Permafrost researchs of Russia 2021

The main results

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Earth Cryosphere Institute, Tyumen Scientific Centre, Siberian Branch, Russian Academy of Science (ECI Tyumen Scientific Centre SB RAS) http://www.ikz.ru/

In May 2021, the Earth Cryosphere Institute commemorates 30th anniversary. Creation of this institute in Tyumen back in 1991 was an event marking an important stage in the development of cryology as a science studying the world of cold:
(http://earthcryosphere.ru//archive/2021_2/eng/Melnikov_EC_2021_2.pdf).

See at the end of this file: The results of the most fundamental and advanced investigations, important results on the programs of the Earth Cryosphere Institute (ECI SB RAS) and of the many others Institutes and organizations specializing on permafrost/cryosphere researches are presented in the journal "Earth's Cryosphere" ("Kriosfera Zemli"). Journal is translated into English since 2014, all the articles are available online for free at the website of the journal: (http://earthcryosphere.ru/ , archive: http://earthcryosphere.ru/arch/). The abstracts of the most interesting papers are submitted for the consideration of readers.

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Melnikov Permafrost Institute, Siberian Branch, Russian Academy of Science (MPI SB RAS, Yakutsk) http://mpi.ysn.ru

Selected Research Results

In 2021, MPI initiated a new long-term project on "The Evolution of Permafrost and Glacial Deposits and the Pleistocene Chronostratigraphy of Northeast Siberia" in collaboration with the Arctic Research Center, Sakha Academy of Sciences (Yakutsk), the Institute of Geography, RAS (Moscow), the Faculty of Geography, Moscow State University (Moscow), the Institute of Earth Crust (Irkutsk) and the Department of Geoscience, Aarhus University (Denmark). The project, with Dr. Alexey Galanin as principal investigator, commenced with four expeditions carried out during the summer season of 2021 in the Yana, Kolyma and Lena basins. The Lena expedition (Fig. 1) focused on Pleistocene periglacial features and Verkhoyansk morainic complexes along the Undulyung River and Point Mavra near Zhigansk, as well as on reference sections at Ust-Buotama and Diring sites near Yakutsk. Samples were collected for radiocarbon, optically stimulated luminescence, and cosmogenic isotope dating.

Fig. 1. Field party riding up the Undulyung River, July 2021.

An expedition to the northern Tien-Shan (Kazakhstan) was conducted in July 2021 by a team of MPI's hydrogeologists led by Nadezhda Pavlova. It included field measurements and sampling in the Ozernaya River basin near the Kirgizia border to characterize stream runoff and water chemistry, as well as the influence of rock-glacier discharge on river systems (Fig. 2).

Fig. 2. Measuring stream discharge, northern Tien-Shan, July 2021.

A new mathematical model for permafrost table dynamics in the subzero temperature field was developed by Sergey Razumov and applied to the Laptev and East Siberian shelves. The rate of permafrost degradation is dependent on the depth to permafrost and is roughly similar to the diffusion rate of sea salts at 3-4‰ concentration in bottom sediments. The degradation rate decreases non-linearly with increasing depth to permafrost. The model predicts that approximately $4 \cdot 10^9$ m^3 of permafrost is lost annually in the Laptev and East Siberian shelves due to salt diffusion. The thaw front is at depths of 40-60 m from the sea bottom in most of the shelf region. Large-scale salt-induced degradation of the relict permafrost began during the postglacial marine transgression and continues today. Considering the scarcity of observational data for the Arctic shelves, the proposed model will be useful in assessing the influence of primary environmental factors on the shelf permafrost systems (Fig. 3).

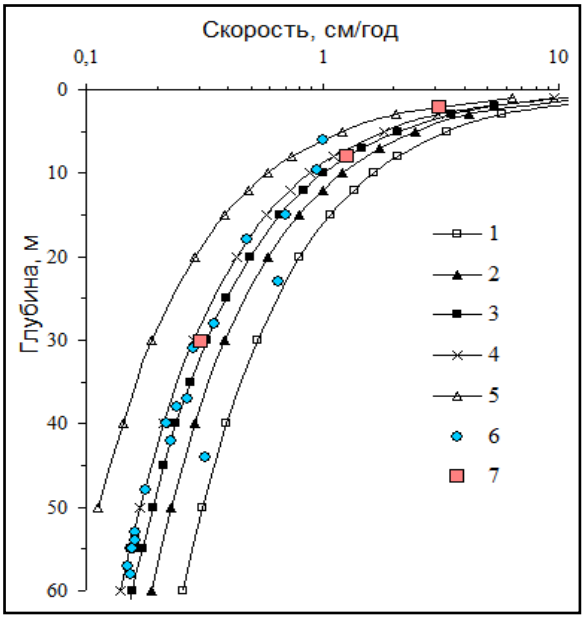

Fig. 3. Model of permafrost table dynamics in the Laptev and East Siberian shelf region in the subzero temperature field. Salt diffusion rates for concentrations at the moving phase-change boundary: 1 – 1‰, 2 – 2‰, 3 – 3‰, 4 – 4‰, 5 –10‰. Permafrost degradation rates: 6 – modelled, 7 – estimated from drilling data from the Laptev shelf [Rachold et al., 2007].

Related publications:

1. Razumov, S. O. (2021). Model of permafrost degradation in the subzero temperature field for the Laptev and East Siberian shelves. Nauka i Mir, 9(97), 71-75 (in Russian).

2. Angelopoulos, M., Overduin, P. P., Jenrich, M., Nitze, I., Günther, F., Strauss, J., Westermann, S., Schirrmeister, L., Kholodov, A. L., Krautblatter, M., Grigoriev, M. N., Grosse, G. (2021). Onshore thermokarst primes subsea permafrost degradation. Geophysical Research Letters, doi: 10.1029/2021GL093881

Based on the Permafrost-Landscape Map of the Republic of Sakha (Yakutia), 1:1,500,000 scale, digital thematic maps of ground temperature, active-layer thickness, ice content and permafrost processes were compiled by Alyona Shestakova with her colleagues at MPI and several Japanese universities (Fig.4). Mapping indicates that ice-rich permafrost (with ice contents above 0.4) is widespread in Yakutia, underlying about 40% of its surface. This makes permafrost environments highly vulnerable to anthropogenic impacts and climatic warming. The maps provide a baseline for evaluation of future changes. They can also be used in planning of infrastructure development and environmental protection.

Shestakova A.A., Fedorov A.N., Torgovkin Y.I., Konstantinov P.Y., Vasyliev N.F., Kalinicheva S.V., Samsonova V.V., Hiyama T., Iijima Y., Park H., Iwahana G. and Gorokhov A.N. (2021). Mapping the main characteristics of permafrost on the basis of a permafrost-landscape map of Yakutia using GIS. Land, 10 (5), 462.

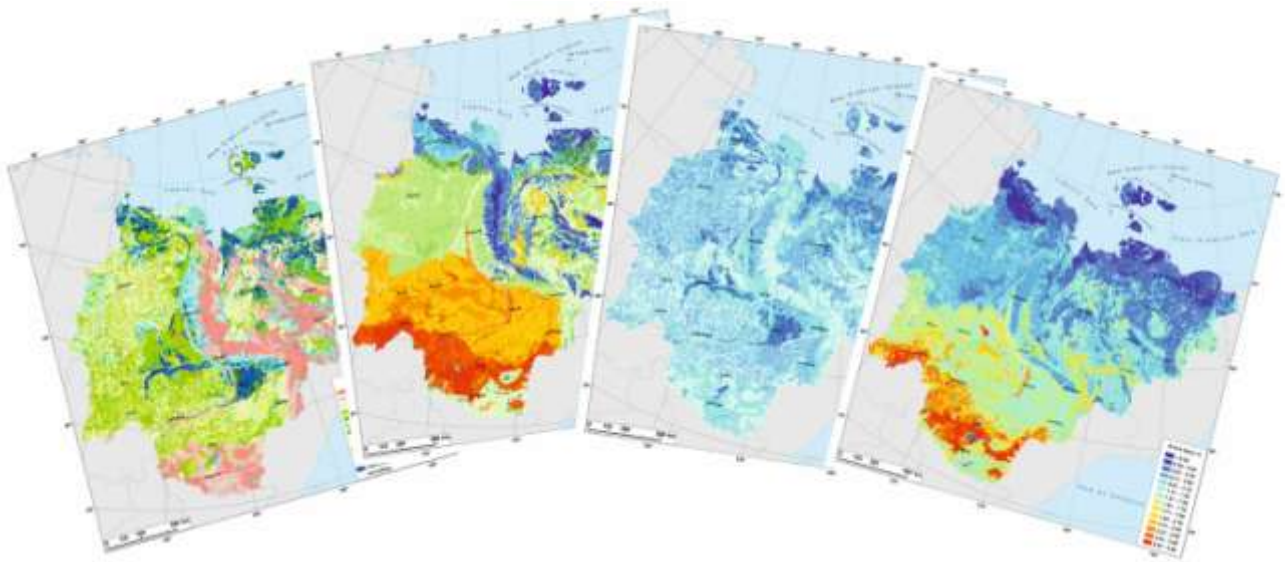

Fig. 4. Thematic maps of mean annual ground temperature, active-layer thickness, ice content and permafrost processes.

The Sixth Forum for Young Permafrost Scientists was held at MPI from June 29 to July 13, 2021, commemorating 100th Birthday of two prominent figures in Russian permafrost science, Evgeny M. Katasonov and Nina P. Anisimova. The Forum program included a four-day conference with in-person and online attendance of about 140 people from Russian and foreign universities, research centers and companies. The conference was followed by a field trip featuring cold deserts of central Yakutia (Fig. 5). The trip participants took part in field studies of the D'Olkuma Formation exposure at Ust-Buotama, the active Saamys-Kumaga Dune Field and the Lena Dune. In the Makhatta and Kysyl-Syr sand fields, ground and surface water sampling and groundwater discharge measurements were conducted. Results will be compared with historical data taken in 1974-1975 to assess water resource changes over the last 50 years.

Fig. 5. Examining cover sand stratigraphy, Makhatta Tukulan dune field, July 2021.

Among the MPI's important publications in 2021 are the monograph titled "Kurums, a Cryospheric Phenomenon" by V.R. Alekseev. Published by Geo, Novosibirsk, the book summarizes the current state of knowledge on the distribution, morphology, structure and dynamics of kurums. These features are shown to have profound effects on the surface energy balance, surface and subsurface runoff, permafrost thermal status and weathering processes, as well as flora and fauna. In the book titled "Ecogeochemistry of Atmospheric Particulate Matter in Yakutsk", V.N. Makarov and N.V. Torgovkin present findings from geochemical research of particulate matter in the urban atmosphere of Yakutsk for summer and winter seasons. The book "Monitoring of Ground Thermal Regime in Central Yakutia" by S.P. Varlamov, Y.B. Skachkov and P.N. Skryabin provides a comprehensive summary and analysis of the results of long-term research on the ground thermal regime in Central Yakutia conducted by the MPI's Laboratory of Permafrost Geothermics since 1981. It presents a regional overview of the natural environment, as well as a description of the landscape classification and distribution. Further, the monograph discusses the current state of geocryological monitoring in the region, including monitoring methods, site establishment procedures and network development. Using data from the long-term observations, thermal response of permafrost landscapes to recent climate warming is estimated. The dynamics of the main thermal parameters of near-surface permafrost are discussed in relation to disturbance type.

Fig.6. New books published in 2021

In November 2021, two MPI researchers successfully defended PhD dissertations: Tatiana Vinokurova, "Numerical modeling of anthropogenic changes to the permafrost thermal regime using inverse problem methods", and Ivan Vakhrin, "Thaw strain of frozen soils and changes in their physical properties in one-dimensional consolidation tests".

Mikhail Grigoriev, Deputy Director of MPI, and Hans-Wolfgang Hubberten, former Director of the Alfred Wegener Institute's Potsdam Unit, received the Officer's Cross of the Order of Merit of the Federal Republic of Germany in recognition of significant contributions to research cooperation between Germany and Russia. Ceremonies of bestowal were held in Yakutsk on October 6, 2021 (Fig. 7) and in Potsdam on November 29, 2021 (Fig. 8). Prof., Dr. Viktor Shepelev was awarded the Polar Star, Order of

the Republic of Sakha (Yakutia), for his research achievements and long-term service as full member of the Sakha (Yakutia) Academy of Sciences and Editor-in-Chief of Nauka i Tekhnika v Yakutii (Science and Technology in Yakutia) Journal (Fig. 9).

Fig. 7. Consul General of the Federal Republic of Germany in Novosibirsk, Bernd Finke (left) presents the Officer's Cross of the Order of Merit to Mikhail Grigoriev, Yakutsk, October 6, 2021.

Fig. 8. Hans-Wolfgang Hubberten receives the Officer's Cross of the Order of Merit in the presence of the Minister of Science, Research and Culture of Brandenburg, Dr. Manja Schüle, Potsdam, November 29, 2021.

Fig. 9. Head of the Republic of Sakha (Yakutia) Aysen Nikolaev (left) and V.V. Shepelev at a ceremony of bestowal, Yakutsk, September 27, 2021.

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Sergeev Institute of Environmental Geoscience RAS (IGE RAS, Moscow)
http://geoenv.ru/index.php/ru/

The Institute of the Earth's Crust SB RAS, together with the Sergeev Institute of Environmental Geoscience RAS, continued the regular geocryological observations in the southern geocryological zone adjacent to the shores of Lake Baikal (Fig. 1). Areas with significant changes in landscapes associated with long-term thawing of permafrost have been identified.

Fig. 1. Observation of coastal processes in the southern geocryological zone (western shore of Baikal Lake, photo by M.G. Mnushkin).

In spite of a variable epidemiological situation in Russia in the 2021 summer the regular geocryological observations following GTN-P program was realized (Fig. 2). Permafrost temperatures decreased, which is explained by the cold and little snow winter in 2020-2021.

Fig. 2. Moscow State University educational geocryological practice in Vorkuta. Study of the ground temperature regime and the activity of geocryological processes (photo by A.P. Bezdelova).

References:

1. Tananaev, N.; Isaev, V.; Sergeev, D.; Kotov, P.; Komarov, O. Hydrological Connectivity in a Permafrost Tundra Landscape near Vorkuta, North-European Arctic Russia // Hydrology 2021, 8, 106. https://doi.org/10.3390/hydrology8030106.

2. A.A. Plotnikov, V.P. Merzlyakov. Increasing the Bearing Capasity and Durability of Building Foundation on Frosen Soils // Soil Mechanics and Foundation Engineer ing. Vol. 58, No 1, 2021, pp. 71 – 77. DOI: 10.1007/s11204-021-09708-0.

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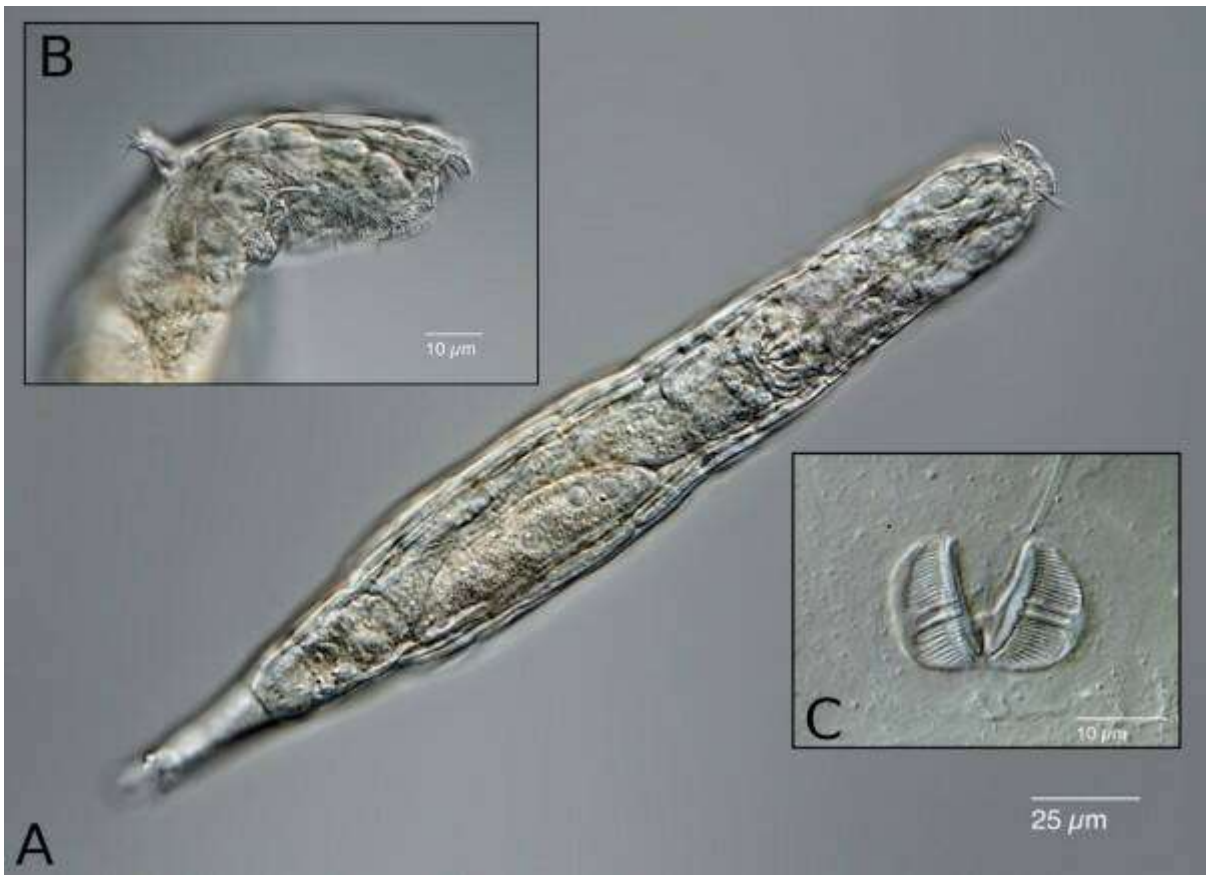
Institute of Physicochemical and Biological Problems in Soil Science, RAS (Soil Cryology Laboratory)(Pushchino, Russia) http://www.issp.psn.ru/

1. The survival of an obligate parthenogenetic bdelloid rotifer, recovered from northeastern Siberian permafrost radiocarbon-dated to ~24,000 years BP was reported. This constitutes the longest reported case of rotifer survival in a frozen state. We confirmed the finding by identifying rotifer actin gene sequences in a metagenome obtained from the same sample. By morphological and molecular markers, the discovered rotifer belongs to the genus *Adineta*, and aligns with a contemporary *Adineta vaga* isolate collected in Belgium. Experiments demonstrated that the ancient rotifer withstands slow cooling and freezing (~1°C min−1) for at least seven days. We also show that a clonal culture can continuously reproduce in the laboratory by parthenogenesis.
-Shmakova, L., Malavin, S., Iakovenko, N., Vishnivetskaya, T., Shain, D., Plewka, M., & Rivkina, E. (2021). A living bdelloid rotifer from 24,000-year-old Arctic permafrost. Current Biology, 31(11), R712-R713.



Strain Ad01 (SCL-15-7) frozen deposits (Shmakova et al. 2021). A – whole animal, B – head side view, C – inner jaw.

2. Metagenomic studies of permafrost biodiversity are continuing. Analysis of the geological structure of the reference sections of ancient permafrost in the Arctic showed the possibility of continuous existence of permafrost here during the last 1-1.4 million years. This, in turn, coincides with the maximum retention time of viable microorganisms in these deposits. Such long-term preservation of viable cells makes it possible to search for answers to both fundamental biological questions, and is also important in the astrobiological aspects.

-Abramov A., Vishnivetskaya T., Rivkina E. Are permafrost microorganisms as old as permafrost? //FEMS Microbiology Ecology. – 2021. – T. 97. – №. 2. – C. fiaa260.
-Sipes, K., Almatari, A., Eddie, A., Williams, D., Spirina, E., Rivkina, E., Liang, R., Onstott, T.C., Vishnivetskaya, T.A. and Lloyd, K.G., 2021. Eight Metagenome-Assembled Genomes Provide Evidence for Microbial Adaptation in 20,000-to 1,000,000-Year-Old Siberian Permafrost. Applied and Environmental Microbiology, 87(19), pp.e00972-21. 10.1128/AEM.00972-21
-Liang, R., Li, Z., Vetter, M.C.L., Vishnivetskaya, T.A., Zanina, O.G., Lloyd, K.G., Pfiffner, S.M., Rivkina, E.M., Wang, W., Wiggins, J. and Miller, J., 2021. Genomic reconstruction of fossil and living microorganisms in ancient Siberian permafrost. Microbiome, 9(1), pp.1-20. 10.1186/s40168-021-01057-2

3. Lake change trend analysis for a 44,500 km^2 region of the Kolyma Lowland using Landsat imagery in conjunction with TanDEM-X digital elevation model and Quaternary Geology map data was reported. Comparison of drained lake basin area with thermokarst lake extents reveal the overall limnicity decrease by 80% during the Holocene. Current climate warming and wetting in the region led to a lake area increase by 0.89% for the 1999–2013 period and an increase by 4.15% for the 1999–2018 period.

-Veremeeva, A., Nitze, I., Günther, F., Grosse, G. and Rivkina, E., 2021. Geomorphological and Climatic Drivers of Thermokarst Lake Area Increase Trend (1999–2018) in the Kolyma Lowland Yedoma Region, North-Eastern Siberia. Remote Sensing, 13(2), p.178. 10.3390/rs13020178

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The studies of 2021 were conducted in a several main directions, traditionally distinguished in the scientific research of the Department of Cryolitology and Glaciology.

Cryolithological research

V.V. Rogov as part of a team of authors summarized and published the results of long-term studies of the existence and activity of microorganisms in frozen strata (Brouchkov et al., 2021). The results of the study of cryolithological and geochemical features of Yedoma (Ice Complex) have been summarized by V.V.Rogov as part of a team of authors (Rogov et al., 2021; Shmelev et al., 2021).

I.D. Streletskaya summarized field data on key sections of the Kara Sea shores and draw conclusions about the features of the formation of highly icy sediments (Streletskaya et al. 2021). Together with an international team of authors, a database and a map of the distribution of the Yedoma (Ice Complex) have been created. patterns of distribution of these deposits. This is the first complete digital circumpolar map of Yedoma and is an important step towards understanding past and present spatial heterogeneity of Ice Complex deposits, which is of paramount importance for assessing vulnerability and risks in the rapidly warming Arctic (Strauss et al., 2021).

I.D. Streletskaya with colleagues established and characterized new facts of relics of permafrost relief and pseudomorphoses on thawed ice wedges on the Russian Plain, in the Lower Volga region and the pre-Urals (Ryabukha et al., 2021). V.V.Rogov carried out cryolithological, granulometric and micromorphological analyzes of mineral matter and made descriptions of traces of cryogenic processes to assess the paleogeographic conditions of their formation. The time of formation of the cryogenic horizon of the Cherny Yar section was determined by means of OSL dating of the enclosing and forming cryogenic deposits. The filling of pseudomorphoses took place ~ 45-40 thousand years ago (Taratunina et al., 2021). For the first time, four stages of the development of permafrost in the lower reaches of the Volga have been identified and described.

Under the leadership of V.I. Grebents, comprehensive studies of the state of the infrastructure of the Russian Arctic were carried out with an assessment of the degree of deformation of objects and the influence of dangerous cryogenic and nival-glacial processes on the stability of buildings and structures (Grebenez et al., in press). The impact of waste disposal on the infrastructure of the Arctic has been analyzed, and a classification has been carried out according to the degree of their impact on permafrost foundations. Particular attention is paid to the impact on permafrost foundations of mechanized redistribution of snow in built-up areas; the formation of powerful dumps warms the permafrost, activates dangerous cryogenic processes. It has been established that in the economically developed territories of the permafrost zone, special natural and technogenic geocryological complexes are formed, within which a special combination of cryogenic processes is traced and different stability of the infrastructure is recorded, even for objects of the same type.

V.I. Grebents, V.A. Tolmanov and F.D. Yurov analyzed the peculiarities of solid waste storage in permafrost conditions (Grebenets et al., 2021). The research allowed to define 8 main types of waste storage in the permafrost zone, which were different both in terms of waste accumulation and in terms of their impact on the environment in general and the permafrost in particular. These were: industrial waste storage facilities (slag, sludge and tailing dumps, ash dumps); dumps of rock in sites of mining; household waste accumulators; dumps of wood processing waste in the centers of the timber industry; abandoned territories resulting from a decrease in the population of Northern settlements; storage areas for tanks with residues of fuels and lubricants; tank farms for storing petroleum products in settlements and cities of the North; storage areas for contaminated snow exported from built-up areas. Pollution of waste territories and destruction of many ecosystems as the results of waste storage were caused by use of imperfect technologies for the extraction and processing of raw materials, the "legacy" of past years with disregard to the environmental conditions, the lack of special standards for the storage of garbage and by-product industrial materials, undeveloped methods of waste disposal in harsh climatic conditions.

A.I. Kizyakov within a team from the Faculty of Geography of Lomonosov Moscow State University and Earth Cryosphere Institute SB RAS received new data on thermocirques (thaw slumps) growth rates of on the coast of the Yugorsky Peninsula in 2010-2020 (Leibman et al., 2021). The results were obtained by

processing a series of satellite images. The applied method of reconstructing the digital elevation model used for orthorectification, and block adjustment made it possible to achieve sub-meter accuracy of the thermocirques dymanics. The interannual dynamics of individual thermocirques significantly varies due to influence of a number of climatic factors and the local conditions, first of all, the ratio of ground ice and frozen sediments in the retreating walls.

L.I. Zotova reviewed the available scientific achievements in the field of landscape-indicator studies in the permafrost zone, including the issues of clarifying the permafrost zones boundaries by the landscape-structural method (Zotova, 2021). The landscape indication ambiguity of a number of permafrost characteristics was revealed. The large-scale restrictions on this method using are determined.

A.A. Maslakov and L.I.Zotova with co-authors carried out mapping and classification of cryogenic landscapes according to their susceptibility to climatic changes and potential anthropogenic impact (Maslakov et al, 2021). Landscape map and a map of the landscapes potential vulnerability to the cryogenic processes activation on a scale of 1: 200,000 were created within a test site of the coastal plains of Eastern Chukotka.

The most complete systematization of massive ice beds of Eastern Chukotka region has been completed by A.A. Maslakov. Based on isotopic, cryolithological and geochemical studies of 8 natural outcrops, the approximate age and mechanism of formation of ice beds were determined (Vasil'chuk et al., 2021). A 3D-modeling of the thermal regime of permafrost around the underground food storage in the indigenous village Lorino (Chukotka Autonomous Okrug) and a forecast of the dynamics of permafrost temperature up to 2050 was carried out. It was revealed that climatic changes will not have a critical effect on the state of the underground structure, but the anthropogenic factor can provoke the collapse of the storage facility (Maslakov et al., 2021, in press).

The team of S.A. Sokratov, G.A. Rzhanitsyn, D.M. Frolov, V.E. Gagarin and A.V. Koshurnikov developed a new training course for students of the cryolithology and glaciology department on laboratory study of the mechanical properties of snow, ice and frozen soil. In it, by means of the ASIS system installed in a cold room, students can carry out laboratory studies of the mechanical properties of samples by the method of "uniaxial compression", shear and a ball stamp.

V.I. Grebenets and A.A. Maslakov carried out annual active layer monitoring fieldwork to as part of the CALM (Circumpolar Active Layer Monitoring program) program at sites in the Talnakh region (in the north of Krasnoyarsk Territory) and in Eastern Chukotka.

Glaciological research

Under the leadership of V.V. Popovnin, in 2021, a set of field work was carried out in the basin of the representative mountain glaciers in the Central Caucasus and Tien Shan. The long-term series of mass-balance observations were continued. Estimated 2020/21 mass balance values for reference glaciers of the Caucasus (Djankuat) and Tien Shan (Karabatkak, Sary-Tor, Bordu) revealed more favourable natural conditions for the glaciers than their long-term means, though they did not abolish prevalent degrading trends of recent decades. Glacier area recession rate by the end of XXIst century, answering various climatic scenarios, was derived in the course of mathematical simulation, taking important debris cover expansion factor into account. All data of the indicators of mass-balance of the Caucasian and Tien Shan glaciers were included in the annual national report for the World Glacier Monitoring Service (https://wgms.ch/latest-glacier-mass-balance-data). Radio echo sounding was applied for mapping thickness of the flat-topped Grigoryev Glacier in the Tien Shan.

N.A. Volodicheva and A.D. Oleinikov continued snow-avalanche studies to detect changes in snowfall and avalanche activity (November-April) at the Elbrus educational and scientific base of Moscow State University. As instrumental observations have shown, the last decade of 2011-2020. turned out to be the warmest in the studied region, where 8 abnormally warm winters were recorded, 1 - abnormally cold, 1 - within the climatic norm. Winter of 2020/21 did not break the general warming trend. The temperature of the cold period was close to the climatic norm. The amount of precipitation has significantly exceeded the norm, approaching the border of the abnormally humid winter. The distribution of precipitation was characterised by asymmetry - 70% fell in the second half of the winter. In terms of snow cover, winter of 2020/21 was classified as unevenly snowy with a pronounced peak of snow accumulation also in the second half of the season, and of average avalanche danger. The avalanches stopped within the mineral fan loops and did not pose a threat to the infrastructure of the Baksan Valley.

S.A. Sokratov collected data on the height of snow cover in various snow regions of Russian Federation in order to assess the correspondence of the distributions of the maximum height for the year to a certain type of statistical distribution (Sokratov et al. report, 2021). In more than 50% of the analyzed station data

series, correspondence or closeness to the normal distribution was found. In other cases, the series were "distorted" relative to the normal, which can be explained by the influence of temperature conditions on the accumulation of snow cover. The development of an algorithm for statistical modeling of volumes and ranges of avalanche ejection, depending on the parameters of snow accumulation and geometry of avalanches, has been continued.

N.V. Kovalenko, D.A. Petrakov with E. Bashkova and N. Kostenkov continued annual glaciological monitoring of the Kolka Glacier. Data from time-lapse cameras with 3 hours intervals for 2020-2021 have been obtained. Since 2002 volume of the Kolka Glacier has increased more than 50 Mln.cub.m. In contradiction with downwasting of the Caucasus glaciers, Kolka continues to increase mass.

D.A. Petrakov continued a study of the causes and consequences of changes in the Bashkara periglacial lakes. The role of the liquid precipitation anomaly in the passage of floods in the Baksan basin at the beginning of September 2017 was revealed. In collaboration with colleagues from the Department of Land Hydrology and the Institute of Water Problems RAS, an assessment was made of the contribution of breakthrough mudflows to the Baksan peak flow rate (Kornilova et al., 2021).

M.A. Vikulina published a paper on the history of research, including glaciological ones, was completed at the Khibiny educational and scientific base of the Geographical Faculty of Moscow State University (Vikulina at al., 2021a). Expeditionary work was carried out to study the dynamics of small forms of glaciation in the Khibiny Mountains. Analysis of satellite images over the past 15 years has shown significant changes in the size of glaciers, but unlike other Arctic regions, the Khibiny glaciers do not degrade and show a stable state (Vikulina et al., 2021b). The long existence of small glaciation in this area confirms the hypothesis of a stable state of such formations, despite climatic changes.

A.S. Turchaninova, S.A. Sokratov and D.I. Korovina for the first time performed a qualitative and quantitative assessment of the effectiveness of avalanche control measures for the territory of the Krasnaya Polyana ski complex, based on mathematical modeling of snow avalanches with different specified conditions of avalanche formation (Korovina et al.., 2021). For the area under consideration, artificially controlled avalanche discharge (mainly carried out by Gazex® systems) is most effective. Snow-holding structures often do not fulfill their functions, while dams and avalanche breakers can be effective only in combination with artificially controlled avalanche discharges. Areas have been identified where artificially controlled avalanches, which have shorter emission ranges in relation to possible natural avalanches, can still be dangerous for the existing infrastructure due to high values of speed and pressure.

M.N. Ivanov continued studies of the modern deglaciation of the Polar Urals. The first in a decade expeditionary studies of the accumulation of snow cover on the IGAN glacier at the spring maximum of snow accumulation have been carried out. The results of these study is close to the average values for the period of mass balance observations on the IGAN glacier (1957-1981). The study of terminal moraines was continued using electrotomography to monitor ice cores and assess the outburst hazard of moraine dammed lakes.

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The journal "Earth's Cryosphere" ("Kriosfera Zemli")

The results of the most fundamental and advanced investigations, important results on the programs of the Earth Cryosphere Institute (ECI SB RAS) and of the many others Institutes and organizations specializing on permafrost/cryosphere researches are presented in the journal "Earth's Cryosphere" ("Kriosfera Zemli"). Journal is translated into English since 2014, all the articles are available online for free at the website of the journal: (http://earthcryosphere.ru/ , archive: http://earthcryosphere.ru/arch/)**. The abstracts of the most interesting papers are submitted for the consideration of readers.**

(№1/2021)

1. LATE QUATERNARY SAND COVERS OF CENTRAL YAKUTIA (EASTERN SIBERIA): STRUCTURE, FACIES COMPOSITION AND PALEO- ENVIRONMENT SIGNIFICANCE

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A comprehensive study of the Peschanaya Gora (Sand Hill) outcrop and other sections of aeolian coversands in Central Yakutia shows that they, together with the loess-ice (Yedoma) covers, are two related granulometric and mineralogical derivatives, formed as a result of aeolian processing of the Quaternary alluvium during the second half of the Late Neopleistocene. Episodes of desertification took place 22.0-14.0, 12.8-11.8, and 0.6-0.1 ka BP. A decrease in aeolian activity and consolidation of dune massifs by soil-vegetation cover occurred in the intervals of 14.0-13.0, 10.0-0.6 ka BP. The largest episode of desertification took place during the last global thermal minimum (MIS-2) and led to a sharp decline in the mammoth biome, the disappearance of the woolly mammoth and rhinoceros in Central Yakutia.

Aeolian formation, D'olkuminskaya Series, cryogenic-aeolian, niveo-aeolian lamination, desertification, Late Pleistocene, Holocene, Bølling, Allerød, Younger Dryas, Eastern Siberia

(№2/2021)

2. LONG-TERM DYNAMICS OF SEA ICE AREA IN THE NORTHERN HEMISPHERE DUE TO CHANGES IN INSOLATION CHARACTERISTICS

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A correlation analysis of long-term dynamics of sea ice area in the Northern hemisphere with high spatial resolution insolation characteristics was performed. For the period from 1901 to 2018, close negative relationships between long-term changes in the sea ice area, winter insolation and insolation contrast were found in 1° x 1° cells. Maps of distribution of closeness of connection of long-term changes in sea ice area with insolation characteristics for average annual, semi-annual and monthly (March, September) values of sea ice area are constructed. It is shown that the relationship of long-term changes in the distribution of sea ice in the Northern hemisphere with insolation contrast is causal and insolation contrast can be a predictor in statistical models of sea ice dynamics. It is determined that the Northern Sea Route is characterized by close connections of sea ice distribution with insolation contrast throughout its entire length. This creates prospects for long-term forecasting of the sea ice area for the Northern Sea Route based on calculations of insolation contrast for the Northern hemisphere.

Sea ice area, seasonal, interannual and multi-year variability, insolation, insolation contrast, correlation analysis

(№2/2021)

3. SURFACE COOLING AFFECTIVITY OF FROZEN GROUND IN CONNECTION WITH MECHANISM OF TEMPERATURE SHIFT FORMATION

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The analysis of affectivity of frozen soils surface cooling methods based on the theoretical understanding of temperature shift formation with seasonal processes in the upper ground layers is provided here. The surface cooling method for the building with aerated underfloor space is suggested on the base of this analysis. This method includes heat-insulation layer on the surface of the ground and free convection cooling system with its horizontal evaporator under insulation layer. Condenser of the cooling system is out of the building contour and it makes evaporator temperature near to winter air temperature. The results of mathematical modelling demonstrate that suggested method makes sure good and rapid decrease of the ground massif temperature as compared to other methods (up to 1 – 2.5°C due to not more 1.5 year instead of 3-5 years as usual). An additional temperature decrease may be exact by short connecting (in time not more than one summer period) of the forced cooling device to the cooling system.

Frozen soils, seasonal thawing layer, ground temperature regime, heat-insulation layer, GET cooling system, forced cooling, relaxation time to project temperature regime

(№2/2021)

4. RECONSTRUCTION OF THE FORMATION HISTORY OF PEAT-MINERAL SWELLING RIDGE IN THE LOWER REACHES OF NADYM RIVER

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The paper presents new data on the cryolithological structure of a swelling ridge typical on the north of Western Siberia, located in the lower reaches of the Nadym river. The data were obtained as a result of drilling two wells - at the top of the ridge and in the inter-ridge lowering, with subsequent core analysis. Grain size distribution, shape and surface structure of sand quartz grains, botanical composition and radiocarbon age of organogenic deposits were determined. The study revealed the presence of a three-layer peaty-sandy-loamy ridge structure. Lower loamy layer with ice volume content ~60% was affected by swelling. Layers of pure ice are identified below this loamy layer. Swelling ridge has predominantly migratory origin with the complementary influence of ice injection and belongs to the peat-mineral type. Stages of accumulation of loamy and sandy deposits are distinguished in the formation of the ridge, bogging occurred at the beginning of the Holocene (10.6-9.8 ka BP), active swelling - in the subboreal stage (5.5-5 ka BP). Currently, there is a decrease of the upper organic horizon and erosional activity. It is suggested to consider peat-mineral and mineral swelling forms (mounds and ridges) as a separate type of cryogenic relief.

Frost mound, frozen ground, permafrost zone, upper quaternary deposits, Nadym region

(№3/2021)

5. METHANE HYDRATE STABILITY ZONE IN THE REGION OF THE SREDNEVILYUISK GAS CONDENSATE FIELD (VILYUI SYNECLISE)

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Authors present the results of determining for the lower boundary location of methane hydrates stability zone from geothermal measurements in 22 wells at the Srednevilyuisk gas condensate field. A graphical method is applied, which consists in comparison the thermograms and a phase diagram that characterizes the equilibrium conditions for formation of gas contained in the upper deposits of the field. At present the upper gas deposits of the field (depths 1035 and 1057 m) are located below the stability zone by only 60-70 m. The approximate estimations for the changes in the location of the lower boundary of the methane hydrate stability zone in the late Pleistocene-Holocene were carried out. It was shown that during cold periods (~130 and 15 thousand years ago) the stability zone could go lower the upper gas deposits of the Srednevilyuisk field by 20-50 meters.

Vilyuiskaya syneclise, Srednevilyuisk gas condensate field, permafrost, methane hydrate stability zone, boundaries of the stability zone in the late Pleistocene-Holocene

(№3/2021)

6. EVALUATION OF THE COMPONENTS OF THE HEAT BALANCE OF ALDEGONDA GLACIER (WESTERN SPITSBERGEN) DURING THE ABLATION PERIOD BASED ON SEASONAL OBSERVATIONS OF THE YEAR 2019

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The article describes the method for calculation of heat balance components in the case of Aldegonda glacier (Western Spitsbergen). Proposed method is based on the physical model with spatially distributed parameters. Input data for modeling are in situ meteorological and actinometrical observations, collected during the ablation season of year 2019, a digital elevation model and remote sensing imagery, needed to derive the reflective properties of the glacier surface. Model output is represented by the spatial distribution of heat flux available for ice melting with a temporal resolution of one day. The mean radiative balance is estimated to be 89 W/m^2, which is roughly one order of magnitude higher than the heat influx from the turbulent processes (11 W/m^2). The obtained results were verified based on data of the glaciological mass balance monitoring. It is shown that the predicted values of the melted ice layer are in good agreement with the measurements on ablation stakes. The model systematically overestimates the magnitude of ice melt, but the glacier-average value remains inside the confidence interval of the observed value. Thus, modelled glacier-wide ablation equals 698 mm w.e./month, while the measured is 610±150 mm w.e./month.

Glacier ablation, glacier heat balance, physical modelling, Svalbard

(№3/2021)

7. NATURAL ENVIRONMENT DYNAMICS AND MORPHOLITHOGENESIS IN SHALLOW WATERS OF THE EAST SIBERIAN ARCTIC

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The processes that determine modern sedimentation with the formation of islands (Yaya, Nanosny, Zatoplyayemyy, Leikina, etc.) in the shallow waters of the Laptev and East Siberian seas are considered. Shallows where formed on the site of the eroded (in the XVII-XX centuries) islands-remnants of the ice complex of the Late Neopleistocene, which confined to positive morphostructures. It is shown that such processes are a decrease of sea ice coverage, an increase in the duration of the ice-free season and the activation of destructive cryogenic processes initiated by the current climate warming. The decrease in the ice coverage led to the predominance of hydrodynamic processes in sedimentation, in contrast to the priority role of sea ice in the 17th-19th centuries. The lack of sedimentary matter in these centuries is replaced by their excess due to the activation of cryogenic processes at the turn of the 20th and 21st centuries. As a result, the thermal abrasive profile of the underwater slope on shallows is transformed into an accumulative one.

Sedimentation occurs against the backdrop of rising sea level due to climate warming. The rise of the islands and banks surface is recorded on satellite images where there are modern positive vertical movements. The formation of islands and banks is accompanied by their syncryogenesis.

Morpholithogenesis, sedimentation, morphostructures, modern climate warming, remote sensing data, shallows

(№4/2021)

8. CRYOLITHOSTRATIGRAPHY AND CRYOFACIAL ANALISYS

V.E. Tumskoy

The article deals with the actual theoretical problem of stratification of Quaternary ice-rich permafrost formations for the purposes of reconstruction of the history of their development, stratigraphy and mapping. The use of cryofacial and cryoformation methods for this has been substantiated. Cryolithostratigraphy presented as a new scientific direction at the junction of cryolithology and climatic stratigraphy. The concepts of "cryofacies", "cryogenic contact", "cryogenic formation" have been defined; some general types of cryogenic structure of cryofacies and cryogenic contacts have been identified. A sequence of cryolithological studies have been proposed, from the primary dissection of permafrost to the solution of cryostratigraphic problems. The relationship between cryolithostratigraphy and paleocryolithostratigraphy has been revealed.
Cryolithostratigraphy, climatostratigraphy, cryofacies, cryostratigraphy, cryogenic contact, cryogenic formation

(№5/2021)

9. MASS BALANCE MODELLING FOR THE SARY-TOR GLACIER (THE AK-SHYIRAK MASSIF, INNER TIEN SHAN)

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As the direct measurements for the mass balance estimation can be applied only for a limited number of glaciers, alternative methods of estimation need to be developed. One of the most promising approaches is physically-based modelling, that is now being applied globally. In this study the mass balance of the Sary-Tor valley glacier was reconstructed for the period of 2003−2016 with the use of the modified version of the A-Melt energy-balance model. A block of snowpack processes was added to the model, including: head conductivity in the snowpack and in the active layer, water filtration in the snowpack and firn, congelation and regelation. The modelling results were verified using: 1) direct measurements on the ablation stakes net; 2) mass balance estimation according to geodetic method. The calibration parameters are compared to their measured values. Contrasting modeled mass-balance components for 2003-2016 and measured in 1985-1989 provided possibility to reveal climatically induced change of the Sary-Tor glacier dynamics.

Mass balance modelling, glaciers, Tien Shan, A-Melt model

(№6/2021)

10. ADAPTATION OF ARCTIC AND SUBARCTIC INFRASTRUCTURE TO THE CHANGES IN TEMPERATURE OF FROZEN SOILS

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The problem of sustainable economic development is acute in the Arctic regions, due to the vulnerability of the Arctic infrastructure to climate change and landscape transformations. The reasons of deformations of buildings and structures in the Russian Arctic are considered. Problems and prospects of permafrost monitoring network development are identified as the basis for development of technical solutions for adaptation of Arctic infrastructure to climatic changes. Analysis of technological solutions of control and ensuring reliability of bearing capacity of bases is presented, preliminary analysis of economic efficiency of protective actions is performed, the cost of which is at least one order of magnitude less than the expected damage to infrastructure by the middle of the century.

Key words: Arctic zone of the Russian Federation, frozen grounds, climate change, adaptation of infrastructure, thermal stabilization