International Conference

Solving the puzzles from Cryosphere

Pushchino, Russia, April 15-18, 2019

Russian Academy of Science
Institute of Physicochemical and Biological Problems in Soil Science RAS
“Okabiolab” Ltd.

International Conference
“Solving the puzzles from Cryosphere”

PROGRAM
ABSTRACTS

Pushchino, Russia, April 15-18, 2019

The International conference «Solving the puzzles from cryosphere» organized by: Institute of Physicochemical and Biological Problems in Soil Science RAS and "Okabiolab" Ltd.

Conference Committees.

Chair of the Organizing Committe: Andrey Alekseev (Corresponding member of RAS, Director of IPCBPSS RAS)
Chairs of the Programm Committee: Vladimir Melnikov (Full member of RAS), Marat Sadurtdinov (Director ECI Tyumen Scientific Centre SB RAS), Mikhail Zhelezniak (Director MPI SB RAS), Elizaveta Rivkina (Head of Soil Cryology Laboratory, IPCBPSS RAS)
Programm Committee: Andrey Abramov, Dmitry Drozdov, Vladimir Tumskoy, Olga Makarieva, Felix Rivkin, Stanislav Kutuzov, Alexey Lupachev

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Partners
Earth's Cryosphere Institute, Tyumen Scientific Centre SB RAS (Tyumen)
Melnikov permafrost institute SB RAS (Yakutsk)
PYRN-Russia

TABLE OF CONTENTS

PROGRAM

of the International Conference
"Solving the puzzles from cryosphere"

Pushchino, Russia
April 15-18, 2019

15.04.2019	Monday	
9:00-9:50	**Opening ceremony. Introduction** **Chair: Andrey Abramov**	
9:50-10:10	Permafrost studies in 2017-2019 by Permafrost institute SB RAS - results, plans and perspectives	**Zhelezniak M et al.**
10:10-10:30	Seismic and ground penetrating radar application in permafrost zone	**Sadurtdinov M**
10:30-11:00	**Coffee**	
11:00-11:15	Development of philosophical concepts concerning cold: from ancient natural philosophy to cryosophy	**Melnikov V et al.**
11:15-11:30	Problems of understanding the Ice Complex	**Tumskoy V**
11:30-11:45	On the degradation of mountain glaciers in Russia	**Kutuzov S**
11:45-12:00	Soil Diversity of the Bunger Hills (Wilkes Land, East Antarctica)	**Dolgikh A et al.**
12:00-12:15	Does permafrost control evolution of deglaciated coastal landscapes of subantarctic islands? – answers from King George Island , South Shetlands (Antarctica)	**Rachlewicz G et al.**
12:15-12:30	The Cost of Permafrost Hazards to Russian Economy	**Streletskiy D**
12:30-14:30	**Lunch**	
	GENERAL CRYOLOGY PUZZLES **Chairs: Vladimir Tumskoy, Aleksandr Kizyakov**	
14:30-14:45	Gas-emission craters puzzle - 4 years of investigations	**Leibman M et al.**
14:45-15:00	Gas geochemistry of the ground ice samples from the exposure in Central Yamal	**Semenov P et al.**
15:00-15:15	Preliminary Results of a Study the Frost Mound in the North of Western Siberia	**Nikitin K & Badu Y**
15:15-15:30	A physico-mathematical model of the injection mounds of swelling (bulgunnyakh, pingo)	**Marakhtanov V**
15:30-15:45	Methodologic aspects of studyng gas emission craters in permafrost	**Sergeev D et al.**
15:45-16:00	The cryogenic origin of the Yamal phenomenon	**Buldovich S et al.**
16:00-16:30	**Coffee**	
16:30-16:45	Insolation Periods of Climate Change as a Means	**Smulsky J**

	of Solving Cryospheric Puzzles	
16:45-17:00	The study of the transformation of the permafrost zone in a changing climate (projects of the Arctic Research Center of the Yamal-Nenets Autonomous District)	**Sinitskiy A et al.**
17:00-17:15	Geocryological research in the Mesozoic basins of Aldan shield	**Sysolyatin R & Zheleznyak M**
17:15-17:30	Permafrost Degradation in the Western Sector of Russian Arctic under Climate Change	**Vasiliev A et al.**
17:30-17:45	Distribution and dynamics of permafrost in the floodplain of the Pechora river Results of complex geocryological and geophysical monitoring	**Malkova G et al.**
17:45-18:00	Ice complex in the Debin and Susuman river valleys (Cherskiy Range)	**Zadorozhnaia N et al.**
18:00-19:30	**Poster session**	
1	Modeling of thermal abrasion coastal dynamics at the Kara Sea	**Aleksyutina D et al.**
2	Cryostratigraphy of the upper horizon of permafrost at the post-fire sites in vicinity of the town of Chersky	**Andreeva V et al.**
3	Activation of cryogenic processes in Central Yamal as a result of climate change and thermal state of permafrost	**Babkina E et al.**
4	Alpine permafrost geothermal zonation in the Udokan ridge (Zabaykalsky Krai)	**Boyko A**
5	Dendrochronological analyses of tundra plants in the Lena River Delta (Siberia)	**Buchwal A et al.**
6	Sorption interaction of acetic and chloro-acetic acids with quasi-liquid film of ice	**Fedoseeva V et al.**
7	West Siberian geocryological transect: a new site in the northern taiga	**Gubarkov A et al.**
8	Comparison of temperature data in boreholes at the Parisento field station (august 1986 - august 2018)	**Kamnev Y et al.**
9	Coastal dynamics of the Kolguev Island	**Kizyakov A et al**
10	Frost boils of the Pur-Taz interfluve	**Koroleva E et al**
11	Present evolution of Ivashkina Lagoon (Laptev Sea)	**Levochkina O & Tumskoy V**

12	Cryogenic structure of deposits on the 70-75 m terrace of Aldan River (Mamontova Gora outcrop)	**Maleeva A et al.**
13	Variety of characteristic times of cryogenic phenomena	**Melnikov V & Gennadinik V**
14	Statistical analysis of the climatic factors influence on the active layer depth in Russian cryolithozone	**Petrov B & I Streletskaya**
15	Late Pleistocene paleosols in the context of the Quaternary landscape evolution of Northwestern Siberia	**Sedov S et al.**
16	Reaction by climate changing in North Asia mountain region (Verkhoyanian mounts, Suntar-Khayat ridge)	**Sysolyatin R et al.**
17	Heterogeneous ice wedges at study areas on north-east sector West Siberia	**Tikhonravova Ya & Slagoda E**
18	Hydrochemical Features of the Northern Coast of the Kotelniy Island	**Torgovkin N et al.**
19:30-21:00	PYRN-party	

16.04.2019	**Tuesday/Вторник**	
	GENERAL CRYOLOGY PUZZLES **Chairs: Vladimir Sheinkman, Alexey Maslakov**	
9:00-9:15	Quaternary sediments and massive ice beds of the Gulf of Lavrentiya, Chukotka	**Baranskaya A et al.**
9:15-9:30	Accelerated coastal erosion of the Bering Sea (Lorino site, the Chukchi Peninsula, Russia)	**Maslakov A**
9:30-9:45	Modeling of the Dynamics of Subaqueous Permafrostat at Variable Rate of Thermal Abrasion	**Ostroumov V & Vasiliev A**
9:45-10:00	Monitoring of thermocirques, their activation and growth controls, Central Yamal, Russia	**Khomutov A et al.**
10:00-10:15	The long-therm temperature dynamics of the permafrost in the areas of cuttings of larch forests (Central Yakutia, Russia)	**Konstantinov P & Fedorov A**
10:15-10:30	Mathematical modeling of the morphological pattern development for thermokarst plains with fluvial erosion	**Victorov A et al.**
10:30-11:00	**Coffee**	
11:00-11:15	Degradation of ice-wedges in Central Yakutia under the modern climate warming	**Fedorov A et al.**

	Pseudomorphs after polygonal-ice wedges and loess-like but floodplain alluvial deposits at the top of river terraces as new confirmation that Northwestern Siberia during the Pleistocene was a frozen non-glaciated area	**Sheinkman V & Sedov S**
11:15-11:30	Frozen deposits as a material for luminescence dating and a perspective to date them by means of a new TL technology	**Simonov O & Sheinkman V**
11:30-11:45	A Case Study of Morphoscopic and Morphometric Analysis of Quartz Grain Surface	**Kut A**
11:45-12:00	Permafrost islands on the Tersky coast of the White Sea	**Lugovoy N & Romanenko F**
12:00-12:15	Changes in the parameters of the active layer under the influence of climate warming near the southern boundary of the cryolithozone (on the example of Western Siberia)	**Ponomareva O et al.**
12:15-12:30	Dynamics of local conditions of peat accumulation in the Holocene of the southern tundra of the Pur-Taz interfluve	**Kuznetsova A et al.**
12:30-14:30	**Lunch**	
	HYDRO&GLACIO PUZZLES **Chairs: Olga Makarieva, Stanislav Kutuzov**	
14:30-14:45	Laboratory investigation of flow and bank interactions of the river in cryosphere	**Dolgopolova E et al.**
14:45-15:00	Modelling Thermal Regime of an Intrapermafrost Talik in Central Yakutia	**Tananaev N et al.**
15:00-15:15	Hydrological modelling of the maximum runoff characteristics at small rivers in the permafrost zone	**Nesterova N & Makarieva O**
15:15-15:30	Aufeis of the Yana and Indigirka river basin (Russia): the database from historical data and recent Landsat images	**Makarieva O et al.**
15:30-15:45	Possibilities for Estimating the Runoff Components of Rivers in Cryolithozone by Tracer Methods	**Gubareva T et al.**
15:45-16:00	Investigation of water tracks hydrology in the north-west of Yakutia	**Tarbeeva A et al.**
16:00-16:30	**Coffee**	
16:30-18:00	**Roundtable "Verification data for modeling"** **Moderator Gleb Gribovskii**	Page 209

16:30-16:45	River runoff generation at the small research watershed in continuous permafrost environment in Central Yakutia, Russia	**Lebedeva L et al.**
16:45-17:00	Volume change of valley glaciers in the Cherek river catchment (Central Caucasus) from the mid-20 century	**Naydenko A et al.**
17:00-17:15	Small forms of glaciation — Chukotka and the Verkhneangarsky Range: why do they survive?	**Ananicheva M et al.**
17:15-17:30	Changes of small glaciers in sub-Arctic Siberia in XXIst century: a case study of the Putorana Plateau	**Kovalenko N et al.**
17:30-17:45	Avalanche hazard zoning for the land use planning in the Russian Arctic	**Turchaninova A et al.**
17:45-18:00	Geophysical and glaciological investigations for safety arrangements in the area of Progress and Mirny stations and the Bunger Oasis field base (East Antarctica) during the field seasons of the 63-64 RAE (2017/2019)	**Sukhanova A et al.**
18:00-19:30	**Poster session**	
1	The role of avalanches in the restoration of the Kolka glacier	**Bashkova E & Turchaninova A**
2	Glacial lakes inventory in Central Caucasus (2017-2018)	**Bondarev S**
3	The influence of winter seasonal temperature conditions, snowfalls and snow cover thickness accumulation variations on ground freezing depth	**Frolov D**
4	Permafrost-aeolian processes in cold and arid regions of eastern siberia and tibetan plateau	**Galanin A & Qingbai Z**
5	Stages of study of the Kara Sea shelf cryolithozone	**Gavrilov A et al.**
6	Ice core geochemistry of Caucasus mountains	**Khairedinova A et al.**
7	Big data analysis for snow avalanche simulation in Arctic regions	**Kovalenko N et al.**
8	Morphometry of water bodies on Kurungnakh Island (Lena Delta) on the basis of aerial imagery	**Kukarina E**
9	Spatial diversity of the relict cryogenic relief forms of the periglacial region of Western Siberia (Russia)	**Larin S et al.**

10	Permafrost under the River and Forest: How Local Hydro(geo)logy Influences Ground Temperature	**Lebedeva L et al.**
11	Permafrost and hydrogeological conditions at the inwashed reclaimed lands of the Yakutsk city	**Ogonerov V et al.**
12	Hydrochemical and isotopic composition of river waters in Nizhnyaya Tunguska River basin: tracing the fire impacts and permafrost degradation	**Prokushkin A et al.**
13	Research watershed of the Mushketova river at the Severnaya Zemlya archipelago – field observations and modelling	**Sekisov N et al.**
14	Detailed Hydrological Observations in a Small Catchment at Prilenskoye Plateau (a Case of the Shestakovka Creek): Some Evidences and Puzzles	**Shamov V et al.**
15	Cryoturbations, pseudomorphs, postcryogenic textures and involutions in the frozen sediments of the Pur-Taz interfluve	**Slagoda E et al.**
16	The Effect of Snow Hardness on Soil Freezing	**Sosnovsky A & Osokin N**
17	Assessing hydrological connectivity in permafrost catchments using natural tracers	**Tananaev N**
18	Impact assessment of glacial processes on the objects of the northern settlements	**Topoleva A**
19	Seasonal ice of the active layer and stability of ecosystems of the cryolithozone in the conditions of climate fluctuations: the direction of research	**Tregubov O et al.**
20	Samoylov Island scientific research station: current state and trends	**Tsibizov L**
21	About the numerical modeling of snow avalanches in the Russian Arctic	**Turchaninova A et al.**
22	Ratios of methane and its homologues in the lakes of central Yamal as indicator of methane origin	**Vanshtein B et al.**
23	New data on the existence of paleopermafrost in the Yaroslavl region	**Volkova N et al.**
18:30-19:30	**Open meeting of "Earth Cryology panel" Moderator Mikhail Zhelizniak**	
	1.Call for members 2.Future permafrost conferences 3."Russian Cryolithozone" project	
19:30-22:00	**Banquet**	

17.04.2019	Wednesday	
	REMOTE&GEOPHYSICS IN PERMAFROST **Chairs: Marat Sadurtdinov, Nina Nesterova**	
9:00-9:15	Analysis of the global ESA GlobPermafrost map for Scandinavia	**Nesterova N**
9:15-9:30	Experience of usage and new developements of temperature monitoring systems for permafrost soils produced by “Etalon” research and production enterprise” JSC	**Pugach V & Eremin I**
9:30-9:45	Geophysical Monitoring of Permafrost in Yakutia - Observation and Modelling	**Milanovskiy S et al.**
9:45-10:00	The application of electrical resistivity tomography in the study of the underlake talik	**Olenchenko V et al.**
10:00-10:15	Features of Automated Soil Moisture Monitoring	**Volokitin M et al.**
10:15-10:30	Comparison of Lakes Within the Lake-Thermokarst and Erosion-Thermokarst Plains with the Help of Mathematical Morphology of Landscape	**Victorov A et al.**
10:30-11:00	**Coffee**	
11:00-11:15	Acoustic properties of water-saturated sand during freezing and thawing Results of Ultrasonic laboratory measurements	**Sudakova M et al.**
11:15-11:30	Possibilities of wave methods of geophysics for permafrost monitoring on the example of CALM sites (European North)	**Sadurtdinov M et al.**
11:30-11:45	Geotechnical Monitoring of Pipeline Systems in Permafrost Conditions	**Makarycheva E et al.**
11:45-12:00	Application of high-frequency ground penetrating radar (GPR) to studies of permafrost-affected peat plateaus	**Kaverin D et al.**
12:00-12:15	Digital Thematic Mapping of the Current State of Permafrost Landscapes in Yakutia	**Fedorov A et al.**
12:15-12:30	Application of the natural electric field method for studying the outburst lakes of the Larsemann Hills (East Antarctica) during the field season of the 64th RAE	**Grigoreva S et al.**
12:30-14:30	**Lunch**	
14:30-16:00	**Roundtable "Actual problems of Cryopedology"**	Page 210

	INFRASTRUCTURE&ENGINEERING PUZZLES **Chairs: Felix Rivkin, Pavel Tolmanov**	
14:30-14:45	Phase composition and chemical properties of saline soils on the Arctic coast of Russia	**Shimanov A et al.**
14:45-15:00	Problems of reinterpretation of past years in engineering geology (on the example of the Anadyr city)	**Nuteveket M et al.**
15:00-15:15	Influence of urbanization on permafrost: a case study of Yakutsk	**Vasilieva A & Shesternev D**
15:15-15:30	Geotechnical Monitoring UTGKM: tasks&problems&perspectives	**Rivkin F et al.**
15:30-15:45	Hazardous cryogenic processes on Yamal peninsula, Marre-Sale and Bovanenkovo study areas	**Streletskaya I et al.**
15:45-16:00	Application of laser scanning for evaluation of deformations of linear objects in the cryolithozone	**Iurov F et al.**
16:00-16:30	**Coffee**	
16:30-16:45	Infrastructure deformations in the Arctic under the influence of cryogenic processes	**Grebenets V et al.**
16:45-17:00	Geophysical and glaciological investigations for safety arrangements in the area of Progress and Mirny stations and the Bunger Oasis field base (East Antarctica) during the field seasons of the 63-64 RAE (2017/2019)	**Sukhanova A et al.**
17:00-17:15	The dynamics of the individual avalanche risk in the Khibiny Mountains	**Vikulina M et al.**
17:15-17:30	Numerical simulation of heat transfer with ice–water–steam phase change in the permafrost foundation of an elevated flare stack	**Ramanouski Yu**
17:30-17:45	Verification of climatic and geological data in natural conditions using computer simulation of the permafrost ground thermal regime	**Grybovskii G et al**
17:45-18:00	Features of the Temperature Field and the Zone of Permafrost of the oil and gas regions of Republic of Sakha (Yakutia)	**Semenov V**
18:00-19:30	**Poster session**	
1	Bacterial communities of seasonal thawed soil horizons of polar tundra of Russia and Alaska	**Berestovskaya J.J. et al.**
2	Cryogenic landscapes stability to the exogenous	**Donetskov A &**

	processes activation (on the example of the Medvezhye oil field, West Siberia)	**Zotova L**
3	Evaluation of the negative impact of permafrost processes on the transport systems of Eastern Siberia and the Far East	**Grebenets V & Sokratov S**
4	Geophysical surveys on the outburst of Progress Lake (Larsemann Hills, East Antarctica) in the field season of the 64th Russian Antarctic Expedition	**Grigoreva S et al.**
5	Gas-emission crater prediction map: first results	**Khairullin R et al**
6	Modeling of seasonal freezing depth in Western Moscow region	**Komova N & Maslakov A**
7	Cryolitological map on the Barentsburg neighborhood (Land of Nordenskiöld, Svalbard)	**Krotkov V & Kizyakov A**
8	Geochemical Features of Quaternary Perennially Frozen Sediments in Central Yakutia at Example 100 m Borehole	**Torgovkin N et al.**
9	Approximation the soil temperature of piecewise continuous function	**Lapina L et al.**
10	Cryogenesis features of the Kolyma Southern Highlands	**Lukyanov S**
11	The Approaches to the Analysis of the Polychemical Pollution of Cryogenic Soils and Upper Permafrost	**Lupachev A**
12	Error comparison of numerical solutions in various simulation software with analytical solution of the Stefan problem depending on mesh size	**Makoyed A et al.**
13	Influence of Cryogenesis in Soils on Desorption of Lead	**Mironenko K et al.**
14	Cryogenic weathering (destruction) of construction material in the Arctic cities	**Rogov V et al.**
15	Nematode Community Structure as Indicator of Microbial Activity in Cryosol Profile	**Ryss A et al**
16	Cryogenic processes development and soil formation during Sartan Cryochrone (MIS 2) in Transbaikal river valleys (Eastern Siberia, Russia)	**Ryzhov Yu & Moroz P**
17	Comparative analysis of the respiratory response of cryosols and the soils of the temperate zone for short-term freezing-thawing of the surface soil	**Sapronov D & Zanina O**

	layer	
18	About the organization of a unified program for monitoring cryogenic processes	**Tolmanov V**
19	Geocryological conditions for the passage of the railway Obskaya – Bovanenkovo - Karskaya	**Tretyakov I et al.**
20	Advanced stochastic modelling of thermokarst hazard for linear objects in uniform geological conditions	**Victorov A et al.**
21	Analyzing tundra vegetation characteristics for enhancing terrestrial LiDAR surveys of permafrost thaw subsidence on yedoma uplands	**Veremeeva A**
22	The Geoecological Situations Assessment and Mapping on Regional and Local level in the Russia Permafrost Zone	**Zotova L & Dedjusova S**

18.04.2019	Thursday	
	PERMAFROST AFFECTED SOILS **Chairs: Alexey Lupachev, Andrey Dolgikh**	
9:00-9:15	Problems of Permafrost-Affected Soils Classification and Their Places in Different Taxonomic Systems	**Goryachkin S et al**
9:15-9:30	The response of West Siberia tundra ecosystems to experimental warming: results of short and long-term experiments	**Matyshak G et al**
9:30-9:45	Temperature Field and the “Mirror Image” of the Thawing and Freezing processes of the Cryoarid Catenae Soils in Central Buryatia	**Badmaev N & Bazarov A**
9:45-10:00	Carbon and nitrogen distribution patterns in the soils of the Barents sea coastal area	**Shamrikova E et al**
10:00-10:15	Pedodiversity of the Cryolithozone in the Siberian middle taiga	**Golovleva Yu & Krasilnikov P**
10:15-10:30	Pumping-Effect in Soils of Permafrost	**Lapina L & Zyryanov V**
10:30-11:00	**Coffee**	
11:00-11:15	The Soil-Forming Environmental Characteristics of the North-East Arctic Coastal Areas of Russia	**Gubin S**
11:15-11:30	Cryoconites - as a source of carbon for soils and	**Zazovskaya E**

	soil-like bodies of High latitudes	**et al.**
11:30-11:45	Carbon redistribution in soils of hydromorphic ecosystems in the permafrost zone (north Western Siberia, Russia)	**Goncharova O et al**
	PERMAFROST MICROBIOLOGY AND BIOGEOCHEMICAL PROCESSES Chairs: Elizaveta Rivkina, Anna Khodzhaeva	
11:45-12:00	Subglacial South Pole Martian Lake and Hypersaline Canadian Arctic Lakes vs Subglacial Antarctic Lake Vostok – Potential for Life	**Bulat S**
12:00-12:15	Microbial Communities in Permafrost Sediments	**Vishnivetskaya T et al.**
12:15-12:30	Role of the Transient Layer in the Methane Emissions on the Dominant Landscapes of Typical Tundra under Climate Warming	**Oblogov G et al.**
12:30-14:00	**Lunch**	
14:00-14:15	Microorganisms from permafrost ecosystems of marine origin	**Spirina E et al.**
14:15-14:30	Biogeochemical technologies of remediation and diagnosis of contaminated soils of impacted polar ecosystems	**Bashkin V & Galiulin R**
14:30-14:45	Habitat Selection of Protists Communities in Arctic Cryosol	**Shatilovich A & Mylnikov A**
14:45-15:00	Quantitative indicators of prokaryotes and fungi in the tundra soil of peninsula Ribachiy and in Vorkuta	**Nikitin D et al.**
15:00-15:15	Acanthamoeba from permafrost: phylogenetic position and persistence to modern giant viruses	**Shmakova L et al.**
15:15-15:30	Characteristics of microorganisms isolated from different biotopes of the Vechernij region in Tala Hills oasis (East Antarctica)	**Miamin V et al.**
15:30-16:00	**Coffee**	
	PUZZLES FROM THE PAST - PALAEOECOLOGY Chair Oksana Zanina	
16:00-16:15	To a question about the habitat of representatives of mammoth fauna in Late Pleistocene on North-East Russia	**Zanina O et al.**
16:15-16:30	Genesis of Chalky Polygons on the SubUral Plateau	**Ryabukha A et al .**

16:30-16:45	Palaeocryogenic conditions markers of the Sartan cryochron time on Tobol-Ishim watershed (SW Western Siberia, Russia)	**Larin S et al.**
16:45-17:00	Quaternary Deposits of the Gydan Peninsula Coast of Western Siberia and their Cryogenic Structure	**Pismeniuk A et al.**
17:00-17:15	Aeolian accumulation on the surface of peatlands on the north of West Siberia: methodological approaches to the study, the first results	**Babkin E et al.**
17:15-17:30		
17:30-18:30	**Closing ceremony**	

ABSTRACTS

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"Solving the puzzles from cryosphere"

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April 15-18, 2019

Seismic and ground penetrating radar application in permafrost zone

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In this report we present our fieldwork experience and results of researches of near surface and permafrost conditions at various parts of the permafrost zone of Russian Federation. The results were obtained over the past 20 years at the Earth Cryosphere Institute Tyumen Scientific Centre SB RAS. The main method of studying permafrost processes and geological cross-section of frozen and thawed rocks in our investigations is seismic exploration using waves of various types and classes. By using reflected shear SH-waves it is possible to obtain informative data from depths less than two meters. For detailed investigation of permafrost cross-section, seismics is used integrated with ground penetrating radar (GPR). During GPR studies it is necessary to use different-angle reflection method to accurately determine velocity law in research area. Wave geophysical methods are successfully used to study permafrost both in natural and in technogenic conditions.

Wave methods of geophysics and their modifications used in Earth Cryosphere Institute Tyumen Scientific Centre SB RAS are theoretically and experimentally justified. They have been successfully tested in various natural and climatic conditions of the permafrost zone of Russian Federation. Geophysical methods are an effective and reliable tool for solving various near surface and permafrost issues and determining properties of frozen and thawed ground. The work was supported by RSF grant №16-17-00102.

Development of philosophical concepts concerning cold: from ancient natural philosophy to cryosophy

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One of the most important fundamental problems of the modern science in overcoming of growing differentiation of separated fields of knowledge that hinders forming of a total picture of the world. Such situation was evidently shown in the fate of permafrost knowledge. Originally this discipline studied the natural objects and phenomena related to low temperatures using methodological approaches of geographical and geological sciences. In the second half of the XX century many researches of the cryogenic phenomena became consider not only their traditional fields of knowledge but also different problems of physics, chemistry, biology, medicine, anthropology, soil science, ecology, climatology, cosmology, etc. Such situation increased a request for integration of knowledge and application of multidisciplinary approach that founds development in new field in science's philosophy – cryosophy, which is a system of ideas about the cold world. Cryosophy studies the role of cold in origin and evolution of inorganic matter and life in the world. Creating of the concept of cryosophy promoted understanding the following situation: if development of permafrost knowledge is not older than one century, then the history of philosophical views about the cold phenomena spans at least 2500 years and originates in ancient natural philosophy. During this period the philosophers of Ancient Greece formulated a number of fundamental questions about the qualities of cold matter and its role in the nature. Parmenid, Anaksimen, Heraclitus, Aristotle, Plutarch, etc., created the physiophilosophical concepts distinguished cold as one of the subjects in the system of the classical elements, explaining value of cold in the physical structure of the Earth and the Universe, considering substance carriers of cold, etc. Suitable answers for many of the scientific questions formulated in these concepts could not be found within the metaphysical picture of the world, which had dominated during that era. It might be seamed paradoxical, but more than two millennia were required for the understanding of these questions. It became possible because of the following cardinal changes in the scientific knowledge: a) emergence of technical capabilities for studying the diversity of cryogenic objects, phenomena and processes on the Earth and in the Universe; b) change of an axiological paradigm of perception of cold, recognition of its environmental and resource value; c) cross-disciplinary integration of natural, humanitarian, exact and technical sciences studying various objects and processes in the cold world; d) consideration of the cryosphere as a complex system. Cryosophy can be considered as a methodological paradigm designed to create an integral image of the cryosphere in the context of problems of post-non-classical science. It is important to note that unlike natural philosophy of Ancient Greece, which was a universal syncretic science, cryosophy designed to play a role of a peculiar integrator of different fields of knowledge concerning the cold world and an informative frame for creation of its ontology. This situation in general coincides with global trends of development of philosophy of science for which the movement from "real science" to its epistemological studying and creation of the general models, structures, methods and the general regularities of its development is typical.

Problems of understanding the Ice Complex

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Ice Complex (IC) is the geological formation of very ice-rich syncryogenic frozen deposits containing syngenetic ice wedges. This interpretation of IC was included in almost all textbooks published over the past 30 years. But, this definition is very general and currently does not correspond to our level of knowledge about IC. This causes serious communication problems among specialists and difficulties in Quaternary deposits mapping in the permafrost area. It is necessary to bring the understanding of this important cryolitological term to the available data on IC. This path is quite acceptable in the framework of terminology as an alternative to the introduction of new terms.

P.A. Solov`ev introduced the term "ice complex" for the convenience of icy stratum with fossil ice describing and it published in 1959. Fossil ice is ice of ice wedges. P.A. Solov'ev wrote that the IC deposits have the same conditions of occurrence, but they may have different ages, composition, genesis and thickness. According to the principle of the IC determination, it has pre-Holocene age. The roof of the IC is carried out along the upper surface of the ice wedges and the enclosing sediments, the bottom - "... along the lower ice contact in the section of the boreholes". On the basis of this formulation many researchers believe that the IC base is carried out at the lower ends of the ice wedges. Some of them generally associate the IC with the upper ice-containing horizon of frozen deposits. This approach is incorrect from geological point of view. In this case, IC should include the underlying deposits in which introduce the epigenetic ends of the ice wedges. But underlying deposits may be marine or pre-Quaternary deposits, bedding rock or other are not syncryogenic and it have a different cryogenic structure. Thus, the lower boundary of the IC should be held on the base of the deposits containing ice wedges.

Deposits similar the cryolithological structure and occurrence conditions were identified on the coastal lowlands of Yakutia at the same time. It was called yedoma deposits because it usually composed the yedoma highlands. Beginning the 70s of the 20th century, the terms IC and Yedoma deposits used as synonyms. Distribution and paleogeographic conditions, age and some hypothesis of IC genesis were determined during of studying the IC in different areas. The result is that the age of IC deposits may be from Middle to Late Neopleistocene, but nowhere was a continuous section with such an age range found. But, in many sections several horizons (up to 3-4) with a cryolithological structure of the IC type, divided by deposits of a different genesis and structure, were separated. From the cryolitological and stratigraphic points of view is geologically inexpedient to consider them as separate horizons of a single IC. More correctly to consider they as distinguish IC horizons of different ages. The upper (Late Neopleistocene) relief-forming horizon of the IC can be called Yedoma IC. More ancient lower ones may have the name as the suite within which they are identified.

IC is a combination of different genetic types of Quaternary deposits, formed in specific cryolithological conditions. IC is a single geological body only from a cryolitological point of view. On this basis, it is meaningless to consider the common genesis of whole IC. The conclusions about the polygenetic or cryogenic genesis of IC are not productive.

From author’s opinion, the Ice Complex is syncryogenic deposits of different genesis, age, modes of occurrence, composition and ice content, accumulated in the Neopleistocene and containing a closed system of ice wedges.

On the degradation of glaciers in Russia

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Changes in cryosphere elements including glaciers have multiple impacts for social-ecological systems, affecting not only biophysical properties such as sea level rise, runoff volume and sediment fluxes in glacier-fed rivers, and glacier-related hazards but also ecosystems and human livelihoods, socio-economic activities and sectors such as agriculture and tourism as well as cultural values.

Glaciers in Russia experienced significant changes both in the Arctic and in High mountain areas. In recent decade in some regions of Russian Arctic glaciers mass losses doubled compare to previous periods. Similar or sometimes even more rapid glacier recession was observed in mountain regions e.g. glacier mass losses in Elbrus tripled in recent 20 years compare previous 50 years. Here we present an overview of the recent glacier changes in Russia together with its possible implications.

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Soil Diversity of the Bunger Hills (Wilkes Land, East Antarctica)

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The diversity of the soils of the one of largest ice-free area of Antarctica after the Dry Valleys - the Bunger Hills or Bunger Oasis (66°17′S 100°47′E, 900 km2) were studied for the first time over a long field season within the 63 seasonal Russian Antarctic expedition (about 1 month, January 2018). The Bunger Hills are characterized by similar climatic factors and conditions with the coastal and trans-shelf oases of East Antarctica (Larsemann Hills, Thala Hills, Schirmacher, etc.), the maximum thickness of the active permafrost layer is more than 120 cm. Despite the large area, a long warm period (more than 2 months) and a strong intra-oasis effect, incl. and the formation of cumulus clouds, precipitation in liquid form is absent. The long history of the development of the oasis in the periglacial zone has led to the formation of large, flat surfaces of inter-row valleys and inter-hill depressions, in which freshly falling snow is actively blowing. In addition, these valleys and basins are characterized by a wide distribution of moraines with a high proportion of rubble and concentration of coarse clastic material. All this leads to an even more pronounced deficiency of liquid moisture in the summer in the upper centimeters of soil and a smaller proportion of actively wetted surfaces, compared to the previously studied oases of the Larsemann Hills and the Thala Hills. The absence of penguin colonies and therefore small populations of the south polar skua and snow petrel leads to an extremely insignificant transfer of organic matter from the sea, which is typical of many coastal oases of East Antarctica, and the absence of ornithogenic soils. Only in small wind shelters in the stones and rock baths, there is a local ornithogenic introduction of organic matter. The main soil types represented in the Bunger Hills, with the exception of ornithogenic and post-ornithogenic soils, are similar and close to the soils of other previously studied oases of East Antarctica, but the differences are already apparent in the soil cover. On the territory of the Bunger Hills, a substantially smaller proportion of the area is occupied by the soils of the wet valleys, compared to the oases of the Larsemann Hills and the Thala Hills.

An important geochemical feature of the oasis is the extensive distribution of fine crystalline salt inlays of two groups on the soil surface: carbonate-chloride-sulphate and predominant carbonate compositions. For low Holocene (up to 20 m) and a number of Pleistocene marine terraces (up to 40 m abs.), surface incrustations of easily soluble salts are predominantly hydrocarbonate-chloride-sulphate, most of which are of marine nature. For flat, upland surfaces of high (up to 80 m) moraine plateaus of the central part of the oasis, carbonate surface salinization is characteristic, with easily soluble carbonate salts prevailing over insoluble. High hypsometric level, increased compaction and high degree of weathering of the near-surface moraine material, and a weak erosive ruggedness moraine plateau and depressions enable a first approximation to bind carbonate salinity with prolonged weathering massive crystalline and loose rock oasis, the accumulation and redistribution of its products, including in the annual cycle of the permafrost layer.

The soil cover of the Bunger Hills has a mosaic structure that is not determined by the breadth and distance from the ocean or glacier, but by local conditions (geomorphological position, size of the meso-relief forms, the presence of wind shadow for fixing all year snow patches, lateral moisture runoff, granulometric composition of parent rocks, the amount of fine earth material, drainage of melt water of the snow patches in the upper 5 cm).

The obtained data allow us to preliminarily attribute the Bunger Hills to a more arid variant of the Mid-Antarctic snow-patch cryptogamic barrens.

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Does permafrost control evolution of deglaciated coastal landscapes of subantarctic islands? – answers from King George Island , South Shetlands (Antarctica)

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During two austral summer campaigns, in January-February 2016 and 2018, the conditions of relief evolution were investigated on the western coast of Admiralty Bay on King George Island, South Shetlands (62°11'S, 58°26'W). Researches aimed to: 1 – recognize the state of coastal cryosphere in subantarctica, 2 – identify the set of processes contemporarily shaping coastal landscapes, 3 – built a qualitative/quantitative model of the evolution of deglaciated coastal landscape.

On King George Island, that is ca. in 90% covered with ice caps and glaciers, reaching altitude of 600 m a.s.l., western coast of Admiralty Bay Oasis has about 13 km^2 and is the second largest ice-free part on the island. Estimations of ice losses since 1979 are showing the increase of glaciers forefields area by ca. 3.9

km^2. We investigated about 8.5 km of the coast, which comprises hard rock segments, sandy-gravel and stony beaches, edges of raised marine features, sea undercut glacial forms and ice cliffs. It is an area in the marginal zone of Warszawa Ice Cap, directly influenced by the decay of three outlet glaciers tongues: Baranowski Glacier (in transition from the ice cliff to terrestrial margin), Sphinx Glacier (on the land for at least last 60-70 years) and Ecology Glacier (constantly retreating ice cliff located in the coastal embayment, with lateral land based marginal zones). The whole coast is subjected ongoing glacioisostatic uplift.

Climatic conditions in the study area are representing maritime Antarctic type with annual air temperature -1.5°C (Arctowski Station, W coast of Admiralty Bay), higher by 0.8°C than measured on other stations in the western part of the island (Maxwell Bay). Air temperatures are considerably growing during the measurement period of last 60 years. Positive monthly average temperatures are observed from December to March, although melting events occur every month of the year.

Investigations to detect permafrost occurrence in the coastal area were carried with the use of electrical resistivity tomography (ERT) and ground penetrating radar (GPR), supported by geomorphological processes observations. In addition direct measurements of ground (rock) temperatures were carried out between February 2016 and February 2018 in 1.5 m deep boreholes. No traces ofpermanent ground freezing (i.e. existence of permafrost table) were detected in the close vicinity of the shoreline, on lowest raised marine terraces and flat areas abandoned by glaciers during the last 40-50 years (ground moraines). Boreholes temperatures showed no permafrost conditions as well. Possible shallow frozen ground occurrence is suggested at the base of local slopes, characterized by concentration of interflow slope deposits, shadowed sections of slopes (S aspect) and inside of frontal and lateral moraines (ice cored moraines).

Coastal lowlands are influenced by sea water inflows, and the vicinity of the bay itself, year to year less often covered with sea ice, is precluding freezing of the ground for a longer period. Permafrost development conditions are not evolving as well on the surfaces subjected accelerated uncovering from beneath melting glaciers covers as also uplifted by glacioisostasy after the end of Little Ice Age.

Research were carried in the frame of the Polish National Science Center project “POROCO – Mechanisms controlling the evolution and geomorphology of rocky coasts in polar climates”, grant No. 2013/11/B/ST10/00283.

The Cost of Permafrost Hazards to Russian Economy

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Permafrost occupies almost two thirds of the Russian Federation. Several administrative regions of Russia with a total population of 5.4 million people have substantial assets in residential buildings, commercial structures and various types of infrastructure built on permafrost. Numerous studies show that following changing climatic conditions, permafrost degradation occurred in various regions of Russia threatening built-in environment and accessibility of industrial centers and remote settlements. Projected climate suggests that these changes will continue in the future. However there is a lack of quantitative estimates on cost of permafrost degradation to the regional and countrywide economy. This study provides a methodological framework to estimate the cost of permafrost under present and future climatic conditions.

Latest available economic and population data were used to estimate the percent of buildings, structures and infrastructure assets that are affected by presence of permafrost across nine administrative regions, including Komi Republic, Nenets AO, Khanty-Mansi AO, Yamalo-Nenets AO, Krasnoyarsk Krai, Republic of Sakha (Yakutia), Kamchatka Krai, Magadan Oblast', and Chukotka AO. Six GCM outputs from CMIP5 were selected to evaluate changes in climatic conditions between decades of 2006-2015 and 2050-2059 under RCP 8.5 ("business as usual") climatic scenario and as forcing to the permafrost-geotechnical model. The permafrost-geotechnical model was used to estimate two major infrastructure stressors associated with permafrost degradation: loss of bearing capacity of foundations of buildings and structures and ground subsidence effects on infrastructure in areas with ice-rich permafrost. The percent of assets requiring the repair due to permafrost related stressors was estimated for each state in 2016 RUB prices.

The total value of fixed assets in nine states affected by permafrost was estimated at 5.97 trillion RUB and residential real estate was valued at 1.26 trillion. Projected increases in permafrost temperature and the thickness of the active layer will greatly affect engineering properties of permafrost causing decrease in its ability to support structures and infrastructure. According to our estimates, the total cost of infrastructure impacts associated with the climate-induced permafrost changes in Russia will reach 2.52 trillion RUB by the mid-21st century, as 20% of existing structures, 19% of infrastructure and 54% of residential building will be affected.

Gas-emission craters puzzle - 4 years of investigations

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Gas-emission craters (GEC) were under study for 4 years since first reported in June 2014. We are presenting results obtained within the framework of the project funded by Russian Science Foundation №16-17-10203.

Various, often contradictory, ideas concerning the origin of GEC have been published recently, so there is a need to formulate the substantiation for our hypothesis, summarizing the facts presented in different publications of our team.

Some papers are hypothesizing the models of GEC formation by explosion of hydrolaccolith (bulgunnyakh or Pingo). The most consistent in defending this hypothesis are the researchers from Lomonosov Moscow State University (Khilimanuk et al., 2016; Buldovicz et al., 2018). Why do we not accept this hypothesis? First, saline marine sediments of Central Yamal provide poor conditions for the formation of large bulgunnyakhs due to a large amount of remaining unfrozen water. Second, even if cryogenic stress had occurred in the past, it is not clear how the warming may create conditions for the "explosion" of bulgunnyakh due to pressure in the water-gas core nowadays. Third, out of the 5 GEC, for which reliable field and remote-sensing materials were obtained, two GEC are located at the slope foot, two more in close proximity to the channels, and one more on the edge of the terrace. If close to the channels existence of sub-channel talik and its re-freezing can be assumed, in other cases such a talik is improbable.

Several known GEC formed in such different conditions that we should search for other mechanisms of their formation, which can be applied to all known craters. The mechanism we propose is based on the observed facts. One of these facts is high concentration of methane in the air of the crater at the first visit to GEC-1 and later detected in the water that filled all GECs. Second, isotopic analysis of methane from GEC showed its microbial origin. Observed is a decrease in the concentration of methane in the water of GEC lake with time. We conclude that the sources of methane are refreezing.

The essential object for understanding the nature of GEC is the mound-predecessor. It has been established by the dendrochronology that GEC-1 was formed on the place of a mound, which started growing approximately since 1947. Analysis of the Corona images suggests that the mounds have grown at a high rate over the past decades, and could not be the result of freezing of a sublake talik.

We suggest that dissociation of gas hydrates and the release of gases from frozen ground and tabular ground ice follow an increase in their temperature. Plastic gas-tight existed in the form of a thick layer of tabular ground ice, and obvious traces of ice deformation were observed. We should assume the existence of a collector in which gas accumulated up to the critical pressure and explosion of the mound. Such a collector could be a cryopeg. Acceptance of cryopeg in the GEC section can explain the existence of a pronounced niche in the lower and middle part of the wall of GEC-1, which had no explanations before.

Search for ancient GEC ran across complications. Modern GECs were filled with water and sediment from the walls very fast. The inner lakes are now shallow (no more than 4 m the deepest), of irregular shape, no more than 80 m in diameter. With such limited dimensions and depth, we expect their re-freezing. Secondary deepening due to thermokarst processes and new opening of methane emission sources is unlikely. Therefore, deep modern lakes with detected funnel-shaped depressions cannot be considered descendants of ancient GEC.

The main question is prediction of the possible appearance of new GECs, since they pose significant risks for reindeer herders, gas pipelines and railways. We consider the search for "gas-inflated" mounds, positive landforms that formed on a variety of surface elements, but grew fast, as the main method of mapping GEC hazards.

Preliminary Results of a Study the Frost Mound in the North of Western Siberia

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The frost mound (hill) and gas emission crater (GEC) are located near infrastructure of gas fields. In theory and the according to the data of remote monitoring, in the area prior to crater formation the frost mound has grown up in the bottoms of drained lakes (locally called hasyrey) and outside of this area. The new hill sometimes arosed around future craters. This testifies to the ongoing active gasdynamics with possible repeated gas emissions. Today there is no consensus among causes of explosion and generating crater at the collapsed hill site. This problem is paid special attention to geologists, cryolithologists, regional authorities, the indigenous population, gas companies.

From the cryolitological point of view, it is assumed that the crater are a natural stage in the development of the frost mound, and the water, which had frozen in the core of the frost mound array, was saturated with gas, which ignited or exploded only during the destruction of the hill. Gas was involved both in the growth of the mound in a hasyrey, and in the formation of a crater at the site of the mound, which was exploded during the discharge of mechanical stresses from the freezing water in the soil mass of the mound. At the same time, it is necessary to identify the source of gas in the rocks of geomorphological levels.

To solve the problem of the development of the hill, a comprehensive study is carried out: the confinement of the hill to the areas of gas-bearing structures, geomorphological levels, typical landscapes of the Yamal, Gydan, Taz peninsulas to develop a general understanding of the mechanism of formation of the hill and its transformation into a gas emission crater.

Today was performed:

- by topographic maps of a scale of 1:200 000 and published data from «TumenNIIgiprogaz», more than 1400 hills were revealed and the distribution boundaries of gas-bearing structures were shown.

- key sites (KS) with uneven distribution of hills and their highest concentration for a more detailed study on Yamal, Gydan, Taz were identified.

- the sections present the geomorphological structure and the already known craters that appeared at the site of the hills were marked.

- the density of the hills was calculated on the areas of gas-bearing structures and geomorphological levels. The results of calculations were presented in the form of maps and explanatory notes to each KS.

The first results showed:

- the density of hills on the east coast of Yamal is much higher than on the west;

- the connection between the area of gas-bearing structures and the density of accommodation of the hills is not obvious;

- most of the hills are located within the areas of Late Neo-Pleistocene lagoon-marine terraces;

- gas emission craters are located in the contours of gas-bearing structures of different groups within geomorphological levels of different ages.

To continue the complex of studies, it is necessary to identify potentially explosive hills of gas-bearing structures and the landscape conditions of their development within the Late Neo-Pleistocene geomorphological levels. The obtained data will give an idea of the formation of gas emission craters in the cryolithozone.

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A physico-mathematical model of the injection mounds of swelling (bulgunnyakh, pingo)

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For the first time the formation mechanism of hillocks injection (bulgunnyakh, Pingo) was explained V. I. Andreev (1936). From his point of view, the mounds are formed during the freezing of closed taliks under the drying up lakes, where an increase in hydrostatic pressure can cause a bend in the frozen roof of talik, leading to the formation of a hill. More than 80 years have passed since the article by V. I. Andreev, but nothing new has been said about the mechanism of growth of injection mounds.

However, taking the bend as the leading mechanism of formation of injection mounds of heaving, it is impossible to explain the features of their morphology – mainly flattened, and not in the form of a dome vertex surface and cryogenic structure –horizontal (without signs of Flexural deformations) occurrence of ice layers. But the most important thing is that the bending is stretching the frozen ground, which requires much greater deforming forces in comparison with such a deformation mechanism as shear. In the Proceedings of the 6th Canadian conference on permafrost study the results of tests of frozen clay soil tensile method of four-point bending depending on temperature. According to these data, the resistance of frozen soil to stretching (bending) is about 8 times (i.e. almost an order of magnitude) greater than the resistance to shear under similar permafrost-soil and temperature conditions. Given all of the above, it can be argued that the formation of injection mounds of heaving is not through the bend (as is commonly believed), but through the shift up the frozen roof of the freezing talik.

Taking the shift as a leading mechanism for the formation of injection mounds, the author developed a physical and mathematical model of their origin and growth. This model explains the features of the morphology and cryogenic structure of the mounds, and allows us to calculate their morphometric characteristics (the diameter of the top surface of the steepness of the slopes), depending on the lithology and soil temperature.

The model is based on the well-known condition of J.R. Mackay [Mackay, 1979], according to which cryogenic heaving is observed only if the resistance of thawed soil to compression exceeds the resistance to lifting of frozen soil:

$Q > F$ (1).

In expression (1) F consists of the weight of the frozen soil G and the strength of its deformation resistance U: $F = G + U$.

The injection slide is formed by a shift up relative to the rest of the frozen roof of the closed talik, a round block of frozen soil. Inside the block there is an inequality (1), and on the block boundary $Q = F$. Substituting in this equation the parameters that determine the values of Q and F, we can derive a formula for calculating the diameter of the frozen block D:

D, m = $4\tau/(q/\xi - 0{,}01\rho)$ at $q > 0{,}01\xi\rho$ (2).

q – specific overpressure in talik, kPa; τ – specific shear force at the contact of the block with the frozen roof talik, kPa; ξ – the thickness of the roof talik at the shear, m; ρ – the density of the frozen soil composing the block, kg/m^3. The value D is the diameter of the vertex surface of the hillock.

The growth of the hillock is carried out through a series of successive cycles. During each cycle there is a shift and the rise of the frozen block in the form of a disk, accompanied by the introduction into its sole under pressure of thawed soil (water), followed by its freezing and formation of the frozen core of the hillock. Each subsequent cycle occurs with an extension of the area of heaving (and, accordingly, the diameter of the hillock D) in comparison with the previous cycle. So the slope of the hill is formed, the steepness of which α can be calculated by the formula:

$\alpha \approx \mathrm{arctg}[(q/\tau - \mathrm{tg}\varphi)(100q/\xi\rho - 1)]$ $0{,}01\xi\rho \leqslant q \geqslant \tau\mathrm{tg}\varphi$ (3).

φ is the slope of the soles of the frozen roof of talik to the side of the hill.

Gas geochemistry of the ground ice samples from the exposure in Central Yamal

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Tabular ground ice widely distributed in Yamal Peninsula is of special interest due to its geochemical properties evidencing its origin. Activity of cryogenic processes since 2012 resulted in well-exposed geological sections enclosing ground ice of various types. One of such exposures in the area of Vaskiny Dachi research station, Central Yamal peninsula, is of special interest because of complicated character of the section with tabular ground ice body in the bottom, ice wedges above and peat plateau ontop. Tabular ground ice in the study section is represented by various ice facies including vitreous ice (without inclusions), bubbly ice (with easily observed gas bubbles) and stratified ice (thin vitreous ice layers interbedding with layers of icy deposits).

We analyzed a range of geochemical features, including permanent and hydrocarbon gases composition, ion composition of water, dissolved organic and inorganic carbon (DOC, DIC), in 16 monoliths of ground ice collected from the exposure during the 2017 field campaign. The samples were stored frozen until laboratory analysis and showed a vast variability in content of free gas and lithogenic fraction. We present here the results of gas geochemistry analyses.

According to our measurements, permanent gases in the free gas/bubbled gas fraction extracted from the samples are represented predominantly by nitrogen (varying from 86,5 to 98,8 %) and oxygen (5,6% - 17,9%). Methane concentrations do not correlate with the values of a gas bubbles volume, which suggests that methane is stored as dissolved in water.

Methane showed a wide range of concentrations from 6 to 1928 μM in 16 analyzed samples of both tabular ground ice and ice-wedge ice. Maximum methane concentration appeared in four samples from the lowermost part of the exposure represented by tabular ground ice (from 215 to 1928 μM). Stable isotope composition of methane in these samples demonstrates acetoclastic methanogenesis as predominant pathway (Whiticar, 1999).

Based on molecular composition of hydrocarbon gases C1-C5 we split our samples into groups, probably reflecting different stages of successive methane depletion (fractionation) while samples with anomalous methane indicate the source gas composition. The four samples enriched with methane make up two pairs 1708 (Stratified, high lithogenic fraction), 1733 (Bubbly), and 1706 (Bubbly with few lithogenic inclusions), 1730 (Bubbly), with more than 1000 and more than 200 μM methane concentration, respectively, each pair consisting of the samples from different parts of the section. One can see that neither methane concentration nor its isotopic signal (d13C values between −67 ‰ and -88‰) depend on the ice facies.

As result of this work, we may speculate about the common source of the high methane in the analyzed samples, which is predominantly in dissolved form. Methane enrichment of the ground ice may be due to either discharge of methane rich ground water, or is in-situ methanogenesis by archaea community operating at subzero temperature. We suppose that the potential for in-situ methanogenesis is supported by low free gas content in the frozen ground (always holding significant amount of oxygen as follows from our data), high content of the solid fraction responsible for anaerobic micro-niche formation as well as making up the water binding surface. However, we observe high methane concentration in different ice facies including those that contain huge amount of bubbled gas and low amount of lithogenic fraction. So based on our data we assume that contribution from in situ generated methane is minor.

The cryogenic origin of the Yamal phenomenon

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The subject of the report is the results of a study of a unique natural crater-shaped object in the central part of the Yamal Peninsula, carried out in 2015 by the research team of Lomonosov Moscow State University, Geological Faculty supported by Innopraktika and PAO NOVATEK.

Complex studies included field and laboratory investigations: detailed description the territory; drilling 20 m wells for the cryogenic structure study and sampling of soils and ice for determination of physic and mechanical properties; thermometric measurements; topographic works, a complex of geochemical and geophysical studies. Radiological measurements were conducted. Sampling of surface water, soil, frozen and thawed rock, free and adsorbed gases were carried out. Methane and carbon dioxide contents were determined in the wellbores using field gas analyzers and trapping of gases enclosed in frozen soil and ice were performed. Trace elements of soils and ice were determined by ICP-MS. Mathematical modeling of heat exchange processes in the rocks and assessment of the pressure required for a pingo destruction were performed.

On the basis of the materials obtained, the authors developed their own concept of a cryogenic origin of the Yamal Crater, explaining its formation by the process of cryovolcanic event on the Earth. Cryovolcanism is understood as the explosion-like effusive destruction of pingo with the eruption of a substance under the action of high cryogenic pressures as a result of freezing of closed water and gas saturated systems (a closed talik).

It was established that on the site of the crater the injection pingo took place. It was formed as a result of the freezing of the talik after the descent of the ancient lake, which was accompanied by the release of water and dissolved gases from the freezing front into the thawed zone and a significant increase in internal pressure. This pressure at some point led to the destruction of the layer of frozen soils, overlapping the residual part of the talik above. Evaluation of the pressure for the destruction of pingo with a 7–9 m thickness with physical properties of frozen soils leads to 1.0 MPa value. The process of destruction of the pingo was accompanied not only by the scattering of the frozen fragments of the “cover”, but also by explosion of thawed core, which was a water-ground gas-saturated mixture (possibly with some free gas) and formed a cylindrical crater.

As a result of solving a thermal modeling, it was found that the cylindrical shape of the residual talik is formed by the intensive lateral freezing of the initial talik during of decreasing of a lake.

Frozen sediments and ice are surprisingly rich in gases reaching 20 vol. %. The gaseous component in sediments near the crater differs markedly from natural gas of the Bovanenkovo field in the concentrations of carbon dioxide, nitrogen, hydrogen, and methane homologs. The carbon isotope composition of methane is typical of biogenic hydrocarbons ($\delta^{13}C$ = -76‰ PDB). This difference disproves the hypothesis that the gas in the crater would come from deep Bovanenkovo reservoirs. Prevalence of high normal alkanes (above $C_{19}H_{40}$) indicates that the hydrocarbons are derived from buried plant remnants.

The study of the chemical composition showed the difference in the distribution of chemical elements between the mineral component of the soil and ice inclusions, associated with the talik freezing front. These features allowed us to establish the boundary of the ancient lake.

The available materials show that the freezing talik before explosive destruction contained a large amount of water saturated with gas, predominantly carbon dioxide. This is due to a peculiar mechanism of cryogenic separation of gases. During the freezing of the pore water, the gas mixture dissolved in the ice is displaced from the formed ice, while part of this gas is fixed in ice in the form of macro-inclusions (bubbles), and the soluble components of the gas mixture (primarily carbon dioxide) dissolve in the liquid phase inside talik. This is facilitated by the ever-increasing pressure during the freezing of a closed soil volume of rocks.

At a low temperature on the talik surface, in the presence of a long-lasting pingo, the frozen cap turned out to be too thick to break down under hydrostatic pressure. Calculations show that the pressure of the talik core under a 6-8 m thick cap, required for the breakdown of such a cap, is about 1 MPa. This pressure is close to the invariant point in the H_2O-CO_2 system (P = 0.982 MPa; T = -1.4 °C) at which liquid water can coexist with ice, carbon dioxide clathrate and gaseous carbon dioxide. The formation of carbon dioxide clathrate is especially possible at the bottom of the talik core where pressure may reach 1.5 MPa.

The estimates have shown that the explosive destruction of the pingo is not related to the climatic anomalies of individual years. The explosion itself, presumably, took place in several stages. At the first stage, gas is predominantly ejected from the upper part of the talik and scattering of the frozen fragments of the “cover”. At the second stage of the eruption, degassing (“boiling”) of water filling the talik, accompanied by an intense outpouring of the water-soil mixture from the crater. The final stage of the eruption is the release of gas from the thawed soil both by degassing the pore solution and, possibly, due to the decomposition of carbon dioxide hydrates.

Insolation Periods of Climate Change as a Means of Solving Cryospheric Puzzles

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Many processes on Earth, including weather and climate, are determined by the heat of the Sun. Day is replaced at night due to the rotation of the Earth around its axis. Winter comes to replace summer, because the Earth is orbiting around the Sun and its axis inclines to the orbit's axis of the angle 23.4°. Because of these movements, the length of the day along the latitude of the Earth varies from 24 hours to the polar night.

The orbital and rotational movements of the Earth create the contemporary climate on the Earth. However, the parameters of these movements change over the times of tens thousands years and the climate becomes other. For example, the angle of inclination (obliquity) varies from 14.4° to 32.4°. With a small angle of obliquity it is observed a cooling at high latitudes, and with a large angle the warming occurs. For example, 32.28 thousand years ago (ka) with an angle of 32.1° the heat per year at high latitudes is twice more than 46.44 ka at the angle of 14.8°. In these two epochs, in the summer half of the year also doubles the heat more at high latitudes.

However, in equatorial latitudes, the changes are completely different and even reverse in direction. For example, in the warm epoch of 32.28 ka the annual heat is less by a quarter than in the cold epoch of 46.44 ka. In such cold epochs, as 46.44 ka, at latitudes of 53.4° and more the heat in the summer half year is less than now at the pole. Therefore, the snow does not melt over the summer, and in such cold epoch the ice cover forms in high latitudes, i.e. the ice age comes.

What is interesting are the winters in the ice age. They are warmer around the globe than during the warm period. The Warm winters, the warm oceans in winter it is lead to an increase in snow precipitation, which further contributes to the growth of ice caps.

And in yhe warm epochs, for example 32.28 ka in the summer half year, even at a latitude of 80°, there is more heat than now at the equator. Therefore, all ice sheets on the continents are disappearing, and in Greenland and Antarctica they are greatly reduced. At the same time, winters are cold, so little falls during the winters, and glaciers are not restored.

What is interesting is the polar circle. In the warm epoch, it descends to the latitude of the Tyumen, i.e. polar days and polar nights come here, and at the same time it is warmer in summer than at the equator. That is, the Earth's climates are becoming others, and such that no one could even imagine.

Therefore, it becomes clear why the past of the Earth consisted of a number of puzzles, for the solution of which the researchers put forward as many presumptions and hypotheses as there were the researchers. New Astronomical Theory puts an end to these hypotheses. All extremums of insolation are timed to within a few minutes and for 200 ka numbered. Insolation periods of climate change are defined. They coincide with paleoclimate changes according to its study for 50 thousand years. Therefore, the insolation periods are a reliable means for solving cryospheric puzzles.

The study of the transformation of the permafrost zone in a changing climate (projects of the Arctic Research Center of the Yamal-Nenets Autonomous District)

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Since 2016, in the Yamal-Nenets Autonomous District, the Arctic Research Center together with relevant academic institutions and universities has been implementing a number of projects to study the transformation of the permafrost zone and the spatial and temporal variability of the glaciers of the Polar Urals in a changing climate.

Project: Study of the transformation of the permafrost zone under the influence of climate change and anthropogenic load on the basis of the monitoring network of the Gydan Peninsula.

Over the past three years, scientists are engaged in the resumption of research at the scientific field station Parisento, working from 1985 to 1991. Researches include: drilling of permafrost-parametric wells in order to obtain long-term series of observations of the temperature of soils; detailed electrical exploration work on the study of reservoir and cavern-lode ice; surface water analysis in lakes and rivers; drawing up a modern lithological-geomorphological map, etc. Also, after a 30-year break, the temperatures of permafrost soils were measured. For example, in various landscape conditions, at a depth of 10 meters, the temperature of permafrost has increased by 2, and somewhere even by 3 degrees Celsius in 30 years.

Project: Creation of an integrated system for automated geotechnical monitoring of temperatures of permafrost soils in the city of Salekhard.

The idea is to place a network of thermometric wells (10-12 m) under engineering objects to observe the degradation of the permafrost zone and the effectiveness of the methods used for temperature stabilization of permafrost soils of the bases. It is supposed to conduct automated data collection from wells using GSM/Wi-Fi modules. The incoming information will be displayed on the Salekhard map online.

Today, thermometric sensors are installed in six wells, which are located under two high-rise buildings and one building in disrepair in Salekhard. A year-round data recording is performed in "once a day" steps at depths: 0; 0.5; 1; 1.5; 2 - 12 meters.

Project: Monitoring the depth of the seasonally thawed layer and landscape research at the CALM (Circumpolar Active Layer Monitoring) site.

For three years, scientists have been carrying out work on monitoring the seasonally thawed (active) layer at the site, near the village of Kharp. In connection with the degradation of permafrost in recent decades, data on its modern evolution are of heightened interest for predicting future changes. Thus, for three years of observations at the monitoring site, the size of thawing ranges from 94 to 99 cm. It is noted that on average in Western Siberia, the seasonally thawed layer increased by 30 cm in 10 years of observations.

Project: Current climate change, glaciation and monitoring of the glaciers of the Polar Urals.

As a result of many years of complex glaciological work in recent years, intermediate results have been obtained:

the glaciers of the Polar Urals continue to decline at an increasing rate, which depends on the morphology and feeding conditions. The most stable are niche glaciers;

the reason for the reduction is the continuing increase in air temperature, to which a decrease in precipitation has been added in the last decade.

Geocryological research in the Mesozoic basins of Aldan shield

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South Yakutia has significant economic potential. On the territory of the Aldan shield are concentrated large deposits of coal, rare and precious metals and other minerals.

Explored mineral deposits are located in the permafrost zone and deeper than it, which creates the need for a detailed study of the problem of geographical distribution, the dynamics of the development of permafrost and the geothermal parameters.

There are geological and hydrogeological wells with a depth of 500 to 1200 m, some of which have already been surveyed, within the limits of the Chulman, Tokarikan, Guvilgra, Ytymdzha and Tokin basins and in adjacent areas. As a result, unique data were obtained on the temperature regime and thermophysical properties of the rocks of the region, which served as the basis for calculating geothermal gradients and heat fluxes.

Winter temperature inversions have a significant influence on the formation and variegation of geocryological conditions and the temperature of rocks, at which cold air is blocked in low relief areas. The permafrost formed under such conditions was called the Chulman type of freezing. Based on this, later on, when conducting research in single-morphological structures (Mesozoic basins), it was decided to consider geocryological conditions from similar positions on the basis of analogs. However, an analysis of the data obtained from geothermal studies in the depressions revealed significant differences in the formation and regime of permafrost rocks. Different permafrost thickness, its temperature parameters, different thermal conductivity parameters confirm them.

Separate specificity in the formation of geocryological conditions is made by the strong dissection of the relief, as well as by the block structure of the crystalline basement structure, which determines the heat flux values. Within the valleys it varies from 43 to 65 mWt/ m^2

It is also necessary to note the influence of coal seams, which introduce certain subtleties in the zoning and characterization of frozen rocks. As is well known, coal massifs have high heat capacity and low thermal diffusivity, as a result, in some areas they can either prevent more intensive freezing of the Earth's mass, or, as a result of global climate change, keep it at a low temperature.

In 2008–15, work was carried out on the creation of relief areas and monitoring sites for the temperature of soils in selected areas. To date, there are a number of observations on the terraces and watershed areas. Deciphering satellite images, dividing the territory of the depressions according to different landscape conditions, in the future we plan to characterize geocryological conditions using data from key sites.

Thus, the existing range of regime observations made in recent years, the characterization of the thermophysical properties of the main types of rock sections, the analysis of the temperature data of rocks with the nearest weather stations, for the first time in the region, will allow characterization of permafrost. It is also necessary to perform a quantitative assessment of the role of natural factors (dynamics of snow cover accumulation, composition of sediments, terrain relief, etc.) on the formation of the temperature field of rocks in this complex geological and structural area.

Permafrost Degradation in the Western Sector of Russian Arctic under Climate Change

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According to the results of permafrost monitoring in the western sector of Russian Arctic obtained in 1975-2017 by the Tyumen Scientific Center of SB RAS, dramatic changes in permafrost conditions of this region have occurred. Based on observations within the bioclimatic zones of typical tundra, southern tundra, forest tundra, and northern taiga, we detect a new natural phenomenon: wide-spread degradation of permafrost with formation of the lowered permafrost table at depths from 3 to 10 m and occurrence of thin frozen layers, which may remain frozen for one or several summers. This new phenomenon still needs to be studied because we do not have sufficient information on its geographic boundaries and processes of its formation and evolution. However, we may conclude that the continental permafrost in the study area is not stable anymore as a result of changing thermal conditions and properties of degrading permafrost, including decrease in bearing capacity of frozen soils, migration of boundaries of bioclimatic zones, and changes in conditions of traditional land use.

Similar changes affect submarine permafrost. As a result of climate warming and 0.5 to 2.5°C increase in bottom water temperature during the last decades, rates of the permafrost table lowering in the Kara Sea and south-east part of the Barents Sea have significantly increased, especially in the areas with shallow position of the permafrost table. Degradation of submarine permafrost changes its boundaries, thermal regime, and properties. It also results in changing conditions of land use (first of all, for oil and gas industry).

We present the results of a long-term permafrost monitoring obtained at several locations: Kumzha Island, Cape Bolvanskiy (European North of Russia), Marre-Sale (western Yamal), Northern and Southern Urengoy, and the city of Nadym area. Based on these results, the main features related to permafrost degradation were determined, including lowering of the permafrost table with time, decrease in depth of zero annual amplitude, formation of zero curtain, and transition of mean annual ground temperatures from negative to positive values.

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Distribution and dynamics of permafrost in the floodplain of the Pechora River. Results of complex geocryological and geophysical monitoring

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The territory of the Nenets Autonomous Region is about 176000 km2, and 93% of this area is located in the cryolithozone. Large river Pechora has a significant warming effect on the permafrost state in the region. The remaining fragments of the low floodplain or alluvial-sea terraces in the Pechora Delta are locally developed, and there the Islands of permafrost are still preserved. These include the island of Kashin in Korovin Bay (the remnant of the II alluvial-sea terrace with elevations of 6-10 m) and the outlier of the I alluvial-sea terrace between the channels of the Pechora with elevations of 4-7 m, on which is located the preserved area of exploration drilling Kumzhinskoe oil&gas field. Below the surface everywhere overlain by sands, sometimes covered with a thin peat.

Monitoring of the geocryological conditions of the floodplain and the remains of the II and I terraces in the Pechora Delta has been carried out since 2009 on two sites - Kashin and Kumzha. Both sites are located in the southern tundra, in the area of sporadic permafrost distribution. In their territory there are two sites for ALT-monitoring (CALM) and 8 operating temperature boreholes up 10 m deep in different cryogenic landscapes. Basic information about the geocryological conditions of this territory was obtained as a result of drilling shallow boreholes (from 3 to 10 m), testing of thawed and frozen grouds, thermometric observations at special sites and boreholes, as well as a complex of geophysical works (georadiolocation and seismic exploration). The results of geocryological and geophysical monitoring at the sites allowed to obtain important conclusions and the state and dynamics of unstable rare-island permafrost in the Pechora delta in the conditions of modern climate warming:

- Seasonal fluctuations in the grounds temperature within the frozen areas are limited to the active layer, their thickness does not exceed 3 m, and below the permafrost temperature is close to 0°C. The permafrost depth ranges from 5 to 30 m according to geophysical methods.

- The permafrost table of the closed taliks lies at the depths up 4-5 to 9-12 m. Joint analysis of geophysical studies showed that the average increase in the occurrence of the permafrost table in 2015-2018 was about 0.6 m.

- As a result of our research in 2016-2018 the extensive factual material was collected and new scientific approaches were developed. The short-living permafrost layers within closed taliks in the island permafrost zone found at the depths 2-2.5 m, which in the warm summer completely thaw.

- Seismic survey is used as a reference method to identify the main geocryological boundaries of the study area and provides a reliable definition of the depth of the lowered table of the permafrost. With the GPR studies the operative determination of the active layer depth, detailed dissection of the lithological section, as well as tracing short-living permafrost layers and interlayers in the upper parts of the section is carried out.

Our research is being conducted for the state assignment, according to the research Plan, Tyumen scientific center SB RAS in 2018-2020, Protocol №2 from 8.12.2017 (Priority IX.135. Programme IX.135.2 Project: IX.135.2.2. «Changes in the lithosphere and landscapes of the cryolithozone of Russia under the influence of climatic and anthropogenic factors: global, regional and local components of spatial and temporal variability»). Expeditionary work was performed with financial support from the RSF (project 16-17-00102).

Ice complex in the Debin and Susuman river valleys (Cherskiy Range)

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The distribution and cryolitological structure of the Ice Complex deposits (IC) in mountain regions of North-Eastern Russia is studied very poor. These ice-rich syngenetic deposits with wide ice-wedges are known in river valleys around gold minings, but they have not been practically studied.

In the summer of 2018, field studies of the IC in the open-cut minings in the Debin and Susuman river valleys were conducted. Those rivers are the left tributaries of the Kolyma River. IC was traced in the upstream of riv. Debin for about 40 km along its valley. In the Susuman river valley IC studied in the area of creeks Lukich and Ambardakh. The studied area belongs to the continuous permafrost zone with mean annual ground temperatures of -7...- 9°C.

IC deposits are opened in open-cut minings near the surface of II river terrace of the river Debin. It lies above the channel facies of alluvium, represented by gravel-pebble material. Sometimes peat lenses from the latter separate it. The thickness of the IC in the upper reaches of the valley is 3-4 m, downstream it increases to 10-15 m. The IC deposits are represented by silty, gravelly sand, sometimes include admixture of rubble and poorly rounded pebbles, plant residues. The cryotexture is thick layered (ice belts). Ice wedges have a vertical size up to 10 meters or more, a width up to 2-3 meters and a size of polygons of 10-15 meters.

IC deposits overlaid by layer of peaty loams with peat lenses and numerous inclusions of gravel. Layer thickness is 3-4 m. It's divided by thaw unconformity cryogenic contact. This layer contains an independent generation of ice wedges up to 2 m wide, usually penetrating below Ice Complex top.

IC deposits also occur in the upper part of section II river terrace in the Susuman river valley. It can also be traced on the banks of streams flowing into the Susuman River and on adjacent gentle slopes of the watershed. IC thickness decrease upwards of watersheds. IC is represented by silty and gruss sands with a thickness of up to 15 m. The width of ice wedges is 2-3 m; their thin ends penetrate into the underlying deposits. On dredger polygons, the surface of which is cleared along the roof of channel alluvium, there are irregularly shaped tetragonal polygons with a diameter of 15-20 m. The IC is covered by cover layer deposits with a thickness of 1-2 m.

Cryolithological conditions and structure of IC deposits in the Debin river valley allow to suggest that IC deposits are overlapped by Holocene sediments with an independent ice wedges, whereas in the Susuman river valley this horizon is absent. According to geological conditions and composition of the deposits, first of all, a significant amount of coarse material from gravel to pebbles, it can be argued that the IC deposits in the valleys are flood plain alluvium, which were formed simultaneously by significant amount of material from slopes surrounding watersheds. This is also indicated by graded relief of inner margins of II floodplain terraces. From geomorphological point of view IC deposits form altiplanation terrace (terrasouval in Russian) in the river valleys and they can be considered as alluvium-deluvium (alluvial-slope) deposits

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Modeling of thermal abrasion coastal dynamics at the Kara Sea

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The coastal zone of the Arctic seas is characterized by high dynamism due to the presence of permafrost, where the state and stability of soils depend on the temperature regime. Many environmental, climatic, geologic, biologic and anthropogenic factors influence the coastal erosion rates (soils erodibility, fractures, adjacent bathymetry, cliff lithology, waves, wind, vegetation, etc.).

Complex study and research development patterns destruction processes of the coast, as well as investigations the different factors contribution in these processes will enable in the future to use the data for engineering and economic objectives, for example, to produce permafrost and geotechnical forecasts and estimations.

For better understanding destruction processes especially though thermal denudation the potential thickness of active layer were performed using numerical methods using software Qfrost (finite-element model). The model is based on the heat balance equation and the Stefan formula (in enthalpic form). During the simulation the heat transfer coefficients and the air temperature have been take into the model. Climatic parameters were used according to weather station Marre-Sale and ERA Interim reanalysis data. According to hydrometeorological data two different period can be selected: thermal action is about 20% higher in 1995-2017, than in 1973-1995. Also the period from 1995 to present day is characterized by increase in wind-wave energy. Numerical simulation of coastal erosion rates has been done for these periods. Hydrometeorological factors of the Arctic coastal retreat include first of all the thermal regime of the territory, which determines the thermodenudation intensity, and the energy (wind-wave) regime that determines the thermal abrasion intensity and removal of thawed material from the beach. As we know snow bank at the high terrace blocks the slope during first half of summer. Since erosion rate, caused by thermodenudation, strongly depends on slope cleaning process, we simulated different regimes of removal of the thawed layer. Applied for simulations physical soil's parameters were obtained via laboratory tests of the soils samples collected in the field. Clays, silts or sands were as ground materials in the model. Based on previous our research average annual erosion rate of Kara Sea from 2005 to 2016 ranges in interval 1- 3 m and reaches 4-5 m for particular years.

Numeric experiments with resection of the thawed soils indicated that coastal retreat strongly depends on the ice content and cleaning mode of the slope. The highest erosion rates were obtained when thawed material was resected immediately after the thawing. The estimated rates ranged between 1.7 and 7 m for sandy coasts and between 1.1 to 5 m for silty and loamy bluffs. Observed data and results of simulation correlate well. These results demonstrate the crucial influence of slope cleaning mode, ice content in the soils and their reaction under climate changes on the erosion rates caused by thermodenudation.

Cryostratigraphy of the upper horizon of permafrost at the post-fire sites in vicinity of the town of Chersky

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Large-scale development rates along with current and forecasted climate changes make the Arctic ecosystem extremely vulnerable to emergency situations that can cause irreversible damage to the environment. Technogenic effects of various types (fires, removal of vegetation, etc.) lead to changes in geocryological conditions, including the thermal state of landscapes and the development of negative cryogenic processes. The most unpredictable factor is forest fires, which are often the result of human activity. The reaction rate of permafrost to the effects of fires depends on the cryolithological structure of the underlying sediments and fire intensity. Disturbed permafrost landscapes of highly icy sediments that are ubiquitous in the territory of Kolyma lowland are most actively reacting.

In the Chersky, Kolyma lowland area, in 2018 were drilled and equipped by temperature logger two 10-meter boreholes (Bh. 18/2K and Bh. 18/3K) in the field of 70- and 30-year post-pyrogenic successions developed on edoma surface. The goal is to study the impact of forest fires on the degradation of high icy permafrost.

Bh. 18/2K is located on the smooth hillside of the northern exposure of the valley Komarok stream, 5 km to southeast of the village Green cape. The absolute elevation of the bh - 34 m (GPS altimeter). Seasonally thawed layer – 0.8 m (as of 20.09.2018). The surface is horizontal, slightly inclined, small-bumpy. Surface is covered by litter from the needles of larches (up to 4-6 cm), birch leaves, willows and, rarely, deciduous shrubs in varying degrees of decomposition. The plant cover of moss-and-lichen cover reaches 95%. Bh. 18/2K are represented by sandy and clayey aleurites with a coarse silt content of 44.5–64.3%. Sediments are permeated by a net of thread-like roots and plant macro-residues in the form of fragments of wood, irregularly distributed gley spots are noted throughout the section, ferruginization is observed in the upper part of the section. The sediments are characterized by high ice content, massive, micro-thin-, thick-drawing, ataksitovaya, basal cryostructures (thickness of ice less than 0.1–20.0 mm). Ice wedge in the section is observed in the range of 1.7-5.9 m.

Bh. 18/3K is located 0.7 km to the north-west from the Bh 18/2K, on the watershed of the edoma (altitude of 40 meters above sea level) reveals deposits of the ice complex. Seasonally thawed layer – 1.0 m (as of 20.09.2018). The soil surface is covered by thick litter of needles of larch (4-5 cm) and foliage of shrubs in varying degrees of decomposition, as well as fragments of burnt wood are observed. The plant cover of moss-and-lichen cover reaches 90%. The mineral part in section is observed to a depth 1.6 m and is represented by gray silt, brownish-gray with fraction content of 0.05-0.01 mm - 47.7-54.7%. Sediments are characterized by low ice content, massive and thin cryostructure. Ice wedge is observed from a depth of 1.6 m to the bottom.

Studies have shown that forest fires in the considered areas of post-pyrogenic successions underlain by the ice complex did not initiate the thermokarst processes. Appearingly, ground subsidence began to develop on the surface, but inroad of water did not occur in virtue of the high drainage of the sites.

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Activation of cryogenic processes in Central Yamal as a result of climate change and thermal state of permafrost

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Abnormal weather conditions over the past few years significantly affected increase of activity of cryogenic processes associated with ground ice thawing in Central Yamal. Air temperature rise resulted in increased warm season thawing reaching the top of ground ice. Thus thermodenudation started and caused formation of thermocirques. Climate fluctuations also lead to increase of ground temperature, which triggers gas-emission crater (GEC) formation through decomposition of methane clathrates up to formation of high pressure under the tabular ground ice layer until it breaks.

The warm season thawing dynamics was studied along four grids with various surface features in the research station “Vaskiny Dachi” in Central Yamal within the framework of CALM program. All types of surface are characterized by a significant deepening of active layer in 2012 compared to the previous period 1993-2011 by 12-20%. Even larger deepening of active layer was observed in 2016 (by 24-37%). Years of 2012 and 2016 are characterized by the highest thaw index and the largest sum of summer precipitation. Thus, an increase of summer air temperature and amount of summer precipitation influenced the formation of thermocirques through warm season thawing increase.

To explain the reasons for the GEC formation, ground temperature data obtained within the framework of TSP program were analyzed. Dynamics of the measured temperature at different depths in thermometric boreholes located in different landscape and geological conditions (from sparsely vegetated sands to shrubby clay) were considered.

Analysis of climatic parameters showed that there is a warming trend over the period from 1947, the expected year of the beginning of gas release within permafrost and the growth of the mound (Arefyev et al., 2017). The mean annual air temperature increased from the beginning of the mound growth and the date of formation of GEC (66 years) by 1.7°C. The ground temperature is more influenced by winter air temperature and the sum of winter precipitation. From 1947 there is increasing trend of the winter air temperature till 2013 with the highest value in 2012. Trend of the sum of winter precipitation was not observed.

The mean annual active layer temperature tends to substantial increase in 2012 and 2016. Also, there is a significant increase of the ground temperature at 10 m depth, starting from the moment the borehole was established (the growth over 5 years is 0.5°C).

The current temperature of the permafrost near GEC-1 is from -1 to -5°C (Buldovicz et al., 2018). Measured in August 2015 ground temperature at 10 m depth in the boreholes near GEC-1, was from -4.3°C on shrubby upper part of slope to -2.7...-1.6°C on khasyrey and thermokarst lake coast, and to -1.2°C in the nearest vicinity of GEC-1 edge. An approximate calculated temperature gradient near GEC-1 is 1°C. According this the ground temperature at 70 m depth must be -0.5°C. A regression analysis was carried out to reconstruct the ground temperature in earlier periods of time in the years preceding the appearance of GEC. It was found that the mean annual ground temperature increased by approximately 0.4°C at the shrubby landscape most similar to that around GEC. It follows then that in 1947 ground temperature at a depth of 70 m was -1°C, which corresponds to our observations of the temperature at which ice lenses exist in saline clay. Most likely, ground temperature increase in the clay from -1 to -0.5°C provoked increase of unfrozen water content, provided permeability of clayey deposits to migration of gas and its accumulation under tabular ground ice.

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Alpine permafrost geothermal zonation in the Udokan ridge (Zabaykalsky Krai)

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The study area is located on the watershed of the Chara and Naminga rivers on the northwestern slope of the Udokan ridge and is mainly tied to the river Lev. Nirungnakan, adjoining the Chara basin.

In the summer of 2018, a landscape description of the territory was made in order to typify the area to create a map. In route studies on the right bank of the river. Lev Nirungnakan, Emegachi pass, near the brook. Belenky, in the valley of Nizh. Ingamakit stratificated the plant composition of the area by vertical structure.

Within the watershed (<5º) surfaces grows: rare larches with deadwood in tree layer, dwarf birch with marsh ledum in shrub layer and reindeer moss and moss in moss layer.

On the slopes of watersheds (<5º-<20º), the larch forest grows with alder, dwarf birch and marsh ledum in shrub layer and moss-cowberry soil cover. In the river valleys grows a mixed larch-spruce-birch forest with undergrowths of main trees and moss-cowberry-grass cover. There is no vegetation in the alpine belt. Tree line is located at an altitudes of 1100-1300 m on the northern slopes of the northern exposure, at an altitudes of 1300-1600 m, on the southern slopes of the south-western exposure.

The area belongs to the zone of continuous distribution of permafrost with average annual temperatures from -6°C to 1°C (from reports of the Integrated Expedition of the Baikal State University, 1984, 1989; reports of production companies; data of the IEG RAS researcher D.O. Sergeev). It is characterized by the presence opened and closed underfloor and floodplain taliks. This territory is characterized by absolute heights from 700 m in close proximity to the Chara River up to 1800 m between the Naminga and Nizh. Ingamakit at their tributaries brooks Skolzkii, Uchelistii, Zaozerny, etc. According to numerous data, there is a definite correlation between the average annual temperature of the permafrost and the altitude of the measuring point: the average annual temperature of the rocks increases with increasing altitude. This can be attributed to the formation of the inversion distribution of air temperature in winter, due to which January air temperature at 708 meters (Chara) is 9°C lower than at 1570 meters (Udokan). Because of this, the average annual temperature of rocks in the valley of the Chara River is 2°C lower than at the watershed. Together with relatively thin snow cover, this can lead to the fact that the average annual temperature of permafrost in the valleys is lower than at the watershed.

Dendrochronological analyses of tundra plants in the Lena River Delta (Siberia)

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Tundra plant habitats are exhibited to transformations associated with climate change. These lead to changes in vegetation composition as a result of plant adaptation (or growth limitation) to current environmental conditions. Contemporarily it is observed in the Arctic as a process of the so-called "greening", but various factors and their interrelations may lead to great heterogeneity, both in space and species. To extend the possibility of environment reconstruction and assessment, we find a great advantage of investigating tundra shrubs annual growth rings, which can be used to study for e.g. growth-climate relationships.

The sampling campaign was performed in August 2018 in the south-central part of Lena River Delta (72°N, Northern Yakutia, NE Russia), based on the logistics of Samoylov Island Station. Study sites were located on Samoylov and Kurungnakh Island, and northernmost part of the mainland, in the coastal area of Verkhoyansk Mountains. In order to estimate dendrochronological potential of tundra plants in the study area the following species were sampled: Salix spp., Betula nana, Rhododendron adamsii, Alnus and Larix.

The common procedure of analysis was to collect from 10 to 20 shrubs (entire plant) for each site and species. On each shrub serial sectioning was performed, including above- and below-ground parts (i.e. root, root collar, stem, up to two main branches). Thin-sections were prepared from each woody specimen using a sledge microtome. First inspections of shrub micro-slides are allowing to count on the age of selected plants. The most advanced age, up to now, was observed for Rhododendron adamsii, which was found to be over 90 years old. Future studies will aim to link both shrub growth rings and wood anatomy to selected geomorphological processes, such as spring river flooding and permafrost lake draining events. Lena River spring floods may increase the water level by more than 7-8 m, carrying ice floes and transforming islands surfaces and covering plant habitats. Surviving woody specimens are holding visible scars, which may be dated by dendrochronological analyses. The dwarf (i.e., less than 40 cm tall) Larix trees, found on southern Kurungnakh Island (72⁰), for our knowledge, may be recognized as one of the northernmost growing trees in the Northern Hemisphere. First analyses highlighted that some Larix individuals reach over 50 years of age.

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Sorption interaction of acetic and chloro-acetic acids with quasi-liquid film of ice

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Ice is an important component of the natural environment. In natural conditions, its presence is due to negative temperatures existing in the moisture-containing systems. Ice is present as inclusions in permafrost rocks or an independent component in glacial systems. Soluble indicator chemicals move to the surface from different depths in permafrost due to migration through unfrozen water films. Taking into account the composition of permafrost, it is possible to distinguish water films that exist due to the adsorption properties of mineral and organic rock components and the so-called quasi-liquid films on the surface of ice inclusions. If a noticeable degree of salinity is, unfrozen films can include a layer of bulk aqueous solution substances.

To estimate its influence on migration processes, it was necessary to study the physico-chemical properties of the film. By sorption from solutions in hydrophobic solvents, it was established that organic substances (methanol, ethanol, carboxylic acids with the low molecular weight) having a high partition coefficient between water and the phase of the organic solvent pass into the quasi-liquid film from the solution.

The presence of a transition layer was also established at the ice-water interface when studying sorption molybdate anions from an aqueous solution. The addition of a magnesium salt facilitated the sorption of molybdate anions, while the addition of ethanol lowered it. In the latter case, the authors hypothesized the influence of the hydrophobic part of the alcohol molecule on the "strengthening" of the water structure in the film, as well as the adsorption of polar molecules of ethanol on the surface of ice particles. The latter was confirmed by the aggregation of ice particles in aqueous solution if ethanol was added. The assumption of such behavior in a system of organic matter with polar molecules required experimental verification.

Acetic and chloroacetic acids were selected for sorption experiments. Three sections are evident on the isotherms of sorption of these acids. The first, similar to experiments with solutions in hydrophobic solvents, should be associated with the transition of acid molecules from the aqueous solution into a quasi-liquid film of ice. The subsequent increase in sorption may be due to the thickening of the transition film due to the additional melting of the layers of the solid phase of ice adjacent to the quasi-liquid film. If the acid concentration increases further, the acid molecules are adsorbed on the surface of the ice particles. The difference in adsorption isotherms for two acids can be due to their different relation both to the components of the solution and to the quasi-liquid film itself.

West Siberian geocryological transect: a new site in the northern taiga

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In the 1970s, a regional geocryological transsect of observation sites was organized in Western Siberia to study the spatial and temporal variability of permafrost. Transsect is replenished with new sites to cover all climatic zones from the Northern Taiga to the Southern Arctic Tundra, as well as to observe the latitudinal variability. The temperature of the permafrost and the thickness of the active layer are measured. Since the 1990's the measurements, coordinated with international TSP and CALM programs.

In 2006, a new observation polygon was organized in the Northern taiga (left bank of the Pur river, 18 km west from Tarko-Salé town, discontinuous permafrost, minimum ground temperature -2°C, average annual air temperature -5.7°C). The depth of boreholes is 30 m. However, only one cycle of measurements was carried out. It showed that at a depth of annual zero temperatures variation (~10 m) the temperature was: (1) -1.7°C on a flat, smooth peatland; (2) -0.4°C on a near river peat-covered ridge; (3) +2.0°C in a medium-dark larch-spruce-cedar forest (no permafrost).

In 2018, the CALM site was organized and the temperature measurements according to the method TSP were renewed here. On the peatland and in the forest, which have not changed their landscape appearance, the temperature of the soil remained the same as in 2006. On the near river ridge the open cedar-larch forest has grown for 12 years As a result, the permafrost temperature increased to -0.2°C, and the permafrost table descended to 4 m depth.

The CALM site was placed on a flat, smooth peatland with an area of 5.5 hectares (130 × 350 m), near the geocryological borehole. The peatland is located within old drained lake (“khasyrey”). The peatland and the bottom of the “khasyrey” is well expressed in the relief. The excess of the surface of the peatland over the bottom is 2.0-2.5 m. The CALM grid size is 100×100 m. Distance between measuring points of active layer is 10 m.

Vegetation cover by dominant species divides into five types of plants community.

1. Lichens and dwarf shrubs such as wild rosemary prevails in the central smoothest part of the peatland. The number of measuring points of the active layer was 45.

2. Dwarf birch (“ernik”) grows on the edge of the north, east and south-east sloping surface of the platform. The number of measuring points of the active layer was 41.

3. The transient type of vegetation cover between (1) and (2) sporadically revealed on a slope surfaces. The number of measuring points of the active layer was 23.

4. Carex, cottongrass and sphagnum moss with rare lichen community revealed on a flat surface with reduced microrelief. Measurements of the active layer were carried out in 13 points.

5. Sphagnum mosses prevail on a small area on the northeast side of the platform. The active layer was measured in 3 points.

The depth of the active layer was measured totally at 121 point. The average depth of the active layer is 47 cm. The active layer in 89 points less than or equal to 50 cm, in 28 points – 70 cm, more than 70 cm – 4 points.

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Comparison of temperature data in boreholes at the Parisento field station (august 1986 - august 2018)

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The territory of the Gydan Peninsula is one of the less developed and underexplored areas. To implement plans of environmentally safe commercial development of Tazovsky District in Yamalo-Nenets Autonomous Okrug, one requires an assessment of a current state of the Gydan Peninsula cryolithozone and monitoring of the cryolithozone conversion under the influence of climatic changes and human-induced load in all terrestrial subsystems of the peninsula. This will make it possible to improve design techniques of field facilities and hydrocarbons transportation systems placed in complex engineering geocryological conditions to ensure their mechanical safety and reduce geotechnical risks through increasing design performance as related to the development of activities on implementing technologies of temperature stabilization of bottom soils, geotechnical monitoring, and other advanced technologies.

One of key tools for monitoring the cryolithozone conditions and evolution is the borehole temperature field determination. In the 80s of the past century, there was an entire network of profiles to observe thermometric boreholes at the Parisento field station. However, several decades on, being abandoned, boreholes became useless. Arctic Research Center of Yamalo-Nenets Autonomous Okrug was given a task to reinitiate investigations at the field station and to locate new boreholes near the existed ones in the past for comparing earlier temperature values with the current ones and continuing the monitoring.

Locations for boreholes placement were planned in areas with different geomorphic conditions typical for this region. Drilling operations were carried out via mobile boring machine UKB 12/25I applying a combined method of core and auger drilling. The screw diameter was 62 millimeters; the boring bit width was 70 millimeters; the spoon bits' widths were 108 millimeters and 60 millimeters correspondingly. Upon passing the permafrost line by the spoon bit of maximum diameter, a temporary surface casing, i.e., an iron tube with a diameter of 108 millimeters, that protected the borehole against meltwater during drilling, was installed in the borehole. Further drilling was made by a tool with a smaller diameter. Upon achieving the target depth, the borehole was lined with a one-piece metal-reinforced plastic pipe with a diameter of 32 millimeters and a wall thickness of 3 millimeters. 6 boreholes 10 meters dip were placed in total.

To compare temperatures with the received earlier data properly, at least one-year monitoring is needed. However, even now, we can compare the first data received in August 2018 with data known upon reports of All-Russian Institute of Hydrogeology and Engineering Geology from August 1986. For instance, the temperature increased by 2.5-3 degrees in two boreholes at a depth of 10 meters, which is close to the depth of zero-point annual variations. Monthly data of other boreholes aren't at our disposal, so we didn't get a chance to compare them.

Summarizing, permafrost temperature monitoring was renewed at the Parisento field station. According to the first received data, one can say that the permafrost temperature is rising. Continuing the monitoring will help in answering the questions about the further evolution of cryolithozone.

Coastal dynamics of the Kolguev Island

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Kolguev Island is the most western point in the Russian Arctic with tabular ground ice occurrence. Since the Barents Sea is characterized by strong sea ice decline, it is very interesting to study coastal dynamics in conjunction with cryogenic processes in this region. Ice exposures on coastal bluffs favor the activation of thermal abrasion and thermal denudation. Headwall retreat of retrogressive thaw slumps causes not only thermocirque formation, but also leads to increasing coastal destruction rates. This study on Kolguev Island continues and expands our earlier research efforts on coastal dynamics in the region.

As a result of field and remote sensing data analysis, coastline classification and segmentation were done according to the morphodynamics principle. The following types are defined: 1) thermo-abrasion wave exposed cliffs, 2) abrasion (thermo-abrasion) with stabilized cliffs, bordered by beaches or accumulative terraces, 3) sheltered abrasion (thermo-abrasion) cliffs, 4) accumulating coasts and accumulative forms, 5) accumulated coasts with sheltered tidal flats, 6) deltas. Thermo-abrasion cliff coasts are predominantly distributed in the west, north and northeast of the island, and accumulative shores in the south, southeast and east of the island.

New data on thermal denudation and thermal abrasion rates for Kolguev Island have been obtained using a whole set of multi-temporal satellite images of high and very-high spatial resolution (GeoEye, WorldView, Alos Prism, SPOT, Formosat, RapidEye and Kompsat) covering the period from 2002 to 2017.

For image orthorectification purposes, the 12 m TanDEM-X DEM has been used. However, since the TanDEM-X DEM is based on averaged bistatic SAR surveys acquired during the period 2010–2012. This DEM can be used only for orthorectification of images newer than 2012 to determine the exact coastal bluff position and thermocirque edges. We therefore reconstructed the relief along erosive coastline segments by modifying the initial TanDEM-X DEM through extrapolation of coastal bluff edge elevations and restoration of the coastal plain relief at 200–300 m towards the sea for orthorectification of images prior to 2012. All raw images were terrain-corrected and georeferenced using a comprehensive block adjustment, resulting in a very high absolute and relative accuracy of all images.

On the western coast of Kolguev Island, average coastal bluff retreat rates between 2002 and 2012 varied from 1.7 to 2.4 m/year. Within key-sites that included three large thermocirques maximum headwall retreat rates were 1.9-15.1 m/year for 2002-2012 and 2.2-13.5 m/year for 2012-2017 yrs. In comparison, activation of thermo-denudation has been also noted along the Kara Sea coast where rates raised up to 13 m/year and were generally correlated with changing environmental factors, particularly expressed in an increase on the thaw index during recent years.

Accumulative forms in the southern part of Kolguev Island are also being eroded. Thus, on Vostochnye Ploskie Koshki (on the south of the island), the retreat of formerly accumulative coasts from 2009 to 2016 in some areas amounted up to 62 m.

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Frost boils of the Pur-Taz interfluve

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In 2016 at the Gydan peninsula in conditions of a warm season there was a massive draining of slopes and khasyreys, the increase of peat plateau thawing height. In polygonal peat plateau, located in khasyreys of the 3 field on the northeast of the Pur-Taz interfluves in 2016-18 there were identified the numerous black stains, analogous in form with the frost boils. In tundra there are well known frost boils, formation of which is connected with freezing of a seasonally thawing layer and thaw settlement.

Frost boils fines of a decomposed organical mass in khasyreys is located in decreases between hillocks on poligons, which are composed with permafrost peat. There were studies sections, cryogenic structures and there were set properties of peat in a seasonally thawing layer: wetness, density, heaviness, and chemical composition. In seasonally thawing layer there were distinguished buried soil and plant layers, upper and middle solid layers of weakly decomposed peat, lower layer of a well-decomposed peat. Under the decrease between hillocks the permafrost rocks roof is lowered and thickness and wetness of a loose peat is increased due to the present thawing relatively to the heightened plots of microrelief.

The one of the reasons of frost boils formation in a polygonal peat plateau of khasyreys in warm periods of year, probably, appear to be the gas accumulation under the solid decomposed peat in local depressions of permafrost roofs. Their accumulation leads to the growth of pressure in local depression, composed by loose water peat; to the shift up and breach of the overlying solid peat; the outpouring of water and gas-saturated mass onto the surface. It is established that frost boils in polygonal peat plateau are being formed during the warm seasons of the year and are not associated with the process of seasonal freezing. Frost boils on the surface and injections in the polygonal peat plateau outcrops may be used as an indicator of uneven local lowering of the roof of permafrost against the background of an increase of summer temperatures.

Present evolution of Ivashkina Lagoon (Laptev Sea)

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On the coastal lowlands of the Laptev Sea thermokarst depressions are widespread. They formation associated with development of thermokarst lakes in the Holocene. Substrate of its growth was syncryogenic Yedoma deposits, whose thickness reaches 60 m. After flooding thermokarst depressions by sea the special cryogenic geological objects called by N.N. Romanovskii thermokarst lagoons were formed. The thermokarst lagoons keep the structural features of thermokarst depressions during its evolution, but changes in the hydrological regime and salinity of water leads to the formation of specific geocryological conditions within their limits, which are currently poorly studied.

The study of the thermokarst lagoons evolution in the past and present is important for understanding the cryolithological structure of the East Arctic shelf, within which relict forms of this lagoons can be widespread.

Thermokarst lagoons are known on the Bykovsky Peninsula, where they have been studied since 1999. Ivashkina Lagoon is a classic thermokarst lagoon, within which in 2014-2015 detailed bathymetric studies, monitoring of changes in temperature and salinity of bottom waters were carried out. During the work of the Russian-American expedition bottom sediments were drilled to a depth of 40 m with sampling in 2013-2014.

The Ivashkina Lagoon is located on the southern coast of the Bykovsky Peninsula, extends for 2 km from west to east and 2.5 km from south to north. It is separated from the sea by a narrow sandy spit. The average depth of the Ivashkina Lagoon is 2-2.5 m, however, the water level in it varies depending on the wind tide of 1-2 m. In the north part of the lagoon, near the coast, there is a deepening with a length up to 700 m and depth up to 4-5 m. At its bottom, with the side-scan sonar, the small forms like thermokarst mounds were discovered. These features are currently forming in the subaqual conditions. The depth of the top of permafrost within the limits of deepening is only 12 m. Up to this depth, the sediments are cryotic, their temperature gradually decreases with depth, i.e. at present, and there is a degradation of permafrost. The boundary between cryotic and frozen deposits is clearly fixed by the chemical composition of aqueous extracts from sediment pore water.

According to drilling in the center of the lagoon, before the sea flooded it, it’s been alas depression with residual lake in the northern part. In the center of the depression alas deposits after drainage were frozen to about 15 m, while the bottom of the primary talik was located at depths of at least 20 m, but rather more. At present, frozen alas deposits are degrading from above. There are cryotic in the wintertime deposits from the bottom to a depth of 3-4 m, and thawed deposits below, to the top of frozen alas deposits.

At the present, a number of processes are simultaneously taking place in the water area of the Ivashkina Lagoon. These include modern lagoon sedimentation, salinization of lake sediments and degradation of underlying permafrost by its thawing or transition to the cryotic state, which is sometimes accompanied by a bottom thermokarst.

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Cryogenic structure of deposits on the 70-75 m terrace of Aldan River (Mamontova Gora outcrop)

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Mamontova Gora is exposure on the Aldan River left bank, located 325 km upstream of the Aldan mouth. The exposure extends along the coast for 10 km and consists of two altitudinal levels. The upper level with a relative height of 80-90 m is the original denudation surface, the lower level with a height of 70-75 m is a high terrace of Aldan. The research area is located in the zone of continuous permafrost with a ground temperature of -3 ...- 5°C.

The exposure of Mamontova Gora has been studied since the 50's of the 20th century. The Mamontova Gora section is one of the most complete sections of the continental Neogene-Quaternary deposits of Eastern Siberia and is a reference for them. A large number of plant remnants (leaves, cones, nuts, fruits and seeds) allows for a rather detailed stratigraphic dissection of the section. Despite the long history of the section investigation, the researchers still have not reached a common opinion on the age and relationships of the sedimentary strata that make up Mamontova Gora.

The work on the outcrops carried out by the authors in 2016 and 2018 made it possible to obtain new data on its cryostratigraphy in the central part of the 70-75 m terrace.

Fine- and medium-grained sands with lenses of ferruginous lie at the base of the visible part of the section. They overlap by the horizon of gravel-pebble deposits with a thickness of about 7 m, at the base of which lies the basal horizon with boulders up to 25 cm in size. Above lies a series of light gray, fine-grained, horizontal and cross-bedded sands with a total thickness about 30 m. In this stratum there are large lenses of dark gray, horizontally layered loams, up to 2-2.5 m thick. The length of the lenses reaches the first tens of meters. All deposits are in the frozen state and it has massive cryogenic structure in sands and horizontally layered and reticulated structure for loams, thickness of ice lenses is 1-2 mm. Like previous researchers, we believe that the sandy stratum is represented by alluvial sediments, the loamy lenses may be sediments of the flood plain facies. In the upper part of the section sandy sediments have a Middle-Pleistocene age according to palynological data.

The sandy stratum overlaps by the layer of blue-gray loam with thickness up to 3.7 m. In the upper part it is horizontally layered, with reticulate cryogenic structure. The pseudomorph of a vertical length about 2 m, filled by loams, was first discovered on the contact of sands and loams in 2018.

We assume that at the end of the Middle Neopleistocene, in very cold conditions, a polygonal net of ice wedges was formed on the surface of sand deposits. At this time on the territory of Eastern Siberia the average annual air temperatures were 8–12°C lower than modern, and on the right bank of the river Aldan were spread glaciers, descending from the Verkhoyansk Ridge. At the beginning of the Late Neopleistocene, climate warming occurred, resulting in ice wedge thawing and lacustrine loams and pseudomorphs formation.

The upper contact of the loams is a pronounced cryogenic contact. Over loams lie silty loams of an Ice Complex (IC) with a thickness of 15-17 m. The width of the ice wedges reaches 2-3 m, the size of the polygonal net is about 10-15 m. In 2016, a lens of loamy lake deposits, embedded in the IC, was described. A cover layer of silty brown loams has thickness of 1.5 m.

According to the available radiocarbon datings, the upper part of the IC belongs to the Kargin-Sartanian time. The character of the boundary between the IC and underlying lake deposits suggests that IC deposits could have been formed continuously since the end of Zyryan time. The lake deposits, embedded into the IC, was formed during the Holocene.

Variety of characteristic times of cryogenic phenomena

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Traditionally, the subject of cryology is understood by natural objects and processes occurring in the cryosphere. In general, it is more appropriate to speak not about cryogenic processes and objects, but about phenomena - the difference between them depends on the frequency of observation. If the phenomenon is stable on certain time and spatial scales, if there are negative feedbacks that prevent qualitative changes, and if they are intense enough – it is perceived as an object. If positive feedbacks accelerating changes dominate, we tend to describe the phenomenon as a process. Thus, the determination of the nature of the observed phenomenon and the appropriate choice of methodology depends on the time scale of the subject of research.

Diverse speeds increase cryodiversity - a variety of objects and processes associated with cold and aggregative states of ice. Speaking of the diversity of cryogenic phenomena, it is advisable to distinguish three main characteristic properties of ice, defining the features of the cryosphere: atypical thermodynamic and electromagnetic properties, intermediate intensity of the hydrogen bonds and wide prevalence of cryogenic systems and conditions.

The presence of cryogenic formations or conditions can significantly change the characteristic times of the processes, increasing them in some cases, and reducing them in others. Since microvibrations compensate each other, the smaller the period of observation, the higher the speed of the processes. Thus, the rate of change of the velocity in relation to the change in the observation period is less than zero — the instantaneous velocity is always higher than the average one (Cauchy's theorem). The dependence of oscillations of the system characteristics (for example, temperature) on the scale makes it possible to determine the Hurst exponent for time series H related to the fractal dimension of the process graph curve (Hausdorff) D: $D = 2 - H$.

For processes occurring in conditions close to the phase transition point, a smoothing of oscillations and a decrease in the fractal dimension of the graphs of system characteristics (primarily temperature) are observed. Thus, near the phase transition point, smoother dependencies are observed, which is a sign of a possible phase jump. Such behavior is consistent with the observed decrease in mini-oscillations of systems before qualitative changes and corresponds to an increase in the length of correlations in critical phenomena.

Geological time is hardly perceived by human consciousness, functioning according to Vernadsky in accordance with biological time. The average life expectancy does not allow a particular person to physically perceive slow processes. Annual and circadian cycles that determine cryogenic processes, coincide with the sensations and conditions of a person, are the background of his existence. Climate change trends form a historical memory of humanity as a social phenomenon, its ideas about the "arrow of time".

A person perceives the dynamics of the planet largely through the dynamics of the Cryosphere. It acts as a reducer that increases its own geological processes' speeds to the speeds perceived by humans. Therefore, it is not surprising that exactly the geological processes those are connected with and indicated by the cryosphere (first of all, the so-called global warming) are at the center of public attention. A broader view that takes the long-period cyclical nature and multidirectional climate trends into account is in this case more adequate and more practical. It allows evaluating the present moment as the moment of approaching the next climatic optimum with the subsequent probable cooling.

Statistical analysis of the climatic factors influence on the active layer depth in Russian cryolithozone

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Active layer is a very sensitive natural object to climate change. The response of permafrost to air temperature increasing followed by active layer thickening, is usually characterized by the correlation of active layer thickness (ALT) and the sum of positive daily temperatures of warm season (DDT). Besides climate, geological and landscape characteristics affect ALT values. We have estimated the significance of DDT effect on seasonal thawing and examined the spatial variability of correlations between them.

For the analysis, Circumpolar Active Layer Monitoring program's ALT data from George Washington University website (http://www.gwu.edu/~calm/) were used. 21 sites on the territory of Russian cryolithozone with 9 years and more observation series were taken. Daily air temperatures were taken from neighbouring weather stations (http://www.meteo.ru/data and http://www.rp5.ru).

The statistical coefficient R^2 — the coefficient of determination (the fraction of the variance explained by the statistical model) as an indicator characterizing the relation between ALT and DDT was adopted. Data processing and analysis performed in the Statistica software.

The coefficient of determination in Russian permafrost zone varies widely: from 0 at the R42 and R43 sites in Central Siberia to 0.82 at the R21 site in Northeastern Siberia. Thus, the dependence of annual seasonal thawing depth on the sum of summer temperatures varies depending on the location of the site: from zero to a very strong relation. On average for 21 sites R2 is 0.26, which in general, characterizes the low dependence of the inter-annual variability of the active layer depth on DDT.

The high relationship variability between the ALT and DDT is due to the influence of geological landscape factors.

Statistical analysis revealed that the influence of non-climatic factors in zonal landscapes is lower than in intrazonal landscapes.

Changes in the parameters of the active layer under the influence of climate warming near the southern boundary of the cryolithozone (on the example of Western Siberia)

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A significant transformation of cryogenic landscapes, increase of permafrost temperature and active layer depth are taken place under the influence of the directed climate change at the end of XX - beginning of XXI century. Geocryological monitoring at Nadym site (65°N, 72°E) revealed that at the southern borders of the cryolithozone climate change are much more diverse. This is happening due to the following reasons: a significant role and variety of vegetation, high temperature permafrost, large spatial variability of lithological composition of rocks.

Climate change in the study area appeared from the 80's years XX century in an increase in air temperature by an average of 0.03°C per year, an increase in the amount of precipitation by 100 mm and an increase in the thawing time by almost a month. The greatest climate change has occurred in the twenty-first century. After 2001 year, extremely warm years are repeated through the year, the trend of increasing the average annual air temperature increased to 0.1°C per year.

Permafrost table lowering to 2 m has been occurred on the flat peatlands under the impact of these climate changes. In such areas the seasonally frozen layer does not merge with permafrost. The area of these locations is different every year, but there is a steady tendency to its increase. In 2018, the permafrost table in 111 points was below 2m (out of 121) and in 10 points the depth of permafrost table did not exceed 1.55 m.

Climate change led to the formation of the layer of the zero curtain in the edge parts of the mires. In the XX century, the layer of rocks with zero temperature appeared occasionally at a depth of 2-3 m, in the XXI - its thickness increased to 10 m. The temperature of rocks in this layer varies slightly from year to year, both in the positive and in the negative direction, but remains close to 0°C. In that case there was a new permafrost formation in these areas when the cold occurred several years in a row.

The increase of air temperatures and the increase in the depth of seasonal thawing led to the complete or partial destruction of those frost mounds, in which the peat layer is thin. On some of the mounds there were cracks, landslides on the slopes. The complete destruction of the frost mounds and the formation of thermokarst lake in its place was established in the vicinity of the site due to the use of the dendrochronology method.

Directed climate change favorably affects the vegetation cover and can contribute to the degradation of permafrost. But it was found that the increase in crown closeness leads to strong shading of the surface in the summer and can positively affect the safety of permafrost.

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Methodologic aspects of studyng gas emission craters in permafrost

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To date, it has been established that gas emission craters (GEC) discovered over 2014–2017 in the northern part of West Siberia are the result of naturally occurring explosive physical processes. They are caused by pressurized gas of various geneses contained in perennially frozen soils.

Having reviewed how work on detecting GECs is typically organized, we learned that it has so far been chaotic and haphazard. The results of such surveys are sketchy and sporadic. The first gas emission crater known as the Yamal crater was found four years ago. Since then, understanding of the processes responsible for the formation of these craters and the logic behind their distribution has remained nearly unchanged, despite all the hard work put in by numerous research teams.

The problem is further aggravated by the fact that gas emission craters may cause severe damage to engineering structures. This dictates the need for a methodologic basis for conducting observations, which would provide for a possibility to pre-detect hazardous processes associated with potentially explosive subsurface natural phenomena. The difficulty lies in identifying a process that has not yet manifested itself, as it may originate in perennially frozen soils without melting.

This could be overcome by adopting a common organizational and methodologic basis for GEC investigations. The procedure for carrying out studies at the craters that have already taken shape shall be redesigned. There is also a need for developing a GEC surveillance system that would account for randomly generated GECs as well as their dynamics.

Studying GEC manifestations involves examining random events that have already taken place. Future studies should comprise searching for and examining potential foci where craters will likely appear. Alongside studies into newly appearing craters, the main efforts should be concentrated on detecting and studying, with the help of geophysical methods, areas with higher gas content in perennially frozen soils. These areas are distinguished by their specific geomorphology and properties, which provides for a possibility to examine their structure and geomorphology, predict their dynamics and development trend.

This approach will allow developing an efficient technique for protecting engineering structures against explosive processes driven by the formation of gas emission craters.

The time has come to establish a united information center where information on gas emission craters will be collected or, even better, subjected to preliminary processing.

The methodologic recommendations are proposed that take into account not only the specific nature of these features but also different ways of organizing GEC-related research. These proposals discuss short-term and long-term field trips, stationary monitoring, detecting hazardous areas in the vicinity of engineering structures and equipment for monitoring sites.

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Pseudomorphs after polygonal-ice wedges and loess-like but floodplain alluvial deposits at the top of river terraces as new confirmation that Northwestern Siberia during the Pleistocene was a frozen non-glaciated area

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In respect to the events happened during the Pleistocene cryochronres, the area of Northwestern Siberia to the north of the Middle Ob' River has been so far a subject of very hot discussion. In addition to previous materials of the present authors which demonstrated that at the background of strong rock freezing no ancient ice sheets could cover that area (Sheinkman, 2016; Sheinkman et al., 2017), new data received for the last years confirmed such a conclusion.

To the west of the Ural Mountains, accumulation of loessic sediments is usually observed as an indirect evidence of the Pleistocene ice sheets to the south of their margins. Also, some researchers considered Northwestern Siberia as an area of development of giant ancient glaciers which merged with the North-European ice sheet and, correspondingly, the loess cover to the south of them were merged (Grossvald, Hughes, 2002). However in Siberia, within the Arctic and Subarctic zones, loess-like sediments are spread in the regions which were not covered by glaciers during the Pleistocene cryochrones. Recently the approach supposing much more modest spread of the ice sheets in Northern Eurasia were developed, and within these concepts West Siberia was completely free of the ice cover (Krapivner, 2018; Sheinkman et al., 2017).

During our study of the Quaternary sequences in the upper and middle reaches of the rivers running down from the Siberian Uval (a not high upland at the right-hand bank of the Middle Ob' River), we encountered in many exposures of the high river terraces (at a relative height of 15-20 to 35-40 m) the layers of loamy sediments that capped extensive sandy alluvial sequences. The most profound and well-developed superficial loamy stratum has been found in the top exposure of the terraces. The loams consisted predominantly of silt fractions, were not laminated evidently, and showed well-developed cryogenic structure. They were severely affected by pseudomorphs after middle-size polygonal ice wedges often outlined by thin paleosols. Set of ^{14}C determinations produced from the paleosoils the ages between 10 and 20 ka BP. It attributes the loam accumulation and its cryogenic transformation to MIS-2 (the Sartan cryochrone, in Siberian schemes). So, interpretation of the loams as the floodplain alluvium met firstly certain difficulties because in this case evident thin rhythmic lamination is expected.

The latter becomes a base for some paleoecological scenarios to suppose for West Siberia wide development of extra-arid cold ecosystems in the Late Glacial and Last Glacial Maximum. Such scenarios imply activation of eolian processes which could also give rise to loess accumulation. So that alternative hypotheses of eolian accumulation of loess-like sediments, and simultaneous impact of cryogenic processes in the cold and dry landscapes were developed and fit into the “Cold desert model” (Velichko et al., 2011). At present the environment yielding severe conditions for development of such an accumulation occurs only in the Antarctic McMurdo Dry Valleys (Abramov et al., 2010), and it is unreal, in our opinion, in Siberia.

All-in-all, we have carried out special micromorphological studies of the considered Northwestern loamy deposits and revealed typical features of floodplain sediments. These are: a) well-expressed microlamination, b) occurrence of organic plant fragments oriented parallel to the lamination, c) iron hypocoatings along the layers – an indicator of gleying, d) relics of fresh water aquatic microfossils – diatoms, sponge spicules. So, we suggest these facts evidence in favour of floodplain alluvium origin of the loamy sediments although incorporation of the windblown material is still not excluded. Within the floodplain hypothesis, recent tectonic uplift should be considered to explain the elevated present day position of the loams.

Reaction by climate changing in North Asia mountain region (Verkhoyanian mounts, Suntar-Khayat ridge)

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The problem of studying the patterns of formation of the cryolithozone is extensive and multifaceted. One of the fundamental and promising ways to understand it is the study of the temperature response of soils of different landscape conditions on climate change and the impact of various structures, as well as a change in the relief of man. This, together with the assessment of environmental parameters and geohistorical analysis of the development of territories, allows one to substantiate the geocryological conditions, determine their characteristics and predict changes that are necessary to ensure the effectiveness of the development of the region (assessment of future changes and their dynamics).

The Suntar Khayat ridge is located in the southern spurs of the Verkhoyanian mountain region within 62-63° N and 138-141° E in the middle reaches of the river Eastern Khandyga. In geocryological terms, it is one of the most poorly studied areas, which is associated with inaccessibility and low population

The main factors determining the formation of the temperature regime of rocks in the layer of annual heat turns of the Suntar Khayat ridge are the terrain, under the influence of which a microclimate is formed, the conditions of heat transfer on the surface, the thermal properties of rocks. It is these factors, along with the internal heat flow, to the greatest extent determine the parameters and conditions of the distribution of permafrost in the study area.

A network of observations of the thermal regime of the upper part of the layer of annual heat turns was equipped on the territory of the key section, within the South Verkhoynian. At the moment, studies are being carried out at 18 monitoring geothermal points. Additionally installed air temperature sensors. The obtained data on the dynamics of soil temperature over a more than seven-year observation period allow us to make some analysis of the nature of the formation of the average annual temperature of soils in the active layer, at different depths and absolute elevations.

It was possible to establish that, within altitudes from 800m to 1200m, the distribution of the temperature of rocks at a depth of 1 meter has a wide range, about 3.3°C (from -3.9°C to -7.2°C) and forms referred to as the belt of intensive temperature distribution related to the forrest zone.

At altitudes from 1200 to 1600m, this range narrows to 1.2°C (from -6.2°C to -7.4°C) and forms a belt of moderate temperature distribution. This is the sub-hollow zone. Anomalous site is a platform located at an altitude of 1750m, at the top of the rocky divide. Here, the average annual temperature has a higher value of -5.2 °C, compared to the average annual temperature at the point located in the underlying areas. Perhaps this is where the winter temperature inversions occur, about which other researchers wrote, as well as the special conditions of snow accumulation at the watershed.

Heterogeneous ice wedges at study areas on north-east sector West Siberia

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The syngenetic ice and composite wedges on khasyrey (drained lake) and interalas plateaus (remnants of terrace) of the 2nd lacustrine-fluvial terrace on the North of the Gydan Peninsula near the Gyda village were studied. Radiocarbon age of the studied sediments varies from 16640 to 854 years BP.

In the khasyrey and interalas plateaus the ice wedges with vertical bands structure include zones with vertical wavy interbeds of mineral particles. Different ice types (ice vein, segregated ice) were revealed in the ice wedge composition due polarization light. The ice veins compose wedge ice; segregation ice formed in composite part of ice wedges.

The ice veins are indicators thermal contraction cracking during ice wedge formation. The thawing gutters with segregation ice into the ice wedge structure demonstrate the participation of local thermokarst processes during the ice wedge formation. The composite wedges formation occurred by the repeat of ice wedge melting. The composite wedges formation during syngenetic frozen of the terrace sediments due irregular thermokarst process in different environments and climatic conditions at the Early Pleistocene and Holocene.

Structure of arctic peatlands with massive ice and structure-forming ice were studied in khasyrey of the Pur-Taz interfluves. The peatland formation (2 meters thick) cover period from 8413±90 to 897±90 years BP. The massive ice is represented by large ice wedges with difficult morphology complex. Ice wedges have the number of the structure elements: the central part of ice wedge, shoulders, young ice wedges. Ice-rich peat contains different types of ice inclusions, subhorizontal ice belts, ice lenses. The different ice types (ice vein, closed-cavity ice, segregated ice) were found in the structure of the ice wedges through structural and textural features. The central part of the ice wedges is composed by recrystallized crystals of ice veins. Melting zones (elongated crystals of segregated ice and closed-cavity ice) were found in the shoulder of ice wedge and in the upper part of the young ice wedge. Young ice wedges are represented by the ice veins or closed-cavity ice with segregated ice. Ice lenses in the peat can be formed from the segregated ice and/or infiltrated-segregated ice. The hydrochemical composition of the ice wedges, ice lenses, surface water samples and the aqueous extract from peat were determined. The hydrochemical composition of the ice wedge is similar to the composition of precipitation and surface water from a low-centre polygon. The ice in shoulder of the wedge has a mixed hydrochemical composition with the features of the wedge ice and enclosing peat. The hydrochemical composition of the ice lenses is similar to the composition of the lake water and peat underlying the active layer. The methane concentration and its distribution within the ice wedges, peat and lens ice were determined. The closed-cavity ice does not contain methane; the ice wedges with ice veins have minimal methane concentrations; large ice lenses have differentiation of methane concentrations. High methane concentrations were determined in the frozen peat with inclusions of closed-cavity ice in the uppermost part of permafrost; maximum methane concentration was determined inside peat with ice lenses. The heterogeneous structure of ice wedges, distribution of hydrochemical compounds and methane strongly depend on the dynamics of the thawing depth of during the peatland formation in a changing climate of the Holocene in the Arctic.

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Hydrochemical Features of the Northern Coast of the Kotelniy Island

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In August 2018, the Yakutian Branch of the Russian Geographical Society and the Academy of Sciences of the Republic of Sakha (Yakutia), with air support from the Ministry of Defense, organized a scientific expedition to Kotelny Island (Stakhanovtsev Arktiki Bay and Kozhevin River mouth) and Stolbovoy Island .

Our research team focused on the area east of the Kozhevin River mouth where a mammoth carcass had been discovered. Ice-complex deposits are exposed along the coast, which consist of peaty ice-rich silts, occasionally containing grayish-yellow sands and peat layers. The Ice Complex in the study area is generally less than 10 m high, covered by polygonal forms and baydzherakhs.

For water chemistry characterization, samples were collected from surface water bodies and tabular ground ice. A titration technique was used to measure salinity and major components (16 elements). Minor components were analyzed with the ICP-AES (28 elements), ICP-MS (43) and spectral analysis (14). The water stable isotope ratio, O^{18}/HD was determined.

Tabular ground ice was found to be of sodium-calcium bicarbonate type, with salinity ranging from 0.05 to 0.11 g/l. Minor elements with concentrations above the crust abundance include lead, ytterbium, manganese, cadmium, aluminum, iron, zinc, cobalt, chromium, copper, nickel, titanium, tellurium, phosphorus, barium, rubidium, strontium, arsenic and boron. The isotope analysis suggests that the coastal ice was formed in a dry, cold environment (δO18 = -27; δHD = -212), while the ice from the lower part of the peat unit was formed in warmer and wetter conditions (δO18 = -16; δHD = -123).

The surface water samples are of magnesium-calcium bicarbonate type. Salinities range from 0.05 to 0.15 g/l. Concentrations of lead, iron, manganese, ytterbium, cobalt and nickel exceed the crust abundance values.

The water type in the tidal zone is sodium chloride. Salinities are 1.7 to 11 g/l. Concentrations of Lead, boron, zinc, manganese, strontium, aluminum, ytterbium, iron, rubidium and cobalt exceed the crust abundance values.

Soils mainly consist of loess-like loams and are non-saline. Soil pore solutions are dominated by calcium and magnesium bicarbonate, and pH levels are, on average, 5.8.

Quaternary sediments and massive ice beds of the Gulf of Lavrentiya, Chukotka

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The coasts of the Gulf of Laverntiya, Bering Sea and eastern Chukotka remain a largely underexplored region in terms of Quaternary stratigraphy and permafrost. Apart from relatively recent studies at Pinakul outcrops (Brigham-Grete et al., 2001), a large part of coastal bluffs to the south of Lavrentiya settlement revealing a complex stratigraphy has not been yet described in details. In this region, numerous massive ice beds outcrop (Gasanov, 1969, Ivanov, 1986, Vasilchuk et al., 2018); questions of their origin and relation with the main sedimentary units remain challenging.

Here, we present the preliminary studies on Quaternary geological fieldwork made in August 2018. We explored 5-km long coastal outcrops south of Laverntiya settlement. The lower part of the cliff exposes dark brownish grey non-laminated silts and clays with abundant boulders and gravel, with deformed clasts of white sands, light grey loams and blue clays preserving traces of initial lamination. This unit presumably is of glacial origin, and can be interpreted either as glacial moraines or glaciomarine sediments (Brigham-Grete et al., 2001). Its top rises and dips in different segments of the bluff; its elevation occasionally reaches 15-20 m a.s.l. and is never lower than 1-2 m a.s.l. Above this layer, a 10-15 m thick sequence of interbedded sands, boulders, pebbles and loams lies, giving evidence of changing active hydrodynamics. These layers contain shell debris and are broken by numerous fractures; the layers are often shifted or deformed.

On top of this sequence, dark grey ice-rich non-laminated clays and silts with non-rounded gravel and cobble outcrop. These clays and silts are associated with massive ice beds, which are generally exposed below them. The bottom of the ground ice was never seen in outcrops, therefore we can suppose their stratigraphic position either below or within the dark grey silts and clays.

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Accelerated coastal erosion of the Bering Sea (Lorino site, the Chukchi Peninsula, Russia)

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Climate change causes air and permafrost temperature growth, active layer thickening, and especially, shrinking sea ice in the Arctic. These shifts lead to the intensification of coastal destructive processes. Acceleration of coastal erosion in unlithified frozen sediments was detected in many high-latitude areas that may affect freshwater, sediments and carbon discharge to the arctic seas. Engineering facilities can be under threat of destruction in economically developed regions.

The study presents the results of monitoring of the Bering Sea's coastal section near Lorino settlement. Studied coast is 750-m length remnant of marine terrace. Application of archival maps, engineering surveys data, field geodetic measurements, and UAV shooting allowed covering the period of coastal dynamics up to 50 years. Quantity relationship between retreat rate of bluff edge and coastal zone parameters was analyzed; influence of thermo-abrasion and thermo-denudation on coastal destruction intensity and erosion rate of coastal deposits was assessed. Studied coast section retreat rate was increased for the last 50 years in an order: from less than 0.5 $m \cdot a^{-1}$ in 1967-2010 to 4.2 $m \cdot a^{-1}$ in 2010-2017. Such trend may be explained by increased wave effect on the coast. Retreat distance for study period in western part of coastal section is twice less than in eastern one: the values are 18.1 and 42.6 m respectively. Observed spatial differentiation of coastal dynamics is well explained by predominant destructive processes, coastal parameters and erodibility of the deposits, exposed to coastal erosion. Calculation of Normalized Difference Thermo-erosion Index (NDTI) revealed predominance of thermal abrasion process for western part of the coast and thermal denudation – for eastern one.

Apparently, observed trend of coastal erosion acceleration will continue, that cause destruction of engineering facilities of Lorino community, first, fur farm shedders.

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Modeling of the dynamics of subaqueous permafrost at variable rate of thermal abrasion

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The subaqueous permafrost of the submerged type occurs at the in the coastal strip of Arctic seas. Such deposits were formed as continental syngenetic permafrost. They become to the subaqueous conditions as a result of tectonic lowering of the surface and thermal abrasion. At the subaqueous stage of development, the upper boundary of permafrost has a different morphology at stable shores (i) and at shores that are subject to intense thermal abrasion destruction (ii). As the distance from the coastline increases, this boundary descends relatively quickly, sometimes up to the formation of a through talik, in the case of stable shores (i). On the contrary, near the coast with intensive thermal abrasion (ii), the upper boundary of the cryolithozone slowly sinks with distance from the coastline. The morphological differences in the upper boundary of subaqueous permafrost near stable (i) and rapidly destructible (ii) shores are determined by the time the sediment stay in subaqueous heat exchange conditions (subaqueous age of sediment). For a quantitative assessment of the impact of coastal retreat rates on the upper boundary of the subaqueous permafrost, we propose a mathematical model. The model describes the dynamics of the upper boundary of the permafrost after the transition to the subaqueous mode of heat transfer, depending on the rate of thermal abrasion retreat of the coastline.

The initial data in the model is the time sequence of the coastline retreat rates. This sequence can be obtained using long-term measurements of the position of the coastline on the coast monitoring profiles. The model core calculates the distribution of the subaqueous sediment age with distance from the coast along the coastal traverse line. The depths of the upper boundary of the permafrost are calculated using the Stefan formula depending on the subaqueous sediment age, taking into account the thermophysical properties of sediment.

The output of the model is the distribution of the subaqueous sediment age and the distribution of thawing depth of permafrost along the coastal traverse at a given point in time. In the case of the formation of extensive zones of tidal dehydration and freezing belt, the model can calculate the depth distributions of permafrost new formations on intensively cooled subaerial surfaces.

The simulation results confirm that with an increase in the rate of thermal abrasion retreat of the coastline, the values of the subaqueous age and the depth of the roof of the permafrost decrease. If the retreat rate of the coastline does not change, then the distributions of subaqueous age and the depth of the roof of permafrost along the coastal traverse are linear. In the case of a time-constant coastal retreat rate, the upper boundary of the subaqueous permafrost takes a stepped shape. Sites of slow increase in the depth of thawing correspond to periods of rapid retreat of the coastline. Areas with a rapid increase in the depth of thawing correspond to episodes of relative stabilization of coastal benches. As the phase transition heat of moisture decreases, as well as with an increase in the thermal conductivity of the sediment, the spatial gradient of the depth of thawing increases. The model makes it possible to adequately describe not only the degradation of permafrost during the transition of permafrost sediment to the subaqueous regime, but also the new formation of permafrost during flooding of the surface with negative temperature sea water, as well as during the formation of vast areas of drying and freezing belts with low average temperatures. The results of modeling confirm that temporary changes in the rate of thermal abrasion destruction of the coast determine the distribution of the subaqueous age of sediment in the coastal strip and the morphology of the upper boundary of the subaqueous permafrost deposits. This study was supported by RFBR, project #18-05-60004.

Monitoring of thermocirques, their activation and growth controls, Central Yamal, Russia

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About 90 new thermodenudation features, most being relatively small retrogressive thaw slumps, and at least 20 of those big thermocirques were observed in 2013 in the central part of Yamal Peninsula within the area of 350 sq.km. Thermodenudation features appeared or re-activated in 2012-2013 after extremely warm summer, and actively grow in size since then. While ground ice close to the surface is a prerequisite for thermocirque formation, the process is triggered by warming trend and deepening of the active layer. Expansion of this landform depends on the volume of ice and further warming. Stabilization of this landform is usually caused by either exhaustion of the ice body, or by insulating of the exposed ice by active accumulation of flowing material. The last is resulting from active thaw on the one hand and dry summer weather on the other hand. Observations in Canada show that thermocirques become stabilized within 30–50 summers after their initiation (French, 2017) while near the Kara sea coast it took about 12 years.

According to our direct observations in Central Yamal thermocirques activated in 2012 triggered by extremely warm summer of 2012, and expanded at a various rate. Six thermocirques from 1 to 25 thousand sq.m of initial area annually monitored give approximation of the expansion rates. The annual rates of thermocirque area enlargement for 7 years of monitoring since 2012 vary from 1 to 6 thousand sq.m (4 to 98% of annual growth), and depend in part on climatic features of each year. Those kept stable after 2012, activated or re-activated in even warmer 2016.

Vehicle tracks observed over some thermocirques, most likely appeared before the main event of thermocirque activation in 2012, so the role of man-made disturbances is not crucial in activating the process, but this impact could have played a role in re-activation in 2016 though the tracks look already overgrown by pioneer vegetation. Active layer depth at such disturbances is up to 30% deeper than in the natural conditions.

Other controls of thermocirque growth are: slope aspect (southern-facing slopes are retreating faster), size and position of tabular ground ice in the section (the thicker is the layer and the closer to the surface, the faster growth rate).

While the coastal thermocirques grow under the additional action of the waves, inland thermocirques may rely only on the warming trend and amount of available water to help sediment flow away from thermocirque bottom. If the summer temperature rise is not accompanied by significant atmospheric precipitation, then sediment yield and removal are slowed down by landslide bodies in the transition zone. In this case thermocirque may stabilize in a short time and re-activate due to occasional exposure of tabular ground ice at the next extreme air temperature event and possible man-made effect as was observed in summer 2016 when stabilized thermocirque reactivated.

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The long-therm temperature dynamics of the permafrost in the areas of cuttings of larch forests (Central Yakutia, Russia)

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The data of a 35-year monitoring of permafrost temperature in the areas of cuttings of larch forests at the Umabyt test site (Central Yakutia, Russia) are presented. This region is one of the most developed in comparison with the rest of Yakutia. Natural forests here are greatly disturbed as a result of cutting. In this area, the cutting work reached the greatest volumes in the early 60s of the twentieth century to provide local industrial facilities and housing stock with building wood. By the mid-1970's, mass production of wood here was largely discontinued. The study of the effect of felling of larch forests on perennial temperature changes in permafrost is the main objective of the research. At present, this task is of particular relevance, as in the conditions of modern climate warming there is a tendency towards a decrease in the stability of permafrost in Central Yakutia. Knowledge of the long-term dynamics of the thermal conditions of permafrost in disturbed landscapes is necessary for the rational use of the natural environment, which can minimize the risks of permafrost degradation and enhance unwanted cryogenic processes.

The main method of the research is temperature monitoring in specially equipped temperature boreholes 20 m deep. Studies have revealed that in areas of successive cutting, the mean annual temperature of the upper permafrost horizons at an annual depth of zero amplitudes of the layer increases by 0.2-0.3°C, and the seasonal thawing depth increases by an average of 0.2-0.3 m. The greatest changes in thermal conditions were recorded after complete cuttings of larch forests. The mean annual temperature of permafrost at the sites of such cuttings increases by 0.3-0.6°C, and the thickness of the active layer increases by 0.3-0.7 m.

After the completion of cutting works, the temperature of soils here had a constant tendency to decrease due to increased shading of the surface in the face of increasing areas occupied by growing birch larch undergrowth, accumulation of a thicker layer of forest litter, restoration of green moss cover in micro-reliefs and reduction of soil moisture due to growth of transpiration due to regenerating woody vegetation. Restoration of the initial temperature regime of permafrost in forests, derived from gradual and continuous cutting, mainly occurs 20-25 years after the completion of cutting operations. The process of restoring forest vegetation on the areas of the former clearings, can reduce the amplitude of interannual temperature fluctuations in the upper permafrost due to the impact of current climate change.

Mathematical modeling of the morphological pattern development for thermokarst plains with fluvial erosion

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Landscape developing of thermokarst plains with fluvial erosion is among insufficiently studied issues of the cryolithozone. These plains are characterized by two opposite processes changing the landscapes:

- appearing and increasing in thermokarst lakes size,
- drainage of the lakes by fluvial erosion and their turn into khasireis.

The present research analyzes different variants of development for the thermokarst plains with fluvial erosion. The research uses mathematical models of the morphological pattern of the thermokarst plains with fluvial erosion, based on the mathematical morphology of landscape.

The landscape of the thermokarst plains with fluvial erosion develops under complexly interacting thermokarst, thermoabrasive and thermo-erosion processes, so that

- New thermokarst depressions appear;
-The depressions grow as lakes independently from each other and because of thermoabrasion;
- At any occasional moment, a lake can be drained by fluvial erosion process, turned into khasyrei and its growth stops.

We analyzed four variants of assumptions using mathematical models for sites with uniform natural environments. The first group of models comes from an assumption that the growth rate of the thermokarst lake sizes is under the influence of random factors and proportional to the density of heat losses on the side surface of the lake. But in one case we suggest a synchronous start of thermokarst processes (model 1.0), and in the other one an asynchronous start (model 1.1). The second group of models results from the assumption that the growth of a thermokarst lake occurs quasi-uniformly (according to empirical observations Burn, Smith, 1990) but it also takes into account two variants of synchronous (model 2.0) and asynchronous (model 2.1) starts.

The mathematical analysis of those four variants gives the following results:

All the variants demonstrate the Poisson distribution of a number of lakes as well as khasyreis within a random plot.

All the variants show an exponential distribution of khasyrei areas.

At the same time, all the variants differ by the lake size distribution after a long time of development: gamma distribution of areas (1.0), “integral exponential distribution” of areas (1.1), normal distribution of radii (2.0), exponential distribution of areas (2.1).

We empirically tested the following features:

- the correspondence of the distribution of the number of centers of both thermokarst lakes and khasyreis to the Poisson distribution within a random circular plot (sample size 100);

- the correspondence of the distribution of khasyrei (sample size from 43 to 352) and thermokarst (sample size from 49 to 2108) areas to different types of distributions.

Sixteen key sites chosen for the empirical testing situate at different natural environments. We use remote sensing data of high resolution. We use "Statistica" software package for statistical processing except for the "integral exponential" distribution which needs a special software for Pearson criterion assessment (developed by P.V Berezin).

Conclusions:

1. The mathematical models of the morphological pattern development for the thermokarst plains with fluvial erosion are substantiated; the mathematical morphology of landscape is the basis of the suggested approaches.

2. General laws of the morphological pattern for the thermokarst plains with fluvial erosion in case of uniform natural environment include Poisson distribution for the location of lakes and khasyreis and the exponential distribution for khasyrei areas.

3. Lake area distribution of the thermokarst plains with fluvial erosion is either "integral exponential" or gamma distribution, depending on different conditions.

4. The assumption about the quasi-uniform growth of lakes after a long time of development does not fit the empirical data.

Degradation of ice-wedges in Central Yakutia under the modern climate warming

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The modern climate warming has increased the development of cryogenic processes in Yakutia in the last two or three decades, which negatively affecting on landscapes. One of the most dangerous processes is thermokarst, caused by the degradation of ice wedges in edoma landscapes. In the taiga zone of Central Yakutia, degradation is primarily affected by anthropogenic and disturbed landscapes devoid of forest cover.

The change in the mean annual air temperature by 2-3 °C from the 1960's – 1970's caused an increase in the mean annual ground temperature 0.5 °C and a significant increase in the depth of seasonal thawing in forestless areas of edoma, with the destruction of the shielding layer which caused mass degradation of the ice wedges.

The mean rate of degradation of edoma with ice wedges on Yukechi monitoring site flat areas is up to 1 cm, in thermokarst depressions is from 10-15 cm to 25 cm per year. The formation of thermokarst lake depends on the size of the catchment and the ice content of the ground.

Almost all forestless areas of edoma have initial thermokarst damage - small holes in the underground cavities formed when the upper head of ice wedge melts and the polygonal micro relief. The thermokarst stages were studied by A.I. Efimov and N.A. Grave and subsequently P.A. Soloviev, and they were completely used Yakut names - rudimentary byllar, byllar, ieye, dyuede, tyympy and alas. All these stages have their own landscape-hydrological and geocryological definition. The report presents data on the morphological structure of each stage of thermokarst.

Young thermokarst lakes on the edoma is rapidly growing with expanding of lake area. From 1980 to 2016, the area of young thermokarst lakes increased by 3-4 times. This has a negative impact not only on the surrounding forest landscapes, but also on communications, roads, buildings and pipelines.

Permafrost landscapes with high content of underground ice, which occupy about 25% of the territory of Yakutia, are in critical condition under the influence of modern climate warming. Results of field research show that any anthropogenic impact can lead to degradation of permafrost and socio-economic value of landscapes. Alases, genetically related to edoma, are the most populated areas in Yakutia. Therefore, understanding the trends in the dynamics of permafrost and landscapes is not only ecological, but also has socio-economic, cultural and historical significance.

Geochemical features of quaternary perennially frozen sediments in central Yakutia at example 100 m borehole

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In the spring of 2018, we drilled a 100-m-deep borehole in the watershed between the Lena and Amga Rivers (Central Yakutia), which penetrated the entire sequence of Quaternary sediments. A permafrost core, 94.5 m in length, was recovered. Based on comprehensive studies, we identified five stratigraphic stages in the deposition of Quaternary sediments. Geochemical characterization of each unit was made (from top to bottom).

Holocene deposits of slope origin (I), subject to seasonal freezing and thawing. The thickness is 1.1 m. The unit is characterized by low mineralization, magnesium bicarbonate calcium type and slightly alkaline pH.

Ice complex (yedoma) (II) represented by massive loams with lenticular cryostructure containing ice wedges. The thickness is 25.1 m. Anions are dominated by bicarbonates, mixed cation type, with a gradually increase in chlorides. The sample taken near the bottom of the active layer (2.2 m) has a calcium and magnesium sulphate composition with high mineralization of 430 mg/l, and slightly alkaline pH. Permafrost acts here as a geochemical barrier, and the bulk of soluble salts remain in the active layer. At a depth of 15.5 m, which is thought to be the depth of zero annual temperature amplitude, the chemical composition changes to calcium-magnesium sulfate type and mineralization is 329 mg/l. The unit occurs in the depth interval between 1.1 and 26.2 m.

Lacustrine deposits (III) consists of silts with horizontal and wavy, occasionally gently sloping, bedding. Inclusions of freshwater shells and plant residues are encountered. Cryostructure is massive. Some "blind" cracks filled with ice are present. The unit is 37.3 m thick. The chemical composition of the deposits is of bicarbonate, mixed-cation type. Ammonium ion has a higher content compared to the other units, up to 21%. Ammonium results from decomposition of nitrogen-containing organic compounds and is typical for lake sediments. The depth interval of the unit is 26.2-63.5 m.

Lacustrine-alluvial unit (IV) consists of interbedded sands and silts. Cryostructure is massive. The thickness of the unit is 15.5 m. Soil pore solutions are characterized by chloride-bicarbonate composition mixed by cations. Sodium is a dominant cation. In the lower part of the unit, the pH changes from weakly alkaline to weakly acidic. The unit lies in the depth interval between 63.5 and 78.9 m.

Alluvial unit (V) consists of medium and coarse sands. The lowermost part of the section is a pebble horizon overlying bedrock. Cryostructure is massive. The visible thickness of the unit is 15.6 m. Deposits in the upper part of the unit have a chloride-bicarbonate composition, mixed by cations. Sodium is a dominant cation in the lower part of the section. The unit occurs in the interval between 78.9 and 94.5 m.

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Frozen deposits as a material for luminescence dating and a perspective to date them by means of a new TL technology

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Frozen sediments are the material which can be used for thermoluminescence (TL) dating. It is requested only that in the case of use of silicates as the minerals-timers they must undergo, before deposition, an enough intense bleaching during their transportation. In any case, however, there is a pitfall of noise, which influence on the minerals-timers because they are highly sensitive to environment changes (Aitken, 1985). After a number of experiments, we have found out how to avoid the negative effects without losing the advantages of the TL techniques.

The most reliable mineral-timer for this matter is quartz, which stands out against other minerals in its well-defined lattice, chemical stability, high strength, and ubiquitous occurrence in almost any rock. Its pronounced and explicitly documented properties can provide a realistic time reference for most of the objects. Nevertheless, getting the age data is not so easy for technological limitations in the standard dating methods (Aitken, 1985). Recent TL methods and technologies of age diagnostics have been inventoried by authors in order to extend the scope of rocks and related events fit for dating. As a result, the advanced (TL) dating was selected as the best appropriate procedure, which was tested on different objects in Russia and abroad (Sheinkman, Melnikov, 2011; Sheinkman, 2013).

With the aim of obtaining a reliable method, which would allow treating a large number of samples, we refused the previous unreliable dating criteria and cumbersome procedures. In the new approach, they are the coordinates of TL peaks in the dose curve, instead of the peak intensity, that make a more reliable age criterion based on second-order TL kinetics. This criterion, which stems from the more stable thermal rather than optical properties of quartz, was missed in the first-order kinetic TL model as its recognition would require a different problem formulation and instrumental background.

The validity of the suggested approach has been confirmed in repeated tests. The new criterion cancels the drawbacks of the standard methods and changes the very approach to TL dating. The suggested technique is an order of magnitude cheaper and much easier to perform than the classical procedures, which makes it a high-quality and accessible tool for investigating the studied sediments. Its reliability has been validated additionally by checking the new TL dates against radiometric dating.

The suggested approach based on studies in Russia does not claim to be panacea but it allows making good progress in solving the urgent dating problem and, moreover, creates prerequisites for advance in geochronology of permafrost. This is especially important as the chronological constraints of events in geosciences are crucial for synthesis of the existing experience and gaining new knowledge. In this respect the new approach can be used for systematizing all available data with reference to the time scale.

A Case Study of Morphoscopic and Morphometric Analysis of Quartz Grain Surface

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Morphoscopic and morphometric analysis of quartz grain surface as one of methods of sedimentary rock studying and its formation were included a lithological and mineralogical researcher's complex since the end of 19th century (Sorby, 1880). Studying of quartz grain's morphology is on the one hand forms of particles (morphometry), with another texture of its surface (morphoscopy). Many authors described texture features produced because of mechanical and chemical activities corresponding to the different depositional environments (Krinsley, Doornkamp, 1973). The transport and accumulation of grains due to gradual changing of quartz surface and emergence of new features. This is because, interaction of grains and its intensity for each environment to be different. As a result, grain's surface get complex of texture features related various to sedimentary situation.

Morphometric analysis of quartz grains let us to allocate some characteristic regarding roundness and dullness coefficients. Roundness coefficient widely changes along a profile from 28,4 to 72% (for intervals 40-80 cm and 2200-2400 cm respectively). According to roundness coefficient were selected three zones:

Zone 1 (450 cm and 850-2900 cm): roundness coefficient is more than 60%, dullness coefficient widely change from 23,3 to 46,6%. Such different together with texture surface features indicates successive aeolian and fluvial environments. It is interesting to note changing conditions from fluvial to aeolian occurred gradually without abrupt changes.

Zone 1I (30 cm and 160-800 cm) is described by roundness coefficient 40-56%. Dullness coefficient is 23,3-34%. These values indicate on prevalence of shiny particles. Highlight features as V-forms, scratches and conchoidal fractures indicate fluvial environment.

Zone 1II (40-80 cm) were allocated according to low roundness coefficient (28,4%). There well and moderately rounded particles are absence (4 and 0%). There has been a significant increase in non-abraded (68%).Dullness coefficient is 24,5%. Non-abraded particles with shiny surface and imposed conchoidal fracture and scratches indicate cryogenic weathering.

Thus, profile presents successive aeolian and fluvial-transported grains and sediments with cryogenic weathering features. Fluvial-transported quartz grains dominate in profile, as indicate by high and moderately roundness coefficient, shiny surface and grains with V-forms, scratches and conchoidal fractures.

Cryogenic weathering processes clearly represent in low part of the profile and could be relate to cold conditions in a periglacial environment.

Permafrost islands on the Tersky coast of the White Sea

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Permafrost islands in the south of the Kola Peninsula (Tersky coast) is one of the mysteries of life in the cryolithozone. Information about the distribution of permafrost in this area is sparse, and the position of the southern boundary of the cryolithozone is controversial. It would seem that the permafrost islands, located to the south of the Arctic Circle, should disappear with the current warming of the climate. This is what almost all researchers in the 1930's and 1950's assumed.

In September 2015 and 2017, we conducted two expeditions, surveying the area from Kuzomen to Chavanga, and then from Chavanga to Pyalitsa. The position of the permafrost roof and the thickness of the active layer were determined by a metal probe 1.5 m long and certified by the exploring shafts. In the melted areas, wells were drilled with the Giller-1 peat drill with radiocarbon dating sampling. It was carried out in the laboratories of Geology institute RAS and St. Petersburg State University.

Frozen hillocks near of the villages Chavanga, Tetrino and Strelna first described by M.A. Lavrova in 1935. In 2015, we surveyed the in the same places, and only in the place indicated by Lavrovova, we found frozen hillocks up to 2 m high in a large swampy basin at an altitude of 20-22 m. The peat started to accumulate about 8000 years ago. Its capacity reached almost 3 m, significantly exceeding the average capacity of peat in the area. The thickness of the active layer at the tops of the hillocks is only 0.4-0.7 m and increases sharply to the swampy traps made of semi-liquid peat, where frost was not found.

In the vicinity of the villages of Tetrino, Strelna and the basin of the river Chapoma, despite the widespread polygonal swamps with peat capacity of 1.5 m, we have not found permafrost.

But to the East near to Nikodimsky lighthouse and Pyalitsa, region has permafrost. It is located in the nuclei of hillocks up to 2.5 m high, located in areas of pronounced polygonal relief. These are the surfaces of sea terraces 9-10 m high (Pyalitsa) and 20-25 m high (Nikodimsky lighthouse). Waterlogged polygons of 20-30 m width retain regular quadrangular shape and are separated by rolls. But the thickness of peat is different - in Pyalitsa it reaches 4.07 m, and near the Nikodimsky lighthouse - more than 1.5 m. The depth of thawing on frozen hillocks is on average 0.4-0.6 m, sometimes reaching 0.85 m. The slopes of the hillocks are practically bluff. Peat began to accumulate approximately 8600 radiocarbon years ago.

That is, the preserved frozen peat islands in the form of peat bogs with bluff ledges breaking off in to the vast depressions of bizarre outlines, "float" among the melt ground. Their preservation seems to be determined by the thickness of peat - the more it is, the more likely it is to be frozen. But there are exceptions.

For example, in the Strelna area on a flat polygonal bog at a height of about 30 m, the thickness of peat also reaches 4 m, but no permafrost was found there. The bog is covered with destroyed hilly-polygonal relief. The peat started to accumulate about 9000 radiocarbon years ago, around the same time as the Pyalitsa bog.

Thus, small islands of frozen rocks can be found on the Tersky coast only on the surfaces covered with thick peat. Their formation is associated with the cold stages of the late glacial period - the early Holocene or the small glacial period. The preserved and undiscovered permafrost is located in almost the same natural conditions. Practically everywhere there are traces of its degradation in the form of hilly-polygonal relief.

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Dynamics of local conditions of peat accumulation in the Holocene of the southern tundra of the Pur-Taz interfluve

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The dynamics of plant communities of peat in the Holocene are used to reconstruct the natural environment in areas of peat decomposition, including climatic and hydrological conditions and processes. The age and botanical composition of the selected layers, the degree of decomposition, ash content, and peat types were determined. The change of peat types represents the dynamics of the waterlogging tundra conditions during the formation of a peat.

In 2017, in the area of the village of Gaz-Sale, a polygonal peat bog located in the southern tundra of the Pur-Taz interfluves was studied. The polygonal relief of the peatland in a drained lake valley is formed by large polygons with subsidence in the center of the polygon and bulging platens at the edges. The polygons are separated by wide, flat, moistened, drained interpolygonal depressions above the ice veins. Modern vegetation is presented: within subsidence in the center of the polygon - Eriophorum medium, Sphagnum capilifolium, Carex sp. and etc.; on the bulging platens - Cetraria sp., Cladonia sp.; in the interpoligonal depressions, the vegetation is more varied: Sphagnum sp., Ledum decumbens, Rubus chamaemorus, Betula nana, Carex rostrata, Andromeda polifolia and lichens.

In the section of the drained lake valley, opened peat with by 2.3 m visible thick. From the stratification peat were selected: in the seasonally thawed layer - 7 samples; in frozen peat - 3 samples. The botanical composition of peat is determined by microscopy using special atlases-guides and collection of micropreparations of plants. Peat of the seasonally thawed layer is characterized by a decrease in the moss of Shpagnum sp. and an increase in Carex sp., this is associated with local drainage within the platens. Also fluctuations of content of residues of mosses, shrubs and herbaceous plants are revealed in frozen peat. The composition and content of peat-forming plants in the studied peat characterizes the change of conditions: flooding and burial of woody vegetation; overgrowing and gradual draining of the surface.

The accumulation of the studied peat began at the end of the boreal period of the Holocene. The main part of the peat horizon was formed in the warm and humid Atlantic period. The accumulation of upper layers occurred from the end of the subboreal period to the present day. Modern vegetation is characteristic of the drier local conditions of the southern tundra.

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The Influence of Winter Seasonal Temperature Conditions, Snowfalls and Snow Cover Thickness Accumulation Variations on Ground Freezing Depth

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The ground freezing intensity and depth depend on ground internal physical properties (moisture containment, heat conductivity, etc.) as well as on winter seasonal temperature conditions (sum of acting negative temperature-days) and on snow cover thickness accumulation regime variation and snow cover insulating properties. For characterization of influence of external conditions on ground freezing intensity (of warming and cooling action of snow cover on the ground depending on snow cover accumulation regime and its duration) V.A. Kudriavcev suggested an equation including snow cover thickness, its thermal properties and amplitude of yearly air temperature oscillations. We suggest calculating scheme on basis of three-layer media heat conductivity problem (snow cover, frozen and thawed ground) with phase transition on the boundary of frozen and unfrozen ground. Heat balance equation includes phase transition energy, inflow of heat from unfrozen ground and outflow to frozen ground, snow cover and atmosphere. The heat flux is calculated on basis of Fourier law as a product of heat conductivity and temperature gradient. It is supposed, that temperature change in each media linearly. The assumption that snow cover consists of different layers deposited by different snowfalls and having different structure and density and heat conductivity depending on its density is also taken. The density and heat conductivity of each layer and the whole thickness of snow cover are determined and the regional stratigraphic column for snow cover is compiled and the calculation of ground freezing intensity and freezing depth is conducted. The comparison of estimated with calculating scheme and observed values of ground freezing depth is performed and the correlation of equal 0.76-0.77 of them is stated. For validation of calculating scheme the experiment of one-direction freezing of covered with snow sand sample was also conducted in refrigerated chamber under the action of negative temperatures. The intensity of freezing and rate of movement of phase transition front are determined and stated to be in good agreement with the obtained ones by calculating scheme values.

Laboratory investigations of flow and bank interactions of the river in cryosphere

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The large part of the coast of the Arctic Ocean in Russia, Canada and USA (Alaska) is located in the permafrost zone. The territories of watersheds and mouths of the rivers of East Siberia, Alaska and northwest Canada are located in permafrost of different properties (continuous, discontinuous, sporadic). Frozen grounds substantially affect the hydrological regime of the rivers in cryosphere.

The main characteristic features of these rivers are: 1. low ground water feeding; 2. low water flow in winter sometimes resulting in complete freezing; 3. considerable reshaping of the river bed at delta branches during spring debacle and ice drift; 4. regular ice jams, which release causes abrupt increase of sediment flow at the river mouth. Permafrost determines the heat exchange between water and river bed, which causes freezing of a channel throughout the depth and ice mounds formation. Total sediment flow of the rivers in cryosphere is much smaller than that of other rivers, since frozen grounds prevent erosion of the banks of a river during the most part of a year.

However, spasmodic development of erosion at the Mackenzie delta branches and formation of score holes with depths ranging from 13 to 37 m cannot be explained by ice jam release (Beltaos S. et al. // Can. J. Civ. Eng. 2011, V.38, p. 638−649). It is mentioned, that one of the main reasons of these score holes formation is delta channel erosion into floodplain lakes. Some of these captured lakes appeared to be partially drained, suggesting that permafrost may also be a factor in the formation of deep holes. The share of permafrost ground in originating of these score holes is still a problem. Until now, Mackenzie delta is the sole river mouth where such dangerous score holes are observed. Arctic coastal development and climate warming demand research of rapidly changing properties of permafrost under modern conditions.

Thawing of frozen grounds at the banks of meandering rivers was investigated in the annular flume in RUDN University. The Reynolds number of the flow was about Re=6.4×103, that corresponds to local Re near the bank of river flow. Convex and concave banks of the flow were formed of blocks of ice and frozen wet sand, simulating compound structure of nature grounds. The experiments of thawing the banks of laminated structure composed of pure ice and frozen ground show the velocity of thawing of ice layer being 1.5 times larger than that of frozen sand independently of its location at the inner or outer bank. Quick thawing of the ice layers causes large volumes of frozen sand sliding down into the water flow resulting in cliff formation at the convex bank. Blocks of frozen wet sand melting in water becomes the material for sand waves formation at the bottom. Deep niches of thawing are formed at the concave bank, which also lead to breakdown of large pieces of the bank. Thus, riverbanks of laminated structure in cryosphere are susceptible of spasmodic erosion. The thawing of the frozen ground at the shoreline is practically independent of the velocity of the flow in the range used in experiments.

The influence of snow cover on the thawing of frozen ground was investigated. Snow cover decelerates the thawing of the banks from above, but accelerates formation of deep niches under the cover. Crack separates the snow cover above the frozen bank from the snow cornice above the water, which breaks down at some moment carrying along blocks of ice and frozen sand. Modeling of processes of frozen grounds thawing could be useful for forecast the reaches of riverbanks crushing depending on composition of the frozen banks.

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Modelling Thermal Regime of an Intrapermafrost Talik in Central Yakutia

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Intrapermafrost taliks widely occur in sandy deposits of the Lena River alluvial terraces on the right bank of the Lena River, in central Yakutia. Most such talik strata host intrapermafrost groundwaters, discharging in small creeks cutting the valley sides and feeding multiple icings throughout winter. While the source areas of the groundwater flow can be traced at most locations, the question of the origin of non-frozen intrapermafrost layers remains open. Are they a product of the current climate, or of the warmer Holocene optimum conditions? In both cases, is there a significant thermal imprint from the groundwater flow capable of maintaining the non-frozen state of the deposits? Our study aimed at addressing these questions with the means of heat transfer modelling.

Our study site is the well-studied Ulakhan-Taryn valley, at the right bank of the Lena River ca. 50 km from Yakutsk. Local geology is fine to medium sands from the surface Boreholes and ERT surveys provide sufficient details on the permafrost distribution: a topmost frozen layer from surface to 16 m, a top of permafrost at ca. 80 m, and an intrapermafrost talik between the two. Mean monthly ground temperatures vary from -18.6°C (January) to +16.8°C (August) at the ground surface, from -9.3°C (January) to +9.8°C (August) at 1m, and are slightly positive at zero annual amplitude depth (18 m). The active layer depth averages 2.8 m.

Our modelling exercises involved two numerical models, QFrost (Moscow State University) and PFLOTRAN (Sandia National Laboratories, USA), both open-source and distributed under GNU GPL license. QFrost is a conductive heat transfer model with phase changes, and PFLOTRAN is a fully coupled convective-conductive heat and water transfer model. At the current stage of our study, only 1D calculations were performed and only conductive heat transfer was accounted for in both models. Initial conditions were assigned based on borehole descriptions and published thermal properties of central Yakutian sands. Calibration and verification runs were used to test and adjust, if necessary, the major input parameters, of which the most important were the thermal properties of local sands in both frozen and non-frozen state. A uniform temperature distribution (1 °C) was applied, and geothermal flux was neglected in both model settings, based on previous studies.

The variations in thermal properties of frozen and non-frozen sands were found to control the thermal regime of the upper part of the cross-section. Calibration runs have proven that the 'positive temperature shift' effect controls ground temperature distribution in the active layer, where the thermal conductivity in non-frozen state exceeds that of the frozen sands. Our preliminary results from a series of 1D simulations in QFrost, running for 100 y, show that under current climate, permafrost develops to a depth at least 40m in an initially non-frozen profile of sandy deposits. In PFLOTRAN, however, the bottom of permafrost depth limits to ca. 20 m, but further freezing is expected in longer model runs. Therefore, a certain thermal impact from groundwater flow may be assumed sustaining the intrapermafrost talik in its present dimensions.

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Hydrological modelling of the maximum runoff characteristics at small rivers in the permafrost zone

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The reliability of extreme flow characteristics assessments is associated with non-stationary nature of the environment when statistical approaches become irrelevant. The aim of the research was to analyze the applicability of the deterministic hydrological Hydrograph model to assess the distribution curves of instant water discharges at small permafrost catchments in the problem of engineering research and design.

We have chosen the Kontaktovy Creek of the Kolyma Water Balance Station at North-East Russia (21.3 km^2) as the objects of our studies. This area is characterized by the combination of extremely severe climate and continuous permafrost. Historical pluviograph data describing the duration and intensity of rain within extreme precipitation events was analyzed and used as the input data for modelling extreme flow discharges.

The process-based hydrological Hydrograph model was used in the study. The level of model complexity is suitable for a remote, sparsely gauged region such as Eastern Siberia as it allows for a priori assessment of the model parameters. Based on the spatial observations of the Kolyma Water Balance Station the model parameters were estimated for main landscapes and their verification is carried out.

At the first stage, we simulated the daily runoff with a standard meteorological data. The results of daily modeling are satisfactory without extreme situation. Therefore, the model correctly describes the processes at the catchment area.

At the second stage, the simulation of catastrophic floods was carried out using the pluviograph data by the example of the flood in 2013, when catastrophic flood destroyed the gauge at the Kontaktovy Creek and maximum instant discharge for 70 years of observations was not estimated. Simulated instant discharge was 71.5 m^3s^{-1}.

As the results, it is noteworthy that the simulated maximum flood greatly changes the observed discharge curve, which is used in construction and engineering design. We conclude that the Hydrograph model can be used for the analysis of catastrophic floods in permafrost conditions.

Aufeis of the Yana and Indigirka river basin (Russia): the database from historical data and recent Landsat images

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A detailed spatial geodatabase of aufeis (or naleds in Russian) within the Indigirka and Yana River watersheds (600 000 km^2), Russia, was compiled from historical Russian publications (year 1958), topographic maps (years 1970–1980's), and Landsat images (year 2013-2017). Identification of aufeis by late-spring Landsat images was performed with a semi-automated approach according to Normalized Difference Snow Index (NDSI) and additional data. Then, a cross-reference index was set for each aufeis, to link and compare historical and satellite-based aufeis data sets.

Digitized Cadaster contains the coordinates and characteristics of 897 aufeises with total area of 2064 km^2 at the Indigirka River basin and 385 aufeises with total area 739 km^2 at the Yana River basin. Accordingly, the satellite-derived total aufeis area is 1.6 times less than the Cadastre (1958) dataset. The more significant changes occurred to large and giant aufeis (area ⩾ 10 km^2) with total decrease of area by more than 60% of the total reduction. Simultaneously, the historical Cadastre archive is lacking data on over 900 aufeis that were identified using satellite images. This suggests that the Cadastre data is incomplete, while there may also have been significant change in aufeis formation conditions in the last half century.

Most present and historical aufeis are located in the elevation band of 1000 – 1200 m. About 60% of total aufeis area is represented by top 10% of the largest aufeis. Interannual variability of aufeis area for the period of 2001-2016 was assessed at the Bolshaya Momskaya aufeis and for a group of large aufeis (11 aufeis with an area from 5 to 70 km^2) in the basin of the Syuryuktyakh River. The results of analysis indicate a tendency towards an area decrease in the Bolshaya Momskaya aufeis in recent years, while no reduction Syuryuktyakh River aufeis area was observed.

The combined digital database of the Indigirka River aufeis is available at https://doi.pangaea.de/10.1594/PANGAEA.891036.

Possibilities for Estimating the Runoff Components of Rivers in Cryolithozone by Tracer Methods

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The water regime of rivers, thermal, chemical and biological properties of river water, sediment regime and channel processes depend on the origin of the water flowing in rivers. In general, the following types of river components are distinguished: snow, rain, subsurface (underground) and glacial. Quantitative assessment of the runoff components is usually performed by graphical method of runoff hydrograph separating. The main difficulties of this procedure are as follows: the waters coming to the river by surface or subsurface flow pass are themselves a mixture of waters of different origin; the subsurface component of the river flow is divided into individual types – soil water of different horizonte, phreatic water (ground water of free flowing), intermediate water, confined groundwater; lack of direct instrumental measurements; various dynamics of water sources - from the fastest direct flow (rain surface components) to the lowest (deep groundwater water). In such situation, an objective assessment of the main types of water sources into the river is a complicated task requiring detailed special hydrogeological measurements. And the identification and estimating of specific components, for example, soil water, water from aufeis, and bog water in the river runoff is challenge task.

The prospects for identifying stable water sources, including specific ones, as well as their objective quantitative estimation method are associated with the use of a tracer mixing model. The modern version of the mixing model includes a statistical procedure for modeling several complex tracers using the principal component analysis using the entire array of chemical indicators of water. Since the measurement of water river discharges and the deterioration of tracer concentrations in water are performed with sufficient accuracy, it is possible to estimate the components of the river flow by solving the inverse problem of mixing model. The proposed technique has been tested for several small nested catchments in the Nelka River Basin at the Mogot Experimental Hydrological Polygon.

MOGOT Polygon organized by Hydrological State Institute of ROSGIDROMET is located within the central section of the BAM railway, approximately 60 km north of the town of Tynda city. Nelka River Basin is located in the middle part of the southern slopes of the Stanovoy and Tukuringra ridges within the zone of continuous permafrost 100–250 m thick. The seasonal thawed layer is about 1.2–1.5 m. The typical soils are different combinations of frozen mountainous and taiga soils with shortened profiles and an abundance of gravel inclusions. Two types of ice in soil – cement and migrating ice. Peat bogs enriched by ice are commonly found at the bottom of the valleys. The forest cover of the watersheds is 80–90%. There are frost mounds on the slopes and aufeis on river flows.

Using the data of archival hydrochemical and hydrological regime observations obtained from the period of 1978–1984, three component mixing models were adopted for each study catchments. According to the result of modeling three dominant sources of the river runoff was identified. They are rain water, soil water, and water from aufeis. The proportions of each of them were estimated, and their inter-seasonal dynamics are analyzed. Aufeis water demonstrates a specificity of river runoff generation in the permafrost zone and associated with the presence of frozen ground.

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Detailed Hydrological Observations in a Small Catchment at Prilenskoye Plateau (a Case of the Shestakovka Creek): Some Evidences and Puzzles

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Our field detailed seasonal hydrological and hydrochemical observation at the Shestakovka Creek (SC) experimental catchment (the Chabydinsky station of the Melnikov Permafrost Institute SB RAS) in 2015−2018 has been focused on: 1) regularities in the spatial and temporal dynamics of the near-surface water cycle elements; and 2) an assessment and explaining the spatial-temporal variability of main components of dissolved matter. The catchment area is 170 km2. The most typical landscapes there are the pine forests on the sand deposits and beach and larch peat wetlands.

At the key sites, we used TLC (water level, temperature and specific conductivity) loggers as two ones by the Institute of Monitoring the Climate and Ecological Systems (Tomsk, Russia) and one by the Solinst (Canada), the water quality meter as the YSI Professional Plus and the Hanna pH-temperature-conductivity meters, and velocity meter propellers. Water samples have been manually obtained from creeks, lakes, peat bogs, taliks, aufices, snow cover and rains. The most frequent manual measurements/samplings drop on the freshet period (end of April – early May).

We would like to discuss some results preliminarily obtained there. Thus, we have detected a kind of one ~ two-year “memory” in hydrological response of the SC to heat and precipitation. Particularly, according to some our limited hydrochemical data, we have supposed the structure of dissolved organic matter has altered two years later the warmer conditions. We found the most tight correlation between flow rate in a given year and precipitation totals of a given, previous and pre-previous years together.

Along the spring flood periods, we have sometimes distinguished a hysteretic-loop shape of specific conductivity – water level and water temperature – water level relations in the SC. Such loops seem to form a sort of temporal sequence and intersperse with several-days parts of tight feature relation curve. Perhaps, this could be explained by consecutive alterations in flow generation processes as contribution of physically different water masses time-to-time.

Besides, daily fluctuation in spring flood flow is obviously caused by beaded channel of the SC at the upper gauge station: in nighttime, narrow sections are frozen up faster than wider lake-like sections and give quite abrupt increase in water level; in daytime water level is lowered due to melting the narrow sections and releasing the water from wide ones.

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River runoff generation at the small research watershed in continuous permafrost environment in Central Yakutia, Russia

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Hydrology of permafrost area in Siberia is poorly investigated and undergoes significant changes. The study aims at assessment of water balance of permafrost landscapes at the Shestakovka research watershed (170 km^2) near Yakutsk. The study is based on results of field campaigns in 2015-2018 and analysis of streamflow and meteorological data available for the watershed since 1951. Field investigation included landscape description, borehole drilling, geophysics, snow surveys, measurements of river discharges at two outlets, automated collection of ground temperature and moisture, meteorological data, water levels at river, taliks and lakes, regular sampling of snow and water from river, taliks, lakes and precipitation for chemical and stable isotope analysis.

Pine, larch-birch forests and mires occupy 47, 38 and 14% of the Shestakovka river watershed. Remaining 1% is covered by lakes. Geophysical survey showed that subaerial talik aquafers exist in pine forests. Based on assumption that investigated 15 key sites are representative for pine forest within the watershed one can conclude that taliks occupy 20-25% of the watershed. Mean annual values of water balance components for the whole watershed are: rain – 165 mm, snowfall – 75 mm, maximum snow thickness on the ground before snowmelt – 58 mm, snow sublimation – 6 mm in forest and 13 mm in open areas, river streamflow – 25 mm. Landscapes contribute to the evaporation and streamflow differently. Long-term estimates of the flow from the pine and larch-birch forests are 50 and 15 mm/year. Water input from the local watersheds to lakes and mires contributes to evaporation that is 400 and 240 mm/year. Evaporation from pine and larch-birch forests is 180 and 220 mm/year. Shestakovka river spring flood is formed mainly by surface flow in larch-birch forests while in pine forest snowmelt water infiltrates to talik aquafer through dry frozen sands. Summer flow is maintained by suprapermafrost groundwater flow in pine forests while evaporation dominates in other landscapes.

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Volume change of valley glaciers in the Cherek river catchment (Central Caucasus) from the mid-20 century

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Mountain glaciers serve as an important freshwater source for population, irrigation, economic needs and power generation. Ongoing change of mountain glaciers leads to the shift in runoff and freshwater shortening in some regions. The reduction of their area and volume is currently causing an additional increase of sea level by 0.41 ± 0.08 mm/year.

Direct mass-balance measurements in the Caucasus are carried out only on two relatively small glaciers - Djankuat and Garabashi. It is not clear how this data can be extrapolated to larger glaciers, where the main ice resources in the Caucasus are concentrated. The first assessment of surface elevation changes of large glaciers in the Cherek catchment, including the largest glacier in the Caucasus mountains – Bezengi Glacier was performed in this work.

Mean decrease of surface elevation at the Bezengi glacier from 1957 to 1999 was -3.8 m, from 1957 to 2011 -7 m respectively. The surface of the Mizhirgi glacier changed from 1957 to 1999 at -0.9 m, and from 1957 to 2011 at -1m. The surface of the Djankuat glacier for the period from 1958 to 1999 changed to -4.8 m. from 1968 to 2007 - -6 m. For the Elbrus glacial system, the value of the change in the height of the glaciers surface from 1957 to 1999 was -8 m.

At the studied glaciers, Djankuat and the glaciation of Elbrus, the value of the surface elevation is intensively decreased, and accordingly, they are intensively reduced in volume. But the rates of the process are different for each glacier. These differences depend on the aspect of glaciers, their size, altitude, etc. The main part of valley glaciers considered in this work, lies significantly below equilibrium line. Rate of glacier volume reduction in Cherek catchment is comparative to the benchmark glaciers, Djankuat and Garabashi.

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Small forms of glaciation — Chukotka and the Verkhneangarsky Range: why do they survive?

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Small mountain glaciers are extremely sensitive to climate variations, regional first of all. Their balance parameters are good indicators of climate change in the region and, importantly, they indicate the threshold for its transition to another state. For example, a certain combination of climatic parameters can contribute either to melting glaciers in the system, or to the beginning of their increase and advancement. In addition to climate, the state of small glaciers in the glacier system is affected by their enclosing relief form, localization of glaciers on the ridge slope and orientation of the ridges themselves. The underlying permafrost has a very important role in maintaining small forms of glaciation in the Russian North.
The paper discusses the conditions for the existence of the Chukchi Highlands glaciers, according to climate data, satellite imagery and our own field observations. The areas of glaciers are defined for periods from the beginning of the 1980's to 2005 and up to 2017 according to various satellite images and data from the catalog of R.V Sedov, the investigator of these glaciers in 1980's. Glacial objects of the basin of the left bank of the Amguema River, Gulf of the Cross and Lawrence Bay reduced most since 1980's. Also the paper presents new studies of the glaciers of the Verkhneangarsky Range, which were discovered in 2017−18. The Verkhneangarsky glacial group unites glacial formations of the morphological type —corrie; in size they belong to small forms of glaciation. During field studies 2017-2018 four glacial formations have been found, measured and described, as well as several perennial snow patches and rock glaciers.
The existence of these glaciers at altitudes of 1800−2000 m, below the snow line is ensured, in addition to the relief forms, by permafrost soil and sufficient solid precipitation (snowstorm and avalanche type of glacier nourishment prevail). The climate (changes in temperature and precipitation over the 2nd half of the 20th century and the beginning of the 21st) generally does not contribute to the preservation of glaciers. The degree of armoring with a stone cover and the duration of the presence of seasonal snow on the surface of the glacier also play a large role in the preservation of glacial formations.

Total glaciated area in the Arctic and Sub-Arctic comes to 56125 km^2 [Sarana, 2005]. Small glaciers, whose dimensions do not exceed 0,1 km^2, represents peculiar objects there. In the Sub-Arctic they are widespread within the 400-1400 m a.s.l. altitudinal span in the Khibiny Mts., in the Urals, on the Putorana Plateau, in the Byrranga Mts., on the north of the Verkhoyansk Range and in the Chukchi Highlands. They lie below the climatic snowline, and their existence is predetermined mainly by oro-climatical conditions.

Small glaciers are particularly sensitive to present climate change. They are rather unstable snow/firn/ice formations, which can shift from the glacier category towards snow patches under certain climatic alterations. Studying their current state, development and relationships with other nival and glacial objects is an actual glaciological problem. Its solution is aimed at revealing evolutionary tendencies of polar glaciers. Contemporary ice masses in the Arctic and Sub-Arctic, including small glaciers, render appreciable influence upon many natural processes, attaching thereby great geographical importance to relevant investigations.

Changes of small glaciers in sub-Arctic Siberia in XXIst century: a case study of the Putorana Plateau

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The Putorana Plateau remains one of the most poorly studied regions hitherto. Being located north of the Arctic Circle at the NW edge of the Central Siberian Tableland, this glaciated region is one of the very seldom visited in our country due to accessibility problems. This is the reason for scanty information on the local glaciers and their long-term regime. Rare fieldwork and imagery processing in the recent past resulted in identifying there 61 glaciers that occupy 7,18 km^2 totally [Sarana, 2005]. Obviously, small glaciers in various plateau sections belong to peculiar elements of the geographical shell promoting the specific character of local eco-systems.

The Lama Mts. was selected as a key area for glacier evolution research within the Putorana Plateau. A series of field observations have been carried out there formerly for 2 neighbouring small glaciers called Marlborough and Prives. In 1973 the first one has been 0,15 km^2 and the second 0,16 km^2 large, but by 2004 their area diminished to 0,092 and 0,109 km^2, correspondingly (i.e. their dimensions were reduced by 39 and 32 per cent during 31 years). Data on their state in 1973-2004 are compared now with satellite images of 2016 and 2018.

The borders of both objects experienced considerable transformation throughout the last 1,5 decades. Their degradation proceeded with progressive intensifying, so that dimensions of Marlborouogh and Prives Glaciers almost equalled each other: in 2016 their areas were 0,083 and 0,083 km^2, correspondingly, and further on in 2018 they came to 0,062 km^2 и 0,060 km^2. Thus, Marlborough lost 33 per cent of its area during the last 14 years, its contours shrinking more or less uniformly along the perimeter. The Prives Glacier area after 2004, however, reduced stronger than that of its neighbour, that is, by 45 per cent. Separation of a huge glacier fragment in 2017 contributed considerably to this reduction. In general, the present degradation of both reference glaciers is ongoing continuously. Marlborough and Prives Glaciers became smaller by a factor of 2,4 and 2,7, correspondingly, over the 45-year-long period since 1973.

Glacier response to the global change of the glaciosphere becomes apparent much more dramatically in the provinces with small glaciers like the Putorana Plateau. Moreover, settling and maintaining measurements of main components of water and ice balance for glacier basins seem easier just in such regions. Therefore, investigations undertaken on the Putorana Plateau are of both theoretical and methodical interest. They should be continued with establishing regular water- and heat-balance monitoring on 2-3 representative glaciers in Putorana.

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Avalanche hazard zoning for the land use planning in the Russian Arctic

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In the Russian Arctic, the avalanche hazard territories occupy significant areas. Snow avalanches are the most significant natural hazards in the most highly developed Khibiny Mountains and some areas of Magadan region. In recent years, the attention to the land-use of the Russian Arctic has been considerably increased. The legislation on the land-use planning in Russian Federation requires the natural hazards and their characteristics to be accounted for and available in the form of maps. For the sustainable development of the Russian Arctic mountain regions it is critically important to know which areas are endangered by snow avalanches and what characteristics they may reach.

There is a long-term practice of the large-scale avalanche hazard zoning in different countries, presenting areas endangered by avalanches of different intensity. Avalanche zoning plans are used by land planning authorities to prevent or restrict the construction of buildings in avalanche hazard zones, for avalanche protection planning and assessing risks. Despite the wide experience in the avalanche hazard assessment and mapping accumulated so far in Russia, the practice of avalanche hazard zoning is not yet used by land planning authorities in our country.

In this research, the importance of the avalanche hazard zoning implementation in Russian Arctic mountain regions is discussed on the example of Khibiny Mountains. First, we applied internationally-accepted Swiss avalanche hazard zoning approach (BFF/SLF, 1984) when avalanche hazard zones were indicated according to avalanches return period and impact pressures. Second, avalanche risk in the large scale was assessed using the approach developed by Komarov et al. (2016).The avalanche hazard zoning and risk maps was developed through the following steps: (1) analysis of terrain using large-scale topographic maps and DEMs; (2) analysis of climate and snow data; (3) analysis of historical and recently obtained avalanche events since 1930th; (4) analysis of remote sensing data (5) winter and summer field work: detailed topographical and forests structure and state check; identification of snow conditions and avalanche activity; (6) avalanche release zones and the corresponding avalanche fracture height indication depending on the avalanches return period; (7) analysis of applied avalanche protection measures and their reliability; (8) numerical simulations of snow avalanches using avalanche dynamics program RAMMS; (9) avalanche hazard and risk zones indication depending on the avalanches frequency and intensity, type of the land use. The numerical simulations were performed for understanding the avalanches dynamics (runout distances and impact pressures) and were applied as a basis for the avalanche hazard zoning.

The developed large-scale avalanche hazard zoning and risk maps were analyzed in respect to already constructed infrastructure and applied avalanche protection measures. The criteria for determination of the boundaries between the zones with different level of avalanches hazard and risk can be discussed. However, incorporation of avalanche hazard and risk zoning as a component of land use planning in Russian Arctic fulfills the requirement of legislation and helps to increase safety of people and decrease avalanche risk and consequences of emergency situations.

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Geophysical and glaciological investigations for safety arrangements in the area of Progress and Mirny stations and the Bunger Oasis field base (East Antarctica) during the field seasons of the 63-64 RAE (2017/2019)

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The principle task for the Russian Antarctic Expedition (RAE) as well as for all logistic organizations, which work in Antarctica, is related to the safety of personal, vehicles and aviation. The most important point is connected with applied investigations near the stations, field bases and along the glacier routes, including ice and snow-strip. RAE pays special attention to the safety issues. For this reason, since 2012 multidisciplinary investigations, including GPR, have been performed in the area of Russian stations Progress and Mirny (East Antarctica). These works were focused on to study crevasses, especially their revealing, studying and future evaluation. For solution of this complicated practical and scientific problem GPR technique is believed to be the most reliable geophysical method. Some works based on this methodology were accomplished in the area of stations Progress and Mirny and, in addition, in Banger Hills oasis in the period of 63 and 64 RAE (2017-2019). The research was focused on safety arrangements for using the snow-strip, which was built nearby the Mirny Station in the area of crevasses. Moreover, it was related to finding the reliable place for the new snow-strip. In Progress Station our investigations were connected with searching of a new way on Dålk Glacier around the dip that was formed due to the outburst of the intraglacial lake. This depression destroyed the route between the station, the aerodrome and start point of the logistic traverse of the Vostok Station. Geophysical works in the Banger Hills were carried out in 2019 in order to find the reliable place for new airfield.

The role of avalanches in the restoration of the Kolka glacier

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The object of study - the Kolka Glacier - is located on the side ridge of the Central Caucasus. The glacier is known for its catastrophic events — large-scale moves and glacial landslides. This glaciological object can also be considered unique due to the fact that despite the general degradation of the Caucasus glaciation, the Kolka glacier is rapidly gaining mass. Due to the rapid recovery of the glacier, the repetition of previous catastrophic events is possible, and that is why it is necessary to constantly monitor its condition. It's safe to assume that such rapid rates of recovery occur due to the significant share of avalanche feeding that the glacier receives from the steep rock framing of the town of Dzhimaray-Khokh.

Currently, there are techniques to assess the role of avalanche nutrition, one of them being a two-dimensional RAMMS model, created on the basis of the one-dimensional hydraulic Velmi-Salm model. This model allows us to simulate the movement of the avalanche flow in a three-dimensional relief.

This work's purpose consists in evaluation of the role of avalanche feeding on the Kolka glacier. The tasks that were performed in the course of the work were to isolate avalanche foci on the rocky frame of the glacier, identify zones with different friction coefficients, and simulate avalanche flows via RAMMS model in three-dimensional relief conditions. The result of this work is the avalanche deposits distribution pattern on the Kolka glacier and the boundary comparison of the sediments with their previous distribution estimate.

Glacial lakes inventory in Central Caucasus (2017-2018)

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At present, the rapid retreat of glaciers in the Central Caucasus plays an important role in the formation of glacial lakes and glacier lake outburst flood (GLOF). It is important to make a periodical inventory high-altitude reservoirs, but due to the inaccessibility of mountain regions, it is not always possible to conduct route studies. Remote monitoring based on satellite imagery data can help solve such problems.

The inventory of the glacier lakes of the Central Caucasus was carried out on the basis of Sentinel-2A/2B satellite images for the period from August to October 2018 and SPOT-6 for August and September 2017. The data on the altitude of the water levels in the lakes are obtained on the basis of two digital elevation models (DEM): ASTER GDEM and DEM, based on the stereo pair of SPOT-6 images.

Based on the results of automated and visual interpretation, the contour of 105 lakes was identified. Reservoirs are located at absolute altitudes from 1320 to 3890 m. The total area of the lakes is estimated at approximately 1 km^2. The average area of one lake is about 10 thousand m^2. The lake, whose water surface area does not exceed 1 thousand m^2, can be considered safe even in case of a breakthrough. However, if such a lake is located in a cascade of other water bodies, in the event of a breakthrough it is possible to sum up the water components and increase the volume of the resulting flood.

According to the methodology, the total volume of all high-mountainous reservoirs in the region is estimated to be 6000 thousand m^3. The average value of the volume of water is estimated at about 60 thousand m^3. According to the classification of reservoirs relative to glaciers, the glacial lakes of the Central Caucasus can be divided into proglacial (60%), periglacial (28%), extraglacial (10%) and supraglacial (2%).

Information on the current state of glacial lakes differs from the data of the previous catalog of lakes in the Central Caucasus (2005–2006), in which only 71 glacial lakes were identified. The increase in the number of lakes is probably due to the rapid retreat of glaciers occurring in the region.

Permafrost-aeolian processes in cold and arid regions of eastern siberia and tibetan plateau

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Despite significant differences in latitude, Eastern Siberia and broad areas of Tibetan Plateau are located within the cold and ultra-arid climates. The consequence of a close interaction of permafrost and aeolian processes are high diversity of specific polygenetic permafrost-aeolian landforms and sediments.

On the flat areas of Eastern Siberia, the surface soils are widely represented by sheets of ice-rich loess-like loams (Yedoma), permeated with massive polygonal ice wedges (PIW). Another widespread formation are continuous sand sheets and dune massifs. Unlike Yedoma, they are almost devoid of moisture and do not contain ground ice. Yedoma's loams and aeolian formed simultaneously in close proximity as a result of progressive cooling and desertification during the second half of the Pleistocene. Despite of catastrophic desertification the abundant moisture condition persisted in some areas with the cellular-polygonal microrelief due to regulation of water runoff as well as uplifting of permafrost table. The continuous supply of aeolian dust and simultaneous freezing together led to the formation of a specific high-productive ecosystem of the polygonal tundra-meadow-steppe (Yedoma steppe).

In Tibetan Plateau the permafrost distributed over 4000 m a.s.l. and its temperatures is mostly higher than -3°C. The depth of seasonally thawed layer is varied from 2 to 4 meters. Unlike Eastern Siberia plains, Tibetan Plateau has been an area of predominant denudation for millions of years. Therefore, permafrost formations have a number of significant differences here. The most significant difference is the almost absence of loam deposits that intensely carried by the wind beyond the Plateau. Surface frozen soils are mainly represented by Late Pleistocene sediments of eluvium, glacial and alluvium consisting with mixture of debris, coble, pebble, gravel and sand. All frozen soils are richly saturated with ice schlieras and segregations.

On the space imagery the hidden-polygonal structures often observed in Tibetan Plateau on areas consisting with Late Pleistocene coarse-fractured deposits. Some researchers consider the absence of polygonal ice wedges (PIW), which so common in East Siberian Yedoma. All investigated polygonal formations only contained arc-shaped polygonal sand-casts of Middle Holocene age. Also the various types of aeolian sand dunes are widespread in the Tibetan plateau. They are usually thawed, do not contain of ground ice, overlapping of frozen Late Pleistocene coarse-clastic deposits by layer of 2-8 m depth.

Many other landforms and sediments produced by wind erosion and accumulation in Tibetan Plateau. They are wind-valleys, corridors and basins of blowing, deflationary plateaus, aeolian remains, venticrafts, etc. The deflation develops due to low natural closeness of the vegetation cover and systematic sod breaks as a result of permafrost swelling and cryoturbation, as well as technogenic violations associated with the engineering activity.

To study the interaction of cryogenic and aeolian processes of the Tibetan Plateau, on elevation 4700 m a.s.l. the special high-altitude research station of State Key Laboratory of Frozen Soil Engineering (SKLFSE), Northweest Institute of Eco-environment and Resource (NIEER) was established. To protect of the deflation along Trans-Tibetian Railway, various systems of guard fences and riprap constructions are used by the employers of SKLFSE.

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Stages of study of the Kara Sea shelf cryolithozone

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There are research results of the Kara shelf cryolithozone in the report, performed by the Foundation «National Intellectual Resource» (with the involvement of scientific specialists of Lomonosov MSU) together with «Arctic Research Center» (Rosneft Corporate Research and Engineering Division).

The history of the study of permafrost of the Kara Shelf is divided into three stages. The first stage (from the XV-XVII centuries to the 1930s) was associated with the search for passage from Europe to Asia through the Arctic seas, the development of the Northern Sea Route and mineral exploration. At this time, mainly the distribution of frozen rocks was recorded. The studies of frozen rocks and groundwater of the Varneke Bay (southern coast of Vaigach) and Amderma (Ponomarev, 1936; 1940; Wittenburg, 1939) are conducted in the 1930s. As a result, ideas about the wide distribution of permafrost on the Arctic shelf of the USSR were developed. They are reflected in the cartographic form (Parkhomenko, 1937).

During the second stage (1940 - 1970s), research on submarine permafrost is expanding. The formation of frozen sediments on mud flats (Usov, 1966; 1967), cryopegs (Neizvestnov, Semenov, 1973) has been investigated on the Kara Shelf (Yeniseysky Bay, Vilkitsky Island). Information on the geotechnical properties of rocks has been published (Melnitsky, 1972; Ivanov et al, 1978, Neizvestnov, 1981). The relationship between the average annual temperature of bottom water and sediments with the depths of the sea has been established. The permafrost of the Arctic shelf is characterized on the geocryological maps of the USSR (Baranov, 1960; 1977) and on the zoning scheme of the cryolithozone (Neizvestnov, 1978). In the 1970s-1980s, computational methods began to be used to estimate the distribution and thickness of frozen rocks (Chekhovsky, 1972; Neizvestnov, 1981; Soloviev, 1981; Zhigarev et al., 1984); ; Soloviev, 1981). At the same time, a methodology for predictive mapping of permafrost is being developed (Neizvestnov, 1981; Soloviev, 1981). As a result, by the beginning of the 1980s, the basic ideas about the distribution and thickness of frozen rocks, captured on the maps by V.A. Soloviev and Ya.V. Neizvestnov. They are published as an integral part of the Geocryological Map of the USSR on a scale of 1: 2,500,000 (1991).

The third stage begins in the first half of 1980 with studies of promising oil and gas structures on the Kara Shelf using drilling and seismic acoustic methods (AMIGE, MSU) (Melnikov, Spesivtsev, 1995; Zhigarev, 1997; Bondarev et al., 1999; 2001; 2003; Neizvestnov et al., 2005). The Igarka Permafrost Station and PNIIIS began work on the crossing of the Yamal-Center gas pipeline through the Baidaratskaya Bay (“Natural conditions of the Baidaratskaya Bay”, 1997) and in the coastal zone of the western Yamal (N. Grigoriev, 1987; Baulin, 2001; Baulin et al. 2005). The series of maps created as a result of these (and ongoing AMIGE) studies reflects the sequence of knowledge of the cryolithozone of the southwestern part of the Kara shelf (Rokos et al., 2007; 2009; Kulikov et al., 2014; Kulikov, Rokos, 2017). A map based on the results of mathematical modeling was also created for this part (Portnov et al., 2013). A map created from seismic acoustic data was used as a reference (Rekant, Vasilyev, 2011). By 2018, such a map was drawn up for the entire Kara shelf (Vasilyev et al., 2018). However, according to the authors, the boundary of the permafrost on the northeastern and central parts of the shelf is uncertain.

According to the results of these and a number of other studies, the modern understanding of the cryolithozone of the Kara shelf can be formulated as follows. 1) Permafrost distributed along the continental coast. In the southwestern part of the shelf it is sporadic. 2) In addition to the relict and modern frozen rocks that are formed during modern sedimentation, there is a type of frozen rocks represented by ice-ground of the near-bottom diapir-like hillocks. The mechanism of their formation is discussed (Dlugach, Antonenko, 2096; Melnikov et al., 1998).

Ice core geochemistry of Caucuses Mountains

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Anthropogenic activities as well as different natural processes bring chemical elements (major ions, trace elements, etc.) to the atmosphere to change its geochemical composition. After being released into the atmosphere, mineral dust particles with different chemical elements can be transported over large distances. Mineral dust is regularly deposited on the glaciers in Caucasus. These events disturb the chemistry of snow deposits. The knowledge of the chemical composition can be used to determine the main source of precipitation and specify the geochemical environment of glacier formation.

Our data were obtained from the ice core drilled at the Elbrus Western Plateau (5150 m a.s.l.) in 2017 and from the snow pit samples at the lower elevations. In this research we present a geochemical and mineralogical characterization of snow, firn and ice of Elbrus glaciers. Twenty-four trace elements were also investigated in the study. As absolute concentrations do not show the geochemical pattern adequately, the special index, i.e., enrichment factor (EF), was calculated. Mineralogical composition was analysed by X-ray diffraction using an Ultima IV X-ray diffractometer.

According to the calculated degree of enrichment, three groups of trace elements were distinguished. The first group ($EF \leqslant 10$) includes Li, La, Ca, Ti, Pr, V, Cr, Mn, Ni, Sr, Fe, which content corresponds to the clarke. Elements of the second group (EF = 10-100) Cu, Mo, Ag, Cs are characterized by moderate enrichment. The elements of the third group (Cd and Zn) show abnormally high enrichment ($EF \geqslant 100$).

The main hypotheses of the trace element's sources were considered: weathering from local sources (rock outcrops) and subsequent aeolian transport, dust (long-distant transport), volcanic aerosols and anthropogenic aerosols (emissions). To reveal the contribution of local sources due to weathering and aeolian transfer, the average EF of ice core was normalized to the trace elements concentration in samples of potential sources in the Elbrus region. A significant difference was found between the EF of the trace elements studied in the Elbrus core and EF in the samples. Regarding these ratios, it was concluded that trace elements have rather non-local origin. The maximum enrichment correlates with the human activity (industry).

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Big data analysis for snow avalanche simulation in Arctic regions

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According to existing building codes, quantitative parameters of snow avalanches (maximum volume, flow height and velocity, runout distance, impact force) in Russia are determined on the basis of mean values for avalanche catchment area. Typically it is snow height in avalanche starting area and slope angle. Calculations are made for one or a few situations arbitrary designated by the operator. Real situation might significantly differ from this simplified approach. It leads to significant increase of losses caused by substantial increase in the cost of engineering protection or, on the contrary, underestimation of risks leading to life losses and destructions.

Modern computers could process vast amounts of numerical data with high speed and minimal efforts. A team of authors has created a project on automatic numerical simulation of snow avalanches to provide reasonable design decisions for efficient development of mountain areas. Our project is a system working with big data, using the principle of a neural network that learns itself as information from various projects accumulates in the common cloud. The clear advantage of the model is that the calculations take into account the entire set of factors with different genesis and scale in the full statistical aggregate that affects the parameters of snow avalanches within the considered avalanche catchment.

This approach allows to exclude from the calculations a significant part of the uncertainties and tolerances that undoubtedly arise in the classical version of the calculations. The developed technique takes into account local features of snow accumulation and drift, meso- and microforms of the terrain, its snow capacity and change of slope angle along the avalanche path, microclimatic conditions unevenly distributed over the catchment area. Final calculations of simulated snow avalanches are carried out according to regulations of Russian national standards and building codes.

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Spatial diversity of the relict cryogenic relief forms of the periglacial region of Western Siberia (Russia)

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Relict cryogenic relief forms of the periglacial region of Sartan cryochron and Late glacial time is widespread in the South of Western Siberia and Kazakhstan. It is characterized by complex of landforms with different degree of expressiveness and size. Middle-sized landforms include a combination of crest relief, shallow gullies and deflationary hollows, formed as result of Aeolian processing of deposits on the river terraces and in melted glacier water hollows in the interval 20-14 thousands of years ago [The Development of..., 1993]. The evidence of the Aeolian origin of crest relief forms and their constituent deposits and also their paragenetic link to Aeolian-cryogenic processes of the Sartan cryochron are the following [Volkov, et al., 1969]: 1) the same type of morphology, subparallel orientation of crest forms in direction WSW-ENE, 2) spatial association with deflationary hollows, strong connection of basins (denudation landforms) with accumulative ridge and crest complexes which are located as a rule to the East and North-East of them, 3) the lack of connection with the modern and ancient river network, the unconformity overlay on the ancient river valleys [Tarnogradsky, 1966; Alekseeva, et al., 2016; Larin, et al., 2016]. The morphological structure, which is clearly defined at the autumn or late-spring satellite images of areas of arable land as the form of near-square blocks with size 40x90 m and the system of superimposed blocks with a side length of about 19-23 m, geological structure, the planning figure, and the confinement of block-polygonal microrelief to a relatively low and slightly drained surfaces testify to his relict cryogenic origin. On relatively well-drained slopes the traces of relict cryomicroforms are found as a dense network of shallow hollows. The basins of modern lakes and swamps often have a tetragonal shape and are confined to the junctions of relict polygonal cracks (interblock depressions). The scalloped picture of the shoreline of lakes, riverbeds of small rivers, as well the outlines of swamps correspond with the polygonal pattern of the adjacent slopes.

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Permafrost under the River and Forest: How Local Hydro(geo)logy Influences Ground Temperature

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Although close interconnections between permafrost and hydrology is recognized, influence of surface and ground water on temperature field of upper permafrost at small scale is not well documented.

At a key site at the Upper Shestakovka River watershed near Yakutsk ground temperature is measured at 7 boreholes with depths from 3 to 20 m. Boreholes are located within 1 km^2 in forest, river valley and channel. One of them was drilled in larch forest that is typical landscape for the region. Active layer depth is less than 1 m, mean annual ground temperature at 3 m depth is -3.1°C. Two boreholes are located in pine forest with talik aquifers 5-7 m thick. There is seasonally freezing layer 2-3 m deep. Ground temperature at 6 m depth is 0°C and constant throughout the year. Another borehole was drilled in pine forest with deep (4-5 m) active layer and no evidences of talik groundwater. Ground temperature at 10 m depth is -0.3°C. Temperature measurements at the two boreholes in the Shestakovka river channel showed that there is a talik 3 m depth under the beaded stream pool and cold frozen deposits under the channel between pools. Ground temperature at 10 m depth is -0.9 and -2.1°C under the beaded stream pool and channel respectively. Temperature at a borehole in the seasonally flooded river valley is -5.3 °C at 10 m depth and increases up to -3.8°C at a depth of zero annual amplitude that is equal to 20 m. The river valley is affected by naled' formation in late autumn and early winter that leads to thinner snow cover.

Beaded streams, groundwater aquifers, naled' and landscape properties explain high variability of ground temperature and complicated permafrost distribution. Understanding of small-scale variability of permafrost properties is important to project its reaction to human activities and observing climate change.

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Permafrost and hydrogeological conditions at the inwashed reclaimed lands of the Yakutsk city

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Expansion of Yakutsk to the low floodplain of the Lena River dates back to 1977, when the land reclamation at the Quarter 202 had started. Upon alluvial material inwash, numerous former oxbow lakes underlain by natural taliks were covered with sediments. Later, the technogenic taliks had developed under the former river sandbars. Numerical heat transfer modelling results suggested that complete ground freezing in previously thawed areas should have occurred no later than from 12 to 20 years after land reclamation (Roman et al., 2008). Nonetheless, foundation grounds are presently at positive temperatures, and are highly water-saturated, over these reclamed lands. There is high risk of loosing the buildings stability.

One of the reasons of the taliks persistence under inwashed areas is the Lena River proximity. Hydrogeologic and geothermic monitoring had started recently in Yakutsk, in the reclamed area of the Quarter 203, to study the connectivity between groundwater and surface waters, i.e. the Lena River flow, and its potential influence on the ground temperature field in the inwashed soils.

The observation network consists of four coupled hydrogeologic and geothermic boreholes from 10 to 22 m deep. Two boreholes were drilled through relict lake taliks, the other two – over the former river sandbars. Suprapermafrost taliks were found at all drilling locations. The seasonally frozen layer depth above taliks is from 3.8 to 5.0 m. The aquifer table was found at variable depths from 8 to 10 m, and the top of permafrost under inwashed layer is from 13.5 to 14.8 m. The uniform dynamics of groundwater levels all over the territory of the Quarter 203 indicate the presence of a single common aquifer.

Hydrogeological observations support the existence of a hydraulic connection between groundwater of the inwashed massif and the Lena River flow. This connection is clearly observed during the spring freshet period, when the Lena River water level exceeds the groundwater table. The suprapermafrost aquifer is then under backwater conditions, and the Lena River water enters the aquifer through relict taliks, then the alluvial sands are saturated from beneath. Groundwater table rise is observed in all boreholes.

During summer, water level drops in the Lena river, and and the grounwater table lowering is observed. The suprapermafrost aquifer discharges to the Lena River through alluvial sand and and dries out relatively fast owing to its high filtration capacity. In the autumn and winter, the groundwater discharge to the Lena River occurs through compacted natural sands interlaid with sandy clays, andthe aquifer drainage rate decreases. The annual amplitude of changes in the groundwater level is in the range between 2 and 3 m.

The total dissolved solids (TDS) content in groundwater varies throughout the year. Its maximum values, from 593 to 795 mg/l, are reached in March. During the spring freshet, the TDS content decreases, and remains within the interval from 412 to 536 mg/l throughout summer. This variation in TDS values in groundwater also confirms its connection with the river flow.

Constant groundwater filtration through the suprapermafrost aquifer results in a certain thermal impact that limits the permafrost development within the reclamed areas. The expansion of the network of observational boreholes, planned for 2019, will allow quantifying the thermal impact of river flood waters on the inwashed sand massif and underlying permafrost.

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Hydrochemical and isotopic composition of river waters in Nizhnyaya Tunguska River basin: tracing the fire impacts and permafrost degradation

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Inorganic solute exports are expected to increase with thawing permafrost, but these patterns vary geographically depending on the underlying parent material and vegetation. Here we present one of the first comprehensive examinations of river chemistry from the Central Siberian Plateau (CSP), a globally significant yet relatively unexplored Arctic environment, allowing us for the first time to put this large landmass into a Pan-Arctic context. Streams draining the CSP have unique watershed characteristics, as they contain extensive larch forest, growing on continuous permafrost and experience frequent forest fire. Therefore, we use a space for time approach to examine the role of forest fire return intervals on DOC and inorganic constituent concentrations across the different order streams within the CSP. We studied 17 streams located near the settlement of Tura, Krasnoyarsk Krai region of Russia. Burn histories ranged between 3 to 100 years since the last fire. Several larger rivers, tributaries of Nizhnyaya Tunguska River, which finally drains to the

Yenisei River, were also studied to understand variability in element concentrations and water isotopic content dynamics across the larger landscape.

The major research tasks were: (1) to specify the changes in sources and composition of solutes released from watersheds in response to permafrost degradation and fire-caused disturbance, (2) to analyze the role of post-fire forest succession in stream biogeochemistry dynamics. We examined seasonal and annual dynamics of concentrations of dissolved organic carbon and inorganic constituents (major anions and cations) in rivers during several hydrologic years (2006-2018). Water samples were collected from just beneath the water surface at the mid-point of rivers at monthly intervals under ice conditions (October-April), at least once a week at snowmelt freshet (from mid May and beginning of June) and in summer and autumn (mid-June-September). Stream waters were sampled on weekly basis during frost-free season. Samples were immediately filtered (pre-rinsed 0.22 mkm cellulose filters, Millipore) and stored refrigerated prior to analysis. DOC and DIC concentrations were measured via high temperature combustion by TOC vario cube (Elementar). Major anion concentrations were obtained using ion chromatography (ICS-1100, Thermo Scientific) and major cations by ICP-MS or AAS methods. Isotopic composition of waters ($d^{18}O$ and $d^{2}H$) was measured by Picarro 2120-i. Historic data for discharges and inorganic solute concentrations in the Nizhnyaya Tunguska River at Tura were obtained in the regional office of the Roshydromet (Srednesibirskoe UGMS, Krasnoyarsk) for the period 1956-2018.

Major results of our study are following:

Sodium and chloride ions in river waters are the effective indicator of permafrost degradation in the region, reflecting the input of solutes via the through taliks from the saline brines (evaporitic rocks) lying beneath the permafrost;

The long-term trends (1956-2018) in inorganic loads of the Nizhnyaya Tunguska River demonstrate decreasing concentrations of major ions in winter period suggesting decrease in freezing depths and input of less enriched solutes from soils, and, in opposite, elevated concentrations of inorganics. in open water period as a result of larger input of deep saline solutes and more weathering material from soils.

Wildfires increase the inorganic solute concentrations in streams as a result of deepening active layer. Specific marker of fire effect on stream chemistry was sulfate-ion, which concentrations increased more than 10-fold right after the fire impact and gradually decreased to pre-fire values ca. 25 years after the fire. Bicarbonate ion concentrations peaked 20 years after the fire impact and followed the soil active layer depth dynamics.

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Research watershed of the Mushketova river at the Severnaya Zemlya archipelago – field observations and modelling

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Arctic regions are the subject to active development and exploration. Most of the Arctic is ungauged in hydrological sense, including small mountainous watersheds in the coastal area of the Arctic Ocean. The aim of the research is to adapt a hydrological model based on collected experimental hydrological data for the study of runoff formation processes at poorly gauged territory.

New research watershed was found by Arctic and Antarctic research institute in recent years. It is the watershed of the Mushketova River with basin area 51 km^2. It is located in the Bolshevik island in the southern part of the Severnaya Zemlya archipelago.

The observations were conducted in 2014-2015. They include meteorological information, streamflow and snow data. In 2014-2015 the streamflow had been observed only during the period from July to September. The climate of this territory is islanding Arctic. Mean annual temperature is about -11,4ºC, annual precipitation reaches 520 mm.

The process-based hydrological model Hydrograph was used in the study. It describes hydrological processes in different permafrost environments. The model uses basic meteorological data as the input. The level of model complexity is suitable for a remote, sparsely gauged region. The model parameterization was developed for main landscape (rocky talus slopes with the vegetation limited by moss and lichens) using available observed data and based on the Morozova creek data of the Kolyma water balance station (Makarieva et al., 2018).

The simulations of streamflow generation were conducted without calibration of the model parameters. The results of initial model runs confirmed the transferability of the parameters values assessed based on detailed field observations. The study shows the importance of observations in small-scale research basins.

Cryoturbations, pseudomorphs, postcryogenic textures and involutions in the frozen sediments of the Pur-Taz interfluve

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Development of cryolithozone in time may be presented by a sequence of stages of deposits thawing and freezing. Phasic changes of frozen and thawed stage are preserved as cryogenic and postcryogenic textures, deformations of deposits together with genetic and facial features.

In 2016-18, the structure of frozen deposits upper part of 2nd lake-fluvium terrace of the Pur-Taz interfluves was studied. Interalass surface 30 – 40 m high is dry and with polygons and numerous frost boils. Khasyrey and stage erosive – thermokarst hollows 6-18 m high and occur to be marshy with high – power polygonal peatland and ice wedges.

Section of interalass surface includes: Layer 1 (2 m) icy alluvial sands (W% 20-30%) grey stratified medium- fine-grained sorted with mosses, Drepanocladus, Calliergon and Brachythecium, with the age around 50 thousand years. Layer 2 (3 m) flood sandy loams, loams, sands with low ice content (W% 20-25%) with postcryogenic textures, ferruginous spots, vivianite, with shrubs, grass roots and Drepanocladus sp., aged around 45 thousand years. In sediments prevail a slant vertical crushed stratification, which is characteristic for pseudomorphs. Layer 3 (1,5 m) subaerial deluvial and proluvial sands, sandy loams with low ice content (W% 18-20%) with ferruginous and gray spots, washed detritus and slant light wavy stratification, which is characteristic for pseudomorphs and involutions. Estimated age – karginsko-sartan. Layer 4 (2,5 m) subaerial deluvial sandy loams, thin silty sands with filliform roots and ocher stains. Permafrost rocks with microlense ice texture construct icy (W% 31-40%) transition layer, thawing active layer have post-cryogenic textures. Layer 5 (0,7-1 m) - seasonally thawing sands and sandy loams (W%10-18%) ferruginous with cryoturbations, grass roots and overlapped by the soil (0,2 m).

Cryogenic structure, pseudomorphs, postcryogenic textures, microstructure of frozen deposits indicate that Kargin syncryogenic alluvial thickness between alas thawed to the depth of 7 m. Pseudomorphosis, postcryogenic texture is composed with the thawing of the syncryogenic thick with ice wedges. Involutions in sands were probably connected with epigenetic frozen penetration of a closed system.

In the outcrop of the erosive – thermokarst hollow there are involved the frozen alluvial thin sands; taberal complex – sandy loams with mashed stratification, ocher stains and involution; ice deposits of flow lake and early Holocene peat with polygonal ice wedges. Involutions in the taberal complex are educated with the thawing of deposits under the water reservoir in the end of Sartan.

In interalass in the layer of hole under the soil there are the stratified silty sands and sandy loam with 2 horizone of cryoturbations opened. Repeated injection of sandy loams, sands taken from the different depths into the surface frost boils occurred with freezing of pinched thawed rocks in early Holocene. Deformations of cryoturbation of the active layer are connected with the creep of thawed ground onto the slopes. The absence of injections under the frost boils in the lower part of the slope between spurs indicates the displacement of the soil mass.

In khasyreys on the surface of polygon peatland frost boils and injections are connected with the increase of peat thawing depth. Constant seasonal thawing layer is constructed by the dense unfolded heaving peat. In recent years during the summer the intermediate layer and upper part permafrost undecomposed of peat is thewed. The frost boils are formed in warm seasons excluding processes of freezing and fixate uneven lowering of the permafrost roof.

Cryoturbations, pseudomorphs, postcryogenic textures and involutions in the outcrops of the perennial frozen sediments fixate the evolution of cryolithozone connected with the long period fluctuation climate changes in late Neopleistocene and early Holocene. Dynamics of the upper cryolithozone part appears in cryoturbations of thawed layer and its deformation due to the seasonal thawing depth changes on the interalass and khasyreys, related with short period climate fluctuation in Holocene.

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Assessing hydrological connectivity in permafrost catchments using natural tracers

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Hydrological connectivity refers, in a narrow sense, to water transfer intensity within or between different compartments in river catchments, and can be quantified as such. This approach was found particularly useful in developing a concept of runoff contributing areas and, further, hydrological response units. Hydrological connectivity is variable through time, whence some links may be temporarily down but reactivated later as water seasons change. It can be defined in terms of saturation properties, hydraulic head variations and topography. Natural tracers are used in describing catchment hydrology when tracer concentrations vary significantly between compartments. Such variations may reflect differences in water origin, i.e. precipitation vs groundwater; water transfer processes, i.e. surface vs subsurface runoff through topsoil or topsoil; or water source, in geographical sense.

In permafrost hydrology, hydrological connectivity is heavily influenced by the presence of cryogenic aquitards, of which the active layer bottom is by far the most important. In the deep subsurface, the water routing is confined to intra-permafrost and sub-lacustrine taliks. Besides, permafrost soils and catchments host significant transient water volumes, redistributing runoff within and between seasons, years and millenia.

Rare earth elements (REEs) and their ratios were used to trace runoff origin in the Northern Yenisey region rivers, in the extremely dry year (2013) under summer low-flow conditions. In particular, light (Nd) to heavy (Yb) REEs ratio was used, as described in literature. In a medium, ca. 323 km^2, peatland-dominated catchment, most runoff developed as slow subsurface on slopes with mineral soils, while in smaller catchments underlain by sandy and silty soils, water was mostly transferred via topsoil compartment as fast subsurface runoff. The observed runoff distribution is related to permafrost spatial distribution within the Yenisey River terraces, where a double-layer permafrost is found in the 'plateau zone' of the third terrace, while only seasonally frozen layer develops on the younger terrace surfaces, underlain by sands and silts. In a more regional sense, REE concentrations can be used to infer water origin from different parts of the catchment, i.e. from leaching through fissured carbonates or from icing meltdown.

Stable water isotopes, measured in an intermittent creek in the Bol'shaya Zemlya Tundra region in the vicinity of Vorkuta, Komi Republic, were used to trace water origin in a system of watertracks. These features are abundant in the region, resembling minor rivers in their lower reaches. An ERT survey, performed by O.I. Komarov (MSU), confirmed an existence of open taliks under watertracks, and stable water isotope data suggest subpermafrost groundwater discharge through these taliks.

Natural tracers can decrypt hydrological connectivity patterns in permafrost, and showcase both its spatial and temporal variability. Temporal variations in active layer depth and non-frozen zone thickness, connectivity via taliks and double-layer permafrost, water retention in ground ice and icings, as well as spatial distribution of frozen ground in discontinuous permafrost, can be tracked via changes they apport to tracer concentrations and ratios. The development of permafrost-specific hydrochemical indices of these processes is an open task far from being accomplished.

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Investigation of water tracks hydrology in the north-west of Yakutia

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Water tracks (or dells) are widespread hillslope flowpaths in permafrost areas. They are shaped as hollows with gentle slopes and are 1-30 m width and several hundred meters length. Devoid of pronounced talveg, they stretch from the top of uplands down to the valley bottoms, forming a dense network on gentle and medium slopes. Depending on the slope topography, they develop parallel to each other, branch downwards or form dendritic system. There is still no consensus on genesis of water tracks. They are considered a rudimentary channel network that is not fully developed due to the erosional resistance of permafrost [McNamara, 1997], a result of thermokarst processes on ice wedges, or a consequence of uneven movement of slope material [Katasonova, 1959]. Water tracks are known as preferential suprapermafrost flowpaths, providing an area for fast runoff generation [McNamara et al., 1997].

We investigated the mechanisms and pathways by which water travels through the small basin of Krestyakh River located in continuous permafrost near the Lena Delta. The slopes of the basin are composed of ice rich silt (up to 300% of dry weight). The Paleozoic rocks (aleurolites) are exposed in the upper part of the ridges and in the incised channel of the creek, where gravelly material appears in the sediments. The active layer of an average thickness of 20–25 cm is over saturated. Slopes are covered with tussock sedge tundra and dissected by numerous water tracks.

We measured level and water temperature at three gauging stations located in the nested basins: in the water track (0.015 km^2), in the stream with an overgrown channel (1.41 km^2) and the stream with an incised pebbly channel (2.07 km^2). During the measurements (Aug 1-11 2018) the air temperature increased in the absence of precipitation. Suprapermafrost groundwater level measured in water track consistently increase during this period, which can be explained by seasonal thawing of ice rich sediments. Water level in the overgrown channel also rose, but at a lower rate. Water level in the incised pebbly channel had no significant dynamics. Discharge measured by floats in the incised pebbly channel was 1-1.5 l/s.

The water temperature at all gauging stations had a pronounced daily variation with amplitude of up to 3°C and changed from 1.85°C at the water track to 6.4°C at the middle and 4.9°C at the lower gauging stations. The decrease of the water temperature at the pebbly channel we credit to local percolation of water through cold gravel sediments upstream the gauging station.

Despite the polar day, there was a pronounced diurnal variation of water level in the water track with minimum values in the evening and maximum in the early morning. Since the fluctuations in the levels were in antiphase with fluctuations in water and air temperature, this can be explained by evapotranspiration in the daytime and condensation as dew at night. The absence of significant variations of water levels in the overgrown channel can be explained by the high accumulating capacity of the wetland and by larger drainage area.

Filtration rates in active layer measured using the NaCl-tracer in the water track and in the intertrack are close (3−4 m/day). However, the active layer in the water track is deeper and the volume of filtered water there is somewhat larger. At the same time, in case of the appearance of surface runoff in the water track, discharge can increase significantly. The maximum filtration rates (14 m/day) occur on the top of uplands covered with patterned ground, where loamy aggregate is washed out of the gravelly material.

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Impact assessment of glacial processes on the objects of the northern settlements

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If in the last millennia Svalbard was the abode of snow and ice, today there is not much ice reserves. Arctic glaciation is rapidly decreasing due to the effect of global warming. The average air temperature in the region quickly rises and the heating rate is about + 2.68 °C/100 years (faster than in the rest of the world).

Officially, Svalbard is a Norwegian territory, but other countries are allowed to stay on the archipelago if they conduct economic activity there. Thus, the Russian village Barentsburg mines coal and is also a center for Arctic tourism. But due to current climatic changes, human activities here can be difficult and even dangerous.

Such a dangerous phenomenon as avalanches threatens life in the Norwegian village of Longyearbyen. During the thaw in winter, usually rainy weather, which is a catalyst for avalanches. So, recently two snow avalanches have fallen on the residential quarter. Part of the road was closed. Some houses have cracks.

The cause of avalanches can also be snow storms, the number of which has increased in recent years. Thus, in Longyearbyen, as a result of a snow storm, 7 meters of snow fell overnight. Huge masses of snow that came down from the mountains damaged 10 buildings, moving them from the foundations and dragging several tens of meters.

Destruction of houses may occur due to other reasons. Many specialists have noted warm and snowy winters, unprecedented before. Snow, in turn, serves as a heat insulator between the atmosphere and the ground. Because of such a barrier, the soil does not freeze and taliks, non-freezing areas within frozen soil for several years, are formed. Taliks threaten the sustainability of residential and farm buildings.

The current rate of degradation of glaciers can greatly affect freshwater supplies in the vicinity of the village. The Bienda-Stemme Glacial Lake is a source of drinking and household water for residents of the village of Barentsburg. The lake is powered by the influx of water from the Vardeborg Glacier. This single source of drinking water for the winter period is almost completely exhausted.

Seasonal ice of the active layer and stability of ecosystems of the cryolithozone in the conditions of climate fluctuations: the direction of research

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In modern conditions, it is possible to achieve an original and significant result in fundamental research only on the verge of contact between different areas and branches of science. In cryolithozone, in the Eastern Arctic and Subarctic all natural processes without exception are carried out with the participation of cryogenesis, due to the internal laws of permafrost development, its reaction to abnormal external effects - anthropogenic and climatic. Surface waters of permafrost landscapes are closely connected with climatic conditions, they are influenced by the structure of the roof permafrost, seasonal and long-term dynamics of the active layer.

In 2018, the project was supported by the Russian Foundation for Basic Research (RFBR): "The impact of climate change and fluctuations in the depth of seasonal thawing on the water balance of small rivers in the cryolithozone of the North-East of Russia". This project aims to study the short-period dynamic relationships of the active layer and the water balance of small rivers in the Pacific and Siberian climatic regions of the Arctic and Subarctic. In the base research on actual observations (1994-2017) weather, active layer and the exogenous cryogenic processes on the network of CALM in Eastern Siberia and Chukotka. The project provides for regime observations of the super-frozen aquifer, drainage of condensation waters, conditions of feeding and runoff of rivers and streams of 1-3 orders. Among the expected results: the establishment of a mechanism of feeding the rivers in dry years, due to melt and condensation water of the roof of permafrost; balance calculations and simulation of the river flow of lowlands and plains of the permafrost zone; the study of the dynamics of temperature and chemical composition of the supra permafrost, lake and river waters in the conditions of fluctuations of the climate. Retrospective and prospective model conditions of supply of small rivers of the permafrost zone will give a new theoretical basis for forecasting and water quality of hydro systems of the Arctic Zone of the Russian Federation.

The actual materials obtained within the framework of the project will be placed in open access on a special page of the North-Eastern Interdisciplinary Scientific Research Institute. N. A. Shilo Far East Branch Russian Academy of Sciences. We invite interested scientists to cooperation and joint research in other regions and countries of the cryolithozone.

Samoylov Island scientific research station: current state and trends

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The Samoylov Island research station (SI RS) was built in 2010 in order to develop Arctic environmental studies. Trofimuk institute of Petroleum Geology and Geophysics, Siberian Branch of Russian Academy of Sciences (IPGG SB RAS) has been an operator of the station since 2012. The station operates in a full-year regime and is equipped with a set of modern scientific instruments and tools which may require in different fields of research (bio- and geochemistry, geophysics, climatic studies, hydrology, etc.). There are several laboratories and workshop rooms and a number of additional utility spaces. Speaking of accommodation, the station provides very high level of comfort, standing in a row with best world analogues (comfortable living rooms, modern kitchen and dining room, conference hall, shower, sauna, recreational rooms, internet connection with Wi-Fi). The available transportation means (several boats, cross-terrain vehicles, snowmobiles) provide access to the wide area around the station in radius up to 200 km all the year round.

Common use center is organized on the basis of the station in 2018 with following goals:

- elaboration and realization of interdisciplinary studies program;
- research and development support of international research teams;
- monitoring organization and maintaining;
- collaboration with scientific and educational organizations in the field of joint projects, student practices, etc.

IPGG SB RAS together with a number of Russian and foreign partners develops a joint Arctic research program to organize and perform a multidisciplinary research in geocryology (permafrost research), paleogeography, climatic and paleoclimatic sciences, hydrology and hydrobiology, geomorphology and quaternary geology, soil science, geobotany, microbiology and study of gas emission from permafrost soils, geophysics, zoology and biology. The station is a key site for these studies. IPGG SB RAS with the Samoylov Island RS is open for new scientific and educational projects and will be happy to provide its resources for partners considering three ways of collaboration: joint scientific or/and educational project; participation in IPGG SB RAS research team; independent project with the use of the station facilities.

About the numerical modeling of snow avalanches in the Russian Arctic

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Every year numerous avalanches of different types and volumes occur in mountain regions in the Russian Arctic, where seasonal snow cover is one of the most important components of the environment, making continuous development of hazard management strategies through research and experience highly relevant. Numerical modeling of snow avalanches is the most important step of the large-scale avalanche hazard assessment in the unpopulated regions without historical records providing data about the avalanche dynamics: runout distances and impact pressures. However most state-of-the-art two-dimensional avalanche dynamics models have never been calibrated in the Arctic regions.

The Khibiny Mountains region at Kola Peninsula is an exception among other Arctic mountain regions because of the available most well-documented longest avalanche database in Russia. The accurate information (including maps with avalanche outlines) from powder and wet snow avalanches, extreme rare and the frequent small ones has been being collected from 1930's by the local mining avalanche warning service. This database was digitized and put to the detailed GIS with more than 80 years of observations for certain avalanche tracks. GIS was used to analyze the initial conditions of avalanches and numerical models input parameters as well as to compare measured parameters with model results.

The two-dimensional Swiss numerical avalanche dynamics model RAMMS was used to back-calculate more than 50 well documented avalanche events recorded in the Khibiny Mountains with volumes from 2, 000 up to 167,000 m^3. As a result, most of observed avalanches were back-calculated. While RAMMS was calibrated for large avalanches (> 60, 000 m^3) in Switzerland it produced realistic results with modified friction values in completely different conditions in the Khibini Mountains. We confirmed that the friction values (μ and ξ) may be taken from the upper altitude limit «above 1500 m.a.s.l.» of the table recommended for Switzerland (RAMMS User Manual, 2017) for simulations in the Khibini Mountains (highest point is 1200,6 m). A high level of correspondence of observed and simulated run-out distances, deposition heights, flow channels and flow widths was found for avalanches with medium (25 – 60,000 m^3) and large (> 60,000 m^3) volumes in such a way.

Back-calculation of avalanches in the unchanged avalanche track (Mt. Ukspor) as well as in the same track after the construction of mitigation structures (two catching dams) were performed using 5-m resolution "historical" DEM with no mitigation structures as well as recently obtained DEM including them. While it is not recommended to apply RAMMS for simulating avalanches over dams lying perpendicular to the flow, in this case the RAMMS reproduced the observed avalanches behavior.

The long-term experience and received results from the Khibiny Mountains should be accounted during the numerical avalanche modeling in other mountain regions in the Russian Arctic.

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Ratios of methane and its homologues in the lakes of central Yamal as indicator of methane origin

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In our study of Central Yamal lakes, we analyzed the distribution of dissolved methane and volatile hydrocarbon gases composition. Comparison of methane and other hydrocarbon gases concentration, particularly ethylene, allows concluding the nature of the methane source.

Sampling of water was carried out from both bottom and surface water layers. Hydrocarbon gases composition was determined by conventional gas chromatography using GC2014 with flame ionization detector (FID).

Methane concentration in the studied samples varies from 7,24 to 61,04 ppm. Distribution of methane values is characterized by left-side asymmetry, which indicates the heterogeneity of the selection and, thus, may point at several sources of methane enrichment.

Concentrations of C2+ compounds are low and their sum ranges from 0,04 to 0,39 ppm with average value 0,06 ppm. However, distribution of the total concentration of C2+ compounds is log-normal with distinct left asymmetry which also clearly evidence several methane sources.

The maximum content among the C2+ compounds belongs to ethylene. In the samples with relatively high concentration of ethylene, its enrichment may be also attributed to decomposition of plant residues.

Ratio of methane to C2+ hydrocarbon gases as a first approximation reflects their origin. Positive correlation coefficient between methane and heavy hydrocarbon gases may reflect the common source, probably, related to deeper-seated accumulations. Negative correlation indicate the biogenic nature of methane. It is clearly manifested when considering the binary diagram CH4-∑(C2-C5) in which two groups of samples differentiate in average methane values as well as in correlation coefficients. When methane values are below 30 ppm, the coefficient of correlation between methane and C2+ compounds is -0,22, which can be evident of the absence of deeper sources contribution. When methane concentrations are above 30 ppm, the coefficient of correlation is +0,74 that may indicate the contribution of thermogenic gas.

If we exclude ethylene, which is knowingly biogenic, from the sum of heavy hydrocarbon gases, three groups of samples with various ratios of deeper and in situ sources show up on the binary diagram. The fist group combines the values above 30 ppm with average 40,2 ppm. In these samples correlation coefficient is +0,75, which probably indicate mostly thermogenic source of methane. Within the second group, methane values are below 30 ppm and averaged at 16,8 ppm while correlation coefficient is -0,96 indicating the definitely biogenic source. The third group is characterized by extremely low methane values (<15 ppm) and lack of any correlation links. Methane source for this group seems to be biogenic also.

Comparison of methane concentrations in bottom and surface water displays the decrease towards the lake surface by 7-60%. Further fieldwork, particularly when the regular greed sampling is realized, the possibility would appear to calculate the methane budget and atmospheric emission during the summer season.

Thus we conclude that low concentration of methane indicates biogenic methane generation, while higher values (>30 ppm) suggest the contribution of thermogenic methane enrichment in the total pool of dissolved methane of the Central Yamal lakes. Higher values of ethylene may probably reflect the coastal erosion processes providing plant debris and peat inflow into the lakes.

New data on the existence of paleopermafrost in the Yaroslavl region

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The morphological and geochemical differentiation of modern soils, the intensity and spatial distribution of erosion-accumulation processes on open slopes are influenced by relict cryogenic morphosculpture. Regularities of the distribution of cryogenic forms, their relationship with the relief, landscapes, and geological structure in the cryolithozone can serve as a basis for reconstructions in the paleocryolitic zone.

In the area of lake Nero in the Yaroslavl region sections at various geomorphological levels have been explored. Traces of cryogenesis have been established, which manifest themselves in the form of residual polygonal relief, pseudomorphs of polygonal-veined ice, cryoturbations and initially soil veins.

Large relic polygonal relief is clearly interpreted on satellite images, and it present a polygons with a block length of more than 80-100 m separated by elongated depressions. Inside these polygons, a second-generation system with a side of 10-30 m polygons is visible on the surface. The connection with the polygons of the second generation has drainless, often swamped depressions on the raised surfaces of large blocks, bunk ground wedges and cryoturbations with soil veins.

The two-tier structures consist of an upper wedge 40 cm high and 30 cm wide, filled with lighter sand. One of the forms had a characteristic narrow 1-2 cm “tail” penetrating into the lower part of the wedge. The lower parts of the wedges are pseudomorphs on the thawed ice, this is indicated by dislocations and drips from top to bottom along the walls of the wedge, ledges and faults formed during ice thawing and filling the cavity. The height of the ice wedges is more than 1.5 m, and the width along the top is 60 cm. Bunk veins are characteristic of the paleocryolithozone and indicate the spread of continuous permafrost in the past, and the narrow “tail” is an elementary ice vein of ice core formation time.

A cryoturbated layer with a thickness of 90-100 cm was examined at the ravine side. For the occurrence of deformations a long frozen state of soils is necessary, which serve as a support for the pressure forces developing during the freezing of the seasonal thawing layer. Cryoturbation are almost always found with wedges. In section, inclined lenses and wedge-shaped structures with a height of 15-30-100 cm and a width of up to 30 cm were embedded in the underlying deposits, which indicates shallow frozen rocks. Deposits before freezing were highly water saturated, as indicated by the post-cryogenic texture. In loam, cracks of 1.0-1.5 cm through 10 cm form a clear grid. Large mesh cryo-textures are characteristic of the upper horizons of epigenetically frozen rocks. The upper boundary of the cryoturbing layer is the position of the paleosurface, and its thickness is the depth of seasonal thawing in the past. With the current climate in central Russia, cryoturbation is not formed even during very severe winters, when the freezing depth is more than 1.5 m.

Traces of severe permafrost conditions of the past, the formation of low-temperature solid frozen rocks, polygonal vein ice with several generations and a thawing layer in the summer not exceeding 100 cm have been established. Researchers have noted such severe conditions of “Yaroslavl cryogenesis” much farther north of lake Nero. The studies were carried out with the support of the Russian Foundation for Basic Research (grant 18-05-01118) and partial support within the framework of the State Assignment on the topic “Changes in the Earth’s Cryosphere Under the Influence of Natural Factors and Technogenesis” Research work AAAAA-A16-116032810095-6.

SESSION 3: REMOTE&GEOPHYSICS IN PERMAFROST

Analysis of the global ESA GlobPermafrost map for Scandinavia

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Due to its high vulnerability, permafrost is one of the key features studied in the field of climate change impacts. Permafrost is widespread in the Arctic region. The majority of the area underlain by permafrost is however difficult to access for in-situ monitoring and it is difficult to get an overview of the current state of permafrost in many areas.

Permafrost modeling provides a solution, which overcomes this difficulty and allows studies on permafrost distribution as well as some characteristics, i.e. ground temperatures over large remote areas. Temperature at the top of the permafrost (TTOP) is one of several permafrost modeling approaches, which conceptually represents a steady-state equilibrium model. In this study, two TTOP-based models were used; the GlobPermafrost model which was used to produce the most recent global permafrost map (Alfred-Wegener-Institut) and a local Scandinavian model.

The aim of this study was twofold; firstly, the performance of the GlobPermafrost model in Scandinavia was analyzed by comparing the model output with the output from the local Scandinavian model. Secondly, the role of land covers data as an input variable in the TTOP model was investigated. The TTOP-based GlobPermafrost model was run with different land cover input data to evaluate this.

In general, the GlobPermafrost model underestimated permafrost occurrence in Scandinavia (overall r^2 being 0.39). The lowest underestimation is located in the regions with little or no permafrost. The biggest underestimations are found in peatlands and mountainous areas with more likely permafrost occurrence. Unexpected underestimation of permafrost was observed in the forests. This exposed the weaknesses of regional permafrost model overestimating permafrost occurrence in forests.

The rerun of the GlobPermafrost model with three times more detailed land cover input data did surprisingly not have a great effect on the model performance (r^2 only changed by 8%). The small changes detected in the GlobPermafrost output could be explained by the changes in wetland fraction between the two land cover datasets used as input to the GlobPermafrost model.

The overall conclusions from this study are 1) that the GlobPermafrost model underestimates the amount of permafrost in the study area, especially in the mountains and 2) that improved input land cover data was only of minor importance to the TTOP model performance and future research should hence focus on other forcing input data to improve model performance.

This study was performed as a master thesis in Lund University, Sweden, under supervision by Sebastian Westermann, Margareta Johansson, Jaroslav Obu

Link to this publication: http://lup.lub.lu.se/student-papers/record/8955040

Experience of usage and new developements of temperature monitoring systems for permafrost soils produced by "Etalon" research and production enterprise JSC

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To prevent risks of negative consequences of construction on permafrost soils and costs of their repair and restoration, it is necessary to conduct constant geotechnical monitoring at all stages of the life cycle of structures.

For these purposes "Etalon" Research and Production Enterprise JSC has developed temperature-monitoring systems for contiguous areas, which are designed for field determination of soil temperature in accordance with GOST 25358-2012. The introduction of the developed technical solutions allows increasing the measurement accuracy and reliability, simplifying the existing temperature monitoring systems, and expanding their application areas.

The architecture of the measuring systems is very flexible and allows, depending on the task, carrying out operational, autonomous or continuous monitoring of the soil temperature under the object of observation.

In October of 2012, the equipment was installed and is functioning at the facilities of Cryogenic station of the Engineering Constructions Research and Diagnostic Center of Russian Railways JSC, Tynda town, and on the turntable of Obskaya station of GazpromTrans LLC, Labytnangi town. The analysis of the system showed high accuracy and reliability of the devices, qualitatively new information on the temperature conditions of the roadbed object was obtained. Over the past period there was not a single failure.

At the request of the Institute of Physicochemical and Biological Problems of Soil Science of the Russian Academy of Sciences the system for measuring the temperature and heat fluxes of the soil was developed and installed. The system was installed at the monitoring point of the soil regimes at the observation site of the North-Eastern Scientific Station of the Pacific Institute of Geography of the Far Eastern Branch of the Russian Academy of Sciences, 2 km south-east from Chersky settlement (Republic of Sakha Yakutia). The measurements have been carrying out since October 22nd, 2014. The system has been installed and is still in operation.

Since 2014 the specialists of the geotechnical monitoring service of the engineering and technical center of “Gazprom dobycha Nadym” LLC use the thermometric equipment produced by “Etalon” Research and Production Enterprise” JSC such as thermistor chains of multipoint digital temperature sensors 0922 (MCDT 0922), LCD-1/100 RM temperature loggers of digital sensors, as well as PKCD-1/100 digital sensors portable controllers to control the temperature of the soils of the gas field infrastructure facilities bases.

By now, about 150 sets of the radio channel thermometric equipment (such as thermistor chains of multipoint digital temperature sensors (MCDT) and LCD-1/100 RM temperature loggers of digital sensors, as well as about 90 thermometric chains of multipoint digital temperature sensors (MCDT) used within the periodic polling mode from PKCD digital sensors portable controllers are used at gas condensate fields of the company (Bovanenkovskoe, Yubileynoye, Medvezhye).

At present, “Etalon” Research and Production Enterprise” JSC is developing a Remote Data Collection System. The system allows polling LCD-1/100-RM radio loggers within a radius of 1.5 km in direct line of sight, providing the possibility to connect two thermistor chains as well as there are 2 RS-485 channels for connecting digital sensors controlling systems (SKCD 1/100, SKCD 6/200) or other equipment with this data interface. The system transmits all received data via GSM to the server, it is planned to provide data access and operations with it through the WEB interface. Thus, this system allows collecting data remotely from the systems of temperature monitoring of soils, without the need to travel to the site.

It shall also be noted that “Etalon” Research and Production Enterprise” JSC is a developer and manufacturer of the standard metrological equipment for calibrating the various temperature sensors, and is ready to equip the metrology laboratories of thermometry with complete sets of this equipment.

Geophysical Monitoring of Permafrost in Yakutia - Observation and Modelling

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Regular water and energy supply in permafrost areas are vitally important conditions for inhabitants of the large North territories of Russia. Dam and flank shore stability is the key point for safety of reservoir (power pool, water supply, tailing pit, etc.). In permafrost areas stability of many engineering structures, including hydraulic work, associated with thawing - freezing process. Increasing thawing of Yedoma permafrost may have positive feedback for greenhouse effect when gases emitted to the atmosphere. The presence of artificial reservoirs in permafrost environment gives an additional effect for deeper thawing for active layer due to seepage development. Emergency situation of Hydro Unit we have when seepage occurs in permeable talik zone adjoining to reservoir or directly in dam body. Hydro Units are natural laboratory for the study the interactions between permafrost environment - hydrosphere - climate.

We present results of long-term geophysical monitoring on hydro technical objects of Western Yakutia (Sitikan and Viluy Hydro units) and testing active layer thickness (ALT) area of near Svetliy settlement in Western Yakutia. Geophysical monitoring included Electrical Resistivity Tomography, Method of a Natural Field, Georadar, Seismic Profiling and Sounding. Down-hole observations included complex of logging studies - Thermometry, Resistance, Flow meter survey, Radio Wave Geo – Introscopy (RWGI). Ground level and down-hole geophysical survey focused on detecting thawing zones (talik) in dam, its flank and tail-water zone. Long-term geophysical monitoring shows up spatial-temporal permafrost evolution and talik development in the flank shore of Sitikan dam. Detecting of inflow zone and seepage velocity performed for right-bank contiguity of Vilyui HPS-1.

Geophysical information was used for constructing reliable numerical models of interaction of human impact (Hydro units) on the system "Permafrost-Reservoir-Climate". We solve non-steady problem of heat-mass transfer in fractured-porous saturated frozen environment. Model analyzes conditions causing origin and development of talik near reservoir, such as air temperature variations, snow cover, seasonal change of water temperature in storage basin, permeability evolution in frozen soil and inner structure of frozen massif. Numerical evaluations of originating and development of talik-zones near the dam, performed for two cross-sections: normal and orthogonal to general direction of filtration flow (quasi 3D). Proposed model can be used for analyzing more complex situation.

The application of electrical resistivity tomography in the study of the underlake talik

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Study of permafrost underwater permafrost is necessary for estimation of thaw depth and calculation of greenhouse gases emission to the atmosphere. Drilling makes it possible to determine talik depth under a lake, but it is expensive and sometimes quite difficult. The alternatives to drilling are geophysical techniques such as electrical resistivity tomography (ERT) and ground penetrating radar (GPR).

The purpose of the work is to study the appearance of hydrogenic talik in electrical resistivity distribution in underlake medium on the basis of 2-D and 3-D inversion.

We used ERT and GPR on the one of thermokarst lakes on Samoylov Island (Lena River delta). The lake size is 340x90 m, its maximal depth is 5 m. ERT sounding was conducted on 9 parallel profiles with length of 355 m (electrode spacing - 5 m) and distance between profiles of 50 m. Dipole-dipole and Schlumberger arrays were used during the measurements. 2-D and 3-D inverse resistivity models were obtained with Res2Dinv and Res3Dinv software. GPR survey was conducted with 150 MHz antenna. Two GPR profiles were done from the water surface.

It is found that dipole-dipole array measurements yield false low-resistive anomalies on the lower part of the sections (this effect is found only on profiles in the nearby of the lake margin). In the middle part of the lake results of 2-D inversion of Schlumberger array data show that talik depth is about 30-40 m. In contrast 2-D inversion of dipole-dipole array data determine the border between thawed and frozen matter at the depth of 20 m. Joint inversion of dipole-dipole and Schlumberger data yields the most representative result – the border is determined distinctively, beyond that features of permafrost structure in coastal area.

In consequence of 3-D inversion of ERT data it is found that maximal depth of thawing under the lake is 21 m. Horizontal slices of 3-D model show that the main part of melted matter (limited by 400 Ohm·m isoline) is situated under the most deep part of the lake (more than 4 m depth).

Numerical modeling of ERT confirmed the false low-resistive anomalies on the profiles near the lake margin. Beyond that it was clarified that starting geoelectrical model should include an area of elevated temperature in the neighborhood of the talik and complex permafrost structure along the coast.

GPR survey from water surface empowers to determine lake bottom relief with high precision and the border between thawed and frozen matter in the case of its shallow occurrence.

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Features of Automated Soil Moisture Monitoring

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Automated systems are used to monitor soil moisture (W) in geocryological and environmental monitoring programs. We consider the methods used in the most common commercial measurement systems. Such systems convert moisture or potential moisture into electrical signals. This includes measurements of the electrical resistance of a standard porous body in equilibrium with the soil (RM) and the dielectric constant of the soil or the standard porous body placed in it.

To assess the reproducibility and accuracy of measurements while monitoring soil moisture, we compared the values of W measured using the RM technique (Watermark sensors), reflectometry in the time domain (TDR sensors Soil Probe EC20, EC10 and EC05), as well as measuring the real and imaginary components of the dielectric constant (Vitel Moisture Probe), on the one hand, and W values obtained by the thermo-weight technique, on the other hand. The results show that the use of systems with sensors of all three types lead to systematic errors in measured W values.

RM Watermark moisture potential sensors with gauges and loggers were installed at the Pushchino monitoring site in the seasonally freezing gray forest loamy soil. The soil has an average annual temperature of +6°C. The amplitude of the annual temperature variations on the ground surface is 9°. We consider the measurement data at depths 20, 50 and 95 cm, recorded 4 times per hour. The two-year sequence of measurements was accompanied by a quarterly monitoring of soil moisture using the thermo-weighting method. For control measurements, soil samples obtained at the monitoring site in small diameter boreholes were used. The data obtained show that the Watermark sensor, supplied with a factory calibration of the moisture potential in the range from 0 (full capacity) to 180-200 centibars, allows to obtain in this potential range moisture values underestimated by 18-30% compared with control values (thermo-weight technique). Changes in this error in time were not observed, which indicates the absence of a drift of indicators for two years of monitoring.

To take into account the systematic error of RM measurements in the laboratory, an individual calibration of the Watermark sensors was carried out using samples of loam obtained at the monitoring site. Calibration was performed at 5 points in the range of the weight moisture content of loam from 10 to 36% (full capacity). The thermo-weight technique was used to obtain the control W values. A comparison was made of the sequence of monitoring data derived from individual calibration with reference values. It is shown that the individual calibration of sensors on the soil samples from monitoring site allows obtaining data from RM measurements of W, which coincide with the values measured by the thermo-weight method.

Similar systematic errors were detected in the series of soil moisture measurement data obtained using the Soil Probe and Vitel Moisture Probe dielectric meters with factory calibrations. As in the case of the Watermark RM sensors, individual calibration allows one to take into account the systematic error and to obtain accurate and reproducible data.

We recommend including in the monitoring protocols the individual calibration of sensors before their installation at observation sites to improve the quality of data from automated soil moisture measurement.

Advanced stochastic modelling of thermokarst hazard for linear objects in uniform geological conditions

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There is widespread practice of construction of linear infrastructure within Russian permafrost areas. We use stochastic approach and remote sensing as the best option in case of lack of data.

The aim of this work is to improve stochastic model of thermokarst depressions appearing and expanding along the road paved on the icy ground.

We assume that thermokarst depressions are constantly appearing (i.e. asynchronous start). This stochastic process is running independently for the non-crossing strips during non-crossing periods. So, we can find an equation of the probability of the depressions to appear within a sample strip, which depends exclusively on the strip length and time. The main results of this model are: density of lake location should fit Poison distribution and thus the distance between lakes projections to the road should fit exponential distribution. This means that depression appearances are independent events. Projections of the edges of depressions (semi-axes) should fit lognormal distribution. Ratio between two types of projections (to linear object and perpendicular to it) should have correlation.

Empirical testing includes:

- Revealing provoked thermokarst depressions using RSD,
- Measuring the length of the focus projections on the linear structure,
- Detecting the centers of the focus projections on the direction perpendicular to the linear structure,
- Estimating correlation coefficients for the length of the focus projections on the linear structure and the direction perpendicular to the linear structure,
- Comparison of the empirical distribution of projections with the theoretical lognormal one by Pearson's criterion.

When allocating the thermokarst depressions, we always used archival Corona images taken before the construction of a linear structure (1960-1970). Thus, we are sure that all detected thermokarst depressions either appeared or radically changed under the man impact.

We used modern high resolution images captured at 2005-2017 years with resolution 0,3-0,7 m/pix (R&D Centre "SCANEX", Digital Globe by DigitalGlobe Foundation, Russian Space Systems (Research Center for Earth Operative Monitoring)).

For verification of the model we used several sites in different conditions with linear objects (unsealed roads) with total length 69 km. There were found 750 newly appeared depressions at its sides.

Distributions of the lengths of the projections on the linear structure and the perpendicular to the linear structure are lognormal is confirmed for all the samples at a significance level of 0.99.

We analyzed the change of the proportionality factor between the projections of the depressions on the linear structure and perpendicular to it. In the majority of cases the testing results confirm the suggested model at the level of significance 0,99.

For newly appeared lakes in homogenous environment the distance between projections of lakes centers to the road fits exponential distribution. It means that lakes location along the road fits Poisson distribution.

The approach can be implement to the prediction of lake appearance and thermokarst hazard forecast for the unsealed roads in similar environment.

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Acoustic properties of water-saturated sand during freezing and thawing. Results of Ultrasonic laboratory measurements

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Physical properties of soils in both frozen and thawed states are quite well studied. A large amount of literature is devoted to the acoustic properties of grounds and soils; for example, such books as [Zykov, 2007, Frolov, 1998, Gorjainov, 1992]. A number of recent articles are devoted to ultrasound measurements, for example [Kurfurst, 2011, Li et.al, 2017]. Nevertheless, still only one acoustic waves parameter are been studying mainly - the arrival time of the longitudinal wave. This situation has been preserved to this day. Authors could find only one scientific publication, in which dynamic characteristics of longitudinal waves of dispersed saline soils at temperatures of -30…+10 ºC were concerned [Dou, 2015], dynamic characteristics of shear waves are not considered at all. In the report we present results of ultrasonic (100 kHz) measurements on a sample of full water-saturated sand on both p (longitudinal) and s (shear) waves in temperature range -20…+20ºC. In the report we discuss not only waves velocities but also signal amplitude and central frequency either. In our ultrasonic measurements we obtained p and s waves data quite detailed over the time of the freezing and thawing process and, accordingly, quite detailed over the sample temperature changing. The type of dependences of kinematic and dynamic parameters is the same for p and s waves and for the freezing and thawing cycles. For all parameters there are constant maximum value at a large absolute negative temperature and constant minimum value at positive. In temperature range -5…0 ºC smooth changing from maximum to minimum during thawing and vice versa during freezing was observed. A stable change in the amplitude and frequency of the signal during freezing and thawing was observed, therefore, the dynamic parameters of the signal can be used to accurately determination of soil state. Dynamic parameters of the signal reach the maximum value at lower negative temperatures than velocities, which fact indicates the presence of unfrozen water in the partically frozen sample. Estimation of unfrozen water amount by dynamic characteristics will be more accurate than by using waves velocities [Huang, 2013]. Central frequency of the p and s waves is almost everywhere below the “passport” 100 kHz, even at negative temperatures. This fact indicates the frequency-dependent absorption elastic waves energy in the sample, which may be caused by heterogeneity of the sample and unfrozen water and gas presence observed even at temperatures significantly below 0 °C.

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Possibilities of wave methods of geophysics for permafrost monitoring on the example of CALM sites (European North)

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Determination permafrost table depth and its shape in depth and plane, as well as the properties of the seasonally thawed layer are main tasks of permafrost research. Direct geocryological methods do not always allow to solve the tasks. In these cases, geophysical methods should be used.

Successful using of geophysical methods in permafrost zone are based on a significant difference in the physical properties of frozen and thawed ground [Frolov, 1998]. In particular, during transition from the thawed state to the frozen state, the velocities of elastic waves increase by order. Differences in electrical properties of ice/water/air provides successful using of ground penetrating radar (GPR) [Vladov, Sudakova, 2017]. Permafrost table and bottom are “strong” boundaries for elastic and electromagnetic waves, which allows these methods to be used to determine the configuration of permafrost boundaries and the taliks shape [Melnikov et al. 2010; Shean, Marchant, 2010].

Integration of seismic and GPR allows, on the one hand, to reduce labor costs and increase productivity, and on the other, to investigate the near surface part of geocryological section in detail and determine the physical properties frozen and thawed ground [Sadurtdinov, 2016; Sudakova et al., 2017].

In this report we present results of seismic and GPR integration results, obtained at the CALM sites of the European North in the Pechora river delta. Using wave methods of geophysics for solving engineering and geocryological issues proved to be of high efficient. Without “a priori” data, seismic exploration makes it possible to unambiguously identify permafrost boundaries, and GPR - to investigate the upper part of the section in detail.

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Geotechnical Monitoring of Pipeline Systems in Permafrost Conditions

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The purpose of geotechnical monitoring is to ensure the safe operation of pipeline system facilities and to implement efficient, responsive protective measures. Observation is the first step in monitoring the pipeline.

Transneft possesses the largest pipeline network in Russia and one of the largest networks in the world. Four of these oil pipelines are located in complex climatic conditions and are monitored by the Pipeline Transport Institute. At the moment, The Pipeline Transport Institute performs geotechnical monitoring of the Transneft pipelines with a total length exceeding 6000 km, most of them located in permafrost zone. Due to the length of the pipelines, their operation in the permafrost condition and the inaccessibility of large parts of the survey area, improvements of observation methods and techniques are necessary.

The application of airborne laser scanning method (LIDAR) has opened up new opportunities in the remote monitoring for observe environmental and technical conditions of the pipeline and pipeline facilities. Two laser scanners were tested at the test sites of pipeline. The possibilities and limitations of LIDAR technique to observe environmental conditions are defined.

In the taiga zone the detail and precise of digital terrain models depends of the scanning systems type, scanner settings and flight characteristics. The test results allowed determining the minimum sizes of the relief forms, which possible to identify by the LIDAR data.

LIDAR data analysis is used to identify and classifying exogenous geological phenomena (erosion forms, ravines, thermokarst lakes and depressions, pingos, landslides, etc.), as well as areas of polygonal relief with the possible presence of ice wedges in the pipelines survey area. Transneft information system on the base of GIS allows us to do a complex analysis of observation and survey results. Complex analysis of the monitoring results (LIDAR data, in-line inspection, ground and remote observations data) allows to increase the accuracy of identification of exogenous geological phenomena and ice wedges distributions areas.

Permafrost and other geological processes can put stress or strain on the pipeline, which may result in displacements and bends of pipe sections and loss of pipeline stability and strength. The use of LIDAR results is recommended for ground geological survey planning on the complex geological conditions and for identification the reasons behind displacements and bends development of pipe sections.

The local automated geodetic network has created a basis for comparing airborne laser scanning cycles. A comparison of the “clouds” of laser reflection points over a two-year (2017-2018) observation period made it possible to estimate the geodetic referencing precise of two digital elevation models.

Surface change maps which compares DEMs from 2016-2017 were created using ArcGIS program. The automated analysis methods of the LIDAR results developed by The Pipeline Transport Institute made it possible to quantify surface changes, spatial and altitude position changes of pipeline.

Surface changes measurements allows us to estimate the development of such processes as erosion, karst, thermokarst, frost heaving and etc.. The development of processes can manifest itself as an increase in the size of previously identified forms, and in the emergence of the new ones. Estimations of the processes development rate by LIDAR methods are the most successfully in drained areas. According to results of the LIDAR in 2017-2018 on the ESPO-1 main pipeline was found subsidence of ground associated with insufficient compaction of the ground at the repair work sites, as well as with ice thawing at the ice-rich permafrost. Using LIDAR method made it possible to identify the amount of ground subsidence in the oil pipeline survey area for the observation period.

The results of observations, surveys and instrumental measurements are the initial data for prediction models of the current and future state of the pipeline system facilities. Approaches, methods and program design are universal and recommended for use in other long linear infrastructure (e.g. railroads, roads, other pipelines etc.) to ensure their safe operation.

Application of high-frequency ground penetrating radar (GPR) to studies of permafrost-affected peat plateaus

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High-frequency GPR study of the permafrost-affected soils in peat plateaus of Russian Arctic regions (European North and Western Siberia) have been conducted. Permafrost table depth was measured by GPR using “Zond-12E” system (Radar Systems, Inc., Riga, Latvia) with shielded ground-coupled high-frequency antennas. The obtained GPR data were processed in Prizm 2.60.02 software package. Applied algorithms recommended by the manufacturer for the processing of the obtained GPR data are: removal of «ringing» noise from the GPR data; bandpass filtering using a cosine filter; automatic gain adjustment; signal conversion from time to depth scale. When converting the signal from time to depth scale, the average velocity of electromagnetic wave (v) was taken into account, which in the active layer (AL) is 10 cm / ns at soil dielectric permittivity of ε=9. For permafrost v=15 cm/ns, =4, for water-mass (water-logged areas) v=3.3 cm/ns, =81.

In the discontinuous permafrost zone of the Russian European North, where there are considerable variations of permafrost table depth in the upper 10-meter soil strata, both high-frequency antennas surface shielded antennas (300 and 900 MHz) have been used. The combined use of 300 and 900 MHz-frequency ground-coupled shielded antennas is an effective solution for determining significant variations (0-10 m) in the depth of permafrost table and lithological contacts (the lower limit of the peat layer and technogenic soils) in peat plateaus. Deeper penetration of the 300 MHz antenna signal allows studying the topography of deeper closed taliks (2-8 m) within the road warming impact zone and beneath the fens. A high frequency antenna (900 MHz) allows studying in detail the permafrost table topography in the 0-2 m depth strata, which is critical in the investigations of soil-permafrost complexes. The results of high-frequency GPR surveys revealed that the construction and operation of a cement-concrete highway running across peat plateaus in the southern parts of the permafrost zone contributes to a significant subsiding of the permafrost table (down to a depth of 8 m). The warming (defrosting) effect of the road is significant in the zone up to 50 m in width, comprising the road embankment, roadside depressions and adjacent sites of peat plateaus. The undisturbed sites of peat plateaus are characterized by spatial heterogeneity of permafrost table depth caused by the mesotopography of peat mounds and fens.

In the continuous permafrost zone of Western Siberia high-frequency GPR study (antenna 300 MHz) revealed spatial heterogeneity of permafrost table depth and assessed water content in active layer in the polygonal peat plateaus. An increase in thaw depth is associated to higher water content in active layer (up to 100%), which is resulted from waterlogging due to the presence of ice wedges.

The use of modern high-frequency GPR technologies allows studying the spatial differentiation of permafrost table and lithological contacts depth as well as configuration of ice wedges, assessment of volumetric water content in active layer.

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Digital Thematic Mapping of the Current State of Permafrost Landscapes in Yakutia

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In 2017, the Melnikov Permafrost Institute SB RAS compiled a digital 1:1,500,000-scale map of permafrost landscapes in the Republic of Sakha (Yakutia) and an accompanying catalog of permafrost landscapes. The map identifies 20 terrain types and 35 plant associations characterized by relatively homogeneous geocryological conditions. The catalog characterizes 54 permafrost-landscape units.

Based on this map, a GIS model of current permafrost conditions has been developed in the form of thematic maps in ArcGIS format, depicting ground temperature, active layer thickness, ice content, depth to wedge ice, transient layer thickness, and geocryological processes, for rapid sensitivity assessment of permafrost environments to anthropogenic impacts and climate change.

Quantitative analysis of the spatial patterns of permafrost conditions has shown that landscapes with ground temperatures from −2 to −4°C are most widespread (34% of the region), while warm permafrost (0 to −2°C) is least common (4%). Landscapes with active layer thickness of ~1 m make up 36% of the region, which is the highest value. Less than 3% of the region has active layer thicknesses up to 3-3.5 m. Sediments with low ice contents (<0.2) make up 38.7% of the region, while high ice content (>0.4) sediments occupy 31%. Thermokarst, a process presenting most serious hazards, has been found to be active in inter-alas and poorly drained terrain types. In general, low ice contents in most landscape units imply limited development of cryogenic processes. Depths to wedge ice vary from 0.5 to 2.3 m depending on geographical location and range from 1.7 m in northern taiga to 2.1 m in central Yakutia. Arctic tundra and typical tundra have lowest values of this parameter, 0.5 m and 0.9 m, respectively. The transient, or ice-rich protective, layer varies in thickness from 0.2 to 0.6 m in the tundra, from 0.7 to 1 m in larch woodland of the northern taiga zone, and averages 0.9 m in old-growth larch stands of the middle taiga zone. The protective layer is absent in disturbed, deforested areas in the northern and middle taiga zones.

The spatial patterns identified by this study should be considered in the development of enactment acts to the Republic of Sakha (Yakutia) Law on Permafrost Protection.

The GIS model will be useful in short-term and strategic socio-economic planning, which would account for changes in permafrost landscapes. It can also be used in GIS modeling of the Late Pleistocene to Holocene evolution of permafrost environments in Yakutia and future changes with projected climate warming.

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Application of the natural electric field method for studying the outburst lakes of the Larsemann Hills (East Antarctica) during the field season of the 64th RAE

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One of the main features of the hydrological network of the Larsemann Hills (Princess Elizabeth Land, East Antarctica) is the presence of numerous lakes, where periodical outbursts can take place. The study of such catastrophic phenomena is important both from a scientific point of view and for the practical aspect because abrupt discharges of water masses can cause significant damage to objects of human activities. The Russian Antarctic Progress Station is located in that area, which is a key structure in securing of the functioning of the inland Vostok Station. Outburst floods of lakes, which are situated near the infrastructure facilities, especially used in summer periods, can significantly complicate their operation. For example, the dip, which was formed in the Dålk Glacier and destroyed the active sector of the route connecting Progress Station with the airfield and the point of formation of logistic traverse to the interior of Antarctica.

Ensuring the safety of the station’s infrastructure in the summer period should be accompanied by the monitoring of the state of outburst lakes. Hydrological observations of such water reservoirs can be effectively supplemented with data from geophysical surveys. In particular, the application of the natural electric field method, which is commonly used in hydrogeological studies, is suitable for the assessment of the state of snow and ice dams pondering lakes. The workers of the engineering glaciological detachment carried out a survey based on this method on Boulder Lake during the field season of the 64th Russian Antarctic Expedition. A linear negative anomaly of the natural electric field potential was spotted, and its position coincides with the previously identified channel of the flow of lake waters. The presence of flooded areas within the anomaly is confirmed by drilling results.

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SESSION 4: INFRASTRUCTURE&ENGENEERING PUZZLES

Phase composition and chemical properties of saline soils on the Arctic coast of Russia

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The phase composition of saline frozen soils is a standard parameter for foundation design in Russia (Soil bases and foundations on permafrost soils, Appendix B, 2012). Saline frozen soils have lower deformation and strength properties, lower freezing temperatures and high unfrozen water content. The objective of the study is accurate identification of phase composition using field and laboratory data of frozen soils that is improving a design. The phase composition of frozen soils was investigated using thermodynamic modeling method on the basis of the Pitzer model. Algorithm of phase composition calculation is as follows:

freezing temperature (FT, °C) and unfrozen water content (UWC, %) using software «FREEZBRINE»;

FT and UWC including soils water content;

FT and UWC including solid soil particles influence;

heat capacity of soil (J/kg*°C).

Input data are:

soil and water chemical composition;

water content (%), plastic limit (%), plasticity index of soils (%);

soil density (g/cm3), dry soil density (g/cm3), solid particles density (g/cm3).

Output data are freezing temperature of soils and solutions, unfrozen water content.

Nearly 80 soil samples (sands, sandy loams, loams, and clays) from onshore and offshore at Yamal and Gydan peninsulas were analyzed. The freezing temperatures of sands ranges from -3,32 to -0,37°C; of loams from -10,32 to -0,27°C. The possible cause is an increased salinization (up to 7 %) of several samples offshore and onshore. This potential salinization anisotropy must be taken into account in foundation design.

Standard deviation of the some measured and calculated freezing temperature is 0,2°C for sands and 0,7°C for loam. The calculated values of FT are higher than measured. This may be caused by the presence of organic matter in the soil.

The results are using for geotechnical and thermal models. For example, to calculate the soil thawing under the foundation or to predict the change of soil temperature. Also, unfrozen water content is a necessary parameter for soils heat capacity calculation that is potentially interesting for the design of thermosyphons.

Problems of reinterpretation of past years in engineering geology (on the example of the Anadyr city)

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Large-scale engineering investigations for building were conducted in the 60-80s of the last century on the extreme north-east of the USSR. Engineering and geological works were carried out by regional divisions of the trest engineering and constructional investigation of the Ministry of construction of the USSR (TISIZ). The main method of research was drilling small wells (up to 20 m). In the sections previously distinguished underground veins of ice in hard rocks and the formation of ice in marine sediments. Description of reformed ice wedges for the engineers of the past years was difficult. To indentify and distinguish repeatedly-wedge ice on the cuts began in 1990 only.

The construction and reconstruction of buildings in the settlements of Chukotka is carried out within the territories of building in the present time. The building was previously studied in engineering researtchs by the enterprises of TISIZ. The quality of engineering geological materials of the past years is questionable. This is due to the frequent use of auger drilling, with large number of rejected wells, with an ungrounded determination of the age and genesis of precipitation, with a preference for layered sections with multi-level massive ice. The use of archival data requires reinterpretation of geological materials with certification of adjusted geological sections by core drilling wells. This is possible by paleogeographic reconstruction of the conditions of formation of permafrost, the use of objects of analogues and the application of engineering geophysics.

On the territory of the city of Anadyr there are several sites with the occurrence of problematic ice sandy loam soil of glacial-marine Genesis, accommodating massive ice of variable power of 1,5-3,5 m. Absolute marks of heights of these sites of 30, 50 and 75 m, an interval of depths of occurrence in a section of the ground containing ice of 3,5-12 m. This is 15-50 m above the roof of the section of glacial-marine sediments in the outcrops of the cliffs of the Anadyr estuary. Granulometric composition, salinity, organic matter content of sandy loam indicate lake-alluvial origin. For these characteristic syngenetic reformed ice wedges. These continental sediments are located at different hypsometric levels. They are described in detail in the breaks of thermal erosion and thermal abrasion in the vicinity of the city of Anadyr. All of this suggests that the glacial-marine sandy loams are actually syncryogenic lacustrine-alluvial sediments. At the same time, exploratory wells of the past years at different depths do not detect layers of ice, but various stages of multi-disc ice.

The proposed hypothesis has been successfully confirmed in the course of research for the construction of engineering structures in 2014 and 2018. The method of Ground Penetrating Radar (GPR OKO-2, AB 90, AB 400) were identified, delineated in the plan and in the section of buried sub-vertical and linear wedge bodies of underground ice complex morphology. The results of the geological interpretation of the radarograms were certified by drilling. In the first area of the well in the range of 2,6-10 m opened gravelly sandy loam. In the section of the neighboring well drilled at a distance of 14 m in the depth range of 3,3-15 m were found 2 stage of underground ice with a thickness of 3,6 and 2,8 m. One well was drilled in the second section. At the point designated by georadar as the location of the buried vein, underground ice is revealed in the depth range of 3,5-7 m.

In conclusion, it should be noted that construction sites with multiple-wedge ice differ in the activity of thermokarst deformation of buildings and structures.

Influence of urbanization on permafrost: a case study of Yakutsk

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The term "urbanization" was first used in Spain in 1867 and introduced into the Russian literature in 1957. At present, urbanization is understood as a historical process driven by higher comfort of cities for life, activity and societal progress. There are two forms of urbanization: agglomeration and megalopolis. Urban agglomeration refers to a group of closely spaced urban and rural settlements connected by strong economic and social links, as well as by common use of surrounding environments. A megalopolis is a union of agglomerations along transportation routes.

The largest cities in the Russian permafrost region developing currently as an agglomeration include Chita, Tyumen, Vorkuta, and Yakutsk. Despite differences in age, the process of urbanization in these cities is determined not only by socio-economic factors, but also by permafrost and its variation in space and time.

Yakutsk is one of the first subarctic cities in Russia and probably in the world. The urbanization problems pertinent to Yakutsk appear to be characteristic of younger cities built in permafrost areas. The cities listed generally develop as agglomerations. Undoubtedly, urbanization problems in the permafrost region are determined by geographical location, history and socio-economic development of the city, as well as by natural and man-induced changes in the environment.

Based on population, Yakutsk can be defined as a city starting from 1911 when it had about 10,000 inhabitants. The period from its establishment in 1632 to 1911 can be considered as the first stage in urbanization of Yakutsk. The second stage of urbanization, between 1911 and 1967, was significantly shorter, with the population growing to 100,000. The third stage of urbanization identified by our study was from 1967 to 2001, when the population grew to about 200,000. This stage marked the intensive construction of three- to five-story buildings. First small-size plants and factories for raw material processing appeared. During the fourth stage of urbanization, from 2001 to 2015, the population of Yakutsk increased to 300,000. First buildings of nine and twelve floors appeared, and large-size social and commercial facilities were built. Construction of elevated, surface and buried linear utility lines was continued. As a result, permafrost conditions were significantly modified in the urban area. The current, fifth stage of urbanization began in 2015. Buildings with increased comfort levels and more floors are under construction. Most of the city's roads are paved with asphalt concrete meeting current standards. All this causes further changes to the urban environment and climate. With a possible increase in air temperature due to natural climatic variability, as well as anthropogenic impacts, we can expect further changes in the geocryological conditions.

The urbanization stages identified for Yakutsk are generally applicable to other Russian cities on permafrost, although stage lengths and details are city specific depending on urban and natural environments. This predetermines the organization and specificity of studies of the effect of urbanization on permafrost.

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The South-Tambey Gas Field (Yamal Peninsula) and system for Gas extraction and processing is the most Nord the fuel-energy international project in Russian Federation. The Project includes: a Gas Field, Gas training systems and internal gas transport system, LNG, Airport and Seaport. The implementation of the project and the expansion of economic interests in the Arctic as a whole are associated with the construction of very complex technological facilities in extremely complex and diverse geocryological conditions. This often needs using new methods of construction and engineering protection, using new types of foundations, not previously used in the Arctic.

The analysis of engineering-geocryological conditions shows that at least 44% of the territories are very difficult conditions for construction: high ground ice content, dangerous cryogenic processes, salty grounds, cryopegs and so on. Deep, up to 50 m, pile foundations and factually continuous ground thermal stabilization system (TSG) to a 25m deep were realizated during the construction of LNG complex. As a result, the thermal and mechanical impact of engineering structures on the grounds is very significant.

The initial geocryological conditions of the construction area were very diverse. After construction all this variety of grounds and permafrost conditions turned out in the intense cooling zone as result of TSG work. At depths of 15-20 meters the annual grounds temperature often reaches -8^{0}C. Near the surface the soil temperature reaches -25^{0}C or more during the most of the year period. That is, during the first year of operation of TSG the grounds influenced by deep and fast cooling.

Geotechnical monitoring, which is implemented within the framework of the project, is a system of stationary and periodic observations of both the parameters of geocryological environment (including background) and the state of structures foundations.

General methodological principles of geocryological monitoring and principles of interaction of frozen grounds with engineering objects are well known. However, there is no reliable information about the geocryological and engineering consequences of long-term interaction of deep foundations with frozen, saline and iciness grounds in the conditions of a deep and permanently cooling of grounds.

The basis of monitoring system development is systematization of the effect types on an engineering structure. Indirect and direct impacts on the grounds and on the aboveground structures are included in the systematization. Each type of impact is differentiated due to the cause of violations, which finally lead to a decrease in the operational reliability of engineering structures.

Justification of the number of measurements is one of the most important elements of the observation methodology because the optimal frequency of observations ensures the sufficiency of the information field for making control resolutions. Several levels of observations range depending of the state of foundations and activation of hazardous processes are substantiated: normal, detailed, intensive and emergency.

Observations results are presented in a space-time form, which contains all observations results and results of measurements automated analysis. The results of observation for each object are collected in separate file which contain: basic engineering-geocryological information, the scheme of observation, the results of the measurements, and the state of the monitoring network, a photo gallery and an overall object state assessment. Thus, the file contains full information about the object and its monitoring during the cycle of its operation. The system is accumulative and is an information base for the development of engineering protection of structures and management of a control decisions.

Hazardous cryogenic processes on Yamal peninsula, Marre-Sale and Bovanenkovo study areas

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Cryogenic processes in the cryolithozone are caused by the reaction of the upper horizons of sediments to the changes of thermal regime on the surface or the thermal and mechanical impact of water on the banks water bodies. Thermokarst, thermo-erosion, cryogenic slope processes, frost heaving, frost cracking, gas emission craters are the most dangerous of them, especially to the industry, due to the possibility of the sudden activation on the large areas. Although, the duration of such activation periods does not exceed several years because northern permafrost regions have frozen ground of low temperatures and relatively short summer period.

The purpose of the work is to establish the conditions that trigger the activation of hazardous processes on two study sites on the Western Yamal — one on the coast (Marre-Sale) and one in the inner region (Bovanenkovo).

Observations on Marre-Sale site show the extremely high spatial variability of the rate of retreat of the sea coasts within one year. During 40 years of observations the average coastal retreat rate was 1.6 m/year; the maximum reached 3.7 m/year (2012); the minimum — 0.5 m/year (1978, 2017). Long-term general course of the coastal retreat rate has oscillatory nature: between high rates periods (1987–1995; 2005–2012) there are low rate periods, where minimum retreats were recorded.

No direct relationship between air temperatures and the rate of bank destruction were detected, but the periods with low retreat rates correlate well with low average summer temperatures. Moreover, the coastal retreat rates have a high correlation with the Arctic oscillation index. Another factors that affect coastal retreat rates on the Western Yamal are the seasonal sea ice regime, the number of storms and the rate of thawing of shallow water permafrost.

While seacoast on Western Yamal was relatively stable, in the inner region on Bovanenkovo site the retrogressive thaw slumping associated with the melting of tabular ground ice was observed more frequently. In recent years relief is being reshaped — a new cycle of activation of previously stabilized forms has been noted. Snow accumulates in the newly formed depressions, which leads to an increase in the temperature of the sediments below. In this case high rate of retrogressive thaw slumping process where tabular ground ice is exposed in the outcrops of 6-12 m height may pose a real danger to the infrastructure.

The surface of the tabular ground ice deposits is heavily eroded, but the absolute elevations of the bottom of the tabular ground ice bodies is the same over large areas - absolute depths between 10 m and 40 m below sea level (21.5 m b.s.l. on Bovanenkovo).

The cavities filled with gas are being formed, when tabular ground ice is thawing from the bottom. The gas pressure in such cavities may exceed the strength of above permafrost sediments, especially when the above layer of frozen ground is too thin. At first this may result in formation of small mound on the surface, which may then burst into the gas emission crater, which later will transform into lake. Gas emission craters are expected to appear in areas of the floodplains where fragments of tabular ground ice deposits with cavities and gas caverns on the bottom are preserved, permafrost above is thin enough and is characterized by high temperatures.

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Application of laser scanning for evaluation of deformations of linear objects in the cryolithozone

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Permafrost is a key characteristic of the arctic environment, which is sensitive to current trends in climate change. The increase in air temperature leads to warming and degradation of frozen soils. The permafrost engineering and permafrost parameters, in their turn, are directly dependent on temperature conditions, which is a great problem for buildings and infrastructure in the cryolithozone.

The Svalbard Archipelago is a "global leader" in global warming. Existing studies indicate a significant increase in air temperature, for example, according to ACIA, the increase in average annual temperatures in the region from 1954-2003 exceeds 30°C. The strong increase in air temperatures in Svalbard is also adverted in the IPCC report, for example, for the period 1986-2005 temperature rise is estimated at 3...4°C. A number of authors predict an increase in average annual temperatures over the period 1990–2050 at 1,160-2,50 °C. The NCCS data published in the 2018 report also show a significant increase in air temperature.

Taking into account trends to climate warming, the issue of monitoring buildings and structures in the Arctic regions for deformations caused by geocryological causes becomes particularly relevant. In the case of linear man-made objects, monitoring by traditional geodesic methods is difficult, which requires new approaches and methods for detecting deformations. One of the most promising methods for examining extended objects is laser scanning.

To study the deformations occurring on the roads in the city of Longyearbyen, was used a laser scanner Riegl VZ-1000. This device has a high measurement accuracy (less than 5 mm) and shooting distance about 1400 m. The time, required to conduct a survey from one point, is from 5 to 15 minutes (depending on the selected scanning parameters).

To process and analyze the scanned materials were used RISCANPro and CloudCompare software. These programs allows us to compare scans made at different times, which allows you to evaluate the change in surface height. This method allows us to identify and evaluate the deformation. In addition, it is possible to build surface profiles, calculating the parameter of geometrical asperity, which makes it possible to detect roughness with dimensions from the first millimeters. The spatial resolution of the resulting 3D models is significantly higher than that of the «traditional» DEM.

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Infrastructure deformations in the Arctic under the influence of cryogenic processes

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Risks and damages associated with deformations of buildings and structures in permafrost zone are increasing in recent decades. The deterioration of the permafrost-ecological situation, the reduction of engineering and geocryological safety is due to technogenic effects on the permafrost soils of the foundations and to climatic changes. More than 60% of the objects in the permafrost zone of Russia in such cities as: Vorkuta, Igarka, Dixon are deformed, about 40% in Yakutsk, 35% in Norilsk, Talnakh, Mirny. In fact, 100% in old national settlements are deformed, more than 80% of ground dams with a frozen filtration core are in poor condition.

Dangerous cryogenic processes develop in the economically mastered territories of the Arctic. For example, increasing in the depth of the active layer increases frost heaving of pipeline supports; thawing zones, often accompanied by thaw subsidence of soils, develop in areas of laying underground pipelines. The intensity of negative manifestations determine by regional geocryological features, characteristics of an antropogenic loads and the climate warming trends are most pronounced in the Arctic. Analysis of dozens of thermal fields formed in different permafrost and ground conditions in urban areas showed that almost 70% of cases are characterized by degradation tendencies, 20% are caused by permafrost aggradation, and 10% are preserved by the frozen conditions. There are numerous deformations of large buildings, gas pipelines, water mains, industrial facilities, and utility structures. The nature and intensity of deformations, depend on: a) from complexity of the geocryological engineering conditions; b) from imperfect methods of engineering preparation of the territory to the building; c) on the type and technology of foundations; d) on the degree of deviation from the design modes of operation; d) from the effects on the bases of the object of the neighboring elements of the urbanized environment; e) on the duration of anthropogenic impact on permafrost bases; e) on climate change.

We identified and classified deformations of the infrastructure of the Arctic, depending on the activation of various groups of cryogenic processes: a) associated with warming of the permafrost ground; b) bases caused by additional cooling; c) sloping; d) specific) cryogenic weathering of artificial media, technogenic salinization, etc.). Regional features of the negative impact of cryogenic processes on the stability of various facilities in the Arctic regions are identified. For the first time, a "Map of activation of hazardous geocryological processes in cities and settlements of the cryolithozone of Russia" was compiled.

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Geophysical surveys on the outburst of Progress Lake (Larsemann Hills, East Antarctica) in the field season of the 64th Russian Antarctic Expedition

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The Russian Antarctic Progress Station (Larsemann Hills, East Antarctica) is considered as key infrastructural facilities of the Russian Antarctic Expedition (RAE) that provides the operation of Vostok Station. Intensive logistic operations require special attention to the necessity of checking the safety of routes, which are used during the summer season for heavy vehicle transportation. Lakes of this area are characterized by annual catastrophic outburst floods, which have destructive power and can cause significant damage to people, machinery and transportation networks. For instance, during 62nd RAE field season after the outburst of the Boulder Lake, the depression with the size of 183 x 220 m and 43 m in deep was formed in its western part. It destroyed the active sector of the route, which connects Progress Station with the airfield and the point of formation of logistic traverse to the interior of Antarctica. This example indicates the importance of periodical monitoring of the status of outburst lakes located near the station infrastructure objects from the point of view of safety for transport operations. Geophysical methods are an efficient and reliable way to study such processes.

Over the years, the station staff has been observing annual outbursts of Progress Lake, which were destroying the section of the route operated during the summer period. During the field season of the 64th RAE, a complex geophysical survey using the methods of GPR and the methods of natural electric field was carried out on a snow-ice bridge that crosses the lake. Fortunately, the work had been accomplished a few hours before the outburst took place. This allowed the authors to obtain information at the time of the near-critical state of the snow dam. According to GPR data, the presence of a lake water flow was spotted inside the dam, which was accompanied by a negative anomaly of the natural electric field potential. Presented possibility of mapping the state of dams in outburst lakes by geophysical methods is an important methodological aspect of further studying of such objects from a scientific point of view and for practical purposes.

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The dynamics of the individual avalanche risk in the Khibiny Mountains

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Khibiny Mountains are located in the center of the Kola Peninsula, North-West of Russia in the Arctic. The region of the Khibiny Mountains is unique because of the long-term and well-documented dynamics both in industrial development (started in 1929) and in avalanche hazard activity. The industry appeared in a previously almost unsettled area during a few years. The development of the region was carried out without avalanche hazard taking into the account.

While the altitude of the Khibiny Mountains is relatively low, the release zones are steep enough (35-40 deg. on average). In the Khibiny Mountains 0,8-1 avalanche release zones fall within 1 sq.km of a slope. In average, the duration of an avalanche activity period in the Khibiny Mountains is 240 days. Avalanches endanger mining and touristic infrastructure, roads and settlements, locals and numerous tourists. Most victims during the last years are off-piste winter sport participants (skiers and snowmobile drivers) who trigger the fatal avalanche themselves.

While some old mines with the entire corresponding infrastructure are abandoned, new mines in other locations appear. Simultaneously, the constant growth of winter sports and tourism is taking place in the region. Due to these changes the dynamics assessment of the avalanche risk in the region is critically important.

Avalanche risk assessment has been conducted in the Khibiny mountains for 2008 and 2018 years on the scale of 1: 200 000. Full social (collective) and individual risk was assessed. Full social risk shows the annual number of fatalities as the result of an avalanche impact. Individual avalanche risk is the probability of fatal accident led to the death of an individual from some group of people within the investigated territory for the period of one year. To evaluate the avalanche risk changes during the last 10 years, a technique based on a combination of social and natural indicators assessment was applied.

To get the values of avalanche risk indices of investigated territory subsequent calculations of population vulnerability to snow avalanches in time and space were made. Population vulnerability in time defines the duration of stay (time of exposure) of an individual in avalanche hazard areas during the average day and year. It was estimated as a function of the duration of stay of an individual and his possible location within the dangerous territory. Population vulnerability in space is a function of a degree in which a territory is exposed to the impact of snow avalanches.

The presented assessment of the avalanche risk dynamics in the Khibiny Mountains allowed to conclude that while in 2008, 98% of the Khibiny Mountains territory corresponded to the acceptable avalanche risk level, in 2018 more than 50% corresponded to the admissible and unacceptable risk according to (Vorob'ev, 2005). The dynamics of the avalanche risk in the Khibiny Mountains clearly demonstrate that more efforts and resources must be spent to protect the population and infrastructure in the region. The long-term experience from the Khibiny Mountains should be accounted for in the planning of the future development of other regions in the Russian Arctic.

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Numerical Simulation of Heat Transfer with Ice–Water–Steam Phase Change in the Permafrost Foundation of an Elevated Flare Stack

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An elevated flare stack is a long vertical pipe, used to transport and burn gas, which creates the risk of fire or explosion, if uncontrollably mixed with air, and is toxic for humans and animals, if not burned, and is neither used as a fuel, raw material or working agent nor injected back underground. Typically, elevated flare stacks are installed in oil fields for burning oil gas.

At the top of an operating elevated flare stack, there is a flame with a temperature of about 1950 °C. The thermal radiation from the flame that reaches the surface of soil (or fire-resistant layer) can heat up the surface dozen times harder than the solar radiation at noon in a clear sky.

If such a heat-producing structure is built on permafrost, several risks for the load-bearing soil under this structure (and neighboring structures, if any) arise: subsidence due to melting of underground ice, thaw settlement due to permafrost degradation, shrinkage due to drying. Moreover, permafrost foundations experience thermal expansion and loss of strength, if thawed and further heated.

The aim of this research is to investigate the dynamics of the temperature distribution in the permafrost foundation of a continuously operating elevated flare stack. In lack of experimental data (Gorelik, 2014) numerical experiments have been performed with the software package Frost 3D.

The burning flame has been considered a line isotropic source of radiation with a time-dependent spatially constant power density. The radiation intensity at a given distance has been determined by Lambert's cosine law.

A circular piece of land around the flare stack has been marked as a “dry area”: during a heavy rainfall (snowfall) there is no water accumulation, because the radiation from the flame, absorbed by raindrops (snowflakes), causes evaporation, which is faster than precipitation, inside this area. When the soil near the flare stack is heated, the soil moisture not only evaporates but also migrates deeper into the soil under the influence of high temperature gradient. So, within the dry area, snow cover and suspended soil moisture have been considered missing.

Heating leads to thawing of both seasonal frost and permafrost, as well as to intensive evaporation in soil pores, long before the boiling point is reached. When hot water (and water vapor), circulates inside the soil, it carries the latent heat of wetting (and condensation), which gets released when the mineral matrix of the soil gets wet (and when water vapor condenses in a soil pore). That is how the observed high values of the effective thermal conductivity (Campbell, 1994) can be explained. The worst-case (within the bounds due to the maximum hygroscopic moisture of soil and the moisture capacity of the capillary fringe) temperature-dependent effective thermal conductivity has been specified in the model. The moisture boiling, occurring in the range of 100...105 °C (Kronik, 2006), corrected due to negative capillary pressure, has been taken into account using the method of effective heat capacity.

The temperature-dependent heat capacity in the zone of aeration has got dry-state values.

The results of the simulations show that, without sufficient fire-resistant insulation, the upper several meters of permafrost can thaw during the lifetime of an oil field with an elevated flare stack.

Verification of climatic and geological data in natural conditions using computer simulation of the permafrost ground thermal regime

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In the design of engineering constructions on permafrost ground it is necessary to carry out thermal regime prediction of their thermal influence on frozen ground, importance of which, at a stage of geotechnical investigation, is described in SP 11-105-97, SP 25.13330.2012 and other references. Performing this prediction of the dynamics of permafrost temperature by numerical simulation it is necessary to consider not only thermal influence of engineering constructions on frozen ground, but also the meteorological influence. Carrying out prediction of temperature distribution in frozen ground is a sophisticated problem and depends largely on the accuracy of the provided initial data on meteorological observation and geotechnical investigation. Performance of long-term prediction of temperature distribution in frozen ground with use of inaccurate initial data or their incorrect account can lead to considerable divergences of predicted and observed temperatures in ground and, as a result, to making the incorrect design decision.

For the purpose of exception of making wrong decisions based on the predicted temperature distribution by numerical simulations performed with use of inaccurate initial data it is necessary to carry out their verification by performance of so-called "calculation under natural conditions" which is carried out without thermal influence of the designed engineering constructions and fill ground. This type of calculations allows to reveal divergences between the initial data (on meteorological observation and geotechnical investigation) provided for numerical simulation and its actual values.

Performance of calculation under natural conditions is an important stage of heat transfer numerical simulation in the design of constructions on permafrost ground. Also, necessity of carrying out "the prediction of change of geocryological conditions under natural conditions" in areas of distribution of permafrost is stated in SP 47.13330.2012.

The initial data necessary for carrying out numerical simulations of a non-stationary thermal regime of permafrost ground and also features of its verification performance by simulation software, such as Frost 3D, are considered in this work.

It was revealed that the main reasons for errors in initial data for the planned construction site are the following:

- the climatic data provided for numerical simulations differs from really observed meteodata on the planned construction site as it is received on a meteorological station which is far from it;
- thermophysical properties of ground were defined according to reference books, and their laboratory measurements were not taken.

While analysing the initial data and ways of its receiving, it was concluded that thermophysical properties of snow cover, in particular, properties of its effective heat conductivity have a special impact on the results of prediction of temperature distribution in frozen ground. Heat conductivity of snow cover is in most cases calculated by empirical formulas of various authors depending on its density, disregarding other snow properties. Depending on the chosen methods the difference in calculation of snow cover heat conductivity can make 100-250%. Also it should be noted that properties of snow cover heat conductivity are not regulated by the specifications and technical documentation of the Russian Federation, and true values of snow heat conductivity coefficient and its change on time are almost unknown and are not provided in initial data.

Features of the Temperature Field and the Zone of Permafrost of the oil and gas regions of Republic of Sakha (Yakutia).

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Republic of Sakha (Yakutia) is currently regarded as the main center for the extraction of natural hydrocarbon resources in eastern Russia. On its territory more than 30 different hydrocarbon deposits are discovered, belonging to the Leno-Vilyuiskoy and Lena-Tungusskoy oil and gas provinces. In structural and geological terms, the territory belongs to the Vilyui Basin and the Nepa-Botuobia Arch. In the first, the non-stationary nature of the permafrost sequences is noted, in the second one it is stationary. The fields are concentrated in the harsh climatic conditions in the territory, mainly with continuous distribution of permafrost.

Since the 1970's, the staff of the Institute of Permafrost of the SB RAS has received extensive material on the geothermal field and the thickness permafrost of the territory under consideration, which makes it possible to characterize their current distribution and thermodynamic state.

The analysis of geothermal data showed that the thickness of the permafrost thickness the Vilyui Basin varies from 45 to 820 meters and tends to decrease in the eastern direction, which is associated with an increase in the isolated heat flow in this direction. Within the Nepa-Botuobia Arch, the permafrost thickness varies from the first dozen in its central part to 750−800 meters in the northeastern part and is caused by the latitudinal zonality of the territory. Within the framework of the structures under consideration, it has been established that the thickness of permafrost in individual structures (fields) has significant amplitude of oscillations, which reaches 200 meters.

Significant heterogeneity has been established and features of the temperature regime of unsteady frozen strata have been identified, in which four intervals differing in magnitude and sign of the geothermal gradient are distinguished by geothermal curves. The available data of geothermal studies revealed a significant heterogeneity of the ground temperatures, which within different areas varies from 0.2 to −3.3 °C (at a depth of 20 m) from -1.4 to 13.7 °C (at a depth of 500 m) and from 1.2 to 17.6 °C (at a depth of 1000 m).

To assess the response of the zone of permafrost of the region to climate change, the formation of a permafrost monitoring network has begun. Currently, 11 monitoring sites are equipped. An electronic geocryological database of the structures under consideration has been formed, in which the actual data on of the permafrost thickness, the temperature of the rocks, and the thermal properties of the rocks are collected and systematized. The database provides functions for viewing, analyzing and supplementing information.

Bacterial communities of seasonal thawed soil horizons of polar tundra of Russia and Alaska

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Bacterial communities from Russian and Aliaskan polar tundra soil were investigated. New aerobic psychrophilic and psychrotolerant bacteria were isolated from tundra wetland soil: Methylobacter psychrophilus, Methylocella tundra, Methylorozula polaris, Asticcacaulis benevestitus and some others. They belong to different physiological groops: methanotrophs, methylotrophs, geterotrophics.

Emission of methane from tundra soil was investigated. It was demonstrated that there is psychrophilic methanotrophic community of microorganisms capable of oxidizing one of the greenhouse gases methane at 5°C. First psychrophilic methanotroph was isolated from tundra north of Vorkuta (Polar Ural) and is represented by new species Methylobacter psychrophilus (optimum temperature growth 6°C). Methane oxidizing bacterial filter is active over the entire permafrost area of northen Russia from the Chukotka Penninsula and Kamchatka Penninsula to the east to the Polar Urals to the west. As part of the representatives of the microbial community of the soil were methylotrophic (Methylocella tundra, Methylorozula polaris) and hydrogen bacteria (Acidovorax sp. и Arthrobacter sp.) that prevent the ingress of C1- compounds in particular methanol and gas (CO_2) in the atmosphere. Maximum specific rates of growth and oxidation of CO_2 and H_2 Arthrobacter sp. and Acidovorax sp. (3.54 and 5.125 (h-1*10-^{3}) respectively) were obtained at 6°C.

Thus, in the soils of the polar tundra of Russia, located in the permafrost zone, a multicomponent psychrophilic bacterial community develops, which includes organisms of different physiological groups. All members of the bacterial community are well adapted to the cold conditions of the polar tundra of Russia and Aliaska.

Cryogenic landscapes stability to the exogenous processes activation (on the example of the Medvezhye gas field, West Siberia)

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The resistance of cryogenic landscapes to surface damage is the ability of the land to resist anthropogenic activation of cryogenic processes that may lead to irreversible deterioration of the environmental situation and unacceptable deformation of engineering structures. Cryogenic processes are a key indicator of northern landscapes' reaction to external influences. The mechanical damage arising during the operation of engineering facilities, such as mining, are widespread in the cryolithozone. The current research is based on identifying factors that influence the lithocryogenic state of the landscape and reduce in landscape stability, and, as a result, cryogenic process activation. The evaluation procedure includes several stages. At first we select the main factors that influence landscape resistance to cryogenic processes activation, such as ground composition, permafrost temperature; ice content of the ground and its composition, protective properties of vegetation and its recoverability. Then we create the table of these factors to assign numerical scores to each landscape. As a result, we rank all landscapes, basing on vulnerability to the economic development considering the calculated indexes. Yhe last stage is compiling evaluation maps. With this technique, mapping lithocryogenic stability is performed on a landscape basis. To test the method, a site was chosen in the northern part of the Medvezhye gas field, with an area of 110 km2. The study area includes southern tundra landscapes with complicated geocryological conditions.

Materials and Methods:

Field landscape descriptions; analysis of literary and stock materials; interpretation of high resolution satellite images (Landsat-8, GeoEye-1).

Elaborating natural landscapes cadastre and landscape map according to the method by A.G.Isachenko.

Analysis of the landscape structure of the site and the choice of indicators of permafrost conditions; identifying the leading exogenous processes in each landscape, their classification based on the degree of danger.

Determination of the nature of anthropogenic "pressure", its typification and significance.

Selection and justification of permafrost-environmental factors affecting the sustainability of landscapes.

Evaluation of each factor influence on a 4-point scale; assignment of weight (qualimetric) coefficients by an expert; calculation of the complex integral index of permafrost stability.

Ranking all landscapes on the 4th gradation stability permafrost.

Estimated GIS-mapping and spatial analysis of the territory according to the degree of sustainability.

Environmental protection measures.

Results. GIS analysis of the permafrost resistance map showed that the sustainable landscapes group occupies 12.6% of the territory. These are the floodplains of large rivers, composed of thawed sand, occupied by spruce forests with good thermal insulation. Dangerous processes are not observed. Groups of unstable landscapes occupy 37.9% of the territory. They are the most dangerous for economic activities. These are peatlands, complexes of swamps, tundras, as well as larch stands and dwarf birch communities on gentle slopes. Thermokarst, seasonal and perennial frost heaving, thermoerosion, waterlogging are actively manifesting. The reasons for the low stability are high ice content in bedrock, good thermal insulation properties and slow recovering rate of vegetation.

Conclusions. The landscapes stability estimation using integrated multi-qualitative-quantitative technique for Medvezhye gas field was held for the first time. A series of maps has been compiled, such as landscape, temperature and ice content of soils, hazardous processes and sustainability. The percentage of stable and poorly sustainable landscapes was defined for the test site, which is a representative for the southern tundra of Western Siberia landscapes. This technique can be applied to pre-stage construction, and in prospecting and monitoring of the ecological environment.

Evaluation of the negative impact of permafrost processes on the transport systems of Eastern Siberia and the Far East

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The Arctic is the territory of perspective development. Strengthening of antropogenic influence and noticeable climatic changes affecting the state of permafrost are negatively manifested for linear technogenic systems. The main feature is its continuity and declining of variability in the choice of the routes. We conducted complex field studies, numerical modelling, forecasting of the LTS state under changing conditions in the Arctic regions and defined five main types of LTS: pipelines (aboveground, onground and underground), city waterlines, electric lines, autoroads and railways. Pipelines, paved on the permafrost are traditionally arranged on supports that are raised above the surface and frozen into the ground; the main problem in this case is uneven frost heaving in the active layer. Deformations associated with dangerous cryogenic processes - thermokarst and thermoerosion develop in the zone of discontinuous and sporadic permafrost, which intensity is increasing due to climatic changes of recent decades; revealed that 30-40% of such LTSs are substantially deformed or even destroyed after 5-10 years of operation. Water pipelines of various purposes located in industrial centers of the north are laid in underground reservoirs (utilidors): uneven thawing of soils of different composition and ice content leads to intensive destruction of these systems. About 70% of underground communications in the largest Arctic cities of Russia are in poor condition. The electric lines are pulled out due to the frost heaving in the active layer and wind loads that have intensified in the Arctic due to climate change. We have analyzed the potential hazards for the first time for all regions of Eastern Siberia and the Far East (about 300 administrative areas: uluuses, kujuuns) for roads and railways associated with thermokarst, thermoerosion, thermoabrasion, icing, frost heaving, frost cracking, moving of the rock glaciers. Negative effects from dangerous cryogenic processes are manifested in the form of frost cracks, formation of ice, dips, sliding slopes, wavy deformations, strengthening thixotropy of soils, lowering the bearing capacity of frozen bases. Linear technogenic systems of the Arctic are most vulnerable to the impact of dangerous cryogenic processes.

Fieldwork was supported by the grant. RFBR 18-05-60080 “Dangerous nival-glacial and cryogenic processes and their impact on infrastructure in the Arctic”. Mapping and risk calculation performed within support of the grant of the Russian Geographical Society No. 15/17: “Current state and dynamics of hazardous natural processes affecting the existing and prospective transport network of Siberia and the Far East”

Gas-emission crater prediction map: first results

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Gas-emission craters (GEC) are relatively new types of hazardous natural phenomenon, which may have a significant influence on the infrastructure in the Arctic as well as on indigenous communities. Therefore, prediction of such processes in permafrost environment is highly important. Within this research, we tried to create a prediction map based on several potential controls of GEC formation included in our current hypothesis.

We have chosen a depth of tabular ground ice (TGI) table as a first control. According to our current hypothesis, we consider tabular ground ice bodies close to ground surface more favorable for GEC formation. Mapping of TGI depth is based on a methodology described in Khomutov et al. (2012). This implies a delineation of landscapes where drilling revealed the TGI table on a certain depth (classified as 1-5 m, 5-10 m, more than 10 m). Land cover classes for Central Yamal, which correspond to these landscape types, were obtained from Sentinel-2 satellite image applying "Maximum Likelihood" supervised classification. Training polygons for this classification was undertaken using previously created field-based landscape map. We have further generalized this classification down to two classes: 1) with TGI table depth < 10 m, 2) > 10 m.

Second main control was a concentration of dissolved methane in lake water. Dissolved methane concentration in lakes formed after GEC formation was much higher compared to other Yamal tundra lakes. We have chosen a water colour index to map the potential dissolved methane concentration in lakes. We used the same Sentinel-2 satellite image for quantifying the lake water colour and classifying all the lakes in the area by dissolved methane concentration. As a result, an area has been manually divided into 3 classes: regions with a predominance of lakes with high dissolved methane concentration, regions with a predominance of lakes with low dissolved methane concentration and lake-free areas. Regions with predominance of lakes with high dissolved methane concentration are the most dangerous for GEC formation and with low concentration are the safest. Temporarily lake-free regions are considered as medium hazard for absence of data about methane concentrations in these areas.

An overlay procedure was further applied to these two classifications in order to create a GEC prediction map. We have defined three final classes:

Most hazardous: areas with TGI table depth < 10 m and with predominance of lakes with high dissolved methane concentration;

Non-hazardous: lake-free areas or areas with TGI table depth > 10 m and areas with predominance of lakes with low dissolved methane concentration;

Medium hazard: all other combinations.

All known GECs on Yamal were located within the areas with a medium hazard or specifically within lake-free areas with TGI table depth < 10 m. This probably can be explained by the fact that absence of lakes limits the possibility of methane evacuation from the section and its accumulation in the possible collectors thus providing more options for GEC formation.

By continuing research, we hope to fill the data gaps in lake-free regions and upgrade presented map.

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Modeling of seasonal freezing depth in Western Moscow region

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Seasonal freezing is one of the most widespread cryogenic processes is the world. Seasonal freezing layer forms during cold season and underlain by thawed deposits (Kudryavtsev et al., 1978). When soil freezes, it often experiences frost heaving, which causes uneven movements of soil surface and thus, deformations of low-loaded facilities and asphalt cracking. Current methods of seasonal freeze accounting at construction are listed in state documents (construction codes and requirements, or SP), but they provide approximate estimations of seasonally frozen layer thickness and do not consider factor of changing natural conditions.

This study is attempt of numerical calculation of seasonal freezing layer thickness in different landscapes. Moscow river valley near Zvenigorod Biological Station was considered as key site for in-situ observations during cold season of 2017/18. Climate data was retrieved from Novy Ierusalim weather station (https://rp5.ru) and data loggers installed within study area. Representative points (e.g. floodplain, river terrace slope and surface, ravines, etc.) were chosen for acquisition field data sets: landscape conditions, soil type and moisture, snow thickness and soil freezing depth. In order to trace the dynamics of snow accumulation and freezing layer increment, filed studies were divided into 2 stages: the beginning (early December) and the end (mid-February) of cold season. Field dataset was used for calculations of seasonal freezing depths with simple Stefan model and regression equations.

The winter of 2018/19 was relatively warm and snowy: cold sum (accumulated air daily average temperature) was -420…-430°C; average snow cover depth was 26 cm. Increased snow cover hindered intensive cooling of grounds, thus cold sum on soil surface was only about -8°C. As a result, majority of representative points displayed less than 10 cm of freezing by the middle of February. Calculated seasonal freezing depths closely match the observed values after validation. Modeled estimations of seasonal freezing layer thickness in combination with prognostic climate data allow to predict impact of frost heaving on engineering facilities and infrastructure and to optimize construction expenses.

The study was supported by RFBR grant 18-08-60080.

Cryolitological map on the Barentsburg neighborhood (Land of Nordenskiöld, Svalbard)

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Field-based courses for students of the Cryolithology and Glaciology Department were held since 2017 on the base of Russian Science Center on the Svalbard Archipelago in the context of the agreement on scientific cooperation between Federal State Budget Institution Arctic and Antarctic Research Institute (“AARI”) and Faculty of Geography of Lomonosov Moscow State University. Standardized methods of cryolithological studies were used to describe the territory. Along the routes observations were done including determination of relief forms, based on terrain, satellite images of very-high spatial resolution and mosaic of aerial photographs (tied to the terrain by GPS). Morphological and morphometric characteristics of cryogenic relief forms were determined.

A peculiarity of the archipelago is the presence of permafrost and above-ground glaciation. Cryolitological map of the practice area in the Barentsburg neighborhood being created based on the collected field data during the practices of 2017-2018, remote sensing data and Geomorphological map, created by V.V.Sharin with co-authors.

This map includes information about cryolitological conditions of studied area, characteristics of sediments cover and spatial distribution of permafrost processes. The map key is based on morphodynamic principle. The following geodynamic areas were highlighted: 1) denudation cryogenic weathering and local transit, 2) prevailing transit of sediments, 3) prevailing accumulation. Each of those areas has specific composition of permafrost layer and set of cryogenic processes with relevant relief forms.

In the denudation area, freezing-melting processes lead to intense cryogenic weathering. The cryogenic materials are being moved for short distances and accumulated on the surface of flattened surface of Grenfiord, Bikollen mountains and Kharitonov plateau. Week cryogenic weathering layer, consisting of gentle slopes clay loam mantle, is formed on gentle slopes. Within this layer, processes of cryogenic sorting and heaving are very active. High relief dissection provides different variety of snow patches. These snow patches form nival niches.

Slope processes mostly common in transit area. Slopes and particles mobilization due to cryogenic weathering in denudation area lead to intense formation of cryogenic creep, solifluction, cryogenic landslips and screes. Sediments movement also occurs in small erosion valleys.

In more or less stable areas, frost cracking is widely spread. Polygonal microrelief with patterned ground is very typical there. Areas of sediments accumulation are located in lower topographic levels, bottoms of river valleys, marine terraces and contemporary beach of Isfiord and Grenfiord bays. In the accumulation zone cryogenic heaving leads to formation of hummocky microrelief and mezorelief forms of injection open type pingo. The group of these pingos 5-6 meters high is located in Grendalen valley.

This study was supported by RFBR grants № 18-05-60080 (cryolithological study) and № 18-05-60221 (satellite images processing).

Morphometry of water bodies on Kurungnakh Island (Lena Delta) on the basis of aerial imagery

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Morphometric parameters of water bodies on periglacial landscapes can serve as effective indicators of changes in permafrost state. A number of papers are dedicated to remote sensing data analysis in order to detect surface signatures of permafrost processes and its structure features (degradation, pingo forming, thermokarst, ground ice). Water bodies can be easily extracted automatically from infrared images because of high absorption coefficient of water and then digitized and processed with corresponding software. Nevertheless such calculations require verification, which could be effectively done using aerial imagery and ground observations. Aerial images usually have high resolution, which makes possible not only verify regularities obtained from satellite data but also downscale them and sometimes find new features in water bodies' morphometry.

The work is dedicated to basic morphometric analysis of water bodies on Kurungnakh Island in Lena river delta on the basis of aerial imagery. Kurungnakh Island in Lena river delta is an object of study for many years: Yedoma ice complex is presented on this island as well as in outcrops, beyond that the island is quite accessible - Russian-German expedition "Lena" implements multidisciplinary research in this region more than 20 years. Therefore a number of different studies were conducted on the island during last years, so now it can function as polygon for development of permafrost research methods. High-resolution aerial imagery (5 cm/pix) of southern part of Kurungnakh Island was conducted in July 2016. We used manual digitizing and processed part of this data focusing on high representativity of small-size water bodies (up to 1 m in diameter). Such ponds could be hardly both detected from satellite data and distinguish from noise. The goal of our work was firstly to obtain database of small water bodies in this area of multidisciplinary interest and secondly to compare morphometric parameters (including area, perimeter, circularity index, elongation index, orientation of major axis, and the coordinates of centroids) obtained from aerial and satellite data (Morgenstern et al., 2011) in the light of their relation with permafrost state.

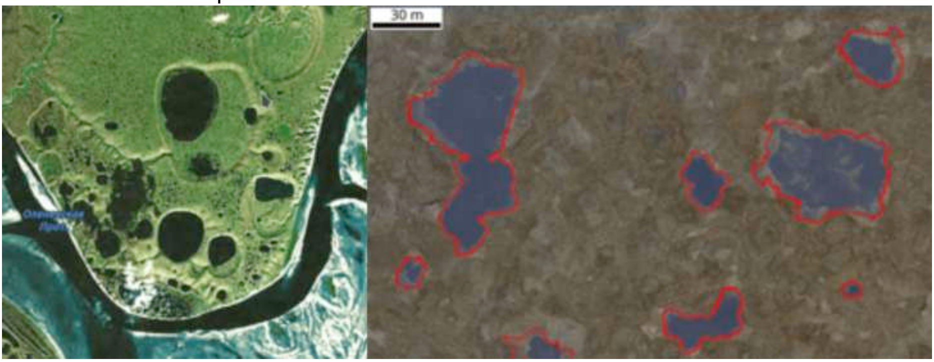

Figure 1. Southern part of Kurungnakh Island (left) and example of digitized water bodies (right)

Approximation the soil temperature of piecewise continuous function

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Data analysis of temperature condition was carried out for the mineral and peat soils located on section in a subband of the typical tundra (the basin of the Kolva River, the European Northeast of Russia). The soils given measurements were divided into two periods: winter (from October 15, 2014 to May 14, 2015) and summer (all others). In spite of the fact that observations were carried out incomplete year (about 11 months) nevertheless it was succeeded to recover the missed data proceeding from the function constructed according to measurements. For assessment of approximation error used mean value of the soil temperature for the period both calculated, and calculated on observations.

On every period approximation in the form of function of a look is looked for:

where ω – the frequency of annual fluctuations, A – amplitude (^{0}C). For the winter period of t changes from 0 to 7/6π, for the summer period of t from 0 to 5/6π. Time is measured in hours.

	Winter					Summer				
	A	B	ϕ	Sred obs	Sred calc	A	B	ϕ	Sred obs	Sred calc
0	5,06	-1,9	2,75	-4,54	-4,54	13,37	-3,84	0,38	5,03	5,81
2	5,24	-1,66	2,71	-4,4	-4,38	12,15	-3,9	0,34	4,2	5,04
5	5,22	-1,5	2,67	-4,2	-4,19	10,32	-3,41	0,29	3,49	4,2
10	5,21	-1,22	2,64	-3,9	-3,89	9,59	-3,19	0,26	3,22	3,89
40	4,56	-0,99	2,46	-3,2	-3,18	4,89	-2,01	0,06	1,2	1,52

Mean value of function is calculated analytically and has an appearance: for the winter period and for the summer period

Amplitudes significantly differ during the winter and summer periods. Results show that such division into the winter and summer period will justified and well be coordinated with data of observations. The calculated mean value for the summer period is more calculated on observations, as there was no month of summer measurements.

Cryogenesis features of the Kolyma Southern Highlands

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Main reserves of mineral resources are highly concentrated in the northeast of Russia - Kolyma Highlands area is a highly representative example of such circumstances. Moreover, the natural conditions of the cryolithozone there are very diverse, which affects the noticeable differentiation of the permafrost conditions in this territory. Due to the industrial development the changes may occur within the frozen sediments, leading to the activation of hazardous exogenous processes, which may pose the main danger to engineering structures.

Key site within the Omchak river valley was chosen as typical one for this region - its permafrost-geological conditions are common for southern part of the Kolyma Highlands. The author performed Engineering and permafrost studies in 2013-14 including drilling of geotechnical wells with sampling with subsequent laboratory processing of the physical and mechanical properties of soils, description of landscape conditions, as well as geophysical studies.

Kolyma river headwaters are located within the midlands and can be characterized by continental climate with harsh snowy winter and short cool summer. The average annual long-term air temperature is −11.7°C.

In the permafrost-hydrogeological terms, the research area is located in the area of continuous distribution of permafrost, but through and above permafrost taliks may be present. Permafrost thickness varies from 60 m in the river valleys (Omchak river) to 300-400 m on the watersheds. Stable taliks have a limited distribution: in the Omchak river floodplain and in the mouth of its inflows. The upper boundary of permafrost mainly repeats terrestrial landforms and depends on the exposure of the slopes, lithology, thickness and water permeability of unconsolidated sediments, the presence of vegetation and proximity of surface waters. Temperature of sediments ranges from −0.1 to −5.4 º C. Field investigations have shown that at a depth of 10.0 m, the temperature was −0.7 ÷−3.2 º C, with an average of −2.4 ºC. In some drills lenses and interlayers of ice were found at depths of 0.2-14.5 m, the thickness of these layers is up to 0.1-4.9 m.

Ice content and the formation of cryogenic textures in sediments are determined, primarily, by their lithological composition, and within the same lithological group - with its genesis. In general, fine-grained soil is characterized by a decrease of ice content from fine sediments to macrofragmental and from the top to the bottom of the cross-section.

Technogenic soil composed with rubble, gravel and pebbles with sand (rarely - loam filler), is characterized by the ice content in the range of 0.05-0.45 (this band is associated with poor sorting of a bulk material); cryostructures are mainly massive and crustal, rarely loose frozen.

Activation of hazardous exogenous processes is mainly driven by cryogenesis. Main hazardous cryogenic processes are represented by: solifluction, frost cracking and frost heaving, thermokarst processes associated with the melting of ground ice and weathering of bedrock.

The economic development of this territory is getting complicated due to the uneven ground composition, ice content of soils, ground thermal regime variations, active layer depth.

The Approaches to the Analysis of the Polychemical Pollution of Cryogenic Soils and Upper Permafrost

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Nowadays Russia experiences the new wave of increasing exploration in the Arctic: oil and gas production, coal mining, military objects, and Arctic Ocean sea-pass development. All this activities are strongly connected with hydrocarbon consumption and environmental pollution due to high rate of risks. In some cases, the ecological damage can be partly eliminated by bioremediation and recultivation actions. Still unknown is the fate of large part of pollutants' volume which can potentially migrate downwards due to the active processes of cryogenic mass-exchange then laterally redistribute over the surface of permafrost and even penetrate into it. Geochemical evolution of these contaminants in polar ecosystems under global climate change and local impacts is poorly studied.

The reaction of soil-permafrost complex to the environmental changes results in changing of thickness of the active layer of permafrost, intensity of cryogenic mass-exchange, cryolithological structure of the upper permafrost. In some cases (at the construction sites, road building, soil insulation etc.), the decreasing of the active layer thickness is often obtained. It results in cryoconservation of pollutants in the upper permafrost. Later, after the environmental and climate change these layers of permafrost can thaw again and can be included into the biogeochemical cycle.

Besides the local pollutants (e.g. anthropogenic hydrocarbons), the supertoxicants can be accumulated in polar ecosystems: persistent organic pollutants, heavy metals, polyaromatic hydrocarbons, radionuclides etc. Some of them migrate via atmosphere, some via trophic chains. However, the same as local pollutants, these toxicants' fate in cryogenic soils, upper permafrost and in polar ecosystems themselves is very poorly studied. Arctic region became the depo of global pollutants from other regions of the planet.

The special case of Arctic exploration is the ecological damage from nuclear testing which led to the accumulation of Cs, U, Pu, Sr artificial isotopes.

The complex concept of assessment and forecast of polychemical pollution of soil-permafrost complex and future decreasing of negative technogenic impact is of high importance in terms of governmental and social requests.

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Error analysis of the numerical solution of soil freezing problem depending on mesh size

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While predicting temperature dynamics of permafrost under the thermal influence of various buildings and constructions with simulation software one of the key steps of numerical model preparation for calculation is optimal choice of mesh size. Mesh size directly influences the accuracy of the received results and also the speed of obtaining results. Small mesh size allows to receive the accurate results, however slows down the speed of receiving. Big mesh size allows receiving results faster, however their accuracy can decrease.

In this paper the accuracy and speed of solving Stefan problem of frost penetration into ground, in FROST 3D simulation software, depending on the meshing step, is considered. Relative error and time of computation results of numerical solving of non-stationary spatial heat transfer problem with phase transitions by discrete element method, which implemented in FROST 3D, was obtained. Comparison was carried out directly in the mesh nodes. All the calculations have been performed with Intel Core i3-2100 CPU.

The problem statement for all the simulation software and all mesh sizes is the following: the computation domain is a column of sand soil of size 1x1x25 m; the meshing step along X-axis and Y-axis is 0.5 m and for Z-axis changed from 1 to 0.05 m.; the initial temperature of the soil is T_0=1.5°C; on the upper boundary, the first-type boundary condition T_{bnd}=-27°C is specified; the specific heat capacity of the sand in thawed and frozen state is C_t=2.44 kJ/(kg*°C) and C_f=2.02 kJ/(kg*°C); the density of sand is ρ=1850 kg/m^3; the thermal conductivity of the sand in thawed and frozen state is K_t=1.83 W/(m*°C) and K_f=2.11 W/(m*°C); phase transition temperature is T_{bf}=-0.05°C; the water content is W_{tot}=0.2; the prediction period is 300 days.

The accuracy of results in all simulation software increases with reduction of the meshing step, except for ANSYS where the minimum relative error (1.74%) is observed for the meshing step of 0.25 m and increases to 6% in response to further mesh reduction. The minimum relative error in COMSOL (1.95%) is observed for the meshing step of 0.05 m. In FROST 3D the minimum relative error (0.15%) is observed for 0.1 m, and is slightly increase for 0.05 m. The maximum relative error in all the software packages is observed for the meshing step of 1 m. The smallest relative error for the a meshing step of 1 m is observed in FROST 3D (3.76%), and the highest one is observed in ANSYS (12.01%). In COMSOL the relative error is 4.40% for the meshing step of 1 m.

Mesh refinement leads to rapid increase of computation time in all the simulation packages. The computation time in FROST 3D is much smaller (1–4 sec.), than in ANSYS (5–80 sec.) and in COMSOL (72–7468 sec.). In COMSOL, computation is substantially longer, than in other software packages.

Comparison with the analytical solution shows that all the simulation software has received quite good coincidence with the analytical solution. However, the best results, regarding the accuracy and calculation speed at the same time, have been shown by FROST 3D, in comparison with FROST 3D, ANSYS and COMSOL.

Influence of Cryogenesis in Soils on Desorption of Lead

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Diagnostic horizons of the podzolic soil and high peat in the Onega region of the Arkhangelsk Oblast were investigated for modeling the desorption of lead ions in conditions of cryogenic process. For this, soils samples were taken and poured with lead solution with concentration 13.7 mg/l and held during 12 hours at temperature of +4°C. Thereafter samples were kept in a cold thermostat with a temperature of -18°C until frozen (12 hours). After, suspension was transferred back to area with temperature of +4 °C until it melts, and then 20 ml of the solution was substituted with distilled water. Taken volume was sent to analysis. The procedure was repeated 5 times. For comparison with the conditions without freezing, a similar experiment was performed at a temperature of +4°C.

The content of lead ions was determined by atomic absorption spectrometry with using the ContrAA-700 instrument (Analytik Jena).

Studied soils showed the highest sorption capacity and resistance to the desorption of lead ions in conditions without freezing, what can be explained by the absence of separation under freeze from the system of the least weakly bound lead from the system due to physical adsorption (table).

Table – Concentration of Pb in soils mg/l

№	Without freezing				Cryogenic conditions			
	Peat	Gumus horizon	Alfegumus horizon	Podzolic horizon	Peat	Gumus horizon	Alfegumus horizon	Podzolic horizon
1	1,892	1,812	0,708	0,824	1,771	1,772	0,493	0,666
2	1,892	1,812	0,708	0,756	1,771	1,765	0,439	0,614
3	1,882	1,797	0,694	0,758	1,725	1,754	0,370	0,615
4	1,880	1,765	0,613	0,661	1,741	1,708	0,244	0,615
5	1,880	1,754	0,556	0,661	1,681	1,708	0,238	0,611

Analysis of the relative lead content in soils after desorption under the influence of freezing and without it showed the highest resistance of soils rich with organic matter (peat and gumus horizon), what can be explained by the predominance of the mechanisms of complex formation and ion exchange during process of binding of lead and higher resistance of soil colloids of organic origin compared to with inorganic gels.

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Cryogenic weathering (destruction) of construction material in the Arctic cities

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One of the most important problems in the modern engineering geology and geotechnics in permafrost zone is to provide sustainability of buildings, constructions and infrastructure. The number of injured objects reached critical level in Nothern regions of Russia in last decades. More than 50% of the buildings were damaged in Vorkuta and Dudinka; more than 60% - in Dixon, Khatanga and Igarka, etc. One of the most common reasons for objects deformation is premature material run-out of underground and above-ground structures caused by the influence of natural and man-made factors.

It is known that the frost resistance of crystalline rocks and building materials is the ability to maintain their strength during repeated freezing and thawing in a water saturated condition. Due to the concrete structure and its properties we can state that the wedging effect of unfrozen water in microcracks (including cracks between aggregate rubble and cement stone) under the low temperature (below -35...-40 ˚C) is the trigger for destruction mechanism of concrete structures.

We selected basements of buildings located on frozen ground with the permafrost condition preservation of various period of exploitation (from 3 to 40 years), as well as other geotechnical as research. It was revealed, that, for instance, the run-out of foundation materials within the seasonally thawed layer in the Norilsk industrial area ranges from 15–20% to 70–80% of the projection values which depend on the permafrost-ground characteristics, conditions and duration of exploitation.

According to the destruction level, zones with the greatest destruction of concrete were identified: at a depth of 0.3–0.6 m from the ground surface, at contact with the surface and at a height of up to 0.2–0.4 m from the surface, as well as connection places of pile and columnar foundation with grillage. A reduction in the carrying capacity of frozen grounds and the corrosion of the concrete grillages, the material of which is also under the force of destruction, is noted almost everywhere. The level of destruction varies widely in the same foundation: sometimes up to 5-8 zones are allocated within the same underground with different conditions of the foundation material, and the average values of concrete strength in one zone may be 2-3 times more or less than in the other. Basically, the most destroyed piles or pillars are located in the central parts of the underground, next to the drainage trays and communications, and also in the flooded areas.

The main causes of the building materials destruction can be divided into 4 groups:

caused by climatic and geocryological conditions;

caused by man-made effects on permafrost-geological processes;

caused by technological factors;

caused by the exploitation conditions of the foundations.

There are three main ways for the protection and reconstruction of foundations:

arrangement of ferroconcrete outer layer with reinforcement in 1 or 2 rows around damaged pillars or piles to a depth exceeding 0.3 m of the maximum seasonal thawing, waterproofing of the surface;

restoration of the piles by the pipe-concrete fragment method: the arrangement (on a depth exceeding by 0.3 m the maximum thawing layer) of the iron cage made of the two halves of the casing around the damaged section of the piles with filling of the near-lining area with concrete and waterproofing the surface;

local, strengthening of the foundation areas (including the use of gunning), poorly affected by the destruction, waterproofing of the surface.

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Nematode Community Structure as Indicator of Microbial Activity in Cryosol Profile

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The nematode diversity and richness is known to dependent on the many soil biotic and abiotic factors. Changes in soil properties with depth lead to a vertical differentiation of the nematode communities. Enrichment of its environment by organic matter is an important factor in community organization, particularly in the trophic structure. We investigated the dynamics of nutrient contents and microbial activity, indicated amounts of available organic matter in Cryosol profile and analyzed the correlation of these values with density and trophic structure of community nematodes.

The main goal of the study was to investigate the patterns of diversity and abundance of nematode community and to analyse the interrelations of the chemical properties, microbial activity and trophic structure of nematodes communities in the profiles of Cryosols.

The study area was located in the southern and arctic tundra subzone in the region of Kolyma and Yana–Indigirka Lowland. The Cryosol is a zonal soil of polygonal tundra with an active-layer thickness about 30-50 cm. This type of soil is characterized by different processes of cryogenic mass-exchange that redistributes the fragments of the uppermost soil horizons along with soil microfauna. A total of 89 samples of organic and organo-mineral material collected from different genetic horizons and cryoturbated layers in the cryosol profiles were analyzed.

Nematodes were extracted from fresh soil using the traditional method of centrifuge flotation in a saturated $MgSO_4$ solution and counted under inverted microscope. Each sample was extracted repeatedly (n=5, V= 10 cm^3). The nematode species separated into six trophic groups - bacterial feeders, fungal feeders, root hair feeders, ectoparasitic plant feeders, omnivores, and predators (according to Yeates et al., 1993). Nutrient contents (C, N, C:N) and microbial activity (V_{basal}, VSIR, Q_r and C_{mb}) were determined by standard methods.

The species diversity and community structure were investigated by using multivariate statistical methods. The soil properties, nutrient contents and values of microbial activity were included in analysis of the data set. A non-metric multidimensional scaling was performed to explore the environmental relationships and species composition in the nematodes data set.

A total 32 nematode species from six trophic groups were isolated from studied samples. The composition of the nematode communities was strongly affected by soil horizons and depths: the population densities and the species number first increase roughly in organogenic horizons, and promptly decreases down the soil profile. In the cryoturbation profiles the number of nematodes may suddenly increase strongly (7-20 times) in deep cryogenic horizons. Total nematode densities vary from 828 ths to 8499 ths/m^2. In profiles the nematode number (total and that of bacteriophages and fungal feeders counted separately) is correlated with soil respiration values (Pearson's r=75-95%). In case of extraction by centrifugal flotation the dormant stages were revealed: coiled, immobilized, with dense body content, sometimes exceed 50% of total nematode communities.

Our result demonstrates that nematodes community structure would be seen as the indicator of the decomposition function in the Arctic soil.

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Cryogenic processes development and soil formation during Sartan Cryochrone (MIS 2) in Transbaikal river valleys (Eastern Siberia, Russia)

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Sartan Cryochrone (MIS 2) soils in the Transbaikalia have different thickness, formed in permafrost rocks, cryoturbated. They (soils) trace in Sartan river terraces deposits, 12.8- 10.8 ^{14}C years BP (14.6 and 12.7 ka) are dated. There are a single soil and pedocomplex from 2-3 humus horizons up to 50 cm thickness, separated by sediments layers. These soils are cryoturbated often and be an important stratigraphic mark.

More ancient MIS 2 cryosoils in sediment sections in the Transbaikalia are found and diagnosed much less frequently and more difficult. On the Ust-Menza-5 ancient settlement on the fourth (height 20-22 m) Chikoy river terrace, humic acids are dated 19430±1290 years BP (23300±1570 ka) (LU-7200) (Ryzhov et al., 2015). Cryosoil formed ~24.8-21.7 ka. On the archaeological site Sakhyurta-1 (first Khoyto-Aga river terrace, high 6-8 m) are revealed the Early Sartan (Early MIS 2) pedocomplex. Cryomorphic buried, humus horizons lie wavy, strongly deformed by cryogenic and partially zoogenic (digging of holes) processes. Soils have coarse sand with grus grain size distribution, mild severity of illuvial horizon. Two radiocarbon dates 18250±1080 (LU-9003) and 18900±740 (LU-9004) years BP (22260±1340 and 22930±900 cal.) were obtained for top of the upper and lower soils. Pedocomplex formed ~23.4-21.3 ka. Pushchinskaya buried soil on the East European plain have equal age (Gugalinskaya, Alifanov, Ovchinnikov, 2015).

Pedocomplex was formed in a cold semarid climate after the Last Glacial Maximum (LGM) in the stages of short-term warming and partial humidification, when the sedimentation rate decreased, pedogenic processes intensified. Cryosoils have yellowish-brown (chestnut?) color, thickness 0.16-0.25 m. They are separated by aeolian-colluvialal fine and medium sands with grus layer. Early MIS 2 cryosoils of archaeological sites Ust-Menza-5 and Sakhyurta-1 correlate with the Greenland Interstadials GI 2.1and GI 2.2 are dated 23.34-22.9 ka (Rasmussen et all., 2014).

During Sartan Cryochrone were severe climatic conditions. There are cryogenic epoch with two stages of permafrost processes activity and several phases. The first stage of cryogenic activation is dates Last Glacial Maximum (LGM) – 27.5-23.3 ka, second Younger Dryas (Greenland Stadial-1) – 12.9-11.7 ka. In the Kuitunka river basin (right tributary of Selenga river) three layers with cryogenic deformations were dated to ~14.2–14.0, ~12.7–12.5 and 11.9–11.7 ka (Ryzhov, Golubtsov, 2018). At the beginning of the Sartan Cryochrone in the

Transbaikalia polygonal-block relief was formed. The sizes of polygons vary from 4 to 50 m, height 0.5-2 m. In the Holocene polygonal-block relief was transformed into hummock-pothole relief with discontinuous permafrost.

There are different cryogenic relief forms in the Sartan Cryochrone deposits. Ice wedge pseudomorphs, frost cracks, microfaults, upward and downward involutions distributed widely. The largest cryoturbations have Early Sartan (29-21.4 ka) ages. In the Last Glacial cryogenic stage (12.9-11.7 ka) permafrost microrelief was formed. It is imposed on the more ancient permafrost polygon network, represented by cryoturbations.

Consequently, in Transbaikalia during Sartan Cryochrone took place cryogenic epoch with permafrost processes activity phases – 29-23.3, 12.9-11.7 ka, soil formation stages – 23.4-21.3, 14.6-12.7 ka.

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Comparative analysis of the respiratory response of cryosols and the soils of the temperate zone for short-term freezing-thawing of the surface soil layer

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The influence of periodically recurring short-term freeze-thaw cycles on CO2 emissions from soils was investigated in the laboratory experiment. The objects of the study were Cryosols from Kolyma lowland (Histic Cryosol, Turbic Cryosol, Spodic Cryosol), Podzol (Moscow region, Verbilki), grey forest soil (Moscow region, Pushchino) and typical Chernozem (Voronezh region, Kamennaya Step' reserve). During the experiment (55 days), two cycles of freezing-thawing with a total duration of 35 days were carried out. The temperature was changed from +5°C to -5°C during freezing-thawing cycles.

The emission of carbon dioxide from soils studied during the freezing-thawing cycle differed in magnitude, but it had a similar dynamics. The organogenic horizon demonstrated a more intense release of CO_2 compared to stronger mineralized, humus horizons, both during the freeze-thaw cycles and during the pre-incubation period.

At the beginning of freezing, the emission of CO_2 was 0.02-0.15 μg C/g/hour and decreased to values closed to zero from completely frozen soils. Respiration of frozen soils was not significantly different. The low rate of CO_2 emission was associated with high humidity, which caused a monolithic freezing of the samples, and made difficult diffusion of carbon dioxide. The freezing and subsequent thawing of the soil promoted the enhancement of the emission of

CO_2, regardless of the type of soil. The burst of CO_2 emission began immediately after the beginning of thawing of the soil and lasted approximately 1-3 days. The intensity and duration of the burst depended on the soil type. During the first thawing, the rate of CO_2 emission reached 0.07-0.34 μg C/g/hour. The rate of CO_2 emission during the second burst was almost two times less in all variants than during the first one.

During both freeze-thaw cycles, it was released from humus horizons about 8-11% of carbon of the total amount for the whole experiment. The contribution of each CO_2 emission burst to the total emission for the experiment was about 1%. From organogenic horizons, up to 20% of carbon was released and the contribution of single burst reached 4-6%.

Thus, the differences between the respiration of the soils during freezing-thawing were determined not by the zonal affiliation, but by their properties and especially by the content and availability of organic matter for microorganisms.

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The Effect of Snow Hardness on Soil Freezing

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Effect of the snow thermal resistance on soil freezing is comparable to the influence of mean temperature in the cold period. The thermal resistance of snow cover depends on the thermal conductivity of snow. The scatter of snow thermal conductivity in 2-3 times arises from differences in the microstructure of snow at a given density. Our measurements have shown that average value of coefficient of efficient thermal conductivity of the depth hoar with density of 280 kg/m^3 is 0.12 W/(m K) that in 3 times smaller than the same coefficient of granular frozen together snow with density of 370−390 kg/m^3.

The thermal conductivity of snow depends on the contacts between ice crystals. The larger the contact area, the better the heat transfer from one layer to another. But the strength characteristics of snow, and especially its hardness, depend on the bonds between ice crystals, so the thermal conductivity and hardness of snow depend on the structure of snow. Note, that measurements of snow hardness are less laborious than measurements of its thermal conductivity.

The results of experimental investigation of thermal conductivity of snow on the Svalbard archipelago in the conditions of natural occurrence are considered. The observations were carried out in the spring of 2013−2015 in the vicinity of the meteorological station “Barentsburg”. The obtained data were processed using the Fourier equation of thermal conductivity. That allowed deriving relationship between thermal conductivity and snow hardness and determination of the coefficient of thermal conductivity of the snow with different structure and density. To verify the reliability of the approach to the determination of snow thermal conductivity, numerical experiments were performed on a mathematical model, which did show good convergence of the results. The obtained formulas for the coefficient of thermal conductivity of very loose, loose, medium and hard snow (according to the international classification of seasonal snow falls) are compared with the data of other studies. It was found that when the snow density is within the range 0.15–0.40 g/cm^3 these formulas cover the main variety of thermal conductivity of snow. This allows estimating the coefficient of thermal conductivity and to determine the thermal resistance of snow cover in the field by measuring the density and hardness of different layers of snow.

The thermal conductivity of snow with a density of 200 kg/m^3 at different hardness varies by 3-4 times, for snow with a density of 300 kg/m^3 - by 2.5 times and for snow with a density of 400 kg/m^3 - by 1.7 times.

The effect of the snow cover hardness on dynamics of the soil freezing is analyzed with the use of numerical modeling. Model calculations show that soil freezing depth differs by 2.9 and 2.1 times for snow of different hardness at a snow cover height 0.5 m and an average negative air temperature of −5 and -15 °C. With a snow cover height of 1 m, this ratio increases to 3-4 times. The results of calculations show that for a more accurate assessment of the depth of soil freezing it is necessary to take into account the structure of snow cover.

The mathematical modeling was carried out according to the framework of fundamental scientific studies within the project reg. № 0148-2019-0004, field studies on Svalbard were conducted with financial support from the state assignment and logistical assistance of the Russian Scientific Center on Spitsbergen (RSCS), processing and analysis of experimental data was supported by the Russian Foundation for Basic Research, grant No 18-05-60067.

About the organization of a unified program for monitoring cryogenic processes

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The problem of monitoring and accounting of cryogenic processes arose at the very beginning of the development of the permafrost zone, when, due to underreporting of the permafrost factors, buildings, structures and infrastructure were subjected to deformations and destruction almost immediately after their construction.

At present, monitoring of cryogenic processes is mainly carried out in antropogenically-developed territories: the mitigation against processes is mainly carried out along the main oil and gas pipelines, along roads and railways (for example, Obskaya-Bovanenkovo). On the territories of cities and towns, this problem is less relevant, cause of using preliminary prepatrations. In modern monitoring studies, only pinpoint applied problems are solved: ensuring trouble-free operation of infrastructure facilities (problem areas), with neutralization of cryogenic processes. With the advent of remote sensing techniques, the study of cryogenic phenomena and processes has become devoted to areal changes that make it impossible to evaluate the modern mechanism for the development of processes and to identify their regional features.

Due to climatic changes, the intensity of certain cryogenic processes (in particular, warm ones, such as: thermokarst, thermoerosion, thermoabrasion, thermodenudation, which have a negative effect on permafrost conditions) has increased, and therefore the question of a detailed study of the formation of cryogenic processes in "new reality" arises in the changed environmental conditions. Of course, during the 20th century, permafrost scientists in the Soviet Union and the United States did a great job of studying the mechanism for the development of cryogenic processes, which should first of all be used for modern monitoring, but it is necessary to have continuous modern series of direct field observations of the processes for further modeling and forecasting the development of processes.

There are several huge international scientific programs established in the 1990's devoted to monitoring the thermal state of permafrost: TSP and CALM. These programs cover data on monitoring permafrost temperatures in deep boreholes, as well as data on the depths of the active layer, but we still have no programs, dedicated to monitoring cryogenic processes.

What is needed is the development of uniform methods for the long-term monitoring of processes, an attempt to create a modern classification of cryogenic processes from the position of finding the "triggers" for their activation.

The paper discusses the main classifications of cryogenic processes, reveals the general parameters necessary for the selection of triggers.

It is planned to study the main methods of monitoring processes and phenomena, assess their effectiveness, as well as study the cost of using each of the proposed measurement methods.

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Geocryological conditions for the passage of the railway Obskaya – Bovanenkovo - Karskaya

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The world's largest oil, gas and gas condensate deposits are located in the North of the West Siberian District. In this regard, the Yamal Peninsula is one of the most important strategic oil and gas regions (in the world/country). The development of the region requires a streamlined transport system. One of the key transport routes is the Obskaya-Bovanenkovo-Karskaya railway line. The complex engineering and geological conditions of the railway construction are associated with the presence of permafrost. The entire route is located north of the Arctic Circle, where climatic and natural conditions are extremely harsh. The processes that take place on the territory of the railway, affect the stability of objects. Soils experience an additional load, which creates difficulties in the operation of the roads.

The purpose of this work is to analyze the influence of geocryological conditions on the construction and operation of the Obskaya - Bovanenkovo - Karskaya railway, and to identify the main dangerous cryogenic and glacial processes affecting the roads.

The methodology of the study included actual field studies at the transport infrastructure facilities both in winter and summer and the analysis of scientific articles and production reports.

Considering that practically throughout the Bovanenkovo - Karskaya section, permafrost low-temperature soils are found at the base, the railway line was designed according to I principal, i.e. preserving the soil base in the frozen state. However, throughout the entire road, the unfolding of dangerous cryogenic processes is typical, which does not allow the use of the same construction and operation technologies in different parts of the road, which leads to various deformations of the railway. When studying the scientific literature and stock sources, it was noted that most of the deformations are typical for sections of culverts as a result of their flooding and the development of thermokarst, as well as when using strong icy silty sands as a soil base. The processes of thixotropy, which significantly affects the stability of roads on the Yamal, remain practically unexplored. Methods of improving the sustainability of the railroad tracks should be based on eliminating the causes of deformations, i.e. the conditions in which cryogenic processes occur. Obtaining up-to-date information on the changes in geocryological conditions at the base of the roadbed and the unfolding of dangerous cryogenic processes should be prioritized during geocryological monitoring. This will allow for the timely development of methods for disrupting hazardous processes leading to deformations.

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Comparison of lakes within the lake-thermokarst and erosion-thermokarst plains with the help of mathematical morphology of landscape

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Erosion-thermokarst and lake-thermokarst plains are widespread in the permafrost zone. A number of studies have been carried out on the thermokarst-lake plains, in which various characteristics of the lakes were studied (F.E. Are, CR Burn, MW Smith, V.Yu. Polishchuk and Yu.M. Polishchuk, A.S. Viktorov, V.N. Kapralova., V.I. Kravtsova, T.V. Tarasenko, S.N.Kirpotin, N.A. Bryksina, et al., Grosse G., Jones BM, Nitze et al). Erosion-thermokarst plains more complex and dynamic territory, which is associated with the activities of the erosion system, the descent of lakes and the appearance of hasyree (degenerate center of thermokarst lake), were also studied by group of researchers (N.N. Romanovsky, A.S. Viktorov, V.N. Kapralova et al).

Comparative analysis of the distribution of lake areas and the prediction of their changes within the erosion-thermokarst and lake-thermokarst plains is an interesting task, which has not previously been studied. The use of mathematical morphology of the landscape and the use of remote sensing data can give perspective results for modeling the distribution of lake areas within the erosion-thermokarst and lake-thermokarst plains and, subsequently, to assess the risk of damage to the thermokarst process of various engineering structures.

The purpose of the research was a comparative analysis of the distribution of lake areas within the erosion-thermokarst and lake-thermokarst plains based on the approaches of the mathematical morphology of landscape using remote sensing data. The mathematical morphology of landscape approach allows a quantitative analysis of the spatial patterns, formed by the land cover.

We used the multitemporal satellite imagery of a high and very high resolution (5-30 m) as the input data. We selected about twenty study sited of lake-thermokarst plains and twenty study sited of erosion- thermokarst plains across the circumpolar region so they would represent the areas with different geomorphological, permafrost and physiographic conditions.

For the selected lakes we evaluated the relationship of empirical and theoretical distributions of the lake areas. The distribution of lake areas within the lake-thermokarst plains in different physiographic, geological and geocryological conditions is confirm with log-normal distribution.

The distribution of lake areas within erosion-thermokarst plains in different physiographic, geological and geocryological conditions in general confirm both with gamma distribution and log-normal distribution of lake areas. In quantifying the probability of damage to an engineering structure within the lake-thermokarst and within the erosion-thermokarst plains, various methods should be used that can be obtained by analyzing the corresponding mathematical model.

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The Geoecological Situations Assessment and Mapping on Regional and Local level in the Russia Permafrost Zone

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Some methodical ways of permafrost-ecological conditions estimation under economic development in terms of northern geosystems sustainability to the manifestation of dangerous cryogenic processes are described. All types of evaluation studies are carried out on the landscape basis with the help of expert scores. The mechanical load intensity is compared with natural landscape stability gradations using the matrix method. The various intensities of anthropogenic load are ranked with regard to the development type based on type of mechanical damage, residual deer capacity, the vegetation recovery rate, and the share of disturbed land.

At the overview-regional scale, the most significant permafrost factors are.

1. The permafrost distribution area is estimated as a percentage of the total landscape area where continuous permafrost is more than 90–95%, interrupted is 50–95%, massive-island 5 to 10–15%, and sporadic is less than 5%. 2. The annual mean temperature of the permafrost from below −11°C up to 0°C with separate scales for plains and mountains. The most universal temperature scale is as follows: 0–1°C, −1 to −2 (3)°C, −2 (3) to −5°C, −5 to −10°C, and below −10°C. 3. Ice content permafrost is estimated in parts or as a percentage. The following values are most common: less than 20%, 20–50%, and more than 50%.

According to these considerations two small-scale maps were prepaired by N.Tumel. On the first - five groups of potential processes activation are allocated: from weak to very strong. The second map shows the leading anthropogenic processes combination within this area, which are united in 11 groups according to the zone and regional varieties in the permafrost, landscape, and climatic conditions. The atlas maps, designed on a common landscape basis, have universal value, allowing us to analyze and generalize information about permafrost zone landscapes.

At the local level, the range in estimative factors is wider. The ice content degree and temperature of the permafrost, the depth of seasonal thawing or freezing, the relief, the heat-insulating properties of the vegetation and the rate of its self-recovery, the bioclimatic indicators are all influential factors. During the process of evaluative mapping various techniques were used: methods of statistical calculations, indicative signs, maps-indicators, scientific hypotheses, and extrapolations. The ecological indicators are based on expert estimates and rely on the long-term experience of regional research. Based on analysis of the chosen factors, we calculated the integrated indicator of their cumulative influence. This value can be either the simple sum of factor points, their geometric mean, or the calculated coefficient developed in the multiple regression equation. The formation of different ecological situations based on the consideration of the mechanical damage degree of the topsoil cover and the landscape resistance to these types of violation.

On local level two geoecological situations maps of Tyumen North test sites (compiled by the authors) are shown. In matrix table five-stage gradation of ecological situations is defined in the standards of the Russian Ministry of Natural Resources: satisfactory, tense, emergency, critical and catastrophic. Each situation is characterized by a specific set of cryogenic processes of different intensities. The critical situation is formed in the landscapes which are unstable in permafrost relation (such as peatlands with patterned vein ice) due to strong mechanical damage. The illustrations of the main situations categories are presented. Scientific and methodological approaches of this evaluation can be applied in engineering geocryology, at predesign stages of the research, and for strategy decision-making for cryolithozone development.

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Analyzing tundra vegetation characteristics for enhancing terrestrial LiDAR surveys of permafrost thaw subsidence on yedoma uplands

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Surface subsidence is a widespread phenomenon in Arctic lowlands characterized by permafrost deposits. Together with active layer thickness dynamics surface subsidence is an important indicator of permafrost degradation in climate warming conditions. Due to small changes of surface heights of several centimeters or less per year, high-resolution and high-accuracy data are necessary to detect thaw subsidence dynamics in tundra lowlands. An appropriate method to receive such data is repeat terrestrial laser scanning (LiDAR). However, for LiDAR data analysis, uncertainties connected with vegetation dynamics should be taken into account. The vegetation type and its succession reflect the microrelief features, resulting in an areal differentiation of surface heights changes. Depending on wetness, possible influences might result from moss-lichen cover and its thickness dynamics. In this study we present some results of the vegetation characteristics and dynamics in context of its impact on the terrestrial LiDAR investigations for thaw subsidence assessment on yedoma uplands.

During expeditions to the Lena Delta and the Bykovsky Peninsula in Northern Yakutia in 2015-2016, repeat terrestrial laser scanning was conducted on yedoma uplands formed by very ice-rich Yedoma Ice Complex deposits. On the Bykovsky Peninsula, detailed vegetation descriptions of the main vegetation types were done including all species projective cover, cotton grass tussocks height and area sizes, moss-lichen thickness and ALT measurements. Subsidence was about 3.5 cm on average and is mostly observed on drained inclined sites with dwarf-shrub graminoid, cotton-grass, moss-lichen tundra, representing initial baydzherakhs (thermokarst mounds). Surface heave is observed mainly within bogged depressions with sedge, moss tundra. The average ALT was 39±4.1 cm and 32±5.6 cm in 2015 and 2016, respectively. However, the ALT significantly varies locally and depends on the vegetation type and species.

Cotton grass leaves average length decreased from 14.4 in 2015 to 12.9 as well as tussock area size (0.32 m^2 in 2015, and 0.13 m^2 in 2016). This data can be used for the interpretation of LiDAR data for sites with cotton grass prevalence.

Less deep ALT and cotton grass size in 2016 indicate that climate conditions were less favorable for seasonal subsidence development in 2016. The sum of positive daily air temperatures was almost in the same order of magnitude in 2016 as in 2015 for the period until end of August (636 degree days in 2015 and 628 degree days in 2016). However, interannual surface subsidence was progressing, indicating a decreased resistivity of yedoma uplands in terms of thaw subsidence under current, generally warmer conditions.

The thickness of the moss-lichens layer in average is about 5 cm for the live part and 12 cm for both live and non-live parts. The lab drying in the 20°C conditions shows the decrease of moss-lichens layer samples thickness from 12,4 to 11,8 cm in average. The changes of moss-lichens thickness could be ignored as drying resulted in small changes it is very unlikely to have such drying in really tundra conditions

Our results show the importance of considering vegetation and their dynamics for the interpretation of repeat terrestrial LiDAR data for thaw subsidence estimation.

SESSION 5: PERMAFROST AFFECTED SOILS

Problems of Permafrost-Affected Soils Classification and Their Places in Different Taxonomic Systems

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Since 1978, when Cryosolic order has been established in the Canadian soil classification system the permafrost-affected soils are recognized as very important ones in several classification systems of the world. In the Canadian system and in the US Soil Taxonomy soils of the world are divided into those with permafrost and other soils. In WRB system permafrost-affected soils are also very high. In Chinese and national Russian classification systems the permafrost are recognized only on the 3rd-4th taxonomical levels. However since that time when all these classification systems came into being the community of soil scientists got new challenges for the classification of permafrost-affected soils. 1. The problem on the classification of soils in loose materials which have permafrost below 2 m, but this permafrost results in cryoturbations and accumulations of different soil materials in deep soil horizons and even subsoils because of impermeability of the deep permafrost. These soils are typical for regions of ultracontinental climates with very cold winter and hot summer (Saha

(Yakutia), Transbaikalia). Traditionally for these areas, such soils are classified as permafrost affected, as they differ from non-permafrost soils by many features. 2. The problem of shallow soils of cold climates, whether we can accept them as Gelisols, as they theoretically have permafrost within 1 or 2 m of solid rock, or they should be classified as Gelorthents as nobody can see permafrost in the profile because of shallow lithic contact. 3. The problem of soils with well-pronounced cryoturbations but without permafrost. 4. The problem of division of cryoturbated soils to those with mineral horizons and ones enriched by organic material.

The new draft list of cold soils on the middle level of classification is proposed for wide discussion to be used in the different soil classification systems. It includes all the soil features that Gelisols/Cryosols have in Soil Taxonomy and WRB soil classification systems. Several amendments are proposed – AHUMIC (for soils with <0,02% organic carbon content), CRUSTIC- (for soils with crusts on the surface that is typical for arid landscapes), HOMOGENIC (for soils where cryoturbations result in soil mass homogenization), MUCKIC- (for soils with mucky organic horizon), PAVIC (for soils with stony pavement). Turbic Cryosols and Turbels should be divided for Organi-Turbic Cryosols and Minera-Turbic Cryosols. Bathy-Gelic subqualifier should be included for soils with deep permafrost (>2m) but with active cryogenic processes.

Several amendments to the Russian system are also recommended. 1.Expand the understanding of the subtype "frozen", bending it to the international standards (Cryosols/Gelisols), - soils with permafrost within the limits of 1 meter (a species is shallow-frozen), and also soils with permafrost within 2 m under the presence of cryoturbations (a species is mid-frozen). Expand the frozen subtype of deep-frozen species for soils with the appearance of cryogenic processes and the presence of closed permafrost >2 meters. 2. Enter the diagnostic features and subtypes "supra-permafrost-organo-accumulative", "supra-permafrost-retinized", "supra-permafrost-gleyic", "supra-permafrost-salinized", "supra-permafrost-calcified".

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The response of West Siberia tundra ecosystems to experimental warming: results of short and long-term experiments

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In the last decade, laboratory incubations and field experiments have been conducted at different levels, from the scale of microbiological processes to the landscape level, to study the effect of warming on the carbon balance in northern ecosystems and the development of more accurate models. Under laboratory conditions, there are understandable limitations on both long-term experiments and the possibility of modeling the entire complex of ecological conditions of northern ecosystems. Therefore, more and more attention is paid to field experiments simulating climate warming, which, however, also have a lot of significant drawbacks, which is a problem for interpretation of the obtained data.

The original author's approach was tested to study the reaction of the soils of the North to warming. The construction and operation of gas pipelines in the permafrost zone has a significant warming effect on the surrounding ecosystems, the permafrost degrades to big depth and width along the pipeline. This fact allowed us to use the “heated” ecosystems along the gas pipeline as an experimental object. A set of ecosystems that transformed as a result of the warming effect of the gas pipelines in the tundra and northern taiga of West Siberia, Russia were investigated. The research sites were located along gas pipelines in the southern tundra of the Taz Peninsula (Novy Urengoy), in the Bolshezemelskaya tundra (Vorkuta) and in the northern taiga of Western Siberia (Nadym). The effect of changes in ecosystem parameters in the heating zone (10–30 m from the gas pipeline) has led to thaw depth and increase in the soil temperature and biomass of vegetation cover. A slight increase in CO_2 fluxes from heated soils has been revealed, and the activity and amount of microbial biomass in soil horizons is reduced. Carbon storage in heated soils (0–20 cm) is reduced, however, an increase in the storage of aboveground biomass is observed. On the key site within the palsa, the short-term experiments on the heating of peat soils are organized. We used transplantation method (Sjogersten, 2002) that showed a significant positive short-term response of soil biological activity (CO_2 efflux) being 4 times higher than control values after 2 weeks of heating. This positive short-term trend tended to continual slight decrease after 2 years of transplanting reflecting only 1.5-2 times higher CO_2 efflux of heated soils compared to control.

The results show an ambiguous, hardly predictable response of the soils and ecosystems of the North to warming in a long period of time. Under certain conditions, with time, heated areas may become carbon sink, but not a source.

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Temperature Field and the “Mirror Image” of the Thawing and Freezing processes of the Cryoarid Catenae Soils in Central Buryatia

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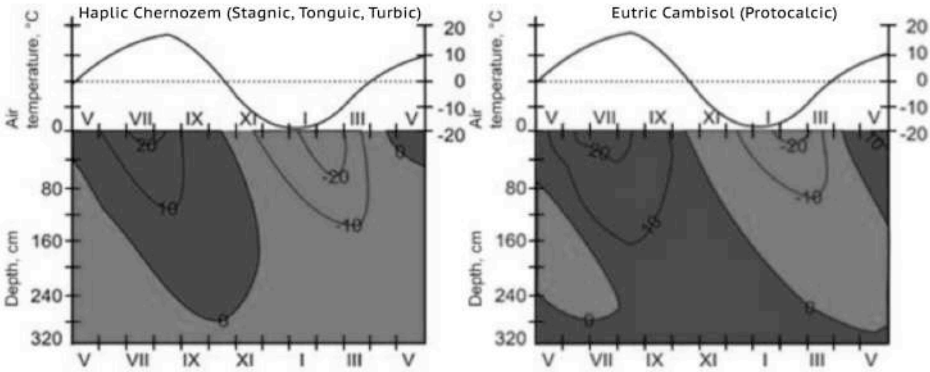
The southern boundary of the distribution of the cryolithozone passes across the Vitim plateau south territory of the Transbaikalia. It is here, in the transition zone from the continuous cryolithozone to the sporadic, that the dynamics of changes in the temperature field of soils is most pronounced due to global climate change.

A contrasting soil cover represents Cryoarid catenae. Stagnic Phaeozem (Tonguic) forms at the top and near-watershed part of the gentle slope of the northern aspect under the sparsely larch-birch forest (N 52°28’02.3”, E 111°04’06.9”, 893 m a.s.l.). Haplic Chernozem (Protostagnic, Tonguic, Turbic) is formed below the slope in the middle part of the hill beneath a grass-gramineae meadow (N 52°28’06.1”, E 111°04’13.6”, 880 m a.s.l.). Haplic Chernozem (Stagnic, Tonguic, Turbic) occupies the accumulative part of the slope under gramineae-grass vegetation with legume admixture (N 52°28’14.6”, E 111°04’35.0”, 865 m a.s.l.). The middle part of the steeper slope of the southern aspect (6-8°) under sparse forb-grass vegetation with the participation of xerophilous species is represented by Eutric Cambisol (Protocalcic) (N 52°27’56.1”, E 111°03’59.3”, 890 m a.s.l.).

Comparison of the soil temperature measurements thermoisoplethes of contrasting aspects shows a fundamental difference between them. Haplic Chernozem (Stagnic, Tonguic, Turbic) of northern oriented slope thawed only seasonally (4.9–5.0 months) in summer, and remained in a frozen state in the subsoil for most of the annual cycle. The soils of the southern oriented slope - Eutric Cambisol (Protocalcic), on the contrary, were only 5.8–6.0 months in a frozen state, remaining thawed in the subsoil for most of the year. These spatial-temporal differences of heat and cold (frost) are proposed to be called "mirror images" of thawing and freezing processes in permafrost-affected and cool soils.



Temperature and permafrost regimes and "mirror images" of the soil thawing and freezing processes, — frozen layer, — thawed layer

Carbon and nitrogen distribution patterns in the soils of the Barents sea coastal area

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Nowadays, the Arctic attracts the attention of polar researchers from many countries. The theoretical interest in this area is due to the peculiarity of landscapes formed at the junction of the lithosphere, atmosphere and hydrosphere. The relevance of ecosystems knowledge of the seas coasts in the Arctic has been increasing due to the global changes, which affect polar ecosystems.

In the soils developed in the undisturbed landscapes of the Barents sea coast the relevant landscape heterogeneity distribution of different forms of C and N has been identified. According to the elements' contents two groups of soils have been subdivided, which spatial distribution coincides with the boundaries of vegetation areals: saline soils are marching, forming in the conditions of flooding and tidal surges of sea water and non-saline soils of tundra ecosystems, developing elevated sites affected by zonal type of soil formation.

In saline marsh soils the content of Corg varies across horizons from 5 to 75, Norg – from 1 to 5 g/kg. The elements proportion of water-soluble forms is 0.3-13%. The number of elements in soils and water extracts from them are interrelated, the trend equations are similar. In the middle part of the soil profile (3-30 cm) humus-accumulative horizons buried by modern marine sediments have been identified. Fixation of N-containing compounds by soils' clay fraction (CF) is confirmed, $\varpi CF= 0.06 \cdot \varpi\ (N_{tot})$.

In soils of tundra ecosystems organic carbon content is 430-470 g/kg, organic nitrogen content is 4-7 g/kg. Relevant figures for aqueous extracts of peat horizons are equal to 4-10, ~0.3 g/kg. In the mineral part of the Histic Reductaquic Cryosols, further correlation have been revealed $\varpi CF = 0.06 \cdot \varpi(N_{tot})-0.50$. The supra-permafrost stratum (solid and liquid phases) is characterized by the accumulation of elements (up to 1.6 times) in comparison with the underlying permafrost.

In the Tidalic Fluvisols the carbon content of inorganic compounds varies between 0.4 and 1.8 g/kg (4-20 % of the element total content), in aqueous extracts – between 0.02-0.11 g/kg. Bicarbonate-ion accumulation has been observed in the three upper horizons of the marsh primitive soils. The main sources of inorganic carbon are sea water and carbonate deposits.

Affinity of C/N values of the studied soils and extracts from them has been proven, taking into account that aboveground biomass parameters of dominated present-day plant communities were the same. In the marsh zone C/N of soils and their water-soluble fraction is 10-16. In peat horizons of tundra soils C/N = 64-95, in aqueous extracts of them - 20-50, C/N is reduced with a depth by 3-7 times. The value of C/N plants phytomass of saline habitats corresponds to the range of 12-21, lichens and mosses – 80-140, indicators of the substrates liquid phase are 4-18 and 30-60 respectively.

The differences in the humus content and the composition of the liquid phase of the low marsh soils have been revealed, in comparison with similar characteristics of the coast soils with similar positions the Kandalaksha Bay. The difference in salinity of compared waters determines 2-4-fold excess of the soluble forms content of Ca^{2+}, K^{+} and Na+, Cl^{-}, $SO4^{2-}$ the first in comparison with the second. The studied marsh soils are more saline and more spatially differentiated according to this parameter in comparison to the soils of White sea coastal area.

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Pedodiversity of the Cryolithozone in the Siberian middle taiga

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Siberia is characterized by specific climatic conditions with cold winter and hot summer. For a long time Western Siberia was considered to have low soil diversity with peat soils being the most abundant component of soil mantle. However, the studies in the middle taiga zone of Western and especially Eastern Siberia showed the presence of various loamy soils both with and without textural differentiation, which differ in morphology and properties from podzolic soils. We aimed at revealing the driving factors responsible for the pedodiversity of loamy soils in the Middle taiga zone of Siberia.

The research was done in Western and Eastern Siberia. We studied soils on the Severo-Sosvinsk Upland, the Agan Uval, the left bank of the Kiryas's creek in Western Siberia and the Prilenskoye plateau in Yakutia. Western Siberia has flat topography. The climate is moderately cold with mean annual temperature -4 - 2°C, mean January temperature -20°C and mean June temperature +18°C; the annual precipitation is 580 mm. Central Yakutia (Eastern Siberia) is located on an undulated plateau. Its climate is more continental with mean annual temperature -10.2°C, mean January temperature -38,6°C, and mean June temperature +19,5°C, the annual precipitation is 238 mm. Both areas are covered with taiga forest with larch, pine and Siberian pine. The parent materials are loams, sandy loams, and sands of alluvial and ancient alluvial origin. The areas have permafrost: insular in case of Western Siberia and continuous in case of Eastern Siberia.

The studied soils in Weatern Siberia have brownish colors, specific caviar structure in the B horizons, clay coatings and strongly acid environment. Micromorphological study of soil thin sections in transmitted and reflected light showed the presence of numerous rounded aggregates with and without Fe-Mn nodules in their centers. Mercury porosimetry showed the presence of a large number of pores of different configurations, predominantly of small and medium size. The mineralogical composition of clays is characterized by the presence smectite. Soils in Eastern Siberia are pale with cryogenic platy structure in lower horizons that is typical for permafrost-affected soils and neutral-alkaline. There are several types of coatings in voids and on soil aggregates: clay, humus-clay and carbonate. The mineralogical composition of clays is characterized by the presence of chlorite-vermiculite and kaolinite. The vertical distribution of organic carbon concentration is accumulative in both regions.

The pedogenetic processes in the studies soils in Western Siberia include intense leaching, clay dissolution in acidic environments in surficial horizons, poorly clay illuviation, aluminum penetration in the crystalline lattice of layered silicates, structure forming and gleying. Solodization, carbonate illuviation, iron hydroxide formation process, humus accumulation, structure forming and cryoturbationare were suggested as active pedogenetic processes in the soils of

Eastern Siberia. Soils were identified as Cambisols and Alisols in Western Siberia, Cryosols and Planosols in Eastern Siberia according to the WRB.

Differentiated vs. poorly differentiated soils form due to local hydrothermal, topographical and lithological conditions. Cold environments with seasonal and perennial frost action are the major factor, which influence pedogenesis and appearance of the soils. We hypothesized that initially similar substrated transformed into different soils due to divergent evolution. The texturally differentiated loamy soils could form in warmer areas with earlier seasonal thawing, and have percolative water regime practically throughout the growing season. In recent decades, global climatic changes could impact current pedogenesis, and may lead to increased textural differentiation in soils.

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Pumping-effect in soils of permafrost

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The one-dimensional equation is considered

$\partial T/\partial t=\partial/\partial z\ (K(T)\partial T/\partial z)$,

Where T - soil temperature, K(T) – function of heat diffusivity of the soil, axis z is directed upright down (z=0 – the surface of the soil). Boundary conditions:

$T(z=0)=f(t),\ \ z\to\infty\ \ T<C<\infty,$

where f(t) is periodic function with the period τ .

In this work function of thermal diffusivity K(T) of a look is considered

$K(T)=\alpha T^2+\beta T+C+\gamma T^{-2/3}.$

It is known that solution at $z\to\infty\ T\to T^{(\infty)}$, where

$T^{(\infty)}=\Psi^{-1}[\langle\Psi(f(t)\rangle],\ \ \Psi(T)=\int K(T)dt,\ \ \Psi^{-1}(\mathrm{T})-inverse\ function.$

Pumping-effect for permafrost soils has the negative value, i.e. increase in a oscillation amplitude at the surfaces of the soil leads to cooling of the soil at larger depths and, on the contrary, decrease of a oscillation amplitude leads to temperature increase of the soil. For example, for conditions of Yakutsk a pumping-effect is estimated at minus 2 degrees.

The Soil-Forming Environmental Characteristics of the North-East Arctic Coastal Areas of Russia

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Coastal environments and the soils on the shores of the Laptev, East-Siberian and Chukchi seas in the North-East part of the Russian Arctic are very poorly studied. They provide very important ecological function being the buffer geochemical zone between the marine and terrestrial environments, especially keeping in mind the possibility of dangerous anthropogenic impacts.

Regional peculiarities of pedogenesis in these areas are determined by the features of the sea coasts–their relatively young age, processes of thermoerosion and thermoabrasion, shallow depths of the sea shelf, wide areas of the upsurge, low degree of the sea water salinity, dominance of the Ice Complex material enriched with organic carbon in the marine and terrestrial deposits etc. The important feature of the local pedogenesis is the active input and deposition of the organic material in the synlithogenic soil profiles. This material comes from the uppermost organogenic horizons of the Late Pleistocene and Holocene watersheds and slopes' soils. The activeness of this process and the volume of the allochtonous material are determined by activeness of the thermoabrasion and the lithological structure (e.g. ice content) of the coastal deposits. During the evolution of the coastal areas, the alas depressions turn to the shallow lagoons and the hydrothermal regime and physico-chemical properties of the soils here completely change.

The cryogenic processes take a very significant part in the pedogenesis here–the factors of the shallow depths of the active layer, high ice content, abundance of the Ice Complex deposits, permafrost surface microrelief completely determine the features of the deposits' and salts' accumulation.

The first results of the East Arctic coastal soils' structure and properties' studying show the necessity of the future development of the soil diagnostics and classification system taking into account the shallow active layer depths and active processes of the cryogenic mass exchange.

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Cryoconites - as a source of carbon for soils and soil-like bodies of High latitudes

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Cryoconites are the sediments of mostly aeolian genesis, which accumulate on glacier surfaces and include both mineral and biological components. Accelerated ice melting beneath aeolian accumulations leads to the formation of so-called cryoconite holes, which are characterized by a specific microclimate that allows colonization of these habitats by communities of primary producers – cyanobacteria and algae that concentrate biogenic elements within the substrate. Fragments of mosses are transported together with windblown dust to the glacier surface where they can resume growth under favourable conditions. The retreat of the glacier is accompanied by the redeposition of cryoconite material by melt waters and its accumulation within wind-sheltered locations. The cryoconite material serves as a unique soil-forming and plant-supporting substrate because of its properties, particularly, a high content of biogenic elements and a fine particle size, as compared to other deposits within the modern periglacial zone. The objects of our research were cryoconites, soils formed on cryoconite material in the preglacial zone of the Aldegonda glacier (Nordenscheld Land, western Svalbard), and fine earth, cryoconites, soils and soil-like bodies of the nival-glacial complex of the Schirmacher oasis and nearby nunataks (East Antarctica). A complex of modern instrumental methods they are radiocarbon AMS dating, isotope mass-spectrometry, ^{13}C-NMR, and traditional physico-chemical and morphological methods of research were applied for these objects. On the basis of isotope, chemical and morphological analyses, it was revealed that the cryoconite material is the primary carbon source for soil organic matter (SOM) on the moraines studied. Judging from the radiocarbon dates, the cryoconite material is supplied as a result of rapid melting of deep layers of the glacier. The morphological features of cryoconite material are preserved for several decades within the soils studied, with cryogenic differentiation being the main process of reorganization of mineral mass and the organic matter being inherited from cryoconites. Therefore, soils with well-developed profiles, rich in biogenic elements are formed on the cryoconite material within a period of first few decades. In the absence of cryoconite material in similar geomorphological situations, a period of a few hundred years would be required for the formation of similar soil profiles. It is important that carbon accumulated within the glacier body during the Holocene is incorporated into the carbon cycle. The data obtained on the radiocarbon age of the fine earth, cryoconites and soil organic matter of nunataks in the Schirmacher oasis suggests that the cryoconite material released during the melting of glaciers, due to its properties can serve as an additional source of biogenic elements for soil formation in Antarctica. The results of radiocarbon dating show that the cryoconite material is a kind of depot of ancient carbon in glacier. The average residence time of carbon in the material of the studied cryoconites in Antarctica ranges from 2000 to 2500 ^{14}C-years. Studies show that organo-mineral interactions like in the soils also take place on the surface of the ice. They are recorded in the fine earth as an accumulation of carbon and nitrogen compounds. We suggest separating cryoconite soloids (soil-like bodies). Their distribution, apparently, is much wider in the Polar Regions than off-glacial land.

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Carbon redistribution in soils of hydromorphic ecosystems in the permafrost zone (North-Western Siberia, Russia)

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Northern ecosystems are important for the global carbon cycle, because they are rich in organic carbon, which is contained in both soils and permafrost (Natali et al., 2011). Possible permafrost degradation can change both the export values and the composition of dissolved organic carbon from permafrost-affected soils, especially peatlands, through a change in the hydrological regime, the structure and functioning of ecosystems. Cryogenic landscapes are a unique representative of border systems. Sharply contrasting and rapidly changing parameters of functioning characterize them. The main objectives of the study were to assess the mechanisms, patterns and drivers of the redistribution of soil, water and atmospheric carbon fluxes in the peat-bog complexes of the north of Western Siberia (discontinuous permafrost). The starting point of all experiments was the assumption of the key role of the permafrost as a mechanism for the redistribution of organic and inorganic carbon fluxes in the permafrost ecosystems. The objects of this study were palsa, surrounding wetlands other water bodies. Field and laboratory methods for studying dissolved, particulate and gaseous carbon in soils, natural waters of permafrost ecosystems were tested and adapted taking into account their specific genesis and functioning. The study included a simultaneous measurement of some labile indicators of soils and natural waters, as well as environmental factors (August 2016, 2017, and 2018).

The interannual variability of weather conditions determined the difference in soil temperature, the active layer thickness, and the CO_2 efflux. However, all the patterns of spatial distribution of these indicators were identical. The minimum active layer thickness was at the middle part of the peatland, and the maximum was in the center and on the edge. The minimum soil temperatures were observed in the middle part of palsa, in areas with shallow permafrost. In the same part, the minimum values of CO_2 efflux from the soil surface and CO_2 concentrations in the suprapermafrost layer were also noted. Directly near the edge of the palsa, high values of dissolved organic carbon (DOC) (up to 90 mg/l) and CO_2 concentration (headspace equilibration method, up to 17000 ppm) in bog water were recorded. With increasing distance from the palsa CO_2 and DOC concentration decreased.

We assume that such variations in CO_2 flux and DOC concentrations are due to its lateral transport in the soil, especially in the suprapermafrost layer. Thus, the peatland edge is a hot spot of carbon exchange between soil, natural waters and the atmosphere. And the redistribution of carbon flux depends largely on the topography of the permafrost table.

This research was supported by the Russian Foundation for Basic Research (Grant 18-04-00952).

SESSION 6: PERMAFROST MICROBIOLOGY AND BIOGEOCHEMICAL PROCESSES

Subglacial South Pole Martian Lake and Hypersaline Canadian Arctic Lakes vs. Subglacial Antarctic Lake Vostok – Potential for Life

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The objective was to search for microbial life in the subglacial freshwater Antarctic Lake Vostok by analyzing the uppermost water layer entered the borehole following successful lake unsealing at the depth 3769 m from the surface. The samples included the drillbit frozen and re-cored borehole-frozen water ice. The study aimed to explore the Earth's subglacial Antarctic lake and use the results to prospect the life potential in recently discovered subglacial very likely hypersaline South Pole ice cap Martian lake (liquid water reservoir) as well as similar subglacial hypersaline lakes (reservoirs) in Canadian Arctic.

The Lake Vostok is a giant (270 x 70 km, 15800 km^2 area), deep (up to 1.3 km) freshwater liquid body buried in a graben beneath 4-km thick East Antarctic Ice Sheet with the temperature near ice melting point (around -2.5°C) under 400 bar pressure. It is extremely oligotrophic and poor in major chemical ions contents (comparable with surface snow), under the high dissolved oxygen tension (in the range of 320 – 1300 mg/L), with no light and sealed from the surface biota about 15 Ma ago.

The water frozen samples studied s howed very dilute cell concentrations - from 167 to 38 cells per ml. The 16S rRNA gene sequencing came up with total 53 bacterial phylotypes. Of them, only three phylotypes passed all contamination criteria. Two phylotypes were reported before - hitherto-unknown and phylogenetically unclassified phylotype w123-10 likely belonging to Parcubacteria Candidatus Adlerbacteria and 3429v3-4 showing below-genus level (93.5%) similarity with Herminiimonas glaciei of Oxalobacteraceae (Beta-Proteobacteria) – water-inhabited ultramicrobacterium isolated from a deep Greenland ice core. The new third finding (the phylotype 3698v46-27) proved to be conspecific with several species of Marinilactobacillus of Carnobacteriaceae (Firmicutes). All three bacterial phylotypes may represent ingenious microbial communities in the subglacial Lake Vostok.

Two newly discovered (RES) subglacial hypersaline lakes (5 and 8.3 km^2 areas) in the Canadian Arctic are settled in bedrock throughs beneath 560 and 740 m ice cap with modeled temperature below -10.5°C and isolated by a glacier for at least 120 Ky ago. The biology is not yet studied (lakes are not unsealed), but the life potential is rather high (while dissimilar to the Lake Vostok). Their estimated salinity (140-160 psu) is in a range of that observed for brine-rich water body beneath Taylor Glacier (−7.8°C, 125 psu) and the ice-covered Lake Vida (−13°C, 200 psu) in Antarctica, both inhabited by active unique microbial communities.

The just discovered (RES) 20 km-wide subglacial lake beneath the South Pole ice cap on Mars should be ultra-hypersaline because it is buried beneath 1.5 km water ice cap with modeled temperature -68°C. It is well below known low-temperature limits supporting terrestrial microbial cell propagation and metabolism as well (-18°C and -33°C, respectively). Such conditions may indicate zero-level life potential for this lake from the Earth-bound point of view, but its exploration may give us surprises.

In general, all three subglacial lakes (complexes) – two Earth-bound and one Martian, may host unique life forms never met before but their exploration (unsealing) is challenging as it happened with the Lake Vostok.

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Microbial Communities in Permafrost Sediments

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The permafrost environments, which occupy 20-25% of the Earth surface and extend to 1 km deep, serve as a reservoir of microbial diversity and biogeochemical activity, which is likely to increase upon permafrost thawing and degradation. To learn more about pristine permafrost microbial communities, permafrost samples were studied using integrated approach consistent of classical microbiological and state-of-art "omics" techniques.

Perennially frozen sediments were collected from two drill holes at the Alazeya River (Site 1), and one drill hole on Cape Chukochy along the East Siberian Sea coast (Site 2). Frozen cores were collected with a slow rotary drill using quality assurance and quality control procedures. A total of 132 samples from Site 1 and 75 samples from Site 2 were aseptically subsampled with sterile knife into sterile Whirl-Pak bags and stored frozen. Two boreholes from Site 1 contained freshwater lake-alluvial permafrost samples with age from 3 thousand to 1.2 million years. Temperature inside drill holes ranged from -5 to -8°C. Methane detected in these samples varied from below detection level to 0.2 mol kg^{-1}, total carbon was in range of 0.3-2%, iciness varied between 15-50%, pH was neutral. Samples from Site 2 represented marine permafrost sediments about ~100-120 K years of age. Temperature was -8°C. Organic carbon ranged from 0.5 to 1.8%, and total carbon from 1.7 to 2.2%. Methane was detected only in 2 samples with concentrations of 0.08 and 0.01 mol kg^{-1}. Concentrations of anions, Cl- and SO42-, were respectively 1.5 and 0.5 mmol 100 g^{-1} in the upper 4 m layer and increased to 15.7 and 2.1 mmol 100 g^{-1} in the deeper layers, iciness was up to 90% in upper layer and decreased to 20% below 6 m, while pH was neutral. The total community genomic DNA (gDNA) was extracted from 4 g of permafrost using the PowerSoil® DNA Extraction Kit (MO BIO Laboratories) and concentrated using Genomic DNA Clean & Concentrator® Kit (Zymo Research). The gDNA isolated from these samples was in range of 0.3-0.5 µg g^{-1} soil for Site 1 and 0.9-3.5 µg g^{-1} soil for Site 2. The gDNA sequencing libraries prepared using Nextera XT reagents (Illumina) were sequenced on an Illumina MiSeq. Metagenomes obtained for samples collected from different depth were annotated using the MG-RAST.

The total cell counts detected using staining with DAPI were in the range of 1.6 x 105 to 1.7 x 106 cells g^{-1} of sediment. Cultivable cell counts were in range from 1.1 x 102 to 1.0 x 104 cfu g^{-1} of sediment. The analyses of Site 1 permafrost samples showed that bacteria grown on nutrient media belonged to the genera Arthrobacter, Micrococcus Aeromicrobium, Ancylobacter, Brevundimonas and Pedobacter. Two Yedoma permafrost samples were used for single cell sorting and following genome sequencing with identification of Bacillus bataviensis, B. alcalphilus, Caldilineales aerophila, Ethanoligenes harbinense and Candidatus poribacteria. The metagenome-assembled genomes were identified as Actinobacteria, Bacillus, Atribacteria, Bacteroidetes, Micrococcaceae and methanogenic Archaea. Microbial communities from Site 2 samples dominated by Actinobacteria in upper layers and their abundance decreased with depth. On the contrary abundance of the anaerobic, spore-forming, sulfate, sulfite, and metal-reducing Firmicutes increased with depth from 6.8 to 36.3%. The highest abundance of Archaea with dominance of methanogenic Methanosarcinales, Methanomicrobiales, and methylotrophic Thermaplasmata was detected in samples with methane. Other sequences were affiliated with halophilic, sulfate or sulfur reducing Archaea. Among Deltaproteobacteria dominance of sulfate and sulfite reducing bacteria was detected, other deltaproteobacteria were related to halophilic and marine myxobacteria.

Analyses of the lake-alluvial and marine permafrost samples showed evident decrease of DNA yield and increase of DNA damage in older samples for both sites. Uncultured bacteria identified in both sites had closest cultivable relatives that were halotolerant, nitrate reducing, grew well at 15% NaCl, and were isolates from Arctic soils or marine sediments.

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Role of the Transient Layer in the Methane Emissions on the Dominant Landscapes of Typical Tundra under Climate Warming

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The Arctic is the one of the largest natural sources of methane (CH_4) emissions. In these high-latitudinal regions, permafrost is almost universally occurs and serves as a natural waterproof layer. This causes a high degree of swamping and ensures the existence of anaerobic conditions within the seasonal thawing layer. In these conditions, methanogenic microorganisms are actively reproducing.

It was established, that in addition to entering significant amounts into the atmosphere, methane could persist in the frozen soil horizons throughout the winter. In horizons that thaw seldomly for many years, more quantity of the methane accumulating for a longer time. In this regard, particular interest is the quantifying the methane content in the transient layer of cryolithozone, that is the layer that thaws periodically only in some particularly warm years. The content of methane in frozen soils depends on the composition (particle size distribution) of the soil and the moisture content (ice content). In this regard, we conducted studies on determine the methane content in the active layer and the transient layer of permafrost in dominant landscapes of the Marre-Sale geocryological station (western coast of the Yamal peninsula) located in typical tundra.

Sampling in the dominant landscapes of Marre-Sale was made in 2016, 2017 and 2018. Degassing of samples was performed using the "head space" method. All samples have doubles. The methane content in the gas phase was determined at the Institute of Physicochemical and Biological Problems in Soil Science (Pushchino town) on a KHPM.4 gas chromatograph (Russia) with flame ionization detector (FID) and in the laboratory of the "VNIIIOkeangeologiya" (St. Petersburg) on a gas chromatograph Shimadzu GC-2014 (Japan) with FID. A total of 189 samples were selected. Concurrently with, samples to study the particle size distribution, moisture content, density, and organic carbon content were taken.

Analysis of the data obtained presented the methane content in the studied landscapes of typical tundra varies within very wide limits. In the seasonally thawed layer, the methane content varies from 0 to 12546 ppmV (6.9 ml/kg), 1372 ppmV (0.8 ml/kg) on average. Within the transient layer the methane content varies from 25 ppmV (0.01 ml/kg) to 19933 ppmV (8.9 ml/kg), 4191 ppmV (2.2 ml/kg) on average. Practically everywhere, the methane content from the transient layer is increased compared with the overlying and underlying sediments. The increased methane content in the transient layer can be explained by the extrusion of methane during the autumn freezing and the conservation of the displaced methane in the intermediate layer. The climate warming in the Arctic leads to a partial or complete thawing of the transient layer, which is reflected in an increase in the annual budget for the methane emission into the atmosphere.

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Microorganisms from permafrost ecosystems of marine origin

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Permafrost is one of the most vulnerable parts of our planet. Interest in the study of permafrost deposits and preserved into them paleobiota is largely due to the increase in the permafrost temperature, which was recorded as a result of long-term monitoring. One of the main factors causing warming is an increase in the concentration of such carbon-containing greenhouse gases like carbon dioxide and methane in the atmosphere. Since in the sediments of marine and lacustrine origin geochemical processes associated with the transformation of biogenic elements take place, ancient permafrost deposits of marine and lake genesis are a promising object for studying the biota response to permafrost degradation.

In the mid-80s - early 90s, a team of soil cryology lab under the leadership of D.A. Gilichinsky established the presence in the permafrost of viable aerobic microorganisms, as well as products of their metabolism. In 1998 was shown that sediments in of marine origin contain anaerobic microorganisms carrying out denitrification, iron- and sulfate reduction, and methanogenesis was detected. Later, a few new species of methanogenic archaea were isolated from methane-containing deposits: Methanobacterium arcticum and M. veterum, etc.

It was concluded that the presence of biogenic methane in permafrost is an important indicator of epicryogenic sediments of lacustrine and marine origin, while in the syncryogenic deposits of Late Pleistocene ice complex methane was not detected or was present in trace concentrations. Later, in 2016, this was confirmed by the results of the comparative metagenomic analysis.

Despite the long-term study of permafrost microorganisms, we have not previously focused on studying the permafrost microbial diversity of marine origin. Cryopegs - overcooled water brines - ecological niches into the permafrost of marine origin are an exception. Several isolates of strict and facultative anaerobic microorganisms from cryopegs represent new species: Psychrobacter cryohalolentis, Clostridium algoriphilum, Desulfovibrio arcticus, 'Desulfovibrio gilichinskyi' K3ST, Celerinatantimonas yamalensis, and others.

Our interest in this study is associated with the aerobic representatives of these communities, which are interesting for biotechnological research capable of synthesizing proteins and enzymes that are active at lower temperatures and high salt concentration. In this study we have shown that 32 bacterial strains isolated from geographically distant cryopegs (Cape Barrow, Alaska; Kolyma Lowland and Yamal Peninsula) with varying degrees of salinity, were able to hydrolyze fatty acids. According to the phylogenetic analysis of the 16S rRNA gene some of isolates producing lipase and esterase possibly represent new species.

Recently, bacterial strain Microbacterium sp. producing a new restriction endonuclease with a new specificity was isolated from sincryogenic marine sediments of Gydan Peninsula ice complex (Russian arctic region). The draft-genome sequence of Microbacterium sp. Gd 4-13 was determined with whole-genome sequencing by using Illumina HiSeq technology.

The results of our research give us a reason to consider permafrost marine sediments and cryopegs as a source of microorganisms with high biotechnological potential and ecological significance.

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Biogeochemical technologies of remediation and diagnosis of contaminated soils of impacted polar ecosystems

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Understanding of the fundamental mechanisms of quantitative parameterization of biogeochemical cycles allows us to identify a number of new areas of development of biogeochemical research, at the junction of fundamental and applied research. A new area of research is engineering biogeochemistry that is aimed to the development of innovative nature-like biogeochemical technologies. These technologies are based on the modeling and management of ecosystem biogeochemical cycles. Applications–mining, biofuel production, biogeochemical standards, risk management and remediation of polluted and disturbed soils and grounds in impacted ecosystems.

Technologies of reclamation of disturbed and contaminated tundra soils in polar areas are of special interest. These technologies are aimed at preserving the biogeochemical structure of natural tundra and polar ecosystems with a closed cycle of biogeochemical circulation of various biofil elements and their deposition on the biogeochemical barrier of most zonal soils, as a rule, in the peat horizon. These peaty horizons, as established in experimental work with natural isotopes of carbon and nitrogen, occur in the range from 50 to more than 400 years and therefore peat, as a natural resource, is technologically non-renewable. Accordingly, we should pay the attention to the given technologies.

Conducting joint research works with "Gazprom VNIIGAZ" LLC and "Gazprom Dobycha Yamburg" LLC was expressed in a number of biogeochemical technologies, protected by patents of the Russian Federation for inventions, in relation to remediation and the diagnosis of polluted and disturbed soils. It is noteworthy that these biogeochemical technologies are adaptive to the climate of the Far North, now characterized by the strengthening of its continental character. It is in such conditions that in vitro and in situ the given nature-like technologies have been tested on the territory of the Taz Peninsula. Furthermore, at present these technologies of reclamation of tundra soils disturbed due to the production and transportation of natural gas are being successfully implemented. The viability of a number of biogeochemical technologies proposed for practice was confirmed by their in vitro and in situ testing on the Bely Island (Kara Sea) during the reclamation of the tundra soils disturbed and buried with coal, as well as the recultivation of pyrogenic and hydrocarbon-contaminated soils, and neutralization of hydrocarbon slimes in other soil and climatic conditions of the country (Moscow and Stavropol regions) for their implementation, if necessary, in the impacted polar ecosystems.

Thus, the development of fundamental and applied research in a new direction–engineering biogeochemistry allowed us to create innovative biogeochemical technologies. These technologies are based on the modeling of biogeochemical structure of ecosystems and, as follows from the above examples, their application is highly effective in the impacted zones of gas and oil industry.

On the basis of the above criteria, the development of biogeochemical technologies was implemented for the management of geoecological risks in the oil and gas complex, including the study of fundamental biogeochemical mechanisms of formation of geoecological risks. At the same time, geoecological risks are understood as the interdependent impact of the oil and gas industry on the environment, as well as the impact of the polluted environment on the functioning of the industry and the health of workers. Taking into account the extremely diverse natural conditions in the prospective and existing regions of the Russian oil and gas industry (Yamal Peninsula, Eastern Siberia, Arctic and North-Eastern seas), it is necessary to take into account the geoecological factors of soil, biogeochemical, cryological, sedimentation, geodynamic and geophysical nature. Ultimately, the development of these biogeochemical studies will allow solving fundamental and applied tasks of risk management, including system analysis, quantitative assessment and management of geoecological risks. The technology of calculation of geoecological risks in the development of gas condensate fields in Polar Regions was also patented.

A number of other patents of the Russian Federation for biogeochemical remediation technologies have been also obtained.

Habitat Selection of Protists Communities in Arctic Cryosol

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There are evidences that resting cysts of soil protists can survive in the permafrost at subzero temperatures for thousands of years. The transition of resting cysts through the permafrost-affected soils to permafrost sediments is considered as the period of pre-adaptation of organisms and formation of communities capable to withstand a prolonged cryptobiosis. These communities represent a natural cryobank of soil biota in the permafrost.

To better understand of ancient viable protists species diversity patterns in the permafrost sediments, we study the contribute of environmental conditions in spatial distribution and variability of protists community in the profile of Arctic tundra soil.

The aims of this study were to (i) evaluate the distribution of protists (ciliates and heterotrophic flagellates) along a depth gradient in tundra soil profile; (ii) differentiate protists habitats within the profile; (iii) determine environmental parameters affecting protist communities in profile of tundra soil.

The study sites were located in the southern and arctic tundra subzone in the region of Kolyma and Yana–Indigirka Lowland. The Cryosol is a zonal soil of polygonal tundra with an active-layer thickness about 30-50 cm. This type of soil is characterized by different processes of cryogenic mass-exchange that redistributes the fragments of the uppermost soil horizons along with microbial inhabitants. Two types of cryogenic mass-exchange processes – slope solifluction and cryoturbation were recognized. A total of 89 samples of organic and organo-mineral material collected from different genetic horizons and cryoturbated layers in the cryosol profiles were analyzed.

The habitats of organisms in the upper organogenic horizons and at the bottom of the profile differ significantly. The organic material is compacted and excessively moistened, the total porosity and oxygen concentration decrease, and the duration of time in the thawed state is reduced to 1–2 months per year.

The taxonomical analysis of cultivable protists isolated from Cryosol revealed 43 species of ciliates and 72 species of heterotrophic flagellates. Species richness significantly varied with depth and habitat type. The highest species richness was determined for the upper organic horizons, including litter, and buried by solifluction organic material. Lower diversity was observed in cryoturbated organic material and mineral horizon in the middle and deep layers of the soil profile. A considerable part of the community (68% of ciliates and 61% of flagellates species richness) maintained its viability in the dormant state in cryoturbated and buried organogenic material.

The species diversity and protists community structure were investigated by using multivariate statistical methods such as the hierarchical cluster analysis and the non-metric multidimensional scaling. The soil properties (C, N, C/N, pH, water content, depth, ground temperatures, porosity) were included in analysis of the data set. A non-metric multidimensional scaling was performed to explore the environmental relationships and species composition in the protists data set. Advanced methods of data analysis based on multivariate logistic regression were applied to build a model allowing to predict species occurences depending on environmental conditions.

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Quantitative indicators of prokaryotes and fungi in the tundra soil of peninsula Ribachiy and in Vorkuta

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The biomass structure, mycelium's length, numbers of prokaryotes and fungi, rDNA genes of prokaryotes and fungi in the tundra soil of Peninsula Ribachiy and in Vorkuta were evaluated. The biomass of microorganisms is <0.1 mg/g of soil. Dominants in the microbial biomass of the studied soils are fungi, the mass of which is 2 orders of magnitude higher than prokaryotic.

The minimum mass of fungi (about 0.1 mg/g of soil), the proportion (10–18%) and length (4–7 m/g of soil) of mycelium are noted in cryogenic heaving soils without vegetation and under cinders with a low content of organic matter, and the maximum biomass of mycobiota (about 0.7 mg/g of soil), the proportion (65-80%) and length (400-500 m/g of soil) of mycelium were found in peaty soil horizons and moss tows under shading. The number of fungal spores averaged up to 7 × 105 cells/g of soil, and their diameter usually did not exceed 3 microns.

The minimum biomass of prokaryotes (about 4 × 10-4 mg/g of soil) is noted in samples of anthropogenically transformed soils with the lowest carbon dioxide emission, and the maximum (about 3 × 10-3 mg/g of soil) in soils with peaty horizons.

The length of the actinomycete mycelium in the samples varied from 0 (in postagrolandscapes) to 120 m/g of soil (in the moss-hummocky tundra). The number of prokaryotic cells ranged from about 107 (in soils of cryogenic heats and in postagrolandscapes) to 107 cells/g of soil (in soils under the willows). The highest number of archaea and bacteria is characterized by a sample under the burning area since 1994, 6.6*1010 and 2.6*1011 copies/gr soils, respectively, and its smallest number at the point with the maximum flow of CO_2 from the anthropogenically disturbed soils: archaea 1,2*109 copies/gr soil, bacteria 9.8*109 copies/gr soil.

The maximum number of micromycetes is observed in samples of topsoil of birch-crimped wood, and is 1.2*1010 copies/gr soil. The minimum number of micromycetes is typical for samples of cryogenic crack 1.7*108 copies/gr soil.

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Acanthamoeba from permafrost: phylogenetic position and persistence to modern giant viruses

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We isolated six viable strains of amoebas of the genus Acanthamoeba from permafrost sediments of Kolyma Lowland, Bykovski Peninsula, and Gydan Peninsula aged from 10 to 30 thousand years. This is the third published finding of a viable protist in the permafrost layers of Pleistocene origin. All strains were successfully cloned and axenised.

The phylogeny of the nuclear 18S SSU rRNA gene showed that all isolated strains belong to the most widespread Acanthamoeba group (genotype) T4. Sub-genotype clusters mentioned previously by other researchers were obtained with high confidence. Three of the strains from permafrost had similar 18S sequences and always grouped together inside sub-genotype T4B. Three others appeared more distant and fell into different clusters inside sub-genotype T4A.

To further investigate the diversity of the isolated strains, we performed the detailed morphometrics of cysts and trophozoites and measured the rate of growth of the cultures at different temperatures. These data, taken together, corresponded to the 18S phylogeny, with trophozoite measurements (usually neglected in Acanthamoeba studies) reflecting genetic structure the best. The measurements of cysts obtained on agar plates (most common settings used in the morphologically-based system of the genus) did not correlate with genetic distances. Also, we found that all but one our strains grew slowly and accumulated multi-nucleate cells at 30ºC, this being the common temperature at which "canonical" strains of Acanthamoeba are cultivated. The strain, which grew well at this temperature, SCL-14-12, also possessed the most distant 18S sequence and measured characters, as well as the distinctly different appearance of trophozoites.

It is well known that one-gene phylogenies are often biased. We thus sequenced two mitochondrial genes in our strains, 16S SSU rRNA and Cox1, and inferred their phylogenies based on the sequences available in GenBank. Surprisingly, both revealed the complete identity of all strains except SCL-14-12. At the same time, the obtained phylogenies supported the presence of infra-genotype clusters and allowed to identify their contents. Sub-genotypes T4A and T4B, as well as T4C and T4F, while being significantly different in the 18S gene sequence, were blended together in both mitochondrial genes, in spite of the faster evolution of the later. Supposedly, these sequence types represent the alleles of the 18S gene that partially coexist (or coexisted previously) in cells possessing the same mitochondrial genomes (acanthamoebas have several tens of 18S copies per cell). In spite of this, several clusters with absolute support were always present inside T4A/B clade, and SCL-14-12 and other strains always got into different ones (unfortunately, we cannot compare those clusters directly, because only a few strains coincide in the sets for both mitochondrial genes). Taking into account stable morphometric and physiological differences from other permafrost strains that strain SCL-14-12 demonstrated, these clusters might well represent species. The investigation of more strains from different clusters, involving morphometrics of trophozoites and tests of culture growth rate in different settings, is needed to clarify this.

Soon after the isolation of strain SCL-am8, giant virus-like particles have been observed in the vacuoles of its trophozoites on TEM pictures. We tried to isolate this virus but in vain. Probably, it was lost during subsequent rounds of subculturing. Later, two new giant viruses, Pithovirus sibiricum and Pandoravirus sibiricum, were isolated from the samples of the same sediment layer from which SCL-am8 originates. We tried to infect this strain with two other Acanthamoeba viruses, Mimivirus sp. and Megavirus chilensis, and compare the dynamics of infection with a laboratory strain ATCC 30010, belonging to another T4 sub-genotype, T4Neff. Surprisingly, modern viruses had almost no effect on SCL-am8. Further testing is needed to figure out is such persistence resulted from the evolution that modern acanthamoebas and their viruses have undergone or reflected the genetic heterogeneity in the genus Acanthamoeba.

This study was conducted in the framework of the Governmental Program AAAA-A18-118013190181-6 and supported by Russian Foundation for Basic Research (RFBR) grant 18-04-00824 (strain isolation and culture establishment), RFBR-CNRS grant 17-54-150003 (work on acanthamoeba strains), and CNRS grant 1484 (virus infection experiment).

Characteristics of microorganisms isolated from different biotopes of the Vechernij region in Tala Hills oasis (East Antarctica)

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The Vechernij region (S67°39', E46°10') of the Tala Hills oasis is located in the western part of Enderby Land. Its area is 6,7 km^2, stretched sub-latitude by 6,8 km, width up to 1,9 km, located 4 km east of the Molodezhniy region, where the Molodezhnaya station is located. The main part of the territory is the low mountains of Vecherny Mountain, composed of Precambrian gneisses, enderbites, crystalline schists, and granite-intrusions.

A collection of microorganisms has been created, containing more than 300 cultures isolated from various ecosystems of the coastal part of the Vecherniy region−snow cover, water and bottom sediments of freshwater bodies, endolitic and hypolithic soils, soils with a high content of oil products, penguin and seal remains, starfish shells and hedgehogs.

Forty-five bacteria strains were isolated from two samples of "green snow", as one of the richest in cultivated microorganisms. Bacteria were identified by analyzing the nucleotide sequences of the 16S rDNA genes. The isolated bacteria belonged to the genus Arthrobacter, Cryobacterium, Leifsonia, Polaromonas, Pseudomonas, Psychrobacter, Salinibacterium, Rhodococcus. Microorganisms were screened for an ability to produce enzymes, which have a potential to be used in biotechnology. Many of these have been found to have proteolytic, amylolytic, cellulolytic, DNAse and lipolytic activities. In addition, one strain was an overproducer of the extracellular polysaccharide. By using FTIR spectroscopy, we identified that Pseudomonas veronii srtain, when cultivated in minimal medium, are able to synthesize extracellular polysaccharide, which could be easily separated from the cell biomass by centrifugation. Further, attenuated total reflectance (ATR) FTIR spectroscopy was used to obtain biochemical fingerprint of the produced extracellular polysaccharide. The obtained ATR-FTIR spectrum indicates the presence of protein and polysaccharide components, as well as NH4-groups in the separated polysaccharide.

The analysis of metabolites in 33 isolates of bacteria isolated from the water of temporary reservoirs of the coast of Lazurnaya Bay, Cosmonauts Sea was carried out. Representatives of 4 types of bacteria were identified among these bacteria by analyzing the nucleotide sequences of the 16S rDNA genes: Proteobacteria (19 isolates), Actinobacteria (6 isolates), Firmicutes (5 isolates) and only one isolate of the Bacteroidetes class. Five isolates showed active production of carotenoid pigments. They belonged to the species Agrococcus jenensis, Leifsonia rubra, Flavobacterium degerlachei, Arthrobacter agilis and

Arthrobacter alpinus. The primary HPLC analysis of pigment for cell extracts Arthrobacter alpinus and Arthrobacter agilis isolates indicates the presence of carotenoids – probably neurosporen and spiriloxanthin. During the study, infrared spectra were obtained and processed for all studied microorganisms. We have discovered the ability of some members of the genus Pseudomonas to accumulate lipids during growth in a medium, which was determined by the presence of characteristic peaks in the spectrogram.

To study the molecular mechanisms of adaptation to extreme environmental conditions and evaluation biotechnological potential of antarctic microorganisms, it was determined the nucleotide sequence of the genome of one strain of yeast (Glaciozyma antarctica), and 7 strains of bacteria of different taxonomic groups (Pseudomonas guineae, Pseudomonas lundensis, Pseudomonas sp., Leifsonia rubra, Sporosarcina psychrophila, Carnobacterium sp., Porphyrobacter sanguineus). The genomes are analyzed on the basis of the previously studied physiological and biochemical characteristics of these microorganisms. Metagenomic studies of samples from different biotopes (water, snow, soil) are also conducted. Bacteria with high antimicrobial activity against phytopathogenic bacteria and fungi were isolated. Currently, this work is carried out with two isolates of Bacillus mojavensis.

SESSION 7: PUZZLES FROM THE PAST - PALAEOECOLOGY

To a question about the habitat of representatives of mammoth fauna in Late Pleistocene on North-East Russia

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Permafrost is a unique natural cryoconservant, which preserves abundant remains of Pleistocene organisms, e.g. ancient mammal wool. The ancient hairs (collection of the Ice Age Museum) were found in the Allaikha (coll. № F-4168) and Chukochya (coll. № F-2362) river basins in the Northern Yakutia, Russia.

The aim of this study is to analyze the complex of animal and plant remains from the fossil hair. Indeed, different animal and plant remains in the hair form a specific taphocoenosis, specially rich of remains are clumps of hair. The trapped debris were extracted manually, sieved and examined under a stereomicroscope. The material from hair clumps includes plant remains (bit of twigs, small leaf parts, seeds, phytoliths, spore and pollen) and invertebrate and vertebrate remnants (bird feathers, small hair fragments, insects, crustaceans and other arthropods).

Most of the investigated hairs to those of the woolly mammoth (based on their colour, thickness and microscopically structure). But besides them, hairs of ancient bison and woolly rhinoceros were detected. In addition, the bird feathers of several types were found. Most of the insects belonged to the Coleoptera, and some - to Hymenoptera. The mats of hair contained remains (mandibles, resting eggs, ephippia) of the branchiopod crustaceans. Numerous ephippia of Daphniidae of several different morphological types were found.

The plant material consisted mostly of tissues, pollen and phytoliths of Poaceae, which were well preserved, showing distinct cell structure and stomatal complexes. We identified Poa sp., Calamagrostis sp. and Bromus sp. Remains of Carex sp. and Eriophorum sp. (Cyperaceae) were less common, and those of moss (Aulacomnium sp.) and undershrubs (probably willow, blueberry and bearberry) were rare. No tree remains were found.

The samples contained considerable amounts of Scenedesmus sp, a colonial freshwater alga inhabiting still, usually endorheic, lakes, and typical of the flora of northern regions. The absence of diatom algae may be related to the taphonomic peculiarities.

Some parts (small hair mats) retain information from the time when the animal was living, and from the time soon after its death. During subsequent periods of thawing and redeposition, the sample may have been contaminated with organic objects from more recent times. The plant association restored from the phytoliths and plant tissues is characteristic of wetland biotopes, including boggy tundra. However, the accumulation of permafrost-preserved ancient hair from northeastern Russia turned out to be a valuable additional source of palaeoecological data.

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Genesis of Chalky Polygons on the SubUral Plateau

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Specific landscape complexes occur locally in steppe and semi-desert part of East European Plain. They occur locally within the Ural Plateau, in the areas of shallow chalk layers of Maastrichtian ageand represent the micro-relief up to 50 cm height, which is formed by chalky material coming to the surface, and hasdifferent degree of turfness. The microrelief has a regular linear distribution and forms a polygonal network. Its local name is"chalk polygons". The main feature of the chalk polygons is the annual spring extrusion of soft liquid chalk eluvium to the surface, resulting in the formation of white microhights devoid of vegetation, which look similar to the spots-medallions in the tundra. The genesis of the chalky polygons so far has no unambiguous interpretation, their formation is associated with both modern cryogenic processes, and with swelling and intrusions of clays.

The detailed study of soil morphology of the chalky polygons was organized in 2018 in a trench from the tops of two chalky microhights across the microlow in between. The size of the trench was: about 4 meters long and ~ 120 cm deep. The soil layers in the trench revealed their spatial heterogeneity and mosaic structure instead of normal horizonation. We identified a two-layer soil structure with the upper grayish-pale yellow loamy stratum, up to 1.5 m thick, underlied by chalky material of varyous consolidation. A characteristic morphological feature is the presence of chalky intrusions rising at an angle ~ 45o through the loam from the center of the micro-depression to the top of the micro-elevation, where they erupt at the surface in the form of a "cap". A wedge-shaped structure can be traced in the micro-depression to a depth of 120 cm. Based on its morphology and size, we assume that it is a relic permafrost wedge. The soil material has a vortex pattern and is characterized by a schlieren texture throughout the depth.

We believe that the chalky polygons are a kind of relict cryogenic micro-relief formed in the late Pleistocene cryoarid climate characterized by permafrost, frost cracking of soils and development of polygonal ice wedges. The formation of the polygonal internal structures was facilitated by a two-layer structure of the strata, light textured upper loamy layer with a small thickness about 1-1.5 m and dense lower one (chalky eluvium); by distribution of the active layer to the upper part of the chalk eluvium; and by specific physical, mechanical and chemical properties of chalk rocks and chalk eluvium.

We assume that the system of blocks (polygons) was formed in the Late Pleistocene due to permafrost processes, and cracks filled with ice veins. As a result of the penetration of ice veins into the permafrost, the seasonally thawed layer disintegrated into a series of closed systems. In the latter, in the process of growing of ice veins, great stresses were created that squeezed up the thixotropic chalky material and resulted in chalky intrusions across the overlying loam.

After the polygonal vein ice had melted, once the entire frozen massif disintegrated into multiangular blocky remnants separated by narrow hollow-shaped depressions. Over time, the micro-relief acquired the appearance of gentle, flat-shaped mounds overgrown with vegetation. However, the areas of the chalky polygons originated in Late Pleistocene locally undergo at present time the modern movement and effusion into the surface the liquid chalky material. These processes occur under the conditions of additional ground moisture, contributing to the transition of the chalky subsurface material to the thixotropic state and their further intrusion into the top layer under the pressure of upper dry layer.

Late Pleistocene paleosols in the context of the Quaternary landscape evolution of Northwestern Siberia

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Recent development of non-glacial scenario for the Quaternary landscape evolution of North-Western Siberia (Sheinkman 2016, 2017) stimulated search for the paleopedological archives in this region. During the 2013-2018 field surveys we identified and studied 3 major Late Pleistocene pedostratigraphic levels in the sedimentary sequences of the high terraces of the rivers, which run to the north and south from the Siberian Uval (a not high upland at the right-hand bank of the Middle Ob' River).

The lowest level identified in the Middle Ob' terrace sections Kiryas and Belaya Gora yielded U/Th dates 100-120 kyr BP and thus is attributed to the MIS5 – Kazantsevo thermochrone. It is represented by a pedocomplex in which the lower paleosol unit has signs of clay illuviation (indicative of taiga pedogenesis) whereas the upper one consists of the peat and gleyic horizons. MIS3 paleosols (with C^{14} dates from the soil organic materials in the range 25-35 ka BP) lie above the MIS5 level being separated by the alluvial sediments containing dropstones. These paleosols show the features of redoximorphic and cryogenic processes and are indicative of pedogenesis under tundra or tundra-steppe ecosystems.

The paleosol level corresponding to the Late Glacial – end of MIS2 (C^{14} dates 10-12 ka BP) was identified in the uppermost parts of the high terrace sections of the basins of the rivers Taz and Nadym. This strongly gleyed paleosol is associated with a cryogenic horizon and partly is presented by pedocediments filling large ice wedge casts. We suppose that it is associated with the warming events at the end of the last cryochrone. Paleoenvironmental interpretation of the paleosols agrees with the palinological and paleontological records.

Palaeocryogenic conditions markers of the Sartan cryochron time on Tobol-Ishim watershed (SW Western Siberia)

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Sediments and relief forms of Tobol-Ishim watershed contain different traces of periglacial conditions during Middle and particularly Late Pleistocene and Late glacial time.

The main palaeocryogenic markers of such events are the following: covering loess-type deposits and paragenetically associated special crest relief with deflationary hollows and the dune-ridge land forms, block-polygon microrelief and attended by it microcomplexed in soils and vegetable cover, cryogenic textures, deformation of sediments and buried soils, ground veins on the border of covering loess-type sediments and bedrocks and also paleontological and palynological data.

The covering loess-type rocks are the main product of the Sartan time periglacial period. They cloak-like overlap relief forms and rocks of different composition, origin and age except the complex of low terraces. They have small thickness up to 2-4 m and sharp lower boundary, often split with ground veins.

The block-polygon microrelief is mapped by space images and represented by gently sloping (up to 0.2-0.3 m) increase in relief and network of flat shallow gullies complicated by depressions often occupied by lakes and swamps. Such a big flat-bottom depressions are morphologically similar to Central Yakut alases. There were found as single pseudomorphes along the ground and ice-ground veins and fragments of polygonal networks during the field works.

The cryogenic origin of such a palaeomarkers in most cases is verified by the following: 1) presence of cryogenic textures at the base of the cuts of the covering deposits and sediments of the crest relief, 2) the predominance of aeolian and cryogenic processing on the surface of quartz sand grains (up to 96%), 3) values of cryogenic contrast ratio (introduced by V.N.Konishchev) in lower (up to 1.99) and upper (up to 1.35) parts of ground veins, 4) low values of Chemical index of alteration (CIA=51-60) and Chemical index of weathering (CIW=55-66), increased values (> 1) the Index of Compositional Variation (ICV=1.09-1.36), 5) an evidence of sediments weak transformation in cold arid climate, 6) Relative Sr/Ba = 0,23-0,47 [Retallac,2001,2003; Syso, 2007] reconstructed cold but relatively humid climate.

Climate variability during the Sartan cryochron time appears in 2-3 levels of cryogenesis. There are fixed three layers with minor pseudomorph in Lipovka section, in sediments with lay over the data ^{14}C 21400±290 (ЛУ-7259).

Acknowledgments

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Quaternary Deposits of the Gydan Peninsula Coast of Western Siberia and their Cryogenic Structure

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Permafrost is the most sensitive part of environment under current climate change. To understand the processes involved in the permafrost degradation it is necessary to characterize its evolution. The data on spread, morphology and isotopic composition of the ground ice are the basis of paleoenvironmental reconstruction in the Arctic region.

The fieldwork was conducted between 2008-2010 by MSU, the Earth Cryosphere Institute, and the All-Russia Scientific Research Institute for Geology and Mineral Resources of the World Ocean (VNIIOkeangeologia). The description of the geological and geocryological structure of two outcrops near Matyuisale factory (Gydan Bay) and Dorofeevskiy settlement (Yenisey gulf) was made. These results are partially published. Isotopic composition of syngenetic ice wedges was determined by Isotope Laboratory of Alfred Wegener Institute for Polar and Marine Research, Research Unit Potsdam. The particle size distribution was analyzed in Lithology and Mineralogy Laboratory (VNIIOkeangeologia). Radiocarbon datings of the peat received in Geomorphology and Palaeogeography Laboratory of Polar Regions and the World Ocean (KÖPPEN-Lab, Institute of Earth Sciences, St.Petersburg State University) survey confirmed the author's conclusions. The new data on isotopic and chemical composition of ground ice, texture and age of deposits were processed and paleoenvironmental reconstruction was made.

Quaternary deposits were formed by the sequence of transgressions and regressions. The features of cryogenic structure help to specify paleoenvironmental reconstruction of the Late Pleistocene and the Holocene. The last regression (MIS-2) was accompanied by freezing, dry climate and generation of syngenetic PWI (polygonal wedge ice) on the land and drained shelf area. During the climatic optimum of the Holocene degradation of the Late Pleistocene ice wedges occurred at the Kara Sea coast and caused erosion and slope processes. After thawing of the Pleistocene PWI ice-ground-wedge casts were formed. Subsequent cooling in the Late Holocene caused freezing and formation of new generation of PWI. The Holocene ice wedges provide a smaller square lattice than the Pleistocene ice and occasionally they were infiltrated into ice-ground-wedge casts. According to the data by Oblogov et al. (2012) the Pleistocene PWI remains in the areas remote from the sea coast of Gydan Bay and Yenisey gulf. This differentiation is caused by hard thermal abrasion and heating effect of the Kara Sea. Late winter ice melting in Gydan bay blocks thermal abrasion and lowers temperature. That creates conditions for relict ice conservation in the steeps.

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Aeolian accumulation on the surface of peatlands on the north of West Siberia: methodological approaches to the study, the first results

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The area of West Siberia north of Arctic Circle can be described by frequent occurrence of strong and stormy winds. Sands on the surface, which are not fixed with soil and vegetation cover are deflated and transferred to the different distances. Wind-blown sands are not a rare phenomenon in the north of West Siberia. The destruction of soil and vegetation cover can be of natural and anthropogenic origin. The removal of the ground from quarries and the formation of positive artificial landforms is a repeatedly occurring widespread process while constructing on the permafrost. Thus, deflation, aeolian transport and accumulation of deposits should be considered as both natural and anthropogenic processes.

It is well known that in general, larger particles are deposited closer to the source of the deflation, and smaller ones are able to move over a greater distance. However, the intensity of deflation is uneven over time and depends on a number of changing factors. One of the main factors is the protection of the surface from deflation. This depends on the presence or absence of vegetation cover, its projective cover, the composition of deposits on the unprotected surface, the time of liquid precipitation fall, etc.

Studies of aeolian accumulation on the surface of peatlands are necessary to establish the absolute values and the rate of sedimentation of mineral rocks in the peat.

To achieve this goal, the following tasks are being solved: selection of the object of research by complex remote and field methods; development of approaches of sampling points selection spatially and in cross-section, selection of their number and determination of single sample volume; elaboration of methods for laboratory studies of peat samples with the inclusion of mineral particles; determination of mineral particles content in the peat via calculation methods; estimation of the aeolian sediments layer formed at the distance from the source of material supply; determination of aeolian accumulation activity in different time periods corresponding to the stages of peat accumulation; identification of the intensity and distance of aeolian transfer of mineral particles.

In 2018, within the Pur-Taz interfluve, studies of aeolian accumulation, which is a consequence of sand deflation from positive landforms, were started. In the field, grids and sampling points for laboratory analysis were established at one of the study sites.

Road embankment was used as an accumulative positive landform, from which eolian transfer occurs. In the laboratory the amount of mineral rocks in peat samples was determined and the sediment layer depending on the distance from the source of the material was calculated.

The decrease in the layer of aeolian deposits with the distance from the source of deflation occurs quite sharply. The process is described by a degree equation with decent approximation $R^2 = 0.82$ for natural processes.

The study in 2018 was funded by RFBR and the government of Yamal-Nenets AD, grant № 18-45-890013.

ROUNDTABLES

ROUNDTABLE "INITIAL CLIMATIC AND GEOLOGICAL DATA VERIFICATION AND CALIBRATION FOR PERMAFROST THERMAL REGIME SIMULATION"

Moderator: Gleb Gribovskii, Speakers: Gleb Gribovskii and Yuri Ramanouski
(Simmakers Ltd)

Whether it is necessary to check and calibrate initial data for simulation of ground thermal regime in the conditions of cryolithozone? How is the calibration carried out and by means of which parameters?

The perspective of verification and calibration of initial climatic and geological data by means of calculations under natural conditions will be considered during the roundtable discussion. This type of calculations is carried out without thermal influence of the designed engineering constructions including ground fill. Calculation under natural conditions allows revealing divergences between the initial data (on meteorological observation and geotechnical investigation) provided for numerical simulation and its actual values.

The process of computational model creation and verification of its initial data by carrying out the calculation under natural conditions will be shown using Frost 3D software package.

ROUNDTABLE "ACTUAL PROBLEMS OF CRYOPEDOLOGY"

Moderator: Aleksei Lupachev, IPBPSS RAS

1.“The specifics of frost boiling and cryoturbation in terms of soil classification and diagnostics” (George Matyshak, Lomonosov Moscow State University).

Abundant cryogenic and pedogenic processes that take part in formation of the permafrost-affected soils are poorly defined and mentioned in modern Russian and international soil classification systems. The possible reflection of such significant processes and their results in the structure of soil profile will be discussed.

2."Classification and diagnostics of the cryogenic marsh soils" (Svetlana Deneva, IB Komi SC UB RAS).

Arctic coastal areas have again become the point of interest for the soil scientists but the coastal environments and soils in the Russian sector of Arctic are very poor-studied. The systematics and diagnostics of these soils have to be significantly improved.

3.“On the issue of year-round field scientific station organizing in tundra zone” (George Matyshak, Lomonosov Moscow State University).

The complicated and expensive logistics in the Russian Arctic determine the irregular and sporadic fieldwork conducted by the small groups of scientists and do not allow ones to receive actual and precise data using the state-of-the-art methods and instruments. The possibilities of the year-round field scientific station organizing in tundra zone will be discussed.

4.“The experience of running the Samoylov Island scientific research station” (Leonid Tsibizov, Trofimuk Institute of Petroleum Geology and Geophysics SB RAS).

A number of Russian and foreign partners develop a joint Arctic research program at the Samoilov Island research station to organize and perform a multidisciplinary research in geocryology (permafrost research), paleogeography, climatic and paleoclimatic sciences, hydrology and hydrobiology, geomorphology and quaternary geology, soil science, geobotany, microbiology and study of gas emission from permafrost soils, geophysics, zoology and biology.

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- Fate of water and glacial ice in subzero areas
- Permafrost-affected soils

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