RUSSIAN ACADEMY OF SCIENCES

NATIONAL GEOPHYSICAL COMMITTEE

РОССИЙСКАЯ АКАДЕМИЯ НАУК

НАЦИОНАЛЬНЫЙ ГЕОФИЗИЧЕСКИЙ КОМИТЕТ

NATIONAL REPORT

for the
International Association of Cryospheric Sciences
of the
International Union of Geodesy and Geophysics
2007–2010

НАЦИОНАЛЬНЫЙ ОТЧЕТ

Международной ассоциации криосферных наук
Международного
геодезического и геофизического союза
2007–2010

Москва 2011 Moscow

Presented to the XXV General Assembly
of the
International Union of Geodesy and Geophysics

К XXV Генеральной ассамблее
Международного геодезического и геофизического
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This National Report was prepared by the Section of Cryospheric Sciences of the National Geophysical Committee of Russia for the XXV IUGG General Assembly in Melbourne, Australia, 28 June – 07 July 2011. Some main results for the 2007–2010 period are presented on the following topics: Russian IPY cryo activities, the New journal «Ice and Snow», Glaciers and Ice Sheets, Snow and Avalanches, Permafrost, and Marine Cryosphere.

Contents

Foreword

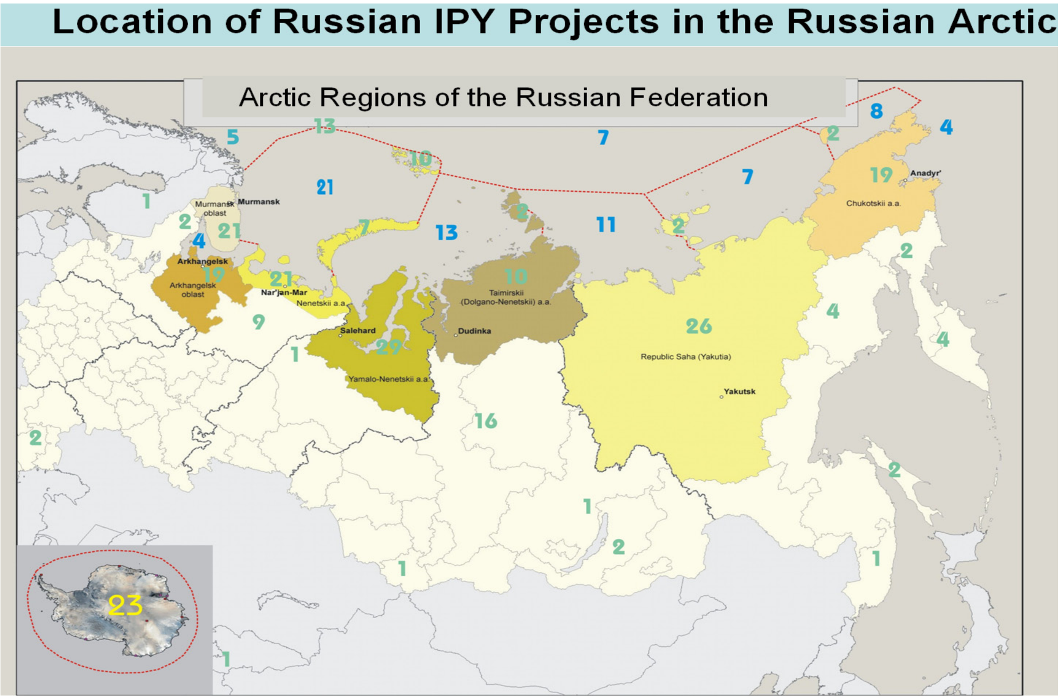
This report containing a review of the selected activities and scientific researches in 2007-2010 in Russia has been compiled for the presentation to the International Association of Cryospheric Sciences at the XXV General Assembly of IUGG.

The preparation of this report has been organized by the Section of Cryospheric Sciences of the National Geophysical Committee of Russia as a collective effort of the team of authors. Only minimal editorial work has been done when putting all these parts together, preserving, thus the diversity in styles and approaches.

The report cannot be considered as comprehensive review of the principal achievements during this period of time in this field of science in Russia. Moreover, some arbitrariness in the choice of the material makes the report far from being complete. Many important results are not mentioned at all. Bearing in mind all these restrictive circumstances we hope that the readers who are interested in this field of science can find useful sources of information in this report.

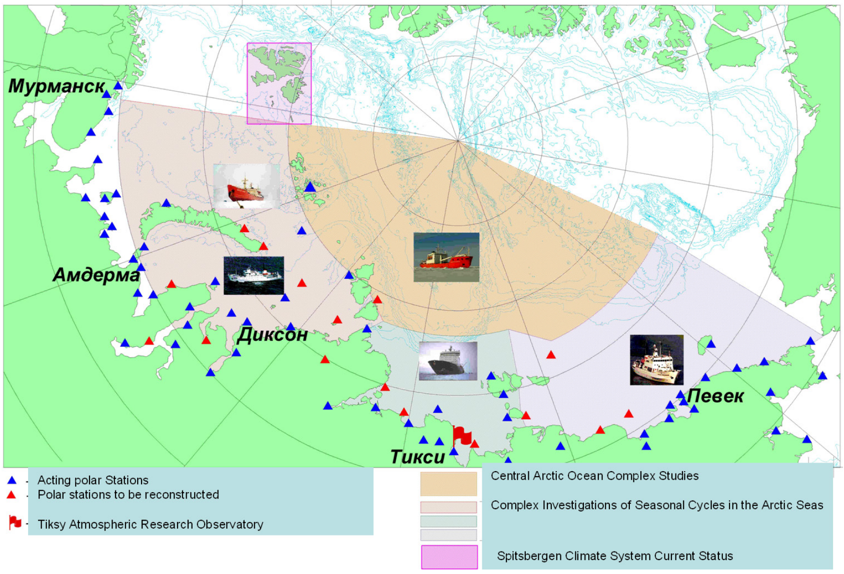
Russian IPY cryo activities

Russia was very actively involved in IPY. The main target of Russia's participation in the IPY 2007-2008 was in obtaining new knowledge about hydrometeorological and geophysical processes in the polar regions of the Russian Federation and the Antarctic on the basis of considerable increase of synchronized, coordinated and consistent in methodical aspect hydrometeorological and geophysical observations in the key regions of the polar areas and intensification of means and methods of natural environment complex study development, evaluations and predictions in the Arctic and the Antarctic in varying climate conditions.



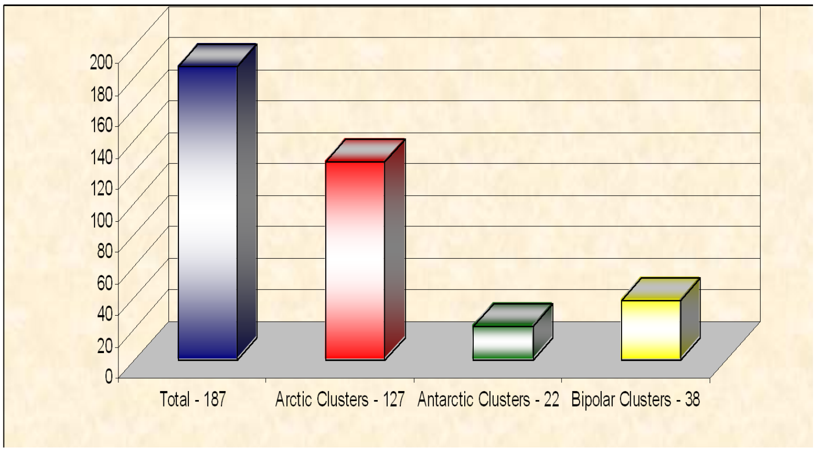
Coordinated observations in the Arctic and the Antarctic with application of ongoing monitoring systems, by conducting special experiments on sea vessels, stations and bases, using autonomous means of observations and space exploration facilities, were a practical baseline of the IPY 2007-2008 tasks' solution. Wide range of field studies was carried out during 2007-2008. The subject matters included complex studies of natural environment state, researches of climate and paleoclimate, atmosphere, marine environment, cryosphere, lithosphere, near-Earth space, as well as ecosystems of the polar areas.

Arctic Ocean Research Russian IPY Clusters



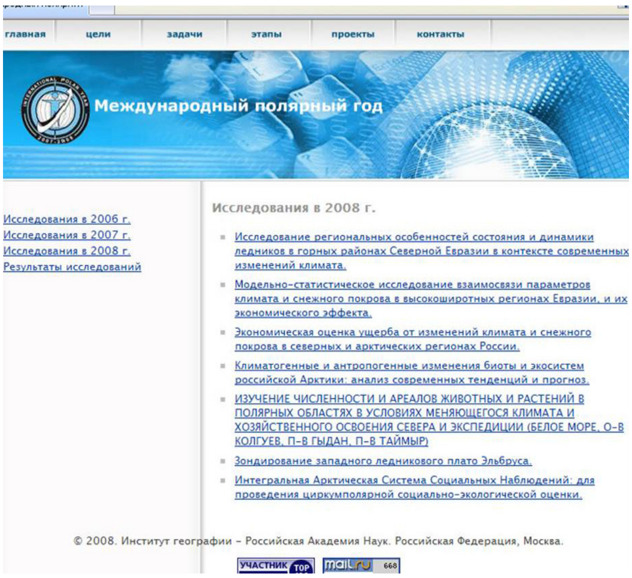
These developments were carried out on the basis of the Action Plan for the participation of the Russian Federation in the preparation and carrying out International Polar Year 2007-2008 and the Scientific Programme of the Russian Federation participation in carrying out the IPY, developed by joint efforts of Roshydromet (the Federal Service for Hydrometeorology and Environmental Monitoring) and RAS (the Russian Academy of Sciences). More than 80 institutes and organizations, 8 ministries and agencies, non-governmental organizations, associations, foundations (the Polar Foundation, Community Organization for Native Minorities of the North, Siberia and Far East of the Russian Federation and others) take part in the IPY events.

IPY clusters with Russia participation



There has been collected the unique volume of the field data throughout all directions of the Scientific Programme. Set up of integrated surveillance systems and databases is being carried out. Hundreds of solid data descriptions, obtained in the national projects as well as numerous descriptions of historical data have been already registered at the IPY-Info website.

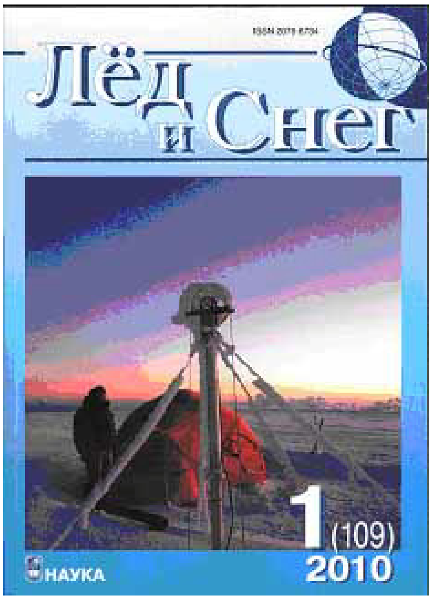
The IPY Information Center in Institute of Geography RAS as a part of Russian national and International IPYDIS has been designed for acquisition, cataloging, and sharing of the unique results of intensive glaciological studies during IPY for Polar and high mountain areas as well as Russian historical data sets. **http:// mpg.igras.ru**



The results of IPY studies were discussed during Russian IPY meetins in Sochy on September – October 2008, 2009, 2010. In the course of International Polar Year 2007-2008 extensive and comprehensive investigations of cryoshere were carried out in Russia, mainly owing to efforts of Arctic and Antarctic Research Institute of Roshydromet and a number of institutes of the Russian Academy of Sciences. The meetings elucidate the great scale and variety of the Russian field investigations in both Polar Regions of the Earth. The scientific results cover the following issues and problems: state of the Arctic Ocean and its sea ice; exploration of the Svalbard Archipelago and glaciers in other Arctic regions; studies of the ice mass balance and its discharge on the Antarctic continent; observation in near-top part of the Elbrus mountain in the Caucasus; investigations of interconnections between snow cover the atmosphere circulation, and the river runoff features under permafrost conditions.

The New journal «Ice and Snow»

New journal «Ice and Snow» (http://ice-snow.igras.ru/) is a professional academic periodical publication in the field of glaciology. It continues the series «Data of Glaciological Studies» that was started in 1961 by the Section of Glaciology of the Geophysical Committee at the Presidium of the USSR Academy of Sciences (now the Russian Academy of Sciences – RAS). 108 issues of the series were published since that time. Two to four issues regularly published the journal with this title in a year, and the each one contained about 240 pages in volume and 500 copies in printing. More than 250 copies were sent abroad, to libraries of leading glaciological organizations and many universities. This series became rather popular among professional Russian glaciologists.



Since 2010, instead of the former «Data of Glaciological Studies» the «Ice and Snow» journal that continues traditions established during almost a half of century of the previous publication is published. Its themes cover the whole of the glaciology area, including studies of the atmospheric ice, snow cover and avalanches, mountain glaciers and polar ice sheets, sea, river, lake and underground ices, glacial flows (torrents) and icings as well as past glaciations on the Earth and possible cooling in future. Its scope contains also an applied direction, embracing processes of icing, snow storms and drifts, movements of surging glaciers and glacier floods, like the known catastrophe of 2002 on the Caucasus Kolka Glacier.

Founders of the journal are Institute of Geography of the RAS, Glaciological Association, and the Publisher «Nauka». Its editorial board includes leading glaciologists from Russia and neighboring countries, its electronic version together with appropriate Internet site are being created. There is the present-day system of reviewing and contacts with authors via electronic mail. The journal retains numbering from the «Data of Glaciological Studies», and it will be published four times in a year, i.e. in spring, summer, autumn, and winter. Articles are published in the Russian language with summary in English (explanations of figures are given in two languages as well). Some papers can be published in English with extended summary in Russian. This journal has been registered by Russian Federal Agency for Press and Mass Communication, and it is included into the special list, that the Main Certifying Commission of the Ministry of Education and Science of the Russian Federation approve as a source of publication for dissertations. Volume of each issue will contain not less than 120 pages in the A4 format, and figures will be colorful.

There are the following permanent sections in the journal: glaciers and ice sheets; snow cover and avalanches; sea, river, and lake ices; underground ice and icings; palaeoglaciology; applied problems; criticism and bibliography; reviews and chronicles. Annual annotated bibliography of the Russian glaciological literature will be continuing to publish. The journal issues are to be prepared in the Institute of Geography RAS, where its editorial board and office are located. **Editor-in-Chief is Academician Vladimir M. Kotlyakov.**

Glaciers and Ice Sheets

Radioglaciological studies of glaciers

The Institute of Geography, Russian Academy of Sciences (RAS) has participated in 2007-2011 in a number of International and Russian programs and projects, including programs of International Polar Year (IPY), of Presidium of RAS of Earth Sciences Brunch of RAS, International Project "Glaciology of Svalbard", project of Russian Fund of Basic Research (RFBR), Grant 10-05-00133a**.** A part of these studies were done in collaboration with scientists from Madrid Polytechnical University, Stockholm University, and Arctic and Antarctic Research Institute.

In this period the ground-based and airborne radio-echo-sounding (RES) studies were conducted in Spitsbergen (Svalbard), in the Caucasus, in Franz Josef Land and Nowaya Zemlya.

RES studies in Spitsbegen

In Spitsbergen the RES studies were performed at seven glaciers - Tavlebreen, Aldegondabreen, Austre Gronfjordbreen, Vestre Gronfjordbreen, Tungebreen, Gleditschfonna and Fridtjovbreen (**Fig. 1**).

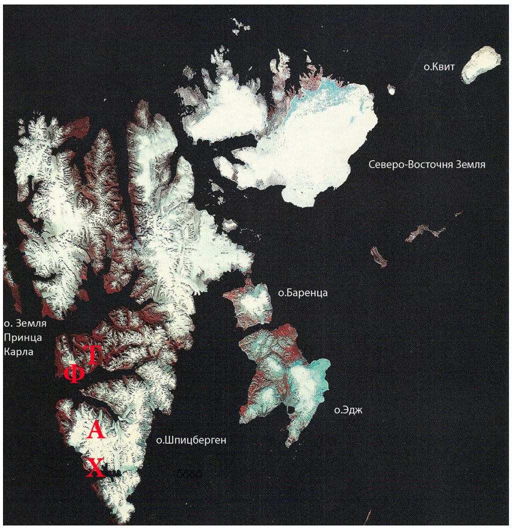


Fig.1. Radioglacilogical studies in Spitsbergen in 2007-2011. T- Tavlebreen, F – glaciers in Nordenskiold Land: Austre Gronfjordbreen, Vestre Gronfjordbreen, Fidtjovbreen, Tungabreen, Gledichfonna.

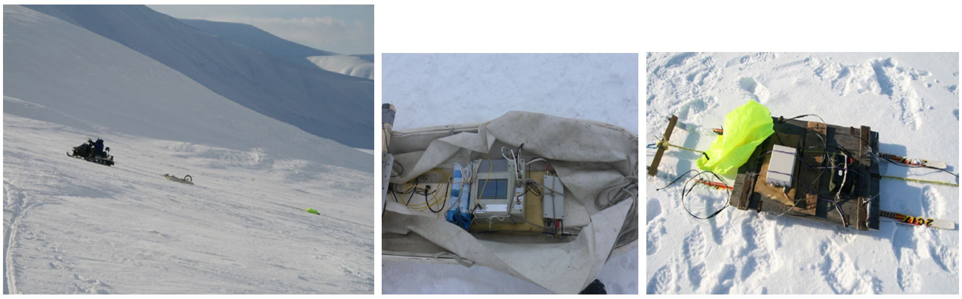
RES studies in the Caucasus

In the Caucasus the RES studies were performed at the Elbrus western firn plateau (**Fig.2**) and at Bashkara glaciers.

Fig. 2. Radioglacilogical studies at Elbrus western firn plateau (a) in 2007 and Bashkara glacier (b) in 2010.

Radar equipment

Different radars with digital recording of radar and GPS data were used: 20 MHz radar VIRL-6, 50, 100 and 200 MHz radars RAMAC, 850 MHz step-frequency radar and helicopter 620 MHz radar RLS-620 (**Fig. 3**).



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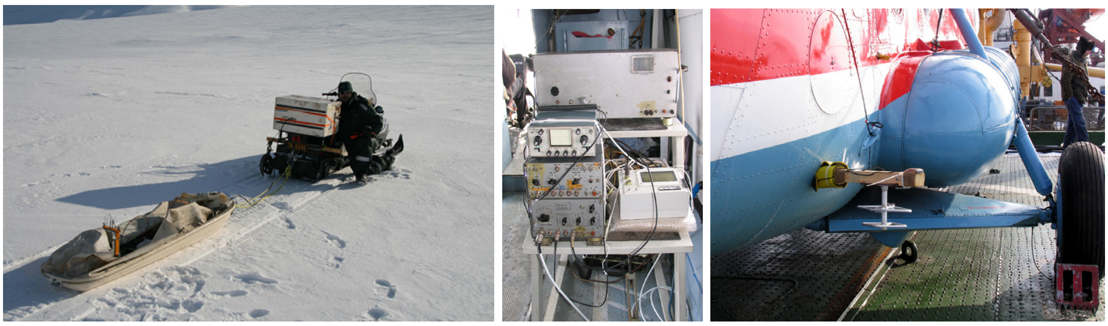


f g h

Fig. 3. Radars, which were used in 2007-2011 for ground-based (a-f) and airborne (g,h) radio-echo sounding of glaciers in Spitsbergen, in the Caucasus, in Frantz Josef Land and Nowaya Zemlya: (a-c) 20 MHz radar VIRL-6, (d) 100 MHz radar RAMAC, (e) 850 MHz step-frequency radar, (f) 200 MHz radar RAMAC, ((g) 620 MHz radar RLS-620 and its external antenna (h).

Glaciers – objects of RES studies

The aerial photos of some of studied glaciers in Spitsbergen and Franz-Josef Land are presented in **Fig. 4.**

a b c

d

Fig. 4. Aerial photos of some of glaciers in Spitsbergen (a-b) in Franz-Josef Land (c), and in the Caucasus (d) where RES studies have been carried out in 2007-2011: (a) Tavlebreen, (b) Austre Gronfjordbreen (1) and Vestre Gronfjordbreen (2), (c) Wilczek Land, (d) Elbrus western firn plateau.

Ground-based RES measurements

Ground-based RES profiles at studied Spitsbergen and Caucasus glaciers are shown in **Fig. 5**.

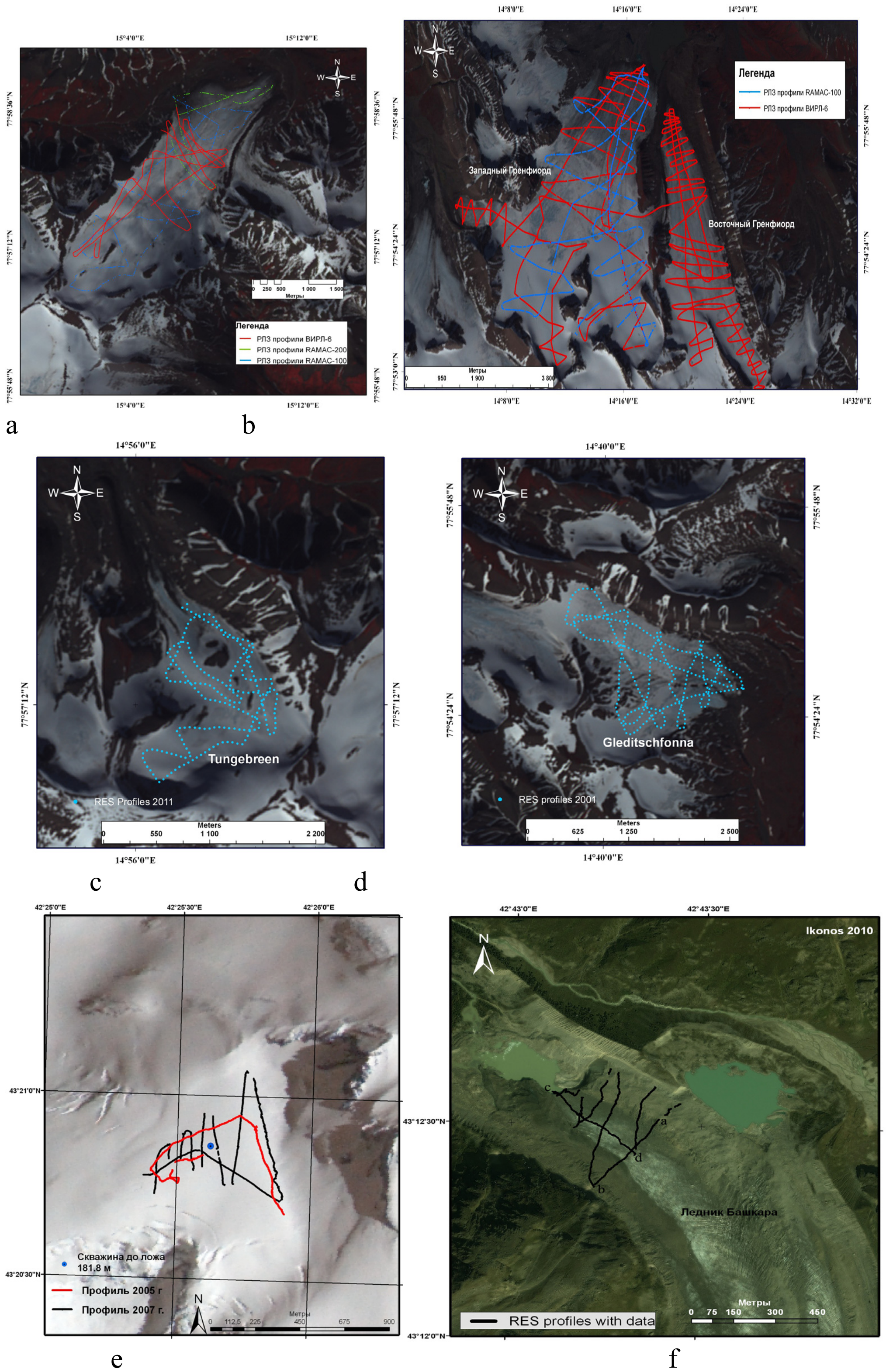


Fig. 5. RES measurements in 2010 at Spitsbergen (a-d) and Caucasus (e, f) glaciers: (a)Tavlebreen, (b) Vestre Gronfjordbreen and Austre Gronfjordbreen (c) Tungebreen, (d) Gleditschfonna, (e) Elbrus west firn plateau, (f) Bashkara glacier.

Airborne RES measurements

The airborne RES studies were carried out in autumn 2007 and 2008 from helicopter MI-8, based on research ship "Mikhail Somov", at several outlet glaciers in Franz Josef Land and

Novaya Zemlya, using an impulse 620 MHz radar RLS-620 with digital recording of radar and GPS (Бузин и др.2010; Kubyshkin et al., 2009) data (**Fig. 3g,h**).

Flight routes in 2007 with airborne radio-echo sounding of glaciers in Franz-Josef Land and Nowaya Zemlya are shown in **Fig. 6**.

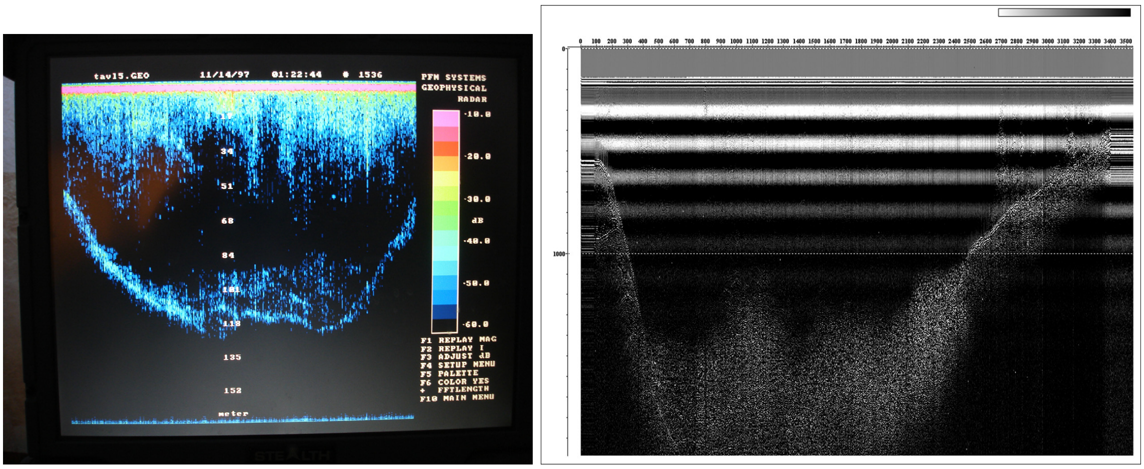
a b c

Fig. 6. Radio-echo sounding of glaciers in Franz Josef Land in 2007 (a) and in Novaya Zemlya in 2008 along its western cost (b) and eastern cost (c).

Examples of ground-based and airborne radar records, collected in Spitsbergen and Franz Josef Land, are presented in **Fig. 7**.

Examples of RES records

By data of RES measurements the reflections from bedrock (B) and internal inclusions in ice were recorded. Typical radar records are shown in **Fig.7**.



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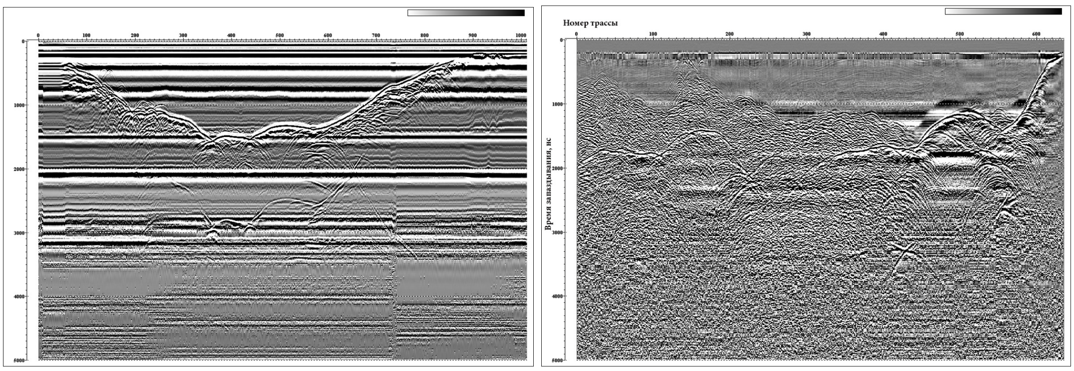

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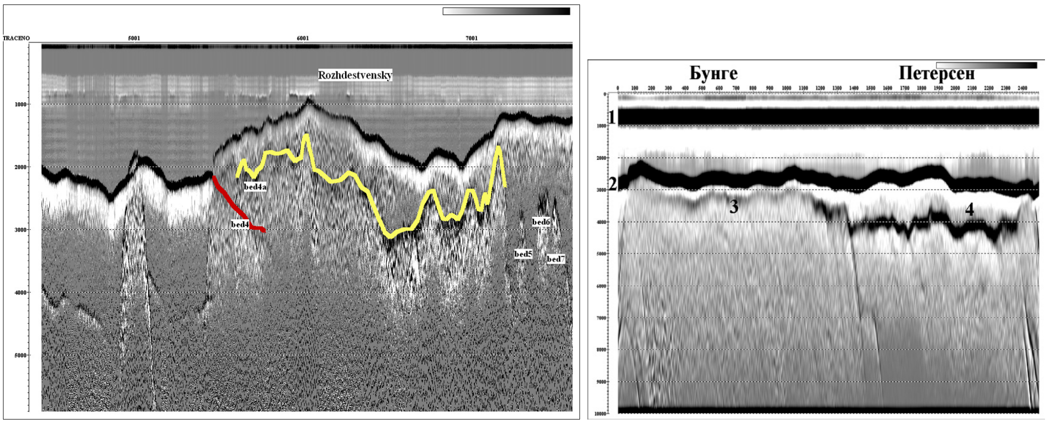

e f

Fig. 7. Examples of radar records obtained at glaciers in Spitsbergen (a-d) and Novaya Zemlya (e-f). (a, c)Tavlebreen: (a) 850 MHz (c) 20 MHz, (b, d) Vestre Gronfjordbreen: (b) 100 MHz, (d) 20 MHz; (e) Rozhdestvensky glacier: reflections from glacier surface, internal boundary and bedrock are shown by black, yellow and red lines, respectively; (f) Bunge and Petersen glaciers: 1 are transmitted pulses, 2 are reflections from glacier surface, 3 and 4 are reflections from bedrock.

RES data from Spitsbergen glaciers

RES data obtained were used to determine the ice thickness, glacier surface and bedrock topography, as well the internal and hydrothermal structure and pattern of subglacial hydtological drainage of glaciers and their spatial and temporal changes.

Radar records in **Fig. 7a,b,d** show the presence of radar reflections from cold-temperate surface (CTS) between the upper layer of cold ice (without internal reflections) and the lower layer of temperate water-saturated ice (with many irregular reflections from water inclusions), which can be considered as an indicator of polythermal structure of glaciers. Note that polythermal glaciers were not detected in the Arctic neither in Frantz Josef Land, nor in western cost of Noway Zemlya, only in Spitsbergen (Мачерет и др., 1992; Мачерет 2006;Глазовский, Мачерет, 2007; Jiscoot et al., 2000) and at Rozhdenstvensky in eastern cost of Noway Zemlya **(Fig. 7e)**

Structure of Tavlebreen by by RES data, obtained in 2007, is shown in **Fig.8**.

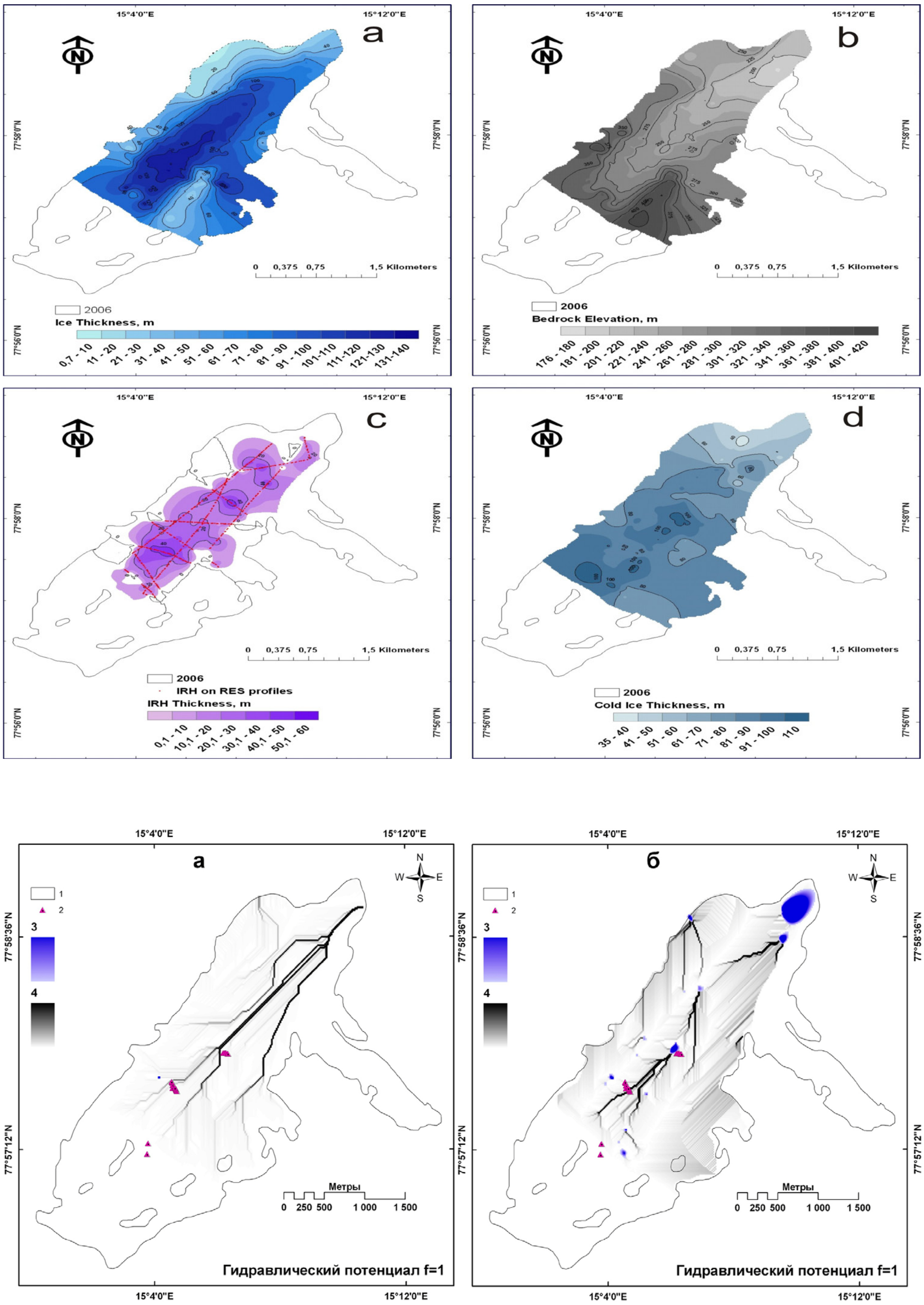

Fig. 8. Structure of Tavlebreen by RES data, obtained in 2007. (a) ice thickness, (b) bedrock elevation (c) thickness of near-bottom temperate ice layer, (d) thickness of upper cold ice layer, (a) hydraulic potential and pattern of subglacial hydrological drainage in 1936 (a) and 1990 (б). Red triangles denote the location of moulins in 2006. Note, that their location coincides with location of main subglacial water flow, indicated by calculated pattern of hydraulic potential.

Structure of Vestre Gronfjordbreen and Austre Gronfjordbreen by RES data, obtained in 2010, is shown in **Fig. 9**.

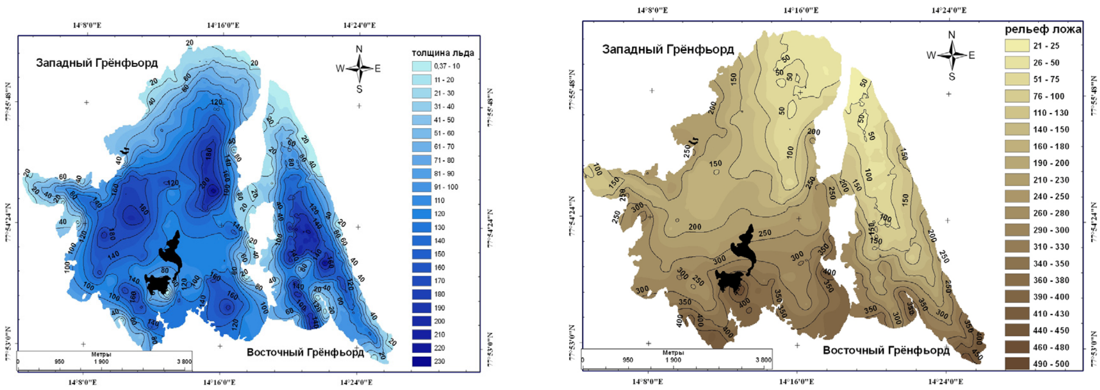

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Fig. 9. Structure of Vestre Gronfjordbreen and Austre Gronfjordbreen by RES data, obtained in 2010: (b) ice thickness, (b) bedrock topogrsphy.

RES data from Caucasus glaciers

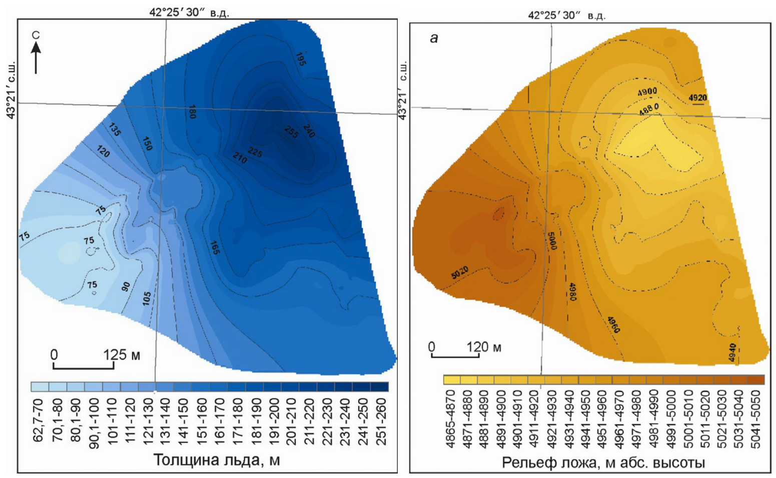
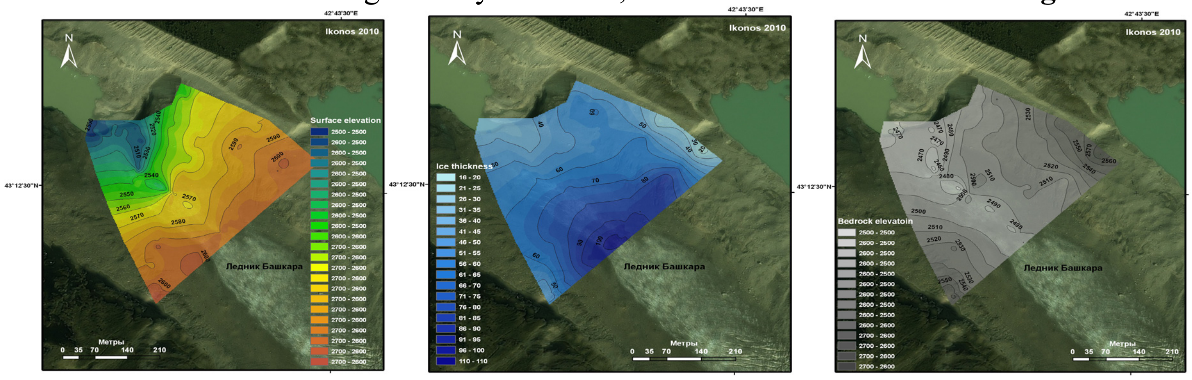


Fig. 10. Structure of Elbrus western firn plateau by RES data, obtained in 2007: (a) ice thickness, (b) bedrock topography.

Structure of Bashkara glacier by RES data, obtained in 2010 is shown in **Fig. 11**.

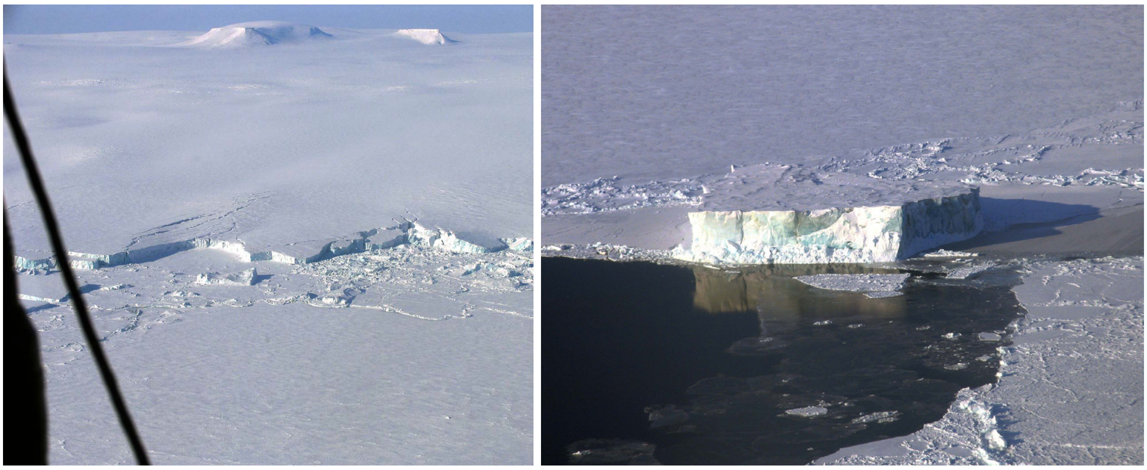


a b c

Fig. 11. Structure of Bashkara glacier by RES data, obtained in 2010: (a) glacier surface elevation, (b) ice thickness, (c) bedrock topography.

RES data from Franz Josef Land and Nowaya Zemlya

Airborne RES data were used to determine the ice thickness near ice fronts of ice caps and outlet glaciers and the thickness of icebergs and to estimate possible places of calving of large icebergs (**Fig. 11**).



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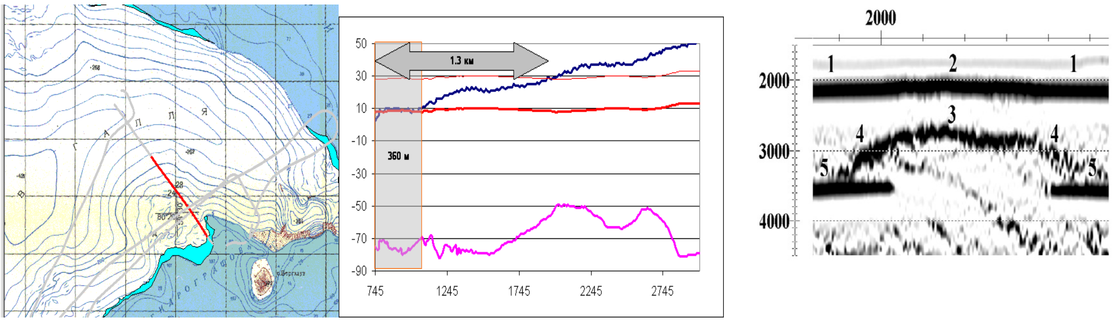

c d e

Fig. **11.** RES data (c, d) , used for estimation of possible places of iceberg calving from ice front (a) of a glacier in Franz Josef Land (a) and for ice thickness determination of icebergs (b, f). Red line in (c) denotes a part of ERS profile along an outlet glacier in shown in (d), where blue, thick red and violet lines denote glacier surface elevation, ice front elevation and bedrock elevation below sea level; gray arrow shows the length of a glacier below see level, gray band shows the possible size of calving icebergs. (f): 2 transmitted pulse, 3, 4 - reflections from iceberg bottom, 5- reflections from sea ice.

Main results of RES studies in 2007-2011

RES data, obtained in this period, allow us:

1. to determine the structure and hydrothermal state of glaciers on Nordenskiold Land in Central Spitsbergen and the structure of glaciers in the Caucasus, including their glacier surface elevation, ice thickness and bedrock topography;
2. to investigate the temporal and spatial changes in hydrothermal structure of glaciers;
3. to determine the ice volume of these glaciers and to estimate its contribution to sea-level rise;
4. to identify four unknown earlier polythermal glaciers in Spitsbergen (Tavlebreen, Vestre Gronfjordbreen, Austre Gronfjordbreen and Tungebreen);
5. to indicate the temporal changes in pattern of subglacial hydrological drainage at Tavlebreen;
6. to detect firstly a polythermal glacier at eastern coast of Novay Zemlya (Rozhdestvensky glacier);
7. to choose an appropriate place for deep ice core drilling at Elbrus western firn plateau;
8. to estimate the hazard of dammed lake at Bashkara glacier;
9. to determine the ice thickness of many icebergs in Barents Sea near Franz Josef Land;
10. to estimate the places of possible formation of large icebergs near ice caps and outlet glaciers in Franz Josef Land and near outlet glacier in Novaya Zemlya;
11. to estimate the maximum sizes of calving icebergs in these areas and the iceberg danger in Barents Sea and Kara Sea for ship operations and marine platforms for extraction of gas and oil;
12. to create a basis for monitoring of changes in structure and hydrothermal regime of glaciers in studied regions and numerical modeling of their dynamics and response to climate change.

Reference

Buzin I.V., Glazovsky A.F., Gudoshnikov Yu.P., Danilov A.I., Dmittiev N.E., Zubakin G.K., Kubyshkib N.V., Macheret Yu.Ya., Naumov A.K., Nesterov A.V., Skutin A.F., Skutina E.A., Redults and prospects of study of icebergs and calving glaciers in Barents and Kara seas and peculiarities of their observations in the frame of IPY program 2007/ 08 — Conference on Russian Program of International Polar Decade, 4–7 October, 2010, Sochi.

Glazovsky A.F., Macheret Yu.Ya. Hydrothermal state and regime of glaciers. In: (Kotlyakov V.M., ed.).Glaciation in North Eurasian in the recent past and immediate future. Nauka, 2007, p. 57-108.

Jiscoot H., Murray T., Boyle P. Controls on the distribution of surge-type glaciers in Svalbard. Journal of Glaciology, vol. 42, No 154, 2000, p. 412-421.

Kubyshkin N.V., Andreev O.M., Boradulin V.V., Glazovsky S.F., Gudoshnikov Yu.P., Zubakin G.K., Macheret Yu.Ya., Skutin A.A. Characterstics of icebergs and their calving sites in Russian Arctic. Results of airborne and direct studies during IPY 2007/08. The Proceeding of the Nineteenth (2009) International Offshore and Polar Engineering Conference, Osaka, Japan, June 21-26, vol. 1, 2009, p. 539-544.

Lavrentiev I.I., Glazovsky A.F., Macheret Yu.Ya., Holmlund P. Polythermal structure of Tavlebreen in Spitsbergen. Procedings of International Scientifical Conference "Nature of shelf and archepelagos of European Arctic. Complex studies of the nature of Spitsbergen". Geos, 2010, p. 417-422.

Lavrentiev I.I., Glazovsky A.F., Macheret Yu.Ya., Holmlund P. Hydrothermal structure and subglacial drainage net work of Tavlebreen in Spitsbergen. Ice and Snow (In press).

Macheret Yu.Ya., Glazovsky A.F. and others. Structure, hydrothermal state and regime of subpolar glaciers. In: (V.M. Kotlyakov, ed.) Regime and evolution of polar ice sheets. St.Petersburg, Gidrometeoizdat, 1992, p. 48-115.

Macheret Yu.Ya. Radio-echo soundinf of glaciers. Moscow, Nauchny Mir, 2006, 392 p.

Lavrentiev I.I., Mikhalenko V.N., Kutuzov S.S. Ice thickness and bedrock topography of Elbrus western firn plateau (in Russian). Led I Sneg №2 (110), 2010, p.12-18.

V.N.Mikhalenko, S.S.Kutuzov, I.I.Lavrentiev, M.G.Kunakhovich, L.G.Tompson Elbrus western firn plateau studies: results and prospects (in Russian) - Data of glaciological studies P.99, 2006 pp. 185-190

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Deep ice-core drilling at the Elbrus western plateau successfully completed

Shallow ice core, 21.41 m depth, has been recovered on the Western firn plateau of Mt. Elbrus (5150 m a.s.l.), Caucasus in 2003. Firn density has been measured at the drilling site and ranged from 210 kg/m3 at the upper part of ice core to 680 kg/m3 at 21.4 m. Temperatures were measured in the borehole and changed from -11.5°C near surface to - 17°C at 10 m. Distinct seasonal fluctuations of stable isotope composition has been defined in ice core. Minimum values of the d18O and dD were -28‰ and -206‰. High correlation between d18O and dD has been revealed and the meteoric water equation (dD = 8,0071 d18O + 15,173) has been obtained. Detailed stratigraphic record indicates absence of surface melting and ice layers in firn pack.

Radio-echo sounding measurements in 2003 and 2004 show that ice depth ranged from 70 m to 240.8 m. This record indicates that Western firn plateau of Mt. Elbrus is the best site for ice-core studies in Caucasus

Ice-core drilling at the Elbrus western plateau was started on 25th of August 2009 when all equipment, outfits and materials, total weight of 2000 kg, and personnel have been brought to the drilling site by MI-8-MTV helicopter of SIMARGL Air Company.
Because of late start of work and logistic difficulties the drilling site was shifted from zone of the thickest ice to the area of ice division between B.Azau and Kukurtlu glaciers in central part of the plateau (43°20'53,9"N, 42°25'36,0"E, altitude 5115 m asl.) (fig.1).

Fig.1. Deep ice core drilling camp.

Drilling was started on 27th August and on the afternoon of the 6th of September the drill has reached bedrock at 181,80 m depth. Drilling was accomplished by three personnel at one shift. Drilling rate was 20 m per day (10-12 hours) in average. An electromechanical ice-core drilling system developed by Geotech Co. Ltd., Nagoya, Japan was used (Fig.2).

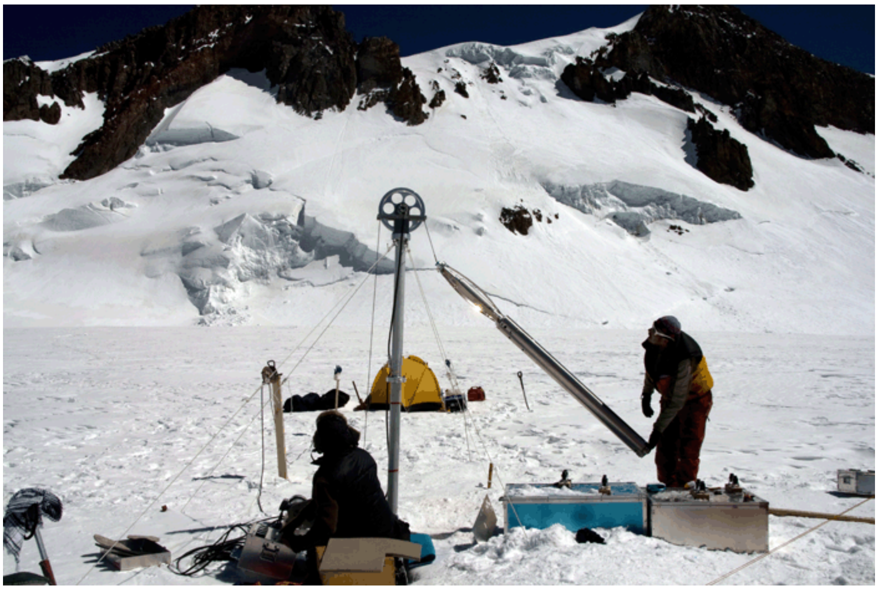

Fig.2. Electromechanical ice-core drilling system.

Collected ice-cores after detailed stratigraphy description were packed and brought to the storage at snow pit with temperature of -10 °C (fig.3).

Fig.3. Ice core storage.

Our studies have also included: borehole temperatures measurements, snow cover researches in snow pits, snow and firn isotopic composition sampling and density measurements. For density studies special device - Speedograph – custom-designed and produced by V.S. Zagorodnov in the USA was used (fig.4). Where rate of penetration of mini thermoelectric drill is registering by a computer every 0,1 s. Drilling rate depends mainly on snow and firn density and temperature. Using Speedograph two boreholes (8 and 33 m depth) were drilled.

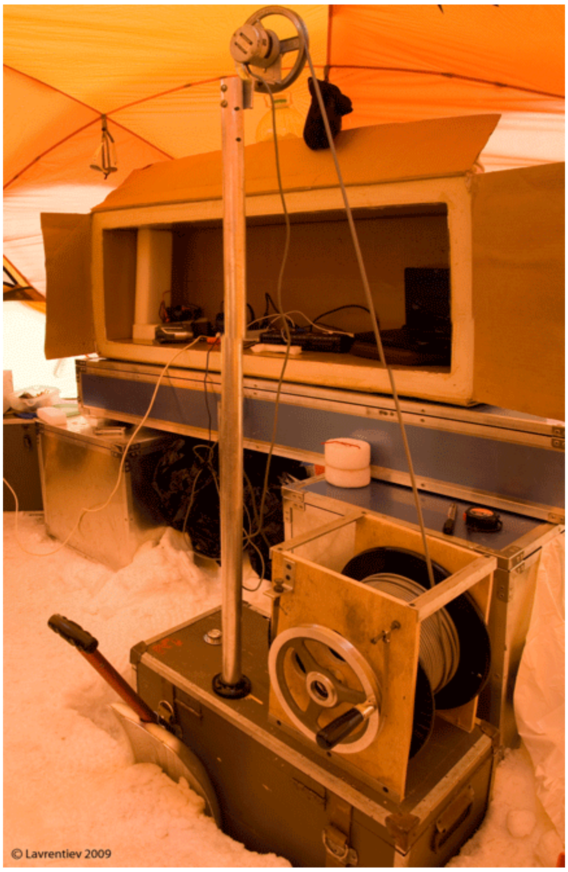

Fig.4. Speedograph.

Temperature was measured in all boreholes using termistor sensor with 0,1°C accuracy. Temperature profiles from different boreholes are in close agreement with each other and with previous studies of 2004. Important result is a temperature profile of the deep borehole where temperature changes from -19 °C at surface to -15 °C at 110 m depth and increases fast below this level to -2,4 °C at the bedrock (fig.5).

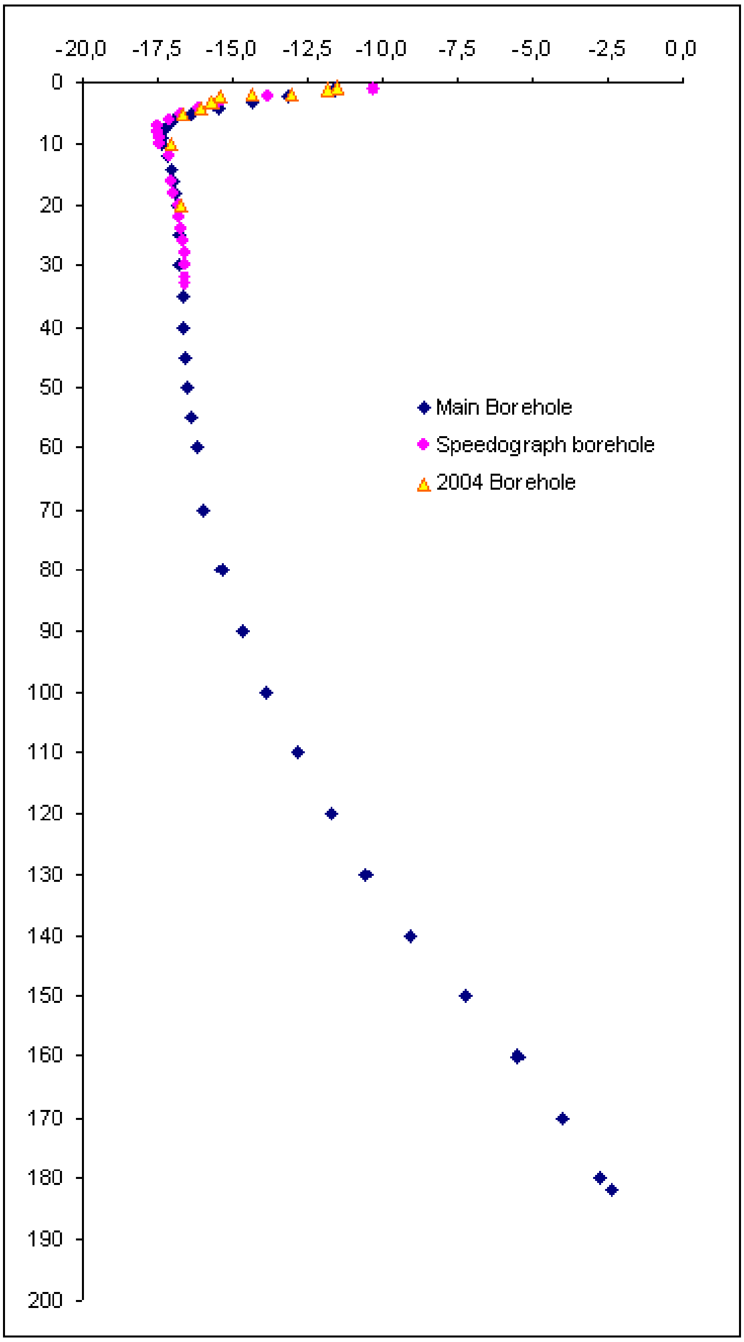

Fig.5. Temperature profile (Mikhalenko and others, in press).

Ice-core stratigraphy and temperature data both show representativity of the drilling site for the vast firn area of the glacier where recrystallization type of ice formation prevails.

One of the most interesting results of ice-core drilling was a discovery of 40 cm layer of pyroclastic material at 107,27 depth (fig.6). This layer has a distinct upper boundary and could correspond to the tephra blowout of one of the Elbrus craters (fig.5).

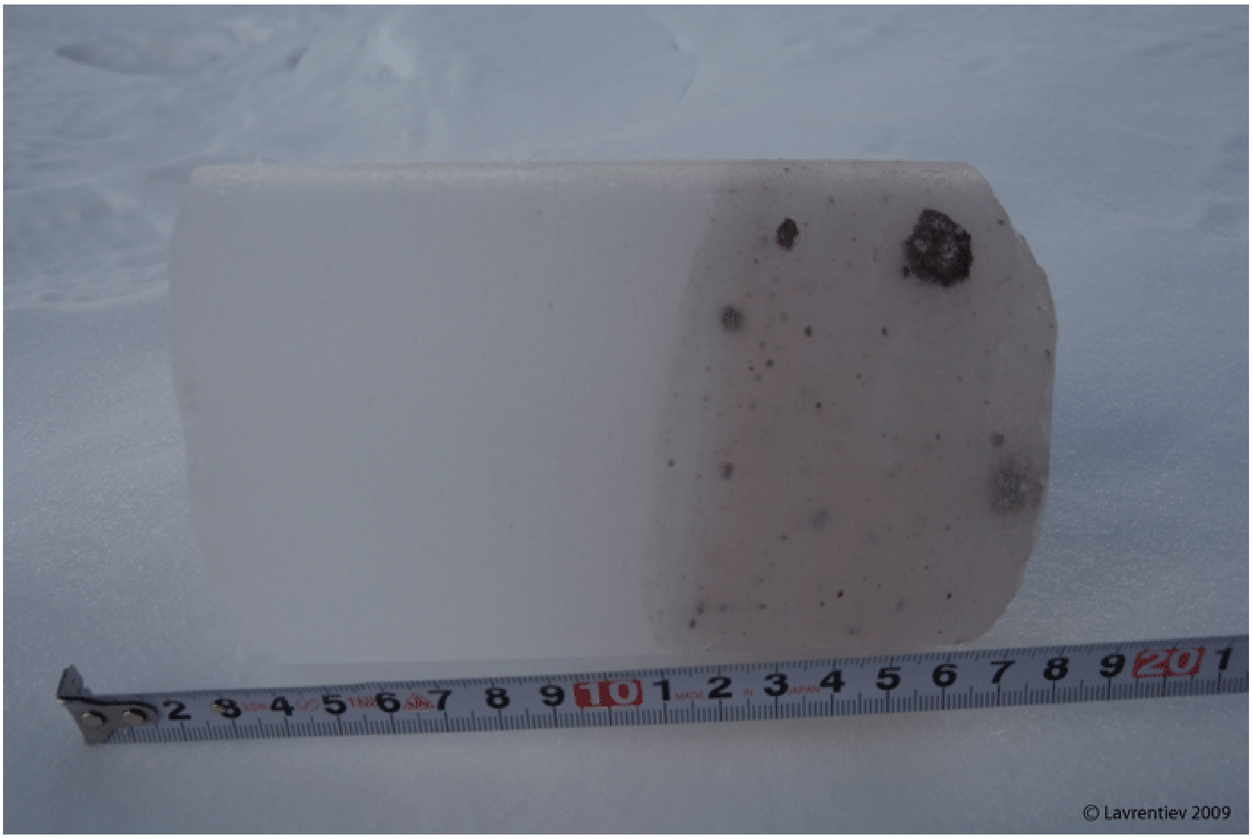

Fig.6. Ice core from 107. 27 m with pyroclastic material.

Following personnel have assisted in work on western Elbrus plateau at different stages: A.A. Abramov, M.N. Ivanov, M.G. Kunakhovich, A.S. Kutuzov, S.S. Kutuzov, I.I. Lavrentiev, V.N. Mikhalenko, S.A. Marchenko, V.I. Okopny, K.E. Smirnov, A.V. Shyshkov.
This study was supported by Russian Academy of Sciences (project №16 of the program №13 Dept. of Earth Sciences RAS) and RFBR grants 07-05-00410 and 09-05-10043.
We are grateful to helicopter crew SIMARGL Air Company and personally to A.N. Semenovich and R.A. Gubzhokov. We thank also Elbrus science-educational base of the geographical faculty MSU and A.D. Oleinikov for help with field studies organization. We would like to thank Mountech official dealer of the Marmot Mountain, LLC. for providing us with quality clothing and equipment.

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Two New Glacier Systems in Northeastern Eurasia

V. M. Kotlyakov, T. E. Khromova, N. M. Zverkova, L. P. Chernova, and G. A. Nosenko

Glacier systems of Northeast Eurasia in the Catalog of Glaciers of the USSR. In the catalog, glaciation of this region, which comprises areas of Russia located east of the Lena River and Lake Baikal, is represented by eight glacier systems [6] (figure, Table 1). They unite 2500 glaciers 1600 km2 in total. The De Long Islands host the only ice shield 80 km2 in size. Other glacier systems are represented by mountainous glaciers. The near_meridional boundary between Pacific
and Atlantic feeding domains divides the region in two parts: western (De Long Islands, Orulgan and Kodar ranges) and eastern (Wrangel Island, Cherskii Range, Suntar–Khayata Mountains, Kamchatka, and Koryak Highland). According to [3], the accumulation–ablation layer on glaciers becomes thinner in the E–W irection from glacier systems of the Koryak Highland and Kamchatka to their counterparts in the Cherskii Range and Suntar–Khayata Mountains and then its thickness again increases on the Orulgan and Kodar anges).

New glaciers. The glacier systems of the Chukchi and Koryak highlands are missing from the Catalog [4]. R.V. Sedov, a researcher from Magadan, was the irst to fill this gap. Beginning from the 1980s, he conducted regular field works in the Chukchi National Autonomous Okrug and systematically published theь results of his observations [8–12]. In total, he visited 182 glaciers, which were not mentioned among glacier systems of the Koryak, Chukchi, and Kolyma highlands presented in the Catalog. Some of them were mentioned in works of other geologists, although
Sedov was the first to visit and thoroughly document them. In the northwestern Koryak Highland, he
described 116 glaciers in addition to their counterparts of this glacier system described in the Catalog. It appears that 66 glaciers form two new systems. Unfortunately, almost all of Sedov's publications are the missing geographical coordinates of the described glaciers. We have determined these coordinates using the Google Earth program. Of 66 glaciers, 19 form two groups 3.61 km2 of the total size in the Kolyma Highland (figure) and 47 glaciers form five groups 13.5 km2 of the total in the Chukchi Highlands. Tables 2 and 3 present their characteristics.

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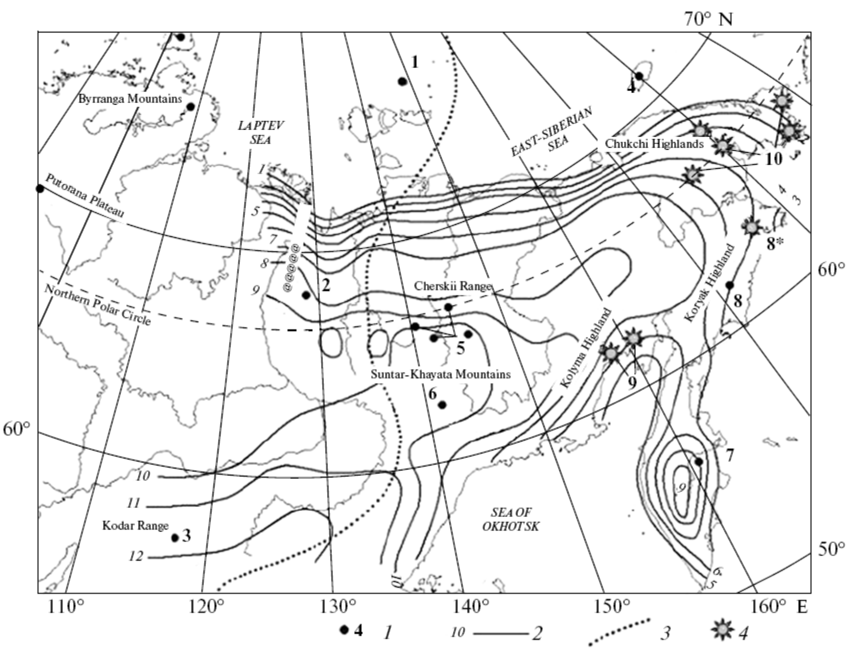
TWO NEW GLACIER SYSTEMS IN NORTHEASTERN EURASIA



Glacier systems in the Atlantic and Pacific provinces of northeastern Eurasia. (*1*) Glacier systems after the Catalog of Glaciers of the USSR; (*2*) isolines of average summer temperature at the altitude of 1000 m, °C; (*3*) boundary between provinces; (*4*) new glacier systems. System numbers: (1) De Long Islands, (2) Orulgan Range, (3) Kodar Range, (4) Wrangel Island, (5) Cherskii Range, (6) Suntar_Khayata, (7) Kamchatka, (8) Koryak Highland, (8*) northeastern Koryak Highland, (9) Kolyma Highland, (10) Chukchi Highlands.

Kolyma Highland. The glacier system of the Kolyma Highland is represented by two glacier groups.
The first group consisting of five glaciers is located on the eastern slope of the Kolyma Highland near the western shore of the Sea of Okhotsk. The larger glaciers (0.2–0.5 km2) occupy a slightly higher hypsometric position with the exposition ranging from the northwestern to the northeastern one. Their host valleys are typical troughs, and lower parts of glaciers are accompanied by end moraines frequently with the ice core. The second group of 14 cirque glaciers with northern and northwestern expositions is located on the Taigonos Peninsula in the northernmost Sea of
Okhotsk. They are each 0.1–0.2 km2 in size with the feeding boundary located at the altitude of 700 to 1000 m and vertical extension ranging from 90 to 200 m. The cirque bottoms are located at altitudes of 600–800 m, and their rocky walls tower over bottoms and ice edges by 400 m and 200–300 m, respectively. All the glaciers exhibit signs of their movements in the form of ogives.

Using the map of average summer air temperatures in northeastern Eurasia at the permanent altitude of 1000 m, we determined the average long_term accumulation–ablation value at the altitude of the glacier feeding boundary (figure). It should be noted that for the first time it is presented with the coordinate grid, which allows these data to be used for determining air temperature at the feeding boundary altitude for particular glacier groups. Superposing these maps on the average altitude of the feeding boundary for each of two glacier groups with consideration of the vertical temperature gradient (t) of 0.4 per 100 m of the altitude and using the formula $A = (t + 8.7)$. [14], we obtained the average value of the accumulation–ablation value A = 300 g/cm3.
land, three groups of glaciers in the Chukchi Highlands are located in the immediate proximity of the seashore. The first group of three glaciers each 0.1 km2 in size was studied in 1998 in the Tenianyi Range in Lavrentiya Bay located in the extreme northeasterpart of the Chukotka Peninsula. They were first mentioned in 1939. The average altitude of the glacier feeding boundary is 500 m, and the accumulation ablation value at this altitude is 140 g/cm2. The second group of 13 cirque glaciers 0.04–0.46 km2 in size occurring in the Provideniya mountainous massif was
visited in 1988. The altitude of the feeding boundary in this area ranges from 400 to 550 m, and the accumulation–ablation value is 220 g/cm2.
The third group located on the Iskaten Range in the Kresta Bay of the Bering Sea consists of 21 glaciers ranging in size from 0.04 to 0.8 km2 with the firn line located at the altitude of 500 to 1000 m, i.e., similarly to that in the Kolyma Highland. At the same time, the average summer temperature in this area is 2°C lower (figure); therefore, its accumulation–ablation value is 200 g/cm2. According to Sedov's measurements at the Pervenets Glacier (no. 4 on the Iskaten Range in Kresta Bay), accumulation in winter of 1987/1988 was as high as 100 g/cm2 and ablation in 1988 was 150 g/cm2; in 2008, it was at least half again as much as that. Melting was in progress from June until the second third of September. The velocity of the ice surface movement was measured in the range near the 1986 summer feeding boundary over 26 days [12]; its annual

value appeared to be approximately 10 m. The fourth group of four cirque glaciers on the Pekul'nei Range was visited in 1982 and 1983. The glaciers each about 0.3 km2 in size were characterized by the convex profile of the ablation area. The average altitude of the feeding boundary is 740 m, which allows the accumulation–ablation value at this altitude to be estimated as 300 g/cm2 (derived from the map in the figure). Five glaciers of the fifth group (from 0.1 to 0.5 km2 in size) on the Chatkal Range in the Amguema River basin were investigated in August 1989.The calculated accumulation–ablation value at the feeding boundary altitude of 1400 m was 140 g/cm2. Thus, according to [3, 4, 7], the region under consideration hosts eight glacier systems 1612 km2 in total size.

Two new glacier systems in Northeast Eurasia were discovered and investigated during the last 30 years. The glacier system of the Kolyma Highland consists of 19 glaciers 3.6 km2 in total size forming two groups near the western shore of the Sea of Okhotsk. The average altitude of their feeding boundary is about 900 m, and their accumulation–ablation value at that altitude is 300 g/cm2. The glacier system of the Chukchi Highlands consists of 47 glaciers 13.5 km2 in total size
united into five groups. Three of them are also located near the coast; the average altitude of the feeding boundary in this area is 500–800 m, and the accumulation–ablation value at this altitude progressively decreases from the south northward from 220 to 149 g/cm2, respectively, in response to the air temperature fall in the same direction. In the fourth group (Pekul'nei Range), the feeding boundary altitude ranges from 600 to 1000 m, and the average accumulation–ablation value at these altitudes amounts to 300 g/cm2. The fifth group of glaciers is located on the Chatkal Range, where the average feeding boundary altitude is estimated to be about 1400 m and the accu_
mulation–ablation value at this altitude is 140 g/cm2. According to [3], the accumulation–ablation value in eight glacier systems of Northeast Eurasia decreases from 300 g/cm2 on the Pacific Ocean shore to 100 g/cm2 in the Suntar_Khayata Mountains and Cherskii Range to increase again to 150 g/cm2 on the Kodar and Orulgan ranges. The maximal accumulation ablation value in two new systems located near the Pacific coast is 300 g/cm2. The climatic characteristic
of these two systems confirms the opinion about significant snow resources of northeastern Eurasia, which decrease from the east westward through the Pacific glaciological province up to its boundary with the Atlantic province and increase again in the western direction toward the Atlantic Ocean. This inference is consistent with climatic characteristics of glaciers developed through this region in [15].

REFERENCES

1. V. M. Kotlyakov and G. A. Nosenko, Materials of Glaciological Investigations, Issue 91, 121–124 (2001).
2. Yu. F. Knizhnikov, V. I. Kravtsova, N. A. Volodicheva, et al., Materials of Glaciological Investigations, Issue 107, 51–56 (2009).
3. *Atlas of World Snow–Ice Resources* (RAN, Moscow, 1997) [in Russian].
4. *The Catalog of Glaciers of the USSR* (Gidrometeoizdat, Leningrad, 1965) [in Russian].
5. V. M. Kotlyakov and A. N. Krenke, Materials of Glaciological Investigations, Issue 35, 25–34 (1979).
6. A. N. Krenke, *Mass Exchange in Glacier Systems of the USSR* (Gidrometeoizdat, Leningrad, 1982) [in Russian].
7. *The Catalog of Glaciers of the USSR: Electronic Version*, www.webgeo.ru/index.rhr?r=47.
8. R. V. Sedov, Materials of Glaciological Investigations, Issue 79, 139–144 (1995).
9. R. V. Sedov, Materials of Glaciological Investigations, Issue 82, 213–217 (1997).
10. R. V. Sedov, Materials of Glaciological Investigations, Issue 89, 206–208 (2000).
11. R. V. Sedov, Materials of Glaciological Investigations, Issue 91, 195–224 (2001).
12. *Materials of R.V. Sedov's Investigations_2009,* www. webgeo.ru/index.rhr?r=50&id=687.

13. A. N. Krenke and L. P. Chernova, Izv. Akad. Nauk SSSR, Ser. Geogr., No. 1, 17–33 (1980).
14. N. N. Bryazgin, E. I. Aleksandrov, A. A. Dement'ev, and V. F. Radionov, Materials of Glaciological Investi_gations, Issue 107, 3–9 (2009).
15. V. M. Kotlyakov, *Snow Cover of the Earth and Glaciers* (Gidrometeoizdat, Leningrad, 1968) [in Russian].

SPACE MONITORING OF THE PAMIR's SURGING GLACIERS

V.M.Kotlyakov, G.A.Nosenko, G.B.Osipova, Institute of Geography, RAS

It is known that surging glaciers are dangerous for population of mountain territory (Allalin glacier, Alps, 1965; Kolka glacier, Caucasus, 2002). Despite the long-term history (half a century) of study of causes and mechanisms of glacier surges, there is now an urgent need to better understand these mechanisms. Satellite-based surveys are the most productive method, especially for distant mountain regions with limited accessibility. The evolution of surging glaciers of the Pamirs, central Asia, has been studied using repeated remote-sensing surveys in the Institute of Geography, Russian Academy of Sciences, since the early 1970s. We use images obtained from national Resurs-F satellites (1972-91), as well as Landsat-7 and Terra (1999-2006). Investigations on Medvezhy glacier and other surging glaciers made it possible to work out the basic principles of surging-glacier monitoring.

We define targeted dynamically unstable glacier monitoring as a system of regular and long-term remote-sensing and ground-based observations of spatial-temporal changes in their size, shape and dynamic regime aimed at timely detection of its activation, as well as projection of time, scale and consequences of possible glacier catastrophes.

This monitoring system includes *regional* and *local* levels; each has its own appropriations, methods and means for observation, data processing and analysis. *Regional* monitoring is designed to reveal and catalogue glaciers with dynamically unstable features. *Local* monitoring of surging glaciers consists of recurrent measurements of the surface elevation change and ice velocity.

We have attempted to highlight the essential role of damming in the dynamic regime of compound glaciers.

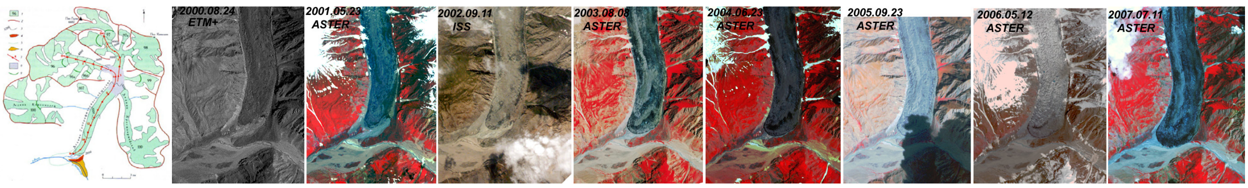
From our study of some surging glaciers of the Pamirs we concluded that such indicators as "critical mass" and the time between surges do not always enable us to forecast reliably the next activation and catastrophic advance of a dynamically unstable glacier influenced by a changing climate.

The only reliable tools for such projection are targeted remote sensing together with ground-based monitoring of the evolution of surging glacier.

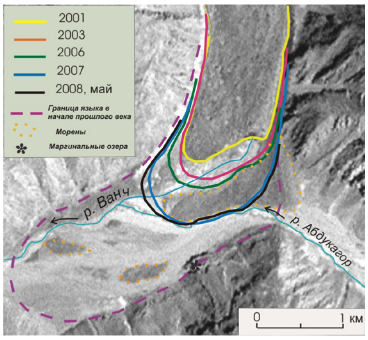
To obtain initial information about the state and development of a surging glacier, it is sensible to use recurrent space surveys of the study arta. The longer the observation period, the more reliable is the result.

The ice-movement rate, shape and of the ice-velocity curve and character of their change serve as reliable indicator of the surge evolution: an increase of ice-movement rate in the lower section of a glacier, where a zone of longitudinal compression exist, directly indicates a surge is imminent.

Space monitoring in real time. Geographicheskogo Obschestva Glacier (RGO).



Ice-rock avalanche on the surface of the RGO glacier, 2002



Glacier RGO tongue advance, 2001-2008

March, 2007

Geographicheskogo Obschestva Glacier (RGO) –the most large surging glacier in the Pamirs (length 21,5 км, areaь 64,4 км2). At the end of XIX - the beginning of XX century the tongue of this glacier put forward in a valley of the Abdukagor river and formed there ice-dammed lake about 50 mln. m3 in volume. The emption of this lake had a catastrophic character. By the end of the last century the glacier had stepped back 2,5 km.

Some attributes of activization of the glacier were fixed in 2001, and since then constant air and space monitoring was conducted by Institute of Geography, RAS and Tajikgidromet.

The glacier surge continued to 2008. Common advance of the glacier tongue was 750-800 m. Now (summer of 2008) glacier advancing practically stopped, not reaching only 350 m the opposite slope of a valley of the Abdukagor river

In winter 2001/02 the ice-rock avalanche fall down to the surface of glacier tongue. However, now its influence was only in insulation the ice beneath it and decreasing the ice melting. Nevertheless, it is necessary to continue space monitoring as in case of continuation of advance the threat menace of dammed lake formation is remained.

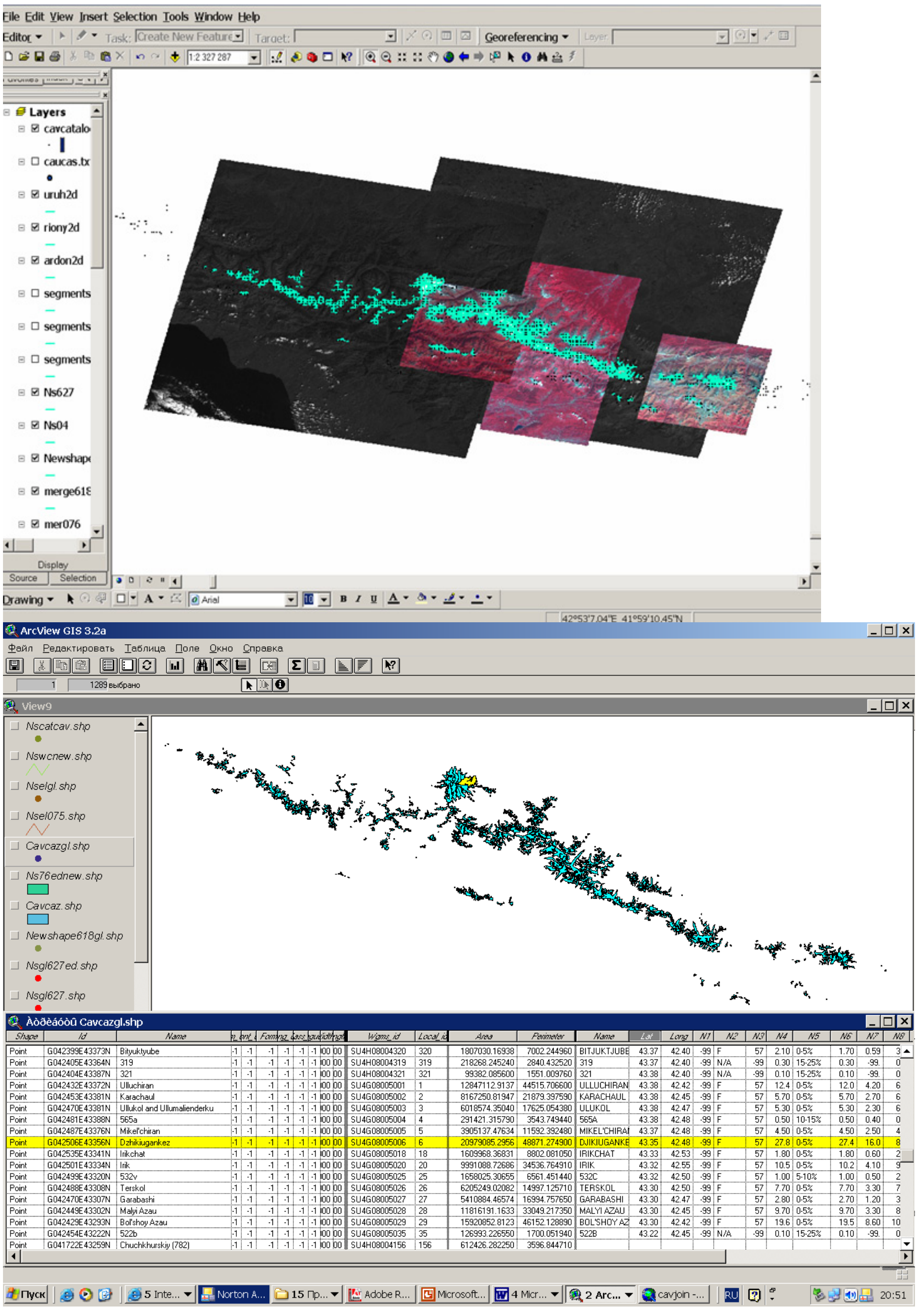
Glacier Response to the Recent Climate Change in the mountain regions: Caucasus, Pamir, Tien-Shan, Altai, Polar Urals, Suntar-Khayata, Cherskiy Range, Byrranga Mountains, Korayk Upland, Kamchatka.

The past century is marked by the global climate warming that set mankind thinking about the environment state and viable interconnections. Glaciers being dynamically unstable systems reveal rapid reaction on climate change manifested in the mass balance processes that is the snow accumulation on glaciers, the type of snow transformation to ice, the melt water and impurities run-off transformation. The glacier melting that saturates the soft till deposits with water leads to the high instability of moraine complexes. Glacier recession implies the landscape changes in the glacial zone, origin of new lakes and activation of natural disaster processes, catastrophic mudflows, ice avalanches, outburst floods, and etc. The presence of glaciers in itself threats to human life, economic activity and growing infrastructure. Economical and recreational human activity in mountain regions requires relevant information on snow and ice objects. Absence or inadequacy of such information results in financial and human losses. One of the major aims is to study the current trends in development of mountain glaciation of Northern Eurasia in conditions of global climate warming; definition of the role of local environment change, specifically in the origin of natural disastrous glacial processes. The unbiased assessment of current and future development of glaciers requires effective system of monitoring including ground-truth and aerospace studies. Decrease of instrumental series of ground observations and increase of remote sensing methods input brings up the actual problem of different information type management to create the mechanism of simultaneous analysis and assessment of glacier extent as a part of glacier monitoring system.

Results have been obtained from analysis of *Landsat* and *ASTER* images and the USSR Glacier Inventory for some regions of Northern Eurasia. The changes involve: a decrease in average size and volume of glaciers, glacier terminus retreat, the appearance of new glaciers after separation, the disappearance of former small glaciers, and moraine development on the glacier surface etc. All the examined glaciers have retreated since IGY (the middle of XX century). Glaciers lost mass through downwasting and retreating.

Caucasus glaciers

The total area for Caucasus glaciers in 1911, 1957 and 2000 was calculated. It was found out that the glacier area decreased from the beginning to the middle of the XX century on 24.7% and from the middle of the XX century to the beginning of the XXI century on 17.7%. For Elbrus glaciers we received 14.8% and 6.28% respectively. The analysis shows that the glacier retreat in Caucasus was faster during the first part of the XX century than during the second part.



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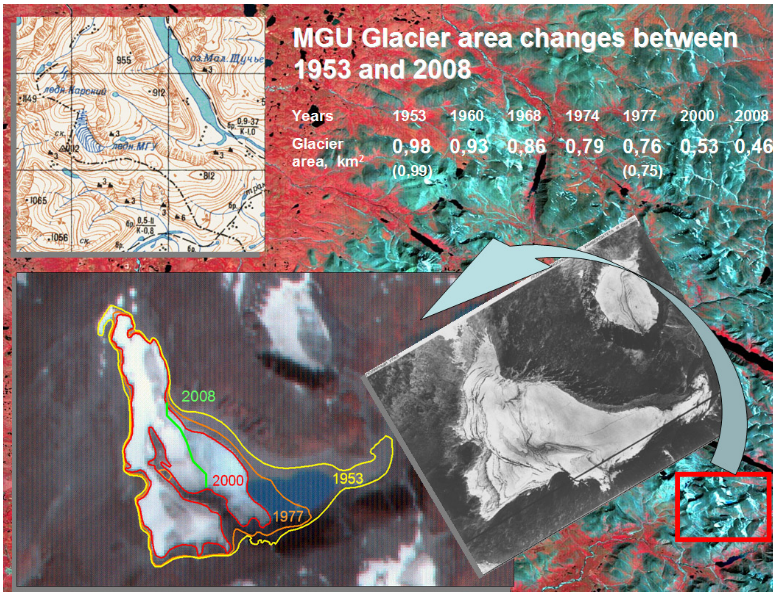
Glacier Response to the Recent Climate Change in the Polar Urals.

The wastage of the Polar Urals glaciers was comparatively slow between 1953 and 1981 but accelerated in the post-1981 period. This is in agreement with variations in the regional summer air temperatures. Both the NCEP/NCAR reanalysis data (Kalnay *et al*., 1996) and data from the regional weather stations indicate that negative temperature anomalies of about 2oC were observed in the late 1960s – early 1970s while a positive trend in the summer temperatures started in the late 1970s when the highest on record values of ablation were recorded. The acceleration of glacier retreat in the PU since the 1980s is also in agreement with assessments of glacier retreat rates in other mountainous regions of Eurasia.

The Polar Urals (PU) are positioned on the border between geographical Europe and Siberia. Their glaciated sector extends from 64°00N to 68.15°N. The elevations range mostly 600 m and 1200 m above the mean sea level (a.m.s.l.). PU is the support region of Russian Subarctic glacier monitoring system. In spite of the small sizes (up to 1 km^2) of present-day glaciers, the research of Polar Ural glaciers has fundamental scientific meaning for understanding of occurring climatic changes. Between the 1950s and 1980s, such surveys were conducted by the Russian Academy of Science. Continuous records of mass balance observations are available for IGAN, Obruchev, and MGU glaciers for the 1958-1981 period. Geodetic measurements of the extent of glaciers and changes in glacier surface elevations were conducted at regular intervals and the early results of these investigations have been summarised in the Catalogue of Glaciers of the USSR (1966). However, all measurements were discontinued in 1981.



Researches were carried out within the framework of projects of the Russian Foundation for Basic Research (RFBR), National Geographic and IPY 2007-2008. For quantitative estimations of reduction of the sizes of glaciers the data received during field works in 2005-2009 on PU glaciers and also results of processing of ASTER and Landsat space images within the framework of GLIMS project are used. Field works included DGPS surveys of changes in glacier surface elevation of selected glaciers and collection of the meteorological and mass balance data using automatic weather stations.

Results show the general and stable trend of glacier recession in the region. The range of recession of some cirque-valley glaciers reaches 56 per cent from their area. Analysis of meteorological conditions reveals that the summer air temperature rise by 3ºC in 1946-2005 is not compensated by increase of winter precipitation, and the glacier mass balance values are negative. Glacier recession proves the unfavorable combination of climatic factors for glacier health in the region. Contact: G. Nosenko[1]*: gnosenko@mail.ru - Institute of Geography, Russian Academy of Science*

Glaciers of the Pamir.

Analysis shows that during the last 30 years, glaciers of the Pamir have continued their recession. All the glaciers we lost area. Glacier area for the region analyzed decreased 7.8% over the interval 1978-1990 and 11.6% over1990-2001

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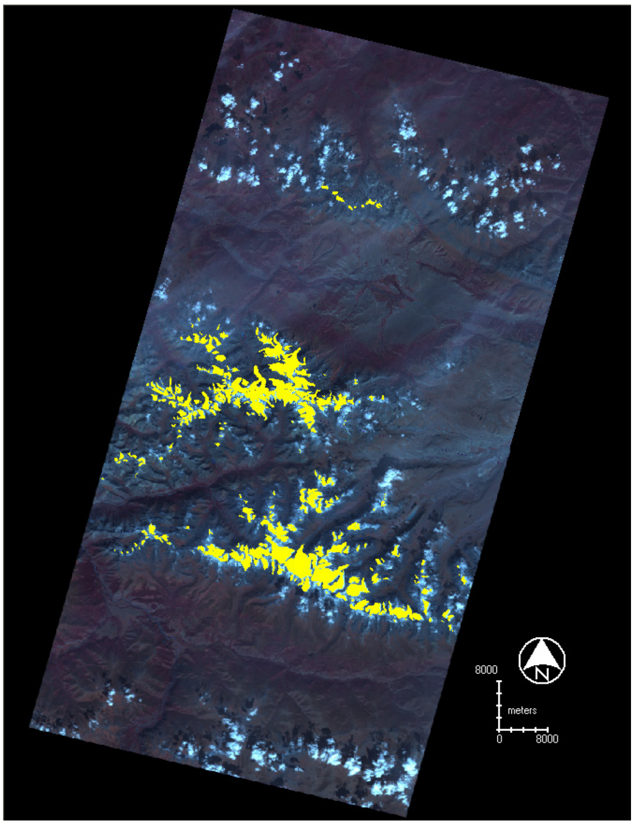
Altai

All glaciers of the North and South Chuya Ridges (Altai region) have retreated between the 1950s and 2004. Larger glaciers have separated from their tributaries and in the future this may accelerate their retreat. The glaciated area declined by19.7% of its 1950s value. The two main climatic factors, the ablation season's temperature and annual precipitation, drive glacier change in the Altai. Climatic warming began in the Russian Altai in the mid-1980s, which is later than in the mountainous regions of Eurasia located further west, e.g. in the Caucasus.



North and South Chuya Ridges on ASTER images 2004/09/10

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Siberia glaciers

Comparison analysis was applied for poorly explored mountain ranges of Suntar-Khayta and Chersky which surround wide elevated depressions famous for the low winter temperatures and sharply continental climate (The Pole of cold of Eurasia), Byrranga Mountains (Taimyr Peninsular) and Korayk Upland (Northern Far East).

The assessment for entire glaciers area change for Northeast Siberia are the follows: 19.3% for Suntar-Khayata (1945-2003) and 28% for Cherskiy Range (1970-2003).

Since 1967 to 2003 the total reduction of Byrranga Mountains glaciers is 17%. The shrinkage of the glaciers of the Koryak Upland (Northern Far East) is the largest- more than 50% since the inventory, 1950. The latter assessment is now under checking and validation.

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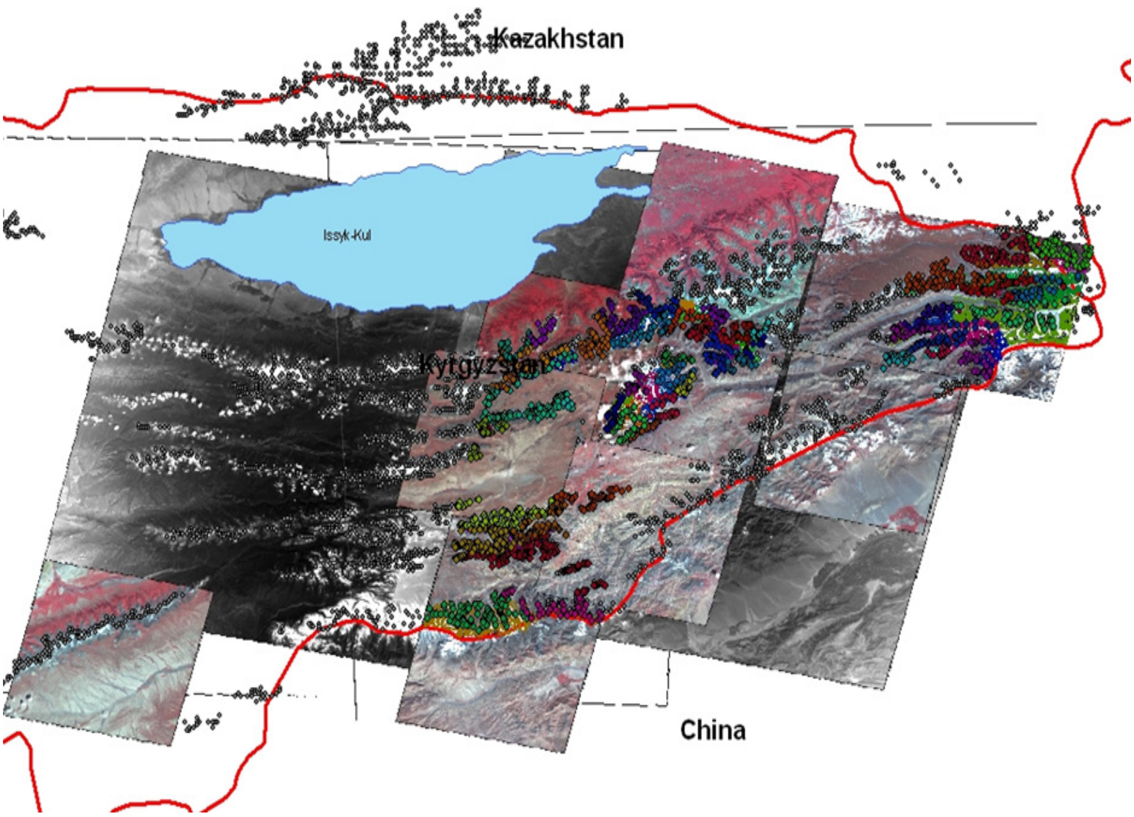
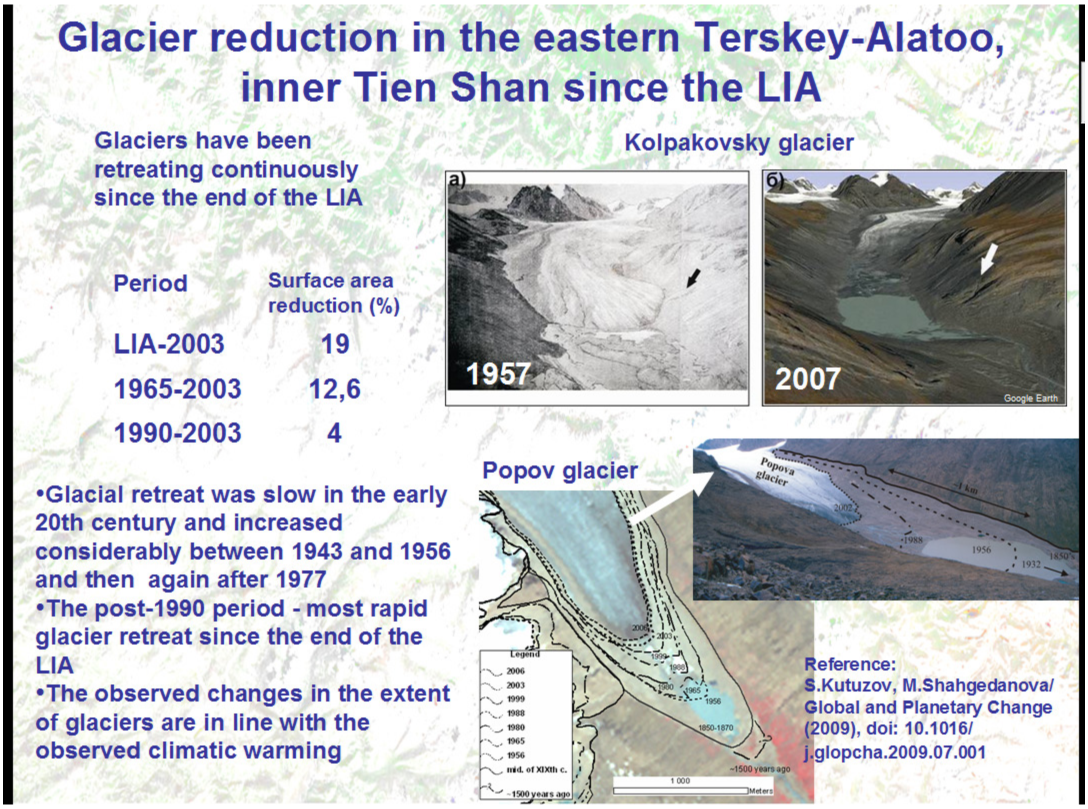
Tien Shan mountains

The retreat of the terminus of glaciers and loss of glacier areas from their maximum extend during the "Little Ice Age" maximum (LIA) (XVIIth-XIXth centuries) have been estimated using aerial photographs (from 1956 to 1987) and the latest satellite images (from 2001 to 2004) in the central Tien Shan mountains (Kyrgyz Republic). In order to increase the accuracy in the identification of the moraines at the satellite and aerial images, all kinds of published information about the front positions of glaciers in the end of XIX century was used. The glaciers under investigation are located on Teskey Alatau, Suek and Dzhetim-bel. There is a great diversity of types, exposure, and size of glaciers in the area. On average, the glaciers in these areas have retreated by 900-600 m since the LIA maximum. Thus in the second part of XXth century, glaciers area has changed by about 25-30% comparing with 5-8% between 1880 and 1970s.





Present warming is also the reason of structural changes of glaciers in addition to retreat of glaciers' terminus. Five shallow ice cores have been recovered from the summit of the Gregoriev Ice Cap (41.98 °N; 77.92°E; 4609 m a.s.l.) in Tien Shan, Central Asia, between 1990 and 2003. These ice cores have been dated on the base of set of reference horizons and annual microparticle concentrations. The detailed stratigraphic records for the top sections of the 1990 and 2001 cores indicate that 3.8 m of snow/firn accumulated in the 11 years. The mean annual net accumulation derived from this comparison is 0.35 m in ice equivalent (i.e.) (260 mm w.e.) for the period from 1990 to 2001. The net accumulation from 1963 to 1990 was 0.42 m i.e. (320 mm w.e.). Moreover decrease of firn pack depth from 9 to 6 m has been observed at 4450 m site between 1962 and 2003. Over the same period infiltration ice concentration has been increased as a result of more intensive melt water percolation. Considerable enrichment in stable isotope composition for the top section of the 1990 and 2003 ice cores has been measured. Considerable warming has been measured in boreholes drilled at 4450 m in 1962 and 2003. The temperature rise is ~2.5°C at the depth 10 m and 0.5°C at 30 m.

Unprecedented wastage and structural changes of glaciers in the Tien Shan from the mid- 1970s till the beginning of the XXI century most likely resulted from the increase of summer air temperature and decrease of summer precipitation witch have been recorded at the meteorological stations (the Tien-Shan station etc.). The change in atmospheric pressure over the central North Atlantic Ocean during the mid-1970s can be one of the possible reasons for these processes. This study is supported by ISTC grant nr. 2947

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Projection and reconstruction the glacier systems.

The method of projection and reconstruction the areas, altitudinal distribution and mass balance of glacier systems as a whole according the climate scenarios using calculation of ELA changes and altitudinal distribution of ice in a system by linear and non-linear hypotheses has been developed. Method is applied to 17 glacier regions, totally covered 1040 km^2 in the North-East Siberia and Kamchatka for a period 2040-2069 using ECHAM4.

The projected glacier systems changes are the follows: the upward shift of ELA is less in the northern parts of Northeast Siberia (230m as against 500m in the south), while in Kamchatka ELA change as a rule is greater and depends on precipitation rate. Our calculations also predict the disappearance of southern Orulgan and Suntar-Khayata glacier regions (NE Siberia) as well as some Kamchatka (Ichinsky volcano and others) systems (It happens when ELA shifts above mountains tops), while others (Kluchevskaya volcano) will preserve 70% of their present area. It will result in decrease of glaciated area coverage for NE Siberia regions from 250 to 55.4 km^2 (22% will be preserved) and for Kamchatka regions - from 786 to 242 km^2 (31% of preserved area) in total.

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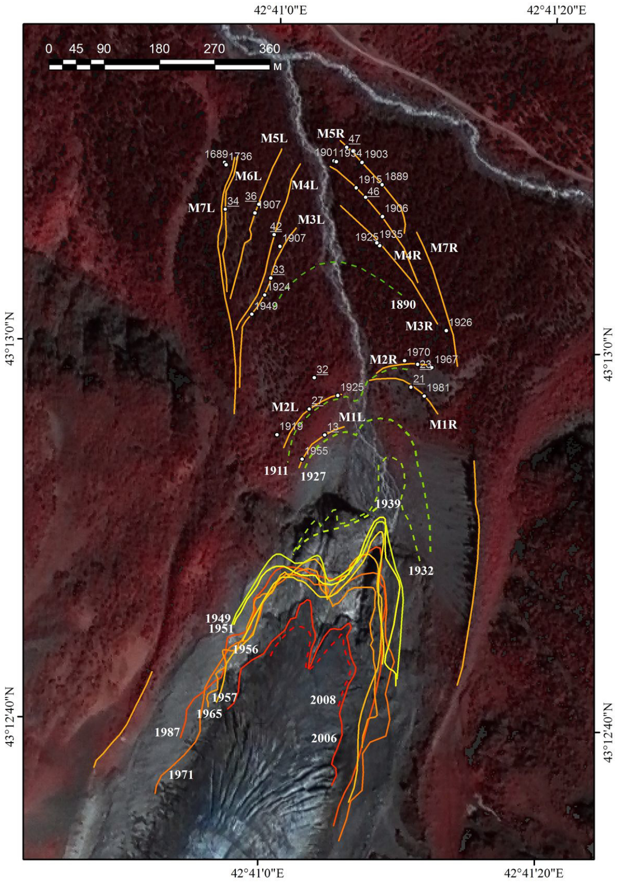
Fluctuations of Polar Urals Glaciers in the last centuries

Lichenomety was used to study fluctuations of 7 glaciers in the Polar Urals over the last millennium (viz: IGAN, Obruchev, Anuchin, Shumsky, Avsuk, Berg, and MGU glaciers). In order to estimate the growth rate of *Rhizocarpon* subgenus *Rhizocarpon* lichens we used recently deglaciated surfaces as calibration sites. These sites, on glacier forelands, were dated using topographic maps, aerial photographs (from 1953, 1958, 1960, 1968, 1973, 1989), terrestrial photogrammetry, field photographs (from the 1960s to 2005), and satellite images (from 2000 and 2008). We also used pits and quarries abandoned between the 1940s-1980s and a road built in the early 1980s. Optimum diametral growth rates of *Rhizocarpon* subgenus *Rhizocarpon* are estimated by the new curve to be ~0.25 mm/year for the last 100 years, assuming linear growth following the analogues growth curve in the Northern Sweden (Denton and Karlen, 1973). Due to the lack of old control points we used a reconstructed mass balance curve (from 1816-2008) to indirectly constrain the age of pre-20th-century moraines. The following moraine groups were identified near the modern fronts of glaciers: ablation moraines deglaciated during the last 40 to 60 years; lateral moraines formed in the early 20th century (DLL = 20 mm), ice-cored moraines, probably from the 1880s (DLL = 24 - 26 mm); moraines probably deposited in the middle of the 19th century and ca. 200 years ago (DLL = 30-33 mm and 44-47 mm, respectively); as well as several more ancient moraines (DLL = 70 mm, 90 mm and 110 - 153 mm) deposited during glacier advances of almost identical extent. According to our tentative lichenometric-age estimates most moraines were formed during the last 450 years – consistent with upper tree-limit altitude variations previously identified for this region. Glacier fluctuations in the Polar Urals are in agreement with tree-ring based reconstructions of summer temperature spanning the last millennium, and are also in tune with glacier behavior elsewhere in the Northern Hemisphere. **Full text in: Solomina, O.N., Ivanov, M.N and Bradwell, T., 2010: Lichenometric studies on moraines in the Polar Urals. Geogr. Ann., 92 A (1): 81–99.**

Fluctuations of Kashkatash Glacier during the last four centuries (Elbrus Area, Nothern Caucasus, Russia)

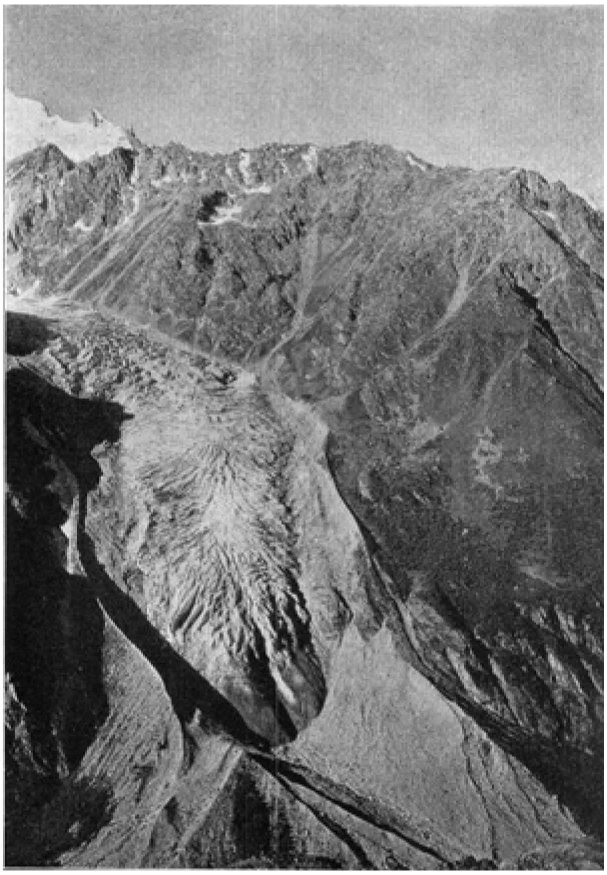
Like most mountain glaciers those in the Caucasus are currently retreating, although this process is rather poorly documented in this area. We focused our study on the retreat of a typical valley glacier Kashkatash (43,18 N, 42,7 E; area - 2,5 km^2; length - 4,6 km, front elevation - 2600 m), located in the Elbrus Area. We compared the oldest high quality photograph of the glacier forefields, taken by H. Burmester (1913) in 1911 (fig.1) with the aerial photographs of 1957, 1965, 1987, map of scale 1:25 000 based on the data of 1950s, satellite images (Corona of 1971, ASTER of 2005, EROS+ASTER of 2006) and oblique photographs taken in 1990s-2000s (fig.2). We estimated the linear glacier retreat and the age of numerous stadial moraines over the last centuries basing on geomorphic, tree-ring and lichenometric data and discussed our results in the context of previous sparse glacier fluctuation reconstructions in this region (Serebryanny et al., 1989; Solomina, 1999, Zolotarev, 2008). For this purpose we first georeferenced and digitized the map of Kashkatash glacier tongue and forefields, created DEM and made orthorectification of the aerial photographs (using the DEM). The accuracy of our georeferencing is limited by GPS capacity (15 meters). Lichonometry was quite successfully used to date moraines in the central Caucasus since 1980s (Serebryanny et al., 1989) due to quite regular growth rate of

Rhizocarpon geographicum (sensu lato) anda number of reference points controlling the growth curve for the last millennium. We used traditional lichenometric approach measuring the maximum diameters of these lichens on the whole surface of each moraine and using the mean of five largest diameters as the predictor of the age of moraines. More than 100 samples of pine (cores and disks) collected in summers 2008, 2009 and cross-dated against the regional pine ring-width chronology were used to estimate the minimum age of moraines and the rate of wood colonization of the glacier forefields. We identified several end moraines at Kashkatash glacier within the distance of 900 meters from the front position of the glacier in 2005. The minimum age of the outer moraine is at least 450 years according to the tree-ring data. This moraine is adjacent to one of the most prominent end moraine deposited in the middle of the 18th century. This date is based on the age of the oldest tree (AD1803) plus five years correction for the height of the sampling, plus approximately 50 years of excesis – time required for colonization estimated by the modern aerial photographs in Baksan valley. The position of the moraine of the middle 19th century shows that the glacier was approximately 80 meters shorter than a century before. We identified the moraine of the 19th century at the photograph of 1911 as well as 3 to 4 younger moraine ridges. At this photograph all of them look very fresh and they are totally lacking any vegetation (fig.2). If we take into account the modern rate of moraine colonization the freshness of moraine surfaces indicates that all these advances of Kashkatash glacier occurred between 1850s and 1911. This conclusion agrees well with the Bolshoy Azau glacier advances occurred in 1876, 1880-1881, 1884, 1890 and described by the first travelers (Bogatikov et al., 2004). These dates also agree well with our tree-ring data. In the late 19th to the early 20th centuries the retreat of the glacier was most dramatic (approximately 400 meters). However Kashkatash glacier was almost stable between 1911 and 1957, and it retreated from these positions by 100 meters by 2005. The comparison of aerial photograph and space images also shows that up to the middle of 20th century only very sparse vegetation occupied glacier forefield. Dramatic changes happened in the last 50 years while the whole surface of the sandur and young moraines is covered now by a dense pine wood. The increased rate of glacier retreat and plant colonization of the forefields agrees well with the global warming trends in the second half of 20th century.



Forefields of Kashkatach glacier and positions of the moraines. Regular font without underscore is used for the minimum tree-ring dates (without correction), regular font with underscore – maximum diameters of *Rhizocarpon geographicum sensu lato.* In bold – the numbers of lateral left (L) and right (R) side moraines.

Fig.1 Fig.2



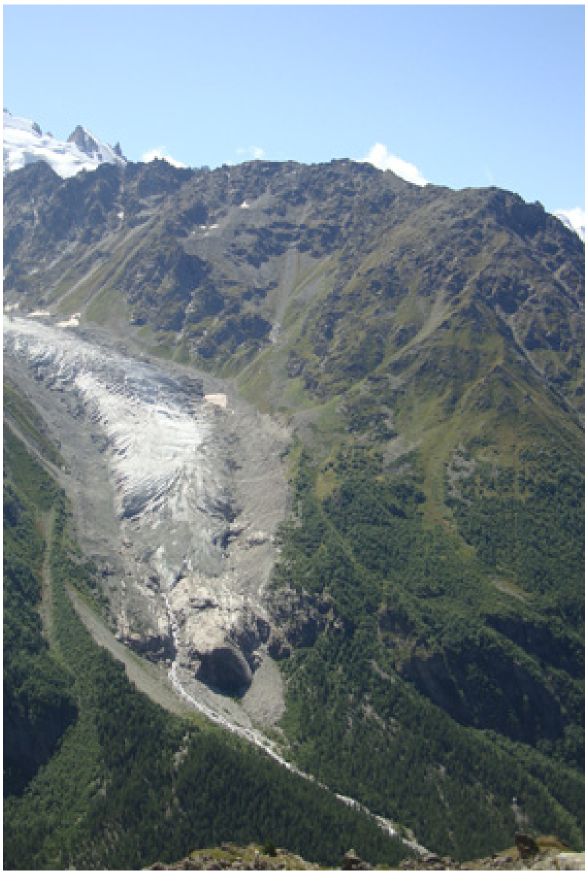
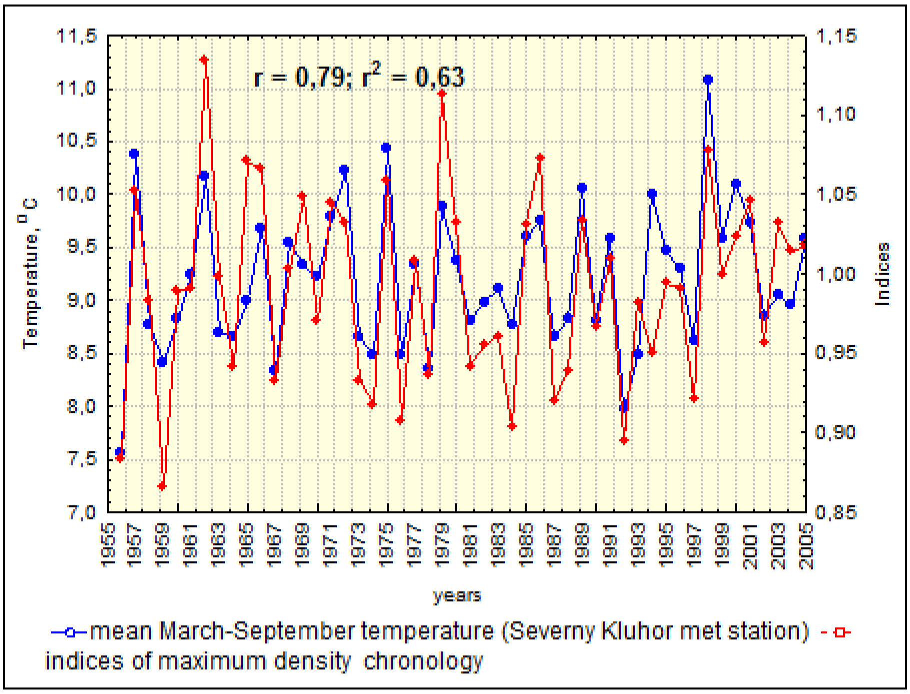


Photo by Burmester (1911) Photo by Bushueva (2009)

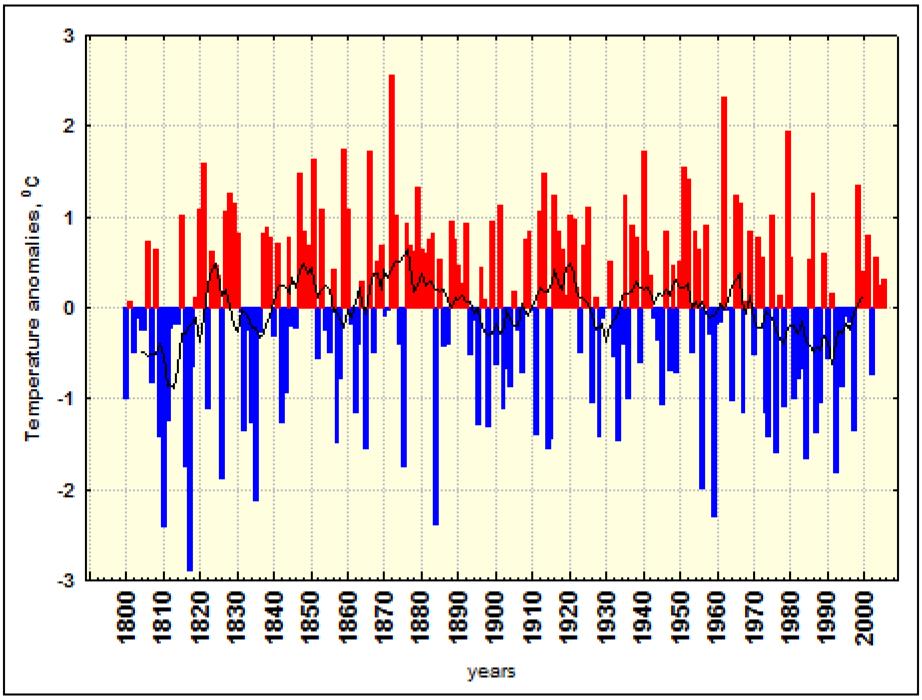
Contacts. Irina Bushueva and Olga Solomina. Institute of Geography Russian Academy of Science

The first quantitative warm period temperature reconstruction in the caucasus mountains derived from tree-ring data

Here we present the first temperature reconstruction of vegetation period (March-September) in the Caucasus Mountains derived from tree-ring data. The material (Pinus sylvestris (L.) was collected from upper-tree limit (2200-2400 m a.s.l.) in the Teberda river valley. Optical density measurements of resin-extracted samples were obtained by using flat-bed scanner and commercially available software. Final maximum density (MXD) chronology covers the period AD1759-2005 and includes 43 tree-ring series. The EPS (> 0.85) indicates that the chronology is reliable and can be used for the reconstruction from AD1800. The nearest meteorological station Severny Kluhor is located at the altitude of 2042 m a.s.l. and represents climatic conditions close to the tree-line. The MXD chronology indices show a positive correlation ($r=0.8$; $p<0.05$) with March-September mean temperature. The calibration model explains 63% of variance in the instrumental climate records (1956-2005). According to our reconstruction the coolest summer in the Caucasus occurred in the year AD1817 (2-years lag response to Tambora eruption). The reconstructed temperature correlates with the Piatigorsk met.station records (1891-1997) which is located at the altitude of 500 m a.s.l., more than 200 km away from our site. This correlation means that the reconstruction verifies well for a century long period and is valid to assess not only the local but also the regional warm period temperature variations.



Mean March-September temperature of "Severny Kluhor" met station and indices of MXD pine chronology with the coefficient of correlation.



Reconstructed March-September temperature anomalies for the period of AD1800-2005 based on tree-ring data.

Contacts. E. Dolgova, O. Solomina. Institute of Geography RAS

Teberda valley runoff variability (AD 1850–2005) based on tree-ring reconstruction (Northern Caucasus, Russia)

Seven tree-ring chronologies are used to reconstruct Teberda river (Northern Caucasus, Russia) smoothed runoff for May, July and August. Six chronologies were developed from *Pinus sylvestris* and one from *Abies nordmanniana.* Tree growth is significantly, but weakly, correlated with maximum temperatures (negatively) and relative humidity (positively) during summer.All possible combinations of seven predictors were tried to get the best result on the cross-validation. Two of three reconstructions showed high wavelet coherence with instrumental data on decadal timescales and were analysed for spectrum stability. Minima of moving trends at the end of the reconstructions along with weakening of decadal cycles may be a marker of significant change of Teberda river hydrological regime during the second half of the 20th century.

1. Introduction

Teberda river is a tributary of Kuban' (Azov Sea basin), the largest river of Krasnodarskiy Kray, an important agricultural region of the Russian South. Teberda is 60 km long with the watershed surface equal to 1080 km^2, mean watershed altitude is 2210 m. 55.8% of Teberda river's runoff (measured at Teberda hydrological station) is provided by snow and ice melt. 60% of runoff occurs in summer, 17% – in the fall, 5% – in winter, 18% – in spring. Mean annual water discharge is 26.8 m^3/sec [1]. Teberda monthly runoff correlates with spring temperature (up to 0.62 for April) and with autumn precipitation (up to 0.72 for October). Significant negative trends were identified both in summer and full year runoff for AD 1927-2005. Extending instrumental observations into the past is essential for understanding of the runoff long-term variability and response to changing climate.

2. Materials and methods

2.1. Tree-ring data

The study area is located in the Caucasus Mts. at the territory of Teberda Biosphere reserve and Elbrus National Park. The current timberline of Scots pines (*Pinus sylvestris L.*) rises up to the elevation of 2500-2700, depending on the slope orientation and local environmental conditions. Tree ring samples (cores) were collected from nine sites in the vicinity of the upper-tree limit (from 2200 to 2500 m a.s.l.) and at glacier's forefields. Location of these sites are shown on the figure 1.

Living trees of Scots pine (*Pinus sylvestris L.)* and fir (*Abies nordmanniana (Stev.) Spach*) were sampled according to standard dendroclimatological principles and conventions [2], [3]. LINTAB equipment was used for measuring of the annual ring-width with precision of 0.01 mm. To cross-date tree-ring series and for graphical comparison we used Rinntech TSAP 0.53 software. To cross-date, check for missing rings or dating errors COFECHA software was used [4]. Samples that showed low correlation (<0.33) with master-chronology were excluded from the analysis. The final dataset comprised 145 tree-ring series.

We used program ARSTAN software [5] for developing the chronologies. Tree-ring series were standardized using a conservative procedure to maintain in the series as much low-frequency variance as possible. Negative exponential or linear curves were used for removing the non-climatic signals.

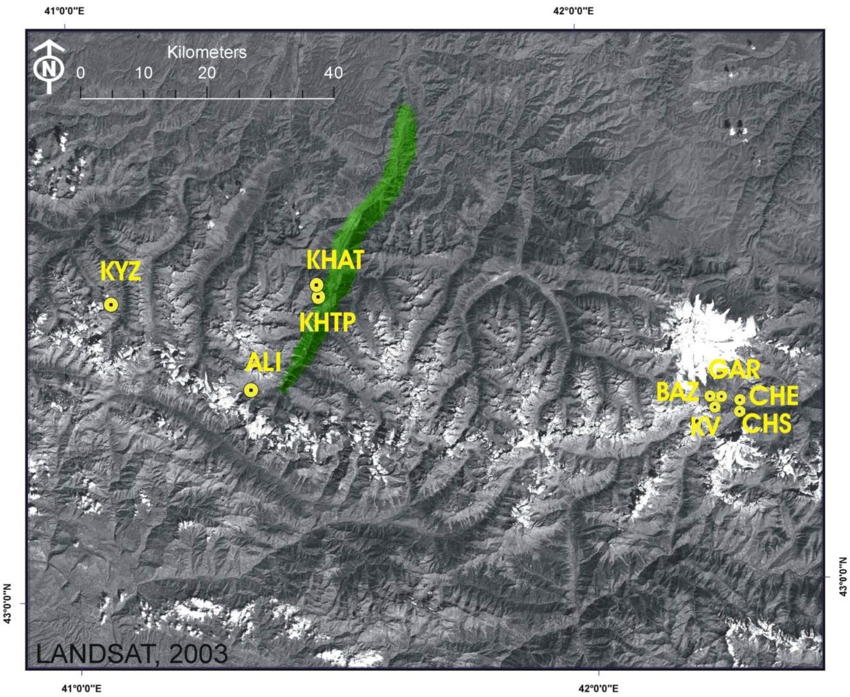


Figure 1. Tree-ring sites (yellow) and Teberda river valley (green). Elbrus mount (white) is clearly seen at the right side of the figure.

The ability of each chronology to represent the ideal population signal was assessed using the mean between-tree correlation and the expressed population signal (EPS) statistics [6].

2.2. Runoff data

Monthly values of Teberda river runoff at Teberda hydrological station for AD 1927-2005, corrected for nonstationarity were provided by Teberda Biosphere reserve. They contain missing values from August of 1941 to December of 1947 and from January of 1971 to January of 1972.

2.3. Methods

We built principal component chronology to extract a common climatic signal from our local chronologies. It showed the strongest response to climatic variability (calculations in Dendroclim2002 [7]), correlating negatively with May-July maximum temperature and positively with May-July relative humidity. A significant correlation (at 99.9% confidence level) is identified between PC chronology indices and July Teberda river runoff (r=0.41). But none of the chronologies showed really strong response to any individual climatic variable. However, the absence of a strong linear correlation with a single climate variable does not mean that tree-growth in this region is not sensitive to climate [8].This suggests more complex tree-climate relationships, but this complexity shouldn't stop our efforts to get as much as possible from determined connections.

We used principle component regression [9] to generate the runoff reconstruction models, separately for each month and for the full year. Seven standard chronologies that are listed below were used as predictors. To determine the best set of predictors, all possible combinations were tried and the set, that showed maximum R^2 statistics on leave-one-out cross-validation, was chosen.

Wavelet coherence analysis [10] was applied to determine common properties of instrumental and reconstructed data. Continuous wavelet transform with the Morlet base wavelet [11] was used for analysis of spectral characteristics of reconstructions through time.

Significance of all trends was tested under the assumption of signal as trend plus AR(1) noise.

Missing values of instrumental runoff data were ignored in all the analyses.

3. Results

3.1. Chronologies

We developed 6 pine (KHTP, KV, KYZ, CHS, GAZ and BAZ) and 1 fir (ALI) ring-width chronologies. KHTP chronology consists of samples from KHTP and KHAT sites, CHS chronology consists of samples from CHS and CHE sites (figure 1). Commonly used statistics such as standard deviation, first order autocorrelation, mean sensitivity that is a measure of the relative difference in width between consecutive rings [2] are listed in table 1. All the chronologies are characterized by relatively low mean sensitivity and high autocorrelation.

3.2. Reconstructions

Annual reconstructions showed unreliable results on cross-validation that's why we smoothed reconstructed series with 10-years moving average filter. Three of thirteen smoothed reconstructions (for each month and for the full year) showed R^2 higher then 0.6 on cross-validation. They are: May runoff (the best set of predictors is ALI, BAZ, CHS and KHAT, R^2=0.6487), July runoff (ALI, BAZ and KHAT, R^2=0.6567) and August runoff (ALI, CHS and

KHAT, R^2=0.6615) (figure 2a). During these months occurs 12%, 22% and 17% of annual runoff correspondingly (according to instrumental records), all together more than a half. We considered only those parts of the reconstructions, for which EPS of all chronologies-predictors is higher than 0.8. So, in all the cases, ALI chronology limited them to AD 1850.

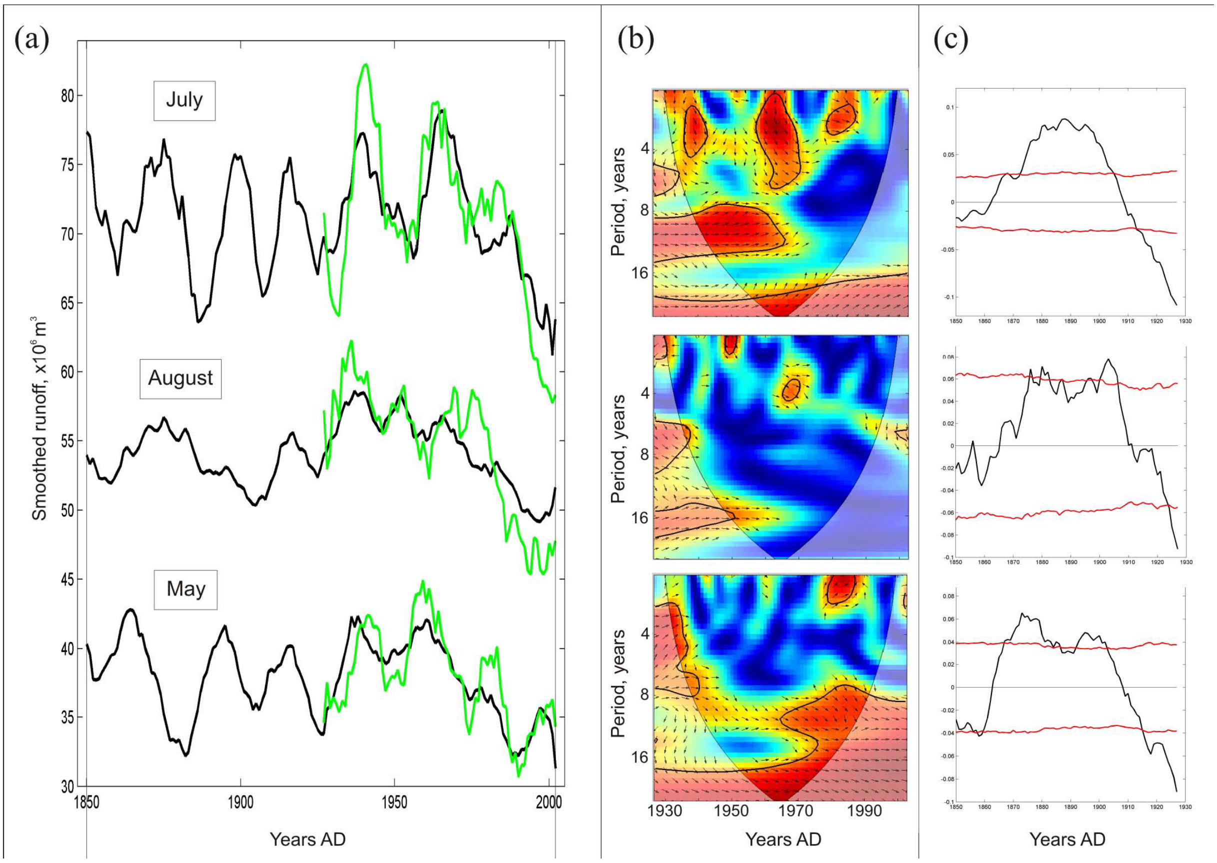
Wavelet coherence analysis was applied to instrumental and reconstructed (not smoothed) data to estimate the ability of reconstruction to reproduce low-frequency variations. May and July reconstructions showed strong and stable coherence with instrumental records on periods more than 25 years, August reconstruction didn't (figure 2b).

Table 1. Tree-ring chronologies statistics.

Site name	KYZ	KV	KHTP	GAR	CHS	BAZ	ALI
First year	1550	1640	1678	1693	1738	1660	1800
Last year	2006	2002	2005	2002	2002	2004	2005
Cores (trees)	20 (10)	8 (4)	57 (29)	13 (7)	15 (8)	18 (11)	24 (13)
Inter-series correlation	0.649	0.551	0.507	0.614	0.526	0.436	0.282
Standard deviation	0.221	0.176	0.221	0.221	0148	0.140	0.125
Mean sensitivity	0.157	0.125	0.155	0.128	0.110	0.119	0.118
1^{st} order autocorrelation	0.648	0.550	0.505	0.612	0.524	0.435	0.282
Mean segment length	227	283	175	160	160	233	114
EPS > 0.8	1797	1863	1752	1939	1833	1768	1850

Two of three reconstructions and sum of three reconstructed months rich their minimum values in 1997 (ignoring last 5 years because of 10-years smoothing). May's reconstruction has the second lowest value in 1990.

Continuous wavelet transform for May and July reconstructions (not smoothed) (figure 2d) both show weakening of low frequency cycles (16 to 32 years periods) for the years after AD 1927 comparing to the previous years. We didn't perform wavelet analysis for August reconstruction because of weak wavelet coherence of reconstructed and instrumental data. For wavelet spectra diagrams watery colors show the cone of influence, black border shows regions of greater than 95% confidence for red-noise process.



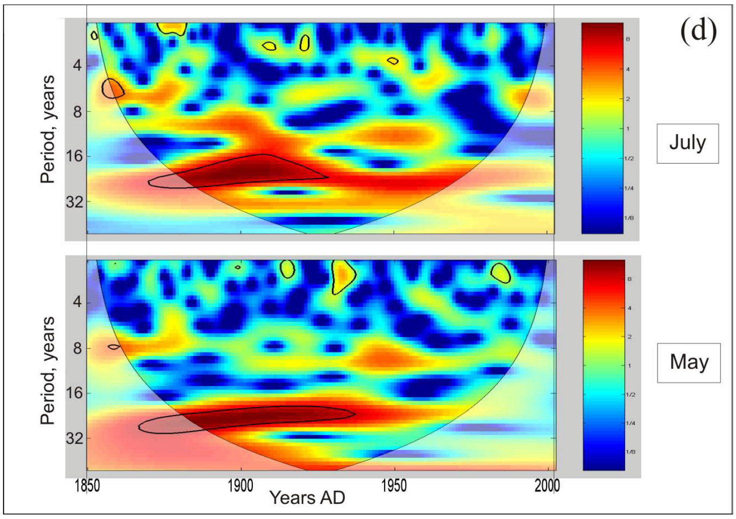


Figure 2. (a) Smoothed instrumental runoff (green) and its reconstruction (black). **(b)** Wavelet coherence of instrumental and reconstructed runoff, AD 1927-2002. **(c)** Moving trends of the reconstructed runoff (76 years window), AD 1850-2002. Year corresponds to the first year of the window. For (a), (b) and (c) the upper picture refers to July, middle to August and the lower to May.
(d) Continuous wavelet transform of the reconstructed runoff.

3.3. Trends

Runoff of all three months (May, July and August) as well as full year's runoff have significant negative trends for the period AD 1927-2005, with values -0.063, -0.140, -0.165 and -0.429 $x10^6$ m^3/year correspondingly.

We calculated moving trends for our three reconstructions (without smoothing) and for their sum for AD 1850-2002 in 76 years moving window. The years on the plots correspond to the left side of the window, namely 1850 means years from 1850 to 1925 (figure 2c). All trends showed their minimum values for the last window (AD 1927-2002). Trends for other moving windows (60, 50 and 40 years, not shown) sometimes have minimum values in another (not last) window, but not more than for one reconstruction for each window. Sum of the reconstructions showed its minimum in the last window in all the cases.

4. Discussion and summary

Although we didn't create annually resolved quantitative reconstructions of Teberda river runoff because of insufficient correlation between tree growth and hydrological parameters, our smoothed reconstruction of May, July and August runoff can tell much about low-frequency variations of these parameters.

Almost all explored characteristics, such as trends, spectra and smoothed values of the series have minima near the end of the reconstructions. These extremes along with weakening of decadal cycles may be a marker of significant change of Teberda river hydrological regime.

We made our reconstructions only back to AD 1850 yet some of our chronologies begin in 16th century. Adding new samples to these chronologies will increase common signal and let us extend our reconstructions into the past.

References

[1] Lurye P M, Panov V D and Tkachenko Yu Yu 2005 *Kuban' river: hydrography and runoff regime* (in russian) (Sankt-Petersburg: Hydrometeoizdat)

[2] Fritts H C 1976 *Tree Rings and Climate* (London: Academic Press)

[3] Cook E R and Kairiukstis L A 1990 *Methods of Dendrochronology: applications in the environmental sciences* (Dordrecht: Kluwer)

[4] Holmes R L 1983 Computer-assisted quality control in tree-ring dating and measurement *Tree-Ring Bulletin* **43** 69-78

[5] Cook E R and Holmes RL 1984 *Program ARSTAN and Users Manual* (NY: Lamont Doherty Geological Observatory)

[6] Wigley T M L, Briffa K R and Jones P D 1984 On the average value of correlated time series, with applications in dendroclimatology and hydrometeorology. *J. Climate Appl. Meteor.* **23** 201–13

[7] Biondi F and Waikul K 2004 DENDROCLIM2002: A C++ program for statistical calibration of climate signals in tree-ring chronologies *Computers & Geosciences* **30** 303–11

[8] George S S, Meko D M and Evans M N 2008 Regional tree growth and inferred summer climate in the Winnipeg River basin, Canada, since AD 1783 *Quat. Res.* **70** 158–72

[9] Aivazyan S A, Yenyukov I S and Meshalkin L D 1985 *Applied statistics. Study of relationships* (in russian) (Moscow: Finansy i Statistika)

[10] Grinsted A, Moore J and Jevrejeva S 2004 Application of the cross wavelet transform and wavelet coherence to geophysical time series *Nonlinear Processes in Geophysics* **11** **5/6** 561-6

[11] Torrence C and Compo G P 1998 A practical guide to wavelet analysis *Bull. Amer. Met. Soc.* **79** **1** 61–78

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Last millennium glacier variations and four centuries climate change in Elbrus area, Caucasus, Russian Federation

Moraines of Elbrus area were studied using tree-ring analysis and lichenometry. Six new control points for *Rhizocarpon* section *Rhizocarpon* obtained in 2004 on the moraines of Baksan valley, agree in general with the data reported previously by Serebryanny et al. (1984) and Seinova & Zolotarev (2001). We propose a new version of the growth curve, based on 55 surfaces ranging from 3 to 700 years old, which is valid for Ebrus area as well as for Central Caucasus (FIG). Although there are three control points older than 700 years, they contradict each other and are not used so far for the growth curve construction. than 700 years, they contradict each other and are not used so far for the growth curve construction. The oldest one reported Serebryanny et al. (1984) for the moraine of Khalde glacier (3360+/- 90 ^{14}Cyears BP) is probably too old to be used for lichenometry (FIG). We also applied an alternative approach for growth curve construction based on a combination of extreme value theory and Bayesian theory (FIG.) (Naveau et al., 2005, Jomelli, et al., 2005; Cooley et al., 2005), in order to estimate correctly the standard error of the lichenometric dates. We used the new growth curves to re-estimate the age of moraines of Elbrus area and provide the statistical error estimates of the datings.Minimum tree-ring dates were obtained for several moraines of Bolshoy Azau, Terskol and Schkhelda glaciers. The tree-ring dates of moraines of Terskol glacier (1800s, 1850s and 1880s) are in a good agreement with the lichenometric and historical data. The age of the oldest trees growing on an end moraine of Bolshoy Azau glacier (AD1614) brings evidence that the older lateral moraine, which terminates at the lower elevation and was previously dated as 17th century (Tushinsky, 1958, 1963; Baume et al., 1998) is in fact older than 17th century and most probably even older than 13th century, judging by the lichenometric age of the end moraine mentioned above.Temperature sensitive, well-replicated ring width pine chronology (1614-2004) was constructed using the trees growing on the floor of Bolshoy Azau valley in the vicinity of the glacier to estimate climatic changes in the area during the last four centuries.

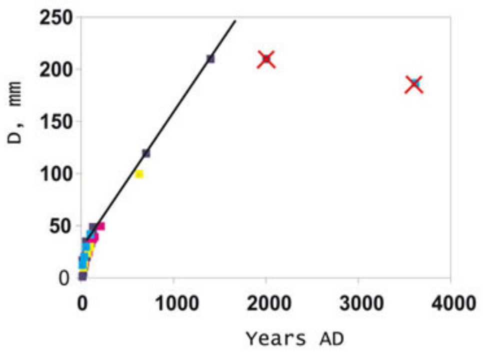


Fig. 1

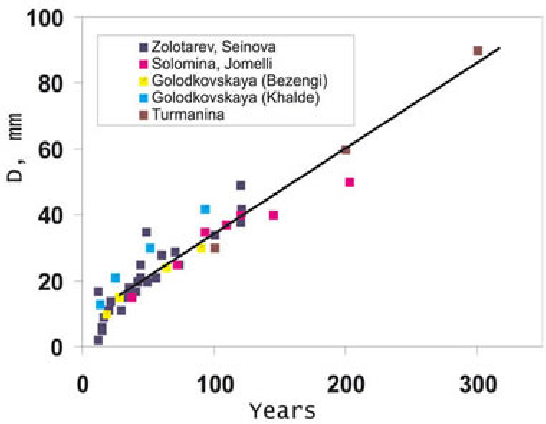
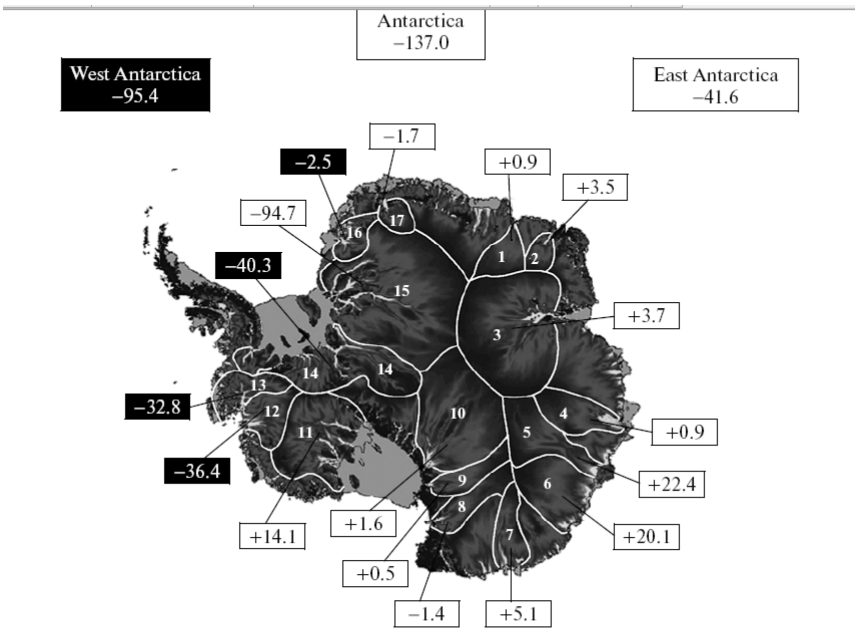


Fig. 2

In cooperation withVincent Jomelli[2], Zolotarev[3], Irina Seinova[4], Natalia Volodicheva[3] and Aleksandr Oleinikov[3].[1]Institute of Geography RAS, Moscow, Russia; [2] CNRS-IRD GREAT ICE MSE, Montpellier, France; [3] Moscow State University, Russia

Changes in the Mass Balance of the Antarctic Ice Sheet over 50 Years

The mass balance of the Antarctic Ice Sheet has been calculated based on instrumental estimates of the grounded ice discharge and snow accumulation data. The boundaries and sectional areas of the main ice catchment basins in West and East Antarctica have been determined, and the data on the grounded ice discharge and snow accumulation in these basins have been systematized. The intensity of accumulation and ablation processes in Antarctica has noticeably increased over the last 50 years. The mass balance of the ice sheet in East Antarctica has been and remains positive, while in West Antarctica it was positive in the middle of the last century and has become negative by now. The mass balance of the entire Antarctic Ice Sheet has been and remains positive, while the mass growth has noticeably decreased over the last 50 years.



Changes in the mass balance of the examined ice catchment basin of the Antarctic Ice Sheet over the last 50 years. The figures in the rectangles are the values of the changes in km3; + or – denote the change tendency. The color denotes the present day status of the mass balance: black is negative, and white, positive. The examined ice catchment basins are the following: (*1*) Shirase, (*2*) Rayner, (*3*) Lambert, (*4*) Denman and Scott, (*5*) Totten, (*6*) Power and Frost, (*7*)

Mertz and Ninnis, (*8*) David, (*9*) Malloch, (*10*) Byrd, (*11*) Ross, (*12*) Thwaites, (*13*) Pine Island, (*14*) Western part of the Weddell Basin, (*15*) Eastern part of the Weddell Basin, (*16*) Stancomb_Wills, (*17*) Jutulstraumen.

Sectional areas, accumulations, and grounded ice discharges of the examined ice catchment basins in Antarctica

Ice catchment basin	Sectional area (ths. km^2	Accumulation (km^3/year)		Discharge (km^3/year)	
		mid 20th century	first decade of 21st century	mid 20th century	first decade of 21st century
East Antarctica					
Eastern part of the Weddell Basin	1530.2	166.5	97.0	53.9	79.1
Stancomb-Wills	99.9	18.6	17.1	16.6	17.6
Jutulstraumen	122.5	17.5	16.7	12.5	13.4
Shirase	195.7	18.6	28.2	12.5	21.2
Rayner	167.2	15.9	24.1	10.2	14.9
Lambert	953.7	41.1	62.8	39.5	57.5
Denman and Scott	203.6	36.5	50.8	30.6	44.0
Totten	547	83.1	119.9	52.1	66.5
Power and Frost	355	54.0	78.6	33.8	38.3
Mertz and Ninnis	253.7	35.0	48.7	35.2	43.8
David	265	29.6	35.8	9.9	17.5
Malloch	115	8.5	10.2	5.6	6.8
Byrd	1070.4	59.9	60.3	31.5	30.3
Subtotal	5878.9	584.8	650.2	343.9	450.9
West Antarctica					
Pine Island	162.3	64.1	74.2	47.0	89.9
Thwaites	115	65.1	61.3	64.5	97.1
Ross	720.9	92.9	111.0	75.8	79.8
Western part of the Weddell Basin	558.6	109.5	127.0	87.6	145.4
Subtotal	1556.8	331.6	373.5	274.9	412.2
Antarctica as a whole	7435.7	916.4	1023.7	618.8	863.1

V. M. Kotlyakov, M. Yu. Moskalevskiy, and L. N. Vasil'ev. *ISSN 1028_334X, Doklady Earth Sciences, 2011, Vol. 438, Part 1, pp. 686–689.* © *Pleiades Publishing, Ltd., 2011.*
Original Russian Text © V.M. Kotlyakov, M.Yu. Moskalevskiy, L.N. Vasil'ev, 2011, published in Doklady Akademii Nauk, 2011, Vol. 438, No. 2, pp. 263–266.

Remote sensing database of Antarctic Ice Sheet marginal zone

The goal of the project is to develop a remote sensing database of Antarctic Ice Sheet marginal zone against a background of climate change as a base of GIS to model this unique natural object, its reaction on climatic changes and a contribution to sea level rise. The topicality of the project consists in the creation of the united data base for remote sensing data of all types classified by wave bands, density of information and main morphological regions of Antarctic Ice Sheet marginal zone together with results of direct instrumental geodetic and glaciological studies and meteo data of coastal and island stations. It allows to extend time frames of information for Antarctic Ice Sheet marginal zone change estimation and to correlate the glacier and climate dynamics. During the project the structure and content of the data base has been developed; an inventory of information of different types has been done; an optimization of data input technology has been carried out and the process of information input into data base has been organized; algorithms of images of visible range and maps processing for studies of Antarctic Ice Sheet marginal zone dynamic have been developed; the basis cartographic database has been developed; several sources of spatial information have been analyzed, methods of incorporation these data sources into database have been developed and realized. All this information exists now in database as a set of ARCGIS coverages in vector and raster formats. Such a way of data arrangement allows to analyze any set of coverages at the same time and also allows to put new information into data base on-the- fly and plan field studies. The database of ground base, remote sensing and meteo information for ice drainage basins II, III, IV, V and VI has been formed. These data were analyzed together with information on ice movement, sheet marginal zone dynamic and accumulation. It was found out that the mass balance of these basins was positive for all period of instrumental observations.

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Snow and Avalanches

Snow accumulation over northern Eurasia

Snow accumulation over northern Eurasia was studied using 283 February mean snow depth time series (1936–2001), interpolated into 5 x 5° grid points, from the former Soviet Union, Finland and Norway. Results of EOF analysis and correlation with Northern Hemisphere teleconnection patterns for the 700 hPa height revealed that atmospheric circulation significantly influences the spatial variability of snow accumulation over northern Eurasia. The PC1 describes snow depth variation over the major portion of the territory to the north from 55–60 °N between the White Sea and the Lena river basin, and is positively correlated with PNA, NAO and POL indices, and negatively with SCAND. Besides that, the PC1 demonstrates very close correlation to wintertime surface air temperature, averaged for the former USSR territory. Multiple stepwise backward regression, applied for 1951–1974 and 1975–2001, implies that in the first subperiod, the leading role in snow depth variability belongs to Scand. During 1975–2001, SCAND passed over its prevalence to NAO. Similar analysis applied to temperature shows that the general features are the same: in the last 25 years SCAND passed over the leading role to NAO. The PC2 describes quasi-decadal snow depth variability over the East European plain. Increased (decreased) snow accumulation in these regions is associated with negative/positive phase of NAO and POL. The pattern of PC2 seems to be demonstrating the linkage between snow accumulation in East Europe and wintertime surface air temperature since 1975. For the Baltic and White Sea coasts, Fennoscandia and central regions of the East European plain, decrease of snow accumulation related to positive NAO phase is likely to be caused by mild winters with enhanced snow melting and larger fraction of liquid precipitation (Popova, 2007).

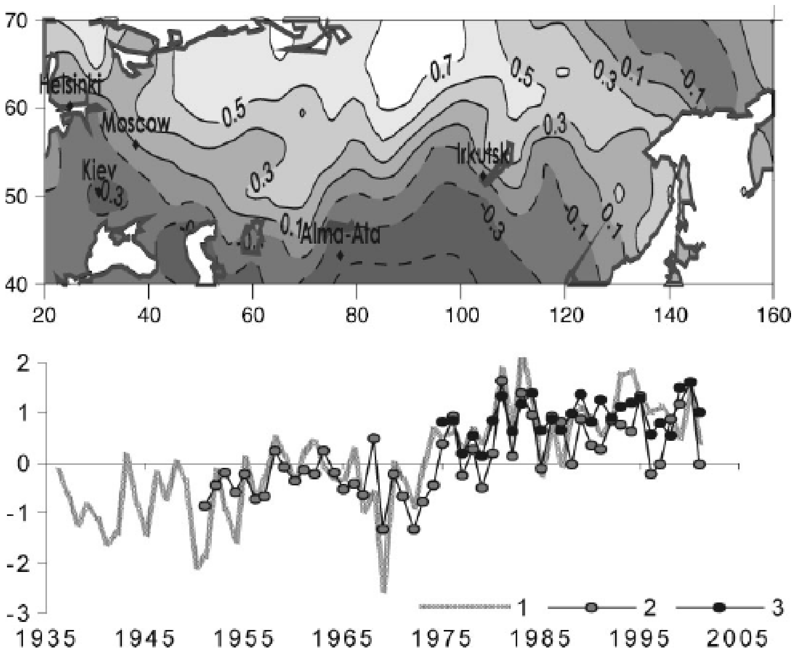


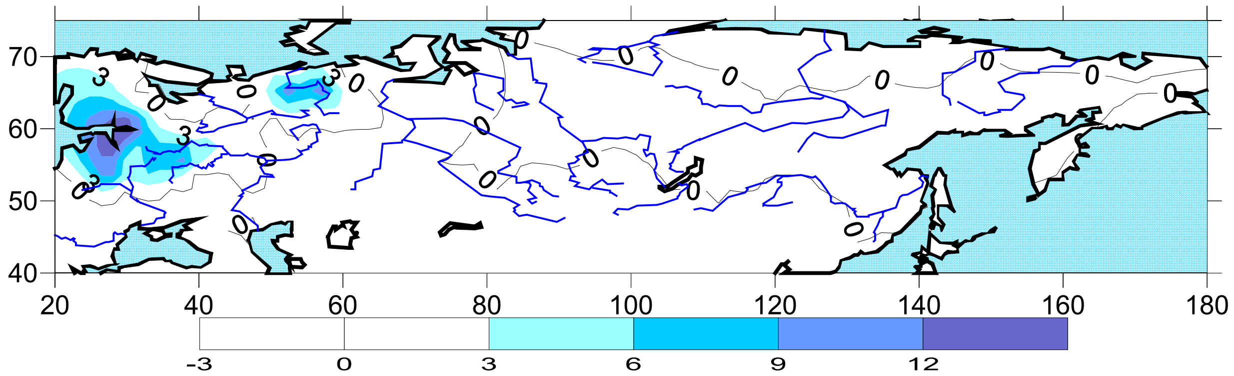
Figure 1. Pattern, upper panel, and time series, lower panel, of February snow depth PC1: observed (1) and calculated based on multiple stepwise regression with included circulation indices $\boldsymbol{I}_{\mathbf{SCAND}}$ and $\boldsymbol{I}_{\mathbf{PNA}}$ (2), $\boldsymbol{I}_{\mathbf{SCAND}}$**,** $\boldsymbol{I}_{\mathbf{PNA}}$ and $\boldsymbol{I}_{\mathbf{NAO}}$ (3). Hatched lines indicate the regions containing no data.

Popova, V.V. 2007. Winter snow depth variability over northern Eurasia in relation to recent atmospheric circulation changes. *International Journal of Climatology*. V **27**, pp.1721-1733.

Snow cover characteristics and their changes over North Eurasia

A detailed statistical analysis is carried out on snow cover characteristics and their changes over North Eurasia. Comparison between the period of contemporary warming (since 1989) and the base period (1951-1980) is done. On most of the sub-continent, the snow depth is increasing in the recent decades, while in some regions (mostly western and south-western ones) some decrease of the snow depth takes place. The main reason for that is higher frequency of the cyclones, bringing more solid precipitation to North Eurasia. Trends in the length of the snow season are insignificant. The largest growth of the snow depth takes place in January – March. The snow depth just before the fast air temperature rise in spring is increasing in several regionsof the sub-continent, most notably in Pechora basin in the north-east of Eastern Europe. Number of days with fast air temperature growth above snow is increasing in the north-east of

Eastern Europe, in some areas of Western and Eastern Siberia. Strong rains falling on the snow surface have become more frequent near the Baltic coast, in the center of East European Plain and in Pechora basin. Frequency of the situations potentially dangerous for the spring floods is increasing in some regions of the North Eurasia (such as Pechora basin and some parts of Western and Central Siberia), but overall for the sub-continent, their frequency is not changing significantly.



Change of the liquid precipitation sum over 4 mm per day, falling on snow deeper than 3 cm, in 1989-2006 as compared to 1951-1980. The regions with insignificant changes are shown in white.

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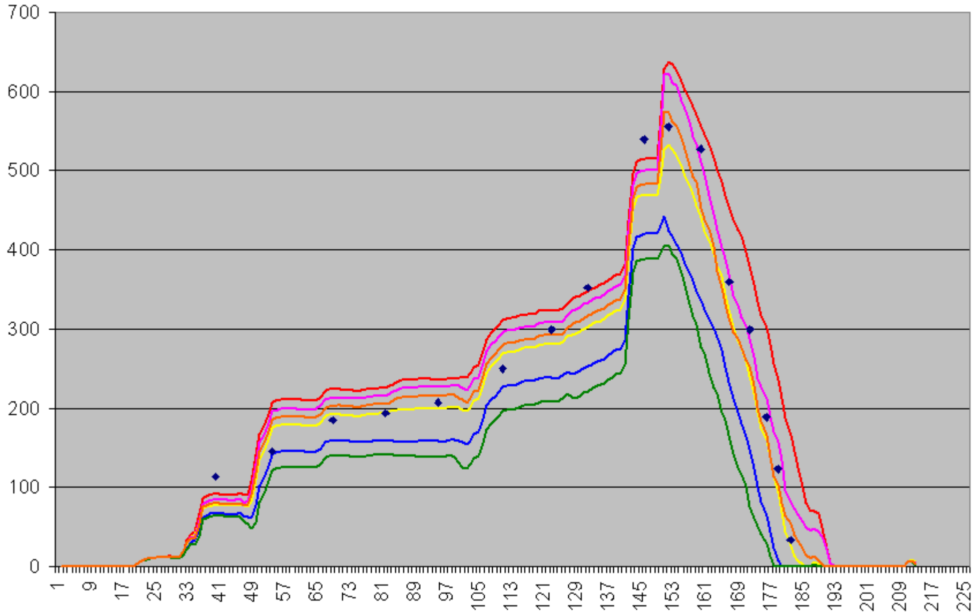
A numerical model SPONSOR of snow cover seasonal evolution

A numerical model SPONSOR of snow cover seasonal evolution, including total cycle of energy/water exchange, phase transitions, layered structure and other features, has been improved by adding and testing several procedures. Namely, new parameterization schemes of solar radiation absorption by snow, water transfer through snow, infrared radiative fluxes and others were developed. New version of the snow cover model has been tested against observed data, obtained at Cervenec site in Western Tatra mountains in Slovakia. As several key model parameters have inherent uncertainty within some range, one cannot guarantee that each particular run could reflect real situation. Thus, instead of single model experiment, it is desirable to carry out a series of experiments with the same input parameters and different values of model parameters within reasonable range. A set of runs can be suggested successful if the observed values fall within the range of uncertainty corresponding to different values of model parameters. Total snow water equivalent (SWE) according to evaluations and observations is shown in Fig. 1. As the observed points are mostly within the range of the modeled curves, the results are quite successful. The conditions in 2008-2009 are quite unusual: slow increase of the snow mass during several months, then several heavy snowfalls with sharp increase of SWE, then fast melting. However, the seasonal evolution has been reproduced with good accuracy. Further work on the model is devoted to better reproducing of the snow layers with their structure and seasonal evolution.



Observed (blue points) and modeled by SPONSOR model (colored curves) seasonal evolution of the snow water equivalent at Cervenec (Western Tatra mountains, Slovakia) in 2008-2009. Different curves reflect model runs with different values of parameters having significant uncertainty.

Contact. Andrey Shmakin (andrey_shmakin@mail.ru).

Modelling of snow avalanche dynamics: influence of model parameters

The three-parameter hydraulic model of snow avalanche dynamics including the coefficients of dry and turbulent friction and the coefficient of new-snow-mass entrainment was investigated. The 'Domestic' avalanche site in Elbrus region, Caucasus, Russia, was chosen as the model avalanche range. According to the model, the fixed avalanche run-out can be achieved with various combinations of model parameters. At the fixed value of the coefficient of entrainment m_e, we have a curve on a plane of the coefficients of dry and turbulent friction. It was found that the family of curves (m_e is a parameter) are crossed at the single point. The value of the coefficient of turbulent friction at the cross-point remained practically constant for the maximum and average avalanche run-outs. The conclusions obtained are confirmed by the results of modelling for six arbitrarily chosen avalanche sites: three in the Khibiny mountains, Kola

Peninsula, Russia, two in the Elbrus region and one idealized site with an exponential longitudinal profile. The dependences of run-out on the coefficient of dry friction are constructed for all the investigated avalanche sites. The results are important for the statistical simulation of avalanche dynamics since they suggest the possibility of using only one random model parameter, namely, the coefficient of dry friction, in the model. The histograms and distribution functions of the coefficient of dry friction are constructed and presented for avalanche sites Nos 22 and 43 (Khibiny mountains) and 'Domestic', with the available series of field data.

Bozhinskiy, A.N. Moscow State University. Annals of Glaciology, Volume 49, Number 1, October 2008 , pp. 38-42(5)

Simple relations for the close-off depth and age in dry-snow densification

A physical model for the snow/firn densification process (Salamatin and others, 2006) and Martinerie and others' (1992, 1994) correlation for the firn density at the pore closure are employed to perform a scale analysis and computational experiments in order to deduce simplified relations for the close-off depth and ice age in quasi-stationary ice formation conditions. The critical snow density at which ice-grain rearrangement stops is used to take into account variability of snow structures subjected to densification. The results obtained are validated on a representative set of ice-core data from 22 sites which covers wide ranges of present-day temperatures and ice accumulation rates. A simple analytical approximation for the density-depth profile is proposed.

Salamatin, Andrey N.; Lipenkov, Vladimir Y.a. Annals of Glaciology, Volume 49, Number 1, October 2008 , pp. 71-76(6)

Applying machine learning methods to avalanche forecasting

Avalanche forecasting is a complex process involving the assimilation of multiple data sources to make predictions over varying spatial and temporal resolutions. Numerically assisted forecasting often uses nearest-neighbour methods (NN), which are known to have limitations when dealing with high-dimensional data. We apply support vector machines (SVMs) to a dataset from Lochaber, Scotland, UK, to assess their applicability in avalanche forecasting. SVMs belong to a family of theoretically based techniques from machine learning and are designed to deal with high-dimensional data. Initial experiments showed that SVMs gave results that were comparable with NN for categorical and probabilistic forecasts. Experiments utilizing the ability of SVMs to deal with high dimensionality in producing a spatial forecast show promise, but require further work.

Pozdnoukhov, A.; Purves, R.S.; Kanevski, M.. Annals of Glaciology, Volume 49, Number 1, October 2008 , pp. 107-113(7)

Winter regime of temperature and precipitation as a factor of snow-cover distribution and its stratigraphy

The investigation of spatial and temporal variability of the snow cover in northern Eurasia (snow depth, density, thermal characteristics, water equivalent) includes large-scale fieldwork, modelling and analysis of meteorological data of two winters (2004/05 and 2005/06) from 38 weather stations situated in different climatic conditions and physico-geographical zones. Common regularities and features of snow-cover variability are revealed for these winters, despite their contrasting temperature and precipitation regimes and differences from an average winter, as the time of appearance, duration and depth of snow cover, the number of snowfalls and date of melting. The modelling of snow-cover stratigraphy is based on viscous compression and recrystallization laws. Meteorological information (temperature, wind velocity and precipitation) is used as input for the model. The output is the specific snow-cover stratigraphy according to positioning in different physical-geographical regions and due to the possible variation as determined by winter temperature and precipitation regimes. The peculiarity of snow-cover stratigraphy at the regional scale depends on the meteorological conditions of its formation as well as on the character of landscapes. A satisfactory correlation of the modelled typical columns of the snow cover formed in 2004/05 and 2005/06 in different regions of Russia and of real columns is revealed.

Golubev, Vladimir N.; Petrushina, Marina N.; Frolov, Denis M.. Annals of Glaciology, Volume 49, Number 1, October 2008 , pp. 179-186(8)

Assessment and mapping of snow avalanche risk in Russia

The term 'risk' can be defined as the probability of unfavourable consequences or negative effects. Risk can be expressed by means of various indices, such as collective or social risk (possible number of dead), individual risk (probability of a person's death within a certain territory during 1 year), probability of losses, etc. This paper is a case study of the small-scale assessment and mapping of individual avalanche risk focused on the two regions of Russia with the highest levels of avalanche activity: the northern Caucasus and the mountainous parts of Sakhalin island. The basic indices applied for individual avalanche risk estimation are:

recurrence interval of avalanches (avalanche frequency), percentage of the whole investigated territory that is occupied by avalanche-prone areas, duration of avalanche danger period, probability of a person's stay in an avalanche-prone area during 1 day (24 hours) and during 1 year, total population of the area and its density. The results of individual avalanche risk assessment, undertaken for the territory of Russia as a whole, show that its values generally do not exceed the admissible level (from 1×10^{-6} to 1×10^{-4}). However, some areas of the northern Caucasus, including famous alpine skiing resorts (Krasnaya Poliana, Dombai, the Mount Elbrus region, etc.), and of Sakhalin, including the environs of towns (Kholmsk, Nevel'sk) and other smaller human settlements, are characterized by an unacceptable level of risk. In the aggregate, areas with an unacceptable ($>1 \times 10^{-4}$) level of individual avalanche risk comprise about 7% of the whole avalanche-prone territory of the northern Caucasus, those with an admissible level comprise 52% and those with an acceptable level ($<1 \times 10^{-6}$) 41%. The corresponding values for Sakhalin are 0.1%, 14.8% and 85.1%.

Seliverstov, Yuri; Glazovskaya, Tatiana; Shnyparkov, Alexander; Vilchek, Yana; Sergeeva, Ksenia; Martynov, Alexei. Annals of Glaciology, Volume 49, Number 1, October 2008 , pp. 205-209(5)

Permafrost

Russian permafrost studies in 2009-2010. Contact -Anna Kurchatova (kanni@mail.ru)

In 2009, the research of Russian geocryologists has focused on the exploration of the spatial and temporal characteristics of the cryosphere, on the inhomogeneous reaction of the cryosphere to global and regional climate change, and on the geoecological and the engineering-cryolithological peculiarities of the northern regions. A series of basic research projects are carried out on the following issues: “Cryosphere as life support and biodiversity conservation environment”, “Evolution of cryosphere in conditions of varying climate”, “Permafrost of the Arctic seas and the continental margins of the Western sector of Eurasia: assessment of the contemporary state, characteristics of the dynamics, geocryological history, transformation of frozen and cryotic rocks, hydrocarbon emanation”, “Permafrost and Arctic shelf in conditions of the varying climate, ecosystem stability and gas-hydrates, processes of organic matter disposal” (ECI SB RAS).

Mass settling of the permafrost table at the depth of zero annual amplitude has been observed and verified by drilling and seismic investigations (microseismics) in the western Siberian forest-tundra. Over a period of 25-30 years, the pre-tundra light forest has moved approximately 30-40 km northward (ECI SB RAS).

Researchers at Moscow State University demonstrated that the change in a number of permafrost characteristics under climate warming conditions is determined by the aggregation of features and components of the landscape changing under climate warming. Changes of the permafrost characteristics of the aggradational type (decrease and stabilization of the permafrost temperature, diminishing of the seasonal thawing layer, ice enrichment of permafrost upper horizons) are observed in certain landscape conditions against the background of degradational trends (increase of the permafrost temperature, extension of the talik’s area) (MSU, Geographical Department).

Monitoring of permafrost parameters (rock temperature and active layer depth) have been continued at the steady-state-stations in the framework of Russian and International IPY projects: Thermal state of permafrost, Arctic monitoring of active layer, Dynamics of the Arctic coasts, Change of vegetation cover. At the anthropologically-disturbed sites of Nadym and Urengoy steady-state-stations the network with long series of observations on ground temperature has been renewed (ECI SB RAS).

Results on changes in ground temperature, active layer thickness, daylight surface settlement, variations in CO_2 emissions have been obtained at the field steady-state-station and monitoring sites on the permafrost territory of Yakutia over a period of 10-15 years. The degree of reaction of permafrost landscapes to various anthropogenic disturbances (logging, plowing area, fires, etc.) in a changing climate have also been a focus of these investigations (IMZ SB RAS).

A series of observations on ground temperature on the accumulative surfaces of the Yenisei Gulf (with new temperature loggers) are being pursued. New data on the two-stage structure of the Ice Complex in the Dixon village and on the development of thermokarst processes on the Sibiryakova Island have been obtained (ECI SB RAS, VNIIOkeangeologiya, MSU).

The works on the geotechnical monitoring of the railroad bed and embankment of the Obskaya-Bovanenkovo railway are in progress. This is the most northern railway in the world and it will go as far as the gas fields of Yamal Peninsula in the north of Western Siberia. A forecast on the evolution of cryogenic hazard processes has been elaborated, with detailed sections on recommendations for engineering protection of the embankment and the surrounding area as well as suggestions on improvement of the embankment construction for the sustainable exploitation of the railway (PNIIIS).

Researchers at Fundamentproject conducted a large range of research projects with the objective to create special GIS geocryological maps: A 1:1 000 000 scale geocryological map of European North of Russia, an album of the landscape, soil, vegetation maps and maps of cryogenic processes activity for the Eastern part of Yamal Peninsula (1:100 000 scale) and an album of maps along the prospective path of the Murmansk-Volkhov gas-pipeline (Fundamentproject).

Using GIS technology, a series of digital permafrost maps of various scales including its characteristics (ice content of surface sediments, ground temperature, active layer thickness and freezing layers as well as moisture content) have been compiled for the natural environment of Yakutia (IMZ SB RAS).

Based on the results of engineering-geological surveys, a series of special electronic maps on the projected route of the Polunochnoye-Salekhard railroad along the foothills of the eastern slope of the Northern and Polar Urals has also been created (PNIIIS).

At the Geology Department of Moscow State University, two methods have been developed: 1) A method of determining of the long-term strength, the durability and the rate of deformation of frozen ground in order to evaluate its bearing capacity for the construction foundation and 2) a method for the determination of the minimum values of thawing ground strength taking into account the changes in the physical and mechanical properties and in the pore pressure observed during thawing (MSU, Geology Department).

A series of experimental methods for the strengthening of the foundations of large constructions have been conducted in the Norilsk region. These setups include (in addition to the conventional cooling from underground or the use of seasonal cooling devices in the perimeter of constructions) static pressing down of piles to the bearing horizons, partial cementation of thawed gravel-pebbly or sandy soils, installation of buried subsidiary beams in the grid as well as widening of the upper part of the pile etc. (MSU, Geographical Department).

The international student field courses on permafrost in the North of Western Siberia were carried out this year again. In 2009, the student field courses were organized on board of the ship "Sovetskaya Arktika" by the Geographical department of Lomonosov MSU, IKZ and LIN SB RAS and VNIIOkeangeologiya. Research took place at the Yenisei River, the Yenisei Bay, the Kara Sea and the Gydan Bay.

The following publications have been released by Russian researchers in 2009:

- The sixth part of the book "Fundamentals of permafrost" - "Geocryological forecast and ecological problems of geocryology" has been prepared by a group of scientists, edited by L.S. Garagulya and E.D. Ershov (MSU, Geological Department).

- A unique Monograph on parametric drilling and core sampling through permafrost strata including a complete set of laboratory research was released under the name “Structure and properties of the frozen ground in the southern part of the Bovanenkovo gas-condensate field. Advice on the prevention of problems linked to cryogenic structures and gas blasts encountered during permafrost drilling and well operations” (MSU, Geological Department).

- The monograph "Cryogenic metamorphism of rocks and underground waters " by S.M. Fotiev has been prepared for publication. For the first time, the conditions and results of the cryogenic metamorphism of rocks and underground waters during the Late Cenozoic have been examined. The geocryological interpretation of the unique Baikal paleoclimatic sequence has been used to do so (ECI SB RAS).

- The monograph "Cryology of Mars and other planets of Solar System" has also been prepared for publication (Geology Dept., MSU).

In 2010 the scientific investigations on the spatial- temporal regularities of cryosphere, the heterogeneous reaction of cryosphere on the global and regional climate changes, the geoecology and the engineering-cryolithological peculiarities of the northern regions have been proceeded by Russian geocryologists.

The fundamental researches are kept on the following lines: “Natural and technogenic systems in Earth’s cryosphere and their interactions” (coordinator – Melnikov, V.P., the academician of RAS), “Permafrost of shelf and coastal zones” (includes the assessment of the geocryological history and contemporary cryolithozone’s state, the explorations of regularities of the dynamics and transformation of the frozen and cryotic rocks, the emanation of carbohydrates) (Earth Cryosphere Institute SB RAS).

The preparation of the new edition of the “Geocryological map” of the Russian territory is carried out (the corresponding problem is posed in the plan of subjects of Earth Cryosphere Institute SB RAS).
The “climate-permafrost-space-time” dependence during the last 20-100 years, the parameters of cyclicity of the changes of natural complexes under the technogenic impact are studied (Earth Cryosphere Institute SB RAS).
The investigations of the coastal-shelf permafrost in Russian Arctic are held on using the seismic hydro-technique and hydro-technologies. The GIS of Russian Arctic regions including shelf are worked out (Erath Cryosphere Institute SB RAS).

In 2010 the department of the cryolithology and glaciology of the geographical faculty of the Lomonosov Moscow State University has carried out the following investigations.
The phenomena of northward increase of thickness of the intermediate layer (layer with 1 higher relative ice content) and its protective role has been studied. It has been determined that the coast of the Western Taymir peninsula is the westernmost areas where not typical sediments of the “ice complex” are found. The underground ice is situated on the host grounds.

The fact that 2/3 of failures of objects in cryolithozone are caused by the development of dangerous engineering-geocryological processes has been determined. A significant increase (20-30% in the last 10-15 years) in shear forces caused by frost heave is observed. It explains the failure of the pipeline supporting piles of all kinds. This demands an intensive labour on cutting off about 5-8 thousands of piles supporting long distant and in-facility pipelines annually.

The main reason of high rate of breakdown and catastrophically fast wear out of materials in underground water collecting systems of engineering communication facilities in cities situated in the cryolithozone is uneven in time and area thawing in host permafrost grounds. This leads to uneven settlement of constructions and fast wear down of them. These processes are very hard to predict and do not match the expected rates of deformations estimated according to national standards and procedures. In the region of Norilsk city about 70% of water collecting systems are deformed. The situation is furthermore complicated by frost weathering of steel concrete used for building.

A decrease of area of glaciers of the Central Caucasus by 16% in the last 40 years is reported. Along with this, the glaciers of the Polar Ural Mountains are experiencing transition to stationary conditions after a period of fast retreat in 1990-2000.

During 2010 the interdisciplinary field expeditions were carried out in order to study the permafrost and mountainous regions and glaciations in the Elbrus region. Expeditions for study of ice complex on the north of Taymir were run in cooperation with Earth Cryosphere Institute. Expeditions for estimation of the engineering-geocryological conditions, geotechnical, ecological, landscape and permafrost conditions in Igarka and Norilsk regions on the north of Siberia were carried out. Study of dynamics of seasonal freezing processes in the Moscow-city region was fulfilled. Participation of students and PhD students was an important part of all expeditions.
In Sergeev Institute of Environmental Geoscince RAS (Moscow) the permafrost hazard evaluation for Yamal's gas field recultivation territories was completed. The complete geocryological survey of East Siberia-Pacific Petrol Pipeline was started to estimate the exploitation risks in conditions of climate change.

Geological Research Institute for Constructions carried out the geotechnical monitoring of the railway roadbed Obskaya-Bovanenkovo to the gas fields on the Yamal Peninsula in the north of Western Siberia.

The road was built in an extremely complicated engineering and permafrost conditions. The results of monitoring observations are following:

- the dynamics of technogenic disturbance of area, the thermal state of the embankment and the development of dangerous cryogenic processes during the construction and the maintaining of the railway road were determined;
- the simulation of the temperature regime of soils in the embankment for different variants of design solutions was made;
- the potential danger of anthropogenic cryogenic processes was assessed and the recommendations on the engineering protection of the area and the railway embankment were provided;
- the proposals for improving the design of embankment and the technology of its filling for an accident-free maintaining of the railway road were developed.

Due to the international cooperation and especially under the aegis of IPA, the geocryologists succeeded in carrying out the expedition researches, maintaining the observations on stations and communicating during the international meetings. Russian geocryologists kept on close contacts with their colleagues from Canada, Germany, Japan, Norway USA and other countries.

On the 5-6 of July, 2010, the international workshop under the chairmanship of academician V.P.Melnikov was held in Tyumen, the priority lines of the geogryology were discussed.

Russian geocryologists took part in the International Congress on engineering geology held on 5-11 of September, 2020 in Auckland (New Zealand). During the Congress, the protocol on the expansion of the engineering-geological mapping in the cold regions has been accepted.

The results of the geocryological researches have been widely published as monographs, articles in the scientific journals and material of conferences.
In 2009-2010 the monographs by V.V.Rogov “Foundations of cryogenesis” (Lomonosov Moscow State University, Geographical Department), Yu.B.Badu “Cryolithology” (Lomonosov Moscow State University, Geographical Department), L.N.Kritsuk “Ground ices of Western Siberia” (VSEGINGEO) have been published.
The monograph by L.N.Chrustalev, S.Yu.Parmusin, L.V.Emelyanova “Reliability of northern infrastructure under the climate change conditions” (Lomonosov Moscow State University, Geological Department) has been prepared for publication.
The fruitful activity of the journal “Earth’s Cryosphere” ought to be especially marked out. The

subjects of the journal embrace all the variety of researches on earth's and planets' cryosphere. Since 1997, 4 issues of the journal "Earth's Cryosphere" have been published annually.

Recently the conception of the complex researches of Earth's and planets' cryosphere developed by academician V.P.Melnikov has obtained the recognition. It is significant to mark the effectiveness of the interdisciplinary contacts in the view of the enrichment with ideas and methods of the adjacent sciences and the determination of the perspective lines of the scientific and practical activity.

In 2010, the Melnikov Permafrost Institute at Yakutsk (MPI) celebrated the 50th anniversary of its foundation. Celebration events held on November 25-26, 2010 included the scientific session "History, Results and Future Prospects of Geocryological Science". Sixty three MPI members were awarded various national and regional awards for their significant contribution to the field of geocryology.

In August 2010, Russian Prime Minister Vladimir Putin visited Samoylov Island in Arctic Yakutia, where the Permafrost Institute in cooperation with the German partners conducts joint field studies on climate, permafrost and ground ice interactions as part of the intergovernmental program "Laptev Sea System". As a result of this visit, a decision was taken on the federal level to construct a new international research station on Samoylov Island.

MPI members took part in 20 international meetings during 2010. The Forum for Young Permafrost Scientists was held in August 2010, which consisted of the conference on geocryology at Yakutsk and the field trip in central Yakutia focusing on ground ice, thermokarst and thaw depressions (alases). The Forum was attended by young researchers and students from Russia, China, Japan, and France.

Two issues of "Science and Technology in Yakutia" were published in 2010. This popular scientific journal is receiving increasing attention from both the researchers and the general public. Books published by MPI in 2010 include:

- Zhang, R.V., Shepelev, V.V. (eds.). The Yakutian School of Geocryological Science (Research Scope, Results, and People). Novosibirsk: GEO Academic Publ., 236 pp.
- Neradovsky, L.G. Methodological Manual on Permafrost Investigation with the Dynamic Georadar Method. Moscow: Russian Academy of Sciences.
- Alekseev, V.R. In the Land of Eternal Frost, Notes of the Geographer and Permafrost Researcher. Novosibirsk: GEO Academic Publ., 394 pp.

- Makarov, V.N. Nitrogen in the Yakutian Environment. Yakutsk: Permafrost Institute, 68 pp.

- Gorbunov, A.P., Gorbunova, I.A. Geography of the World's Rock Glaciers. Moscow: KMK Partnership, 131 pp.

The main research results of MPI in 2010 are summarized below:

1. The concept of "cryogenic resource" was introduced to refer to any material or natural force, the origin and development of which are related to the sphere of cold (temperature below 0°C). The classification of cryogenic resources was elaborated, the important class being that of cryogenic construction materials (snow, ice, frozen ground).

2. A glacier inventory 2010 for the Trans-Ili - Kungei glacier system (Central Asia) was compiled based on satellite images. This is the fifth in the series of glacier inventories developed during the period from 1955 to 2010. The inventory provides information important for effective cross-border water management.

3. MPI took part in a fundamental national program to create a digital 1:2,500,000-scale engineering geology map of Russia. The Institute compiled the 12th block of the map covering Central Siberia and North-Eastern Russia. This electronic ArcGIS-based map provides data on soils and rocks, permafrost, and dynamic conditions. The map data can be used to analyze geotechnical parameters individually or in combination, for sites or for the entire mapped area.

4. A physico-mathematical model for permafrost degradation following the Holocene transgression of the Polar basin was developed for variable climatic and hydrologic conditions. The effects of seawater heat and salts on permafrost degradation at subzero temperatures were determined. The modelling results indicate that on the Siberian shelf the subaqueous sediments with temperatures between -1.0° and -1.5°C could have persisted in a frozen state for a long time, as much as tens of thousands of years, due to the significant decrease in the permafrost warming trend over several centuries after the marine transgression and the subzero mean annual temperature of bottom water at depths of 6 m and more.

5. Long-term observations of the ground temperature and moisture regimes were continued at the MPI's monitoring sites. Observations in the eastern Russian Arctic indicate that the maximum erosion rates of ice-rich coasts along the Kara, Laptev and East Siberian seas are up to 20 m/yr.

6. Permafrost research programs were undertaken in support of major industrial developments in Yakutia and adjoining areas, such as the East Siberia-Pacific Ocean pipeline system, the Amur-Yakutsk railway, the South Yakutian hydropower complex, the Elkon uranium mining project, and the Taezhnoe, Dues, Tarynnakh and Gorkit iron mining projects. These investigations resulted in the construction of permafrost, terrain and ecological maps of various scales, the compilation of data sets and data bases on permafrost characteristics, and the development of permafrost impact assessments and control measures.

Assessment report of climate change impacts in Russian permafrost regions: synthesis of observations and modeling.

An assessment of major environmental and socio-economical impacts of climate change in Russian permafrost regions has been published in two languages (Russian and English) by the group of experts from the State Hydrological institute (St.Petersburg), Permafrost institute (Yakutsk), and MIREKO Company for Mineral Resources of the Komi Republic, Syktyvkar with contributions from permafrost researchers at the University of Delaware and George Washington University (USA). Report gives an overview of the current and projected for the future climatic changes in Russian permafrost region, state of permafrost modelling and permafrost projections for Russia. Two regional studies of North-European Russia and East Siberian Arctic coasts synthesize regional observations and results of modelling permafrost dynamics with particular focus on the processes such as thermokarst and coastal erosion that may have detrimental impacts on the infrastructure and regional economies. A special case study addresses the potential impact of enhanced methane emission from thawing wetlands on global climate with the key conclusion that the net change of the radiative forcing due to this mechanism will be very small and will not cause any noticeable warming.

The main focus of the assessment is on the economy of the Russian Arctic under changing climatic and permafrost conditions. Report gives an overview of the current state, including analysis of the population, regional GDP structure with evaluation of contributions from different sectors. The key conclusion of the report is that the projected permafrost change is one of the most serious regional economical concerns in the context of the global warming.

The report in two languages is available online at www.permafrost.su. The full reference information is the following. O.Anisimov (Ed.), 2010. Assessment report of climate change impacts in Russian permafrost regions: synthesis of observations and modeling. Moscow, "Greenpeace publications", 43 p. ISBN 978-6-94442-029-9

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Evaluation of climatic projections for environmental modeling in Russian permafrost regions

Permafrost models of different complexity have been used in many studies to predict changes in the areal extent, temperature, and seasonal thaw depth of the frozen ground in the 21st century and the environmental and socio-economical impacts of such changes. Wide range of results was obtained using essentially different modeling methodologies and forcing climate data. A joint effort of scientists from the Russian State Hydrological institute and the UK Hadley Centre has been made to narrow the uncertainties associated with the forcing data through comprehensive evaluation of climatic projections for Russian permafrost regions. To accomplish this task, the output from 21 GCM runs for the control period in the 20th century was used to calculate several climatic characteristics that are known to govern the thermal state of permafrost, i.e. thawing degree-day sums, annual temperature amplitude, and sums of winter precipitation. Results were compared with observations at weather stations in the Russian permafrost region to evaluate the skills of individual models and to rank them in the specific context of predictive regional environmental modeling. This procedure eliminated the outliers and identified top-end GCMs that "better than average" reproduce the behavior of selected climatic parameters.

Climatic models with "better than average" skills were used to compose several ensembles, each combining results from the different number of GCMs. Ensembles were ranked using the same algorithm and outliers eliminated. Ultimately, data from the top-ranked ensemble for the 2000-2100 period were used to construct the climatic projection that the expert group recommends for predictive environmental assessments in the Russian permafrost region. This projection was used as input to the equilibrium permafrost model to calculate changes in the state of the frozen ground.

The main findings of this study regarding climate scenarios are the following.

- High-end GCMs that demonstrate excellent skills in conventional atmospheric model intercomparison experiments are not necessarily the best in replicating climatic characteristics that govern the state of environment in Russian permafrost regions, and independent model evaluation based on the specific criteria is necessary to identify "better than average" models.

- Each of the ensembles combining results from several "better than average" models replicate permafrost-related climatic characteristics better than any single GCM. The ensemble skills are parameter-specific and depend on models it consists of. The best results are not necessarily those based on the ensemble comprised by all "better than average" models.
- Comprehensive evaluation of climatic scenarios using specific criteria narrows the range of uncertainties in predictive environmental modelling in Russian permafrost regions.

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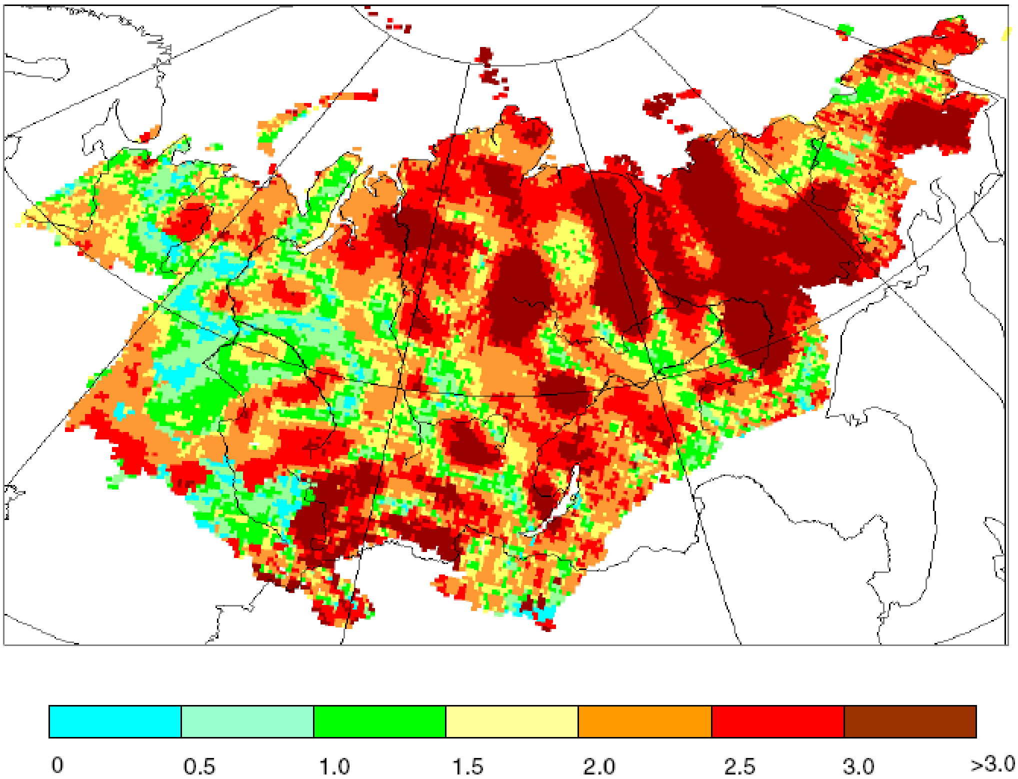
Potential feedback of thawing permafrost to the global climate system through methane emission

Large amounts of soil carbon deposited in permafrost may be released due to deeper seasonal thawing under the climatic conditions projected for the future. An increase in the volume of the available organic material together with the higher ground temperatures may lead to enhanced emission of greenhouse gasses. Particular concerns are associated with methane, which has a much stronger greenhouse effect than an equal amount of CO2. Production of methane is favored in the wetlands, which occupy up to 0.7 million km2 in Russian permafrost regions and have accumulated about 50 Gt of carbon (Gt C). We used the permafrost model and several climatic scenarios to construct projections of the soil temperature and the depth of seasonal thawing. To evaluate the effect of such changes on the volume of the seasonally thawing organic material, we overlaid the permafrost projections on the digitized geographically referenced contours of 59 846 wetlands in the Russian Arctic. Results for the mid-21st century climate indicated up to 50% increase in the volume of organic substrate in the northernmost locations along the Arctic coast and in East Siberia, where wetlands are sparse, and a relatively small increase by 10%–15% in West Siberia, where wetlands occupy 50%–80% of the land. We developed a soil carbon model and used it to estimate the changes in the methane fluxes due to higher soil temperature and increased substrate availability. According to our results, by mid-21st century the annual net flux of methane from Russian permafrost regions may increase by 6–8 Mt, depending on climatic scenario. If other sinks and sources of methane remain unchanged, this may increase the overall content of methane in the atmosphere by approximately 100 Mt, or 0.04 ppm, and lead to 0.012 ◦C global temperature rise.



Projected changes in the soil temperature averaged over the warm period. GFDL climatic scenario for 2050.

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Marine cryosphere of the Polar Regions.

Arctic

Field studies of sea ice at drifting station “North Pole - 36” were carried out from September 2008 to August 2009. It was accompanied:

- 618 measurements of snow and ice parameters (ice thickness, draught, snow thickness) at 35 points of the 100 x 85 m polygon. Continuous ice growth was observed starting from September 2008 until June 25 2009 with average increase of the ice thickness equaled 120 cm. Ice melting continued till mid-August with 15 cm of ice melted down. The way of snow and ice melting points out on late start, short duration and lose pace of melting.
- Detection of wave processes and self-oscillations in the ice cover. The following parameters were determined: ice shift and acceleration caused by compression, motion and ridging with respect to self-oscillations; horizontal acceleration caused by tidal and wind-induced motion; parameters of open water-origin, storm-induced swell in the ice cover; internal waves- and turbulence-induced high-frequency (up to several hours) vertical oscillations in the ice cover.
- Measurements of direct solar radiation, radiation balance components and albedo of dry, melting and wet ice and snow in the melting season.
- Studies of thermodynamic properties and spectral radiation characteristics of the ice-snow surface (measurements of incoming and reflected radiation spectrum over the ice cover and under various clouds; sub-ice casts of vertical distribution of spectral characteristics of reaching under ice solar radiation down to the depth 45m; diurnal time series of reaching under ice solar radiation at 10 cm depth below the ice cover.
- Studies of spatial and temporal variability of the snow cover. Measurements of snow thickness and density: 18 snow cover surveys around 100-meter size polygon with 5 m size grid.
- Studies of the snow cover vertical structure: 151 profiles of temperature were accomplished. The structure of temperature profiles allowed distinguishing specific layers. Density measurements, description of conditions, determination of size and structure of individual snow crystals were carried out in these layers.
- Hourly measurements of surface concentration of ozone and CO2, and 3-hour frequency measurements of the surface concentration of methane with 250-hour duration.

- Daily measurements of CO2 concentration in the air near the surface and determination of CO2 fluxes across the ice-air interface.

In 2008 measurements of sea ice thickness were carried out in 4 cruises of nuclear icebreakers Yamal and 50 Let Pobedy along the track Franz Joseph Land - North Pole (July-August). Measurements from the Research Vessel Akademik Fedorov were conducted to the north of Vrangel Island in August-September.

In 2009 measurements of sea ice thickness were carried out during two cruises of the nuclear icebreaker 50 Let Pobedy along the track Franz Joseph Land - North Pole (July-August), during the cruise of the nuclear icebreaker Yamal when at the mission on recovery of drifting station NP-36 and deployment of drifting station NP-37 (August-September) and during the cruise of the icebreaker Kapitan Dranitsyn (August-September). Total number of sea ice measurements in 2008 and 2009 is about 40000.

Description of methods of measurements and first results, including comparison of ice thickness in August 1977 and in May 1987 with ice thickness in May and August 2005 and 2006, are published in the paper by S.V. Frolov, V.E. Fedyakov, V.Yu. Tretyakov, A.E, Klein, G.V. Alekseev, New data on changes of ice thickness in the Arctic Basin, Doklady Earth Sciences, 2009, Vol. 425, No. 2, pp. 317–321. © Pleiades Publishing, Ltd., 2009).

Antarctic

Main objective of the oceanographic and sea ice studies during last Russian Antarctic Expeditions (RAE) was to investigate the structure of the Antarctic Slope Front and water masses in the Prydz Bay. 169 CTD stations were made from r/v «Akademik Fedorov» in the period 1997 - 2006. During the last three years the processes at the continental slope were investigated in the region to the west of Prydz Bay. CTD soundings of Sea Bird 911+ were made with the high spatial resolution (about 3 miles between stations at the meridional sections). All sections begin on the shelf near the shelf break, cross the continental slope and reach the deep ocean area. Data show Ice Shelf Water (ISW) with temperature below see surface freezing temperature (~ –1.9° C) occupied 100 – 700 m thick bottom layer near the Amery Ice Shelf front. This water goes to the north along western border of Amery Depression and then flows down the continental slope in the region to the west of Prydz Channel (~ 72° E). Data demonstrate that Low Salinity Shelf Water (LSSW) is typical for the Prydz Bay. However, High Salinity Shelf Water (HSSW) which is important for bottom water formation was found at section 66° E in

January 2005. The origin of this HSSW is not determined. Descending water in the region to the west of Prydz Channel results in deep water ventilation and bottom water formation. Prydz Bay Bottom Water with temperatures from –0.3 to –1.9° C and salinities 34.54‰ – 34.62‰ is found in the region between 64° and 72° E.

Marine oceanographic studies from board the r/v "Akademik Fedorov" were continued during the seasonal period of the 52nd and 53rd RAE (2007 and 2008, respectively) in the framework of IPY project "Synoptic Antarctic Shelf-Slope Interaction" (SASSI). The studies were aimed to investigate the structure and parameters of the main fronts of the Southern Ocean and water structure in the areas of the shelf and the continental slope in Prydz Bay and the Amundsen Sea.

In Prydz Bay, based on the studies in 2007, regions of formation and pathways of spreading of Antarctic shelf and modified circumpolar deep water were delineated and typical features of transformation of their properties were determined. A new water mass – Prydz Bay Bottom Water with temperatures from –0.3 to –1.9° C and salinities 34.54‰ – 34.62‰ is found in the region between 64° and 72° E.

At transect in the Amundsen Sea, 19 CTD soundings were made. The main peculiarity of thermohaline water structure at this transect is presence of practically not transformed circumpolar deep water, occupying deep and near-bottom layers on the shelf and at the continental slope. The characteristics of the uniform surface layer were also unusual (its thickness was about 20 m, temperature of -1.4 to -1.7°C and salinity was anomalously low – not greater than 32.8‰). A possible explanation of the existence of layer with such characteristics is spreading of melt water from beneath the nearby outlet and shelf glaciers.

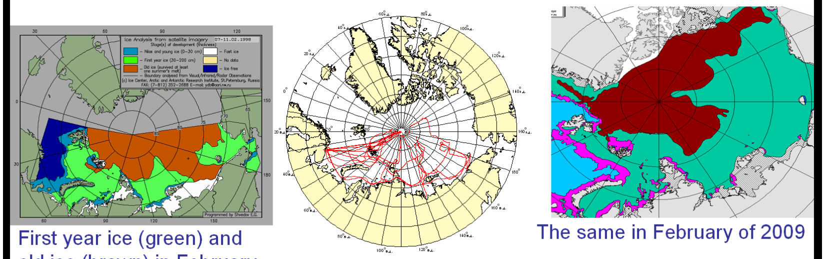
Ship-borne information on drifting ice thickness for 16 cruises of r/v "Mikhail Somov" and "Akademik Fedorov" from 1991 to 2005 have been included to the digital database. The database contains more than 10 000 measurements on ice thickness. The ship-borne observations also include estimates of the snow cover thickness and information on ice concentration, ice age, ice forms and types and pressure ridges. Data from radar measurements of iceberg's quantity and visual observations of iceberg's height and length made from the Russian ships were also included to the Southern Ocean icebergs data base. The data base contains about 35 thousands measurements of the number of icebergs and 2500 estimates of iceberg parameters for the part of the Southern ocean from 62° W to 110° E during the last 50 years. The ship-borne data collected during 12 cruises from 1991 to 2000 as well as fast ice measurements at the stations Progress and

Mirny were used to reconstruct of the Commonwealth Sea (area from 54° to 82° E) ice cover morphological structure.

ICE THICKNESS

From observations on board of nuclear i/b's and R/V Akademik Fedorov during 1977-2008

Mean ice thickness in the Arctic Basin is decreased because multiyear ice area is shrike



First year ice (green) and old ice (brawn) in February of 1998

The same in February of 2009

Year	old ice	firstyear ice	mean thickness	cruise
1987	36 %	64%	180.5 см	(i/b «Sibir", May)
2006	13%	87%	138.0 см	(i/b «Yamal», May)
1977	44 %	74 %	186 см	(i/b «Arktika», August)
2005	26 %	56 %	142 см	(R/V «Akademik Fedorov»)

(Doklady Earth Sciences, 2009, Vol. 425, No. 2, pp. 317–321. © Pleiades Publishing, Ltd., 2009)

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Sea ice modeling

The ability of climate models to simulate ice season length in the Arctic, its recent changes and navigation season on Arctic marine routes along the Eurasian and the North American coastlines is evaluated in comparison with satellite ice cover observations for 1979/2008 (Khon et al., 2009; Mokhov and Khon, 2009). Simulated mean sea ice season duration fits remarkably well to satellite observations and so do the simulated 20th century changes using historical forcing. This provides confidence to extend the analysis to projections for the twenty-first century. The navigation season for the Northern Sea Route (NSR) and Northwest Passage (NWP), alternative sea routes from the North Atlantic to Asia, will considerably increase during this century. The models predict prolongation of the season with a free passage from 3 to 6 months for the NSR and from 2 to 4 months for the NWP by the end of twenty-first century according to SRES-A1B scenario. This suggests that transit through the NSR from Western Europe to the Far East may be up to 15%

more profitable in comparison to Suez Canal transit by the end of the twenty-first century (Khon et al., 2009; Mokhov and Khon, 2009).

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