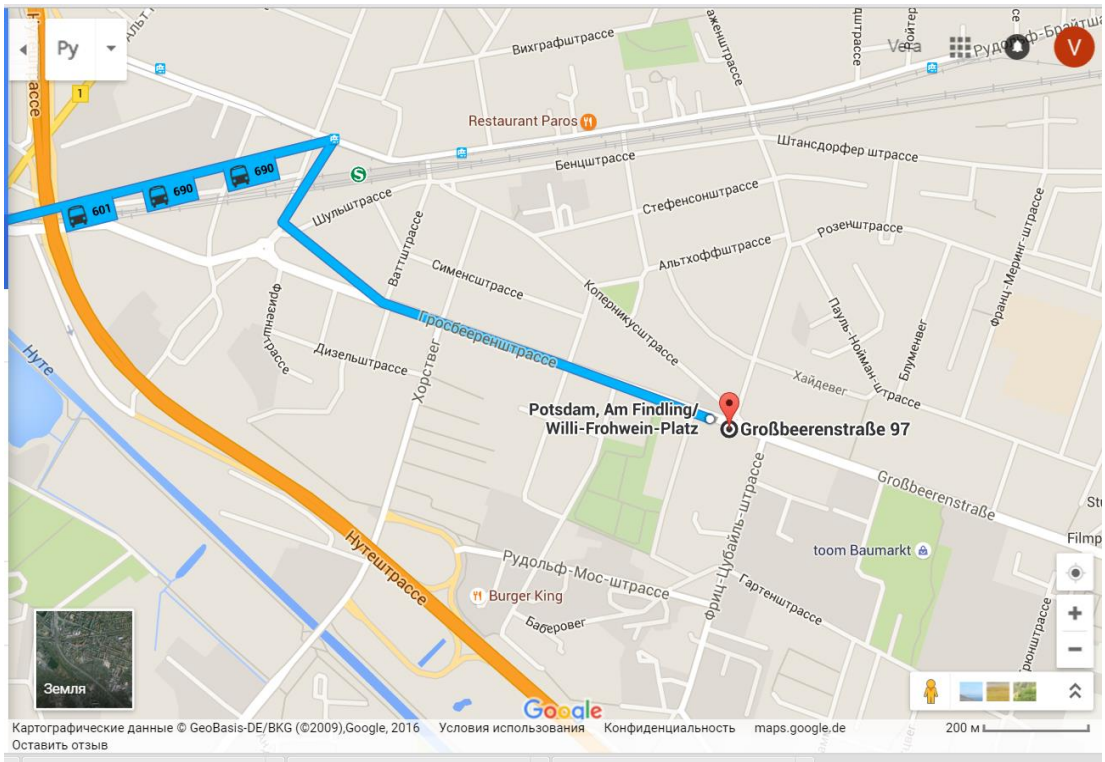

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PELAGIC ECOSYSTEMS OF THE LENA-LAPTEV SEE-REGION: CURRENT STATUS AND TRENDS

Zooplankton is especially sensitive and reactive to external perturbations and therefore is a good indicator of environmental changes. Recent climate warming is expected to support biological invasions. In particular, southern pelagic species will shift northward with warm river waters, and are likely to compete with northern species. The expansion of the boreal species into the more northern areas in the Laptev Sea region is mostly caused by the increasing influence of Lena river run-off. A total of 126 zooplankton species from *Rotifera* and *Arthropoda phyla* were determined in the various lakes and floodplain waterbodies in the southern part of the Lena Delta during fifteen years of our investigations. Sixteen species among them were reported for this area for the first time. During the last decade the highest river water level was observed in spring 2008 and 2014 in the southern part of the Lena Delta. In the same time some elements of the pelagic fauna brought by the river waters found the favorable conditions and start to settle in neighboring reservoirs. Observations clearly demonstrate that invasion of certain species can cause a rapid restructuring of the lakes ecosystem and disturb the ecological balance in it, causing the development of parasitic epizooties. Moreover, preliminary results confirm that the changes in the distribution and phenology of freshwater pelagic fauna are faster and greater than those observed among other groups of organisms in arctic ecosystems.

The data obtained over recent decades on the Laptev See shelf (Transdrift IV-XXII expeditions) clearly demonstrates pronounced changes and strong fluctuations in zooplankton species composition and dominant assemblages distribution in this area too. Changes in dominant pelagic complexes at northern latitudes are likely to have a top down effect on the composition and abundance of species at different trophic levels. Therefore, pelagic species diversity and distribution are important measures of environmental change in the Arctic, and may serve as "rapid-responders"to climate-induced changes in this fragile arctic ecosystem.

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MICROBIAL PROCESSES IN THE LAPTEV SEA PELAGIAL

Marine microbial communities are responsible for more than 40% of newly synthesized carbon flow in plankton food webs [3]. Bacterial abundance, production, and the contribution of viral lysis and grazing by nanoflagellates in the elimination of bacterial biomass were measured in the Lena Delta region and at the adjacent shelf. Sampling was performed in September 2014 and 2015 during the cruise of RV "Mirgirod"and the 63th cruise of RV "Akademik Mstislav Keldysh". Bacterial abundance was determined from direct counts of samples stained with DAPI [6], bacterial production was measured according [7]. The amount of actively respiring bacteria was estimated according [4]. Viral abundance was determined after [5]. Frequency of visibly infected cells (FVIC, %) and viral-mediated mortality of bacteria (VMB, %) of bacteria was calculated after [1], bacterial grazing by nanoflagellates was estimated empirically [2].

In 2014 three regions of the Laptev Sea shelf were compared: the south-western part (Olenek River region), the region affected by the Lena River run-off and the north-eastern part of the shelf. Bacterial abundance and biomass values were relatively stable: in the southern part of the sea the mean values were 370×10^3 cells/ml and $6.58\,\mathrm{mgC\,m^{-3}}$ respectively, and at the north-eastern shelf they were slightly lower: 271×10^3 cells/ml and $4.95\,\mathrm{mgC\,m^{-3}}$ respectively. Bacterial production at the Laptev Sea shelf in 2014 varied from 0.7 to $2.88\,\mathrm{mgC\,m^{-3}\,day^{-1}}$ and achieved $8.39\,\mathrm{mgC\,m^{-3}\,day^{-1}}$ in the surface layer at a single station at the north-eastern shelf. Only the latter region was characterized by uneven vertical distribution of bacterial production: its values decreased twice with depth. The share of FVIC varied from 0.2 to 1.7% of bacterial abundance and in most cases decreased with depth. The value of VMB averaged 7.7% in the region adjacent to the Lena delta and at the north-eastern part of the shelf, while in the south-eastern part of the sea it was only 4%.

In 2015 samples were taken along the transect from the Lena river delta to the open sea. Bacterial abundance varied from 326 to 527×10^3 cells/ml in the surface layer and decreased from 471 to 102×10^3 cells/ml towards the open sea in the bottom water layer. However bacterial biomass decreased northwards both in the surface and in all the water column from 8.51 to $2.9\,\mathrm{mgC\,m^{-3}}$. The input of actively respiring cells in the total bacterial abundance ranged

from 4 to 9% at the two southern stations while along the rest of the transect this value varied from 2 to 32%. The maximal values of bacterial production in 2015 were observed in the upper water layer of the southern station,where it achieved 22.75 $\mathrm{mgC\,m^{-3}\,day^{-1}}$. At the other stations bacterial production varied from 0.46 to 12.87 $\mathrm{mgC\,m^{-3}\,day^{-1}}$ trending to decrease seawards. Bacterial diurnal grazing by nanoflagellates accounted for up to 5.7% of total bacterial abundance. Its values decreased seawards from 5.7 to 1.4% in the surface water layer and varied from 0.1 to 0.3% of total bacterial abundancein the bottom layer. These values correspond to 2–10% of bacterial production in the surface water layer and 0.2–1% in the bottom water

Therefore bacterial mortality both viral induced and due to protozoan bacterivory can achieve a significant part of bacterial production in the Laptev Sea pelagial. This influence is the most prominent in the surface water layer, while in the bottom layer viral pressure decreases and grazing impact becomes almost negligible.

The field work was supported by Russian Science Foundation (project no.14-50-00095), laboratory data processing was supported by Russian Foundation for Basic Research (grant no. 14-04-00130 a; 14-05-00028 a).

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ZOOPLANKTON GRAZING IN THE LAPTEV SEA: INFLUENCE OF THE LENA DISCHARGE

In the Arctic, where the river runoff is large and the shelf shallow and wide, the structure and functioning of the pelagic communities greatly depends on how the fresh and saline waters interact. The Lena River delta is a multi-channel system that discharge about $520\,km^3\,year^{-1}$[2]. The Lena River discharge into the Arctic Ocean is the second largest after Yenisei, and the eights river discharge of the world. The average monthly discharge exhibits large variations with maximum in June. The upper water layer is significantly freshened, and the structure of waters over the Laptev Sea shelf is usually two-layered: the upper freshened layer, which reaches down to 5–10 m, is separated from the underlying saline water by a pronounced pycnocline. The Arctic rivers carry high concentrations of dissolved and particulate material, and pelagic communities are supposed to play an important role in the transformation of the organic matter.

Studies of the Laptev Sea plankton that began about 100 years ago were focused on species composition, abundance and biomass distribution. One of the most complete recent overviews [1] described seasonal and interannual variations of mesozooplankton structure from the coastline to the outer shelf. The functioning of the pelagic ecosystems of the Laptev Sea is virtually unstudied (except fragmentary estimates of the egg production rates in several copepod species, [3], [4]), as severe climatic conditions and the remote location make it difficult.

Recently, P.P. Shirshov Institute of Oceanology has undertaken several multi-disciplinary cruises to the Kara Sea with a leg in the Laptev Sea in September 2015. The aim of the present study was to assess mesozooplankton grazing impact on phytoplankton along a quasi-meridional transect from the Lena Delta to the deep sea area. In the Kara Sea, we have previously shown that biotic interactions, e.g., grazing impact, intensified at the outer front of the desalinated "lens"[6] typical of the Kara Sea [7]. Is there a similar hydrophysical structure in the Laptev Sea? Does a similar grazing response to the freshwater inflow occur in the Laptev Sea?

Salinity, temperature, density, Chl α and oxygen concentrations, turbidity data were obtained at the stations along the transect. Standard sampling methods were used for zooplankton collection, and ingestion rate was estimated with the gut fluorescence procedure.

No large desalinated "lens"of the Kara Sea type (that often covers most of the sea) was found in the Laptev Sea; instead, a mosaic of several differently desalinated smaller "lenses"was observed. Supposedly, this is related to the different patterns of discharge by the Ob and Yenisei, on the one hand, and Lena, on the other. The Lena River runoff enters the Laptev Sea shelf through many channels of the delta instead of the Kara Sea rivers discharging in strong integral flows.

The zooplankton species composition and abundance in our cruise were similar to those reported in the previous studies (e.g., [3]–[5] and [1]). Over the inner shelf, juveniles of *Drepanopus bungii* and *Pseudocalanus* spp. strongly dominated zooplankton community, comprising from 46 to 66% of total abundance. Adults of these copepods were much less abundant. *Acartia longiremis* held the second position with about 11% of total zooplankton abundance. Over the outer shelf, *A. longiremis* and *Oithona similis* dominated (45-80% at different stations). In terms of biomass, *Limnocalanus macrururs* dominated at the inner shelf area. The larger copepods, e.g., *Calanus glacialis* and *Metridia longa*, were never abundant, but dominated the zooplankton biomass in the deep sea regions.

The biomass of mesozooplankton in the water column varied from $749\,\mathrm{mg\,m^{-2}}$ to $42{,}000\,\mathrm{mg\,m^{-2}}$, considerably increasing in the deeper areas. Three peaks of biomass concentration (B, $\mathrm{mg\,WW\,m^{-3}}$) were found at st. 5216, 5219 and 5227). The increase of concentration at the former two stations coincided with salinity fronts at the margin of the small "lenses". The latter peak was probably associated with the salinity and temperature gradient zones typical of the shelf-break area. Day and night sampling revealed pronounced vertical migrations and diel feeding rhythm in *Calanus* spp. and *M. longa*. Small grazers did not exhibit significant diel changes either in vertical distribution, or in the ingestion rate. In general, zooplankton avoided the most freshened upper (usually, 0-10 m) layer. Phytoplankton, on the contrary, showed high concentrations in this layer, which caused vertical separation between zoo- and phytoplankton in the areas with highest desalination. This separation may be the main reason for not very high ingestion rates there, despite the high phytoplankton concentrations.

Mean total mesozooplankton grazing impact on phytoplankton was low (about 2%) in the inner shelf area, increasing to 3 and 5% at the middle and outer shelf, and to 10% in the deep sea areas. However, it was higher at the stations where zooplankton concentration peaked: 7% at st. 5219 in the inner shelf area and 28% at st. 5227 in the deep sea area.

Contrary to the Kara Sea, where one large desalinated "lens"exists for at least a year or even more, in the Laptev Sea several smaller "lenses"originated from the outflow of different channels; duration of their existence is not

yet known. Though the increase of zooplankton concentration and grazing impact were also observed at the edge of such "lenses the effect was less pronounced compared with the Kara Sea. To assess the role of the small "lenses"for the mesozooplankton grazing in the Laptev Sea, more detailed and extensive surveys are needed. The ecosystem effects of the large integral "lens"(the Kara Sea) and fragmented small "lenses"(the Laptev Sea) could be different. Variability of zooplankton grazing in the Laptev Sea is expected to occur on a smaller scale.

A C K N O W L E D G M E N T S

The field work, including hydrophysical studies, was supported by the Russian Science Foundation (project no. 14-50-00095).

R E F E R E N C E S

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PHYTOPLANKTON DATA IN THE LENA DELTA: WHERE DO WE STAND?

The Lena Delta is one of the largest deltaic regions in the world, yet while there is considerable information about the physico-chemical dynamics of the region (including as well-structured time series), information on the biota is still scant and fragmented.

The phytoplankton in particular, although constituting the base of the food web is still very underrepresented in the available data sources for the Lena Delta. Data to be presented include phytoplankton data from cruises between 2009 and 2013, in which the inner delta as well as the coastal Laptev Sea were sampled (although one cruise in 2010 sampled both). These data showed that the biological community seemed to reflect the very distinct hydrography of the area. With the innermost coastal stations (shallow and well-mixed) essentially forming an extension of the river itself and consequently being dominated by freshwater diatoms and some cyanobacteria and green algae. The offshore waters on the other hand were strongly stratified and dominated by dinoflagellates ciliates and different unidentified small flagellates.

To better understand the dynamics of the Lena Delta at the base of the food web, regular monitoring at a limited number of stations would be strongly advisable, although this is difficult due to the lack of ship resources. In this talk the available data will be synthesized as a basis for discussion of potential "next steps"and future collaborations which could include agreements on joint cruises and/or sharing of equipment and taxonomic expertise. The latter is a particular bottle neck in the Lena Delta and impedes the regular generation of consistent time series data.

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A HIGH RESOLUTION PAN ARCTIC BIOGEOCHEMICAL MODEL

The acceleration of the Arctic sea-ice decline observed over the past decade has consequences for the biological production in the area, through for example changes in the nutrient budget and the mixed layer light availability. Nitrogen plays an important role in the nutrient limitation of the Arctic Ocean, but currently, not much is known about the roles of the different sources and sinks of nitrogen for the Pan-Arctic region. To gain further insight into the current state of the large scale nitrogen budget, coupled ocean-biogeochemical models can be used.

At AWI, the Finite Element Sea-ice Ocean Model (FESOM) has been coupled to the biogeochemical model REcoM2. The coupled model has been run in a global setup with high resolution (4.5 km) in the Artic Ocean. Here we present the mean state of the model with special focus on the net primary production (NPP) and the nitrogen budget for the Arctic Ocean. The total Arctic NPP of the run sums up to an average of $0.5\,\mathrm{Pg\,C\,yr^{-1}}$, thereby agreeing well with other models and satellite-based estimates. The nitrogen budget shows that the main source of nitrogen is the Spitzbergen Current in the Fram Strait, while benthic denitrification is the largest sink of nitrogen. The combined input of nitrogen from Aeolian and riverine sources is small. In the future, increased riverine runoff may, however, play a role for the vertical stratification of the water column, and thus for the vertical supply of nitrogen to the surface water.

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MODELING EFFORTS FOR THE LENA DELTA AND LAPTEV SEA REGIONS

The Lena River is one of the largest rivers in the Arctic and has the largest delta. Given the large territory of the Lena Delta, the direct measurements are by far insufficient, calling for a modeling approach. However, most of the models, which include the Laptev Sea shelf zone, do not resolve the Lena Delta and as a consequence lose information about Lena river stream changes using input data with insufficient quality. In the current work we present the hydrodynamics model for the Lena Delta region and full baroclinic model for the Laptev Sea shelf area. The available hydrological information in the Lena Delta was collected, analyzed and used for the model verification. The developed hydrodynamics model provides the first necessary step for the further modeling efforts in the area. It also gives an input for the larger scale models resolving hydrodynamics of more than twenty main Lena River freshwater channels with switched-on wetting/drying option. Additionally the Lena Plume dynamics in the Lena Delta region of the Laptev Sea are explored by us in simulations performed with the FVCOM (Finite Volume Coastal Ocean Model). The impact of winds and tides on the Lena plume propagation is analysed based on simulations for the summer season of 2008 and also on idealized experiments. For that period, the simulated distributions of temperature and salinity agree well with the observations, including the thickness and border position of the buoyant plume. The model simulates the most energetic semi-diurnal and diurnal tidal constituents. The amplitudes and phases of the tidal components at the open boundary were derived from AOTIM5 and TPXO7.1 with corrections. These corrections noticeably improve the agreement of the modelled tidal maps with available tide gauge data.

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MATHEMATICAL MODELS OF BIOGEODYNAMICS: COEXISTENCE OF SPECIES AND COSYMMETRIC APPROACH

We consider an application of the systems of nonlinear parabolic equations to simulate the impact of migration effects on population patterns. In a number of recent articles, similar models were used to analyze the spread of disease and the formation of biological structures and in the study of processes of invasion. We derive an approach based on cosymmetry theory [1,2] to treat the different scenarios with formation of population structures: slow dynamics, coexistence of species, destruction of the steady families of populations.

Firstly we investigate a system with taxis terms that take the inhomogeneous distribution of a resource and the distribution of competing populations into account, without restrictions on the migration parameters and growth factors. Cosymmetry enables the finding of the conditions (parametric dependence) under which there is a continuous family of solutions that admits the coexistence of populations. To analyze the population scenarios that arise from the destruction of cosymmetry, we used a computational experiment. For a system of two populations, we calculated the zones of migration parameters that correspond to different scenarios of the for deformation of population structures: the coexistence of both species and the case when one population prevail. The coexistence of populations in a habitat depends on the joint amount of the factors of migration: the nonuniform distribution of resource and species as well as the response of the population to the distribution of neighboring species (a sign of the appropriate migration coefficient).

Then we study patterns of predators and prey in a two-dimensional habitat. The model is formulated as a system of nonlinear parabolic equations with spatial heterogeneity of resources and species. Conditions on system parameters are determined under which a nontrivial family of steady states (equilibria) is formed due to cosymmetry of a system. Numerical analysis based on the finite difference method and staggered grids is applied. We study the impact of migration on scenarios of local competition and coexistence of species. To analyze the destruction of the family of equilibria we employ an approach with selective equation for cosymmetric systems [2] and special computational technique [3]. Nontrivial effects of migration are determined and scenarios of local competition and coexistence of species are found [4].

The next problems are devoted to the appearance of the families of periodic regimes. We consider the systems that combined the logistic and hyperbolic models to describe the growth of prey. Both for the systems «predator and two prey» and «two predators and pray» we obtain solutions with coexisting species. Families of limit cycles are found and the biogeodynamics under lost of cosymmetry is analyzed [5].

This research was supported by The Russian Foundation for Basic Research (grant No 14-01-00470).

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HYDRO-GEOCHEMICAL CHARACTERISTICS AND TRANSFORMATION PROCESSES OF THE LENA RIVER DELTA BRANCHES

Previous studies have shown that arctic river delta systems are areas of accumulation of geochemical substances at the sea-river mixing zone. In the Lena River Delta our previous work shows the tendencies of water runoff redistribution changes and heterogeneity of suspended supply distribution along the delta branches, accumulation and erosion zone in the different parts of the delta. Nevertheless, the processes of geochemical flow transformation in the subaerial deltas are so far underestimated. In order to close this gap, we sampled water, suspended and bottom sediments in the Lena River Delta in the summer seasons of 2010 and 2014. Most of the sampling points were tight to the profiles of hydrological measurements held in the delta and highlighted in [1].

The results show that geochemical transformation of the Lena River runoff is taking place in the delta. The most active time for the transformation is the summer season due to the activity of sediment accumulation and biogeochemical processes. Hydrological conditions in the delta affect also its hydro-geochemical characteristics. Furcation of the delta branches affects the hydrodynamic conditions of different delta areas.

The factors influencing the geochemical characteristics of the delta were identified on the base of geochemical indexes approach applied to sediments and statistical factor analysis.

Based on geochemical indexes (Al/Na, Si/Al, Fe/Mn and Fe/Al ratios) similar conditions were determined for the main branch of the Lena, the upstream parts of Bykovskaya and Tumatskaya branches and in Olenekskaya branch near Chay-Tumus. Despite of high runoff the branches are characterized by element accumulation, which can be explained by decreasing of flow turbulence and specificity redox conditions in these areas. Bottom sediments are one of the most important indicators of geochemical transformation processes.

The results of statistical factor analysis show three main factors for formation of the these geochemical conditions in the delta: 1) the general water flow

of the Lena River, which is influenced by the lithogenous base of the river catchment, 2) the cryogenic condition of the Lena Delta (permafrost degradation processes and cryogenic weathering) and 3) biogeochemical transformation during redistri-bution of chemical water components, suspended matter and bottom sediments.

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INFLUENCE OF THE LENA RUNOFF ON HYDROCHEMICAL STRUCTURE OF THE CENTRAL PART OF THE LAPTEV SEA IN AUTUMN 2015

Shirshov Institute of Oceanology (SIO) has been performing oceanological investigations in the Laptev Sea during 63th cruise of "Akademik Mstislav Keldysh"(8–15 of September 2015). It was first scientific cruise of SIO to the Laptev Sea region since late 1980s. A cross-section from Tiksi to the continental shelf slope along 130° (14 sites, 700 km length) was performed. Expedition included physical, chemical, biological and geological measurements (so-called complex expedition). The dataset of measured hydrochemical parameters included: pH, dissolved oxygen (O2), total alkalinity (Talk), nitrate nitrogen (NO3), nitrite nitrogen (NO2), ammonia nitrogen (NH4), total inorganic nitrogen(Ntot), silicate (Si), mineral phosphorus (PO4), total inorganic phosphorus (Ptot). Determination of mentioned parameters was performed according to [1]–[3]. Total inorganic carbon (TIC), CO3, HCO3, pCO2 has been calculated from direct measurements of pH and Talk according to [4]. Temperature and salinity were provided by S. Schuka via direct CTD measurements.

Using the diagrams of mixing we can distinguish three types of waters in the study area: the surface transformed water which changes its properties with the increasing influence of sea water, deep sea water, not directly exposed to the influence of the river runoff and bottom water in the river area with sea salinity beneath the freshened lens. We also observed two freshened areas along the cross-section divided by more salty sea water. There was made an assumption that this is water from different sleeves of the Lena Delta but we have no data to confirm it.

The alkalinity has a conservative distribution, which is typical for most areas of the mixing of fresh and marine waters. Silicon deviates from conservative distribution in marine deep water zone, and in the waters of sea salinity in the river part of the mixing zone. Nevertheless, the overall trend of silicon distribution is typical for most areas of mixing and is characterized by a decrease in silicon content as the growing influence of sea surface waters. The diagrams of mixing for phosphates and nitrate nitrogen have shown non-conservative distribution and their absence in the riverine water which is

flowing into the mixing zone. A significant increase in the content of phosphates and nitrates occur in waters with sea salinity. Thus, it can be assumed that the accumulation of mineral phosphorus and nitrate in the study area is deriving not with the riverine water, but due to the decomposition of organic matter from river in the deep waters beneath photosynthesis layer (recycling of nutrients).

The oxygen saturation throughout the cross-section did not rise above 97%. Thus, even the oxygen content on the surface does not reach equilibrium with the concentration of oxygen in the atmosphere. At the bottom layer in the river part of the mixing zone, where the salty sea water penetrates, oxygen percentage drops to 64%, from which it can be concluded that in the investigated area processes of destruction dominate over a production processes.

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ORGANIC MATTER IN ARCTIC OCEAN SEDIMENTS AND ITS LINK WITH ENVIRONMENTAL DATA AND BENTHIC BACTERIAL COMMUNITIES

Marine organic matter (OM) that sinks from surface waters to the seafloor is the energy and carbon source for benthic communities. These communities produce dissolved organic matter (DOM) in the process of remineralization, enriching the sediment porewater with fresh DOM compounds. In the Arctic Ocean, primary production is limited by nutrients and light and is thus strongly influenced by water masses and sea ice cover. Ice cover is expected to further decrease due to global warming, which may have important consequences for primary production and the quantity and quality of OM exported to the seafloor. This study focused on: 1) organic matter variability at the seafloor of the Laptev Sea (1993 vs. 2012) and its influence on benthic bacterial communities; 2) the molecular composition of DOM in sediment pore waters of the deep Eurasian Arctic basins and HAUSGARTEN observatory in Fram Strait; 3) the relation between ice cover, water masses and pore water DOM composition. At the Laptev Sea continental margin, phytodetritus availability increased considerably from 1993 to 2012, entailing higher extracellular enzymatic activities at the seafloor. In the Eurasian Arctic basins, fresh OM and phyto-detritus deposition at the productive ice margin stations were related to higher abundances of molecular formulae of peptides, unsaturated aliphatics and saturated fatty acids, compared to the northernmost, ice-covered stations which had stronger aromatic signals. Furthermore, DOM molecular composition of the Eurasian Arctic sediments was significantly correlated with benthic bacterial community structure. At the HAUSGARTEN observatory, fresh OM signals were also related to higher enzymatic activity and were observed at the stations influenced by the Western Spitsbergen Current, which carries nutrient-rich Atlantic water northward, while stations influenced by the Eastern Greenland Current were characterized by aromatics and highly degraded organic matter. This study contributes to the understanding of the coupling between Arctic Ocean productivity and its depositional regime, and provides first insights into potential links between microbial community structure and DOM molecular composition in Arctic sediments.

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EFFECTS OF SOURCE, DEGRADATION, AND TRANSPORT ON THE COMPOSITION OF PARTICULATE ORGANIC MATTER DISCHARGED BY THE LENA RIVER

The Lena River in central Siberia represents one of the major pathways for relocating pre-aged terrestrial organic matter (OM_{terr}) stored in permafrost soils from its catchment to the coastal zone of the Laptev Sea. Future Arctic warming and permafrost thawing will likely enhance the re-mobilization and export of this pre-aged OM_{terr}. Despite our improving knowledge about the fate of OM_{terr} released from permafrost, the quality and age of particulate OM_{terr} as well as the sources within the large watershed contributing to the exported OM_{terr} are still not completely understood. To characterize the composition and sources of OMterr discharged by the Lena River, we analyzed the lignin phenol and carbon isotopic composition ($\delta^{13}C$ and $\Delta^{14}C$) in Lena Delta soils, total suspended matter (TSM) from surface waters along with surface sediments offshore the delta. A simple linear mixing model based on the bulk lignin phenol distributions indicates that OMterr in TSM samples and coastal surface sediments contains comparable contributions from gymnosperms originating from the taiga forests south of the delta and angiosperms typical for tundra vegetation. Further, we present results of the lignin phenol compositions and inferred sources of OM_{terr} transported with specific grain-size classes (>2mm, 63μm – 2mm, <63μm) of soil and sediment samples associated with different hydrological conditions (spring flood vs. summer low flow). Overall stronger diagenetic alteration in TSM and coastal sediments relative to soils appears to reflect degradation of more labile components during permafrost thawing and transport. Moreover, Lignin phenols and $\Delta^{14}C$ of surface sediments suggest that OM_{terr} deposited offshore is more degraded and older than materials present in river suspended particles and catchment soils.

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ARCTIC RIVER ORGANIC CARBON EXPORT THROUGH THE ICE-FREE SEASON: ISOTOPIC AND COMPOSITIONAL ANALYSES OF DOM AND POM COLLECTED IN THE LENA DELTA

Arctic rivers are known to export large quantities of carbon by discharge of dissolved and particulate organic matter, and in a warming and progressively moister Arctic, these exports may increase resulting in a reduction of continental carbon stocks in the region. In particular, mobilization of fossil carbon from terrestrial reservoirs, stored predominantly in Yedoma deposits, will result in a net carbon loss. Therefore, the radiocarbon (^{14}C) contents of carbon exported via rivers are of great interest to understand the on-going processes.

Recent work has shown that both particulate and dissolved organic matter exported through the Lena Delta into the Laptev Sea, consists of a complex mixture of material derived from multiple sources (e.g., [3], [1]). Organic matter derived from the different sources likely differs in its reactivity once released from the frozen deposits into the river waters. For example, it has been shown that ancient carbon is very rapidly respired, leading to predominantly modern ^{14}C signatures of dissolved organic carbon (DOC) in Arctic river waters discharged to the ocean [2].

Arctic rivers are characterized by highly variable discharge rates with a pronounced maximum during the spring freshet associated with highest concentrations of DOC and particulate organic carbon (POC). Most studies investigating the isotopic composition and quality of carbon exported by Arctic rivers, however, rely on samples taken in summer during base flow, which is due to the logistical challenges associated with sampling in the remote Siberian permafrost regions. Here we present a record of δ^{13}C and Δ^{14}C of DOC and POC collected between late May during the freshet and late August in the Lena Delta, and compare them with δ^{13}C and Δ^{14}C of DOC and POC sampled in central Siberia. The latter represent the hinterland of the large rivers, while

the Lena Delta data are considered to contain an integrated signal of the watershed. The central Siberian POC is generally younger than the Lena Delta POC in spring. Throughout spring and summer, POC becomes progressively older in central Siberia, while an initial trend towards older values in the spring samples from the Lena Delta is reversed in summer, associated with a shift towards more depleted δ^{13}C values. We interpret these aging trends as reflecting progressive thawing throughout the ice-free season, resulting in mobilization of progressively older carbon from deeper thawed layers. The summer reversal indicates admixture of fresh organic matter, likely produced by aquatic organisms.

We furthermore analysed the biomarker composition of Lena Delta particulate organic matter collected in spring and summer. From spring to summer, we observe trends in abundance of individual leaf-wax derived biomarkers indicating higher abundance of algal biomass in the summer particles. Trends in biomarkers associated with soil microbes suggest a shift in sources through the ice-free season. Similarly, the D/H ratio in long-chain alkanes differs markedly between the spring and summer samples, suggesting more southern-derived material to be present in the summer samples. Our data illustrate that considering the seasonal evolution of carbon discharge from Arctic rivers will be required to understand the underlying mechanisms and to predict future changes.

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TRANSPORT AND DEGRADATION OF DISSOLVED ORGANIC MATTER AND ASSOCIATED FRESHWATER PATHWAYS IN THE LAPTEV SEA (SIBERIAN ARCTIC)

The Siberian shelves are seasonally ice-covered and characterized by large freshwater runoff rates from some of the largest rivers on earth. These rivers also provide a considerable amount of dissolved organic carbon (DOC) to the Arctic Ocean. With an annual load of about 6 Tg DOC a^{-1} the Lena River contributes nearly 20% of the annual DOC discharge to the Arctic Ocean. Our investigations are focused on CDOM (Colored Dissolved Organic Matter), which resembles the DOC concentration, interacts with solar radiation and forms a major fraction of the organic matter (DOM) pool. Even though the input of riverine DOM plays a major role in the Arctic Ocean carbon cycle, some question remain unanswered:

- How much of the DOM is remineralized on the shelves, and how much is exported into the Arctic Basin?

- How strong is the influence of CDOM on the optical properties of shelf waters, and do the high CDOM concentrations effect the thermal stratification, ice melt and primary production in the Laptev Sea?

We present a comprehensive dataset collected during multiple Laptev Sea expeditions carried out in spring, summer and fall (2010–15) in order to explore the processes controlling the dispersal and degradation of DOM during the river water's passage across the shelf. Our results show an inverse correlation between salinity and CDOM, which emphasizes its terrigenous source. The distribution of the Lena river water is primarily controlled by winds in summer. DOC concentrations in freshwater vary seasonally and become larger with increasing discharge. Our data indicate that the CDOM concentrations are highest during the freshet when fast ice is still present. Subsequent mixing with local sea ice meltwater lowers CDOM to values that are characteristic for the Lena

freshwater during the rest of the year. Significant loss of CDOM/DOC (non conservative mixing) was only observed in September 2011. A year that was characterized by low mixed layer salinities within a large area of the LS (river plume remained on the shelf), and unusually high sea surface temperatures (induced by an early sea-ice retreat and anomaly high net solar fluxes during summer).

This presentation also highlights the strong temperature variability and the dominant oceanographic processes in the Laptev Sea. Recent years were characterized by early ice retreat and a warming near-shore environment. However, warming was not observed on the deeper shelf until year-round under-ice measurements recorded unprecedented warm near-bottom waters of $+0.6°C$ in winter 2012/2013, just after the Arctic sea ice extent featured a record minimum. In the Laptev Sea, early ice retreat in 2012 combined with Lena River heat and solar radiation produced anomalously warm summer surface waters, which were vertically mixed, trapped in the pycnocline, and subsequently transferred toward the bottom until the water column cooled when brine rejection eroded stratification [1].

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RELATIONSHIPS BETWEEN COLORED DISSOLVED ORGANIC MATTER (CDOM), DISSOLVED ORGANIC CARBON (DOC) AND DISSOLVED MINERAL SUBSTANCES IN DIFFERENT SURFACE WATERS OF THE LENA RIVER DELTA

In order to understand the influence of surrounding catchment characteristics on the CDOM concentration different types of surface waters in the Lena river delta region were investigated regarding their geochemical composition. The Lena River Delta consists of three geomorphological main terraces that differ in their relief, hydrological and cryolithological characteristics, which possibly influences the content of dissolved substances in their associated water bodies and in the neighboring river branches.

During summer seasons of 2013–2014 water samples were collected from river branches as well as from lakes and melt-water streams on the first and the third main terraces and analyzed them for concentrations of colored dissolved organic matter (CDOM), dissolved organic carbon (DOC), and main and trace elements (Na, K, Mg, Ca, HCO_3, F, Cl, SO_4, Fe, Si, Sr). This type of research was carried out for surface waters in the Lena delta region for the first time. Statistical analysis revealed several correlations between CDOM, DOC and mineral ions. For example, R-squared (the coefficient of determination) for CDOM and Cl and for CDOM and Na in Lena River branches were 0.52 and 0.51, respectively. Correlation between CDOM and F was also found for melt-water streams from the Ice Complex (third terrace) (R-squared = 0.5).

Analysis of the relationship between CDOM and DOC showed strong correlation of these parameters for lakes (R-squared = 0.98) and lower correlation for river branches (R-squared = 0.48). In streams formed by the thawing of Ice Complex deposits on the third terrace was found the highest values of CDOM and DOC, but a correlation between them was not observed. A clear dependency was found out between CDOM and DOC correlation and the location of lakes on different terraces with specific permafrost conditions. A stronger correlation was observed for the lakes located on the third terrace (Ice Complex) compared to lakes located on the first terrace (Samoylov Island).

Usually, lakes on the first terrace get flooded by river waters during spring, whereas lakes of the third terrace are not affected by river water inflow and have more stable conditions. The Lena delta branches are influenced by differing surrounding conditions, therefore CDOM and DOC concentrations change during summer season and did not show strong correlations.

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THE POTENTIAL OF OCEAN COLOR REMOTE SENSING TO STUDY SEDIMENT TRANSPORT EVENTS RECORDED BY LONG-TERM OCEANOGRAPHIC OBSERVATIONS ON THE LAPTEV SEA SHELF

The potential of Ocean Color Remote Sensing to study sediment transport events recorded by long-term oceanographic observations on the Laptev Sea shelf The Laptev Sea is located on the Siberian shelf of the Arctic Ocean. Unique datasets for sediment transport investigations were collected during numerous TRANSDRIFT expeditions. However, those measurements are limited to the time of the expedition and to the position of year-round measuring seafloor observatories (moorings). Thus, the spatial and temporal resolution of the dataset is relatively low. Acoustic Doppler Current Profilers (ADCP) included in the seafloor observatories provide an opportunity to measure indirect relative particle concentration in the upper water column by the echo intensity of acoustic signals. The ADCP record from the mooring Khatanga 11 (inner Laptev Sea shelf) shows a sudden increase of turbidity in the upper water column in May 2012, reaching its maximum in the beginning of June. Additionally, the CTD (Conductivity Temperature Depth-meter) record indicates warmer and less saline water during this time period. The increase of turbidity coincides with the period of river-ice break up in the Lena Delta that is caused by the arrival of the spring freshet. Thus, riverine input can be assumed as the source of the turbid surface waters. In order to estimate the surface water turbidity and to determine sediment transport pathways and river plume propagation Ocean Color Remote Sensing technique was used. With data from the Moderate Resolution Imaging Spectroradiometer, "MODIS"(Aqua) sensor it is possible to illustrate the surface water turbidity with high spatial and temporal resolution. Three mosaic images (several scenes merged together) were created to compare different time periods: – 1) before river, 2) ice break up, during, and 3) 1.5 month after the river-ice break up. The image, corresponding to the river-ice break up period, shows a northward propagating turbid plume, which reaches the Khatanga 11 position in the middle of May and confirms the high echo intensities. The turbid plume probably represents the Lena River plume. This is the only observed period where a turbid plume propagates that far north during the whole year. The mosaic images before and after river-ice break up show low turbidities at the Khatanga 11 position and provide no evidence of a northward propagating turbid river plume. This

can be explained by the significantly lower sediment input during the time before and after river-ice break up. The atmospheric situation is an important factor for a possible transport of the Lena River plume northward to the mooring position. Indeed, the analysis of NCEP atmospheric data shows a constant northward wind during May and the beginning of June, supporting the northwards propagation of the plume. Ocean color remote sensing was used in numerous studies as an effective tool to trace sediment transport pathways and river plume propagation. As a quality-check of the remote sensing data, comparisons (match-ups) between satellite-derived turbidity and turbidity field measurements from three TRANSDRIFT expeditions have been performed. These Match-ups show strong correlations (R^2>0.73). However, calculations of satellite-derived absolute concentrations of suspended sediment are not precise in polar regions due to poorly conceived processing algorithms. Nevertheless, relative changes of the surface water turbidity can be observed accurately.

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OPTICAL CHARACTERIZATION AND BIOGEOCHEMISTRY OF DISSOLVED ORGANIC MATTER IN THE LENA RIVER DELTA REGION

Connectivity between the terrestrial and marine environment in the Artic is changing as a result of climate change, influencing both freshwater budgets and the supply of carbon to the sea. This study characterizes the optical properties of dissolved organic matter (DOM) within the Lena Delta region and evaluates the behavior of DOM across the fresh water-marine gradient. Six fluorescent components (four humic-like; one marine humic-like; one protein-like) were identified by Parallel Factor Analysis (PARAFAC) with a clear dominance of allochthonous humic-like signals. Colored DOM (CDOM) and dissolved organic carbon (DOC) were highly correlated and had their distribution coupled with hydrographical conditions. Higher DOM concentration and degree of humification were associated with the low salinity waters of the Lena River. Values decreased towards the higher salinity Laptev Sea shelf waters. Results demonstrate different responses of DOM mixing in relation to the vertical structure of the water column, as reflecting the hydrographical dynamics in the region. Two mixing curves for DOM were apparent. In surface waters above the pycnocline there was a sharper decrease in DOM concentration in relation to salinity indicating removal. In the bottom water layer the DOM decrease within salinity was less. We propose there is a removal of DOM occurring primarily at the surface layer, which is likely driven by photodegradation and flocculation.

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OPTICAL PROPERTIES OF CHROMOPHORIC DISSOLVED ORGANIC MATTER OF THE SURFACE WATERS ACROSS THE LAPTEV SEA

The absorbance and fluorescence properties of dissolved organic matter (DOM) have proved to be "optical markers"for the study of estuarine and coastal mixing, dynamics of quantitative and qualitative changes in DOM, and also necessary as preconditions for remote sensing techniques [1]. In this study the optical properties of chromophoric dissolved organic matter (CDOM) in the Laptev Sea were investigated and supported with salinity and DOC measurements. Water sampling was performed in September 2015 during the 63th cruise of RV "Akademik Mstislav Keldysh" , when the annual average air temperature over land was the highest since 1900 [2]. These surface waters are of particular interest in the optical studies since they allow an exploration of CDOM across a gradient from estuarine to near-oceanic environments with the salinity varying between 3 and 30 psu.

Sea water samples were filtered using precombusted Whatman GF/F filters with a pore size of 0.7 μm. DOC concentration was measured onshore by high-temperature combustion with a Shimadzu TOC analyzer. Absorption spectra were measured in a 1 cm quartz cuvette within wavelength range 200–650 nm. Fluorescence measurements were performed onboard. Emission scans were acquired at excitation wavelengths from 230 to 550 nm at 5 nm intervals and emission wavelengths from λ_{ex} + 10 to 650 nm at 1 nm intervals.

DOC concentration in the studied samples varied from 497 μM (Lena Delta region, St. 5216, sal. 3.0 psu) to 193 μM (continental slope, St. 5225, sal. 30.1 psu). It displayed a negative correlation with salinity. A hypothetic conservative behavior of DOM with respect to salinity can be described by the following equation: $DOC = 548 - 10.5 \times Salinity$. DOC content in the riverine water in this case is estimated as 548$\pm$36 μM. The only exception is a sample from the St. 5227 (sal. 28.6 psu), which differs by abnormally high DOC concentration of 540 μM which is about 2.7 times higher compared with the close located St. 5225.

Absorbance of the studied seawater samples exponentially decreases between 220 and 600 nm. At short wavelengths there is a dramatic difference in absorption properties of the sample from St. 5216. This is most likely the result of coagulation and flocculation of dissolved organic and inorganic matter during

mixing of river water and seawater [3]. Indeed, in the studied samples the total phosphorus concentration drops from 1.7 μM at the St. 5216 to 0.2 μM at the St. 5217 (sal. 9.7 psu) demonstrating about 88% removal. The DOC removal in this case was estimated as 14%. A carbon-specific absorption at 254 nm (SUVA) is similar for the Laptev Sea shelf surface waters (2.41-2.52 $m^2\,g\,C^{-1}$) but it increases significantly at the St. 5225 (5.25 $m^2\,g\,C^{-1}$). Such a change of SUVA indicates an increase of percent aromaticity of DOM from 20 to 38% [4]. Spectral slope coefficient $S_{300-650}$ does not vary a lot and amounts to an average of 17.3 μm^{-1}. S_R ration increases from 0.93 at the Lena Delta region to 1.07 near the continental slope, testifying to 1) distribution of terrestrial DOM throughout the Laptev Sea shelf 2) DOM photodegradation processes occurring in the surface layer [1].

CDOM fluorescence spectrum for the most of the samples comprises a single band in the visible spectral region with a maximum at 425–455 nm which is typical for the humic compounds [1]. As the distance from the Lena Delta increases, fluorescence intensity decreases due to the mixing of river and sea waters, as well as photodegradation processes. For the samples collected near the continental slope fluorescence band in the range of 290–320 nm becomes visible, indicating the presence of labile autochthonous OM. We have also observed intense fluorescence around 320–350 nm at the St. 5227 where unexpectedly high DOC concentration was registered.

Optic measurements were supported by the Russian Foundation for Basic Research, grant no. 16-35-60032 mol_a_dk. DOC analysis was supported by a State Contract of the Institute of Oceanology RAS, project no. 0149 2014 0036.

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SUMMER SURFACE WATER CHEMISTRY DYNAMICS IN DIFFERENT LANDSCAPE UNITS FROM YEDOMA ICE COMPLEX TO THE LENA RIVER

The effect of climate warming on the degradation of permafrost in Arctic coastal lowlands and associated hydrological and biogeochemical processes varies between different types of permafrost deposits. The Lena River Delta consists of three geomorphological main terraces that differ in their genesis and stratigraphic, cryological, geomorphological and hydrological characteristics [2]. The third terrace was formed during the late Pleistocene and consists mainly of Yedoma-type Ice Complex deposits, whereas the first terrace has formed during the Holocene by deltaic processes [1],[2]. Permafrost degradation on both terraces releases dissolved organic carbon (DOC) to thermokarst lakes and via streams DOC gets transported to the Lena River channels and the Arctic Ocean. This presentation shows 1) differences in the surface water chemistry between the first terrace and the Yedoma Ice Complex and their landforms, 2) analyses of the temporal variability of DOC during the summer, and 3) an estimation of summer DOC flux for the considered catchment of about $6.45\,\mathrm{km}^2$. Between June and September 2013 and 2014, respectively summer surface water and soil water samples were collected in a small catchment in the south of Kurungnakh Island in the central Lena River Delta. This catchment covers the first terrace as well as the Yedoma Ice Complex and is characterized by thermokarst lakes and streams on both terraces. Two weirs were installed in the main stream along the drainage flow path to continuously measure discharge during summer 2013. We divided the study area into landscape units and compared pH, electrical conductivity, stable isotopic composition and DOC concentrations between units and between terraces. The considered landscape units are streams and thermokarst lakes on Yedoma Ice Complex and on the first terrace, Yedoma uplands, streams, which are fed by the Ice Complex, a relict lake on the first terrace and the Olenyokskaya Channel, a main branch of the Lena River. DOC concentrations in the landscape units on Yedoma Ice Complex ranged between $3.5\,\mathrm{mg\,L}^{-1}$ (streams) and $52.5\,\mathrm{mg\,L}^{-1}$ (soilwater of Yedoma uplands) and on the first terrace between $2.8\,\mathrm{mg\,L}^{-1}$ (streams) and $15.6\,\mathrm{mg\,L}^{-1}$ (relict lake). The electrical conductivity on Yedoma Ice Complex ranged between $35\,\mu\mathrm{S\,cm}^{-1}$ (soilwater of Yedoma uplands) and 151 μS cm^{-1}

(streams) and on the first terrace between 54 μS cm^{-1} (streams and relict lake) and 140 μS cm^{-1} (streams). δ^{18}O values on Yedoma Ice Complex and first terrace ranged between -22.4‰ (soilwater of Yedoma uplands) and -16.4‰ (streams) and between -20.4‰ and -14.7‰ (streams), respectively. δD ranged between -165.6‰ (soilwater of Yedoma uplands) and 125.5‰ (streams, which are fed by the Ice Complex) and between -160.8‰ and -119.4‰ (streams). Source waters on the Yedoma Ice Complex had higher DOC concentrations and lower electrical conductivity than Yedoma Ice Complex thermokarst lakes and the drainage flow path. This suggests that more labile organic carbon, perhaps derived from permafrost degradation on the Yedoma Ice Complex, enriches the lake but is removed from the lake, for example, by mineralization in the water column. Along the drainage flow path no further decrease of DOC concentration was observed, despite increasing discharge from weir 1 at the beginning of the flow path to almost two and a half times at weir 2 at the end of the flow path, and despite decreasing discharge during the measuring period from 1814 m^3 d^{-1} in the end of July to 199 m^3 d^{-1} in the end of August for weir 1 and from 2819 m^3 d^{-1} in the end of July to 567 m^3 d^{-1} in the end of August for weir 2. The temporal variability of DOC concentration during the sampling periods was low. In 2013 one sample site of soil water collection fluctuated slightly in August between 10.5 mg L^{-1} and 13.3 mg L^{-1} , whereas the remaining landscape units showed no temporal variability. In 2014 the DOC concentration of the relict lake on the first terrace decreased from July (13.5 mg L^{-1}) to September (11.1 mg L^{-1}). Otherwise there were no changes in DOC concentration in the remaining landscape units. DOC measurements of the Olenyokskaya Channel show a decrease in DOC concentration from 12.4 mg L^{-1} in June to 7.6 mg L^{-1} in September. Using discharge data of 2013 a summer DOC flux of about 220 kg in 29 days for the study site above weir 2 with an area of 6.45 km^2 was calculated.

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CONTRIBUTION OF PERMAFROST DEGRADATION LANDFORMS TO SUMMER EXPORT OF DOC FROM YEDOMA-TYPE ICE COMPLEX TO RIVERS, LENA DELTA, SIBERIA

Thermo-erosional landforms (valleys, gullies) and their associated streams are the main connecting pathways between inland permafrost areas and rivers and coasts. Surface and ground waters are routed along these streams, which transport particulate and dissolved matter from the catchments to the rivers and coastal waters. Regions of ice-rich permafrost, such as the Yedoma-type Ice Complex, are not only characterized by a high abundance of thermo-erosional landforms, which formed during the Holocene, but are subject to extensive degradation under current arctic warming by processes such as thermal erosion, thermokarst, and active layer deepening. In the Siberian Lena River Delta Yedoma-type Ice Complex deposits occur on insular remnants of a Late-Pleistocene accumulation plain that has been dissected by Lena River branches and degraded by thermal erosion and thermokarst during the Holocene. This region serves as suitable exemplary study area for estimating the contribution of 1) different permafrost degradation landforms to the export of water and dissolved matter from Yedoma-type Ice Complex to the river and 2) active degradation of old permafrost versus seasonal runoff from the surface and active layer. In the summers of 2013 and 2014 we sampled surface and soil waters from streams and their watersheds in Yedoma-type Ice Complex landscapes of the Lena River Delta and analyzed them for a range of hydrogeochemical parameters including electrical conductivity (EC), dissolved organic carbon (DOC) and stable isotopic composition. The sampling sites were spread over an E-W-extent of about 150 km and are characterized by very diverse geomorphological and hydrological situations in terms of distance to the river branches, catchment size, discharge, degree of thermo-erosional activity, and connection to other permafrost degradation landforms (thermokarst lakes and basins). Three key sites were sampled three and four times from June to September 2013 and 2014, respectively, in order to analyze intra-seasonal changes.

The results show large variances in EC (25 to 1205 μS/cm), DOC concentrations (2.9 to 119.0 mg/l), δ^{18}O (-29.8 to -14.6‰ vs. SMOW), and δD (-228.9 to -117.9‰ vs. SMOW) over the whole dataset, with distinct characteristics in the parameter combination for different degradation landform and water types. The temporal variability at the repeatedly sampled sites is low, which implies that there is not much change in the processes that determine the water composition throughout the summer season. By comparing differences in surface water chemistry between flow path systems that tap into varying amounts of source water (precipitation, surface and ground water, ground ice) and have differing residence times and extents, we explore the effect of future changes in thermokarst and thermo-erosional intensity and resulting changes in flow path hydrogeochemistry for thermo-erosional features draining ice-rich permafrost.

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BOREHOLE TEMPERATURE RECORDS OF THE LENA DELTA AND SIBERIA

Russian-German scientific co-operation over the past 25 years has resulted in the establishment of permafrost boreholes and their temperature records in the Lena Delta and in Siberia. The boreholes are spread out between Cape Mamontov Klyk in the western Laptev Sea and Lake El'gygytgyn in Chkuotka. Their depths range between 18 (Buor Khaya Peninsula) and 140 m (Lake El'gygytgyn) below the ground surface. Temperature records showed a variety of problems, including moisture re-distribution within uncased boreholes, meltwater entering the borehole and sensor malfunction. Temperature measurement accuracy was limited in some holes by coarse signal digitization; in other holes, unexplained jumps in temperature occurred. Many lessons about optimal installation, temperature measurement and maintenance of permafrost boreholes can be gleaned from this data set. Nonetheless, the data are sufficient to provide information on permafrost temperature and its change. Permafrost temperatures measured at approximately 20 m depth range were -12.0, -8.6, -10.3, -10.7 and -5.9 °C at Cape Mamontov Klyk, Samoilov Island, Sardagh Island, Buor Khaya Peninsula, and Lake Elgygytgyn, respectively. Boreholes currently have 3 to 10 year records and showed, with the exception of Buor Khaya, permafrost warming. Mean annual warming rates between 0.10 and 0.14 °C at approximately 20 m depth are typical for circum-arctic cold permafrost. At Buor Khaya, at 18.5 m depths, interannual variability in temperature ranged between -10.6 and -10.9 °C with no clear trend over the three year recording period.

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CARBON OUTFLOW FROM THE ACTIVE LAYER OF THERMOKARST LAKE CATCHMENTS IN THE LENA RIVER DELTA

Nowadays due to climate change the interest to the hydrological processes in the permafrost affected regions is growing. Permafrost soil is important carbon pool and thawing can cause the increase of carbon outflow from Arctic river basins.

During Russian-German expeditions Lena-2012 and 2013 some measurements were carried out on the catchment of the Fish Lake on Samoylovsky Island in the Lena River delta. Fish Lake is a thermokarst-polygonal lake, and the landscape of its catchment is typical for the Arctic polygonal tundra. These measurements were done in order to study the DOC income to the lake from an active layer of the catchment.

Measurements of the DOC concentration in the pore water and the depth of seasonal thawing were made at 21 points in the $1.52\,\mathrm{km}^2$ catchment. The points were selected in different parts of the polygons to consider the heterogeneity of the landscape. Samples for DOC were analyzed in the field using a Spectro::lyser probe and in the lab with a Shimadzu TOC-L probe.

In August the depth of the active layer was between 20 and 60 cm: 20–30 cm on the polygon rims, 30–60 cm in the polygon centers and near the lake. During the month when the measurements were made the depth increased by 10–15%.

For August the DOC concentration in the pore water of the active layer was 8–51 $\mathrm{mg\,l^{-1}}$, for July — 5–30 $\mathrm{mg\,l^{-1}}$, which correlates with the results of other researches in Arctic region. The changes in DOC concentration in pore water for the different thaw depth were examined. Maximum was observed on the depth 35–40 cm for July and 45–55 cm for August. So, for the same depth the variance in the concentration was the most significant. The DOC flux to the Fish Lake was calculated using the mean measured concentration and water runoff from the catchment [1]. The DOC daily flux to the lake is evaluated as about $0.8\,\mathrm{kg\,day^{-1}}$ and the flow rate is $0.5\,\mathrm{kg\,km^{-2}\,day^{-1}}$, which is in ten time less than for the lake catchment of southern areas [2].

Prolongation of field measurements is necessary for reasons clarifying and for better understanding of DOC flux formation processes under different conditions including thawing increase.

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METHANOTROPHIC POPULATION AND METHANE OXIDATION AROUND THE LENA DELTA, SIBERIA, RUSSIA

The Lena River is one of the biggest Russian rivers draining into the Laptev Sea. Due to predicted increasing temperatures the permafrost areas surrounding the Lena will melt at increasing rates. With this melting high amounts of carbon, either organic or as methane will reach the waters of the Lena and the adjacent Laptev Sea. As methane is an important green house gas its further fate in the Lena Delta is of uttermost importance. Methane oxidation by methanotrophic bacteria is the only biological way to reduce methane concentrations. However, the polar estuary of the Lena River is a challenging environment, with strong fluctuations in salinity and temperature. We determined the activity and abundance of aerobic methanotrophic bacteria (MOB), as well as their population structure. Activity was determined with 3H-CH4 as radioactive tracer, abundance was determined with quantitative PCR and the population structure was characterized by a fingerprinting method (MISA). Methane concentrations were rather low (41±44 nM), as well as methane oxidation rates (1.1±1.6 nM/d). In polar water (cold and saline) highest activities were found, whereas the highest abundance of MOB was in surface waters. The relation between methane turnover and abiotic factors will be used to characterize the eco-physiology of these polar and estuarine methanotrophs.