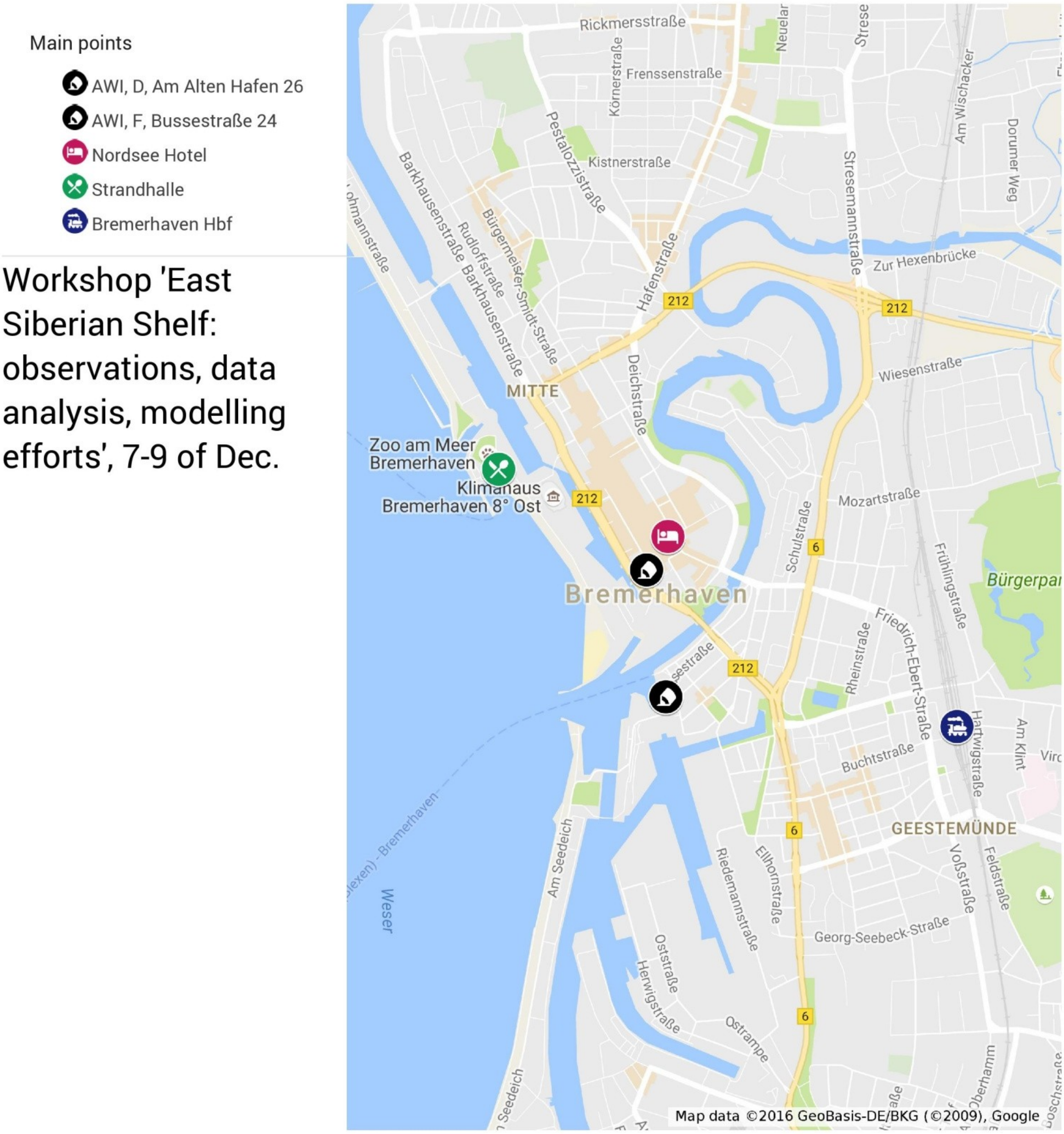
Alfred Wegener Institute

Workshop "East Siberian Shelf: observations, data analysis, modelling efforts",

LenaDNM project, summary

7-9 of Dec, 2016

Place&Date



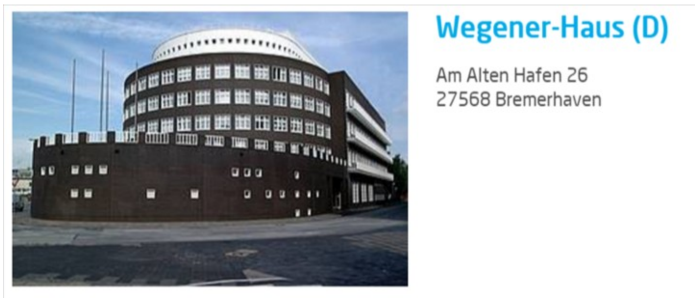
Main points on the Bremerhaven map. Please, find interactive version here.

The map was created using Google Maps application.

Place&Date

7-9 of December, 2016

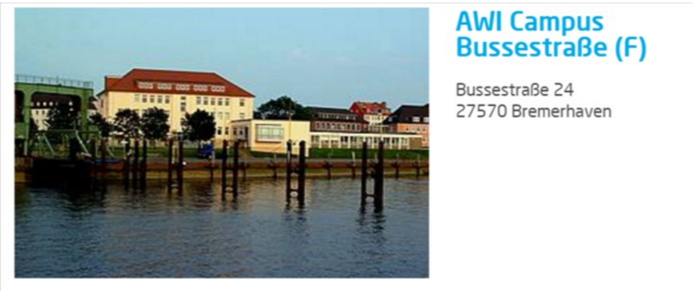
Building D, Hörsaal



To enter building D just ring the doorbell and porter will open you the door. The guided tour around AWI will start in the foyer of building D.

http://www.awi.de/ueber-uns/standorte/bremerhaven.html

Building F, Glashaus



http://www.awi.de/ueber-uns/standorte/bremerhaven.html

To enter building F, please, use the door directly leading to Glashaus, it will be open for you (see the picture above).

Picture is taken from http://www.pages-igbp.org/download/docs/working_groups/sip/sip3_bremerhaven_circular2.pdf

Strandhalle Restaurant

http://www.strandhalle-bremerhaven.de/

Participants

Alexander Georgiadi, Institute of Geography RAS

Alexey Androsov, Alfred-Wegener-Institute

Alexey Fofonov, Jacobs University

Anastasia Drozdova, P.P. Shirshov Institute of Oceanology

Andrey Proshutinsky, Woods Hole Oceanographic Institution

Angelo Rossi, Jacobs University

Antonina Chetverova, Arctic and Antarctic Research Institute

Balthasar Reuter, Friedrich-Alexander-University Erlangen-Nürnberg

Boris Koch, Alfred-Wegener-Institute

Denis Aibulatov, Lomonosov Moscow State University

Dirk Barbi, Alfred-Wegener-Institute

Dmitry Magritsky, Lomonosov Moscow State University

Dmitry Romanenkov, P.P. Shirshov Institute of Oceanology

Dmitry Sidorenko, Alfred-Wegener-Institute

Ekaterina Sofina, P.P. Shirshov Institute of Oceanology

Elena Golubeva, Institute of Computational Mathematics and Mathematical Geophysics SB RAS

Estella Weigelt, Alfred-Wegener-Institute

Gesine Mollenhauer, Alfred-Wegener-Institute

Hauke Flores, Alfred-Wegener-Institute

Igor Kozlov, Russian State Hydrometeorological University

Jens Hoeleman, Alfred-Wegener-Institute

Maria Luneva, National Oceanography Centre Liverpool

Maria Winterfeld, Alfred-Wegener-Institute

Mariia Aibulatova, Lomonosov Moscow State University

Markus Janout, Alfred-Wegener-Institute

Michael Fritz, Alfred-Wegener-Institute

Nikolay Koldunov, Alfred-Wegener-Institute

Rafael Gonçalves-Araujo, Alfred-Wegener-Institute

Roman Vankevich, Russian State Hydrometeorological University

Sara Trojahn, University of Bremen

Sebastian Hellmann, Alfred-Wegener-Institute

Sergey Danilov, Alfred-Wegener-Institute

Svetlana Losa, Alfred-Wegener-Institute

Valeria Selyuzhenok, Nansen International Environmental and Remote Sensing Centre

Vera Fofonova, Alfred-Wegener-Institute

Vibe Schourup-Kristensen, Alfred-Wegener-Institute

Vikram Unnithan, Jacobs University

Wolfram Geissler, Alfred-Wegener-Institute

Program

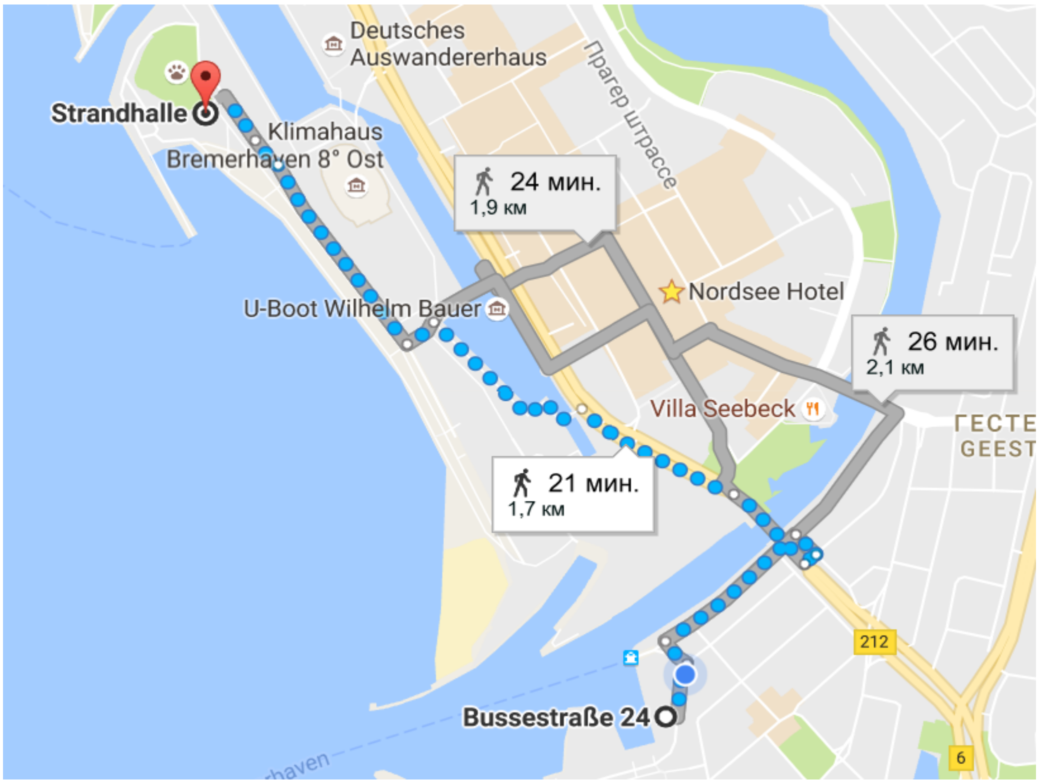
Place 07.12	*Time*	*Presentation*	*Speaker*
AWI, D, Hörsaal	12.15-12.30	Opening remarks	
	12.30-13.00	From fresh to marine waters: characterization and fate of dissolved organic matter in the Lena River Delta Region, Siberia	Rafael Gonçalves-Araujo, Alfred-Wegener-Institute
	13.00-13.55	Lunch	
	14.00-16.00	Guided tour around AWI	
AWI, F, Glashaus	16.15-16.30	Coffee pause	
	16.30-17.00	Transport of dissolved and particulate matter in the Siberian shelf seas: the role of fast ice	Jens Holemann, Alfred-Wegener-Institute
	17.00-17.25	Radiation Budget in the Shelf Areas of the Laptev Sea	Sebastian Hellmann, Alfred-Wegener-Institute
	17.25-17.45	Beginning of the project discussion (LenaDNM continuation)	
	17.45-18.00	Good example of possible collaboration: 'Thumbs up: How to get a hitch-hike on the transpolar highway'	Hauke Flores, Alfred-Wegener-Institute
	18.00-18.40	Soup/Discussion	

Place 08.12	*Time*	*Presentation*	*Speaker*
AWI, F, Glashaus	9.00-9.20	Coffee pause, presentation uploading, poster hanging	
	9.20-9.55	Isotopic and compositional analyses of DOM and POM collected in the Lena Delta between May and August 2014	Gesine Mollenhauer, Alfred-Wegener-Institute
	9.55-10.25	Conservative or Reactive? Permafrost-derived organic matter in the Lena River Delta	Boris Koch, Alfred-Wegener-Institute
	10.25-10.45	Features and evaluations of spatial and temporal variability of water, sediment and heat runoff in the Lena River delta	Denis Aibulatov, Lomonosov Moscow State University
	10.45-11.00	Coffee pause	
	11.00-11.25	The water temperature characteristics of the Lena River at basin outlet in the summer period and modelling efforts in the area	Vera Fofonova, Alfred-Wegener-Institute
	11.25-11.50	Hydrological data and field observations in the Lena River Delta	Antonina Chetverova, Arctic and Antarctic Research Institute
	11.50-12.20	Long-term geo-runoff components changes in Russian Arctic rivers	Alexander Georgiadi, Institute of Geography Russian Academy of Sciences
	12.20-13.20	Lunch	
	13.20-13.55	Hydrographic variability and ecosystem implications for the Laptev Sea	Markus Janout, Alfred-Wegener-Institute
	13.55-14.25	Tidal and wind impacts on a Lena River plume spreading	Vera Fofonova, Alfred-Wegener-Institute
	14.25-14.55	SAR observations of internal solitary waves in the Laptev Sea	Igor Kozlov, Russian State Hydrometeorological University
	14.55-15.15	Coffee pause	
	15.15-15.50	Modeling the long-term and interannual variability of the East Siberian Shelf hydrography	Elena Golubeva, Institute of Computational Mathematics and Mathematical Geophysics SB RAS

AWI, F, Glashaus	15.50-16.25	Effects of tides and inter-annual variability of river runoff on the shelf - deep ocean exchange in the Arctic Seas	Maria Luneva, National Oceanography Centre Liverpool
	16.25-16.40	Coffee pause	
	16.40-17.15	Use of satellite observations for monitoring of variability of fronts, submesoscale eddies and internal waves in the Russian Arctic seas	Dmitry Romanenkov, P.P. Shirshov Institute of Oceanology
	17.15-17.45	Investigating the Arctic biogeochemistry and biodiversity during the period of rapid change based on modelling and satellite retrievals	Svetlana Losa, Alfred-Wegener-Institute
	17.45-18.30	Poster session	
	19.00-....	Workshop dinner	

Workshop dinner

The workshop dinner will take place 8th of Dec at 19.00 in the Strandhalle Restaurant, Hermann-Henrich-Meier-Straße 1, 27568 Bremerhaven.



Place 09.12	*Time*	*Presentation*	*Speaker*
AWI, F, Glashaus	8.45-9.00	Coffee pause	
	9.00-9.25	AWI-CM, local refinement and climate	Dmitry Sidorenko, Alfred-Wegener-Institute
	9.25-9.50	FESOM_coastal	Vera Fofonova, Alfred-Wegener-Institute
	9.50-10.15	The Discontinuous Galerkin method for coastal ocean modeling	Balthasar Reuter, Friedrich-Alexander-University Erlangen-Nürnberg
	10.15-10.35	A high resolution Pan Arctic biogeochemical model	Vibe Schourup-Kristensen, Alfred-Wegener-Institute
	10.35-10.55	Coffee pause	
	10.55-12.55	Discussion: 'East Siberian Shelf Research Unit '	
	12.55-13.40	Lunch	
Informal program			

Publication of the abstracts

The abstracts will be published on the AWI web site and Zenodo portal.

Questions?

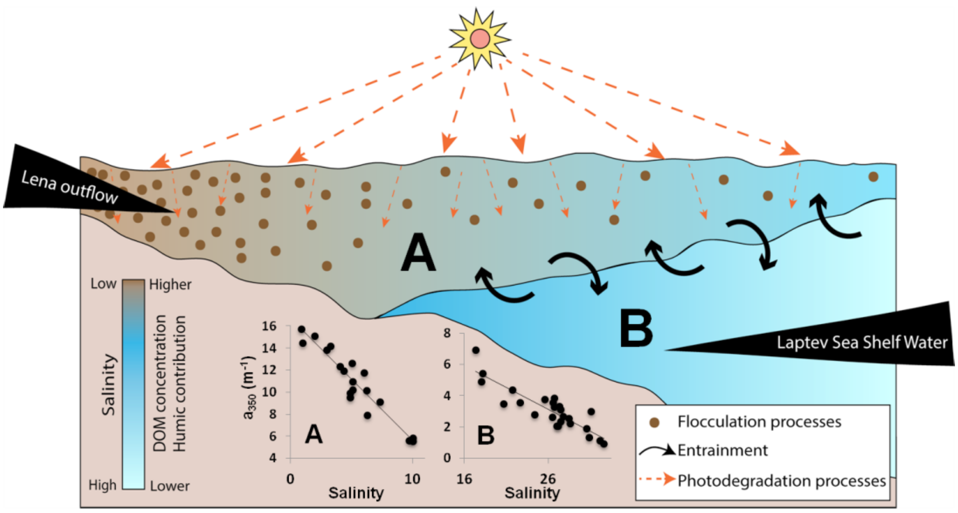
Please, write (vera.fofonova@awi.de) or call (+491773139758) to Vera Fofonova.

Abstracts

From fresh to marine waters: characterization and fate of dissolved organic matter in the Lena River Delta Region, Siberia

R. Gonçalves-Araujo[1], C. Stedmon[2], B. Heim[1], I. Dubinenkov[1], A. Kraberg[1], D. Moiseev[3], A. Bracher[1,4]
[1] AWI, [2] DTU-Aqua, [3] MMBI,[4] IUP-Uni Bremen

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 toward 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.



Transport of dissolved and particulate matter in the Siberian shelf seas: the role of fast ice

J. Hölemann[1], C. Wegner[2]
[1] AWI, [2] GEOMAR

The Laptev Sea is ice covered from October to June. The ice regime of the Laptev Sea (LS) is characterized by a large seasonal and interannual variability in summer. Two main ice areas characterize the Laptev Sea during the ice-covered period: (1) the drifting pack ice in the northern part of the Laptev Sea. This ice is part of the transpolar drift system, which transports ice from the Siberian shelf seas towards Fram Strait, and (2) an immobile belt of fast ice that covers large areas of the southern LS. The fast ice can be further subdivided into nearshore bottomfast ice and landfast ice. The floating landfast ice covers much of the SE LS and in places extends more than 200 km out from the coast. Although fast ice only comprises a small fraction of overall Arctic sea ice extent, it is of particular importance for the coastal systems. In the Laptev Sea, fast ice plays a crucial role in the freshwater cycle of the ocean by storing freshwater in winter and releasing it in spring and summer. Based on stable-isotope data Eicken et al. (2005) estimated that one third to half of the annual freshwater discharge of the Lena is held in the land fast ice cover.

A study of the variability of fast ice extent in the southeastern LS (Selyuzheonk et al., 2015) showed that, while the areal extent of the fast ice exhibits only small variability, the length of the fast ice season has undergone a decrease of 2.8 $d*yr^{-1}$ during the observation period between 1999 and 2013. This was caused by a delay of fast ice formation in fall and a shortening of the period required for the breakup of fast ice. The pattern of fast ice retreat in July and the analysis of stable isotope data from four summer surveys in the LS also suggest a strong impact of river discharge on fast ice and sea-ice melting.

A drawback of nearly all bio-geochemical studies in the LS is that they only included sampling during the summer month. The effect of sea ice formation on the fate and transport of dissolved organic matter (DOM) and particulate organic matter in the LS has not been adequately studied. Although DOM is incorporated to newly formed sea ice relatively more than inorganic solutes the overall effect is that DOM is expelled from the ice crystals and enriched in saline brine. A large proportion of this brine drains into the underlying water column while about 10% to 40% remain in the ice. High concentrations of DOC in bottom waters of the SE LS that are caused by the addition of DOC from brines (Alling et al., 2010) indicated that ice formation could also be a key process for the distribution of DOM on the LS shelf. Beside the formation of sea ice, also the melting of sea ice is important because it can dilute DOM in the underlying water column. In this context, the formation and melting of fast ice near the Lena Delta is of particular importance because of two reasons: up to half of the annual freshwater discharge of the Lena is stored in the fast ice cover east of the Lena Delta (Eicken et al., 2005), and the fast ice in this region melts simultaneously with the spring freshet of the Lena that discharges huge amounts of DOM to the eastern LS. The mixing of DOM rich river water with fast ice meltwater during the spring season has probably a substantial impact on the distribution of DOM.

References

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Eicken, H., I. Dmitrenko, K. Tyshko, A. Darovskikh, W. Dierking, U. Blahak, J. Groves, and H. Kassens (2005): Zonation of the Laptev Sea landfast ice cover and its importance in a frozen estuary, *Global Planet Change*, *48*(1-3), 55-83.

Selyuzhenok, V., T. Krumpen, A. Mahoney, M. Janout, and R. Gerdes (2015): Seasonal and interannual variability of fast ice extent in the southeastern Laptev Sea between 1999 and 2013, *J Geophys Res-Oceans*, *120*(12), 7791-7806.

Radiation Budget in the Shelf Areas of the Laptev Sea

S. Hellmann[1], T. Dinter[1,2], J. Hölemann[1,3], B. Heim[1], V. Rozanov[2], A. Bracher[1,2]
[1] AWI, [2] Institute of Environmental Physics, University of Bremen, [3]Otto-Schmidt-Laboratory

The Laptev Sea around the Lena River delta in northern Siberia is a very remote area that in-situ measurements are only sparsely available. Polar night and long-lasting ice coverage until the end of June makes it difficult to access the area all year round. Here satellite measurements of back-scattered radiation obtained with e.g. the sensor MERIS on-board Envisat satellite and derived inherent optical properties (IOP) may help to generate a time series of changing water constituents, e.g. chlorophyll and coloured organic matter which can be split further into coloured dissolved organic matter (CDOM) and suspended particles (SPM). However, large solar zenith angles and frequent cloud coverage in summer after ice break-off makes it challenging to investigate this region by remote sensing applications. Therefore for a first approximation coupled atmosphere-ocean radiative transfer modelling is a useful method to identify the feedback of changing environmental conditions which influence the composition and abundance of water constituents to the ocean's to the radiation budget in these remote areas.

Within this study we investigate the influence of CDOM and SPM on the radiative heat transfer into the shelf regions of the Laptev Sea. As a first step we use the coupled atmosphere-ocean radiative transfer model SCIATRAN to assess the energy input into coastal waters of this region dependent on different concentrations of CDOM varying significantly for different times of the year. Low solar elevations and high absorption by water constituents in this area extremely reduces the light penetration depth in the water body. An increased absorption in the surface water leads to higher sea surface temperatures and a high energy release into the atmosphere often occurring in late autumn and consequently influences the ice development process. In the context of climate change and thawing of permafrost in Siberia the riverine input of those highly absorbing particles by Lena river may increase in the future. Therefore, a better understanding of these processes is necessary to predict possible future changes for that remote area.

Arctic river organic carbon export through the ice-free season: isotopic and compositional analyses of DOM and POM collected in the Lena Delta

G. Mollenhauer[1,2], M. Winterfeld[1], L. Bodenstab[2], C. M. Mörth[3], B. Koch[1], E. Schefuß[4], B. Heim[1], J. Hefter[1], A. Prokushkin[5], J. Rethemeyer[6]

[1] AWI, [2]University of Bremen, [3]Stockholm University, [4]MARUM center for marine environmental sciences, [5]Forest Research Institution, [6]Cologne University

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., Winterfeld et al., 2015, Dubinenkov et al., 2014). 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 (Mann et al., 2015).

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 $\delta^{13}C$ and $\Delta^{14}C$ of DOC and POC collected between late May during the freshet and late August in the Lena Delta, and compare them with $\delta^{13}C$ and $\Delta^{14}C$ 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 $\delta^{13}C$ 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.

References

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Mann, P.J., T.I. Eglinton, C.P. McIntyre, N. Zimov, A. Davydova, J.E. Vonk, R.M. Holmes, R.G.M. Spencer (2015): Utilization of ancient permafrost carbon in headwaters of Arctic fluvial networks. *Nature communications*, doi: 10.1038/ncomms8856

Winterfeld, M., T. Laepple, G. Mollenhauer (2015): Characterization of particulate organic matter in the Lena River delta and adjacent nearshore zone, NE Siberia – Part I: Radiocarbon inventories. *Biogeosciences*, doi: 10.5194/bg-12-3769-2015

A lignin phenol-based assessment of the provenance of organic matter discharged from a large permafrost affected watershed (Lena River, Siberia)

S. Trojahn[1], M. Winterfeld[1,2], J. Hefter[2], S. Zubrzycki[3], G. Mollenhauer [1,2]
[1]University of Bremen, [2]AWI, [3]Soil Science Institute, University of Hamburg

Particulate organic matter (POM) discharged by rivers and deposited close to their mouth can be used to reconstruct paleoenvironmental conditions, as it is commonly assumed to record an integrated signal from the watershed. However, the particulate riverine load might be trapped in flood plains and the lower reaches of the rivers especially in large river systems with low topographic gradient. As a result, transport of particulate matter, specifically from the distal parts of the watershed, may be inefficient and regionally biased. Furthermore, the POM likely undergoes degradation during its transport from source to sink. Therefore, investigating the different organic matter (OM) sources within a watershed will improve our understanding of OM sources and transport in large river systems. The Lena River is one of these large river systems. The catchment stretches from near Lake Baikal at 53°N to 71°N where the Lena discharges into the Laptev Sea. The permafrost soils within this vast and climatically diverse catchment, which store huge amounts of OM, will most likely respond differently to climate warming and remobilize previously frozen OM with distinct properties specific for the source vegetation and soil. The watershed can be broadly subdivided into two different biomes, arctic tundra and taiga (Amon et al., 2012). The relative contribution of these biomes to the total OM load of the river and its discharge to the ocean is not well understood.

Lignin is the rigidifying component of terrestrial higher plants, and it consists of different phenolic units. Its most important components are vanillic, syringic, and cinnamic units distributed in specific different proportions among the gymnosperm and angiosperm plant tissues. The Cinnamyl/Vanillyl (C/V) and syringyl/vanillyl (S/V) ratios allow to distinguish different vegetation sources, such as woody and non-woody tissues as well as gymnosperm and angiosperm tissues (Hedges et al., 1982).

Previous analyses of surface sediments and sediment samples of the tundra zone have shown that the C/V and S/V ratios clearly depict the catchment vegetation characteristics of the Lena River (Winterfeld et al., 2015). However, suspended particulate matter of surface water samples, taken in highly dynamic systems like the Lena River delta, can only provide very local snapshots of the suspended matter properties. Furthermore, it has been shown that substantial amounts of sedimentary organic matter in the Buor Khaya Bay originates from Lena River catchment.

In this study we present the lignin phenol composition in different grain size fractions (bulk, <63µm and 63µm-2mm), compared with bulk lignin contents, of six soil samples from a latitudinal transect along the river (68°N to 72°N) plus one sample near the city of Yakutsk (63°N), and five marine surface sediments (71°N to 73°N) collected off the Bykovskaya and the Sardaksho-Trofimovskaya channel systems of the Lena Delta. Estimating the relative OM contributions from tundra and taiga vegetation to the coastal sediments will be improved based on the latitudinal transect of soil samples refining the end-member values for the respective biomes. Assuming differential transport and, as a result, degradation during transport of the different grain size classes, the grain-size-fraction-specific lignin phenol compositions can be used to understand which of these fractions is reflected in the marine sediments, and if and how the lignin phenol composition changes from source to sink.

References

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Hedges, J.I., J.R. Ertel (1982): Lignin geochemistry of a Late Quaternary sediment core from Lake Washington. *Geochimica et Cosmochimica Acta* 46 (10), 1869–1877.

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Reactivity and mobilization of permafrost-derived organic matter along the Lena River Delta – Laptev Sea transition

B.P. Koch[1], *I. Dubinenkov*[1]
[1] *AWI*

The impact of global warming on the organic carbon budgets in permafrost systems are not well constrained. Changes in organic carbon fluxes caused by permafrost thaw are dependent on microbial activity, coastal erosion, mobilization of organic matter by increased porewater fluxes, and the inherent chemical stability of organic matter in permafrost soils. Here we aim at the identification and molecular characterization of active and inactive dissolved organic matter (DOM) components within the river-ocean transition. We studied four transects in the coastal Laptev Sea characterized by steep physico-chemical gradients. Molecular information on solid-phase extracted DOM was derived from ultrahigh resolution mass spectrometry. Changes of the chemical composition with salinity were used as a measure for DOM reactivity. Although changes of dissolved organic carbon (DOC) in the estuary suggested conservative mixing, only 27% of the identified molecular formulas behaved conservatively, 32% were moderately affected, and 41% were actively involved in estuarine processes. Surprisingly, the molecular complexity in the DOM samples increased with growing marine influence and the average elemental composition (i.e. relative contribution of organic nitrogen and oxygen compounds) changed significantly with increasing salinity. These chemical changes were consistent with the results of a 20-day microbial incubation experiment, during which more than half of the permafrost-derived DOC was mineralized. We conclude that, although the DOC gradient in the estuary suggests conservative behavior, terrestrial DOM is substantially affected by estuarine processes which in turn also impact organic carbon budgets in the Lena Delta.

Features and evaluations of spatial and temporal variability of water, sediment and heat runoff in the Lena River delta

N. Alexeevsky[1], D. Magritsky[1], D. Aibulatov[1], A. Gorelkin[2]
[1]Lomonosov MSU, [2]Engineering,GEO

In the last 30-40 years, the water runoff, sediment yield and heat flux of the Lena River have undergone significant changes due to, mainly, climatic factors (Fig. 1, 2, 3). Features of hydrological changes on the marine edge of the Lena River Delta are slightly different than in the river. The reason is the transformation of runoff in the large and multi-branched delta. New data and methods allowed not only to clarify the values of water flow, suspended sediments and heat runoff at the closing gauge of the Lena (gauge Kyusyur), but also to estimate the river runoff into the sea (Table 1). Features of long-term and annual fluctuations of water flow, sediment yield and heat flux of the Lena River, their causes have been studied in detail. The role of anthropogenic factors was evaluated. New data about the current distribution of water flow and suspended sediments between the main deltaic branches, its long-term changes, about character of the flooding the upper part of the Lena River delta during spring flood are listed in the report (Fig. 4). The analysis of the accuracy of the stationary hydrological observation data was performed. The possibilities of satellite imagery to study changes in temperature and turbidity of water in the river mouths are shown. The studies were performed due to RSF (No.14-37-0038).

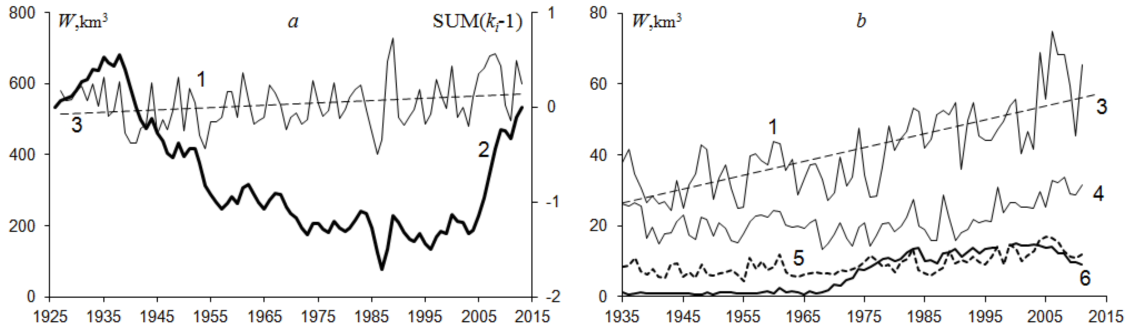

Figure 1. Long-term changes of annual water runoff (*a*) and runoff of winter low-water season (*b*) of the Lena river and its tributaries. 1 – gauge Kyusyur (Lower Lena), 2 – difference-integral curve of annual water runoff (Kyusyur, Lena riv.; right axis), 3 – linear trend, 4 – gauge Tabaga (Middle Lena), 5 – gauge Verkhoyanskiy Perevoz (Aldan Riv.), 6 – gauge Khatyryk-Homo(Vilyuy Riv.)

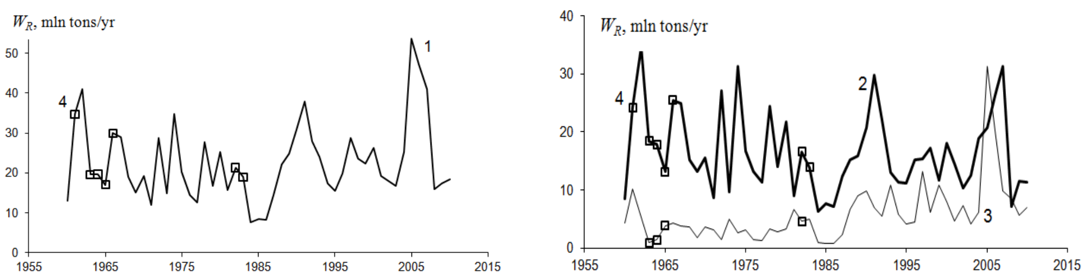

Figure 2. Long-term changes of sediment yield of the Lower Lena (gauge Kyusyur). 1 – annual sediment yield, 2 – snow-melt flood season sediment yield, 3 – summer-autumn season sediment yield, 4 – the squares show the years, for which the data has been restored

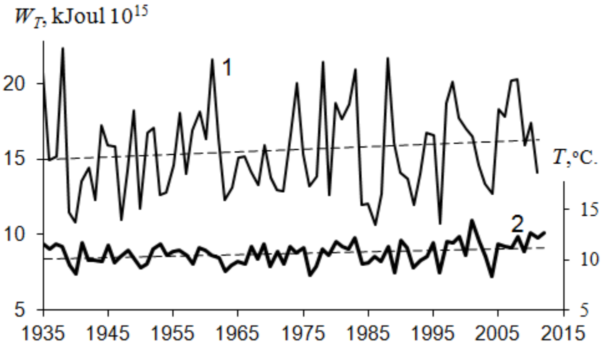

Figure 3. Long-term changes of annual heat flux (1) and mean water temperature for summer season (2) of the Lower Lena (gauge Kyusyur) with the linear trends.

Table 1. The main characteristics of the runoff of the Lena River

Characteristics	Period	Gauge line		
		gauge Kyusyur	head of the delta	marine edge of the delta
Average long-term water runoff, km^3	1927–2013	543	~547	~553
Mean maximum water discharge, m3/sec	1935–2012	135000	–	–
Mean minimum water discharge (winter season), m^3/sec	1935–1979 1980–2012	992 1950	–	–
Mean minimum water discharge (summer-autumn season), m^3/sec	1935–2011	17500	–	–
Average long-term suspended sediment runoff, mln tons/yr	1936, 1944, 1960–2010	22.5	~22.5	~7.9–13.5
Average long-term transported deposits, mln tons/yr	–	~5.4	~5.4	~0
Average long-term heat flux, kJoul 10^{15}/yr	1935–2012	15.59*/~16.6**	~15.6–16.0	~11.75

*based on measurement data, **corrected taking into account the influence of the cold waters of the Ebitem River (the right tributary of the Lower Lena)

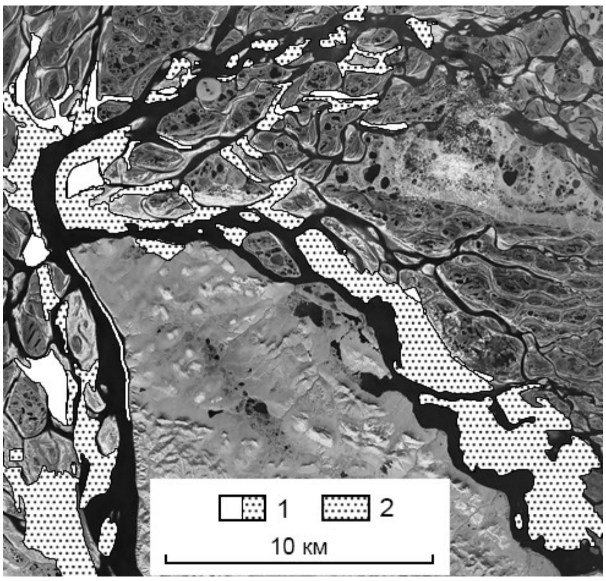

Figure 4. A schematic map of areas flooded at the peak (30.05.2008) and recession (24.06.2008) of snow-melt flood

The water temperature characteristics of the Lena River at basin outlet in the summer period

V. Fofonova[1], I. Zhilyaev[2], M. Kraineva[3], D. Iakshina[3], N. Tananaev[4], N. Volkova[5], K. H. Wiltshire[1]
[1]Alfred Wegener Institute, [2]Southern Scientific Centre of Russian Academy of Sciences, [3]Institute of Computational Mathematics and Mathematical Geophysics, [4] Igarka Geocryology Laboratory, [5] State Hydrological Institute

The water temperature characteristics of the Lena River at basin outlet during the summer season (June–September) are considered. The analysis is based on long-term data series covering the period from the beginning of observation (1936) to the present time at Kusur (Kyusyur) station and complementary data at several stations downstream and one station upstream. These additional data are rarely used, but their analysis is important for understanding processes in the basin outlet area. The differences between the stream surface temperatures at Kusur station and 200 km downstream to the north at Habarova (Khabarova) station have almost always been an anomalously large and negative for the considered period since the beginning of observation during open water season from July to September. The description of this difference and its analysis are presented. To sort the problem out, we consider the observational data in terms of the hydrology and morphology of the Lena River delta and main channel area, apply statistical and deterministic modelling approaches.

Hydrological data and field observations in the Lena River Delta

A. Chetverova[1,2], I.Fedorova[2,1], N. Alekseeva[3], T. Skorospekhova[2]
[1]St. Petersburg State University, [2]Arctic and Antarctic Research Institute, [3]Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of the Russian Academy of Sciences

The abstract presents an observation of hydrological and associated data and measurements implemented in the Lena River delta.

There are two sets of data to reveal new insights into the hydrological, hydrochemical, and geochemical processes within the Lena River delta: long-term hydrometric observations at the stations of Roshydromet from 1951 to nowadays; and field hydrological observations carried out within the delta since 2002.

The collection of long-term observational data describes principal hydrological patterns and processes of the Upper River and big branches of the delta. Analysis of long-term Lena River hydrological data from Kyusyur gauge station show a positive linear trend of average annual water discharge and suspended sediment flux from the middle of the last century until the end of the record.

Three periods were selected that are characterized by similarity of water volume and erosive power in the delta. However, it has also demonstrated the necessity of carrying out more detailed observations of the hydrological, geochemical, and channel processes inside the Lena River delta, complementary studying the estuarine branch areas, and developing an assessment of the sea's impact on the delta edge.

In the conditions of reduction of measurements on gauge stations, additional observations of the Lena River delta become more significant.

New data sets obtained from expedition observations (2002 – 2015) and geoinformation technology have made it possible to obtain a number of new insights into the hydrological and geochemical peculiarities of the Lena River delta, to obtain unexplored object characteristics (Fedotova et al., 2015; Alekseevsky et.al, 2014).

Despite the fact that the data set obtained from expeditions covers mostly summer period (winter measurements have been realized from 2014), it is characterized by the new sort of data such as hydrological, hydrochemical, hydroecological, including tide and surge observations and geochemistry of river sediments. Expedition data have more coverage and includes a variety of water objects – river branches, lakes, streams, pore water, ice complex melt waters.

New data obtained from detailed field observations in the delta show the tendencies of water runoff redistribution and heterogeneity of suspended supply distribution along the delta branches, accumulation and erosion zone in the different parts of the delta. The most valuable of these arose from along-branch hydrological measurements, which yielded new data about sources and sinks regions for discharge and fluvial transport. An increase of water discharge and supply of suspended sediment occurs between the head of the delta and its edge.

New data were also obtained on the geochemistry of main branch suspended sediments in the middle parts of the delta that confirm the ranges of previously published data on Lena River and estuarine coastal waters. Such local factors as ice complex runoff water with higher TSS influence the hydrochemical characteristics of smaller branches.

Relation between hydrological and geochemical, hydrological and hydrobiological (Nigamatzyanova et al, 2015) characteristics of the objects that guides modern observations of the Lena River Delta in an interdisciplinary direction.

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Long-term Changes of Geo-Runoff Components in Russian Arctic Rivers

A. Georgiadi[1], E. Kashutina[1], I. Milyukova[1]
[1] Institute of Geography, Russian Academy of Sciences

Long-term phases of decrease and increase the geo-runoff naturalized components (river runoff, heat flow and suspended sediment yield) of Russian Arctic Rivers during the period of observation (from 1930-1940 till 2000th) were revealed on the basis of normalized cumulative curves. Their characteristics and the effects of impact of anthropogenic factors are evaluated.

It is shown, that since 1930-1940th years till the beginning of the XXI-st century the naturalized annual and seasonal river runoff in the largest river basins (Ob', Yenisei, Lena) were characterized by two main long-term phases of their changes. The phase of runoff decrease, which started in the 1930-1940th and continued during several decades, was replaced in the 1970-1980th years by a long-term runoff increase that has been interfaced in time to the beginning of recent air temperature rise. The duration of phases can be several decades and are characterized by significant runoff differences.

In the long-term variations of the heat flow of the Ob, Yenisey, Lena, Northern Dvina and Pechora also were highlighted two major long-term phases. The decrease phase of the heat flow, which began in 1930-1940-ies. and lasted for 35-55 years, was replaced in 1970-1980 by 20-year phase of its increase (except the Yenisei, where it came in the late 1990-ies.). It lasts until now. A similar sequence and properties of the long-term phases are characterized for river water temperature of considered rivers. Differences in heat flow reaches 20% during the phase of its increase and decrease for the Northern Dvina and the Yenisey, but for other rivers they are not higher than 10%.

Long-term changes of annual suspended sediment yield for the Yenisei and Lena Rivers are also characterized by two major long-term phases, which replaced one another in the 1970-1990-ies in the same sequence as in the case of the heat flow. Character of the changes for Ob' sediment yield is more complex. Differences in the suspended sediment yield during the increase and decrease phases reach 50% for Lena, whereas for Yenisei they are substantially less (10%).

Anthropogenic factors (mainly water reservoirs) have significantly changed the characteristics of the long-term phases on the Yenisei River, especially for the winter and snow flood runoff, and transformed their amplitude in comparison with "conditionally natural" (normalized) runoff. They also fundamentally alter the dynamics nature of the heat flow and suspended sediment yield phases on the Yenisei, while their impact is not significant on other rivers.

The long-term phases of decrease and increase of "conditionally natural" components of Arctic Rivers of Russia geo-runoff, as a rule, are characterized by close temporal conjunction with the respective phases of the decrease or increase of the average annual and winter air temperature (climate cooling and warming), and decrease or increase of the frequency of western forms of atmospheric circulation by G. I. Vangengeim (W), the indices of the North Atlantic (NAO) and Arctic (AO) fluctuations, reflecting the phases of strengthening or weakening of the zonal transfer intensity.

Hydrographic variability and ecosystem implications for the Laptev Sea

M. Janout[1], J.Hölemann[1], D. Bauch[2], G. Laukert[2], L.Timokhov[3], H. Kassens[2]
[1] AWI, [2] Geomar, [3]AARI

The Laptev Sea shelf is strongly influenced by the variable distribution of the Lena River freshwater plume, which dominates the hydrographic and biogeochemical properties of this region. Recent extensive shipboard expeditions in 2013 and 2014, complemented by oceanographic moorings from several locations across the shelf provide detailed insights regarding the impact of the freshwater plume on the water column structure throughout the year. In 2013, weak easterly winds spread the Lena plume across much of the shelf, which lead to extremely low surface salinities. In contrast, strong offshore-directed winds in summer 2014 exported much of the freshwater to the north and east, and low surface salinities were limited to the very eastern Laptev Sea. The presence of the freshwater on the central and northeastern Laptev mooring locations delayed complete mixing of the water column until April 2014. The northwestern mooring remained unaffected by the freshwater and the weaker stratification was eroded by December 2013, which underlines the strong differences in physical processes that we observe in Laptev Sea sub-regions. Stratification strongly impacts the structure of tidal currents and hence vertical mixing, which in turn controls nutrient supply and vertical fluxes of heat and matter, and is therefore a key ecosystem parameter. In this talk, we will present results from recent Laptev Sea expeditions and discuss our current understanding of this complex ecosystem.

Impact of Wind and Tides on the Lena River Freshwater Plume Dynamics

V. Fofonova[1], S. Danilov[1], A. Androsov[1], M. Janout[1], M. Bauer[2], P. Overduin[1], K.H. Wiltshire[1]
[1] Alfred Wegener Institute, [2] Trier University

The Lena plume dynamics in the Lena Delta region of the Laptev Sea are explored in simulations performed with the Finite Volume Coastal Ocean Model (FVCOM) on a mesh with the horizontal resolution 0.4–5 km. The impact of wind and tides on the Lena plume propagation is analysed based on simulations for the summer season of 2008 and also on idealized experiments. All main Lena River freshwater channels (Trofimovskaya, Bykovskaya, Tumatskaya and Olenekskaya) produce buoyant outflows in the summer season. The surface plume buoyancy signature proves to be highly variable in time, especially in case of upwelling favourable wind events. Winds stronger than 6 $\mathrm{m\,s^{-1}}$ can already turn the dynamics of flows from all main freshwater channels to the wind-driven state. During the summer season, the bulk of freshwater from the Lena River stays in the eastern Laptev Sea because of location of the main Lena River freshwater channels, their large Kelvin numbers and light summer winds. Westward and northward plume excursions are wind-driven, and the model skill in simulating them depends on the available wind forcing. The main mechanism of tidal influence in the freshwater plume zone is through tidally induced mixing, except for the northern vicinity of the delta, where residual circulation may contribute to the plume eastward transport significantly.

Interannual variability of Laptev Sea and East Siberian Sea Landfast Ice Extent

V. Selyuzhenok[1], T. Krumpen[2], R. Gerdes[2]
[1] NIERSC, [2] AWI

The fast ice is an importance component of Arctic shelf seas. It protects coast from erosion and controls fresh-water distribution. Along with changes in arctic sea ice cover, fast ice experience changes in duration of seasonal cycle and winter extent. The Laptev and East Siberian Seas are characterized by the greatest fast ice extent. We utilize weekly operational sea ice chart produced at AARI in order to assess seasonal and interannual variability of fast ice extent in the Laptev and East Siberian Seas during 1999-2014. The results show similar tendencies towards shorter period of fast ice season in both seas. However, the variability in maximal fast ice extent appears to be controlled by different factors. In the Laptev Sea maximal fast ice extent is pre-defined by the local topography and bathymetry and shows low interannual variability. Unlike the Laptev Sea fast ice, winter fast ice extent in East Siberian Sea shows high variability and appears to be controlled by wind circulation.

Internal solitary waves in the Laptev Sea: first results of spaceborne SAR observations

I. Kozlov[1], E. Zubkova[1], V. Kudryavtsev[1]
[1] Russian State Hydrometeorological University, [2] Marine Hydrophysical Institute RAS

In this work we present first results on the observation of high-frequency internal solitary waves (ISWs) in the Laptev Sea using a dataset of ENVISAT Advanced Synthetic Aperture Radar (ASAR) images. Analysis of ~500 ASAR images acquired between May-October 2007 and 2011, the period of the maximum Laptev Sea opening from sea ice during ENVISAT lifetime, helped to identify 120 distinct patterns of oceanic ISWs, and reveal key regions of their occurrence in the sea.

As observed, about 65% of all ISW patterns are found over the outer shelf in the vicinity of shelf break. The number of ISW observations has a clear peak in August. The primary regions of ISW observations are located east to the Gulf of Khatanga, and over the continental slope regions north-west to Arctic Cape, east to Maly Taymyr Island and north-west to Kotelny Island, as well as in the Vilkitsky Strait. The horizontal scales of observed internal waves vary between 0.3-1.7 km (average 0.7 km) for the inter-soliton wavelength; 3-72 km (average 20 km) for the crest length, with the average area of internal wave trains of ~40 km^2 (maximum 250 km^2), and average phase speed of ~0.5 ms^{-1}. Detailed maps of spatial ISW parameters are presented, and some features of their propagation, as well as implications for the vertical mixing in the Laptev Sea are discussed. Close comparison of satellite observations with earlier results of in situ measurements suggests that observed ISW could appear to be the mechanism of vertical mixing in the above regions.

This work was supported by RFBR under Grant No. 16-35-60072 mol_a_dk; the President Grant of the Ministry of Education and Science of the Russian Federation under Grant MK-5562.2016.5 ENVISAT ASAR data were obtained from the European Space Agency (ESA) through Cat-1 Project C1F-29721.

Modeling the long-term and interannual variability of the East Siberian Shelf hydrography

E.Golubeva[1,2] , G.Platov[1,2], V.Malakhova[1], D.Iakshina[1] and M.Kraineva[1]
[1]Institute of Computational Mathematics and Mathematical Geophysics, Siberian Branch of Russian Academy of Sciences, [2]Novosibirsk State University

The East Siberian sector of the Arctic shelf (ESAS), including the Laptev Sea and the East - Siberian Sea, is the shallowest and widest shelf region of the World Ocean. Our knowledge of the hydrography of the East Siberian shelf seas and their climate impact on the Arctic Ocean is limited, because of the inaccessibility of the region. The importance of the region is defined, first of all, by the fact that the Siberian shelves supply freshwater to the Arctic Ocean halocline due to the summer Siberian Rivers run-off. We have simulated the hydrography of the ESAS on the basis of a three-dimensional numerical regional ice-ocean model using the atmosphere reanalysis data. Numerical results show the evidence of the relationship between the variability of the summer surface salinity over the shelves and the atmospheric circulation, which was established on the basis of observations.

The ESAS circulation is characterized by an intensive interaction between the marine water masses of the Arctic Ocean and the river run-off and depends mostly on the atmosphere dynamics and the state of the ice cover. During spring and early summer the Siberian shelf seas are covered with ice and, the increased river runoff promotes the development of the low salinity eastward current, originating from the Lena River Delta and following the coast from west to east, extending to the Chukchi Sea. As the ice melts, the atmosphere dynamics starts to play an increasingly important role, the wind forcing makes the ESAS hydrography and primary fresh water transport be highly variable

The heat flux from the Lena River ensures additional 10% to the ice melting as compared to the contribution of the atmosphere to the Laptev Sea region. The highest values temperature anomalies, caused by the river run-off are simulated in the vicinity of the Lena River Delta. Spreading of these anomalies over the Laptev Sea shelf depends on the direction of the water circulation in summer season.

We obtained the warm temperature anomalies in the bottom layer of the coastal region. The thawing of the permafrost from top depends on the sea water temperatures near the sea floor. The simulation of the permafrost shows that a significant change in the permafrost depth occurs at the seafloor warming in the Arctic Sea. The submarine permafrost degradation from above is the most rapid in the near-shore coastal zone of the shelf and in the areas affected by the Lena River outflow. The influence of a heat signal in the bottom layer of water on the thermal regime of the bottom sediments in the area of the river delta was tested in the numerical experiments. The results search has shown that an increase of the Arctic shelf bottom temperature by 1-2 °C in the summer period brings about a growth of the speed of the submarine permafrost thawing in the area of warm river currents.

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Modelling of the surface and internal tides and tidal ice drift on the Siberian continental shelf

E.V. Sofina[1,2], B.A. Kagan[1]
[1] St. Petersburg Branch, Shirshov Institute of Oceanology, Russian Academy of Sciences
[2] Russian State Hydrometeorological University

Ocean tides together with related processes such as tidal ice drift and tidal induced diapycnal mixing are generally not included for global and regional Arctic models. At present, there are only several numerical simulations in which tides are explicitly resolved [Chen et al., 2009; Luneva et al., 2015]. Tidal processes are particularly important in the shallow and ice covered seas of the Siberian continental shelf.

The aim of the study is to evaluate the tidal ice drift, seasonal variability of surface and internal tides and tidal induced diapycnal diffusivity on the Siberian continental shelf. Using the sea-ice coupled model based on 3D finite-element hydrostatic model QUODDY-4 a series of simulations were carried out.

The model domain includes the system of the Kara, Laptev, East Siberian and Chukchi seas. The open boundary locates along the isobath of 300m. The tidal sea level elevations at the open boundary are taken from the high-resolution Arctic tidal model [Padman & Erofeeva, 2004]. The horizontal resolution varies from 2.5 km to 60 km. In the vertical the terrain-following coordinate is used. The tidal ice drift is described by a continuous viscous-elastic approximation. The modelling results show that the tidal ice drift velocity varies from several cm/s to 50 cm/s (wave M_2) and up to 100 cm/s during the spring tide. The tidal induced ridging can happen only in the zones of tidal ice compression–rarefaction co-located with polynyas revealed by satellite passive microwave observations.

In later study of the ice influence on tidal dynamics and energetics in order to exclude the impact of the open boundary the model domain was extended to include the Central Arctic. The ice cover during the winter months represents a combination of drifting and shore-fast ice. The boundary between these two ice covers coincides with the 25 m isobath. During the summer period the Central Arctic is covered by drifting ice and marginal seas are partially clear from ice. The distribution of ice thickness and the boundary of the drifting ice equal climatic. Significant seasonal variability is observed only in the marginal seas. In general, the ice induces a decrease of the amplitudes and lag of the phases but there are against changes too. It is explained that the fast ice can induce the relocations of amphidromic points. The ice induced variability of the tidal energy dissipation may have identical orders of magnitude with the dissipation rate in the ice-free case.

The following experiments were aimed to estimate the internal tides and tidally induced diapycnal diffusivity. Using hydrostatic approximation and low horizontal resolution define the reproduction of low mode internal waves of the tidal period only. The stratification is horizontally uniform and equals climatic distributions in winter and summer seasons. The internal tidal wave generation site was determined on the continental slope to the northwest of the New Siberian Islands. The internal waves have characteristics of trapped waves. Their amplitude is 4 m. The decay scale of the internal tidal waves is defined as several hundred kilometers. The diapycnal diffusivity estimated by baroclinic tidal energy dissipation can reach value 10^{-4} m^2/s in certain areas of the Siberian continental shelf.

The changes in tidal constants caused by the seasonal changes in density stratification can be regarded as small in comparison with the prediction errors almost everywhere in the Arctic Ocean. Consequently, the influence of stratification on surface tide may be negligible.

The research was supported financially by Russian Ministry of Education and Science (project Id RFMEFI58615X0023).

Effects of tides and inter-annual variability of river runoff on the shelf -deep ocean exchange in the Arctic Seas

M.V. Luneva[1], J. D. Harle[1], J.T. Holt[1].
[1] National Oceanography Centre, Liverpool

The coupling between the continental shelves and the deep ocean is a key facet of the Earth System. Physical and biogeochemical constituents are controlled by markedly different processes in the two environments, where continental shelves are strongly impacted by: terrestrial inputs, tidal mixing, growth of coastal-trapped waves and rapid communication with the atmosphere. In the Arctic this issue is modulated by the unique physical oceanographic environment arising from the combination of sea ice, weak currents, weak interior stratification, strong and persistent surface stratification and broad continental shelves. Here we explore the processes mediating this exchange. We examine this with results from a $1/4^{o}$ pan Arctic model, based on an extraction of the NOC global ORCA025 model, but including features appropriate for shelf seas. Modelling the bottom Ekman layer is crucial to these processes and requires tides, sufficient vertical resolution and sophisticated mixing schema to accurately represent bottom stresses.

We compare results of three 30-year long (1990-2010) simulations: with explicitly resolved tides and without any tidal dynamics; with climatology river runoff or inter-annual variability included. For the latter we use Dai et al., 2009 database combined with freshwater source from melting Greenland glaciers.

Effects of inter annual variability of freshwater runoff on the sea ice and water masses in the Arctic are weaker compared with effects of tides. Tides accelerate melting of the Arctic sea ice, increase mixing of colder and fresher surface waters with warm and saltier Atlantic waters. On the multi-decadal scale this results in strong deflection of freshwater pathways of Siberian rivers in the Kara, Laptev with surface salinity anomalies reaching 3-5 PSU compared with non-tidal case.

Topography is a very strong constraint on currents in the Arctic: Ekman benthic and surface drain processes are generally weaker here than in the North Atlantic. Preliminary analysis shows that the Benthic Ekman drain is persistent and continuous, but weak (0.5 SV). Cascades are dominant process of cross shelf exchange with totally 1.8Sv mass flux (~x3 Benthic Ekman), are highly localised, with the strongest cross-shelf volume exchange in the Laptev, Kara, Beaufort and Chukchi Seas. Wind provides only a weak transport (~x0.5 Benthic Ekman). Across slope velocities are about 1/10 the along slope currents. We discuss inter annual variability of shelf-ocean exchange processes related with strong se-ice summer retreat observed during the last decade.

Use of satellite observations for monitoring of variability of fronts, submesoscale eddies and internal waves in the Russian Arctic seas

D. Romanenkov [1], I. Kozlov [2], A. Zimin [1, 2], O. Atadzhanova [1, 2], E. Zubkova [2]
[1] St. Petersburg Department of the P.P.Shirshov Institute of Oceanology RAS
[2] Russian State Hydrometeorological University

Most theoretical and experimental works in the Russian Arctic Seas have dealt with large-scale and mesoscale sea dynamics as well as its inter-annual, seasonal and synoptic variability. In recent years, short-period processes and sub-mesoscale structures of upper ocean such as high-frequency nonlinear internal waves (NIW) and small eddies (SE) are studied intensively because of their significant impact on the vertical and horizontal exchange. Using high resolution spaceborne data we present joint results of observations of surface manifestations of NIWs, SEs and thermohaline fronts in the White, Barents, Kara and Laptev Seas. The study is based on analysis of ENVISAT ASAR and AQUA MODIS images for ice-free months in 2007-2011. More than 4000 packets of high-frequency NIWs and about 3400 surface manifestations of SEs were identified in about 3000 SAR images. Maps of NIWs and SEs observational frequency and their spatial and kinematic properties for the selected Arctic Seas helped to identify main places of their activity. Comparative analysis of these maps and regularities in spatiotemporal variability of the frontal zones of different origins allowed us to refine specific areas and mechanisms for the generation of NIWs and SEs and to explain seasonal patterns in the distribution of these phenomena and their characteristics. In case studies (eg, in the White Sea) specially-designed in situ observations provided the additional information for interpretation of satellite observations and model simulation. Here we propose the idea of monitoring system of short-period processes and sub-mesoscale phenomena combining in situ and satellite observations. The contours of this system are presented in this report. This work is supported by RFBR, research projects No. 16-29-02106_mol_a_dk and 15-05-04639_a, and by the President Grant of the Ministry of Education and Science of the Russian Federation under Grant MK-5562.2016.5.

Investigating the Arctic biogeochemistry and biodiversity during the period of rapid change based on modelling and satellite retrievals

S. N. Losa[1], M. A. Soppa[1], T. Dinter[1], M. Losch[1], S. Dutkiewicz[2] and A. Bracher[1,3]
[1] AWI, [2] MIT, [3]IUP, University of Bremen

We overview our study related to the project "Artic Amplification: Climate Relevant **A**tmospheric and Surfa**C**e Processes, and Feedback Mechanisms **(AC)³**". One of the subtasks of the project is to improve our understanding of possible interactions between the open water, sea ice, snow, ocean biogeochemistry and ecosystem and chemical composition of the Atmospheric Boundary Layer under the recently observed sea ice decline in the Arctic. In particular, the analysis of the changes in phytoplankton functional types (PFT) and Coloured Dissolved Organic Matter (CDOM) absorption observed over the last two decades will be based on long-term time series of satellite retrievals and has to be supported by a modelling study. The CDOM and phytoplankton dynamics as well as phytoplankton diversity in response to Arctic Amplification is simulated with the DARWIN biogeochemical model (Follows et al., 2007, Dutkiewicz et al., 2015) coupled to the Massachusetts Institute of Technology General Circulation Model (MITgcm, MITgcm Group, 2012). This combined model and satellite-derived information will be used for investigating existing relationships and feedbacks between the Arctic climate change, the ocean biogeochemistry and atmospheric oxidative capacity.

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AWI-CM, local refinement and climate

D. Sidorenko[1], D. Barbi[1], S. Danilov[1], H. Gößling[1], O. Gurses[1], S. Harig[1], T. Jung[1], N. Koldunov[1], T. Rackow[1], D. Sein[1], T. Semmler[1], Q. Wang[1]

[1]AWI

Most of climate models used at present for climate research use spatial resolution of 1 degree in the atmosphere and ocean. Such models, as indicated by Climate Model Intercomparison Project (CMIP) 3 and 5 suffer from imperfect parameterizations of relevant processes which is partly the consequence of their by far insufficient spatial resolution. The associated model biases are large and are often attributed in literature to the lack of oceanic resolution. Going beyond the coarse resolution of present-day climate models presents a challenge, because resolving all processes involving sub-mesoscale dynamics over centennial time intervals would require enormous computational resources which are difficult to afford. This explains the interest in the climate modelling community to a new-generation of multi-resolution climate models which allow one to increase the resolution locally where it is needed.

We present the AWI-CM climate model developed at the AWI, which employs a mature sea ice-ocean component based on unstructured mesh technique—the Finite Element Sea Ice-Ocean Model. The scientific aims we follow are (I) to investigate how much the locally increased oceanic resolution combined with improved parameterization for sub-grid scales can help to alleviate the climate model bias in AWI-CM, (II) to validate different strategies for designing the multi-resolution ocean mesh, (III) to elaborate the new physical core of FESOM v2.0 and incorporate it into AWI-CM.

FESOM_coastal

A. Androsov[1], V. Fofonova[1], S. Danilov[1], N. Rakowsky[1], I. Kuznetsov[2], W. Hiller[1], K.H. Wiltshire[1]
[1] AWI, [2] HZG

There is a growing need in the high quality estimations of long-term dynamics and circulation features in the coastal areas to answer major present and future societal, ecosystem and other questions, because of changing climate. On long time scales, the coastal dynamics change not only because of variable forcing, but also due to exchanges with the evolving global ocean.

Over recent years, considerable efforts have been invested into developing regional models and applying them to the coastal areas. These models are used by different institutions to study currents, sediment transport and ecosystem dynamics. They are well-established tools equipped with necessary parameterizations and modules that may be required in shelf or coastal modeling. However, they are regional models with open boundaries. When it comes to applying them to study long-term trends and variability in the regional sea, they have to be coupled to a large-scale modeling system. However, numerical algorithms used by global models can be insufficient to simulate coastal dynamics. There are issues related to vertical advection and mixing, stability in case of very thin sigma layers, absence of wetting/drying option etc. One more point is the choice of time step in case of highly varying resolution. Coastal refinement can be added to the global models, but at the same time they will lose efficiency. Unstructured-mesh coastal models are too dissipative and expensive to simulate global circulation at present.

A way out of this situation is coupling global and coastal models (one or two ways nesting). To reach this goal we present a coastal branch of the global model FESOM (Danilov et al. 2004, Wang et al. 2014). FESOM is a well-established large-scale ocean circulation model which is tested in numerous applications and participates in ocean model intercomparison project (see CORE-II virtual special issue of Ocean Modelling). It is the first model worldwide which provides multi-resolution functionality to large-scale ocean modeling, allowing one to bridge the gap between the scales and has the finite volume version at the current stage. FESOM_coastal treats the input/output characteristics in the same manner and share partly physical core with the global solution. It supports full coastal functionality, has cell-vortex finite volume discretization and works on any configurations of triangular, quadrangular or hybrid meshes.

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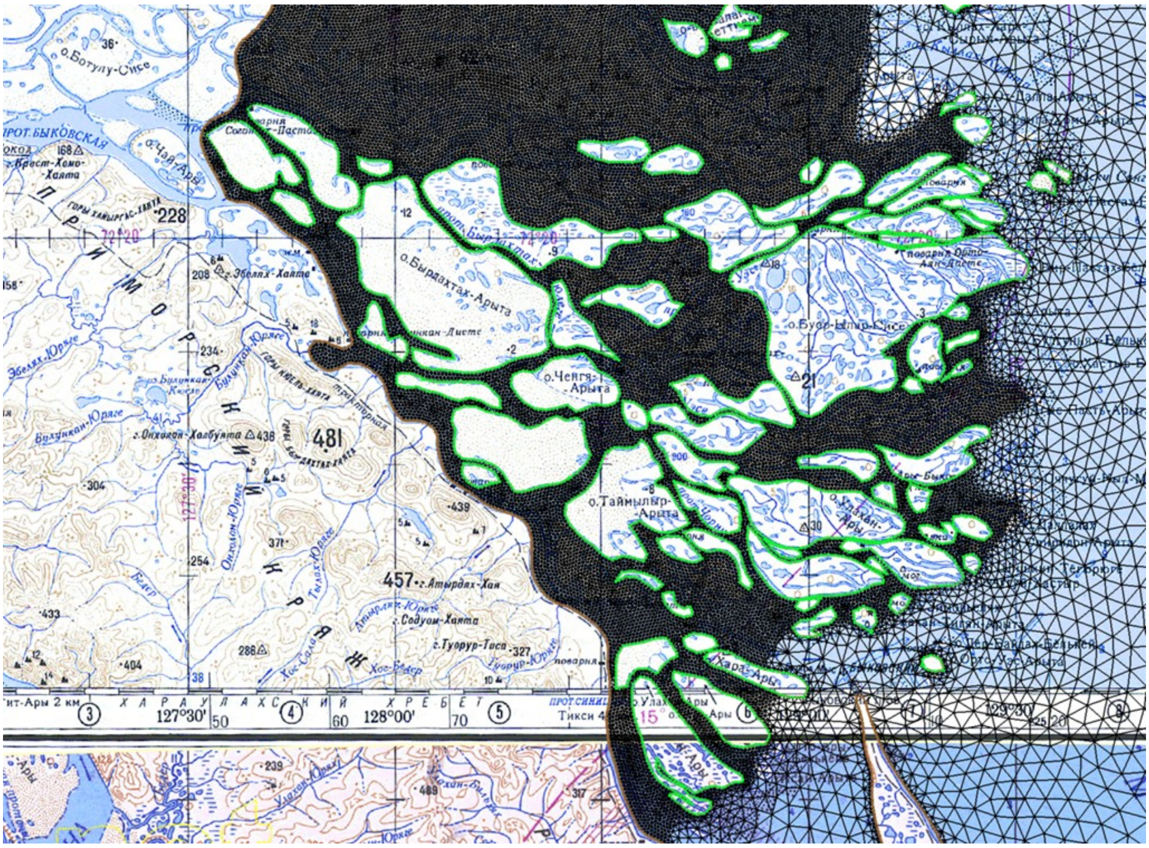
The Discontinuous Galerkin method for coastal ocean modeling

B. Reuter[1]*, V. Aizinger*[1]

[1]*Friedrich-Alexander-University Erlangen-Nürnberg*

We present an application of the discontinuous Galerkin finite element method to flow and transport in regional and coastal ocean. The 3D model utilizes unstructured prismatic meshes and includes a full set of physical parameterizations, including vertical turbulence closures of various levels of complexity as well as wetting/drying algorithms. The goal of the project is to produce highly accurate simulations of cross-scale processes of coastal dynamics in detailed topographic and numerical resolution.

We discuss a number of modeling and numerical technologies realized in our modeling package UTBEST3D. The performance of the method is illustrated using a number of real-life applications, including early results for the Lena Delta.



A high resolution Pan Arctic biogeochemical model

V. Schourup-Kristensen[1], *C. Wekerle*[1] *and C. Völker*[1]
[1] *AWI*

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 (4.5km) 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 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 ni- trogen 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.

Thumbs up: How to get a hitch-hike on the transpolar highway

Hauke Flores[1]
[1] *AWI*

Polar cod *Boreogadus saida* is the most abundant fish species in the high Arctic and the staple food of numerous Arctic seabirds and seals. On the broad shelves inhabited by the spawning populations, a part of the first-year population associates with the under-ice habitat at the end of summer. Recent studies showed that juvenile polar cod residing in the ice-water interface layer are practically ubiquitous in the Eurasian Basin, and probably throughout the Arctic Ocean. These fish feed on sea-ice fauna and copepods dwelling in the ice-water interface layer, and rely to a significant extent on carbon assimilated by ice algae. Satellite-based sea-ice back-tracking enabled to identify the potential areas on the Siberian shelf, particularly in the Laptev Sea. From there, juvenile polar cod associated with sea-ice possibly followed the Transpolar Drift across the central Arctic Ocean, potentially reaching spawning populations around Svalbard and in the Barents Sea. Hence, the Transpolar Drift may act as a vector enabling genetic exchange between coastal populations, and contributing to their recruitment. Further decline in extent and duration of sea ice may thus compromise genetic exchange, juvenile survival and recruitment of shelf populations. We would like to identify Regions in the Laptev Sea where first-year polar cod get entrained in the ice, and investigate their survival conditions in comparison to those staying on the Siberian shelf. The transport of polar cod from the Laptev Sea to the central Arctic pack-ice shall be modelled with coupled regional sea ice-ocean models, and ultimately be combined with IBM accounting for survival parameters, such as food supply.

Seismic and Seismological Investigations on the Southeastern Lomonosov Ridge and the adjacent Laptev Sea Shelf

E. Weigelt[1], W.H. Geissler[1]
[1] AWI

The contribution presents two geophysical projects to investigate the Siberian part of the Arctic Ocean and adjacent continental margin

First project bases on high-resolution multichannel seismic reflection lines collected in 1998, 2008 and 2014 in the Siberian part of the Arctic Ocean (Fig.1). The data provide an insight into the sedimentary cover and crustal surface of the Lomonosov Ridge and adjacent Laptev Sea in which in turn depositional and tectonic processes are documented. Part of the study was to develop a new seismostratigraphic model for the East Siberian part of the Arctic via the incorporation of drill site data to the seismic. Another aim is to propose suitable drilling locations for the upcoming IODP708 project (ACEXII) on the Lomonosov Ridge. Further we intend to tie in our data with seismic profiles of Russian colleagues to improve stratigraphic models and, thus to enhance our understanding of the tectonic development of East Siberian Sea and Margin.

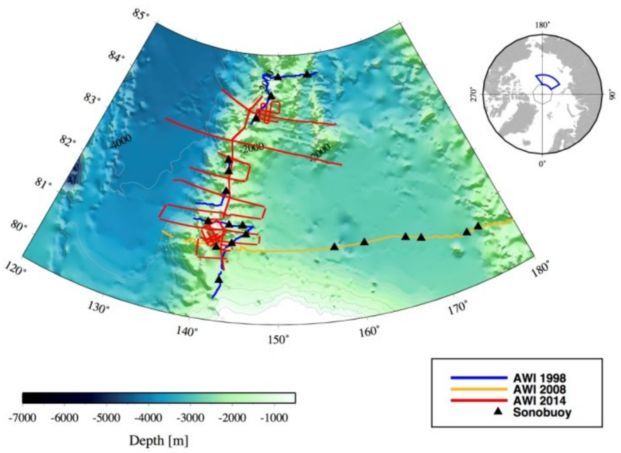


Figure 1. Bathymetric map of the southeastern Arctic Ocean with multichannel seismic reflection lines collected in 1998 (blue), 2008 (yellow) and 2014 (red).

The second project comprises investigations of the seismicity and the lithospheric structure of the SW Lena Delta, which is part of the Laptev Sea Rift System. The distribution and kinematics of active fault zones might also help to better understand regional emissions of gases with deep origin at the surface and the seafloor. In 2016 we installed 12 seismological stations in the Lena Delta to study the local seismicity along the southern part of the Olenek Fault Zone and 13 stations in an array SE of Tiksi to study the regional seismicity of the Laptev Sea. This work is carried out in a cooperation of various Russian and German institutions.

Chemical composition of ferrous concretions of the Laptev Sea shelf

A. N. Drozdova[1]
[1]*P.P. Shirshov Institute of Oceanology, Russia*

Concentrations of 52 elements were determined with ICP-MS and ICP-AES techniques in concretions found in the Laptev Sea at the 63th cruise of R/V "Akademik Mstislav Keldysh" in September 2015. The samples were collected in the continental slope region 77° 39.0' N 130° 30.5' E) at 87 m depth during dredging. Concretions represent thin (up to 3 mm), flat, 3-4 cm in diameter round-shape plats.

In contrast to ferromanganese nodules of the Kara Sea, in which the content of the main ore components, Fe and Mn, were found to be 4.1-25.4% and 2.0-26.5% [1,2], respectively, the studied samples contain relatively low amounts of Mn (0.59%). Fe content was estimated as 15.4%. Thus, the Mn/Fe ratio is about 0.04, while for the Kara Sea nodules it is at least one order of magnitude higher and varies between 0.2 and 2.62.

Table 1. The content of some elements in ferrous concretions of the Laptev Sea shelf.

Element	Content, ppm	Element	Content, ppm
Co	38.7	Zn	156.0
Ni	45.5	Mo	15.9
Cu	7.2	Cd	0.12

The content of Mo was significantly lower (see Table 1) than in the samples from the Kara Sea, were the average content of Mo was estimated as 341.2 ppm and Mo-enrichment of samples collected near the shore was reported [2]. The total content of 14 rare earth elements is 170.6 ppm. The most abundant are Ce (71.2 ppm), La (35.5 ppm), and Nd (31.0 ppm). The contents of noble metal, such as Au and Pt, were below the detection limit, Ag - 0.11 ppm.

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MultiVISA: A Visual Analysis System for Simulation Data

A. Fofonov[1], *L. Linsen*[1]
[1] *Jacobs University Bremen*

MultiVISA was designed to support researchers by novel visualization approaches based on already well known, but significantly improved data representations (histograms, function plots, field visualizations), and on completely new visualization method - multi-run similarity plots. The application consists of several views and numerous interaction tools, which allow to perform an interactive visual analysis on all data aggregation levels.

The range of tasks, which can be solved using MultiVISA, is wide and depends on the purposes of the analysis and on the data configuration. All the methods allow for a comprehensive analysis of single data frames, time series and ensemble of simulations. In particular we aim:

- comparative data analysis

- analysis of field distributions

- analysis of simulation parameters' and initial conditions' impact

- discovering data features and anomalies

- analysis of behavior patterns

- detection of outliers

In our work describe key ideas of the used approaches and show an example of the analysis process using different data sets interactively.

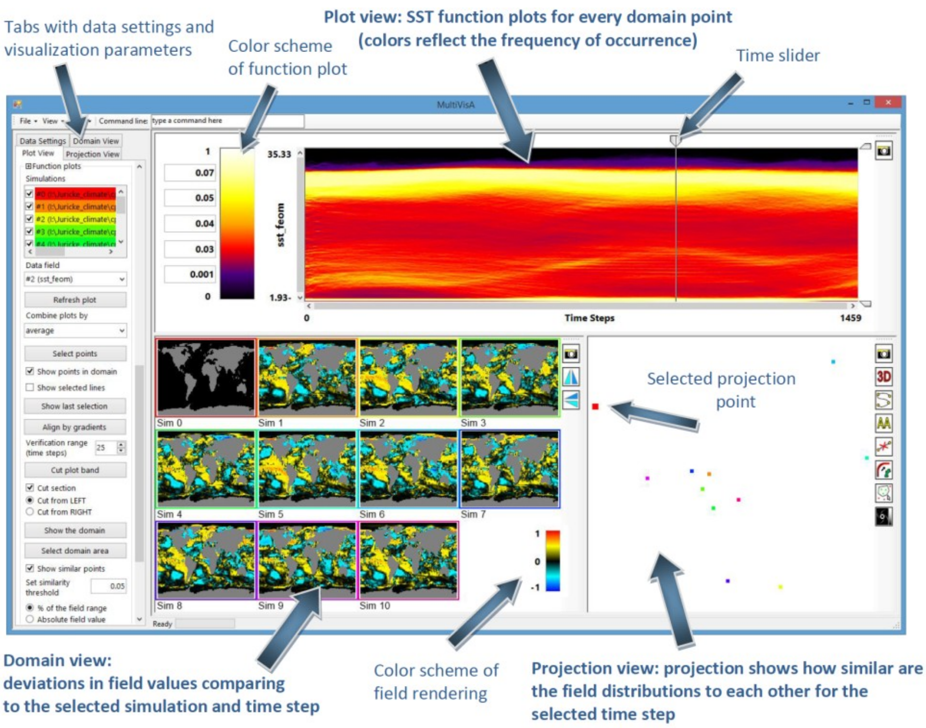

Figure 1. Example of MultiVISA's user interface. The presented data are: world sea surface temperature (SST) during one simulated year, 11 simulations, 1460 time steps per simulation, data field mapped to 192x96 grid.

Notes