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FOREST DISTRIBUTION ON THE CENTRAL RUSSIAN UPLAND: HISTORICAL PERSPECTIVE

ABSTRACT. We studied the change of forestland in the Central Russian Upland within the deciduous forest, forest-steppe, and steppe zones using old maps (XVIII–XX cc.) and current satellite images. The forest distribution within the Central Russian Upland has been relatively stable during the last 220 years. On average, the decrease in the forested area was small. However, we identified significant changes in certain regions. In the southern part of CRU, the significant increase of the forested land is caused by the forest protection of abatis woodland and afforestation. During the last 100 years, reforestation took place mainly in the Oka basin due to both afforestation and natural reforestation. New forests appeared generally in ravines within all zones. The analysis of the abatis forests changes from the XVIII to XX cc. allowed us to identify forested area within the Central Russian Upland prior to active development.

KEY WORDS: forestland, forest dynamic, Central Russian Upland, human impact

INTRODUCTION

The aim of this research is to study changes of forest distribution in the Central Russian Upland and to identify human impact on forests. Analysis of old maps and satellite images indicates that there has been change of forestland during the last 220 years and makes it possible to calculate the rate of deforestation and reforestation and to estimate the role of forest protection and afforestation in forest distribution on the Central Russian Upland. In our study, we specifically focused on changes (cutting) of the abatis forests over the last 200 years. Large forests were transformed to agricultural fields with coppices. Now, these forests are not distinguishable from the adjacent lands. We considered these processes in the estimate of the rate of the forested land change and modeled the percentage of the forested land at the end of the XVI c.

The Central Russian Upland is situated in the centre of the East European Plain. It spreads from the Oka River in the north to the Donetsk Ridge in the south. The Kalachskaya Upland is the south-east part of the Central Russian Upland. The northern part of the upland is composed of Dnepr moraine that is covered with silt. In the southern part, Pre-Quaternary deposits are overlaid with silt [Spiridonov, 1978]. The Central Russian Upland was the refugium for deciduous broad-leaved forests during the glacial periods. The territory has temperate continental climate, good for forests. Average annual temperature is +3° to +7°, annual precipitation amount is 346 to 644 mm, and the sum of active temperatures is 1848 to 2934°. Three phytogeographical zones change each other from the north to the south of the Upland: the zone of deciduous broad-leaved forests, forest-steppe zone, and steppe zone [Ogureeva, 1999]. The chernozem soils dominate in the steppe and forest-steppe, and gray forest soil prevails in the deciduous broad-leaved forests zone. Based on the vegetation map of Russia [Bartalev et al., 2001], we estimated the percentage of the forested land for the entire Upland at 9%; it is 14% within the boundaries of deciduous broad-leaved forests zone and 5

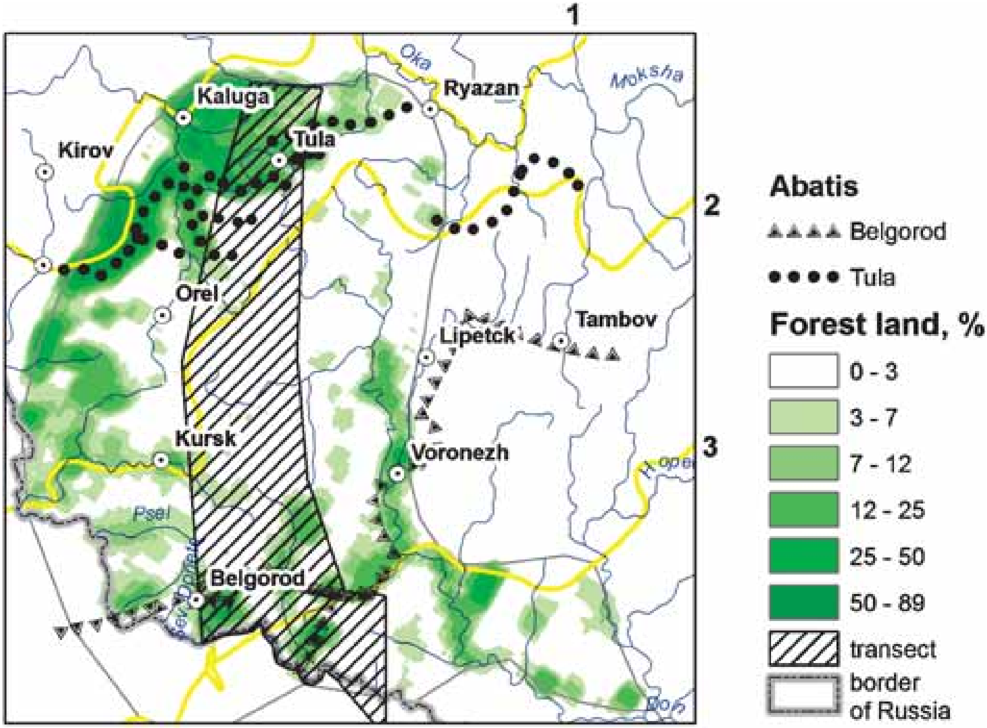

Fig. 1. The percentage of the forested land on the Central Russian Upland; the northern boundaries of the zones:

1 – deciduous broad-leaved forests, 2 – forest-steppe, 3 – steppe.

to 6% within the boundaries of forest-steppe and steppe zones (Fig. 1).

Special attention is given to the abatis forest areas [Zagorovskij, 1969, 1980; Jakovlev, 1916]. The Russian state grew from the north to the south. The abatises were created for the protection from tatar raids. They included engineering constructions and large forests as a natural obstacle for cavalry. The abatis forests were protected from cutting and were the first reserves by this way. They lost their importance when Russia conquered Crimea in the XVIII c. Then, part of the abatis forests continued to be protected as shipbuilding timber or manufactory forests, while another part was cut for agricultural fields.

MATERIALS AND METHODS

For the detailed analysis, we chose a transect with the width of about 100 km and the length of about 500 km, going through the center of Upland from north (the Oka river) to south (the region of Belgorod and Valuiky). The transect crosses deciduous the broad-leaved forest zone in the north, forest-steppe zone in the center, and steppe zone in the south. The transect is divided into 10×10 km cells. All parameters in our research are calculated for every cell.

We used winter satellite images Landsat (2000–2003) to estimate the current percentage of forested land. Non-forest, deciduous, and coniferous forests are clearly seen at these images. The standard supervised classification from Erdas was applied. To exclude tree vegetation in populated places (parks and gardens), we used the settlement vector layer from OpenStreetMap project (www.openstreetmap.org). We removed forest belts along fields and ravines by the Neighborhood functions from Erdas. The result of our work is the map of forests. Using this map, we calculated the percentage of

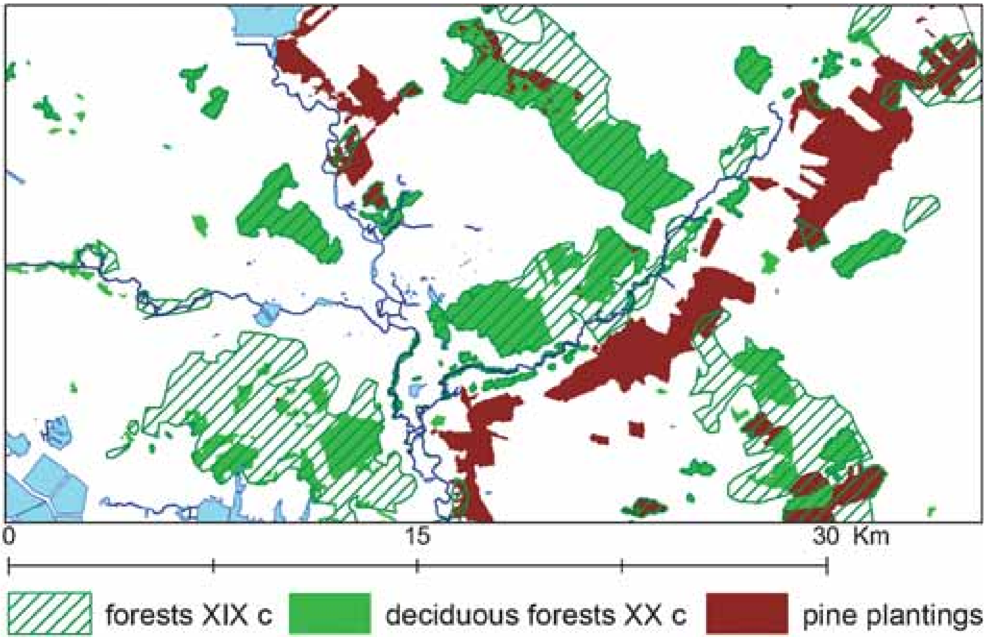

Fig. 2. The pine planted forests near Staryi Oskol.

forested land along the transect for each grid.

The planted coniferous forests were isolated by comparing the satellite images and historical maps (1860–1880) [Strel'bitskii, 1868–1887] (Fig. 2). Using literature, satellite images, and historical maps the remnants of the abatis forests are selected (Fig. 3).

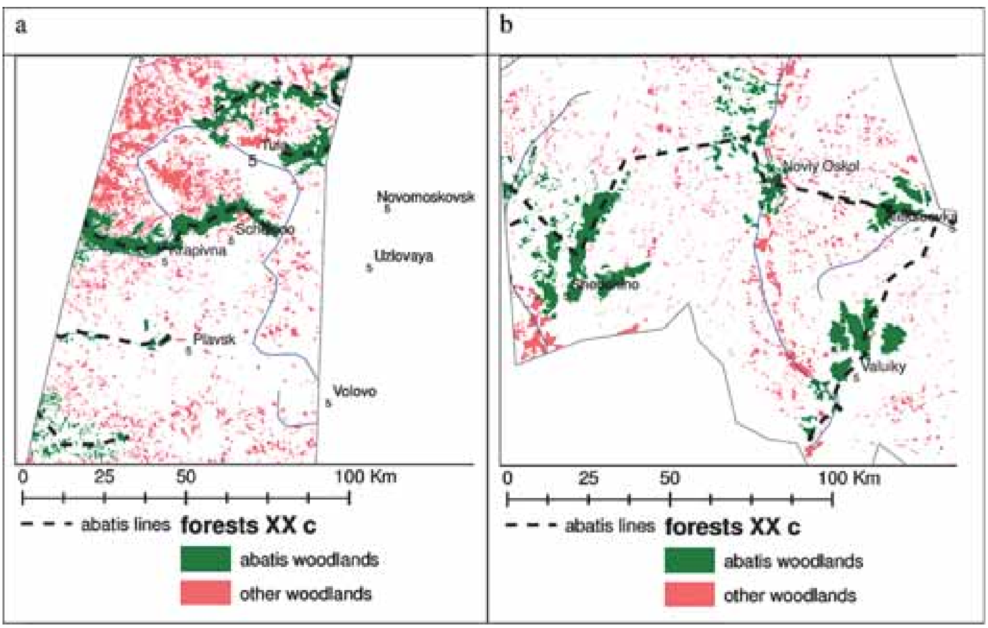

Fig. 3. The remnants of the abatis forests at the end of the XX c:

a – Tula abatis, b – Belgorod abatis.

To calculate the percentage of the forested land at the end of the XVIII c., we used the land surveying maps for the end of the XIX c. [Plans–atlases... 1780] and military maps [Strel'bitskii, 1868–1887]. All cartographic and statistic processing was done in ArcGis and Excel.

RESULTS

Many researchers studied changes of the forested land percent cover of Central Russia. M.A. Tsvetkov [1957] studied the statistical data and has shown the decrease of the forested land percent cover in the center of European Russia from the XVII to the XX c.c. at 13 %, on average. The forested area decreased significantly in the central provinces within the deciduous broad-leaved forests and forest-steppe zones. The most notable decrease occurred in densely populated provinces. Based on old maps and satellite images, I.V. Kuksa [1993] showed the increase of the forested land caused by agricultural activities decrease in the northern part of the Central Russian Upland. The same process is observed at the adjacent south-west Moscow region [Arkhipova, Zamesova, 2006]. The area of the forested land decreased by 5% in the southern part of the Central Russian Upland [Chendev, 2008; Belevancev, 2012].

The statistical data for provinces do not reflect the real situation, because the provinces may have different natural conditions. The key plots studies show different trends of forested area changes in the northern and southern parts of the Upland. That is why we used the continuous transect to determine the forest area dynamics and areas where forest cover changed.

According to the paleogeographic papers written by Ju.G. Chendev [2008], intensive deforestation of Central Russian Upland began about 400 years ago. Today, the forests are distributed on the Upland unevenly. Regions with high percentage of the forested land are in the north of the Upland: the basin of the river Zusha and the area at the contact belt between forest-steppe and steppe (the right banks of the rivers Korocha, Valuy, and Tihaya Sosna, and the basin of the river Oskol); other parts of the transect have low percentage of the forested land (4–7%) within all phytogeographical zonal belts.

Large planted pine stands are situated mainly in the Oskol and Severskiy valleys and in the northern part of the Upland near the town of Aleksin (Fig. 4b). In the southern part of the Upland, coniferous afforestation is generally conducted in flood plains and on terraces, while in the northern part, it is done on watersheds. The coniferous planted stands are 6, 5% of all forested lands within the transect. There are vast forested areas in the upper river Oskol due to man-made afforestation.

Forest preservation in the past also contributed to the uneven forest distribution along the transect. The former abatis forest areas are 32% of all forests within the transect. There are vast forested areas in the contact belt between forest-steppe and steppe due to forest preservation.

The maps of the forested area percentage are made with the help of old maps (the end of the XVIII c. to the end of the XIX c.) and satellite images (Fig. 5).

The percentage of forested area decreased by 6% during the last 220 years. Within the deciduous broad-leaved forest zone, the decrease took place in the XVIII–XIX c.c.; from the end of the XIX c. to the end of the XX c., the forested area slightly increased. At the same time, the intensive deforestation in forest-steppe zone occurred during the last 150 years. The percentage of forest area decreased from 13 % till 8 % (Table 1).

The uneven forest distribution along the transect did not change during the last 220 years. Forested area decreased mainly in the contact belt between forest-steppe and steppe. Here, the former abatis woodlands were cut. The forested land area decreased by 20% (see Fig. 5). Less reduction of the forested land is observed

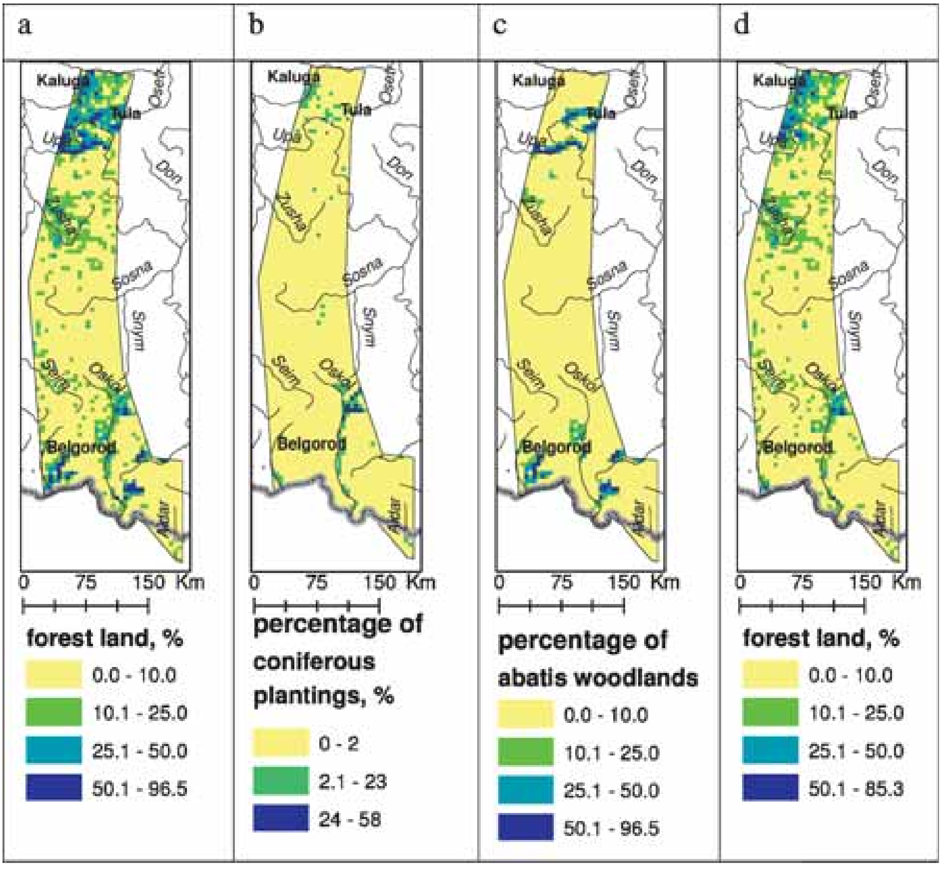

Fig. 4. The forested land distribution along the transect:

a – current percentage of the forested land, b – percentage of the coniferous planted stands, c – percentage of the former abatis woodlands, d – percentage of the forested land without the coniferous planted stands and abatis woodlands.

in the basin of the rivers Upa and Zusha and in the region of the Tula abatis. At the rest part of the transect changes of the forested land are small.

The ability of forest to restore is an important characteristic of natural environments. Using the old maps (1860–1880) and modern satellite images we analyzed the rate of forest regeneration (Fig. 6).

Forest regeneration is going mainly in the north and north-west of the transect within the deciduous broad-leaved forest zone, most intensive in the river basin of Zusha. Fifteen percent of the new forests are coniferous planted stands. The deciduous forests appear mainly in ravines (Fig. 7).

The probable reason of forest regeneration is the reduction of agricultural land during the

Table 1. The percentage of forested area

Phytogeographical zone	End of the XVIII c.	End of the XIX c.	End of the XX c.
The entire transect	16.5%	13.2%	10.5%
Deciduous broad-leaved forest zone	21.6%	14.4%	15.9%
Forest-steppe zone	14%	12.8%	7.9%

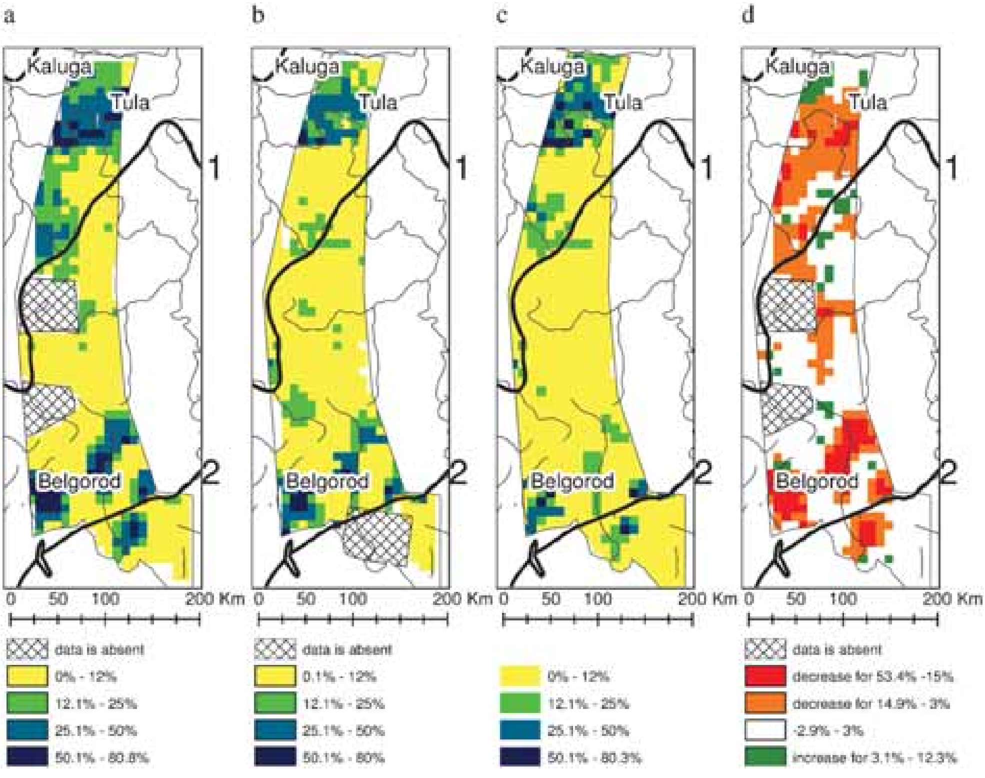

Fig. 5. The percentage of the forested area at the end of:

a – XVIII c., b – XIX c., c – XX c., d – change of the forested area percentage from the XVIII to the XX cc.

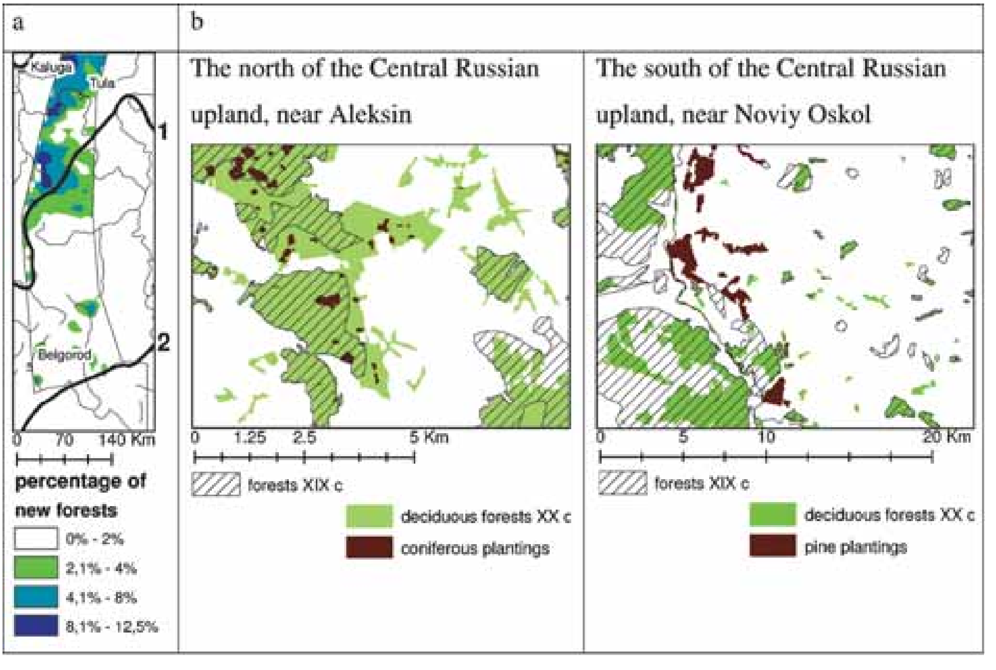

Fig. 6. Forest regeneration along the transect during last 140 years:

a – the rate of the regeneration, b – the examples of the regeneration.

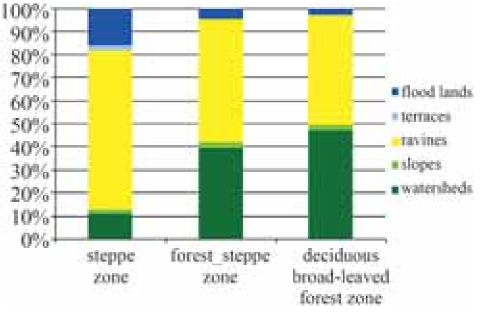

Fig. 7. The distribution of the new forests by the ecotops.

last 100 years. The system of reafforestation contributed to forested area increase also, particularly due to creation of erosion-preventive forest belts.

The data on the abatis woodlands dynamics during the last 220 years (Table 2) allow us to assess the forested area changes under active human impact.

Using these data, we estimated the percentage of the forested land change at the time of abatis creation. Many abatis woodlands after the end of the XVIII c. lost their protected status. Only small forests and coppices remained at the former abatis area, while in the past, the large woodlands were here. We interpolated the rate of the abatis woodlands change to the forests of the adjacent regions and made a model of forest distribution along the transect at the end of the XVI c. (Fig. 8).

According to the model, the forests were distributed evenly within the deciduous

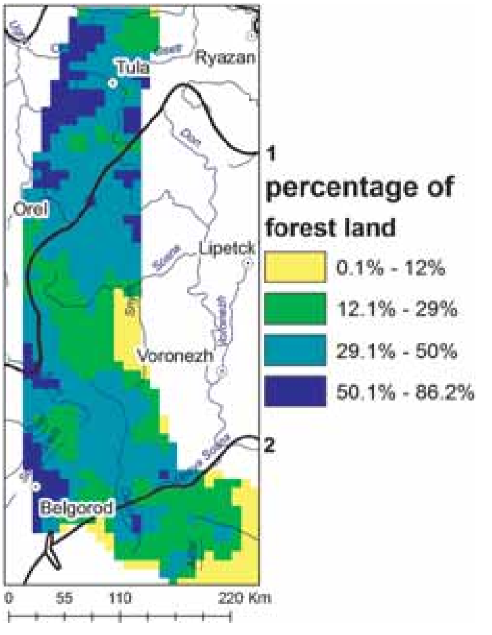

Fig. 8. The model of the forested land percentage along the transect (the XVI–XVII cc.).

broad-leaved forest and forest-steppe zones. The area of the forested land was 45% and 33% within the deciduous broad-leaved forest zone and forest-steppe zone, respectively. The percentage of the forested land was low in the interfluve of the rivers Sosna and Snym and within the steppe zone.

CONCLUSION

The forests are distributed unevenly along the transect. The proportion of forests is lower in the north within the deciduous broad-leaved forest zone and in the contact

Table 2. Dynamics of the the abatis woodlands areas in the XVIII-XX cc.

Region	Forested area in 1770, km2	Forested area in 2000, km2	Preserved forested area, %
Tula abatis	711.4	472.5	66.4
Regions to the north from Tula abatis	673	365.3	54.3
South Tula abatis	28	3.2	11.4
Belgorod abatis in the Oskol region	480.3	108.6	22.6
Belgorod abatis, protected during the last 220 yrs.	1186	620.8	54.3
Belgorod abatis, not protected during the last 220 yrs	237.3	23.1	9.7

belt between the forest-steppe and steppe zones. Such forest distribution has not changed during the last 220 years and is mostly connected with different types of human impact. The forest protection for military purposes and afforestation promoted the high share of the forested land in the south of the transect. The average decrease of the forested land area was 5–6% during the last 220 years. Within the deciduous broad-leaved forest zone, the forests were cut from the XVIII to the XIX cc., then, the percentage of the forested land increased somewhat. Within the forest-steppe and steppe zones, the forested area decreased during the last 220 years; most intensely forests were cut during the last 100 years in the contact belt between forest-steppe and steppe, where the former abatis woodlands were cut. Forest regeneration took place in the north of the Upland. New forests appeared mainly in ravines. Using the data of the abatis woodlands change since the end of the XVIII c., we modeled the forested land distribution in the XIX c. ■

REFERENCES

1. Arhipova, M.V., Zamesova, E.Ju. (2006). Botanical and geographical characteristics of the river Yazvitsy basin // Ecosystems of coniferous broad-leaved forests in the south of Moscow region. Collection of scientific works, Moscow. – P. 20–50.

2. Bartalev, S.A., Egorov, V.A., Ershov, D.V., Isaev, A.S., Lupjan E.A., Plotnikov, D.E., Uvarov, I.A. (2011). Satellite mapping of vegetation of Russia according to spectroradiometer MODIS data // Modern problems of the Earth remote sensing from space. Vol. 8, No 4. – P. 285–302.

3. Belevancev, V.G. (2012). Percentage of forest land and river network in the central Russian Belogor'e in 1780, 1880, and 1980 // Modern problems of science and education. No 6. www.science-education.ru/106-7750.

4. Chendev, Ju.G. (2008). Evolution of the Central Russian Upland forest-steppe soils in the Holocene. Moscow: GEOS. – 212 p.

5. Jakovlev, A. The abatis line of Moscow state in the 17th century: Story from the defense history of Moscow state south boundaries. M.: printing of I. Lissnera D. Sobko. IX. – 312 p.

6. Kuksa, I.V. (1993). A study of the forest distribution dynamics by satellite images and old maps // Synopsis of a thesis for the PhD degree of geographical sciences. Moscow. – 26 p.

7. Ogureeva, G.N. (ed.). (1999). Zones and altitudinal zonality types of vegetation of Russia and adjacent territories. Scale 1: 8 million. Explanation text and legend of the map. Moscow, Moscow State University press. – 64 p.

8. Plans–atlases of the counties of Tula, Orel, Kursk and Voronezh regions (1780). M 1:84000. RSAAA. Surveying storage. Fund 1356.

9. Strel'bitskii, I.A. (ed.). (1868–1887). A special map of European Russia. St. Petersburg: Military Topographical Department of General Staff press.

10. Spiridonov, A.I. (1978) Geomorphology of the USSR European part. Moscow: Higher School publishers. – 335 p.

11. Tsvetkov, M.A. (1957). The change of forested land percentage of European Russia since the end of the XVII century to 1914. Moscow: Academy of Sciences of the USSR publishers. – 213 p.

12. Zagorovskij, V.P. (1969). Belgorod abatis. – Voronezh: Voronezh University press. – 304 p.

13. Zagorovskij, V.P. (1980). Izjumskaja abatis. – Voronezh: Voronezh University press. – 200 p.

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PAN EURASIAN EXPERIMENT (PEEX) – A RESEARCH INITIATIVE MEETING THE GRAND CHALLENGES OF THE CHANGING ENVIRONMENT OF THE NORTHERN PAN-EURASIAN ARCTIC-BOREAL AREAS

ABSTRACT. The Pan-Eurasian Experiment (PEEX) is a new multidisciplinary, global change research initiative focusing on understanding biosphere-ocean-cryosphere-climate interactions and feedbacks in Arctic and boreal regions in the Northern Eurasian geographical domain. PEEX operates in an integrative way and it aims at solving the major scientific and society relevant questions in many scales using tools from natural and social sciences and economics. The research agenda identifies the most urgent large scale research questions and topics of the land-atmosphere-aquatic-anthropogenic systems and interactions and feedbacks between the systems for the next decades. Furthermore PEEX actively develops and designs a coordinated and coherent ground station network from Europe via Siberia to China and the coastal line of the Arctic Ocean together with a PEEX-modeling platform. PEEX launches a program for educating the next generation of multidisciplinary researcher and technical experts. This expedites the utilization of the new scientific knowledge for producing a more reliable climate change scenarios in regional and global scales, and enables mitigation and adaptation planning of the Northern societies. PEEX gathers together leading European, Russian and Chinese research groups. With a bottom-up approach, over 40 institutes and universities have contributed the PEEX Science Plan from 18 countries. In 2014 the PEEX community prepared Science Plan and initiated conceptual design of the PEEX land-atmosphere observation network and modeling platform. Here we present the PEEX approach as a whole with the specific attention to research agenda and preliminary design of the PEEX research infrastructure.

KEY WORDS: climate change, air quality, the Arctic, boreal forest, the Arctic Ocean, atmosphere-biosphere-cryosphere interactions, permafrost, greenhouse gases, anthropogenic influence, natural hazards, research infrastructures.

BACKGROUND

The dynamics between demographic trends, the changes in the demand of natural resources, globalization and climate change and their interactions and feedbacks are the driving forces for the next 40 years megatrends taking place on the northern latitudes and the Arctic regions [Smith 2010]. The Arctic has warmed more than twice the global-average rate during the recent decades, and the summers 2005, 2007, 2010 and 2011 were probably warmer than any other summer during the past 600 years in high northern latitudes [Tingley & Huybers 2013]. The most recent report by Intergovernmental Panel on Climate Change [IPCC 2013] concluded that this pattern will continue, and the Artic regions will warm from 2, 2 ± 1, 7 °C up to 8, 3 ± 1, 9 °C by the end of this century, depending on the selected future emission scenario. To cope with the consequences of the climate change in a global scale the transformation of the civilization and natural ecosystems are one of the ultimate challenges of the 21st century. It is expected that the northern regions, land and ocean areas lying 45 °N latitude or higher, will undergo consequential change during the next 40 years [IPCC 2013].

The warming will affect the demography trends and urbanization and, consequently, the migration to the Northern regions is expected increase. One of the major environmental consequences of the warming is thawing of permafrost and melting of ice over the Arctic Ocean [Christensen et al., 2004; IPCC, 2013]. The thawing of permafrost in the Boreal and Arctic regions will impact the exploration and extraction of large sources of non-renewable natural resources such as oil and natural gas in diverse ways. Navigation in and the transport through the Arctic will increase, if the Northern Sea Route between the Atlantic and the Far East will stay open for shipping for a longer summer-autumn period than presently [Kerr, 2012]. Considering the utilization of the natural resources, while the exploitation will be easier as the permafrost is thawing, instability of frozen ground will generate higher potential risks of accidents, for example, on transportation of oil and gas via pipelines.

One of the major impacts of the Northern Pan-Eurasian region on the climate system is related to the changing dynamics of the Arctic-boreal ecosystems. The changes in ecosystem distribution and productivity, surface energy balance, albedo and in the production volume of the aerosol precursors and greenhouse gases can be significant and probably will play a vital role. The Eurasian area holds a large pool of recently stored-carbon within the biota and an inactive soil carbon pool in permafrost areas, but also a vast storage of fossil carbon storage in the form of oil and gas deposits [Groisman et al., 2013]. Due to these large storages, small changes in the carbon dynamics, release and emissions can have global climate consequences [Piao et al., 2008; Zimov et al., 2006]. The expected shifting of the bioclimatic zones towards Arctic together with replacement of boreal forests in the southern ecotone of the forest zone makes substantial changes in land cover over the Siberian regions [Buermann et al., 2014; Walther et al., 2002; Tape et al., 2006; Elmendorf et al., 2012; Shvidenko et al., 2013; Tchebakova et al., 2009]. The boreal forests can be considered as a tipping element as they may enter into unstable state, where relatively small changes of environment may lead to a nonlinear feedback in functioning of forest ecosystems and death of its components with the least adaptation capacity [Lenton et al., 2008]. These changes are reflected to woody biomass accumulation and net primary productivity (NPP) of northern terrestrial ecosystems [Rustad et al., 2001; Melillo et al., 2002] and may, on the other hand, lead into a negative feedback between climate warming and the terrestrial ecosystems in a form of secondary aerosol formation [Paasonen et al., 2013].

In addition to the land ecosystems – atmosphere processes, understanding planetary boundary layer (PBL) mechanisms has a significant role in the Earth system dynamics. The PBL is the lower, essentially turbulent atmospheric layer immediately affected by the interactions with the underlying land, biosphere, urban, water, ice or snow surfaces, and usually subjected to pronounced diurnal temperature variations. Physical and chemical processes in the PBL control local features of weather and climate, as well as the outdoor and indoor air quality. The PBL is intensely turbulent in contrast to the free atmosphere, where turbulence is significantly weakened due to the dominantly stable stratification [Zilitinkevich et al., 2013]. Shallow stably-stratified PBLs amplify consequences of thermal impacts e.g. from local changes in the land-use or the global climate change and increase the level of air pollution at given intensity of emissions [Zilitinkevich et al., 2007; Zilitinkevich & Esau, 2009;

Esau et al., 2013]. Deep convective PBLs typical of unstable stratification strongly influence weather and climate through ventilation (turbulent entrainment) at the PBL upper boundary, and essentially control air quality and development of convective clouds [Zilitinkevich, 2012].

A new large-scale research initiative "Pan Eurasian Experiment", PEEX was launched in Helsinki, Finland, in October 2012. A group of Russian, Chinese and European research institutes established a process towards writing a science plan underling the most urgent research topics and related to climate change on the Arctic boreal environments and societies of Northern Pan-Eurasian regions (Fig. 1). It was established that the research agenda needs to be complemented with the development of observation networks and data systems, establishing education activities and fast procedures for the Northern societies to cope with the environmental change.

PEEX OBJECTIVES

PEEX is a next generation research initiative, contributing to the future environmental, socio-economic and demography development of the Arctic and boreal regions. Furthermore, PEEX aims to form a strong science community, which coordinates and builds novel observation and data infrastructures in the Northern Eurasian region.

The objectives of PEEX are:

1) to understand the Earth system as a whole and in particular to understand the influence of environmental and societal changes in pristine and industrialized Northern Pan-Eurasian environments.

- to determine the processes relevant to the climate change in the Pan Eurasian region.

2) to establish and sustain long-term, continuous and comprehensive ground-

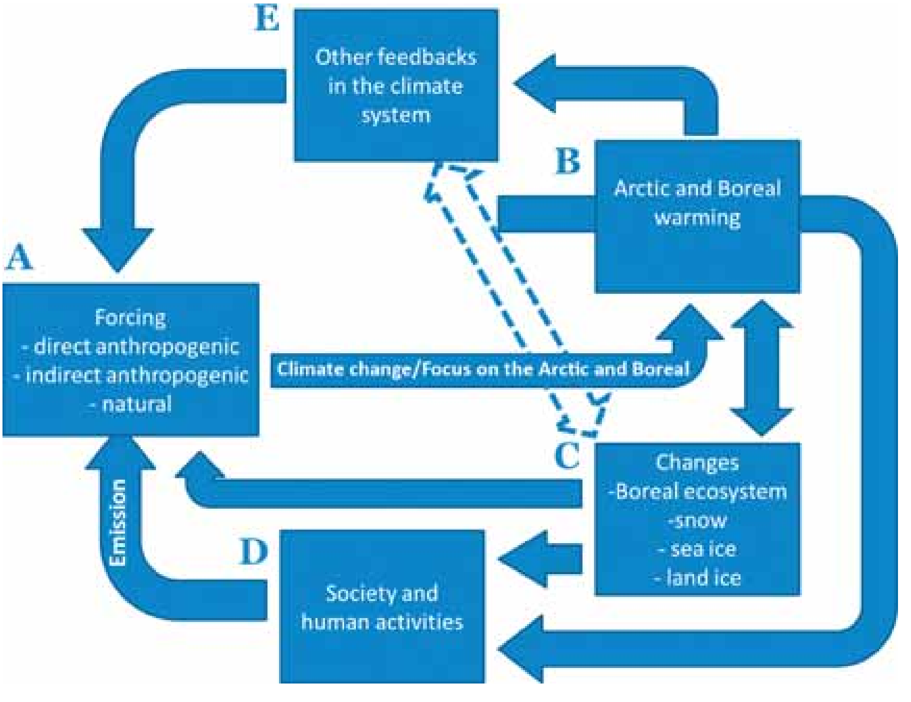

Fig. 1. PEEX large scale schematics addresses the strong role of the Arctic and boreal regions (adopted form Nordic Center of Excellence "Cryosphere-atmosphere interactions in a changing Arctic climate" (CRAICC)-project).

based airborne and seaborne research infrastructures, and to utilize satellite data and multi-scale model frameworks supporting comprehensive earth observations.

3) to contribute to regional climate scenarios in the Northern Eurasia and China, and to determine the relevant factors and interactions influencing human and societal wellbeing.

- to assess the natural hazards (floods, forest fires, extreme water events, risks for structures built on permafrost) related to cryospheric changes in the Northern Pan-Eurasian arctic-boreal regions

- to provide information for the adaptation and mitigation strategies for sustainable land-use, energy production and human well-being.

4) to promote dissemination of the state-of-the-art scientific results and strategies in the scientific and stake-holder communities and policy making.

5) to educate the next generation of multidisciplinary global change experts and scientists.

6) to increase the public awareness on the climate change impacts in the Pan-Eurasian region.

RESEARCH METHODS

The PEEX research agenda is built on large-scale research questions of the main PEEX components: land-atmosphere-aquatic-systems including the key questions of the human activities and society and feedback and links between the systems. The method solving the topical research questions and complex feedbacks, is adopted from the EU-FP6 – "Integrated Project on Aerosol, Cloud, Climate, and Air Quality Interactions" (EUCAARI), the atmospheric aerosol project [Kulmala et al., 2009; Kulmala et al., 2011] and it is based on integration of scientific knowledge from nano- to global scale with multidisciplinary science approach (Fig. 2).

The PEEX research approach covers different spatial and temporal components, where PEEX is investigating various types of natural ecosystems and urban environments. The large scale systems covered by the PEEX approach are the land-system, atmospheric-system, aquatic-system and the human activities on this system as a whole. Each system can be divided into smaller sub-components. For example, the land-system

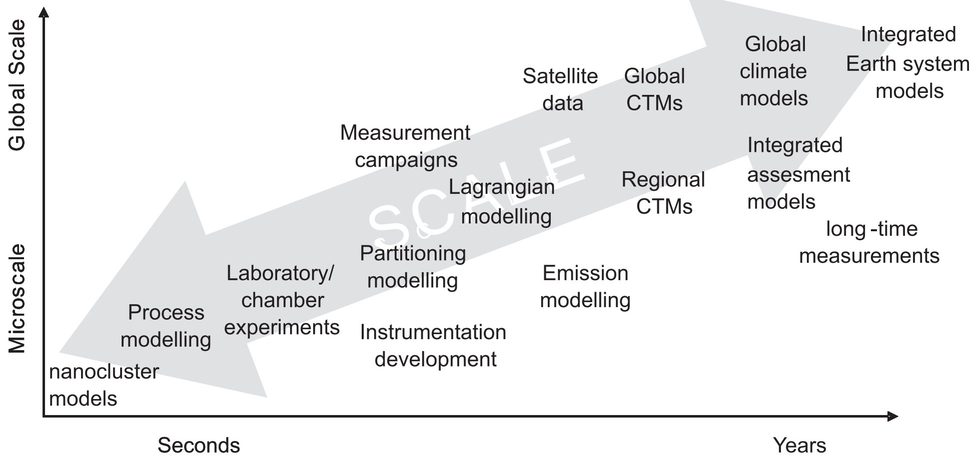

Fig. 2. The "EUCAARI arrow" servers as a methodological concept for connecting scientific results from molecular scale processes with the global scale effects by using integrated measurements, modelling and theory (Kulmala et al., 2009).

Fig. 3. Geographical boundaries of PEEX domain (inside the dotted line). The PEEX covers the Arctic-boreal areas of Pan-Eurasian region including major remote areas of Greenland and the important long-range air pollution, China (map http://en.wikipedia.org/wiki/File:Distribution_Taiga.png).

is divided into boreal forests, burnt or clear-cut areas, grasslands, tundra and peatlands, whereas the Aquatic-system is divided into the Arctic Ocean, freshwater lakes and rivers, and associated catchments, shores, continental shelves and pelagic regions. The Atmospheric-system is classified into boundary layer, troposphere, stratosphere and the human activities include the anthropogenic impact, environmental risks and social transformations.

Geographically, Northern Europe, Siberia and Far East are the ecoregions of the PEEX domain (Fig. 3) with related hydrological areas and catchment areas. China is included as an important source area for the atmospheric PEEX component.

LARGE-SCALE RESEARCH QUESTIONS

PEEX community has identified 15 large scale research questions (Q) pertinent for each subsystem for the next 10 years. Each of the large scale research questions is connected to one of the key topics of the PEEX research agenda. The key topics are introduced in the PEEX Science Plan in more detail.

LAND SYSTEM

Q-1 How could land regions and processes that are particularly sensitive to climate change be identified, and what are the best methods to analyse their responses the future changes?

Key Topic: Shifting of vegetation zones, Arctic greening

Q-2 How fast will permafrost thaw proceed, and how will it affect ecosystem processes and ecosystem-atmosphere feedbacks and interactions, including hydrology and greenhouse gas fluxes?

Key Topic: Risk areas of permafrost thawing

Q-3 What are the tipping points in the changing Pan Eurasian ecosystems in the future?

Key Topic: Structural changes of the ecosystems

ATMOSPHERIC SYSTEM

Q-4 What are the critical atmospheric physics and chemistry processes with large-scale climate implications?

Key Topic: Atmospheric composition and chemistry

Q-5 What are the key feedbacks between air quality, climate and weather at northern high latitudes and in China?

Key Topic: Urban air quality, megacities and changing PBL

Q-6 How will atmospheric dynamics in different scales, such as synoptic scale weather and planetary boundary layer, change in Arctic – boreal regions?

Key Topic: Weather, general atmospheric circulation

AQUATIC SYSTEMS INCLUDING THE ARCTIC OCEAN

Q-7 How will the extent and thickness of the Arctic sea ice, terrestrial snow cover change in the future?

Key Topic: Arctic Ocean as part of the climate system

Q-8 What is the combined effect of Arctic warming, pollution load and acidification on the Arctic marine ecosystem, primary production and carbon cycle?

Key Topic: The Arctic maritime environment

Q-9 What is the future role of the Arctic-boreal lakes, wetlands and large river systems in the biogeochemical cycles including thermokarst lakes and running waters of all sizesand how will future changes affect the society in general, and livelihood, agriculture, forestry and industry in particular?

Key Topic: Lakes, wetlands and large river systems in Siberian region

ANTHROPOGENIC ACTIVITIES

Q-10 How will human actions such as land-use change, energy production, efficient use of natural resources, and use of energy sources influence further environmental changes in the region?

Key Topic: Anthropogenic impact

Q-11 How do the changes in physical, chemical and biological state of the different ecosystems, inland water and coastal areas affect the economies and societies in the region and vice versa?

Key Topic: Environmental impact

Q-12 In which ways are socio-economic areas vulnerable to climate change, how can their vulnerability be reduced and their adaptive capacities improved and what responses can be identified to mitigate and adapt to the climate change?

Key Topic: Mitigation, climate change, natural hazards

FEEDBACKS – INTERACTIONS

Q-13 How will the changing cryospheric conditions and the following ecosystem changes feedback to the Arctic climate system and to the weather and do they pose an increasing risk via natural hazards?

Key Topic: Changing permafrost and associated natural hazards

Q-14 What are the net effects of various feedback mechanisms connecting e.g. (i) land cover changes (ii) photosynthetic activity, (iii) GHG and BVOC emissions (iv) aerosol and cloud formation and radiative forcing varying with the climate change in the regional and in global scales?

Key Topic: Negative and positive feedback mechanisms in the changing environment

Q-15 How intensive urbanization and related processes are changing the local and regional climate and the environment in general and how can this be foreseen via an early-warning system in connection to increased risk for natural hazards and air quality issues?

Key topics: Atmospheric composition change, biogeochemical cycles; water, carbon, nitrogen, phosphorus, sulphur, natural hazards, air quality

THE STRUCTURE OF THE PEEX INITIATIVE

Research agenda

The main goal of the PEEX research agenda is to solve locally and globally important science questions associated with the Arctic and boreal regions. The PEEX large-scale research questions, listed above, are focused on understanding the key processes of the land-atmospheric-aquatic-anthropogenic systems and on the identification and the quantification of the main feedbacks in the Pan-Eurasian Arctic-Boreal region. The large scale research questions (Q-1–Q-15) are linked to the main research topics of the PEEX initiative.

The key to understand the Earth system behaviour and future climate is on the identification and quantification the feedback mechanisms in the land – atmosphere – aquatic – anthropogenic continuum. The scientific outcome of PEEX is to fill current gaps of knowledge in the process understanding, feedbacks and links within and between the systems and in biogeochemical cycles in the Arctic-boreal context. The PEEX research agenda is designed to catch the most relevant processes in each of these systems subsequently integrating them into a holistic understanding of the Earth system. PEEX is interested in the so called COBACC (Continental Biosphere–Aerosol–Cloud–Climate) – hypothesis by Kulmala et al. [2004] (Fig. 4) and CLAW (Feedback loop between ocean ecosystems and the Earth's climate)-hypothesis by Charlson et al. [1987].

The COBACC – hypothesis suggests two loops related to the ambient temperature and gross primary production (GPP). First one is a negative climate feedback mechanism whereby higher temperatures and CO_2-levels boost continental biomass production leading to increased biogenic secondary organic aerosol (BSOA) and cloud condensation nuclei (CCN) concentrations tending to cause cooling [Paasonen et al. 2013]. The second, a positive feedback loop, connects the BSOA to the increasing

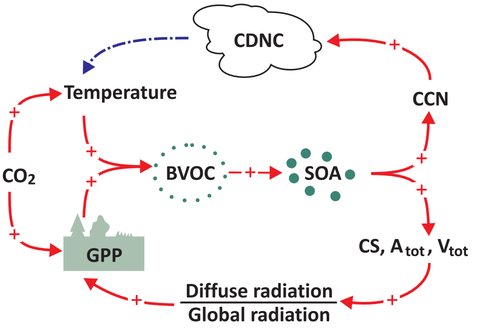

Fig. 4. The two feedback loops associated with the COBACC feedback. BVOC = biogenic volatile organic compounds, SOA = secondary organic aerosol, CS = the condensation sink, A_{tot} = total aerosol surface area, V_{tot} = total aerosol volume, CCN = cloud condensation nuclei, CDNC = cloud droplet number concentration, and GPP = Gross Primary Productivity, which is a measure of ecosystem-scale photosynthesis (Kulmala et al., 2014 in press).

condensation sink that affect the ratio between diffuse and direct radiation and enhancing GPP [Kulmala et al. 2004, Kulmala et al. 2014].

The CLAW-hypothesis connects ocean biochemistry and climate via a negative feedback loop involving CCN production due to sulphur emissions from plankton [e.g. Quinn & Bates, 2011]. These global-scale feedback hypotheses are closely linked to biogeochemical cycles, which are still inadequately understood and have many feedback loops that are difficult to quantify. They are related to e.g., coupling of carbon and nitrogen cycles, permafrost processes and ozone phytotoxicity [Arneth et al., 2010] while some are related to emissions and atmospheric chemistry of biogenic volatile organic compounds [Grote & Niinemets 2008; Mauldin et al., 2012], subsequent aerosol formation and growth [Tunved et al., 2006; Kulmala et al., 2011a] and aerosol direct forcing and aerosol-cloud interactions [Lihavainen et al., 2009; McComiskey & Feingold 2012; Penner et al., 2012;Scott et al., 2014]. For a proper understanding of the dynamics of these processes, it is essential to quantify the range of emissions and fluxes from different types of ecosystems and environments and their links to ecosystem

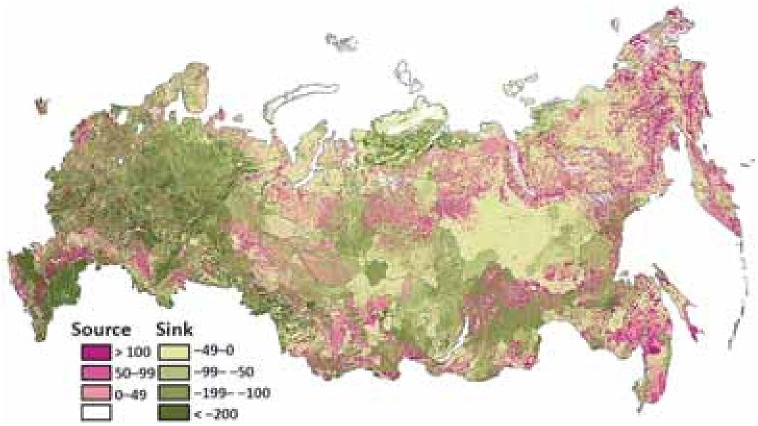

Fig. 5. Net Ecosystem Carbon Balance of Russian terrestrial ecosystem (2009). Dimension in the legend g C m^{-2} $year^{-1}$ (Dolman et al., 2013).

productivity, and to take into considerations that there may be previously unknown sources and processes [Su et al., 2011; Kulmala & Petäjä, 2011; Bäck et al., 2010].

As an example, understanding the complex processes and links of the carbon cycle is crucial for estimating the carbon budget in the Russian region. In spite of a wide distribution of natural and human-induced disturbances, terrestrial ecosystems in Russia served as a net sink of carbon with Net Ecosystem Carbon Balance of 550–650 Tg C yr^{-1} during the last decade out of which above 90% was provided by forests [Dolman et al., 2012; Shvidenko & Schepaschenko, 2013b]. While the overall sink of the terrestrial ecosystems is high, substantial areas serve as a source as well, typically associated with permafrost and with disturbed forests (Fig. 5). The major feedbacks need to be analysed whether they will lead to the decreasing carbon sink by the 2030s which can be substantial by end of this century [Shvidenko, 2012].

The human activities in inland areas can considerably alter the hydrological and hydrogeochemical conditions of downstream lakes, wetlands and coastal waters [Meybeck, Vörösmarty, 2005]. Intensive changes in the human activities within some parts of the Eurasia both in semi-arid and boreal corridor require a new vision to link hydroclimatic, hydrological and hydrogeochemical research with a special focus on the climatic and human change sequences. According to Kasimov, [2013], basin-scale distributions of pollution sources, transport pathways as well as times from the pollution sources and resulting loads after retention along the pathways, through the coupled atmosphere – surface water – groundwater systems to downstream recipients have to be studied.

As whole, Northern Pan-Eurasian Arctic-Boreal geographical regions cover a wide range of human-natural system interactions and feedback processes, with humans acting both as the source of climate and environmental change and as the recipient of the impacts. In urban and industrialised regions the process understanding of biogeochemical cycles include anthropogenic sources such as industry and fertilisers, as indispensable parts of the biogeochemical cycles [Galloway et al., 2003]. The observed changes in the hydrological cycle and biogeochemical cycles are needed to construct and parameterize the next generation of Earth System models.

Natural hazards

A crucial task of PEEX will be to prepare the mitigation and adaptation plans, including forecasting tools to minimize the foreseen risks of natural hazards such as forest fires, floods and landslides and infrastructure (buildings, roads, energy distribution systems) damages due to thawing permafrost and extreme weather events (droughts, storms, heat waves). Due to forest succession and associated accumulations of forest biomass major risks are expected to take place in dark coniferous forests ecosystems. Changing disturbance regimes could lead to dramatic increase of wildfire and outbreaks of forest pests. This generates a high probability of a significant positive feedback between the warming and escalation of wildfire regimes. The increase in the atmosphere CO_2 concentration will extend the prolonged dry periods that will cause the expansion of the fire area and fire severity and lead to a considerable increase in greenhouse gas emissions due to deep soil burning. In turn, as a result of climate change the increase in carbon emissions will potentially increase the risk of fires [Shvidenko 2013a, Kuzminov, 2011].

One area of specific interest is the climate projection of weather hazards with the state of the art classification. Meteorological and climatological classifications are wildly used in weather forecasting. In recent decades, the usage of classifications has widened due to new computer techniques. Now it is considered to be two fundamental approaches of investigating the link between the large-scale circulation and environmental variables [Cannon et al., 2002; Smedsrud et al., 2013; Zhang et al., 2013; Zhou et al., 2013]. In the framework of the first one, so-called the "circulation – to environment" approach, arrangement of the circulation data of interest (e.g. sea level pressure, geopotential height, etc.) is carried out to group them into circulation types (CTs) according to a selected methodology (clustering, principal component analysis (PCA), regression, etc.). Then, one looks for relations of CTs with the local-scale environmental variable (e.g. storm waves). Such an approach has already tested, for example, over the PEEX geographical domain [Surkova et al., 2013; Zhou et al., 2013].

Atmospheric pollution

Atmospheric pollution is one of the key environmental problems in Russia and China that needs to be resolved. The geographical distribution of pollutants is not uniform over the Russian territory and it considerably depends on the strength of the emission source and the emission composition [Baklanov et al., 2012, Bityukova & Kasimov, 2012, Goncharuk & Lapshin, 2012]. Urban emissions changing the gas and aerosol content [Chubarova et al., 2011, a, b] and their adverse effects on the environment and human health [Malkhazova et al., 2012a, b; Malkhazova 2013; Chubarova & Zdanova, 2013] are currently studied in Russia. China's air pollution in 2013 was at its worst for some 52 years, with 13 provinces hitting record-high levels of air pollution. Increasingly, more cities are now monitoring air quality in real time using meteorological towers and remote sensing from satellites to track pollutants [e.g. Ding et al., 2013]. In Beijing concentrations of micro particles in the atmosphere have been found to be more than 10 times the safe level recommended by the WHO. This has prompted authorities to take measures such as limiting industrial emissions and reducing traffic across the nation. Also in these cities the haze is so thick that often in winter it blocks out the sun, reducing natural light and warmth significantly. As a result temperature drops, households use more energy for heating; pollution gets worse, causing respiratory diseases and eventually more people are hospitalized. The country's five-year action plan has provisions to improve environment technology, planning and regulation. The plan aims at reducing heavy pollution by a large margin and improves air quality in Beijing-Tianjin-Hebei province, the Yangtze River Delta and the Pearl River Delta. Awider research observation infrastructure plan of air quality within the PEEX framework will made in order to contribute to the sustainable development of the PEEX area and for the well-being of the population.

INFRASTRUCTURE

General concept of the PEEX in-situ land-atmosphere station network

The main aim of the PEEX land-atmospheric observation network is to fill the current in-situ observational gap in the Siberian and Far East regions and bring the observation setup into international context with standardized or comparable procedures. PEEX serves as a basis for the long-term continuation of advanced measurements on aerosols, clouds, GHGs, trace gases and biosphere processes in the Northern Eurasian and China to be operated by educated scientific and technical staff capable of answering the research questions arising from the PEEX science community.

The PEEX Observation Network program will include the following tasks:

– to identify the on-going measurement routines of the ground stations,

– to analyze the end-user requirements of the global and regional-scale modeling communities,

– to provide an outline for the PEEX labeled network incl. the measurement and data product – archiving – delivery requirements for each station category,

– to identify the most important gaps in the initial phase observational network including long-term observational activities in Europe, in Russia, in China and globally,

– to initialize harmonization of the observations in the PEEX network following e.g. accepted practices from World Meteorological Organization (WMO) Global Atmosphere Watch (GAW) programmed and the European observation networks,

– to carry out inter-platform inter-comparisons between the ground-based and satellite observations,

– to establish education program on the measurement techniques and data-analysis for young scientists and technical experts,

– to establish connections to Northern America.

The PEEX research infrastructure (RI) will consist of a comprehensive field station network in the region covering Scandinavia, Finland and the Baltic countries, Siberia and China, complemented by satellite observations and corresponding integrated modeling tools. The vision of the Pan-Eurasian network will be based on a hierarchical SMEAR-type (Station for Measuring Forest Ecosystem–Atmosphere Relations) integrated land-atmosphere observation system [Hari et al., 2009]. This means that some of the stations will have a minimum instrument setup and data processing for atmospheric monitoring, but providing spatial coverage, whereas the most advanced stations will cover a full setup of instruments and data systems for monitoring energy flows in the land-atmosphere-aquatic continuum providing an integral and comprehensive view.

The PEEX network is based on existing infrastructure representing different environments and different types of stations: (i) standard stations, (ii) flux stations and (iii) flag ship stations with comprehensive ecosystem-atmosphere measurements. For example, the current weather stations like typical meteorological station maintained by Rosrydromet, could represent the standard stations. There are about 1000 weather stations in Former Soviet Union with time series started usually from 1936 (Fig. 6) and which archived data are freely available from World Data Centers (RIHMI-WDC, Obninsk, Russia or NCDC-NOAA, Ashville, USA).

At the beginning the PEEX observation system is based on the currently existing infrastructures, supplemented by a flag ship station network. A flag ship station measures meteorological and atmospheric parameters together with ecosystem-relevant processes

Fig. 6. Maps of weather stations at PEEX domain area. Pink dots – WMO stations, brown – GSOD (global summary of the day) data (adapted from Climate Data Online NCDC NOAA (http://www.ncdc.noaa.gov/cdo-web/)).

(incl. carbon, nutrient and water cycles, vegetation dynamics, biotic and abiotic stresses). Ideally, the PEEX network will contain one flag ship station in all major ecosystems, in practice a station in every 2000–3000 km from each other. The in-situ infrastructure will be completed by aircraft and satellite observations, having also an important role in validation, integration and full exploitation of satellite data for Earth system studies. The role of remote sensing observations is emphasized in remote areas, such as the Arctic Ocean, maritime environments and most of the Arctic land areas with virtually no in situ observations.

Preliminary setup of the PEEX in-situ observation network

In 2013–2014, a suite of ground stations has already been selected for the PEEX Observation network. These stations includes the SMEAR-type stations (Measuring Atmosphere–Ecosystem Interactions) in Finland (SMEAR-I (N 67° 45.295', E 29° 36.598')-II (N 61° 50.845', E 24° 17.686')-III (-IV stations (N 60° 12', E 24° 58') and Estonia (SMEAR-Järviselja) In addition to SMEAR-stations, the network includes: Pallas-Sodankylä-GAW station (Finland), TIKSI-regional–GAW station (Russia), and selected stations in Russia (Nizni Novgorod, Moscow-Borok, Zvenigorod – Obninsk cluster, Tomsk, Kola Arctic / White Sea, Tiksi, Novosibirsk, Zotino, Tjumin, Baikal – Irkutsk – Ulan Ude) and in China (Changbai Mountain Research Station of Forest Ecosystems 42°4' – 42°36'N, 126°55'– 129°8' E, Kashi Satellite Data Receiving Station China Remote Sensing Satellite Ground Station 75.83°E, 39.50°N, Station for Observing Regional Processes in the Earth System (SORPES) E118°57'9", N32°7'13", Beihai Ecosystem Station, CERN

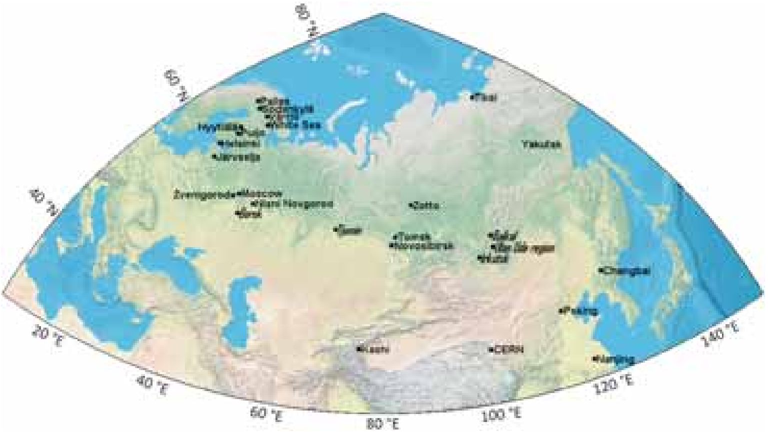

Fig. 7. The first set of the PEEX labeled in situ atmospheric stations across the Pan-Eurasian region.

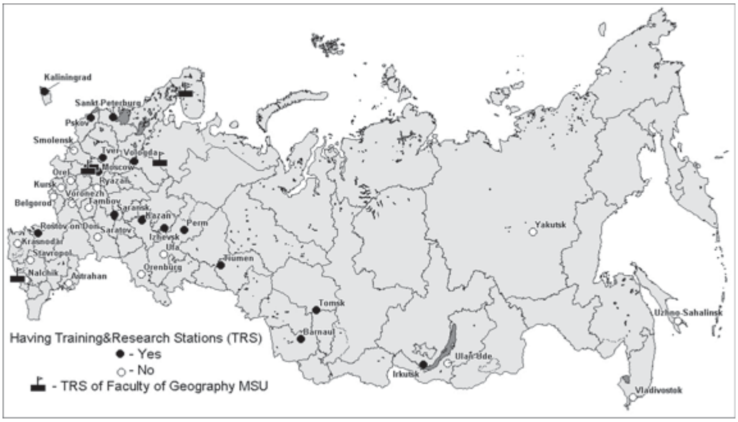

Fig. 8. Research and training field stations (TRS) in Universities of Russia.

Network Station N37°37', E101°19'). These stations are situated in different vegetation and climate zones representing hemi-boreal, boreal, arctic and sub arctic regions (Fig. 7). The Russian PEEX core stations can be supported by the research and training station network of Russian Universities., This network may widen an geographical scope of the PEEX environmental observation in the future [Kasimov et al, 2013] (Fig. 8).

The preliminary set of PEEX stations will be expanded in the future. Good candidates are e.g. the set of remote stations hosted by Russian Academy of Sciences (RAS). Altogether, 30 institutes of the RAS Department of Earth Sciences and the RAS Department of Biological Sciences have indicated that they are ready to contribute the PEEX observation program (Fig. 9). The contribution of RAS institutes will allow a planning of combined

Fig. 9. A map showing positions of the RAS institutes and their field bases or branches. Red circles are institutes, and blue ones are field bases.

observational programs with the ground and aircraft observations and revealing existence of Russian observational stations with instrumentations rather similar to the SMEAR-type stations. For example, the forest station "Spasskaya Pad" of the Institute of Biological Problems of cryolithozone of Siberian Branch of RAS (Yakutsk), is the only station in the world where the observation methods used in Asia and Europe are compared (CarboEurope, AsiaFlux, and ScanNet projects).

PEEX aims to have a special observational program on the comparison of the ecosystem states in such distant areas as North Europe (Finland) and Yakutiya (East Siberia). Zuev Institute of the Atmosphere Optics of the RAS Siberian Branch has own rich observational network including ground stations and aircraft. Central Aerological Observatory of Roshydromet has recently received new aircraft that also may be considered as one of possible platforms for the PEEX.

Preliminary concept of the aquatic observations in the surrounding seas

Similar to the in-situ land – atmosphere observation network, a network of hierarchical stations in the surrounding seas will be established in collaboration with major oceanographic research programs. The Preliminary concept of the Aquatic Observations in a surrounding seas would consist of (A) Simple buys, (B) Sophisticated buoys, (C) Research vessels and (D) Flagship stations (Fig. 10.).

The Category-A refers to buoys deployed on sea ice or in the open ocean with measurements of the location, atmospheric pressure, as well as air and surface temperature. The buoys transmit the data via satellite links. Successive observations on the location yield the ice drift or ocean current vector, in the case of ice and open ocean buoys. Category-B refers to buoys that include more devices that allow measurements of at least snow and ice thickness, temperature profiles through the upper ocean, sea ice, and snow, as well as profiles of ocean currents and salinity. Category-C, research vessels, allows a wide range of measurements on the physical, chemical, and biological properties and processes in the ocean, sea ice, snow, and atmosphere. Research vessel cruises in the Arctic typically take place in summer, include ice stations, and seldom last longer than three months. Hence, they are only temporary stations, but allow numerous measurements that cannot be made by stations in categories A and B; these include turbulent fluxes of momentum, heat, moisture, CO_2, CH_4, as well as many biological and chemical measurements.

Category-D, Flagship stations, includes manned drifting ice stations and manned permanent coastal/archipelago stations. These allow the same kind of measurements as conducted from research vessels, but the Flagship stations have a longer duration and allow much more measurements on sea ice, its snow pack, and the ocean below the

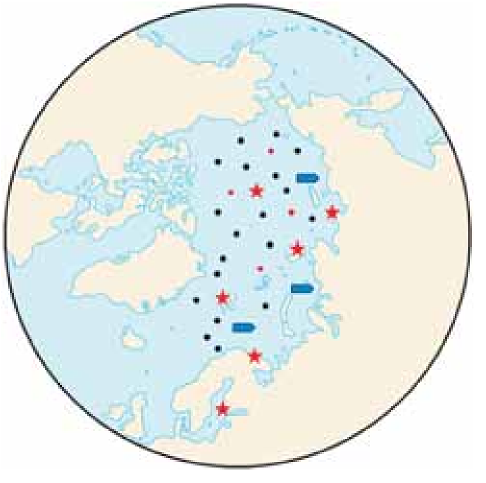

Fig. 10. Schematic illustration on the potential station network in the Arctic Ocean. There are presently a lot of stations of categories A (black dots) and B (red dots), and mostly in summer also some of category C (blue boxes) but their locations are continuously changing and each individual station has a limited operation time. For category D (red stars), the figure only provides a vision for the future; the number and locations of the stations are open, except that the station in the Baltic Sea is already in operation.

ice. Further, the Flagship stations provide a basis for operation of (i) Unmanned Aerial Systems for atmospheric measurements and mapping of the sea ice and ocean surface properties, and (ii) autonomous under-ice gliders for oceanographic measurements (e.g. water temperature, salinity and dissolved oxygen). Such methods will significantly extend the area covered by observations. The measurements of water and air CO_2 concentrations, temperature and photosynthetically active radiation (PAR) are introduced to the standard buoys used in the studies of oceans.The flagship stations include measurements of CO_2, VOC and DMS profiles in water and in the air; temperature, light intensity and ion concentration profiles, phytoplankton mass profiles, fluxes of CO_2, VOC and DMS, sedimentation, ice cover in the surrounding area up to 500 km, reflected radiation, profiles of key enzymes of photosynthesis and synthesis of VOC and DMS.

Eurasian coastal and archipelago stations for sea ice and ocean observations will be essential Flagship stations. One of them is already in operation in Utö in the northern Baltic Sea. The Utö station is a member of the HELCOM (Baltic Marine Environment Protection Commission) marine monitoring network and a founding member of the European ICOS network. The station has long records in physical observations (water salinity and temperature measurements since 1900), and is currently under further developments for greenhouse gas (concentrations and air-sea fluxes of CO_2 and CH_4) and marine biogeochemistry observations, the latter including chlorophyll, nutrient, and fluorescence. Another Flagship station will be constructed in Severnaya Zemlya by AARI.

Satellite observations

One of the key PEEX objectives is to address climate change in the Pan-Eurasian region using remote sensing data from both airborne and satellite observations, together with ground-based in situ and remote sensing data and model, simulations of physical aspects of the Earth system.

The main advantages of airborne and satellite observations are:

- The same type of instrument and technique are used across the globe for extended period of time spanning several decades, providing consistent data sets (on condition that successive instruments provide consistent data sets; it is noted that inconsistencies may exist between like data sets, even from similar instruments).

- Up-to-date information e.g. on atmospheric composition, land surface properties and water environment with extensive spatial coverage.

- Ability to acquire environmental properties and data on various spatial and temporal scales both horizontally and vertically.

- Wide field of view and high level of detail allows studies of processes and phenomena on local, regional and global scales.

- High data reliability (especially together with ground based measurements).

Remote sensing data together with ground-based measurements and numerical modeling outcomes provide information on land, atmosphere and water system properties, as well as on the spatial and temporal changes of their components. It enables to accumulate statistical data, model dynamic processes in different environments, and in addition provides precise guidelines of the data products for ecology departments and agencies and for other consumers.

Satellite observations provide information complementary to the local in situ observations on the spatial distribution of atmospheric composition (aerosols, trace gases, greenhouse gases, clouds) [Burrows et al.; 2011], land surface properties including surface albedo, land cover (vegetation, phenology, tree line, burned area; fire detection) and soil moisture, ocean surface properties such as ocean colour (Chlorophyll, algae blooms), waves, sea surface temperature (SST), salinity and sea ice mapping, snow properties (cover, albedo, snow water equivalent) and lakes (area, biomass, water quality). Vice versa, the PEEX infrastructure has an important role in validation, integration and full exploitation of satellite data for Earth system studies.

The principal quantity measured with the remote sensing instruments is electromagnetic radiation. The radiation is measured at wavelengths spanning from the ultraviolet, visible, infrared to microwaves provide information on:

– atmospheric composition:

- aerosol properties (primary Aerosol Optical Depth (AOD) at several wavelengths, Ångström exponent (AE), absorbing aerosol index (AAI); information on aerosol physical and optical properties is used in AOD retrieval which in principle defines aerosol properties such as fine mode fraction, aerosol composition, single scattering albedo, etc. [Kokhanovsky & de Leeuw, 2009; de Leeuw et al., 2011; Holzer-Popp et al., 2013; de Leeuw et al., 2014];
- cloud properties (e.g., cloud fraction, cloud optical thickness, cloud top height, cloud droplet effective radius, liquid water path, etc.) [Kokhanovsky et al., 2011];
- concentrations of trace gases (e.g. O_3, NO_2, CO, NH_3, H_2O, VOCs, halogens) [Burrows et al., 2011];
- concentrations of greenhouse gases (e.g. CO_2, CH_4) [Buchwitz et al., 2014].

Table 1 contains list of some measured parameters and types of research conducted based on the remote sensing data.

In case of aerosols and clouds over Polar regions, the retrieval is in its initial state of development due to problems arising in discrimination between snow/ice, the reflectance of which overwhelms that of aerosols or clouds. Nevertheless, progress has been made [Istomina et al., 2011; Mei et al., 2013a, 2013b].

Information on the land surface properties that can be obtained using remote sensing data includes land cover, vegetation (e.g., above ground biomass, leaf area index, fAPAR, GPP), fire counts, burned area, air pollutant emission volume, soil moisture, glaciers [Bondur, 2010; 2011b]. It is crucial to study bodies of water including seas and oceans while analysing climate change in Pan-Eurasian region. Information on ocean properties which can be gained using satellite methods includes sea surface temperature, salinity, ocean colour, sea ice extent, sea level, wave information, water environment pollution etc. [Bondur, 2011 a]. Dynamics of short surface waves (including nonlinear waves) and their interaction with oceanic/atmospheric processes (internal waves, long surface waves, non-uniform currents, turbulence, etc.), mechanisms of slick formation on the sea surface [Troitskaya et al, 2012], as far as generally investigation of inland waters is a new area of remote sensing data application within PEEX domain.

The satellite observations provide information on regional to global scales with a spatial resolution varying from meters to tens of km, depending on the instrument and technique used. Likewise, the spatial coverage and repeat time depend on the swath width and orbit. In the context of PEEX, ice, snow, ocean, land, lakes and atmospheric observations are all of interest. In addition to remote marine observations also the remotely and on-situ data from main inflows, e.g. on-going observational network with associated multi-scale approach in the largest freshwater reservoir Baikal Lake should be included [Chalov et. al, 2014]. The remote observations are needed for investigation of large-scale transport of substances through

Table 1. List of satellite parameters measured and research conducted

Instrument/satellite	Parameter	Types of research conducted
MISR (Terra) MODIS (Terra/Aqua) (A)ATSR/SLSTR MERIS/OLCI POLDER CALIPSO SeaWiFS AVHRR (NOAA) --------------- SCIAMCHY OMI (Aura) GOME-2	Aerosol Optical Depth (AOD), and other aerosol properties --------------- Aerosol index (AI)	Effects of emissions from wildfire, megacities and other anthropogenic sources, versus natural emissions on atmospheric aerosol (mapping and vertical profiles generating); of interest for climate and air quality
OMI (Aura) AIRS (Aqua) TIRS(Landsat-8) AATSR(SLSTR NPP MODIS	Cloud properties (layer column cloud liquid water, albedo, Cloud Ice/Water flag)	Cloud cover monitoring for regional climatology needs (cloud cover and precipitation mapping); of interest for climate and aerosol-cloud interaction (precipitation, hydrological cycle)
OMI (Aura) GOME-2 MLS cura) AIRS (Aqua) MOPITT (Terra) TES (Aura)	Atmospheric gases (SO_2, CO, NO_2 , O_3, HCHO, BrO, OClO, ClO, H2O, HCl, HCN, HNO3, HO2, HOCl, N2O, OH, CH4, NH3)	Monitoring of gas content in the atmosphere during volcanic eruption (gas distribution mapping) Wildfire areas research Studies in the sphere of global climate change (mapping of harmful contaminants distribution in atmosphere, vertical profiles generating)
AVHRR (NOAA)	Latent heat flux	Latent heat flux monitoring during starting volcanic activity (mapping)
AIRS (Aqua) TES (Aura) AVHRR (NOAA) MODIS (Terra/Aqua) ASTER (Terra) TIRS (Landsat-8) (A)ATSR/SLSTR	Surface temperature (Surface skin temperature)	Monitoring during starting volcanic activity Wildfires detecting (mapping) Climate (Land temperature and SST)
MLS (Aura) TES (Aura) AIRS (Aqua)	Air temperature (atmospheric temperature, surface air temperature, vertical profiles of temperature)	Research of surface air temperature and middle and upper atmosphere for resolving global climate change problems (mapping and vertical profiles generating)
MERIS/OLCI SeaWiFS MODIS	Ocean color	Oceanic biological cycle, climate

river basins which counteracts the current trend of decreasing occurrence and availability of global hydrological and hydrogeochemical measurement data. At the moment there is a risk of biased large-scale estimates of hydrological and hydrogeochemical fluxes. The three-year framework of Swiss-Russian collaborative research initiative involves the development and deployment of a novel multispectral and hyperspectral remote sensing platform optimised for the sensing of land and water surfaces from an ultralight aircraft in Baikal Lake environment [Akhtman et al., 2014].

Some data are already available for an extended period of more than three decades (e.g. from AVHRR and TOMS) allowing for the detection of trends and the response to changes in climate and mitigation strategies. They also serve as input to models or, vice versa, for model evaluation. The information on aerosols [e.g., de Leeuw et al., 2013], trace gases [e.g. Mijling & Vander A., 2012], GHG or clouds retrieved from satellite observations is complementary to that from the RI stations in that they cover a large spatial area, but usually with less detail (due to lower information content in the satellite data requiring assumptions to retrieve the relevant information) and with lower accuracy. As for the flag ship stations, techniques are being developed to derive information on the emission of atmospheric

Fig. 11. Satellite imagery coverage in Russia and adjacent countries using UniScanT receivers (data from http://www.geogr.msu.ru/science/projects/geoportal)

components from natural and anthropogenic sources as well as forest fires using inverse modelling. As part of ESA's Data Users Element (DUE) programme, this is applied to emissions of aerosols, NO_2, SO_2, CO, isoprene, VOCs (cf. http://www.globemission.eu/index.php), while satellite-derived GHG emissions are provided as part of the Copernicus project MACC-II (http://www.ecmwf.int/research/EU_projects/MACC/). The EU FP7 projects Marco Polo and Panda studying emissions over China will serve as pilots for the PEEX region (www.marcopolo-panda.eu).

The PEEX satellite infrastructure includes data from all open-access data sources (ESA, NASA) as well as from Russian and Chinese satellites with restricted access. The PEEX RI further includes receiving stations in Russia, China and Europe, including a very fast delivery service in Sodankylä (Finland) covering the western part of the PEEX area and a Near Real Time (NRT) service for forest fire data (AEROCOSMOS), and data centres providing access to processed and / or interpreted data. Ground-based and airborne remote sensing facilities complement the satellite observations.

The potential of the national systems of remote sensing data are also involved, e.g. Russian network of receiving centers provided by Scanex (Fig. 11) or UNIGEO (http://www.unigeo.ru/) association which merge capabilities of Russian Universities in remote sensing applications.The ground-based and airborne remote sensing facilities complement the satellite observations.

China's Earth observation system is composed of satellites aimed e.g. at characterizing resources, environmental variables, meteorology and oceans. As an example Beidou navigation satellite program has been formed providing a wide range of services for the nation's economy [Guo, 2013]. China's network of ground stations for remote sensing satellites is one of the world's highest capacities for receiving, processing, and distributing satellite data. With over 3, 3 million images of satellite data accumulated on file since 1986, it is regarded as the largest Earth observation satellite data archive in China. At present, the nationwide ground station network for land observing satellite data is taking shape. Miyun, Kashi, and Sanya stations can receive data simultaneously from satellites covering the whole territory of China and 70% of Asia. At the same time, efforts have been made to construct stations in China's southwest and northeast, and in Polar Regions. To provide users with top-notch data products of Earth observation satellites in the world, the station has built up systems to process data from state-of-the-art satellites such as LANDSAT, SPOT, RADARSAT, ENVISAT, RESOURCESAT and THEOS.

Modelling platform

For supporting the PEEX observational system and answering on the PEEX scientific questions, a hierarchy/ framework of modern multi-scale models for different elements of the Earth System integrated with the observation and data system is needed

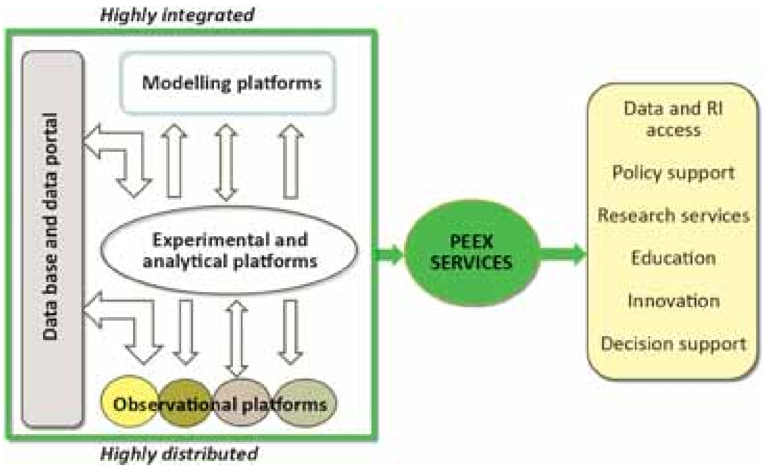

Fig. 12. PEEX data – modelling – service structure.

(Fig. 12). The PEEX-Modelling Platform aims to simulate and predict the biological and physical aspects of the Earth system and to improve understanding of the bio-geochemical cycles in the PEEX domain, and beyond. The environmental change in this region implies that, from the point-of-view of atmospheric flow, the lower boundary conditions are changing. This is important for applications with immediate relevance for society, such as numerical weather prediction, air quality forecasts and climate projections. The PEEX infrastructure will provide a unique view to the physical properties of the Earth surface, which can be used to improve assessment and prediction models. This will directly benefit citizens of the North in terms of better early warning of hazardous events, for instance. On longer time-scales, models of the bio-geochemical cycles in the PEEX domain absolutely need integration with and support from the new monitoring infra-structure to better measure and quantify soil and vegetation properties.

The PEEX Modelling Platform (PEEX MP) is characterized by:

- Complex integrated Earth System Modelling (ESM) approach in combination with specific models of different processes and elements of the system on different time and space scales.
- An ensemble approach with the integration of modelling results from different models, participants, countries, etc.
- A hierarchy of models; analyzing scenarios; inverse modelling; modelling based on measurement needs and processes; from molecular level to global climate and climate-air quality interactions
- Model validation with in-situ observation network, remote sensing data and assimilation of satellite observations to constrain models to better understand processes, e.g., emissions and fluxes with top-down modelling.
- Geophysical/chemical model validation with experiments at various spatial and temporal scales.
- Assimilation of measurement data by models.
- Analysis of anticipated large data volumes coming from PEEX models and infrastructures need to be supported by a dedicated virtual research environment.

Processes that control short-lived climate forcer (SLCF) abundances, ecosystem-climate interactions, aerosol-cloud interactions and boundary layer processes in the PEEX domain are all poorly constrained by observations.

Evaluating Earth system models and process models in this region presents a significant challenge, but is necessary to ensure our confidence in model predictions of future environmental change and its impacts at high latitudes and throughout the Northern Hemisphere. Models are generally unable to capture abundances and seasonality of SLCFs at high latitudes at the surface, with a large range in skill [Shindell et al., 2008]. Aerosol model biases in the North American and European Arctic are highly sensitive to washout processes [Browse et al., 2012], and knowledge of local emissions from sources such as gas flaring [Stohl et al., 2013]. The extent to which model biases persist over the Siberian Arctic and boreal regions is unknown. Interactions between the biosphere and climate system are also poorly understood. Model simulations suggest that boreal fire may be an important source of SLCF [Wespes et al., 2012] and that this source will likely change under future climate [Spracklen et al., 2009]. The boreal forest is also an important source of BVOCs with impacts on aerosol and cloud properties [Tunved et al., 2006; Spracklen et al., 2008] a potentially important sink for Eurasian tropospheric ozone [Engvall & Stjernberg et al., 2012], with potential consequences for the carbon sink [Sitch et al., 2007] and hydrology [Lombardozzi et al., 2012].

PEEX will undertake an unprecedented evaluation of Earth system models, ecosystem models, weather and atmospheric chemistry models, exploiting new observations from the PEEX measurement infrastructure. Model simulations from existing model comparisons, such as POLMIP [Monks et al., 2014], AQMEII [Alapaty et al., 2012] and HTAP [Shindell et al., 2008], will be evaluated in the PEEX domain to assess their ability to simulate processes important for atmospheric composition and climate, and the range in model skill in this region.

Envisioned PEEX Data harmonization

The PEEX infrastructure will deliver critical long-term datasets for climate and air quality research, including evaluation of weather forecast, air quality and climate models. The strategic focus is to ensure a long-term continuation of advanced measurements on aerosols, clouds, GHGs, trace gases, land – and sea surface characteristics and snow and ice properties in Northern Eurasian area. Procedures for improved data quality, including standardization of instruments, methods, observations and data processing, will be developed in coherence to "The European Strategy Forum on Research Infrastructures" (ESFRI) process. Linking PEEX RI approach to the European RI development together with satellite information and the scientific contribution ensures the optimal use of the observational data towards Earth System modelling.

We envision PEEX to collaborate e.g. with the "Integrated Carbon Observation System" research infrastructure (ICOS-RI), "Aerosols, Clouds, and Trace gases Research InfraStructure Network" (EU-FP7-ACTRIS-I3 project), "Analysis and Experimentation on Ecosystems" (EU-FP7-Preparatory Phase of AnaEE), Life Watch (European research infrastructure on biodiversity) and Svalbard Integrated Earth Observing System (SIOS). PEEX willbenefit from Space Agency programmes such as ESA's Climate Change Initiative (CCI), Data Users Element (DUE) and similar initiatives by NASA and the Chinese and Russian Space Agencies. PEEX will also benefit from Space Agency programmes such as ESA's Climate Change Initiative (CCI) [Hollmann et al., 2013], Data Users Element (DUE; http://www.globemission.eu/) and similar initiatives by NASA and the Chinese and Russian Space Agencies. Ground-based remote sensing infrastructure [e.g. Tomasi et al., 2014] will be used to complement and validate satellite measurements over the Arctic region.

In general, PEEX will promote standard methods and best practices in creating long-term, comprehensive, multidisciplinary observation data sets and coordinate model and data comparisons and development. PEEX will also strengthen the international scientific community via an extensive capacity building programme. For this purpose a hierarchy/framework of modern multi-scale models for different elements of the Earth System integrated with the observation system will be elaborated.

The PEEX data initialization, cross-checking and harmonization process will start with the already existing datasets from the Siberian region. For example, datasets of the International Polar Years (1882/1883, 1932/1933, and the last and largest one in 2007/2008) experiments are available in scientific literature and can give a good basis for understanding changes taking place for a period longer than a century. Extensive database on atmospheric chemistry over continental Russia has been collected during unique train-based TROICA (Transcontinental Observations Into the Chemistry of the Atmosphere) experiments in 1995–2010. Furthermore, a series of large international recent programs such as TOWER FLUXNETWORK, and Russian–Swedish–British Project "Climate warming in Siberian Permafrost Regions; tracing the delivery of carbon and trace metals to the Arctic Ocean" may significantly enrich our investigations in the PEEX domain.

A part of the PEEX data initialization is development of a unified information background in form of the Integrated Land Information System (ILIS) for the PEEX region [Schepaschenko et al., 2010; Shvidenko et al., 2013]. The ILIS is based on integration of all relevant sources of remote sensing and ground data and is presented as a multi-layer and multi-scale GIS which will contain geo-referenced comprehensive information about landscapes and ecosystems, their condition, dynamics and stability, and will serve as a benchmark, system background for integrated modelling and depository of all knowledge over the region.

In addition to the land-atmospheric data processing, PEEX will establish a harmonization process towards aquatic observations. RAS Research centers for the realization of the observations on in-situ stations in Kola–Karelian Region as a pilot area, covering e.g. the White Sea and great lakes and their watersheds in Russia west of Ural Mountains, will take part of the PEEX aquatic-observations approach. INKO-Copernicus project ICA2-CT-2000-10014 Sustainable Management of the Marine Ecosystem and Living Resources of the White Sea, State Federal program of "World ocean, Sub-project White Sea", 2007–2011 and RFBR project "The response of water objects to climate change" (No. 10-05-00963), 2010–2012 have already preformed multidisciplinary studies of the White Sea and watershed; sub-satellite and satellite observations of water quality parameter (with NIERSC) and created a database and GIS for the region (include historical many years hydrometeorological observations on stations of Roshydromet. Furthermore, numerical model of water ecosystems of White Sea and Great Lakes and their watersheds and scenario development of water ecosystems under climate change and anthropogenic impacts have been developed and realized multidisciplinary socio-ecological-economical studies in the region.

SOCIETY DIMENSION

Changing socio-economic condition in PEEX domain

The dynamics of the Earth system and the Northern societies are rapidly changing. Within next 40 years, the Northern Eurasian, especially the Artic, will be a region of increased human activity, higher strategic value, and greater economic importance compared to today [Smith, 2010]. The future status of the Northern societies are driven by (i) demographic changes (human population growth and mitigation trends), (ii) natural resources demand (finite and renewable assets, gene pool), (iii) globalization trends (the set of economic, social, technological processes making world interconnected and interdependent) (iv) climate change (global mean temperature increase) and (v) technological breakthroughs (geoengineering, in bio- and nano- and environmental technology) [Smith 2010].

Referring to the demographic changes, the main part of the Arctic and boreal region of PEEX domain is situated in North and East of Russia characterized by very differentiated in socio-economic conditions. Both Russia's North and East have small and diminishing population, mainly due to migration outflows in the 1990s. The combination of outflow and natural decrease (with some regional exceptions in several ethnic republics and autonomous regions (okrugs) with oil and gas industry) led to a steady population decline in most regions in Russia's North and East from 1990. Generally, in post-Soviet time the population of Russia's Eastern part decreased by 2, 7 million people, and the population of Russia's Arctic zone decreased nearly by one third (500 000), opposite to the majority of world Arctic territories [Glezer, 2007*a*, *b*]. Northeastern Russia was particularly remarkable: Chukotka Autonomous Okrug lost 68% of its population; Magadan oblast – 59%; Kamchatka krai – 33%. The differences in the transformation between settlements with predominantly indigenous and predominantly Russian population are evident: for example, in Chukotka Autonomous Okrug: the former mainly remain and only have a slightly decreased population, the latter were depopulated significantly [Litvinenko, 2012, 2013]. When assessing the effects of climate change on human societies, it should be taken into account that urban environment in many Russian cities in the North and in the East is poor and, in its present-day state, could scarcely mitigate unfavorable impacts. Detailed studies of the effects of different climate parameters on health, incidence of diseases, adaptation potential, age and gender structure of population are needed.

One crucial part of the PEEX approach is to make future socio- economic assessments for the Arctic-boreal regions and provide early an early warning system for timely mitigation for local and regional authorities.

Referring to natural resources and the expected increase of industrial activities in the PEEX area, it is important to pay attention to traditional livelihoods of the area and their future position in the Arctic region. Northern reindeer husbandry, along with sea and river fishery, is one of the main branches of the traditional north economy and the main occupation of the nomadic Northern people. This is a source of sustainability of the northern indigenous societies. The number of wild and domestic reindeer has dramatically declined in post-soviet period [Gray, 2000, Hiyama and Inoue, 2010, Litvinenko, 2013]. Field studies in North Yakutiya revealed that availability of drinking water (stored as ice in winter), availability of bio-fuels (mainly wood), pasture and land productivity, and patterns of animal reproduction and hunting are changing [Hiyama and Inoue, 2010].

Both Russia's North and East possess abundant mineral resource potential. The sector of the natural resource economy (mining together with forestry) will continue to prevail in the majority of these territories for the next decades. In the post-Soviet period, the criteria of profitability have become dominant in the decision making of enterprises and federal/regional governments, but it has not incorporated the aspect of the sustainable social and ecological development. The local population is now facing ecological problems in places of industrial natural resource utilization. There is also social and ecological conflict between industrial exploitation of natural resources and traditional forms of nature management (i.e. reindeer husbandry, etc.).

Mechanisms of interaction between regional environmental change and post-Soviet transformation of natural resource utilization at both regional and local levels are of special importance [Litvinenko, 2012]. The local peoples' (indigenous people and newly arrived people) adaptation and response to both environmental and economic changes would improve evaluation of socio-ecological fragility and vulnerability.

PEEX Stakeholders

There is a pressure to ensure that the latest scientific results are effectively available to society. Societies within the PEEX region will have to continue their efforts to reduce greenhouse gas emissions through mitigation efforts, by increasing energy efficiency and exploitation of renewable energy. Simultaneously, there is a need to begin to adapt to the on-coming changes by assessing the vulnerability of the society. To ensure the most efficient use of its research outcome and services PEEX is developing contacts to all major stakeholders in the Arctic and boreal regions and in China. The most relevant end-users here are found in different stakeholder sectors: (i) research communities, research infrastructures and platforms (iii), policy makers and governments, (iv) Northern societies and China (v) non-governmental organizations and (vi) companies. As an example, PEEX relevant stakeholders are the research communities of Nordic Centers of Excellence and IIASA, the research infrastructures and platforms of Global Earth Observation System of Systems (GEOSS) and Digital Earth; the Future Earth (ICSU) and IPCC and the Nordic societies via the Arctic Council.

During the first years of the activity PEEX has already started contact building with GEOSS, Future Earth and China Air quality initiatives. For example, GEOSS connects PEEX to the GEO Cold Regions activity. There PEEX is listed along with the international programs enhancing the Arctic Data-Information coordination for Cold Regions within global research infrastructures and programs such as the Sustaining Arctic Observation networks (SAON), The Svalbard Integrated Earth Observing System (SIOS), The International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT), The Conservation of Arctic Flora and Fauna (ABDS-ABA/CAFF) and The Monitoring the Climate Change in the Cryosphere (Cryoclim).

The IGBP core-projects like iLEAPS are bringing PEEX to an international policy level and opens up opportunities to respond to the Future Earth initiative and Digital Earth programmes. These initiatives and programmes are coordinated by International Council for Science, ICSU's, global environmental change (GEC) programmes and bring PEEX impact closer to social science and economics. They will be indispensable partners for natural sciences on the road to solve the equation of one Earth (Future Earth programme) and a growing human population. Future Earth will mobilize international science community to work with policy-makers and other stakeholders to provide sustainability options and solutions in the wake of Rio+20.

The PEEX activities in China are associated also with Beautiful China. In 2013 China's "two sessions" mapped out concrete steps toward a "beautiful China", which is an initiative stemming from an agenda-setting report to the 18th National Congress of the Communist Party of China (CPC) Congress. China is now actively seeking new environmental solutions that cost less, produces more benefits, leads to reduced emissions and contribute to sustainability, speeds up the construction of a resource-conserving and environment-friendly society, and strives for improving the level of ecological conservation and quality of life [IEAS, 2012].

KNOWLEDGE TRANSFER

The shift from a discipline-tied fundamental education towards multi-disciplinarity is an imperative for a successful career in climate and global change science [Nordic Climate Change Research, 2009]. Therefore PEEX has adopted this approach in the education of the next generation of scientists, instrument specialists and data engineers in a truly multidisciplinary way of thinking and holds this as the chief educational and knowledge transfer goal.

PEEX Education programme addresses the following themes:

– training of multidisciplinary core skills and transferable skills applicable in a range of tasks both on public and private sector;

- opening already existing courses at PEEX institutes to the whole community;
- promoting cross-disciplinary collaboration as well as international and interdisciplinary mobility;
- recognizing the importance of career development;
- training the next generation of research infrastructure experts (best practices, twinning); and
- integrating research and education activities together as part of a larger knowledge framework.

Participatory action research has been acknowledged as the main tool to achieve the goal. We also emphasize the recognition of the research career as a whole. Following the CBACCI (Nordic-Baltic Graduate School on Biosphere-Carbon-Aerosol-Cloud-Climate Interactions) Education Structure [CBACCI, 2003], dedicated work on the national and regional scale has been carried out to develop the multidisciplinary training at all levels. PEEX will bring this task to a more international level including Europe, Russia, and China.

PEEX involves several fields of science, such as chemistry, physics, meteorology, mathematics, biology, agricultural and forest sciences, geosciences, technology and social sciences, combining qualitative and quantitative research methodologies, observations, experimentation and modelling. In such a framework it is crucial that observations are based on unifying theoretical framework and are carried out with various techniques supporting each other. Furthermore, observations should be tested against field and laboratory experiments, and process understanding should be tied to theoretical and modelling development work.

The practical knowledge transfer actions in PEEX involve:

- dedicated training programmes on MSc and PhD level following the Bologna process [The European Higher Education Area, 1999], including Innovative Training Networks and international joint degree programmes;
- targeted training for the technical staff;
- joint coordination of training courses and events for the PEEX community;
- a joint PEEX database of courses (field courses, summer and winter schools);
- active development and utilization of modern technologies supporting learning e.g. learning platforms, online visualization applications and data portals [see Vesala et al., 2008; Junninen et al., 2009];
- use of innovative teaching and learning approaches such as collaborative action research and horizontal learning [Paramonov et al., 2011]; and
- outreach activities for specific target groups (policymakers, journalists and reporters etc.) and for the general public.

PEEX will distribute information for the general public to build awareness of climate change and human impact on different scales of climate and air quality issues, and increase visibility of the PEEX activities in Europe, Russia and China. A major challenge is to explore the means to make PEEX research useful with clear messages to the decision-makers and to integrate the PEEX infrastructure across national and scientific boundaries to build up a genuine international infrastructure. As a part of knowledge transfer PEEX will engage the larger international scientific communities also by collaborating with European observation infrastructures such as the ICOS (greenhouse gases), ACTRIS (aerosols and trace gases) and ANAEE (ecosystem measurements) to build its own in the Pan-Eurasian region.

The PEEX community organizes intensive field courses several times a year, and they have proven to be of great interest to both students and researchers. The forms of working during intensive courses include lectures, interactive exercise sessions, seminars, discussion sessions, field work as well as social activities. Very often the emphasis is placed on intensive work in small groups consisting of students, instructors (usually more advanced postgraduate students), and supervisors (usually senior scientists). From a pedagogical point of view, the intensive courses often represent a form of problem-based learning (PBL; see e.g. Duch et al., 2001]. This instructional strategy has been adopted in order to emphasize the students' own responsibility of their learning process, with support from the instructors and supervisors. The goals for the courses are often set in the beginning of the course, after a few introductory lectures. The teachers take the role of facilitators rather than lecturers. Collaborative learning is carried out throughout the courses. This allows for the social construction, sharing of information and cognition, and finally improves the metacognitive skills of the students which, in turn, enhance self-directed learning skills. We have also noted that motivation and sociability is blossoming in these small groups, which allows the students to easily adopt the studied issues and open their minds for creative problem-solving. The participants of the events come from different disciplines and are specialized in very different topics. Thus, traditional "vertical" training courses have been out of question. Instead, horizontal learning has taken place, taking a broader approach, addressing a cross-section of knowledge from different fields and blending the information to reach new levels of understanding. The students working in small groups take the responsibility to find the best ways to reach these goals in a short time. Often the solution has been horizontal: students from different fields of study give small lectures to each other in the groups. This horizontal learning principle has been shown to be a good example of participatory action research.

CONCLUSIONS

The PEEX initiative emphasizes fast actions for establishing coherent, coordinated, interdisciplinary (i) research programme, (ii) research infrastructures and (iii) education activities the focused in the Northern Eurasian and China. It is important to have fast-track assessments for climate policy making and provide mitigation and adaptation strategies and services to the Northern Eurasian and China. The PEEX initiative can take a position in the international research landscape to be a major initiative integrating the social and natural science communities to work together towards solving the major challenges influencing the wellbeing of humans, societies, and ecosystems in the PEEX region.

PEEX is a solution orientated research programme that will provide gap-filling and integrated scientific knowledge related to many relevant questions in terms of society connected to the impacts of climate change on the Arctic and boreal regions and the need to adapt to them as well as early warning systems against natural hazards. After comprehensive and integrative science plan, one of the first tasks of the PEEX implementationis to fill the atmospheric in-situ observational gap in the Siberian and Far East regions and start the process towards standardized or comparable data procedures.

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REFERENCES

1. Alapaty, K., Mathur, R., Pleim, J., Hogrefe, Ch., Rao, S. T., Ramaswamy, V., Galmarini, S., Schaap, M., Vautard, R., Makar, P., Baklanov, A., Kallos, G., Vogel, B., and Sokhi, R.(2012). New Directions: Understanding Interactions of Air Quality and Climate Change at Regional Scales. Atmos. Environ., 49, 419–421.

2. AMAP, 2011: The Impact of Black Carbon on Arctic Climate (2011). By: P.K. Quinn, A. Stohl, A. Arneth, T. Berntsen, J. F. Burkhart, J. Christensen, M. Flanner, K. Kupiainen, H. Lihavainen, M. Shepherd, V. Shevchenko, H. Skov, and V. Vestreng.2014, Volume 454, Issue 2, pp 158–162.

3 Anisimov, O.A. (2009). Sytochastic modelling of the active layer thickness under conditions of current and future climate. Kriosfera Zemli 13(3), 36–4.

4. Arctic Council (2009), Arctic Maritime Shipping Assessment 2009. http://www.pame.is/amsa-2009-report.

5. Arneth, A., Harrison, S. P., Zaehle, S., Tsigaridis, K., Menon, S., Bartlein, P. J., Feichter, J., Korhola, A., Kulmala, M., O'Donnell, D., Schurgers, G., Sorvari, S., & Vesala, T. (2010) Terrestrial biogeochemical feedbacks in the climate system. Nature Geoscience, 3(8), 525-532. 10.1038/ngeo905.

6. Bäck, J., Aaltonen, H., Hellen, H., Kajos, M. K., Patokoski, J., Taipale, R., Pumpanen, J., & Heinonsalo, J. (2010) Variable emissions of microbial volatile organic compounds (MVOCs) from root-associated fungi isolated from Scots pine. Atmospheric Environment, 44, 3651-3659. 10.1016/j.atmosenv.2010.06.042.

7. Baklanov, A.A., V.V. Penenko, A.G. Mahura, A.A. Vinogradova, N.F. Elansky, E.A. Tsvetova, O.Yu. Rigina, L.O. Maksimenkov, R.B. Nuterman, F.A. Pogarskii, and A.Zakey (2012) Aspects of Atmospheric Pollution in Siberia. Chapter 8. In: P.Ya. Groisman, G. Gutman (Eds.) Regional Environmental Changes in Siberia and Their Global Consequences, Springer, ISBN 978-94-007-4568-1, pp. 303–346.

8. Bityukova, V.R. and Kasimov, N.S. (2012) Atmospheric pollution of Russia's cities: assessment of emissions and immissions based on statistical data // GEOFIZIKA. Vol. 29. 2012. P. 53–67.

9. Bondur, V.G, (2010) Importance of Aerospace Remote Sensing Approach to the Monitoring of Nature Fire in Russia // International Forest Fire News (IFFN) No. 40 (July-December 2010), p. 43–57.

10. Bondur, V.G. (2011) Satellite Monitoring and Mathematical Modelling of Deep Runoff Turbulent Jets in Coastal Water Areas, Waste Water - Evaluation and Management, ISBN: 978-953-307-233-3, InTech, DOI: 10.5772/16134.

11. Bondur, V.G. (2011) Satellite Monitoring of Wildfires during the Anomalous Heat Wave of 2010 in Russia // Izvestiya, Atmospheric and Oceanic Physics, 2011, Vol. 47, No. 9, pp. 1039–1048.

12. Browse, J., Carslaw, K. S., Arnold, S. R., Pringle, K., and Boucher, O. (2012) The scavenging processes controlling the seasonal cycle in Arctic sulphate and black carbon aerosol, Atmos. Chem. Phys., 12, 6775-6798, doi:10.5194/acp-12-6775-2012, 2012.

13. Buchwitz, M., M. Reuter, O. Schneising, H. Boesch, S. Guerlet, B. Dils, I. Aben, R. Armante, P. Bergamaschi, T. Blumenstock, H. Bovensmann, D. Brunner, B. Buchmann, J.P. Burrows, A. Butz, A. Chédin, F. Chevallier, C.D. Crevoisier, N.M. Deutscher, C. Frankenberg, F. Hase, O.P. Hasekamp, J. Heymann, T. Kaminski, A. Laeng, G. Lichtenberg, M. DeMazière, S. Noël, J. Notholt, J. Orphal, C. Popp, R. Parker, M. Scholze, R. Sussmann, G.P. Stiller, T. Warneke, C. Zehner, A. Bril, D. Crisp, D.W.T. Griffith, A. Kuze, C. O'Dell, S. Oshchepkov, V. Sherlock, H. Suto, P. Wennberg, D.Wunch, T. Yokota, Y. Yoshida (2013). The Greenhouse Gas Climate Change Initiative (GHG-CCI): Comparison and quality assessment of near-surface-sensitive satellite-derived CO2 and CH4 global data sets . Remote Sensing of Environment (2013).

14. Buermann et al. (2014) Recent shift in Eurasian boreal forest greening response may be associated with warmer and drier summers. Geophys. Res. Lett., 41, 1995–2002.

15. Burrows, J.P., Platt, U. and Borrell, P. (2011) The Remote Sensing of Tropospheric Composition from Space, 536 pp., Springer-Verlag Berlin Heidelberg 2011. ISBN: 978-3-642-14790-6 doi: 10.1007/978-3-642-14791-3., pp. 315–364.

16. Cannon A.J., Whitfield P.H., Lord E.R. (2002) Synoptic map pattern classification using recursive partitioning and principal component analysis. Monthly Weather Review, 130, 1187–1206.

17. CBACCI, 2003: CBACCI education structure. Annex of the Steering Committee memorandum of the meeting 5.5.2003 in Oslo.

18. Chalov Sergey R., Jarsjö Jerker, Kasimov N., Romanchenko A., Pietron Jan, Thorslund J., Belozerova E. (2014) Spatio-temporal variation of sediment transport in the Selenga River Basin, Mongolia and Russia DOI: 10.1007/s12665-014-3106-z.

19. Charlson, R. J., Lovelock, J. E., Andreae, M. O. and Warren, S. G. (1987). «Oceanic phytoplankton, atmospheric sulphur, cloud albedo and climate». Nature 326 (6114): 655–661.

20. Christensen, T. R., Johansson, T. Ö., Jonas Åkerman, H., Mastepanov, M., Malmer, N., Friborg, T., Crill, P.; Svensson, B. H. (2004) Thawing sub-arctic permafrost: Effects on vegetation and methane emissions. Geophysical Research Letters 31 (4): L04501.

21. Chubarova N., Smirnov, A., Holben, B.N. (2011b) Aerosol properties in Moscow according to 10 years of AERONET measurements at the Meteorological Observatory of Moscow State University //Geography, Environment, Sustainability, 4, 1, 19–32.

22. Chubarova, N.Y., M.A. Sviridenkov, A. Smirnov, and B.N. Holben. (2011a) Assessments of urban aerosol pollution in Moscow and its radiative effects, Atmos. Meas. Tech., N 4, pp. 367-378, www.atmos-meas-tech.net/4/367/2011/ doi:10.5194/amt-4-367-2011.

23. Chubarova, N., Zhdanova Ye. (2012) Ultraviolet resources over Northern Eurasia Journal of Photochemistry and Photobiology B: Biology, Elsevier BV (Netherlands), v. 127, p. 38–51.

24. De Leeuw, G., Holzer-Popp, T., Bevan, S., Davies, W., Descloitres, J., Grainger, R. G., Griesfeller, J., Heckel, A., Kinne, S., Klüser, L., Kolmonen, P., Litvinov, P., Martynenko, D., North, P. J. R., Ovigneur, B., Pascal, N., Poulsen, C., Ramon, D., Schulz, M., Siddans, R., Sogacheva, L., Tanré, D., Thomas, G. E., Virtanen, T. H., von Hoyningen Huene, W., Vountas, M., & Pinnock, S. (2013). Evaluation of seven European aerosol optical depth retrieval algorithms for climate analysis. Remote Sensing of Environment. 10.1016/j.rse.2013.04.023.

25. de Leeuw, G., S. Kinne, J.F. Leon, J. Pelon, D. Rosenfeld, M Schaap, P.J. Veefkind, B. Veihelmann, D.M. Winker and W. von Hoyningen-Huene (2011) Retrieval of aerosol properties. In: Burrows, J.P., U. Platt and P.Borrell (Editors) The Remote Sensing of Tropospheric Composition from Space, 536 pp., Springer-Verlag Berlin Heidelberg 2011. ISBN: 978-3-642-14790-6 doi: 10.1007/978-3-642-14791-3., pp. 359–313.

26. Ding, A.J. , Fu, C.B,Yang, X.Q., Sun, J.N., Peteja, T., Kerminen, V.-M., Wang, T., Xie, Y.N., Herrmann, E. Zheng, L.F., Nie, W., Liu, Q., Wei, X.L., and Kulmala, M. (2013): Intense atmospheric pollution modifies weather: a case of mixed biomass burning with fossile fuel combustion pollution in the eastern China, Atmos. Chem. Phy., 13, 10545–10554.

27. Dolman, A. J., Shvidenko, A., Schepaschenko, D., Ciais, P., Tchebakova, N., Chen, T., van der Molen, M. K., Belelli Marchesini, L., Maximov, T. C., Maksyutov, S., and Schulze, E.-D. (2012): An estimate of the terrestrial carbon budget of Russia using inventory-based, eddy covariance and inversion methods, Biogeosciences, 9, 5323-5340, doi:10.5194/bg-9-5323-2012, 2012.

28. Duch, B. J., Groh, S. E. and Allen, D. E. (2001). The Power of Problem-Based Learning. Stylus Publishing, Sterling, VA, U.S.A.

29. Elansky N.F., Mokhov I.I., Belikov I.B., Berezina E.V., Elokhov A.S., Ivanov V.A., Pankratova N.V., Postylyakov O.V., Safronov A.N., Skorokhod A.I., Shumskii R.A. (2011) Gaseous admixtures in the atmosphere over Moscow during the 2010 summer. Izvestiya. Atmospheric and Oceanic Physics. V. 47. N 6. p. 672–681.

30. Elansky, N. F., O. V. Lavrova, A. A. Rakin, A. I. Skorokhod. (2014) Anthropogenic disturbances of the atmosphere in Moscow region. Doklady Earth Sciences, Volume 454, Issue 2, pp 158–162.

31. Elmendorf, S. C., Henry, G. H. R., Hollister, R. D., & Björk, R. G. (2012). Plot-scale evidence of tundra vegetation change and links to recent summer warming. Nature Climate Change. Journal Article 2, pp. 453–457.

32. Esau, I., R. Davy and S. Outten (2012): Complementary explanation of temperature response in the lower atmosphere, *Environmental Research Letters*, 7, 044026.

33. Galloway et al. (2003); SEE REFERENCE IN IPCC CHAPTER 6.

34. Glezer O.B. (2007b). The Development of the North Abroad: Experience and Lessons // Environmental Planning and Management, no 4 (5), pp. 62–76. (in Russian).

35. Glezer O.B. (2007a).Population and Its Settlement Pattern. In: Space, Population, and Economics of Yugra. Socioeconomic Transformation of the Khanty-Mansi Autonomous Okrug / Artobolevsky S.S., Glezer O.B.(Eds.). M., Ekonomist, pp.169–191. (in Russian).

36. Goncharuk, VV., V.B. Lapshin, M.A. Chichaeva, A.O. Samsoni-Todorov, V.V. Taranov, I.S. Matveeva, G.N. Chikviladze, T.V. Grebennikova, S.S. Pletenev, and A.V. Syroeshkin. (2012) The System of the Efficient Monitoring of Air Quality in Maritime Cities and Health Resort Areas: Pollution of the Nearwater Layer of the Atmosphere with Sea Aerosols// Journal of Water Chemistry and Technology. Vol. 34, No. 2. P. 79–80.

37. Goncharuk, VV., V.B. Lapshin, M.A. Chichaeva, I.S. Matveeva, A.O. Samsoni-Todorov, V.V. Taranov, and A.V. Syroezhkin. (2012) Heavy Metals, Aluminium, and Arsenic in Aerosols of the World Ocean // Journal of Water Chemistry and Technology. Vol. 34, No.1. - P. 1–10.

38. Gray P. A. (2000).Chukotka reindeer husbandry in the post-socialist transition, Polar Research, 19 (1), pp. 31–37.

39. Groisman, P.Ya., Blyakharchuk, T.A., Chernokulsky, A.V., Arzhanov, M.M., Beleli Marchesini L., Bogdanova, E.G. et al. (2013b) Climate change in Siberia. In P.Ya. Groisman, G. Gutman (Eds.) Regional Environmental Changes in Siberia and Their Global Consequences, Springer, pp. 1–17.

40. Groisman, P.Ya., Gutman G., Shvidenko, A.Z., Bergen, K.M., Baklanov, A.A., Stackhouse, P.W. Jr. (2013a) Introduction: Regional features of Siberia. In P.Ya. Groisman, G. Gutman (Eds.) Regional Environmental Changes in Siberia and Their Global Consequences, Springer, pp. 1–17.

41. Grote R, Niinemets Ü. (2008) Modeling Volatile Isoprenoid Emissions - A Story with Split Ends. Plant Biology 10: 8–28.

42. Hari, P., Andreae, M. O., Kabat, P. & Kulmala, M. (2009): A comprehensive network of measuring stations to monitor climate change. Boreal Env. Res. 14: 442–446.

43. Hennessy, S. and Murphy, P. (1999) The Potential for Collaborative Problem Solving in Design and Technology, International Journal of Technology and Design Education 9(1), pp. 1–36.

44. Hiyama T. and Inoue G. (2010). Global Warming and the Human-Nature Dimension in Siberia In:Natural resources development, population and environment in Russia: Their Present and Future in Relation to Japan. Proceeding of the second Russian-Japanese seminar. September 13–14, 2010, Moscow. pp. 8–13.

45. Hollmann, R., Merchant, C. J., Saunders, R., Downy, C., Buchwitz, M., Cazenave, A., Chuvieco, E., Defourny, P., de Leeuw, G., Forsberg, R., Holzer-Popp, T., Paul, F., Sandven, S., Sathyendranath, S., van Roozendael, M., & Wagner, W. (2013). THE ESA CLIMATE CHANGE INITIATIVE Satellite Data Records for Essential Climate Variables. Bulletin of the American Meteorological Society, 94(10), 1541-1552. 10.1175/BAMS-D-11-00254.1.

46. Holzer-Popp, T., de Leeuw, G., Griesfeller, J., Martynenko, D., Klüser, L., Bevan, S., Davies, W., Ducos, F., Deuzé, J. L., Graigner, R. G., Heckel, A., von Hoyningen-Hüne, W., Kolmonen, P.,

Litvinov, P., North, P., Poulsen, C. A., Ramon, D., Siddans, R., Sogacheva, L., Tanre, D., Thomas, G. E., Vountas, M., Descloitres, J., Griesfeller, J., Kinne, S., Schulz, M., and Pinnock, S. (2013) Aerosol retrieval experiments in the ESA Aerosol_cci project, Atmos. Meas. Tech., 6, 1919-1957, doi:10.5194/amt-6-1919-2013.

47. Huadong, G. (2013) "Earth Observation in China and the World: History and Development in 50 Years", Bulletin of the Chinese Academy of Sciences, Vol.27 No.2.

48. IPCC 2013. Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Stocker T.F., Qin D., Plattner G.-K. , Tignor M., Allen S.K., Boschung J., Nauels A., Xia Y., Bex V. & Midgley P. M. (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

49. IPCC 2013. Summary for Policymakers. In Climate Change. 2013. In pHysical Science Basis.

50. IPCC 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

51. Istomina, L. G., von Hoyningen-Huene, W., Kokhanovsky, A. A., Schultz, E., & Burrows, J. P. (2011) Remote sensing of aerosol over snow using infrared AATSR observations. Atmospheric Measurement Techniques, 4, 1133–1145.

52. Junninen, H., Lauri, A., Keronen, P., Aalto, P., Hiltunen, V., Hari, P. and Kulmala, M. (2009) Smart-SMEAR: on-line data exploration and visualization tool for SMEAR stations. Boreal Env. Res. 14, 447–457.

53. Kasimov N.S. (2013). Landscape Ecogeochemistry. M.: Filimonov. 208 p.

54. asimov N.S., Chalov S. R. & Panin A. V. (2013): Multidisciplinary field training in undergraduate Physical Geography: Russian experience, Journal of Geography in Higher Education, Volume 37, Issue 3, 416–431, DOI:10.1080/03098265.2013.794331.

55. Kerr, R.A. (2012) Ice-Free Arctic Sea May be Years, Not Decades, Away. Science 337: 1591. Bibcode:2012Sci...337.1591K.

56. okhanovsky, A.A., and G. de Leeuw (Editors) (2009) Satellite Aerosol Remote Sensing Over Land. Springer-Praxis (Berlin). ISBN 978-3-540-69396-3, 388 pp.

57. Kokhanovsky, A.A., S. Platnick and M.D. King (2011) Remote Sensing of Terrestrial Clouds from Space using Backscattering and Thermal Emission Techniques. In: Burrows, J.P., U. Platt and P.Borrell (Editors) The Remote Sensing of Tropospheric Composition from Space, 536 pp., Springer-Verlag Berlin Heidelberg 2011. ISBN: 978-3-642-14790-6 doi: 10.1007/978-3-642-14791-3., pp. 231–257.

58. Kulmala M, Tuomo Nieminen, Anna Nikandrov, Katrianne Lehtipal[o], Hanna Manninen, Maija K. Kajos, Pasi Kolari, Antti Laur[i], Tuukka Petäjä, Radovan Krejci, Hans-Christen Hansson, Erik Swietlicki, Anders Lindroth, Torben R. Christensen, Almut Arneth, Pertti Hari, Jaana Bäck, Timo Vesala and Veli-Matti Kerminen CO_2 induced terrestrial climate feedback mechanism: From carbon sink to aerosol source and back . BER in press.

59. Kulmala M., Alekseychik P., Paramonov M., Laurila T., Asmi E., Arneth A., Zilitinkevich S. & Kerminen V.-M. (2011). On measurements of aerosol particles and greenhouse gases in Siberia and future research needs. Boreal Env. Res. 16: 337–362.

60. Kulmala, M. et al. (2011a) Atmos. Chem. Phys., 11, 13061.

61. Kulmala, M. et al. (2011b) Atmos. Chem. Phys., 11, 10791.

62. Kulmala, M., & Petaja, T. (2011). Soil Nitrites Influence Atmospheric Chemistry. Science, 333, 1586-1587. 10.1126/science.1211872 01.

63. Kulmala, M., Asmi, A., Lappalainen, H. K., Carslaw, K. S.,P¨oschl, U., Baltensperger, U., Hov, Ø., Brenquier, J.-L., Pandis, S. N., Facchini, M. C., Hansson, H.-C., Wiedensohler, A., and O'Dowd, C. D.(2009): Introduction: European Integrated project on Aerosol Cloud Climate and Air Quality interactions (EUCAARI) – integrating aerosol research from nano to global scales, Atmos. Chem. Phys., 9, 2825–2841, doi:10.5194/acp-9- 2825-2009, 2009.

64. Kulmala, M.,T. Suni, K. E. J. Lehtinen, M. Dal Maso, M. Boy, A. Reissell, Ü. Rannik, P. Aalto, P. Keronen, H. Hakola, J. Bäck, T. Hoffmann, T. Vesala, and P. Hari (2004).A new feedback mechanism linking forests, aerosols, and climate. Atmos. Chem. Phys., 4, 557–562.

65. Kuzminov I.F. (2011). Socio-Economic Challenges to Timber Industry in North-European Part of Russia (Case-Study of the Kostroma Oblast) // Regional Research of Russia, 2011, vol. 1, no. 1, pp. 41–51.

66. Lenton, T. M., H. Held, E. Kriegler, J. W. Hall, W. Lucht, S. Rahmstorf, and H. J. Schellnhuber. (2008). Tipping elements in Earth's climate system. Proceedings of the National Academy of Sciences105:1786–1793.

67. Lihavainen, H., V. Kerminen, P. Tunved, V. Aaltonen, A. Arola, J. Hatakka, A. Hyvärinen, and Y. Viisanen (2009), Observational signature of the direct radiative effect by natural boreal forest aerosols and its relation to the corresponding first indirect effect, J. Geophys. Res., 114, D20206, doi:10.1029/2009JD012078.2009.

68. Litvinenko T.V. (2012). Socioecological Consequences of Transformation of Natural Resources Utilization in Russia's Eastern Part in Post-Soviet Period // Regional Research of Russia, 2012, vol. 2, no 4, pp. 284–295.

69. Litvinenko T.V. (2013) Post-Soviet Transformation of Natural Resources Utilization and its Impact on Population Dynamics in Chukotka Autonomous Okrug //Izvestiya of Russian Academy of Sciences, Geography, 2013, no 2: pp. 30–42. (in Russian).

70. Lombardozzi, D., Levis, S., Bonan, G., and Sparks, J. P. (2012) Predicting photosynthesis and transpiration responses to ozone: decoupling modeled photosynthesis and stomatal conductance, Biogeosciences, 9, 3113–3130, doi:10.5194/bg-9-3113-2012, 2012.

71. Malkhazova, S. M., Mironova, V. V., Kotova, T. V., Shartova N. V., Orlov D. S. (2013) Natural Focal Diseases in Russia: Monitoring and Mapping, Geography. Environment. Sustainability, No 4, p. 4–12.

72. Malkhazova, S. M., Rumyantsev, V. Yu, Soldatov, M. S., Leonova, N. B., Kislov, A. V. (2012a) Forecasted trends in changes of vegetation in European part of Russia in connection witn global warning, Geography, environment, sustainability, v. 4, No 5, p. 4–16.

73. Malkhazova, S.M. & Shartova, N.V. (2012b) The Health of the Moscow Region Population at the End of the 19 - Beginning of the 21st Centuries. Regional Research of Russia, v. 2, No 2, p. 149–159.

74. Mauldin L.,T. Berndt, M. Sipilä, P. Paasonen, T. Petäjä, S. Kim, T. Kurtén, F. Stratmann, V.-M. Kerminen & M. Kulmala (2012) A new atmospherically relevant oxidant of sulphur dioxide, Nature 488,193–196.

75. MEGAPOLI (2011) Megacities: Emissions, urban, regional and Global Atmospheric POLlution and climate effects, and Integrated tools for assessment and mitigation. MEGAPOLI project Final Report, September 2011, 43 pp. http://megapoli.dmi.dk/publ/MEGAPOLI_FinalReport_Part1.pdfhttp://megapoli.dmi.dk/publ/MEGAPOLI_FinalReport_Part1.pdf

76. Mei, L., Xue, Y., De Leeuw, G., von Hoyningen-Huene, W., Kokhanovsky, A. A., Istomina, L., Guang, J., & Burrows, J. P. (2013). Aerosol optical depth retrieval in the Arctic region using MODIS data over snow. Remote Sensing of Environment, 128, 234-245. 10.1016/j.rse.2012.10.009.

77. Mei, L., Xue, Y., Kokhanovsky, A. A., von Hoyningen-Huene, W., Istomina, L., De Leeuw, G., Burrows, J. P., Guang, J., & Jing, Y. (2013). Aerosol optical depth retrieval over snow using AATSR data. International Journal of Remote Sensing, 34(14), 5030-5041. 10.1080/01431161.2013.786197.

78. Melillo, J.M, Steudler, P.A, Aber, J.D, Newkirk, K., Lux, H., Bowles, F.P., Catricala, C., Magill, A., Ahrens, T. and Morrisseau, S. (2002) Soil warming and carbon-cycle feedbacks to the climate system. Science, 298, pp. 2173–2176.

79. Meybeck M, Vörösmarty CJ (2005) Fluvial filtering of land to ocean fluxes: from natural Holocene variations to Anthropocene. Comptes Rendus 337: 107–123.

80. Mijling, B. and R. van der A, Using daily satellite observations to estimate emissions of short-lived air pollutants on a mesoscopic scale. J. Geophys. Res. 117, D17, doi:10.1029/2012JD017817, 2012.

81. Monks, S.A., et al., (2014), Multi-model study of chemical and physical controls on transport of anthropogenic and biomass burning pollution to the Arctic, to be submitted.

82. Nordic Climate Change Research (2009) NordForsk Policy Briefs 2009-8. Mandag Morgen, 2009.

83. Official web site of the project "Global Warming and the Human-Nature Dimension in Siberia: Social Adaptation to the Changes of the Terrestrial Ecosystem, with an Emphasis on Water Environments", Research Institute for Humanity and Nature, Kyoto, Japan. http://www.chikyu.ac.jp/rihn_e/project/C-07.html. Access date: April 28, 2013.

84. Paasonen P. Pauli Paasonen, A.Asmi, T.Petäjä, M.K. Kajos, M.Äijälä, H.Junninen, T.Holst, J.P. D. Abbatt, A. Arneth, W.Birmili, H. Denier van der Gon, A.Hamed, A. Hoffer, L. Laakso, A.Laaksonen, W. R. Leaitch, C. Plass-Dülmer, S. C. Pryor, P. Räisänen, E. Swietlicki, A. Wiedensohler, D. R. Worsnop, V-M. Kerminen, M. Kulmala (2013) Warming-induced increase in aerosol number concentration likely to moderate climate change, Nature Geoscience 6,438–442.

85. Pankratova N.V., Elansky N.F., Belikov I.B., Lavrova O.V., Skorokhod A.I., Shumsky R.A. Ozone and nitric oxides in the surface air over Northern Eurasia according to observational data obtained in Troica experiments. Izvestiya. Atmospheric and Oceanic Physics. (2011). v. 47. N 3. p. 313–328.

86. Paramonov M., Lauri A., Sylvius V., Kulmala M. (2011). Approaches for multidisciplinary research-oriented studies by means of joint programmes: cases, experiences and successes. In Proceedings of International Symposium on Integrating Research, Education, and Problem Solving (IREPS), Orlando, FL, USA, pp. 231–235.

87. Piao S, P. Ciais, P. Friedlingstein, P. Peylin, M. Reichstein, S. Luyssaert, H. Margolis, J. Fang, A. Barr, A. Chen, A. Grelle, D.Y. Hollinger, T. Laurila, A. Lindroth, A.D. Richardson and T. Vesala (2008): Net carbon dioxide losses of northern ecosystems in response to autumn warming. Nature 451, pp. 49–53.

88. Quinn P.K&T.S Bates, (2011)The case against climate regulation via oceanic phytoplankton sulphur emissions, Nature 480, 51–56.

89. Regional Development and Regional Policy of Russia in the Transition Period (2011) Artobolevsky S.S., Glezer O.B.(Eds.). M., Izdatelstvo Bauman MGTU. 317 p. (in Russian).

90. Remote Sensing of Environment (2013), http://dx.doi.org/10.1016/j.rse.2013.04.024.

91. Rustad LE, Campbell JL, Marion GM, Norby RJ, Mitchell MJ, Hartley AE, Cornelissen JHC, Gurevitch J, GCTE-NEWS. (2001). A meta analysis of the response of soil respiration, net nitrogen mineralization, and aboveground plant growth to experimental ecosystem warming. Oecologia 126, pp. 543–562.

92. Schepaschenko, D.G., McCallum, I., Shvidenko, A., Fritz, S., Kraxner, F., Obersteiner, M. (2010). A new hybrid land cover dataset for Russia: a methodology for integrating statistics, remote sensing and in-situ information. Journal of Land Use Science, 6(4), pp. 245-259. doi:10.1080/1747423X.2010.511681.

93. Scott, C. E., Rap, A., Spracklen, D. V., Forster, P. M., Carslaw, K. S., Mann, G. W., Pringle, K. J., Kivekas, N., Kulmala, M., Lihavainen, H., & Tunved, P. (2014). The direct and indirect radiative effects of biogenic secondary organic aerosol. Atmospheric Chemistry and Physics, 14(1), 447-470. 10.5194/acp-14-447-2014.

94. Shindell, D. T., Chin, M., Dentener, F., Doherty, R. M., Faluvegi, G., Fiore, A. M., Hess, P., Koch, D. M., MacKenzie, I. A., Sanderson, M. G., Schultz, M. G., Schulz, M., Stevenson, D. S., Teich, H., Textor, C., Wild, O., Bergmann, D. J., Bey, I., Bian, H., Cuvelier, C., Duncan, B. N., Folberth, G., Horowitz, L. W., Jonson, J., Kaminski, J. W., Marmer, E., Park, R., Pringle, K. J., Schroeder, S., Szopa, S., Takemura, T., Zeng, G., Keating, T. J., and Zuber, A. (2008) A multi-model assessment of pollution transport to the Arctic, Atmos. Chem. Phys., 8, pp. 5353-5372, doi:10.5194/acp-8-5353-2008.

95. Shvidenko, A. (2012) Forest resources and climate change. In "The Russian Federation Forest Sector. Outlook Study to 2030". Food and Agriculture Organization of the United Nations, Rome. – P. 47–50.

96. Shvidenko, A., Gustafson, E., McGuire, A.D., Kharuk, V.I., Schepaschenko, D.G., Shugart, H.H., Tchebakova, N.M., Vygodskay, N.N., Onuchin, A.A., Hayes, D.J., McCallum, I., Maksyutov, S., Mukhortova, L.V., Soja, A.J., Belelli-Marchesini, L., Kurbatova, J.A., Oltchev, A.V., Parfenova, E.I., Shuman, J.K. (2013). Terrestrial ecosystems and their change, in: Groisman,

P.Y., Gutman, G. (Eds.), Regional Environmental Changes in Siberia and Their Consequences. Springer, Berlin, Heidelberg, pp. 171–249.

97. Shvidenko, A.Z. and Schepaschenko, D.G. (2013b) Carbon Budget of Russian forests. Siberian Journal of Forest Science, No 1, 69–92.

98. Shvidenko, A.Z., Schepaschenko, D.G., (2013a) Climate change and wildfires in Russia. Contemp. Probl. Ecol. 6, 683–692. doi:10.1134/S199542551307010X.

99. Sitch, S., Cox, P. M., Collins, W. J., and Huntingford, C. (2007) Indirect radiative forcing of climate change through ozone effects on the land-carbon sink, Nature, 448, pp. 791–794.

100. Smedsrud L.H., I. N. Esau, R. B. Ingvaldsen, T. Eldevik, P. M. Haugan, C. Li, V. Lien, A. Olsen, A. Omar, O.H. Otterå, B. Risebrobakken, A.B. Sandø, V. Semenov and S.A. Sorokina, (2013): The role of the Barents Sea in the Arctic climate system, Reviews of Geophysic , 51, doi:10.1002/rog.20017, pp 1–35.

101. Smith, L. (2010) The New North- the World in 2050.

102. Spracklen, D.V., Bonn, B., Carslaw, K.S. (2008) Boreal Forests, Aerosols and the Impacts on Clouds and Climate, Philosophical Transactions of the Royal Society A, 366, doi:10.1098/rsta.2008.0201.

103. Spracklen, D.V., Mickley, L.J., Logan, J.A., Hudman, R.C., Yevich, R., Flannigan, M.D., Westerling, A.L. (2009). Impacts of climate change from 2000 to 2050 on wildfire activity and carbonaceous aerosol concentrations in the western United States, J. Geophys. Res., 114, D20301, doi:10.1029/2008JD010966.

104. Stjernberg, A., Skorokhod, A., Paris, J., Elansky, N., Nédélec, P., & Stohl, A. (2012). Low concentrations of near-surface ozone in Siberia. Tellus B, 64. doi:10.3402/tellusb.v64i0.11607.

105. Stohl, A., Klimont, Z., Eckhardt, S., Kupiainen, K., Shevchenko, V. P., Kopeikin, V. M., and Novigatsky, A. N. (2013): Black carbon in the Arctic: the underestimated role of gas flaring and residential combustion emissions, Atmos. Chem. Phys., 13, pp. 8833-8855, doi:10.5194/acp-13-8833-2013.

106. Tchebakova, N.M., Rehfeldt, G.E., Parfenova, E.I. (2010).Vegetaion zones to climate types: effects of climate warming on Siberian ecisystems. In A. Osawa, O.A. Zyranova, y. Matsura et al. (Eds) Permafrost Ecosystems: Siberian larch forests. Springer, Berlin, pp. 427–447.

107. The European Higher Education Area. Joint Declaration of the European Ministers of Education. Convened in Bologna on the 19th of June, 1999.

108. Tingley M. P. and Huybers P. (2013). Recent temperature extremes at high northern latitudes unprecedented in the past 600 years. Nature, 496, pp. 201–205.

109. Tomasi, C., A.A. Kokhanovsky, A. Lupi, C. Ritter, A. Smirnov, N.T. O'Neill, R.S. Stone, B.N. Holben, S. Nyeki, C. Wehrli, A. Stohl, M. Mazzola, C. Lanconelli, V. Vitale, K. Stebel, V. Altonen, G. de Leeuw, E. Rodriguez, A.B. Herber, V.F. Radionov, T. Zielinski, T. Petelski, S.M. Sakerin, D.M. Kabanov, Y. Xue, L.-L Mei, L. Istomina, R. Wagener, B. McArthur, P.S. Sobolewski, R. Kivi, Y. Courcoux, P. Larouche, S. Broccardo and S.J. Piketh (2014). Aerosol remote sensing in polar regions, Submitted to Earth Science Reviews on 15 April 2014.

110. Troitskaya Y., Galina Rybushkina, Irina Soustova, Galina Balandina, Sergey Lebedev, Andrey Kostianoy (2012). Adaptive retracking of Jason1 altimetry data for inland waters: the example of the Gorky Reservoir. International Journal of Remote Sensing, vol. 33, no. 23, pp. 7559–7578.

111. Tunved P., H.-C. Hansson, V.-M. Kerminen, J. Ström, M. Dal Maso, H. Lihavainen, Y. Viisanen, P. P. Aalto, M. Komppula, M. Kulmala (2006) High Natural Aerosol Loading over Boreal Forests, Science 14 April 2006: Vol. 312 no. 5771 pp. 261-263 DOI: 10.1126/science.1123052.

112. Vesala T., Launiainen S., Markkanen T., Kulmala M., Aarflot A., Hämeri K. and Lauri A. (2008). E-learning as a teaching tool in international education programmes and recent experiences from CBACCI project. Report Series in Aerosol Sci., 92, pp. 215–218.

113. Walther G.R. et al., (2002), Nature, 416, pp. 389–395.

114. Wespes, C., Emmons, L., Edwards, D. P., Hannigan, J., Hurtmans, D., Saunois, M., Coheur, P.-F., Clerbaux, C., Coffey, M. T., Batchelor, R. L., Lindenmaier, R., Strong, K., Weinheimer, A. J., Nowak, J. B., Ryerson, T. B., Crounse, J. D., and Wennberg, P. O. (2012) Analysis of ozone and nitric acid in spring and summer Arctic pollution using aircraft, ground-based, satellite observations and MOZART-4 model: source attribution and partitioning, Atmospheric Chemistry and Physics, 12, pp. 237–259, doi:10.5194/acp-12-237-201.

115. WMO/IGAC (2012) WMO-IGAC report: Impact of Megacities on Air Pollution and Climate. GAW Report No. 205, WMO.

116. WMO-GAW (2009) WMO Global Atmosphere Watch (GAW) Strategic Plan: 2008 – 2015. WMO TD NO. 1384, GAW Report No. 172, 104 p.

117. Zhang, Y., Mao, H., Ding, A.J., Zhou, D.R., and Fu, C.B.(2013) Impact of synoptic weather patterns on spatio-temporal variation in surface O_3 levels in Hong Kong during 1999-2011, Atmos. Environ., 73, 41–540.

118. Zhou, D.R., Ding, A.J., Mao, H.T., Fu, C.B., Wang, T., Chan L.Y., Ding, K., Zhang, Y., Liu J., and Hao, N. (2013): Impact of East Asian monsoon on lower tropospheric ozone over coastal South China: Environ. Res. Lett., 8, 044011.

119. Zilitinkevich S.S. (2012): The Height of the Atmospheric Planetary Boundary layer: State of the Art and New Development – Chapter 13 in "National Security and Human Health Implications of Climate Change", edited by H.J.S. Fernando, Z. Klaić, J.L. McKulley, NATO Science for Peace and Security Series-C: Environmental Security (ISBN 978-94-007-2429-7), Springer, pp. 147–161.

120. Zilitinkevich, S., Esau, I. and Baklanov, A. (2007). Further comments on the equilibrium height of neutral and stable planetary boundary layers. Quart. J. Roy. Met. Soc. 133, pp. 265–271.

121. Zilitinkevich, S.S., and Esau, I.N. (2009). Planetary boundary layer feedbacks in climate system and triggering global warming in the night, in winter and at high latitudes. Geography, Environment and Sustainability 1, No. 2, pp. 20–34.

122. Zilitinkevich, S.S., Elperin, T., Kleeorin, N., Rogachevskii, I., Esau, I.N. (2013). A hierarchy of energy- and flux-budget (EFB) turbulence closure models for stably stratified geophysical flows. Boundary-Layer Meteorol. 146, pp. 341–373.

123. Zimov, S., Davydov and S., Zimova, G. (2006). Permafrost carbon: Stock and a decomposability of a globally significant carbon pool. Geopys. Res. Letter, 33, L20502, doi:10.1029/2006GL027484.

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^{14}C AGE, STABLE ISOTOPE COMPOSITION AND POLLEN ANALYSIS OF MASSIVE ICE, BOVANENKOVO GAS FIELD, CENTRAL YAMAL PENINSULA

ABSTRACT. The origin of the massive ice is important for understanding the Quaternary history of the Yamal region and to predict the occurrence of massive ice, which is important for gas exploration and the development of infrastructure. Massive ice bodies occur in the Bovanenkovo gas field area within sediments such as layers, laccoliths, rods and lenses. Maximal thickness of the tabular ice is 28,5 m; mean thickness is about 8 m. Deposits of the third terrace underlying and overlapping the tabular ice had been formed from 25 ka BP to 20 ka BP, according to ^{14}C dates. Oxygen-isotope values ($\delta^{18}O$) of massive ices are ranged from 12, 49‰ up to –22, 95‰. Deuterium (δD) values vary from –91, 7‰ up to –177, 1‰. Deuterium excess (d_{exc}) changes from 3, 4 to 10, 6‰. Both homogenous and contrast distribution $\delta^{18}O$ and (δD) vs. depths in massive ice bodies evidences the segregated and/or infiltrated-segregated manner of ice formation. Pollen, spores and algae spectra from ice are similar to pollen characteristics of modern lacustrine and coastal floodplain sediments in the area. The ingression of cold seawaters on a coastal flood plain caused freezing and ice segregation, with the formation of extensive ice layers under the large but shallow lakes. As a result, syngenetic and genetically heterogeneous ice, such as: segregated, infiltrated-segregated, lake bottom congelation ice etc. was formed.

KEY WORDS: massive ice, stable isotope composition, pollen, ^{14}C age, Yamal Peninsula.

INTRODUCTION

Massive ice is a cryogenic phenomenon that is dangerous for building and the exploitation of construction within a permafrost area. Understanding the origin of the massive ice helps to elucidate the Quaternary history of the Yamal region, and to predict the occurrence of massive ice, which is important for gas exploration and the development of infrastructure. It was often supposed that this kind of ice was a relic of Quaternary glaciations. However, much evidence of intrasedimental origin of massive ice has also been obtained [Mackay, 1989]. However, up to the present, there is no clear indicator for the selection of intrasediment massive ice from buried ice. We suppose that permafrost conditions are favourable for the formation of segregated or segregated-infiltrated, injected, mixed type of massive ice and also for the syngenetic burial of bottom ice, coast ice, iceberg ice, glacier ice etc.

The folds and deformation of an ice body and surrounding sediment are usually considered as morphological criteria of glacier activity. Intensely folded massive ice, containing structures such as thrusts, recumbent isoclinal folds, augen structures, is a clear sign of glaciotectonic deformation, and could be glaciotectonically deformed intrasedimental ice, glaciotectonically deformed basal ice, glaciotectonically deformed firnified ice. At the other extreme, massive ice containing, e.g. simple anticlines (e.g. Peninsula Point as shown by Mackay, Dallimore [1992]) probably has nothing to do with glaciotectonic deformation, but such cryogenic slide-like deformations are often formed under freezing conditions, as a result of volume changes in the sediment, both in sub-aerial and sub-aqueous environments. Vertical and horizontal tectonic activity also caused fold formation in frozen, melted and even metamorphosed rock. It is clear that the occurrence of any folds is not a guaranteed indicator of the glacier origin of massive ice.

Waller et al. [2009] accentuated the potential benefits of interdisciplinary research into the formation of basal ice beneath glaciers, and the origin of massive ice in glaciated permafrost regions. We found that palynological analysis helps to distinguish buried glacial ice from ice of other types [A. Vasil'chuk & Yu. Vasil'chuk, 2010a, b, c]. In glacier ices, distant, wind-transported pollen grains dominate; a minor part of pollen spectra is presented by regional pollen and spores, and local components are sporadic and limited by several species only [Andreev et al., 1997; Bourgeois, 2000]. In the massive ice of another origin, regional and local tundra pollen spectra dominate as a rule [A. Vasil'chuk, 2005, 2007]. Certainly, it is necessary to remark that ice derived from groundwater could be identical to basal glacier ice, because it may contain pollen and spores from underlying sediment, which could penetrate into the ice through micro-cracks. Such micro-cracks have been described in glacier models [Knight et al., 2000]. Pollen could also be carried into the basal ice by sub-glacial groundwater flow, and therefore, be flushed out from any periglacial sediments. But the Late Glacial Maximum ice limit is located many kilometers from the Yamal Peninsula [Svendsen et al., 2004], so remnants of Late Pleistocene basal ice are unlikely here.

The chemical composition of the ice may only be an additional method for the detection of massive ice origin because massive ice is mainly fresh or ultra-fresh as glacier ice. Sometimes fresh massive ice is found in salted sediments. Salted ice rarely occurs in salted sediments. In the severe climatic and geocryological conditions of the Yamal Peninsula, the lakes were the exclusive sources which could provide the regular entry of the enormous volumes of ultra-fresh water into the stratum of frozen marine deposits. The hydrochemical similarities of the chemical composition and the mineralization of the repeatedly injected massive ice beds and lake water have been proved [Fotiev, 2012].

The composition of air bubbles have been used as an indicator of massive ice origin in recent studies [Cardyn et al., 2007; Lacelle et al., 2007]. This method will give reliable indicators of massive ice origin in the near future, but it requires high accuracy at all stages of the investigation – at the sampling, preservation and extraction of air bubbles – and contamination is possible at all these stages.

Stable isotope study of massive ice is relatively simple at the sampling and analysis stage, and is sensitive and complex at the interpretation stage. The isotope method requires both detailed vertical and horizontal sampling of all varieties of the ice in the ice body; for example, milk ice, transparent ice, dirty ice etc. It also requires the analysis of all ice varieties in the exposure, such as ice lens, vertical and horizontal schlieren ice in surrounding sediments. It is possible to create an archive of reference isotope signatures for massive ice of different origins, as a result of the isotope study of massive ice. Intrasedimental ice is generally thought to be formed within the surrounding sediments, and includes segregation ice, intrusive ice and segregation-intrusive ice [Mackay, 1971, 1983, 1989; Rampton & Mackay, 1971; Zhestkova, Shur, 1978; Rampton, 1988; Vasil'chuk, Trofimov, 1988; Mackay & Dallimore, 1992; Vasil'chuk, 1992, 2012, 2014; Dubikov, 2002, Khimenkov, Brushkov, 2006]. Buried ice may be formed by the burial of surface or glacial ice. Probably buried ice [Fujino et al., 1988], glacial ice [Dallimore & Wolfe, 1988; Gowan & Dallimore, 1990; Waller et al., 2009] and snow-bank ice [Pollard & Dallimore, 1988] has been identified at several sites in the Tuktoyaktuk Coastlands and on the Yukon coastal plain.

A considerable effort has been devoted over the past forty years to determining the origin of thick bodies of massive ice, which are common throughout the Yamal Peninsula. Buried ice and glacial ice has been identified at several sites in the Yamal Peninsula. The isotopic composition ($\delta^{18}O$ and δD) of Canadian [Mackay, 1983; Fujino et al., 1983, 1988; Dallimore & Wolfe, 1988; Pollard & Bell, 1998; Murton, 2005, 2009; Murton et al., 2005; Lacelle et al., 2007] and Siberian [Vasil'chuk & Trofimov, 1988; Yu. Vasil'chuk, 1992, 2006b, 2010, 2011a; Michel, 1998; Lein et al., 2003] massive ground ice has been used for the adjustment of the ice origin.

STUDY AREA AND STRATIGRAPHY

The study area is located within the limits of the Bovanenkovo gas field, Central Yamal Peninsula, north of Western Siberia (Fig. 1).

A distinctive characteristic of the stratigraphy is the widespread bodies of massive ice

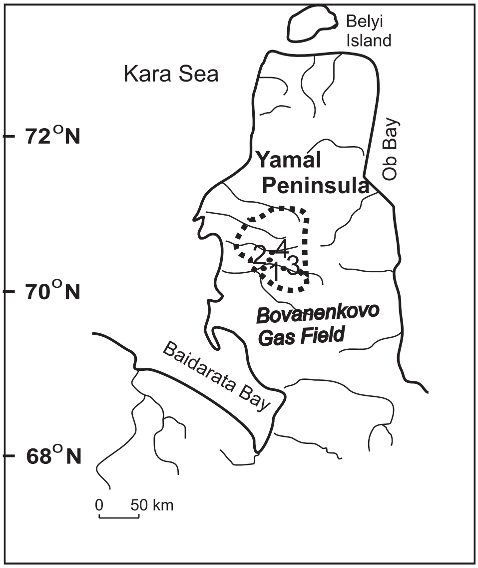

Fig. 1. Location map of Bovanenkovo gas field, Central Yamal Peninsula north of Western Siberia (70°9′N, 68°42′E); and scheme of study sites:

1 – borehole 34; 2 – site Gas compressor stations (GCS); 3 – site K 64; 4 – massive body 4.

revealed in boreholes and natural exposures. We analysed about 260 boreholes drilled in the early 1990s, in the Bovanenkovo area, at the watershed of the Nadujyaha and Nguriyaha Rivers.

As a rule massive ice is found in the borehole profiles at outliers of the third and second terraces (absolute elevation from 15–20 to 40 m), and at the alluvial and lacustrine-alluvial floodplains as well [Solomatin et al., 1993; Parmuzin, Sukhodol'skiy, 1982; Velikotsky, 1987; Baulin et al., 1989; Kondakov et al., 2001; Baulin, 1996; Vasil'chuk et al., 2009; Vasil'chuk, 2006b, 2010, 2012, 2014; Chuvilin, 2007; Streletskaya et al., 2013; Solomatin, 2013]. A massive ice layer from 7 to 9 m was even found under the channel of the Seyaha River [Solomatin et al., 1993]. The cartometric calculations have revealed the insignificant but stable increase of lake areas and number on the low hypsometrical levels over the past 20 years, owing to the melting of icy sediments and ice bodies [Sannikov, 2012].

The massive ice often occurs as layers (Fig. 2, *a*) or interrupted lenses (Fig. 2, *b*, c, *d*).

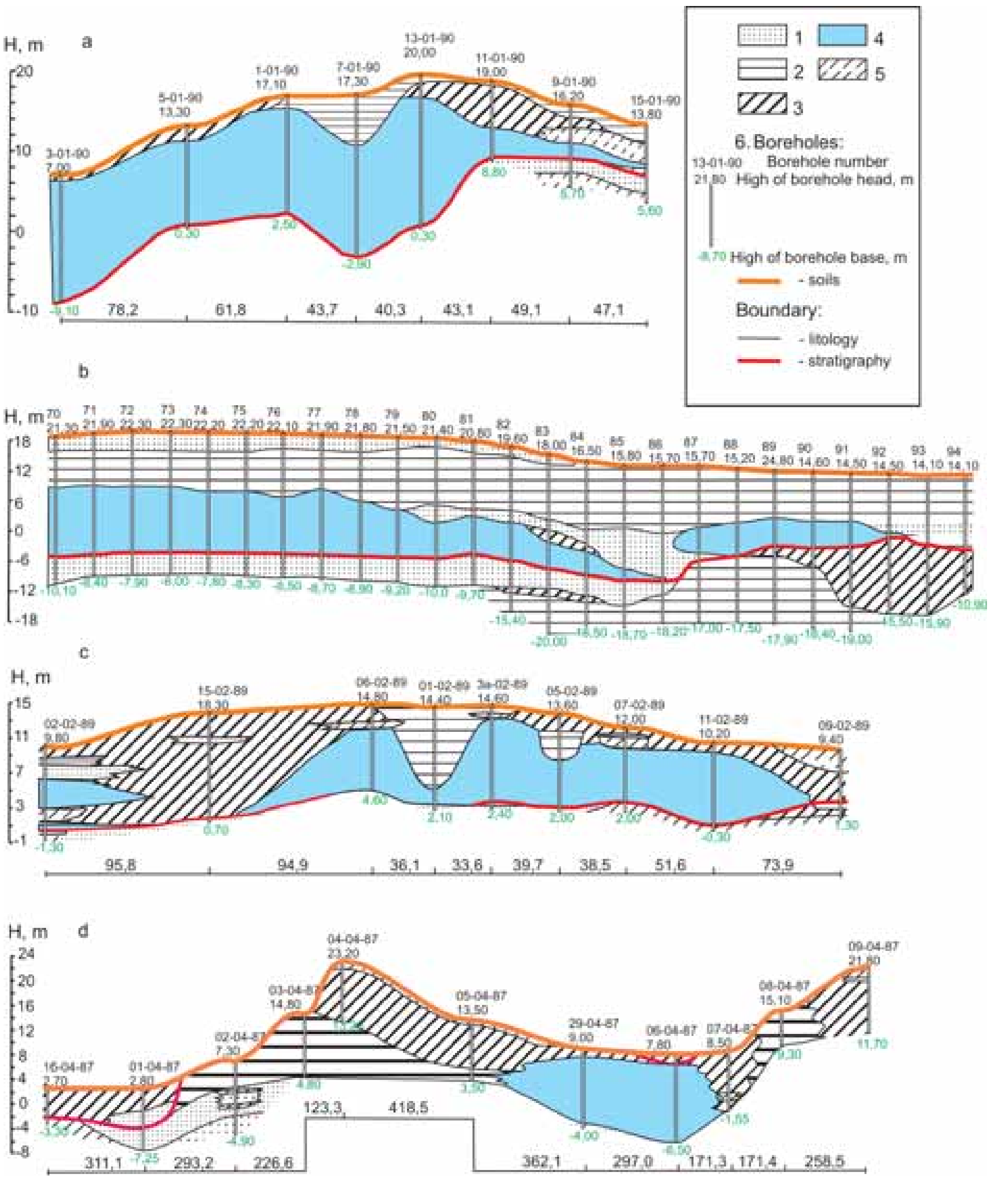

Fig. 2. Massive ice bodies at the third terrace Bovanenkovo gas field:

1. sand; 2. clay; 3. loam; 4. massive ice; 5. clay sand; 6. location and characteristics of boreholes.

The roof of the massive ice is located both at the base of the active layer and at a depth of 52 m. The base of the massive ice occurred at a depth of 1–57 m, but the massive ice base is not located below –21, 5 m of absolute elevation. The roof of the massive ice is relatively uneven, and the roof and the base of the ice are not parallel in many cases (Fig. 2, *c*). Maximum thickness of the ice in borehole is 28, 5 m, and the mean value is 8 m (as a result of 260 measurements). The lateral extent of massive ice bodies is more than 200 m, and the area often is more than 10 km^2. There are two main types of massive ice: pure layered ice (Fig. 3, *a*); and layered ice with a band of ground between white and grey layers (Fig. 3, *b*).

There are primary and secondary contacts between the ice and host sediments. As has

Fig. 3. (a) Stratified massive ice body, and (b) band of ground between layers of white and gray clear (overhead) and clear (below) ice, at the third terrace of the Bovanenkovo gas field. Thickness of single layer is about 25–35 cm. Photo by Ye.Ye. Podborny.

been shown by the investigation, primary contacts are typical for localities where erosion of host Late Pleistocene sediments didn't affect the surface of the massive ice. Clay and loam are characterized by a great number of ice lenses, which form reticulate structures at the contact with massive ice. The height of separate vertical lenses is about 10–20 cm, while the width of horizontal lenses is smaller. Volumetric ice content of sediments covering massive ices is more than 50–60%. Upwards the ice content decreased to 25–30% and the cryogenic structure became quasi-reticulate. A large number of clay particles of 2–3 cm in size often occurred at the contact zones in the massive ice. The amount of clay inclusions decreased with distance from the contact zone [Parmuzin, Sukhodol'sky, 1982].

More than half of the boreholes revealed secondary contact. These boreholes were drilled mainly on the slopes of terraces. Ice bodies here formed near the surface and were covered only by a thin layer of slope deposits. According to Parmuzin and Sukhodol'sky [1982], secondary contacts are peculiar to the majority of massive ice exposed within watersheds. Only in two cases has the ice body been covered by Late Pleistocene sediments. As a rule, primary contacts are observed deeper than secondary ones. The thickness of Late Pleistocene sediments above the massive ice is about 10–15 m. The revealed primary contacts found at the top parts of slopes and horizontal surfaces of a terraces are without thermo-denudation signs.

Within the remaining terraces only one borehole number 27–28 at 6 m abowe see lewel has revealed the contact of fine-grained sand with underlying massive ice. However, the thickness of massive ice is unknown owing to the partial thawing of ice during slope development, and it is obvious that the thickness of ice at some localities is not less than 25 m [Parmuzin, Sukhodol'sky, 1982]. Massive ice bodies are covered by Pleistocene-Holocene delluvial-solifluction clay or loam. The former lies in the terrace pedestal and is covered by the horizontal layer of Late Pleistocene sandy loam and sand. The latter covers the slopes of terraces like a blanket at a thickness of 1–6 m.

According to Parmuzin and Sukhodol'sky [1982], secondary contacts had been formed at the sites where ice bodies partially thawed and were covered by younger sediments, owing to thermo-denudation. These contacts are more contrasting than the primary ones. The cryogenic structure of cover sediments at the contact zone is constant, and ice content is also constant. Massive ice at the contact zone is either clean or has an admixture of mineral particles. The secondary contacts at some

Fig. 4. Secondary downhill contact of massive ice with slope sediment. Photo by G.A. Rzhanitsyn.

cross-sections are formed by the ice layer up to 1 m, with a high concentration of mineral admixture, about half of the bulk volume of the ice [Parmuzin, Sukhodol'sky, 1982]. This formation is a result of the fast freezing of water-saturated ground mass flowing on the surface of the ice body, which is exposed as a result of the thawing of overlapping icy sediments. It was a mixture of thawed soil, water and peaty material, flowing down the headwall of massive ice, exposed in retrogressive thaw slumps and refreezing in the autumn. The mineral inclusions are syngenetic to the ice, and were formed as a result of the segregation of saturated water. Such flows of icy ground slowly moving down from the ledge of thawing ice had been observed at many localities of the watershed. Secondary downhill contact of massive ice with slope sediment is observed at the slopes of the third terrace (Fig. 4; 5, *a*).

Secondary gently sloping contact of massive ice with lacustrine sediment (Fig. 5, *a*) may

Fig. 5. (a) Secondary downhill contact of massive ice with slope sediments; and (b) feather-like secondary contact as a result of lake abrasion. Photos by Ye.Ye. Podborny and F.A. Romanenko.

be a result of surface thermokarst and the formation of a small lake (hasyrey or alas), immediately above the roof of the tabular ice.

Mackay [1989] and Mackay and Dallimore's [1992] called such secondary contacts 'thaw unconformities'. Feather-like secondary contact formed as a result of lake abrasion and the partial melting of the side of the tabular ice (Fig. 5, *b*).

Some data show great sizes, and accordingly, great volumes of ice bodies. In the northern part of the profile near the Nguriyaha River valley, three boreholes revealed massive ice approximately at the same depths. The distance between boreholes was about 1 km, which was too large to assume the existence of single ice body with confidence, with a length of up to 2 km. At the same time, detailed studies of massive ice within the terrace at the right bank of the Seyaha River suggest the existence of ice bodies with a lateral extent of 1–2 km or more [Parmuzin, Sukhodol'sky, 1982].

MATERIALS AND METHODS

Analysis of boreholes and exposures with massive ice allowed us to define some features of massive ice distribution and occurrence in the Middle Yamal Peninsula. In order to specify formation conditions and the age of massive ice around the Bovanenkovo gas field ^{14}C dating, stable isotope analysis and palynologic studies were carried out.

Over forty samples of massive ice, ice-wedge ice and water (lake, river and cryopeg) were brought to the isotope laboratory of the Austrian Research Center (ARC), in Seibersdorf. Stable isotope measurements were performed using isotope mass spectrometers (Finnigan MAT 251 and Delta Plus XL), equipped with automatic equilibration lines. All results were reported as relative abundance (δD and $\delta^{18}O$, respectively) of the isotopes D and ^{18}O in permil (‰), with respect to the international standard VSMOW (Vienna Standard Mean Ocean Water). The accuracy of δD and $\delta^{18}O$ measurements is better than ± 1, 0‰ and ±0,1‰, respectively.

SOME FEATURES OF GLACIATION OF YAMAL PENINSULA IN THE LATE QUATERNARY

According to reconstructions [Svendsen et al., 2004] from the vast lowland areas between Taimyr and the Pechora River, there are no convincing geological data to suggest any Middle Weichselian ice sheet advance (Fig. 6).

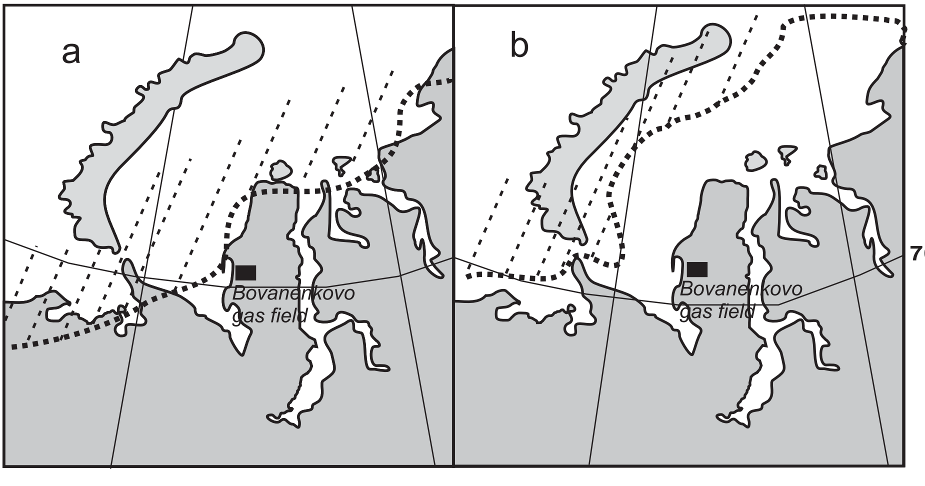

Fig. 6. (a) Location of the Eurasian ice sheet extent (dotted line) during the Middle Weichselian glacial maximum, 60–50 ka BP and (b) at the Late Weichselian glacial maximum (LGM), about 20 ka BP, according to Svendsen et al. [2004].

During the Late Weichselian, the southern ice sheet limit was evidently located on the sea floor, off the Siberian mainland. In the southern Kara Sea, the LGM ice sheet most likely corresponded to a well-defined morainic ridge, SE of Novaya Zemlya. Further north, the ice limit was probably localized along the eastern margin of the Yamal Peninsula, located many kilometers to the east of the LGM ice limit [Svendsen et al., 2004]. Surging from the higher parts of the ice sheet at its Barents-Kara Sea interfluve, north of Novaya Zemlya, could have been very short-lived, and the ice masses may have blocked the northward flow of water from the Yenisei and Ob Rivers for only a brief interval.

Concerning the correlation between the Late Quaternary transgression of the sea and glaciations in the Yamal Peninsula, the majority of scientists marked out the complex of marine terraces on the western coast, and lagoon marine terraces on the eastern coast [Saks, 1953; Danilov & Yershov, 1989; Baulin et al., 1989, 1996; Vasil'chuk, 1992], which accumulated in last 40–50 kyr. However, some investigators believe that dislocated sediments that are usually found on the west coast have a glacial origin [Kaplyanskaya, Tarnogradsky, 1986; Forman et al., 2002]. We have yielded many ^{14}C dates in syngenetic sediments with ice wedges as evidence that, during the last 40–50 kyr, large ice wedges had accumulated both at the west and eastern areas of the Yamal Peninsula [Vasil'chuk, 1992, 2006a]. Such ice wedges have not been found in the glaciated area.

The polar Ural Mountains are supposed to be one of the main regions of glaciation source. However, Mangerud et al. [2008] concluded, on the basis of a 10-year investigation, that glaciers in the Polar Urals were not much larger than at present. A combination of local factors and especially the very low LGM winter precipitation explains the surprisingly small Ural glaciers during the Last Glacial Maximum. A similar situation is described at the middle-high northern latitudes of Severnaya Zemlya [Raab et al., 2003]. Both the Polar Urals and Severnaya Zemlya are located to the east of the Scandinavian-Barents ice sheets, but Severnaya Zemlya is located at 79 °N; i.e. more than 12° further north than the Polar Urals. To our knowledge, the only place with glacier relief is located to the south-west of the Yamal Peninsula, near Bolshoi Sopkai, which sides with the Polar Urals. In the other territory of Yamal, there are three levels of marine accumulative terraces, and Kazantsev (Eem) and Salekhard (Sangamon) coastal lowlands occur within the Central Yamal Peninsula.

RESULTS

The ^{14}C age of sediments containing massive ice bodies

The time of massive-ice formation depends on the age of hosting sediments and the time of their freezing. The thermoluminescence dating (TL) of 6 samples from 300 m borehole reveal an age from 22 ± 7 ka BP (of the sandy horizon directly beneath a massive ice body) to 197 ± 25 ka BP at a depth of 300 m. The upper part of marine sand accumulated at a rate of 5–8 m/kyr, and the lower part at 2–3 m/kyr [Solomatin et al., 1993]. According to these data, the age of perennially frozen marine sand and sandy loam, underlying the massive ices within the third terrace, can be from 22 to 30 ka BP. This is in agreement with our radiocarbon dating of plant residues from sediments containing massive ice within the third terrace (Table 1).

However as thermoluminescence (TL) dating and ^{14}C dating were carried out within a 30-year interval, the location of the radiocarbon and TL-dates is indeterminate. There are also 31 and 34 ka BP dates which can be a result of the active redeposition of organic material in fluvial conditions [Yu. Vasil'chuk, A. Vasil'chuk, 2010]. The dates of 25 and 26 ka BP are closest to the age of loamy sediments of the third terrace. Therefore, the sandy loam containing the massive ice was deposited from 25 to 20 ka BP, or a little later. According to the stable isotope

Table 1. Radiocarbon dates of organic material from sediments including massive ice body (body 1) in the third terrace of the Seyaha River, Bovanenkovo

Depth, m	Dated material	Laboratory number	14C-age, kyr BP
Seyaha River, site GS-1, 2.5 m above river level	Peat	GIN-13311	34200 ± 1000
Seyaha River, site GS-1, 2.0 m above river level	Peat	GIN-13312	26100 ± 150
Seyaha River, site GS-1, 2.0 m above massive ice roof	Peat	GIN-13313	31900 ± 500
Thermo-abrasion circus, 1.1 m above massive ice roof	Peaty loam	GIN-13314	28900 ± 1000
Thermo-abrasion circus, depth 10.3 m	Peaty loam	GIN-13326	25600 ± 700
Thermo-abrasion circus, depth 1.3–1.4 m	Peaty loam	GIN-13327	25100 ± 500

composition of synchronous ice wedges [Vasil'chuk, 2006], this was the period of the most severe climatic conditions of the final stage of the Late Pleistocene cryochrone [Vasil'chuk, 1992]. Winter temperatures were colder than present by 6–8 °C [Vasil'chuk, 1992; Vasil'chuk, 2006a; Vasil'chuk et al., 2000].

The abundance of organic matter in sediments overlying and underlying the massive ice suggests that peaty loams containing massive ice have been deposited either in shallow coastal conditions, or from periodically drained beaches or low coastal floodplains. There, organic material has accumulated as a result of washout and redeposition, as well as during the period of drainage and overgrowing of these areas. As has been established, the modern coastal area of the Yamal Peninsula, are located below the Kara Sea and Ob bay level; 22–11 kyr BP [Vasil'chuk, 1992]. Marine forms are found in the sediments of the third terrace accumulated 22–11 kyr BP [Vasil'chuk et al., 2000].

In the contemporary climate, the beach and low coastal flood plain sediment of the Kara Sea and Baidarata Bay are frozen perennially 25–20 ka BP, and in more severe conditions these sediments froze just after accumulation, and a massive ice body formed during the freezing of water-saturated sediments (mainly sand horizons underlying loam with massive ice). This type of massive ice can be considered as syngenetic bottom-segregated ice [Shpolianskaya, 1989, 1999, 2003; Shpolianskaya et al., 2006]. It was formed most likely about 25–20 ka.

Stable oxygen and hydrogen isotopes

Oxygen-isotope values ($\delta^{18}O$) of massive ices range from –12, 49‰ (standard SMOW) up to –22, 95‰. Deuterium (δD) values vary from –91, 7‰ up to –177, 1‰. Deuterium excess (d_{exc}) changes from 3, 4 up to 10, 6‰ (Table 2).

Earlier it has been shown that $\delta^{18}O$ values in massive ice range from –11, 23‰ up to –25, 2‰ [Tarasov, 1990; Solomatin et al., 1993; Michel, 1998]. According to 142 measurements of stable isotopes [Solomatin et al., 1993], more than 60% of $\delta^{18}O$ values vary in a rather narrow range from –16 up to –20‰. Sampling with 10 cm vertical intervals from 2,5 m massive ice in the Bovanenkovo area shows that variations of $\delta^{18}O$ do not exceed 1‰, and the average value is –18‰ [Michel, 1998].

The similarly homogeneous isotope signal we obtained from the massive ice of bodies 2 and 3 (Fig. 7, 8, *a, b*), where $\delta^{18}O$ variations do not exceed 1‰, and δD variations are less than 4‰. Comparatively small $\delta^{18}O$ variations not exceed 2‰, and δD variations less than 8‰ are observed in deep (about 30 m) occurring massive ice bodies, as revealed by Borehole 34-P (Fig. 10, *a*).

We also studied a massive ice body 4 (Fig. 9) with noticeable variations in the stable isotope composition, where even in the upper layer 0.6 m of the ice $\delta^{18}O$ varies more than 10‰, from –12, 49 up to –22, 75‰, and δD from –91, 7 to –171, 9‰ (Fig. 10, *b*). The sufficient variations we explain [Vasil'chuk,

Table 2. Stable isotopes of oxygen (δ18O), deuterium (δD) and deuterium excess (dexc) in massive ice at the third terrace of the Seyaha River, and also ice wedge, cryopeg samples and water of river and lake in the Bovanenkovo Gas field area

Sample no.	Depth, m	Material	δ18O, ‰	δD, ‰	d_{exc}, ‰
Borehole 34 – P					
YuV-34P-1/0	28.5–32.4	Massive ice	–18.29	–141.8	4.5
YuV-34P-1/1	28.5–29.1		–17.73	–138.2	3.6
YuV-34P-1/2	29.1–29.7		–18.67	–145.0	4.4
YuV-34P-1/4	30.2–30.7		–18.89	–146.0	5.1
YuV-34P-1/5	30.7–31.4		–16.95	–131.7	3.9
YuV-34P-1/6	31.4–31.9		–18.33	–142.1	4.5
YuV-34P-1/7	31.9–32.4		–17.86	–139.5	3.4
Massive ice body 1. Seyaha River near site Gas stations (GS)-1, depth from massive ice roof					
YuV05-Bov/24	0.1	Massive ice	–21.69	–163.4	10.1
YuV05-Bov/25	0.45		–22.74	–171.3	10.6
YuV05-Bov/16	2.25		–21.55	–163.1	9.3
YuV05-Bov/27	3.15		–22.12	–167.2	9.8
YuV05-Bov/28	5.7		–22.62	–170.7	10.3
Massive ice body 2. Lake in 1300 m from site Gas compressor stations (GCS), depth from massive ice roof					
YuV05-Bov/17	0	Massive ice	–22.54	–170.0	10.3
YuV05-Bov/18	0.4		–22.11	–167.6	9.3
YuV05-Bov/19	0.8		–22.75	–171.9	10.1
Massive ice body 3. Thermo-abrasion circus east from site K–64, depth from massive ice roof					
YuV05-Bov/11	0	Massive ice	–22.79	–175.9	6.4
YuV05-Bov/14	0.5		–22.95	–176.4	7.2
YuV05-Bov/15	1.0		–23.13	–177.1	7.9
YuV05-Bov/12	1.5		–22.44	–173.1	6.4
YuV05-Bov/9	2.0		–22.61	–173.5	7.4
Massive ice body 4 near Thermo-abrasion circus , depth from massive ice roof					
YuV05-Bov/54	0–0.2	Massive ice	–12.49	–91.7	8.2
YuV05-Bov/44	0.35–0.5		–18.47	–142.9	4.9
YuV05-Bov/51	0.5–0.85		–21.42	–162.6	8.8
YuV05-Bov/49	0.85–0.95		–22.75	–171.9	10.1
YuV05-Bov/43	0.95–1.05		–18.80	–144.4	6.0
YuV05-Bov/46	1.05–1.15		–19.11	–147.6	5.3
YuV05-Bov/45	1.5–1.7		–18.32	–142.2	4.4
YuV05-Bov/55	1.75–1.8		–19.24	–147.6	6.3
YuV05-Bov/50	1.8–1.95		–22.39	–169.6	9.5
YuV05-Bov/53	2.46–2.63		–16.85	–129.6	5.2
YuV05-Bov/48	2.63–2.87		–20.65	–159.4	5.8
Ice-wedges					
YuV05-Bov/65	1	Ice-wedge Ice	–13.54	–101.2	7.1
YuV05-Bov/3	2		–17.35	–135.5	3.3
YuV05-Bov/70	3		–13.65	–105.7	3.5
Cryopegs					
YuV05-Bov/32	120	Water	–22.36	168.9	10.0

Continue table 2

Sample no.	Material	δ18O, ‰	δD, ‰	d_{exc}, ‰
Lake				
YuV05-Bov/30	Water	−21.92	−165.9	9.8
YuV05-Bov/60		−13.03	−98.8	5.4
YuV05-Bov/62		−18.58	−143.3	5.3
YuV05-Bov/67		−13.88	−97.3	13.7
YuV05-Bov/72		−13.57	−103.2	5.4
YuV05-Bov/74		−13.01	−102.8	1.3
Rivers				
YuV05-Bov/66	Seyaha River water	−14.16	−106.6	6.7
YuV05-Bov/69	Seyaha River water	−13.65	−104.5	4.7
YuV05-Bov/59	Seyaha River water	−18.66	−143.1	6.2
YuV05-Bov/68	Mordiyaha River water	−13.78	−103.5	6.7

2006b, 2010] by the formation of ice during freezing water-saturated ground in closed-system conditions [Vasil'chuk, 2011b].

A similar situation has been described in the mouth of the Gyda River, where lenses of syngenetic segregated ice were characterized by $\delta^{18}O$ variations, from −16 up to −34‰ [Vasil'chuk, 1992]. The variations are the result of isotope fractionation in the closed system. Similar variations are found in the intrasedimental ice in the Mackenzie Delta [Fujino et al., 1983, 1988].

Isotope values of cryopeg water, from a depth of 120 m, are of $\delta^{18}O$ −22, 36‰ and δD −168, 9‰. They are close to the isotope composition of massive ice, but contrast

Fig. 7. Sampling of massive ice body 3. Photo by Ye.Ye. Podborny.

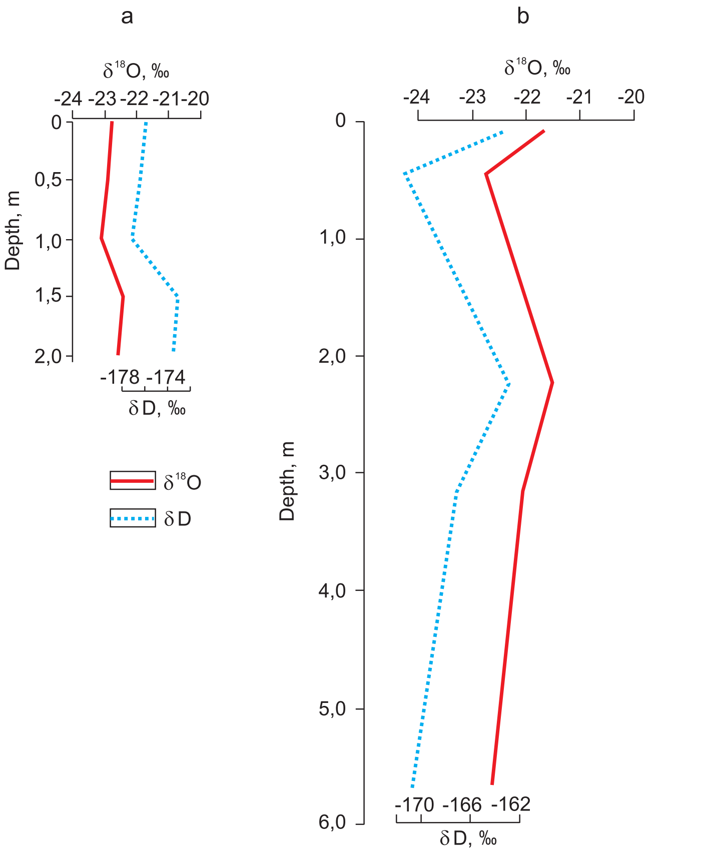

Figure 8. (a) Oxygen isotope and deuterium diagram for massive ice body 3; and (b) massive ice body 1 on Bovanenkovo gas field.

Fig. 9. Sampling from massive ice body 4. Photo by Ye.Ye. Podborny.

with published data value $\delta^{18}O$ of –16, 2‰ in cryopeg water near the Voynungto Lake in the same area [Tarasov, 1990]. The ratio of $\delta^{18}O$ and δD of all the samples of ice in body 4 are close to global meteoric water line (Fig. 11), which indicates rather slow freezing of a water-saturated horizon, which has been uniformly "depleted" both by ^{18}O and ^{2}H, in the final stages of formation.

For comparison, the isotope composition of ice wedges, cryopegs, and lake and river water of the Bovanenkovo gas field area was analysed. It was demonstrated that the main part of massive ice is isotopically more positive than Holocene ice wedge ice, as the isotope composition of massive ice and cryopegs is similar, so massive ice and cryopegs are formed from the same lenses of ground water. Lake and river water, as a rule, is isotopically more positive than

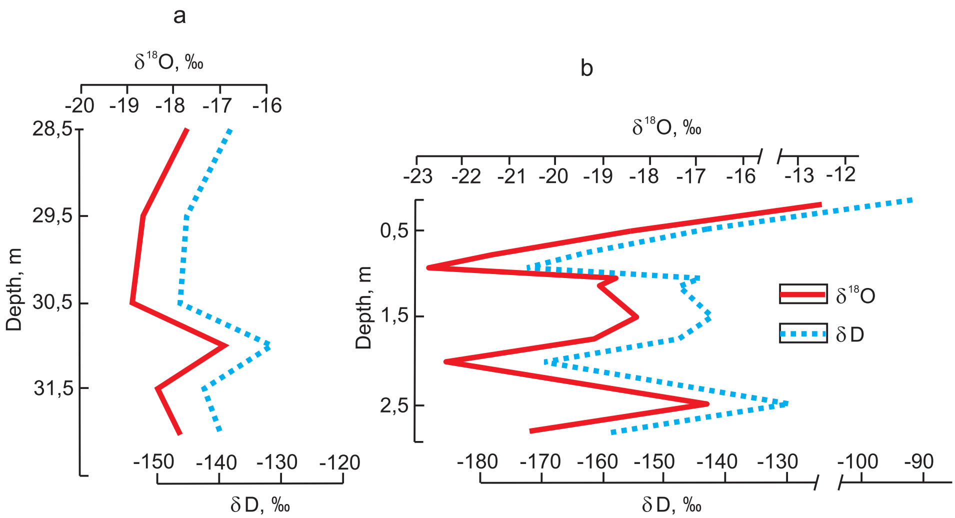

Fig. 10. (a) Oxygen isotope and deuterium plot for massive ice in borehole P-34; and (b) body 4.

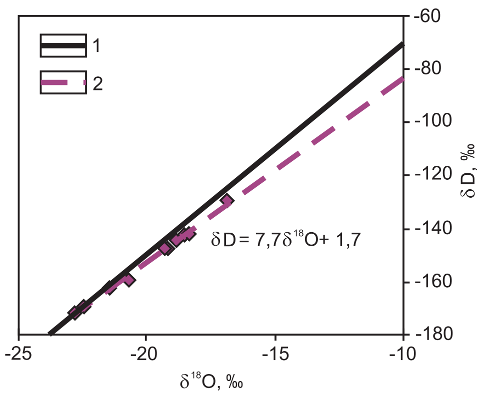

Fig. 11. Comparison of Global Meteoric Water Line (GMWL; 1) with local meteoric water line (2) of massive ice (body 4) at the third terrace of the Bovanenkovo gas field.

massive ice. This indicates that massive ice bodies originated from Late Pleistocene ground water, with a more negative isotope composition than modern river and lake water.

Pollen spectra IN massive ice

In studied massive ice in Bovanenkovo area far-transported pollen of *Pinus* is practically absent, while regional pollen, such as *Betula* sect. *Nanae, Alnaster, Salix, Cyperaceae,* and local pollen, *Ranunculaceae, Polygonaceae, Fabaceae,* are the main components of the pollen spectra [A. Vasil'chuk, Yu. Vasil'chuk, 2010a, b, c]. In the ice of body 4 (Fig. 12) a maximal observed concentration of pollen is 1300 piece/l (sample YuV05-Bov/49). Local pollen prevails (*Cyperaceae, Polygonum sp., Polemoniaceae, Liliaceae, Sparganium*) in the pollen spectrum.

The content of redeposited Pre-Quaternary components does not exceed 9%. Minimal concentration is 5 piece/l (sample YuV05-Bov/46, fine pollen *Cyperaceae* and *Salix* only).

Pollen concentration does not depend on the concentration of clay particles. A high concentration was found with the presence of clay particles (YuV05-Bov/49), as well as without (sample YuV05-Bov/53). In massive ice body 4 the content of redeposited pollen and spores varies from 2 to 9%. This is close to pollen characteristics of modern lacustrine and coastal floodplain sediments in the area. Numerous remains of monocelled green and diatom algae were also found in the ice.

This probably specifies the existence of a fresh-water reservoir, most likely as benthonic silt waters of a large lake or a fresh bay frozen through, or at the bottom.

The general pollen characteristic of massive ice layers of non-glacier origin is the presence

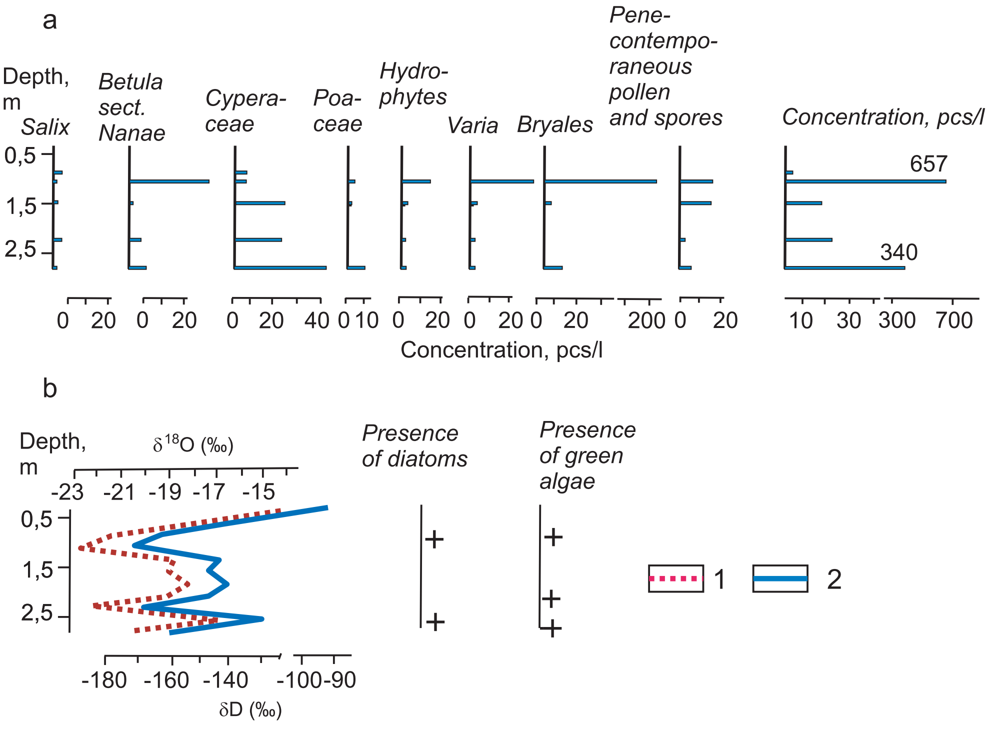

Fig. 12. Pollen diagram of massive ice body 4 at: (a) the third terrace, Bovanenkovo gas field; and (b) isotope plot in the same samples: 1 – $\delta^{18}O$, 2 – δD [A. Vasil'chuk, Yu. Vasil'chuk, 2010a].

of green moss, and often horsetail spores, which are present in buried deposits of pack or ground ice.

DISCUSSION

The massive ices of the Bovanenkovo gas-condensate field are syngenetic and genetically heterogeneous, such as: segregated, any infiltrated-segregated, any lake bottom congelation ice etc. [Vasil'chuk, 2011a]. A possible cause of the horizontal structure of ground ice lenses is burial at the bottom of lake ice. As example is the tabular ice exposure at the bank of the Nedarmato Lake [Parmuzin, Sukhodol'sky, 1982]. The layers of massive ice occur in accordance with host sediments. The thickness of ice layers of various colours and their bedding are similar to the lamination of the overlapping sediments. These facts, together with the shape of the ice lens and thin peaty laminas at the contacts of ice layers, led us to conclude that ice is made up of separate facies of lagoon sediments, which are composed on the third terrace in the region. In coastal areas, as a result of draining, the sea beach began freezing with the active segregation of the ice. Under the cliffs at that time floating sea ice could be buried. Segregation processes in contact with buried tabular ice could be formed in direct contact segregation ice. So paragenesis of buried and segregated massive ice could be formed. Relatively thin layers of segregated ice formed on braids and shallow beaches. However, freezing was differentiated along the coast: some massifs froze quickly; others over a long time; while some thawed. This led to the formation of closed talik, water-saturated areas, typical of injection ice. Paragenesis of injection and segregation ice could be formed along the periphery of the injection massive ice.

However, we suppose that the formation of horizontally stratified ice bodies took place by the interment of bottom ice. This phenomenon could be widespread in shallow lagoons (with a depth of 1–2 m), or deltas in the period from 30–35 ka BP to 10–15 ka BP. The modern analogue is the left coast of Ob Bay, where we observed bottom ice in the shallow lakes in the Northern Yamal Peninsula in a cold summer (in August–September), and also a modern polygonal network in the banks and bottom of the lakes. This revealed that underlake talik is absent or depthless in some lakes. More severe summer conditions, with average annual temperatures of 5–6 °C lower than the present-day, are distinctive for LGM in Yamal [A. Vasil'chuk, 2007], so segregation ice formed beneath shallow lake bottoms in winter do not keep pace to thaw in the sub-lake active layer during the following summer. Another hydrologic feature of Yamal is common aufeis fields along river valleys. Aufeis is a sheet-like mass of layered ice that forms by the upwelling of river water behind ice dams, or by ground-water discharge. Successive ice layers can lead to aufeis accumulations that are several metres thick. In LGM conditions aufeis could also be buried. Waller et al. [2009] show areas that include dykes and sills of intrusive ice, massive segregated intrusive ice, ice wedges and composite wedges, segregated ice, pool ice.

Pollen and spores in massive ice were studied in the Mackenzie River Delta [Fujino et al., 1988], and a high concentration of cretaceous pollen and spores was found in silty layers in the ice. Quaternary pollen in the silty layers showed sporadic far-transported pollen of a pine and a fir tree. In the pure ice, pollen spectra consisted of regional components. We suppose that the origin of the massive ice is similar to the origin of massive ice in Bovanenkovo [A. Vasil'chuk, Yu. Vasil'chuk, 2010 a, b, c]. The difference between pollen spectra is possibly caused by a variation in seawater participation in the case of the Mackenzie River Delta. The application of palynologic methods, together with isotope analysis, could be relevant to the study of genesis of massive ice and water sources for ice formation.

Two new categories could be entered into the systematization of massive ice, such as: homogeneous and heterogeneous ice deposits. The structure and particular properties of homogeneous massive ice are similar to all parts of tabular ice complex. Heterogeneous massive ice complexes consist of two or more homogeneous massive ice bodies, or combinations of homogeneous massive ice bodies, whose structure and properties are different [Vasil'chuk, 2011a, 2012, 2014].

CONCLUSIONS

1. Stable isotope data show that massive ice in the permafrost sediment of the Bovanenkovo gas field is heterogeneous, and has been formed syngenetically as segregated or segregated-infiltrated ice in freezing, water-saturated, unconsolidated deposits (possibly in an underlake talik) about 25–20 ka BP.

2. The massive ice of the Bovanenkovo gas-condensate field is syngenetic and genetically heterogeneous, such as: segregated, any infiltrated-segregated, any lake bottom congelation ice etc. Some massive ice could also be formed in underwater conditions in the zone of fresh and supercooled saline waters. These three mechanisms of ice formation occurred at different stages in massive ice formation. Significant volumetric pressure led to local injections, forming vertical ice veins above massive ice or small rods and dykes, penetrating horizontal bodies of massive ice.

3. One of the factors of massive ice formation under the bottom of lakes or lake-bog complexes could be the ingression of cold (with the temperature essentially lower than –2 °C) seawater on a surface of coastal flood plain with numerous lakes (present third terrace), that led to the sharp cooling of water and ground suspension, freezing and intensive ice segregation, with the formation of extensive ice layers under the large but shallow lakes. As a result, syngenetic segregated (infiltrated-segregated) massive ice was formed.

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REFERENCES

1. Andreev A.A., Nikolaev V.I., Bolshijanov D.J., Petrov V.N. (1997). Results of pollen study of ice core of Vavilov cap, Severnaya Zemlya // Data of glaciologic studies (Materialys of glaciologicheskikh issledovani), vol. 83. pp. 112–120 (In Russian).

2. Baulin V.V., Vasil'chuk Yu.K., Dubikov G.I., Kritsuk L.N., Trofimov V.T. (1989). Massive ground ice / Ershov E.D. (ed.) Geocryology the USSR. Western Siberia. Moscow: Nedra. pp. 103–110 (In Russian).

3. Baulin V.V. (ed). (1996). Permafrost and development of Bovanenkovo Gasfield. Tyumen: Publ. Institute of development of the North, Siberian Branch of the Russian Academy of Sciences. 240 p. (In Russian).

4. Bourgeois J.C. (2000). Seasonal and interannual pollen variability in snow layers of arctic ice caps // Review of Palaeobotany and Palynology, vol. 108, iss. 1–2, pp. 17–36.

5. Cardyn R., Clark I.D., Lacelle D., Lauriol B., Zdanowicz C., Calmels F. (2007). Molar Gas ratios of air entrapped in ice: A new tool to determine the origin of relict massive ground ice bodies in permafrost // Quaternary Research, vol. 68, iss. 2, pp. 239–248.

6. Chuvilin E.M. (ed.). (2007). Structure and properties of permafrost of southern part of Bovanenkovo Gasfield. Moscow. GEOS Publ. House. 137 p. (In Russian).

7. Dallimore S.R., Wolfe S.A. (1988). Massive ground ice associated with glaciofluvial sediments, Richards Island. N.W.T. Canada // Proceedings of the Fifth International Conference on Permafrost. Trondheim. Norway. Tapir Publishers. pp. 132–138.

8. Danilov I.D., Yershov E.D. (1989). Former glaciation and permafrost in Asia // Polar Geography, vol. 13, iss. 2, pp. 92–103.

9. Dubikov G.I. (2002). Composition and cryogenic structure of the permafrost strata of Western Siberia. Moscow, Geos Publ. House. 246 p. (In Russian).

10. Fotiev S.M. (2012). Chemical composition and genesis of water that formed the repeatedly injected massive ice beds on the area of the Bovanenkovo deposit // Earth's Cryosphere, vol. 16, N 3, pp. 3–28 (In Russian).

11. Forman S.L., Ingolfsson Ó.O., Gataullin V., Manley W., Lokrantz H. (2002). Late Quaternary stratigraphy, glacial limits and paleoenvironments of the Maresale area, western Yamal Peninsula, Russia // Quaternary Research, vol. 57, pp. 355–370.

12. Fujino K., Horiguchi K., Shinbori M., Kato K. (1983). Analysis and characteristics of cores from a massive ice body in Mackenzie delta, N.W.T., Canada // Proceedings of the Fourth International Conference on Permafrost. Washington: National Academy Press D.C. pp. 316–321.

13. Fujino K., Sato S., Matsuda K., Sasa G., Shimizu O., Kato K. (1988). Characteristics of the massive ground ice body in the western Canadian Arctic // Proceedings of the Fifth International Conference on Permafrost. Trondheim. Norway. Tapir Publishers. pp. 143–146.

14. Gowan R.J., Dallimore S.R. (1990). Ground ice associated with granular deposits in the Tuktoyaktuk Coastlands area, N.W.T. // Proceedings of the Fifth Canadian Permafrost Conference. Collection Nordicana, N 54, pp. 283–290.

15. Kaplyanskaya F.A., Tarnogradsky V.D. (1986). Remnants of the Pleistocene ice sheets in the permafrost zone as an object for paleoglaciological research // Polar Geography and Geology, vol. 10, pp. 65–72.

16. Khimenkov A.N., Brushkov A.V. (2006). Introduction to the structural geocryology. Moscow. Nauka Publ. House. 279 p. (In Russian).

17. Knight P.G., Patterson C.J., Waller R.I., Jones A.P., Robinson Z.P. (2000). Preservation of basal-ice sediment texture in ice-sheet moraines // Quaternary Science Reviews, vol. 19, iss. 13, pp. 1255–1258.

18. Kondakov V.V., Yazynin O.M., Grachev J.M. (2001). Massive ices of Yamal Peninsula // Proceedings of the Second Russian conference of geocryology. Vol. 1, part 2. Sedimentological geocryology. Engineering geocryology. Moscow State University. pp. 214–218 (In Russian).

19. Lacelle D., Lauriol B., Clark I.D., Cardyn R., Zdanowicz C.H. (2007). Nature and origin of a Pleistocene-age massive ground-ice body exposed in the Chapman Lake moraine complex, central Yukon Territory // Quaternary Research, vol. 68, pp. 249–260.

20. Lein A.Yu., Savvichev A.S., Miller Yu M., Pimenov N.V., Leibman M.O. (2003). Isotopic-biogeochemical peculiarities of tabular ground ice of Yugorsky and Yamal Peninsulas // Proceedings of the Eighth International Conference on Permafrost, vol. 2, pp. 661–666.

20. Mackay J.R. (1971). The origin of massive icy beds in permafrost, western arctic coast, Canada // Canadian Journal of Earth Sciences, vol. 8, pp. 397–421.

21. Mackay J.R. (1983). Oxygen isotope variations in permafrost. Tuktoyaktuk Peninsula area. N.W.T. // Current Research, Part B, Geological Survey of Canada, paper 83-1B, pp. 67–74.

22. Mackay J.R. (1989). Massive ground ice: some field criteria for the identification of ice types // Current Research, Part G, Geological Survey of Canada, paper 89-1G, pp. 5–11.

23. Mackay J.R., Dallimore S.R. (1992). Massive ice of the Tuktoyaktuk area, western Arctic coast, Canada // Canadian Journal of Earth Sciences, vol. 29, N 6, pp. 1235–1249.

24. Mangerud J., Gosse J., Matiouchkov A., Dolvik T. (2008). Glaciers in the Polar Urals, Russia, were not much larger during the Last Global Glacial Maximum than today // Quaternary Science Reviews, vol. 27, pp. 1047–1057.

25. Michel F.A. (1998). The relationship of massive ground ice and the Late Pleistocene history of Northwest Siberia // Quaternary International, vol. 45/46, pp. 43–48.

26. Murton J.B. (2005). Ground-ice stratigraphy and formation at North Head, Tuktoyaktuk Coastlands, western Arctic Canada: a product6 of glacier-permafrost interactions // Permafrost and Periglacial Processes, vol. 16, N 1, pp. 31–50.

27. Murton J.B. (2009). Stratigraphy and palaeoenvironments of Richards Island and the eastern Beaufort continental shelf during the Last glacial-interglacial cycle // Permafrost and Periglacial Processes, vol. 20, N 2, pp. 107–125.

28. Murton J.B., Whiteman C.A., Waller R.I., Pollard W., Clark I.D., Dallimore S.R. (2005). Basal ice facies and supraglacial melt-out till of the Laurentide Ice Sheet, Tuktoyaktuk Coastlands, western Arctic Canada // Quaternary Science Reviews, vol. 24, pp. 681–708.

29. Parmuzin S.Yu., Sukhodol'skiy S.E. (1982). Tabular massive ice of the middle part of Yamal Peninsula and its role in relief formation / Popov A.I. (ed.) Tabular massive ice of permafrost region. Yakutsk. Permafrost Institute of Siberian Branch of USSR Academy of Sciences. pp. 51–61 (In Russian).

30. Pollard W.H., Bell T. (1998). Massive ice formation in the Eureka sound lowlands: a landscape model // Proceedings of the Seventh International Conference on Permafrost. Yellowknife. Canada, N 57, pp. 903–908.

31. Pollard W.H., Dallimore S.R. (1988). Petrographic characteristics of massive ground ice, Yukon Coastal Plain. Canada // Proceedings of the Fifth International Conference on Permafrost. Trondheim. Norway. Tapir Publishers. pp. 224–228.

32. Raab A., Melles M., Berger G.W., Hagedorn B., Hubberten H.-W. (2003). Non-glacial paleoenvironments and the extent of Weichselian ice sheets on Severnaya Zemlya, Russian High Arctic // Quaternary Science Reviews, vol. 22, pp. 2267–2283.

33. Rampton V.N. (1988). Origin of massive ground ice on Tuktoyaktuk Peninsula, Northwest Territories, Canada // Proceedings of the Fifth International Conference on Permafrost. Trondheim. Norway. Tapir Publishers. pp. 850–855.

34. Rampton V.N., Mackay J.R. (1971). Massive ice and icy sediments throughout the Tuktoyaktuk Peninsula. Richards Island and nearby areas, District of Mackenzie // Geological Survey of Canada, Paper 71–21. 16 p.

35. Saks V.N. (1953). Quaternary Ice Age in Soviet Arctic Moscow-Leningrad, Trudy NIIGA 77. 1-627 (In Russian).

36. Sannikov G.S. (2012). Cartometric research of thermokarst lakes within the Bovanenkovo gas field territory, Yamal peninsula // Earth's Cryosphere, vol. 16, N 2, pp. 30–37 (In Russian).

37. Shpolyanskaya N.A. (1989). The Possibility of Freezing of Bottom Deposits in the Arctic Sea // Moscow University Bulletin, ser. 5, Geography, N 5, pp. 72–78 (In Russian).

38. Shpolyankaya N.A. (1999). Cryogenic Structure of Dislocated Deposits with Massive Ice Beds as Indicator of Their Genesis // Earth's Cryosphere, vol. 3, N 4, pp. 61–70 (In Russian).

39. Shpolyanskaya N.A. (2003). Massive ground ice as a basis for paleogeographic reconstruction // Proceedings of the Eighth International Conference on Permafrost, vol. 2, pp. 1045–1050.

40. Shpolyanskaya N.A., Streletskaya I.D., Surkov A.V. (2006). Cryolithogenesis in Arctic shelf (recent and relict) // Earth's Cryosphere, vol. 10, N 3, pp. 49–60 (In Russian).

41. Solomatin V.I., Konyahin M.A., Nikolaev V.I., Mikhalev D.V. (1993). Deposition and structure of massive ice bodies in Yamal Peninsula // Data of glaciological studies (Materialy glaciologicheskikh issledovaniy), vol. 77, pp. 139–149 (In Russian).

42. Solomatin V.I. (2013). Physics and geography of underground glaciaton. Novosibirsk. Academic Publishing House "Geo". 246 p. (In Russian).

43. Streletskaya I.D., Vasiliev A.A., Obogov G.E., Matykhin A.G. (2013). Isotope composition of ground ice of the Western Yamal Peninsula (Marre Sale) // Ice and Snow. N 2 (122). pp. 83–92. (In Russian).

44. Svendsen J.I., Alexanderson H., Astakhov V.I., Demidov I., Dowdeswell J.A., Funder S., Gataullin V., Henriksen M., Hjort C., Houmark-Nielsen M., Hubberten H.W., IngÓlfsson Jakobsson M., KjØr, K.H., Larsen E., Lunkka J.P., LysÅ A., Mangerud J., Matioushkov A., Murray A., Möller P., Niessen F., Nikolskaya O., Polyak L., Saarnisto M., Siegert C., Siegert M.J., Spielhagen R.F., Stein R. (2004). Late Quaternary ice sheet history of northern Eurasia // Quaternary Science Reviews, vol. 23, N 11–13, pp. 1229–1271.

45. Tarasov A.M. (1990). An example of application of ground ice oxygen isotope analysis to geocryologic engineering surveys // Methods of geocryology engineering surveys. Moscow. pp. 118–133 (In Russian).

46. Vasil'chuk A.C. (2005). Pollen spectra formation features in permafrost areas of Russia. Moscow. Moscow State University Press. 245 p. (In Russian).

47. Vasil'chuk A.C. (2007). Palynology and chronology of polygonal ice wedge complexes in Russian permafrost area Moscow. Moscow State University Press. 488 p. (In Russian).

48. Vasil'chuk A.C., Vasil'chuk Yu.K. (2010a). Local pollen spectra as a new criterion for nonglacial origin of massive ice // Transactions (Doclady) of Russian Academy of Scienses, Earth Sciences, vol. 433, part 1, pp. 985–990.

49. Vasil'chuk A.C., Vasil'chuk Yu.K. (2010b). Palynological indication of nonglacier origin of massive ice // Engineering Geology, N 3, pp. 24–38 (In Russian).

50. Vasil'chuk A.C., Vasil'chuk Yu.K. (2010c). Comparison of pollen spectra of massive and glacial ices for cryogenetic indication // Earth's Cryosphere, vol. 14, N 3, pp. 15–28 (In Russian).

51. Vasil'chuk Yu.K. (1992). Oxygen Isotope composition of ground Ice (Application to paleogeocryological reconstruction). Department of theoretical problems the Russian Academy of Sciences. Moscow State University, PNIIIS. In 2 volumes. Vol. 1. – 420 p. Vol. 2 – 264 p. (In Russian).

52. Vasil'chuk Yu.K. (2006a). Ice wedge ice: Heterocyclity, Heterogeneity, Heterochroneity. Moscow: Moscow State University Press. 404 p. (In Russian).

53. Vasil'chuk Yu.K. (2006b). Tabular massive ice / Cryosphere of oil and gas condensate fields of Yamal Peninsula. Vol. 1. Kharasavey Gas condensate field. Tumen–St.Petersburg. Nedra. pp. 160–193 (In Russian).

54. Vasil'chuk Yu.K. (2010). Massive ice of Bovanenkovo gas-condensate field (The Central Yamal Peninsula) // Engineering Geology, N 3, pp. 50–67 (In Russian).

55. Vasil'chuk Yu.K. (2011a). Homogeneous and Heterogeneous massive ice in Permafrost // Earth's Cryosphere, vol. 15, N 1, pp. 3–20 (In Russian).

56. Vasil'chuk Yu.K. (2011b). Experimental study of isotopic fractionation during congelation ice formation // Earth's Cryosphere, vol. 15, N 2, pp. 55–60 (In Russian).

57. Vasil´chuk Yu.K. (2012). Isotope Ratios in the Environment. Part 2. Stable isotope geochemistry of massive ice. 2 Vols. Moscow: Moscow University Press, Vol. I. 472 pp. (In Russian).

58. Vasil´chuk Yu.K. (2014). Isotope Ratios in the Environment. Part 2. Stable isotope geochemistry of massive ice. 2 Vols. Moscow: Moscow University Press, Vol. II. 244 pp. (In Russian).

59. Vasil'chuk Yu.K., Trofimov V.T. (1988). Oxygen isotope variations in ice-wedge and massive ice // Proceedings of the Fifth International Conference on Permafrost. Trondheim. Norway. Tapir Publishers. pp. 489–492.

60. Vasil'chuk Yu.K., van der Plicht J., Jungner H., Sonninen E., Vasil'chuk A.C. (2000). First direct dating of Late Pleistocene ice-wedges by AMS // Earth and Planetary Science Letters, vol. 179, N 2, pp. 237–242.

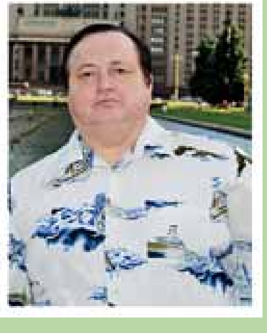
61. Vasil'chuk Yu.K., Vasil'chuk A.C. (2010). Validity of the youngest radiocarbon dates in syncryogenic permafrost // Earth's Cryosphere, vol. 14, N 4, pp. 3–16 (In Russian).

62. Vasil'chuk Yu.K., Vasil'chuk A.C., Budantseva N.A., Chizhova Ju.N., Papesch W., Podborny Ye.Ye., Sulerzhitsky L.D. (2009). Oxygen isotope and deuterium Indication of the origin and ^{14}C age of the massive ice, Bovanenkovo, Central Yamal Peninsula // Transactions (Doclady) of Russian Academy of Scienses, Earth Sciences, vol. 429, N. 8, pp. 1326–1332.

63. Velikotsky M.A. (1987). Dislocation and massive ice in the Quatermary deposits of the Yamal Peninsula / Cryogenic Processes. Moscow: Moscow State University Press. pp. 48–60 (In Russian).

64. Waller R.I., Murton J.B., Knight P.G. (2009). Basal glacier ice and massive ground ice: different scientists, same science? // Periglacial and paraglacial processes and environments. J. Knight, S. Harrison (eds.). Geological Society, London, Special Publications, vol. 320, pp. 57–69.

65. Zhestkova T.N., Shur Yu.L. (1978). On genesis of tabular massive ice // The Bulletin of the Moscow State University. Geology Series, N. 3, pp. 35–42 (In Russian).



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BIOLOGICALLY ACTIVE UV-RADIATION AND UV-RESOURCES IN MOSCOW (1999–2013)

ABSTRACT. The paper contains the analysis of long-term measurements of erythemally weighted UV-radiation (Q_{er}) at the Meteorological Observatory of Moscow State University over the 1999-2013 period. Main features of seasonal variability of Q_{er} as well as the Q_{er} dependence on different geophysical parameters are studied. We showed that the average annual Q_{er} attenuation due to cloudiness, total ozone content, and aerosols, is about 29, 30%, and 7%, respectively. The maximal loss of Q_{er} due to cloudiness is observed in November (48%), while ozone-dependent attenuation is maximal in February–March (44%). We used the original technique to assess the UV-radiation impact on human health in Moscow. Specifically, we have identified the UV potential for the erythema formation and synthesis of vitamin D in humans with different skin types. The UV-deficiency conditions are observed for all considered skin types (1–4) during all days from November to February. The probability of the UV-optimum conditions for different skin types was assessed. It was shown, for example, that for skin type 2, the UV-optimum conditions are dominant from March to April and from September to October (maximum in September – 60%). We have also identified the periods with UV-excess conditions. For skin type 2, these conditions may exist from April to August.

KEY WORDS: UV-radiation, erythemal dose, skin type, vitamin D, UV-resources, Moscow.

INTRODUCTION

UV-radiation at the Earth's surface has a significant impact on human health. On the one hand, the excess exposure to high doses of biologically-active UV-radiation causes human skin erythema[1]. It has been established that frequent exposure of humans to excessive doses of erythemally weighted UV-radiation is a risk factor for skin cancer. On the other hand, 90% of the required level of vitamin D in human body is formed under the influence of UV-radiation [Holick, Jenkins, 2003]. Vitamin D is necessary for the prevention of rickets; moreover, its optimal level decreases the risk of death from different kinds of skin cancer [Reichrath et al., 2008]. However, there are no places on the Earth with the optimal year-around UV-radiation conditions [McKenzie et al., 2009], i.e., the conditions that do not pose the risk of erythema formation in summer and deficiency of vitamin D production in human body induced by UV-radiation in winter. Therefore, it is important to study the UV-radiation regime in Moscow, in a major metropolis with 12 million inhabitants.

Monitoring of UV-radiation is conducted by means of ground- and satellite-based methods [Bais, Lubin, 2007]. The ground-based measurements have the least errors.

1 Erythema (from the Greek erythros [έρυθρός], meaning red) is redness of the skin or mucous membranes, caused by hyperemia of superficial capillaries due to inflammation.

However in Russia, the UV-radiation measurements, besides Moscow, are only organized at few stations: in Kislovodsk, Obninsk, Yakutsk, Tomsk and some other cities.

In photobiology, the term "action spectrum" is used to evaluate the effective dose [Vecchia et al., 2007]. The erythemal action spectrum adopted by the International Commission on Illumination [Mutzhas et al., 1993] defines the relative contribution of different wavelengths in the formation of erythema and has a maximum efficiency in the UV-B range. The erythemally weighted UV-radiation[2] (Q_{er}) is calculated by the expression:

$$Q_{er} = \int_{280}^{400} Q_\lambda E_\lambda d\lambda, \quad (1)$$

where Q_λ – is the spectral UV-radiation in W/m^{2}nm; E_λ – is the erythemal action spectrum.

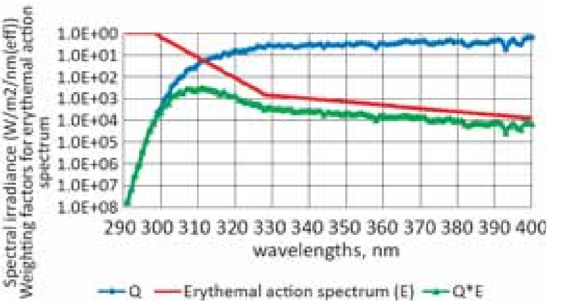

Fig. 1. Spectral distribution of UV radiation (Wm-2nm) (*Q*), erythemal action spectrum (*E*), and UV radiation weighted on erythemal action spectrum (Q_{er}) Wm-2nm$_{eff}$). Model calculation (solar zenith angle 60 degree, total ozone content = 300 DU), clear sky.

An example of the Q_{er} spectral distribution under certain atmospheric conditions is presented in Figure 1. It clearly shows that the maximal Q_{er} efficiency is associated with the UV-B region of the spectrum, where absorption by ozone is significant.

Often, for convenience, the term "UV-index" (*UVI*) is used. The UV-index is dimensionless quantity and equal to the Q_{er} (in W/m^2 (eff)) divided by 0, 025 W/m^2 (eff). Usually, at mid-latitudes, *UVI* varies from 0 to 10.

Estimating the vitamin D weighted UV-radiation (Q_{vitD}), as well as the Q_{er} calculation, can be accomplished by assessing the spectrum of the previtamin D synthesis [Engelsen et al., 2005; Fioletov et al., 2010; Kazantzidis et al., 2009; Krzys'cin et al., 2011; Webb, Engelsen, 2006]. This action spectrum was adopted by the International Commission on Illumination and has the maximal effectiveness in the UV-B spectrum [Bouillon et al., 2006]. At the same time, according to [McKenzie et al., 2009], it has several drawbacks. In particular, it was obtained by the results of the experiment in 1982 with a monochromatic source of UV-radiation with a relatively coarse spectral resolution of 6–10 nm [Olds et al., 2010]. In the adopted action spectrum for vitamin D [Bouillon et al., 2006], an additional error is introduced by interpolation of the obtained experimental spectrum of wavelength 315 nm to 330 nm. At the same time, biologists and doctors in their experiments often use the erythemally weighted UV-radiation as a control during measurement of vitamin D [Holick, Jenkins, 2003], which complicates the assessment thresholds. Therefore, for further evaluation of the contribution of UV-radiation in the vitamin D production in human skin, we will use the quantitative ratio to the Q_{er} values as suggested in [Holick, Jenkins, 2003].

Until recently, analysis of patterns of change of erythemally weighted UV-radiation and vitamin D weighted UV-radiation was considered separately [Engelsen et al., 2005; Fioletov et al., 2004; Fioletov et al., 2010; Kazantzidis et al., 2009; Krzys'cin et al., 2011; Webb, Engelsen, 2006]. However, in order to characterize the complex action of UV-radiation on humans, it is important to have their simultaneous estimation. Earlier, in the evaluation of UV-radiation effects on human health, we suggested the use of

[2] Erythemally weighted UV-radiation is measured in W/m^2 (eff), where the "eff" denotes the impact of weighting by the erythemal action spectrum.

the term "UV-resource", that equals to the ratio of erythemally weighted UV-radiation and vitamin D weighted UV-radiation from the point of view of their effect on human health [Chubarova, Zhdanova, 2013; Chubarova, Zhdanova, 2012]. Thus, in these studies, the UV-resources in Russia [Chubarova, Zhdanova, 2012] and Northern Eurasia [Chubarova, Zhdanova, 2013] were evaluated using the Tropospheric Ultraviolet and Visible (TUV) Radiation Model and satellite data of the basic geophysical parameters as input. However, satellite measurements of cloudiness, albedo, and aerosols have significant uncertainties. Possible errors are linked with the separation of snow and cloud cover, problems with reliable aerosol retrievals in winter, etc. In addition, satellite measurements do not allow consideration of the daily variations of many important atmospheric characteristics. In this connection, we used ground-based measurements to evaluate the UV-resources in Moscow, which are the most accurate and reliable.

The main objectives of this work is the analysis of the erythemally weighted UV-radiation using the experimental data over 15 years of measurements during 1999–2013 at the Meteorological Observatory of Moscow State University (MO MSU), identification of the most important geophysical factors affecting its variations, as well as analysis of the UV-resources in Moscow.

MATERIALS AND METHODS

Continuous measurements of erythemally weighted UV-radiation by broadband devices with a spectral sensitivity close to the erythemal action spectrum have been conducted by MO MSU since February 1999 [Chubarova, 2002]. Registration and analysis of the measurements made with one-minute time increments was done with the help of the specially developed software SUN [Rosental et al., 1999]. Through 2012 inclusively, UVB-1 YES pyranometers were used. Since the beginning of 2013, the measurements were done by a KIPP & Zonen UV-SET pyranometer. The main sources of measurement errors with these devices are the differences between the spectral curve of the device and the erythemal response curve, as well as deviations from the cosine law for UVB-1 instruments. Therefore, according to the WMO (World Meteorological Organization) recommendations and methods developed at MO MSU [Chubarova, 2002], necessary corrections were made in the dataset. For quality control, comparison of the measurements recorded by the UVB-1 devices with the measurements by the control UVB-1 YES pyranometer are done annually; the UVB-1 YES itself is calibrated by the spectroradiometer referenced to the international etalons. In 2005, 2008, and 2011 the instrument calibration was performed against the European reference spectroradiometer Bentham DTM300 at the Medical University of Innsbruck (Austria). Also, the existence of residual temperature dependence of the UVB-1 recording devices of the old series was discovered. This factor led to an underestimation of the radiation measurements in the cold season, because temperature stabilization at 45°C was not provided at low air temperatures. In this regard, additional studies were accomplished, which allowed us to make the corresponding correction taking into account the dependence between the device temperature and ambient temperature [Chubarova et al., 2013]. Homogeneity of erythemally weighted UV radiation measurements in 2013 during the transition to the UV-SET KIPP & Zonen pyranometers was checked and guaranteed by multiple comparisons with the control UVB-1 YES pyranometer and reference to the measurements for the previous observation period.

MO MSU adopted the following scheme for the generation of the electronic archives of erythemally weighted UV-radiation. Hourly Q_{er}, obtained using a constant conversion factor at the solar angle of 30° and the total ozone content (TOC) of 300 DU formed initial the Version 1 UV database. The Version 2 UV database included the spectral-corrected data from the Version 1 database. For the UVB-1 devices, the cosine errors were also considered in the Version 2 UV database [Chubarova, 2002]. Finally, the Version 3 UV database includes in addition temperature-corrected data (only for the UVB-1 YES devices) [Chubarova et al., 2013]. In the present study, we used the Version 3 UV database. The measurement error of erythemally weighted UV-radiation is ± 5% [Chubarova, 2002].

To assess the impact of the main atmospheric parameters on Q_{er}, we used TOC data received by the satellite instruments TOMS and OMI and the aerosol optical thickness at a wavelength of 380 nm (AOT_{380}) using AERONET measurements by MO MSU [Chubarova et al., 2011]. According to the method presented in [Chubarova, 2008], we calculated the effective cloud Q_{er} transmittance (*CQ*), taking into account the frequency of cloud amount at different layers and additional impact of surface albedo on the *CQ* value. Surface albedo, in turn, was estimated according to [Chubarova, 2008] using the following equation:

$$A = w_a A_1 + (1 - w_a) A_2, \quad (2)$$

where A_1 is snow albedo in the UV-spectrum, A_2 is grass albedo in the UV-spectrum, and w_a is the fraction of snow cover.

The average monthly Q_{er} loss due to AOT_{380} was obtained as the relative difference between Q_{er} calculated considering the average monthly AOT_{380} values and Q_{er} at $AOT_{380} = 0$. The TOC-dependent Q_{er} loss was calculated as the relative difference between the model Q_{er} values obtained at the average monthly TOC and the minimal monthly TOC for 1979 and 2003.

In order to evaluate the effect of UV-radiation on human health, it is necessary to know the threshold (minimal) dose of UV-radiation, which may lead to the synthesis of vitamin D and erythema.

Literature sources widely use the term "the minimal erythemal dose (*MED*)" that represents the minimal dose of erythemally weighted UV-radiation needed for appearance of human skin redness. According to the international Fitzpatrick classification [Fitzpatrick, 1988], several skin types are identified based on the *MED* values (Fig. 2). The Fitzpatrick scale represents the modernized Von Luschan skin types scale. The Von Luschan scale determines the geographical distribution of people with different skin color. Most common skin types on the territory of Russia are 1, 2, and 3 according to the Fitzpatrick scale. Therefore, in this study, we estimated the effect of UV-radiation on people with skin types 1, 2, and 3 on the Fitzpatrick scale. In addition, we also discussed skin type 4 that is typical of people living at more southern latitudes. Selected skin types correspond to the following *MED* values: type 1 – 200 J/m^2_{eff}, type 2 – 250 J/m^2_{eff}, type 3 – 300 J/m^2_{eff}, and type 4 – 450 J/m^2_{eff}.

For the assessment of vitamin D threshold, it is necessary to account the open human body fraction that depends on air temperature and, to some extent, wind speed. Therefore, for calculating the open human body fraction

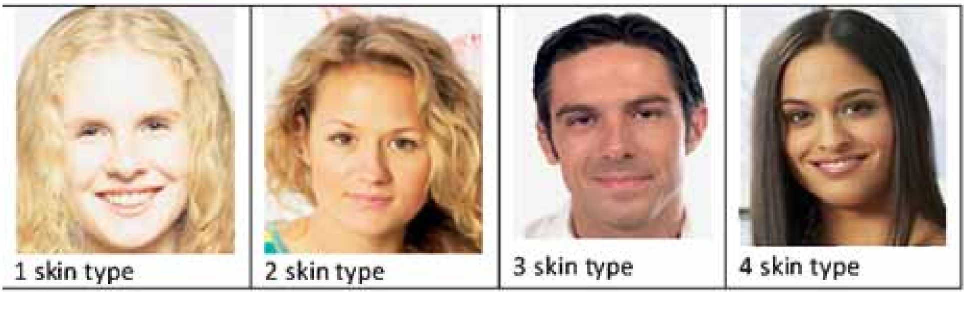

Fig. 2. The Fitzpatrick skin scale (from http://www.skincancer.org/).

the values of effective air temperature were also applied [Chubarova, Zhdanova, 2012; Chubarova, Zhdanova, 2013].

Thus, the threshold for the vitamin D synthesis (*P*) for human skin type *I* is:

$$P_i = \frac{0.06MEDi}{S_{(teff)}}, \tag{3}$$

where *S* is the open human body fraction; *MED* is the minimal erythemal dose.

The transition coefficient 0.06 was obtained according to medical recommendations, which state that the necessary moderate level of vitamin D is 600 IU (International Unit) and that the irradiation by one *MED* of the whole body results in the synthesis of 10, 000 IU of vitamin D. A more detailed description of the methodology used to assess UV-resources can be found in [Chubarova, Zhdanova, 2012; Chubarova, Zhdanova, 2013].

This work used the classification of the UV-resources presented in [Chubarova, Zhdanova, 2013]. The classification consists of several classes: 100% UV-deficiency (vitamin D is not synthesized during 24 hours), midday UV-deficiency (vitamin D is not synthesized at midday), UV-optimum (at midday, a necessary per day amount of vitamin D is synthesized, but erythema is not formed), and several classes of UV-excess identified according to the International Classification of *UVI*. For example, for a person with skin type 2, according to the recommendations, the hazardous conditions from UV-radiation occur at *UVI* greater than 3. For each skin type, different UV-excess thresholds exist. To account for these changes, the hourly *UVI* thresholds for skin type 2 ($j = 2$), according World Health Organization, are recalculated into the hourly erythemal doses for different skin types using a conversion: $UVI\ K_j$ 3600/40, where K_j accounts for skin type difference $K_j = MED_j / MED_{j=2}$ [Chubarova, Zhdanova, 2013].

For assessment of the UV-resources in Moscow, for each day in 1999–2013, the following parameters were selected: the maximal hourly erythemal doses (*ED*) that often correspond to the midday hours, and daily ***ED.*** For the vitamin D weighted threshold calculations, the daily data of air temperature at the height of 2 m and wind speed at the height of 10 m at 12 o'clock (winter Moscow time) were used. Thus, we have identified the categories of UV-resources for each day over 1999–2013.

RESULTS AND DISCUSSION

Variability of erythemally weighted radiation in Moscow

Let us consider the main characteristics of the monthly mean *ED* variability in Moscow over the 15 years of the observations since 1999. Fig. 3 shows pronounced seasonal changes in average and extreme (minimal and maximal) *ED* values. The annual variation is characterized by the maximum in July,

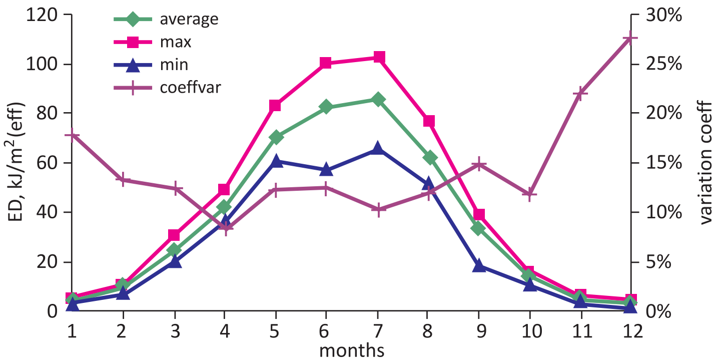

Fig. 3. Seasonal cycle of monthly mean, minimum, maximum ED values (kJ/m$^2_{eff}$), and variation coefficient (in %), Moscow (1999–2013).

Table 1. Statistical parameters of monthly mean ED values

Month	Mean, J/m2(eff)	Maximum, J/m2(eff)	Minimum, J/m2(eff)	Standard deviation, J/m2(eff)	Skewness	Kurtosis
1	113	321	19	55	0.91	0.58
2	293	956	37	155	1.09	1.46
3	791	2011	145	385	0.50	–0.51
4	1394	2846	194	579	0.06	–0.71
5	2278	4099	393	823	–0.17	–0.64
6	2770	4506	458	869	–0.44	–0.42
7	2783	4514	522	808	–0.47	–0.20
8	2003	3727	211	729	–0.20	–0.55
9	1130	2479	135	496	0.13	–0.46
10	422	1191	50	255	0.80	–0.09
11	136	513	25	85	1.23	1.37
12	70	176	15	34	0.85	0.20

while the minimum is observed in February. On average, the annual *ED* in Moscow is 433 kJ/m^2 eff. The bias of the ED maximum to July from June, when the highest solar angles are observed, is explained by slightly lower TOC and, hence, less *ED* absorption in July. It was possible to identify the cause of larger *ED* absorption in June than that in July by comparing the seasonal *ED* variability with the seasonal changes in long-wave UV-radiation (300–380 nm) that is practically not absorbed by ozone [Chubarova et al., 2014] and whose seasonal changes are characterized by maximum in June. The coefficient of variation of monthly *ED* (the ratio of the standard deviation to the mean) is the highest during the period from November to January (maximum – 28% in December) due

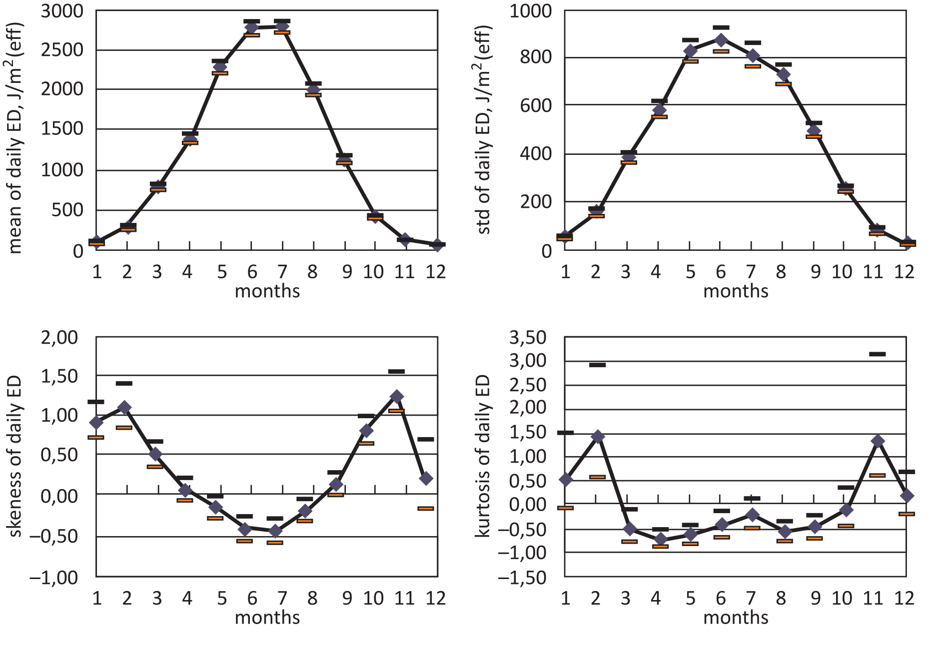

Fig. 4. Seasonal changes in *ED* daily mean, standard deviation, skewness, and kurtosis at a 95% significance level.

to the large variations in synoptic conditions. In the warm season (April to September), the coefficient of variation of monthly *ED* is 8–15% (minimum – 8% in April) due to the decrease of variations in cloudiness and TOC.

Let us discuss the main statistical parameters of the daily *ED* values. Table 1 presents the daily *ED* first four moments of the distribution for each month (average, standard deviation, excess, and skewness) as well as the minimal and maximal values. Fig. 4 shows their seasonal variation at a 95% significance level obtained by the bootstrap method [Efron, Tibshirani, 1993]. The method allows assessing significance levels independently from the type of distribution function. The kurtosis is statistically significant positive from November to February and negative from March to September. The skewness is characterized by significantly positive values from September to April and negative values from May to August. This character of variation is associated primarily with changes in cloud conditions throughout the year. Fig. 5 presents an example of the typical, of warm and cold periods, relative frequency of the average *ED* in January and July. In January, the distribution has right-positive skewness, while in July it is distinctly skewed to the left. This is largely due to the predominance of dense cloud cover in winter with occasional periods of clear sky weather conditions with relatively high *ED* values and predominance of cloudless conditions with high *ED* values during the warm season.

The hourly *ED* are presented in Fig. 6 that shows the isopleths of the mean (a) and standard deviation (b) as functions of solar time (hours) and months. The maximal average hourly *ED* corresponds to the noon time in July; the maximal standard deviation of the hourly *ED* correspond to June, which is associated with large variations of the TOC and cloudiness in June compared to July. Table 2 shows the absolute maximal hourly *ED* expressed in the units of *UVI*. The absolute maximum *UVI* (7.7) was recorded on June 27, 2004, which was associated with partial cloudiness that did not obstruct the solar disk and significantly increased the multiple scattering of UV-radiation, at TOC = 303 DU, and relatively low AOT_{340} = 0,25.

Fig. 7 shows the seasonal changes of various geophysical parameters that determine the level of Q_{er} at ground. Fig. 7b shows the Q_{er} losses due to these parameters. The main factor that determines the seasonal variation of Q_{er} is solar angle. At the same time, variations of other parameters are important for the analysis of the year-to-year changes in seasonal Q_{er} variability. The mean annual

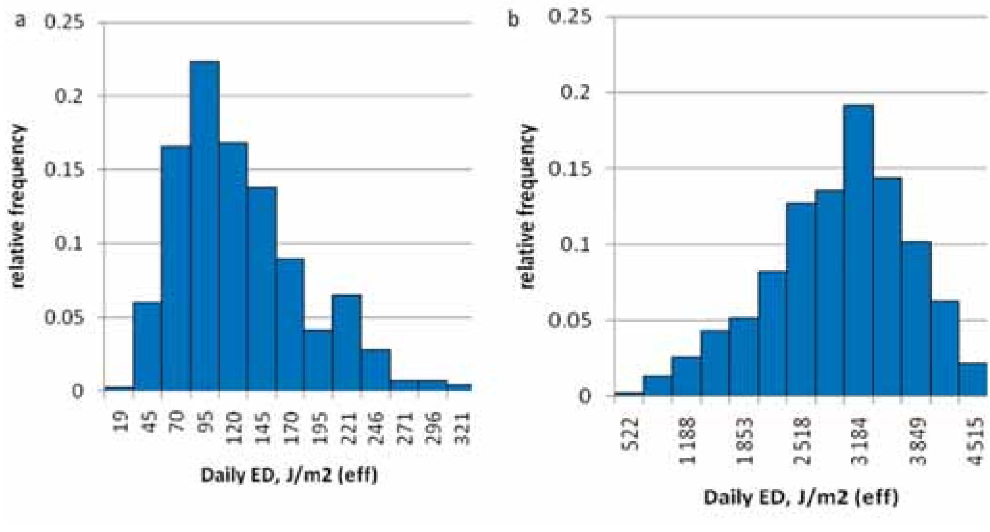

Fig. 5. Relative frequencies of daily mean ED values in January (a) and in July (b), 1999–2013.

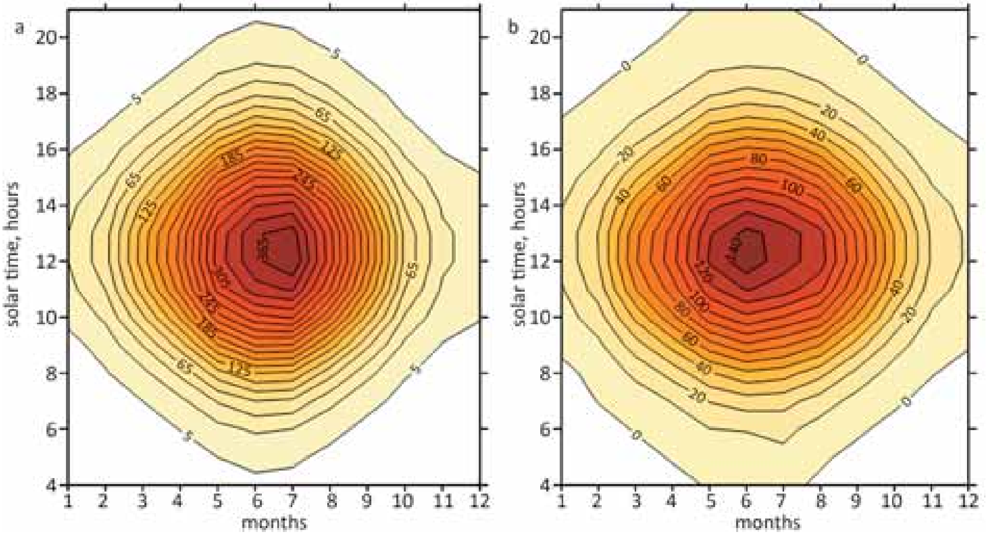

Fig. 6. a) hourly mean *ED* values (J/m^2_{eff}), b) std of hourly *ED* (J/m^2_{eff}) as a function of time and month.

attenuation of Q_{er} due to ozone absorption is 30%. The maximal ozone-dependent Q_{er} loss is observed in February and in March (44%), which agrees with the seasonal variation of the TOC (Fig. 7a). The mean attenuation of Q_{er} due to cloudiness is 29%, which is very close to ozone impact. They are the largest in November (48%) due to the increase in the cyclonic activity in the fall period and are the smallest in March and July (less than 20%). The Q_{er} *loss* due to the aerosol content compared with the loss associated with the molecular atmosphere is about 7% with the maximum (about 10%) in April, August and September (Fig. 7b) and depends on the character of seasonal changes of aerosol optical thickness [Chubarova et al., 2011] (Fig. 7a). Surface albedo may play an important role in the Q_{er} increase in conditions with snow cover. According to some assessments in [Zhdanova, Chubarova, 2011], the increase of Q_{er} in cloudless conditions due to reflection from the surface is 17% of the relative albedo that is equal to zero.

Table 2. Maximal UV indices (UVI)

Months	UVI
1	0.8
2	2.0
3	3.8
4	4.9
5	6.4
6	7.7
7	7.2
8	6.2
9	4.3
10	2.5
11	1.2
12	0.5

Seasonal losses of Q_{er} in Moscow due to the main factors over the considered period 1999–2013 and in 1999–2006, studied in [Chubarova, 2008], are qualitatively the same, but there are small quantitative differences. For example, the Q_{er} losses due to aerosol, over the shorter period of measurements, were larger (up to 12–15% in July–September) compared with that over the 1999–2013 observation period considered in this paper. This indicates a trend of purification of the atmosphere and a smaller aerosol effect in recent years. Due to changes in cloud cover in recent years, Q_{er} losses have increased in March, November, and December (3–6%) and decreased slightly in June (3%).

Fig. 7. a) Seasonal changes in total ozone (X), aerosol optical thickness at 380 nm (AOT_380), effective cloud transmission (CQ_A), sine of noon solar angle over 1999–2013 period. b) Relative seasonal changes in Q_{er} loss due to total ozone, effective cloud transmission and aerosol optical thickness.

The analysis of the UV resources in Moscow

Table 3 shows the categories of UV-resources for different skin types for each month, obtained for the monthly mean *ED* over 1999–2013 period.

The probability of occurrence of different categories of UV-resources for each month for the considered skin types was calculated using the following equation:

$$V_k = \frac{N_k}{N}, \quad (4)$$

where N_k is the number of days corresponding to certain categories of UV-resources $N = 15n$, n is the number of days in a month, and 15 is the number of years of measurements.

Fig. 8 shows the probability of categories of UV-resources for all months. Since each type of skin corresponds to a certain MED, the observed probabilities of the categories UV- resources for different skin types differ significantly.

In winter, UV-deficiency conditions are observed almost for all skin types. Only in

Table 3. Seasonal changes in the average UV-resources for different skin types

	Skin type 1	Skin type 2	Skin type 3	Skin type 4
Jan	100-% UV-deficiency	100-% UV-deficiency	100-% UV-deficiency	100-% UV-deficiency
Feb	Noon UV-deficiency	Noon UV-deficiency	Noon UV-deficiency	100-% UV-deficiency
Mar	UV-optimum	UV-optimum	Noon UV-deficiency	Noon UV-deficiency
Apr	Moderate UV-excess	UV-optimum	UV- optimum	UV- optimum
May	Moderate UV-excess	Moderate UV-excess	Moderate UV- excess	UV- optimum
Jun	High UV-excess	Moderate UV-excess	Moderate UV- excess	UV- optimum
Jul	High UV-excess	Moderate UV-excess	Moderate UV- excess	UV- optimum
Aug	Moderate UV-excess	Moderate UV-excess	Moderate UV- excess	UV- optimum
Sep	Moderate UV-excess	UV-optimum	UV- optimum	UV- optimum
Oct	UV-optimum	Noon UV-deficiency	Noon UV-deficiency	Noon UV-deficiency
Nov	Noon UV-deficiency	Noon UV-deficiency	100-% UV-deficiency	100-% UV-deficiency
Dec	100-% UV-deficiency	100-% UV-deficiency	100-% UV-deficiency	100-% UV-deficiency

February, there is some probability of the UV-optimum conditions for skin type 1. December is characterized by the 100% probability of UV-deficiency for all skin types.

Spring is a transition period from UV-deficiency to UV-optimum and even to UV-excess. Early as March, there can be the UV-optimum conditions for all skin types; there may be even moderate UV-excess in the last decade for skin types 1 and 2, when the solar angle is higher than 35 degrees. In April, the probability of the UV-optimum and UV-excess conditions for all skin types increases. The moderate UV-excess conditions prevail (66%) for skin type 1; there is the equal probability of the UV-optimum and of moderate UV-excess conditions for skin type 2; the probability of the UV-optimum and UV-excess conditions is 63 and 25%, respectively, for skin type 3; the UV-optimum is prevailing (80%) for skin type 4. In May, the UV-excess conditions are of high probability (90%) for skin type 1; the moderate UV-excess conditions prevail (75% and 72%, respectively) for skin types 2 and 3; the UV-optimum conditions are dominant (76%) for skin type 4.

In summer, almost for all skin types, there is the absence of the UV-deficiency conditions while the probability of the UV-excess conditions increases. However, in August, the risk of erythema significantly decreases compared to other summer months, and the probability of the UV-optimum conditions reaches 84% for skin type 4.

In autumn, again, the UV-deficiency conditions are possible. However, in September, for skin types 1, 2 and 3, still even moderate UV-excess is possible. At the same time, the UV-optimum conditions prevail for skin types 2, 3, and 4. In October, the hazard of erythema does not exist for all skin types except the skin type 1. In November, the UV-deficiency conditions are observed for all skin types.

The methodology for the determination of the threshold values of UV-radiation doses necessary for the vitamin D synthesis presented in this paper is not the only methodology that exists; there are other methods for the identification of the threshold values. In [Engelsen et al., 2005], the scientists have selected the threshold considering the UV radiation at three wavelengths using the results of medical experiments in Boston, USA. The results showed that vitamin D is not synthesized in winter at latitudes higher than 50 degrees. Testing of our method also supported this conclusion [Chubarova, Zhdanova, 2013]. The threshold value obtained in the experiments in Boston [Engelsen et al., 2005], was also used to investigate the potential for the vitamin D synthesis in three cities: Thessaloniki, Greece (41°N), Bilthoven, The Netherlands (52°N), Jokioinen, Finland (61°N) [Kazantzidis et al., 2009]. In this study, the effective doses for vitamin D were derived directly from the vitamin D formation spectral curve. It was shown that using the threshold values presented in [Engelsen et al., 2005] in Bilthoven, there was no synthesis

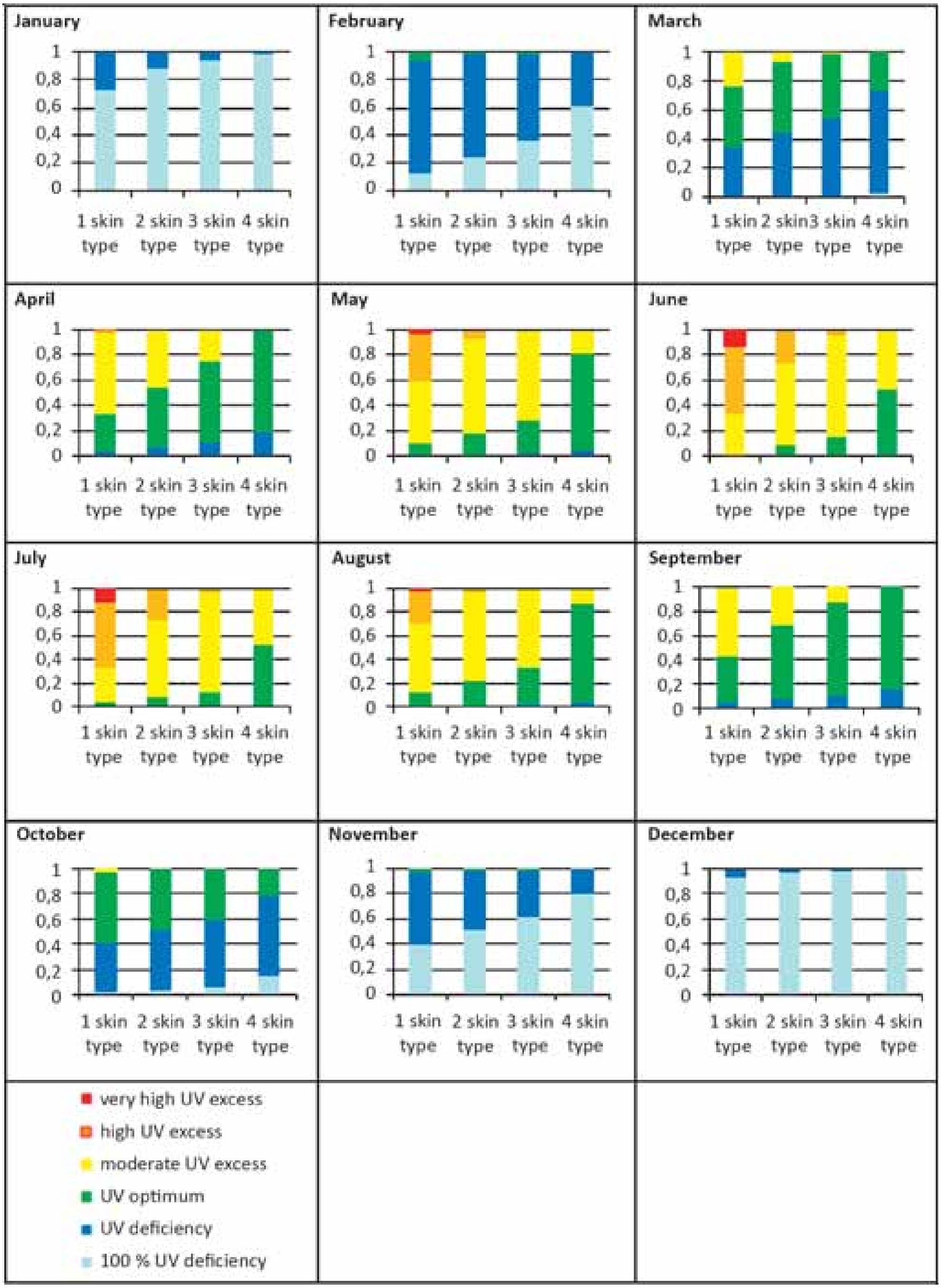

Fig. 8. Probability of different types of the UV-resources for the various skin types

of vitamin D in humans with skin types 1–3 from the middle of November, which agrees with the results obtained for Moscow. In [Krzys′cin et al., 2011], a mathematical model of UV-radiation induced vitamin D synthesis variation showed that in Belsk, Poland (52°N), sufficient vitamin D doses may not synthesize in humans even in summer. The study [Fioletov et al., 2010] showed that vitamin D was synthesized in people with skin type 2 at 54°N in North America during the whole year. Therefore, these two studies contradict each other.

It should be emphasized that the vitamin D synthesis in human skin and erythema formation depend on many factors associated with specific features of a person. These factors include, for example, age, habits, etc. These factors will be accounted for in the future, using parameterization methods.

It is necessary to add that the obtained monthly average values of UV-resources agree completely with the assessments obtained in our previous model estimates of UV resources for the closest to Moscow grid point in conditions of mean cloud cover [Chubarova, Zhdanova, 2013]. This demonstrates the reliability of the earlier assessments for the territory of Northern Eurasia.

CONCLUSION

The continuous long-term measurements of erythemally weighted UV-radiation at MO MSU in Moscow revealed its seasonal variation and the role of different geophysical parameters in its variability. Besides the astronomical factor that mainly controls the seasonal erythemally-weighted UV radiation variations, the main factors affecting Q_{er} in Moscow are TOC and clouds. During the year, the mean Q_{er} absorption by ozone varies from 18 to 44 % with the maximum in February-March. The attenuation due to cloud cover ranges from 17 to 48% with the maximum in October-December. The major role of clouds in the attenuation of UV-radiation was noted in [Belan et al., 2012]. However, in Moscow the effects of cloudiness and ozone on Q_{er} are comparable. The attenuation due to atmospheric aerosol ranges from 4 up to 10 % in April and August-September. The mean cloud effect on Q_{er} in Moscow conditions of about 29% is also in agreement with its 35% effect obtained in Austria at the Sonnblick Observatory [Simic et al., 2008].

Analysis of the statistical parameters of the daily and hourly erythemal doses allowed us to identify differences in the UV-radiation regime for various months. The highest daily and hourly *ED* values are observed in July, while the largest dispersion is observed in June. The distribution of the daily *ED* has statistically significant positive skewness from September to April and negative skewness from May to August.

Using the methodology developed earlier [Chubarova, Zhdanova, 2012; Chubarova, Zhdanova, 2013] and the measurements obtained at MO MSU, we have assessed the daily UV-resources in Moscow in 1999–2013 for people with different skin types. We have demonstrated that the UV-deficiency conditions exist for all considered skin types during all days from November to February.

The UV-optimum conditions are dominant in March and October (maximum in October – 56%) for skin type 1; in March, April, September, and October for skin type 2 (maximum in September – 60%); in April and September (maximum in September – 77%) for skin type 3; from April to September (maximum in August and September – 84%) for skin type 4.

The high probability of UV-excess is observed from April to September (maximum in June – 100%) for skin type 1; from April to August (maximum in July – 93%) for skin type 2; from May to August (maximum in July – 88%) for skin type 3; from June to July (maximum in July – 47%) for skin type 4.

The obtained average values of UV-resources agree completely with the model-based assessments of UV-resources based on satellite data for the closest to Moscow grid point in mean cloud cover conditions [Chubarova, Zhdanova, 2013].

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REFERENCES

1. Bais A., Lubin D. (2007). WMO (World Meteorological Organization), Scientific Assessment of Ozone Depletion: 2006, Global Ozone Research and Monitoring Project–Report No. 50, 572 pp., Geneva, Switzerland, Chapter 7. Surface Ultraviolet Radiation: Past, Present, and Future

2. Belan B.D., Ivlev G.A., Sklyadneva T.K. (2012). Many-year monitoring of total and UV (B) radiation in Tomsk city. Atmospheric and Oceanic Optics, vol. 25, N 1, pp. 61–65, (in Russian).

3. Bouillon R., Eisman J., Garabedian et al., (2006). Action spectrum for the production of previtamin D3 in human skin. Int. Commission on Illumination. Technical report, 174, pp. 1–12.

4. Chubarova N. (editor) (2013). Environmental and climate characteristics of the atmosphere in 2012 according to the measurements of the Meteorological Observatory of Moscow State University. Moscow, MAKS Press, 207 p. (in Russian).

5. Chubarova N., Smirnov A., Holben B.N. (2011). Aerosol properties in Moscow according to 10 years of AERONET measurements at the Meteorological Observatory of Moscow State University. Geography, Environment, Sustainability, vol. 4, N 1, pp. 19–32.

6. Chubarova N., Zhdanova Ye. (2013). Ultraviolet resources over Northern Eurasia. Photochemistry and Photobiology B: Biology, vol. 127, pp. 38–51.

7. Chubarova N.E. (2002). Monitoring of biologically active UV radiation in the Moscow region, Izvestiya. Atmospheric and Oceanic Physics, vol. 38, N 3, pp. 312–322.

8. Chubarova N.E. (2008). UV variability in Moscow according to long-term UV measurements and reconstruction model. Atmos. Chem. Phys. 8, pp. 3025–3031.

9. Chubarova N.E., Zhdanova E.Yu. (2012). Ultraviolet resources over the territory of Russia under clear sky conditions. Vestnik MGU. Series 5. Geography, N 6, pp. 9–19 (in Russian).

10. Chubarova N.Ye., etc. (2014). Climatic and environmental characteristics of the Moscow megapolis for 60 years of observations by the Meteorological Observatory of MSU. Meteorology and Hydrology, in print.

11. Efron B. and Tibshirani R.J. (1993). An introduction to the bootstrap, New York: Chapman & Hall/CRC (Monographs on Statistics and Applied Probability; 57), 436 p.

12. Engelsen O., Brustad M., Aksnes L. and Lund E. (2005). UV radiation, vitamin D and human health: an unfolding controversy daily duration of vitamin D synthesis in human skin with relation to latitude, total ozone, altitude, ground cover, aerosols and cloud thickness. J. Photochem. and Photobiol., vol. 81, pp. 1287–1290.

13. Fioletov V.E., M.G. Kimlin, N. Krotkov, L.J.B. McArthur, J.B. Kerr, D.I. Wardle, J.R. Herman, R. Meltzer, T.W. Mathews, J. Kaurola (2004). UV index climatology over the United States and Canada from ground-based and satellite estimates. J. Geophys. Res., vol. 109, D22.

14. Fioletov V.E., McArthur L.J.B. T.W. Mathews, L. Marrett (2010). Estimated ultraviolet exposure levels for a sufficient vitamin D status in North America Journal of Photochemistry and Photobiology B: Biology 100, pp. 57–66.

15. Fitzpatrick T.B., (1988). The validity and practicality of sun-reactive skin types I through VI. Arch. Dermatol., 124, pp. 869–871.

16. Holick M.F. and Jenkins, M. (2003). The UV advantage: new medical breakthroughs reveal powerful health benefits from sun exposure and tanning, publication of ibooks, inc.

17. Kazantzidis, A., Bais, A.F., Zempila, M.M., Kazadzis, S., den Outer, P.N., Koskela, T., and Slaper, H. (2009). Calculations of the human vitamin D exposure from UV spectral measurements at three European stations. Photochem. Photobiol. Sci., 8, pp. 45–51.

18. Krzys′cin. J.W., Jarosiawski J., Sobolewski P.S. (2011). A mathematical model for seasonal variability of vitamin D due to solar radiation, J. Photochem. Photobiol. B: Biol., vol. 105, issue 1, pp. 106–112.

19. McKenzie R.L., Liley J. Ben, Bjorn L.O. (2009). UV radiation: balancing risks and benefits, Photochemistry and Photobiology, 85, pp. 88–98.

20. Mutzhas M.F., Amlong J.-U., Cesarini J.-P., Ferenczi S., Gange R.W., Gschnait F., (1993). Reference action spectra for ultraviolet induced erythema and pigmentation of different human skin types, "CIE Technical Collection 1993", CIE Central Bureau, Vienna, Austria, pp. 15–22.

21. Olds W.J., Lucas R. M. and Kimlin M. G. (2010). Action Spectrum for Vitamin D Synthesis. http://www.niwa.co.nz/sites/default/files/action_spectrum_for_vit_d_synthesis.pdf

22. Reichrath, Jörg (editors). Sunlight, Vitamin D and Skin Cancer Series: Advances in Experimental Medicine and Biology, vol. 624, 2008, p. 342.

23. Rosental, V., Chubarova N., Izakova, O., Sharaev, G. (1999). Monitoring of radiation fluxes by means of SUN software. Atmospheric and Oceanic Optics, vol. 12, N 1, pp. 82–86. (in Russian).

24. Seckmeyer G., Pissulla D., et all. (2008). Variability of UV Irradiance in Europe. Photochemistry and Photobiology, 84, pp. 172–179.

25. Serrano A., Ant′on M., Cancillo M.L., and Mateos (2006). V.L. Daily and annual variations of erythemal ultraviolet radiation in Southwestern Spain, Ann. Geophys., 24, pp. 427–441.

26. Simic S., Weihs P., Vacek A., Kromp-Kolb H., Fitzka M. (2008). Spectral UV measurements in Austria from 1994–2006: investigations of shot- and long-term changes. Atmos. Chem. Phys. V. 8, N 23. pp. 7033–7043.

27. Vecchia P., Hietanen M., Stuck B.E., van Deventer E., Niu Sh. (editors) Protecting Workers from Ultraviolet Radiation, International Commission on Non-Ionizing Radiation Protection (2007), printed by DCM, Meckenheim, p. 110.

28. Webb A.R., Engelsen O. (2006). Calculated ultraviolent exposure levels for a healthy vitamin D status, Photochem. Photobiol., 82 (6), pp. 1697–1703.

29. Zhdanova E.Yu., Chubarova N.E. (2011). Estimation of different atmospheric parameters impact on biologically active UV irradiance according to calculations and measurements Atmospheric and Oceanic Optics, vol. 24, N 9, pp. 775–781.

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INDIGENOUS AGRICULTURAL DEVELOPMENT FOR SUSTAINABILITY AND *"SATOYAMA"*

ABSTRACT. *Satoyama* is a Japanese term for landscapes that comprise a mosaic of different ecosystems which include forests, agricultural lands, grassland irrigation ponds and human settlements aimed at promoting viable human nature interaction. The Japanese government is seeking to revitalize it locally and promote it internationally, receiving accreditation as UNESCO *Satoyama* Initiatives. Here we explore the dynamics of this system and how it can be used as a model for any intended agricultural development in indigenous communities globally. In this paper we strongly address sustainable agriculture development which takes into consideration the local culture and traditions which exists.

KEY WORDS: satoyama, indigenous agriculture, sustainable development, landscape use, nature conservation

INTRODUCTION

Indigenous people around the world built there lives in specific areas globally which were influenced and shaped in unique ways by the geographic characteristics, climatic conditions, flora and fauna, and access to natural resources [Bruyneel, 2000]. They have been living on the fruits of nature such as fishing, hunting, gathering edible plants, and obtaining materials for clothing and housing [FAO, 2013]. It is a fact that many were migratory, leaving a location when the area would have been exhausted and moving on to a new location to repeat the same steps again, finally returning to the area where they began at a time when the natural environment would have been rejuvenated over time.

Over time, they have been affected by political decisions, exploitation of natural resources such as mining, urbanization, modernization, infrastructural development, climate change, and global warming which have altered their lives dramatically often resulting in a reduction of land capital at their disposal [Climate Frontlines, 2013; FAO, 2013; Nakashima *et al*., 2012; Salick and Anja, 2007]. This reduction in land capital propels them into the direction of agricultural development so as to guarantee the food security of their respective communities [Galloway McLean, 2010]. Agricultural development is crucial since it is prudent that it be done in a way so as to guarantee cohesion with their natural surroundings and a preservation of their culture and traditions [Salick and Anja, 2007].

In this perspective, we investigate how the principles of *Satoyama* can be utilized to guarantee this much needed balance between agricultural development and the preservation of the natural environment as well as their culture and tradition.

CONCEPTUAL ORIGIN AND EVOLUTION OF *SATOYAMA*

The term *Satoyama* (里山) is derived from two Japanese words, namely *sato* (里) meaning village, arable land or homeland, and *yama* (山) meaning mountain. The most widely accepted definition of *Satoyama* is a term for landscapes that comprise a mosaic of different ecosystem types which include secondary forests, agricultural lands, irrigation ponds, grasslands and human settlements [Duraiappah and Nakamura, 2012]. These were formed and developed through prolonged interaction between humans and the nature that surround them.

Nevertheless, the concept is quite flexible and manipulative, with the definition varying from person to person, depending on their perspective [Tsunekawa, 2003]. Numerous groups and individuals have attempted to define *Satoyama* from their own backgrounds and interests, and refer to it as ecosystems, coppices and secondary forests, while others refer to it as rural landscapes including human settlements [Osumi and Fukamachi, 2001].

SATOYAMA LANDSCAPE AND ITS IMPORTANCE

In 1860, at the end of the *Edo* period, Japan was primarily a rural agricultural country [Tsunekawa, 2003]. In the late 1960s, there was a surge of suburban development along with rapid growth. Over time people became increasingly conscious of the environment and citizens voluntarily started to manage the surrounding woodlands. Eventually this movement influenced the entire nation and *Satoyama* evolved into a household name for the traditional Japanese rural landscape [Tamura *et al*., 1983].

The nature conservation movement of the 1960s in Japan was focused on conserving natural areas near human settlements, while simultaneously opposing desctructive development on important remote natural areas. An effective method of preserving local nature was through local residents learning to recognize the beauty and wonder of nature through various events and activities. The conservation of *Satoyama* landscapes required both the cessation of destructive development and adequate management. In the late 1980s, local movements began to appear that focused on *Satoyama* landscape management [Kuramoto, 2003]. *Satoyama* landscape indicates the rural landscape that is comprised of woodlands, farmlands, settlements and reservoirs with considerable secondary nature that allows wildlife and humans to live together [Environment Agency of Japan, 1994; Yamamoto, 2001].

Satoyama landscapes contain nature that is maintained through its use and management by the local human population. Grasslands and diverse woodlands were created around residential areas and water bodies, thus allowing easy access to fertilizer and water for cultivation, fodder for cattle, wood, cogon grass (*Imperata cylindrical* Poales: Poaceae), bamboo for construction material, pine leaves for fuel, and so forth. This facilitated traditional lifestyles based on cultivating rice crops, using organic compost, living under thatched structures, and generating warmth from firewood and pine needles [Washitani, 2003].

The mosaic of various ecosystem types in a *Satoyama* landscape including forest, farmland, reservoirs and water channels is a habitat for a wide variety of wildlife and has maintained rich biota and biodiversity. The diversity of ecosystem mosaics supports ecosystem functions such as primary production, nutrient cycling, soil formation and habitat structure through various processes and mechanisms. It provides a place for agriculture, forestry, a human living space, and plays an important role in nurturing biodiversity [Saito *et al*., 2012].

Firewood and charcoal as fuel was very important prior to the fossil fuel revolution, while timber is an important livelihood resource. Forest materials such as fallen leaves and underbrush were used as

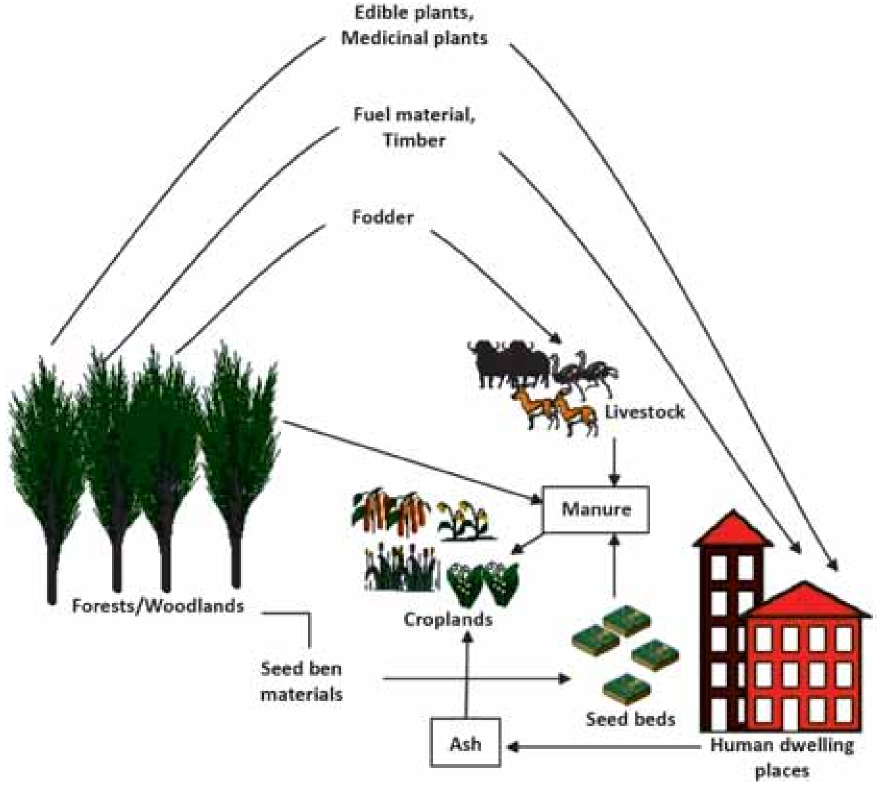

Fig. 1. Resource use and circulation in Satoyama landscapes [After Inui, 1996].

fertilizers prior to the 1960s when chemical fertilizers became widespread (Fig. 1). Rice paddies and vegetable fields, serve as important food provisioning services. Gathering of mushrooms and other edibles from the forests has been traditionally done and in present day the cultivation *of shiitake* mushrooms (*Lentinula edodes* Agaricales: Marasmiaceae) using trees [Inui, 1996; Saito *et al*., 2012].

The main regulating services are climate, water quality and disaster control. The forest is responsible for carbon fixation and clean water supply. The house and forest zone arrangements provide windbreaks and temperature control. The reservoirs and rice paddies are essential for flood prevention and nutrient recycling.

Pollination by pollinators inhabiting the ecosystem, as well as natural pest control as agricultural management are both important regulating services [Saito *et al*., 2012].

The traditional knowledge used in managing these landscapes, as well as the cultural identity they provide for society in general, offers valuable cultural services such as cultural heritage, sense of identity, tourism, and amenity. These vary depending on region, influencing regional cultures, customs and established practices [Tadaki, 2008].

SATOYAMA AND AGRICULTURE

Analysis of ruins and relics of the Paleolithic age reveal that ancient human lifestyles relied upon abundant natural resources from the surrounding mountains and oceans through fishing, hunting, and gathering. Evidence suggests that agriculture was first practiced in Japan in the *Jomon* period during the

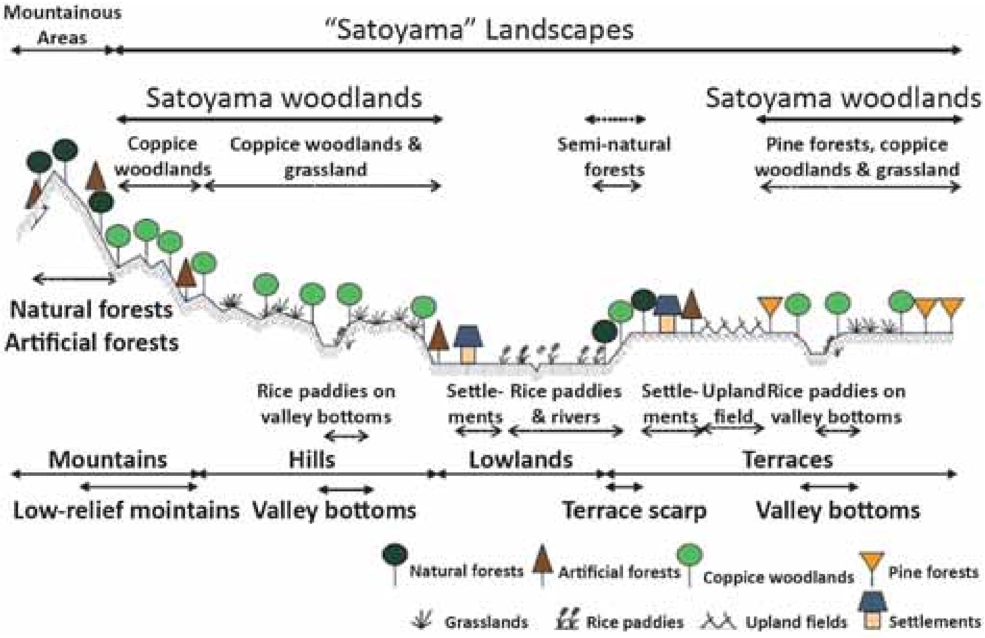

Fig. 2. Transect schematic representation of *Satoyama* woodlands and *Satoyama* landscape [After Yamamoto, 2001].

New Stone Age, a time when agriculture began around the world. Agricultural production apparently did not make a great contribution to food supplies during this time because there was an abundant natural supply of food [Washitani, 2003]. Therefore, the *Satoyama* prototype began when at fixed locations people started to make the transition from gathering, hunting and fishing to a more settled life.

Examples of early villages were Ani in the Akita Prefecture, Akiyama in the Nagano Prefecture, and isolated mountainous villages such as Miomote. Until the end of the 1940s, there were four clearly visible zones as shown in Fig. 2 which are: the village area; agricultural fields such as rice paddies and nurseries, and other crops; grasslands for feed and fertilizer, firewood gathering and managed Japanese chestnut (*Castanea crenata* Fagales: Fagaceae), walnut (*Juglans ailantifolia* Fagales: Juglandaceae), and horse walnut (*Juglans nigra* Fagales: Juglandaceae) forests; and the *"Okuyama"*, a wild area consisting of natural forest [Taguchi, 2009]. In these communities there was a relationship between agriculture and hunting, where wildlife that were attracted by the crops were caught and utilized. *Sato-mataki*, refers to trap hunting in the *Satoyama* zone [Sato, 2009].

Therefore, forests that were located near agricultural villages were maintained by human activities and as such became known as *Satoyama* forests [Kobori and Primack, 2003].

SATOYAMA AND THE INDIGENOUS WAY OF LIFE

Indigenous communities commonly occupy remote rural areas and their livelihoods are fundamentally linked to land and natural resource use. They possess a wide body of knowledge about agriculture, fishing, hunting, gathering, sustainable environmental management, biodiversity, and environmental adaptation. Because of the close and necessary link between indigenous people and the land in which they dwell, the relation between environmental quality and socio-economic prosperity is easily highlighted in the way in which their life has evolved during the course of modernization to this present day. The world's 370 million indigenous people are among the most vulnerable and disadvantaged groups, comprising about 15 % of the total global poor. One of the obvious factors that have exacerbated this fact is that of climate change [FAO, 2013].

These realities of indigenous people the world over are strikingly similar to the circumstances in which *Satoyama* was conceived. Nevertheless, heightened exposure to negative impacts is not the only reason for specific attention and concern. Many indigenous societies are socially and culturally distinct from mainstream society. Therefore, decisions, policies and actions undertaken by the major group, even if well-intended, may prove inadequate, ill-adapted and inappropriate. There is therefore a need to understand the specific vulnerabilities, concerns, adaptation capacities, and longer-term aspirations of indigenous peoples and marginalized communities the world over. Indigenous and traditional knowledge contribute to this broader understanding [Nakashima *et al*. 2012].

THE REVITALIZATION AND INTERNATIONALIZATION OF *SATOYAMA*

Generally, when we think of ecological consciousness; content, attitude, and relation immediately comes to mind. It is in this framework that *Satoyama* exists. Basically, this translates into the position that *Satoyama* improves our attitude and relationship with global environmental problems such as climate change, biodiversity, global warming, food security, poverty, etc.

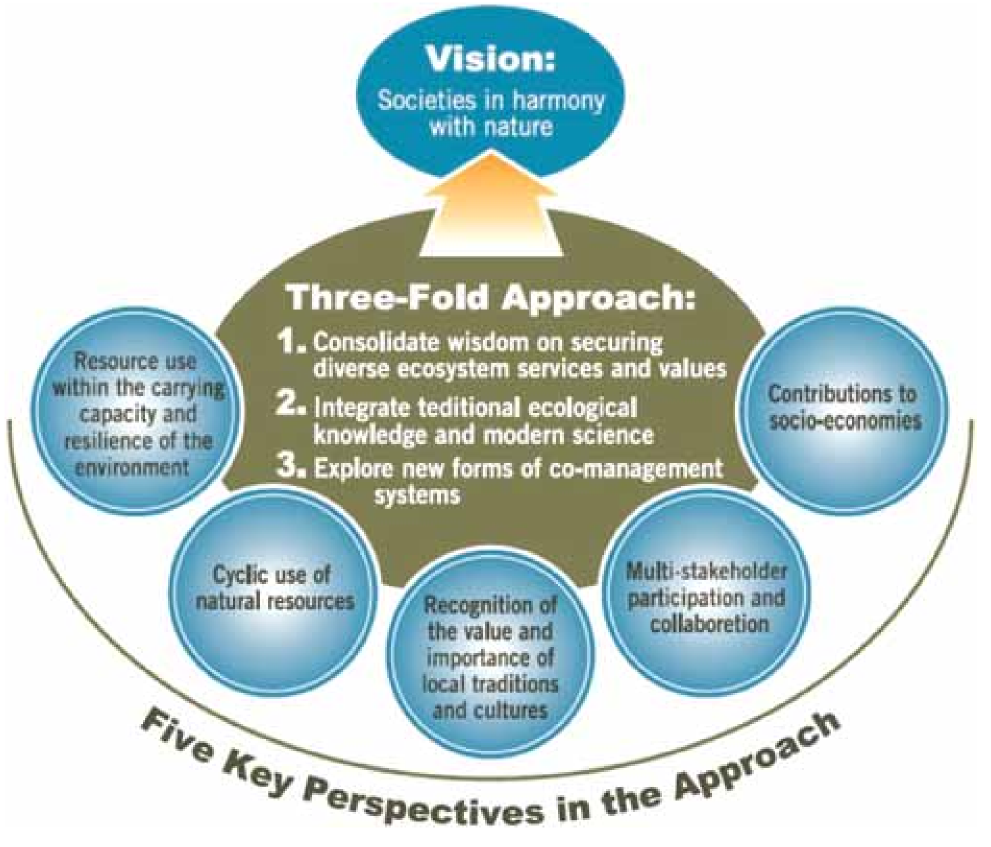

Fig. 3. The five elements that build and constitute *Satoyama* **[IPSI, 2010].**

The International Partnership for the *Satoyama* Initiative (IPSI) has promoted five points as shown in Fig. 3, that are essential for the realization of societies in harmony with nature [IPSI, 2010].

Japan has had fairly good successes in community based management of its resources and this is very notable in fishing villages and farming communities. In addition, the Japanese culture both historical and present day, is one that embraces the necessity of living in harmony and respect of nature which gave rise to the *Satoyama* principle. The Ministry of the Environment of Japan (MOE-J) in collaboration with the United Nations University-Institute of Advanced Studies (UNU-IAS), and co-organized by United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP), and the Secretariat of the Convention on Biological Diversity (SCBD) has resulted in a quest to see this principle globalized and the United Nations recognizing and ratifying this position in the "Paris Declaration" at the Headquarters of the UNESCO in Paris in January 2010.

Notwithstanding, the successful globalization of *Satoyama* is dependent on the perceptions and attitudes of the local residents to their respective environments [Duraiappah and Nakamura, 2012].

SATOYAMA AGRICULTURE MODEL DEVELOPMENT

A diverse, locally adaptable set of agricultural techniques, practices and market branding certifications such as Good Agricultural Practices (GAP), Organic/Biodynamic Agriculture, Fair Trade, Ecological Agriculture, Conservation Agriculture and related techniques and food supply protocols exemplify the varying shades of green agriculture [UNEP, 2011].

Satoyama agriculture development is capable of being evaluated because the necessary indicators are those that are readily available and can be done using a system of survey analysis [Mekush, 2012]. This should include the management of landscape ecology, conservation of natural heritage, and the connection and integration of all components rather than treating them separately [Adams, 2003]. To illustrate how this can be done we utilize the very five criteria as advanced by the IPSI and propose how they can be measured in Table 1.

We posit that this approach would allow us to evaluate the extent to which the perspectives of *Satoyama* are met in any given community. This would be diagnostic in nature and would set the stage for the orientation of the systematic and scientific approach that should be employed to advance sustainable agricultural development in the community in question.

When dealing with indigenous communities, certain things have to be clear and should only come from their perspective:

- What is their aim as a community?
- What is the definition of a community for them?
- What are the views of the residents and what percentage of them share that view?
- What is community involvement and action for them?
- Who or what is/are responsible for social ills such as poverty?
- Is capacity building needed for their participation?

These and other questions needs to be answered since any *Satoyama* type agricultural development would only be successful if done collaboratively with all stakeholders. In addition, because local culture and traditions are to be incorporated, a proper understanding is necessary to capture their perspectives correctly and accurately.

Table 1: Evaluation of Satoyama based Agriculture

Perspectives	Criteria	Variables	Sub-Variables
Cyclic use of Natural Resources	Land Use Variation		
	Biodiversity	Microbial	
		Flora and Fauna	
	Human Agricultural Activities	Crops	
		Livestock	
	Eutrophication		
Resource Use based on Carrying Capacity and Resilience of Environment	Land Size	Threats of Further Reduction	Anthropogenic
			Natural
	Resources	Water	
		Soil	
		Forestry	
		Environment	
Recognition of the Importance and Value of Local Cultures and Traditions	Heritage	Tangible	
		Intangible	
	Tourism	Visitors	
		Activities	
		Impacts	
Collaborative Management of Natural Resources	Organization		
	Decision Making Process		
	Conflict Resolution		
Contribution to Local Socio-Economies	Social	Health	
		Cost of Living	
		Public safety	
		Pathology	
		Education Level	
	Economic	Self-sufficiency	
		Employment Levels	

Inference for success could be obtained from the Royal Project Foundation of Thailand which was established with the express objective of discouraging the cultivation of poppy (*Papaver somniferum* Ranunculales: Papaveraceae) used to produce opium by providing agricultural alternatives that were equally economically beneficial. This approach also curbed the shifting cultivation practices of the Hilltribe communities and thus contributed to the conservation of the neighboring forests. In addition, the social wellbeing of the inhabitants was improved since help was offered to opium addicts, health care improved and educational facilities enhanced [Royal Project Foundation, 2012]. The success of this program has subsequently been extended to other nations with communities plagued with a similar situation of highland poverty and drug-crop production such as Bhutan, Afghanistan (opium poppy) and Colombia (coca plant: Erythroxylaceae) [HRDI, 2007].

CONCLUSION

We conclude by advancing that the flexibility of the term *Satoyama* if considered as a concept can favor its adaptation into a sustainable agricultural management model. Trials should be conducted exploring various models of evaluation based on the aforementioned principles in communities willing to try new approaches in the interest of sustainable development. Success stories can then be shared with other communities around the world. We have contributed directly and indirectly to the ills that affect our indigenous peoples and we should therefore be a part of the solution.

REFERENCES

1. Adams, W. (2003). Future Nature: A vision for nature conservation. revised edition, Earthscan, London.

2. Bruyneel, K. (2000). Politics on the Boundaries: The Post-Colonial Politics of Indigenous People. Indigenous Nations Studies Journal 1 (2): 73–94.

3. Climate Frontlines, (2013). Climate Frontlines Forum, UNESCO. [www.climatefrontlines.org]. Accessed 18. April, 2013.

4. Duraiappah, A. and Nakamura, K. (2012). The Japan Satoyama Satoumi Assessment: Objectives, focus and approach. In: Duraiappah, A., Nakamura, K., Takeuchi, K., Watanabe, M. and Nishi, M. (Editors), Satoyama-Satoumi Ecosystems and Human Well-Being, Socio-Ecological Production Landscapes of Japan. United Nations University Press, Japan, pp. 1–16.

5. Environment Agency of Japan (1994). The New Basic Environment Plan. Environment Agency, Tokyo.

6. Food and Agriculture Organization (2013) Indigenous People. Rome, Italy. [http://www.fao.org/economic/esw/areas-of-work/indigenous-people/en/]. Accessed 18 April 2013.

7. Galloway McLean, K. (2010). Advance Guard: Climate Change Impacts, Adaptation, Mitigation and Indigenous Peoples – A Compendium of Case Studies. United Nations University – Traditional Knowledge Initiative, Darwin, Australia.

8. Highland Research and Development Institute [HRDI] (2007). The Peach and the Poppy: The story of Thailand's Royal Project. Royal Project Foundation, Chiang Mai, Thailand.

9. International Partnership for the Satoyama Initiative [IPSI] (2010). The Satoyama Initiative. United Nations University, Tokyo, Japan.

10. Inui, T. (1996), The history and use of lowland forest in Kanto plain. Kagaku 18: 15–20 (in Japanese).

11. Kobori, H. and Primack, R. (2003). Participatory conservation approaches for Satoyama, the traditional forest and agricultural landscape of Japan. Ambio 32: 307–311.

12. Kuramoto, N. (2003). Citizen Conservation of Satoyama Landscapes. In: Takeuchi, K., Brown, R., Washitani, I., Tsunekawa, A. and Yokohari, M. (Editors), Satoyama, the Traditional Rural Landscape of Japan, Springer, Japan. pp. 23–35.

13. Mekush, G. (2012). Evaluating the sustainable development of a region using a system of indicators. In: Shmeleva S. and Shmeleva, I. (Editors), Sustainability Analysis: An interdisciplinary approach, Second edition, Palgrave, MacMillan, pp. 300–326.

14. Nakashima, D., Galloway McLean, K., Thulstrup, H., Ramos Castillo, A. and Rubis, J. (2012). Weathering Uncertainty: Traditional Knowledge for Climate Change Assessment and Adaptation. Paris, UNESCO, and Darwin, UNU.

15. Osumi, K. and Fukamachi, K. (2001). Note for thinking about Satoyama. Forest Technology 707: 12–15 (in Japanese).

16. Royal Project Foundation (2012). Thailand's Royal Project, Chiang Mai, Thailand.

17. Saito, O., Shibata, H., Ichikawa, K., Nakamura, T., Honda, Y. and Morimoto, J. (2012), Satoyama and satoumi, and ecosystem services: A conceptual framework. In: Duraiappah, A., Nakamura, K., Takeuchi, K., Watanabe, M. and Nishi, M. (Editors), Satoyama-Satoumi Ecosystems and Human Well-Being, Socio-Ecological Production Landscapes of Japan. United Nations University Press, Japan, pp. 17–59.

18. Salick, J. and Anja, B. (2007). Indigenous Peoples and Climate Change. Tyndall Centre for Climate Change Research. Oxford [http://www.tyndall.ac.uk/sites/default/files/Indigenous%20Peoples%20and%20Climate%20Change_0.pdf] Accessed 18. April, 2013.

19. Sato, H. (2009). Ethnoarchaelogy of Trap Hunting Among the Matagi and the Udehe, Traditional Hunting Peoples Living Around the Sea of Japan. In: Sasaki S (Editor), Human Nature Relations and the Historical Backgrounds of Hunter-Gatherer Cultures in Northeast Asian Forests, Senri Ethnological Studies 72: 25–46.

20. Tadaki, Y. (2008). Satoyama Landscapes as Managed Nature. Journal of Environmental Information Science 37 (4): 6–10.

21. Taguchi, H. (2009). Correlative Significance of Trap-placing and Environmental Differences: Traditional Hunting in Mountainous Areas of Central and Northern Japan. In: Sasaki S (Editor), Human Nature Relations and the Historical Backgrounds of Hunter-Gatherer Cultures in Northeast Asian Forests, Senri Ethnological Studies 72: 47–74.

22. Tamura, T., Yamamoto, H. and Yoshioka, S. (1983). A national summary of recent trends of large-scale landform transformation in Japan. Geographical Review of Japan 56: 223–242.

23. Tsunekawa, A. (2003). Transition of Satoyama Landscapes in Japan. In: Takeuchi, K., Brown, R., Washitani, I., Tsunekawa, A. and Yokohari, M. (Editors), Satoyama, the Traditional Rural Landscape of Japan, Springer, Japan. pp. 41–51.

24. UNEP (2011). Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication. United Nations Environment Programme, Geneva.

25. Washitani, I. (2003). Satoyama Landscapes and Conservation Ecology. In: Takeuchi K., Brown R., Washitani I., Tsunekawa A., Yokohari M. (Editors), Satoyama, the Traditional Rural Landscape of Japan, Springer, Japan. pp: 16–23.

26. Yamamoto, S. (2001). Studies on the effect of changes in rural landscape structure on secondary forest plants in Japanese rural areas. Bulletin of the National Institute for Agro-environmental Sciences 20: 1–105.

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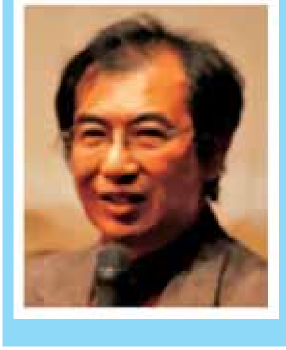

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INTERNATIONAL GEOGRAPHICAL UNION CONFERENCE IN MOSCOW, 17–22 AUGUST 2015: GEOGRAPHY, CULTURE, AND SOCIETY FOR OUR FUTURE EARTH

In 2015, Moscow will host the Regional Conference of the International Geographer's Union (IGU) for the third time since the International Geographical Congress of 1976, when over 2, 000 participants from around the world gathered in the Soviet capital for lectures, discussions, workshops and excursions. The pace of global transformation has since accelerated in directions that seemed unimaginable four decades ago. The 2015 Regional Conference will be an opportunity for the world geographical community to reflect upon these transformations as well as the future course of human civilisation in relation to pressing socio-environmental challenges. The motto of the conference is "Geography, Culture, and Society for our Future Earth".

IGUmoscow2015

ABOUT THE IGU

The IGU is among the world's oldest international research associations. The first International Geographical Congress was held in Antwerp in 1871, and subsequent meetings led to the establishment of the IGU in 1922. Today its members hail from over 100 countries, united in cultivating geographic research and education worldwide. In addition to its General Assembly, Executive Committee and National Committees, the IGU includes special commissions, task forces and study groups engaged in ongoing collaborative projects. Dr. Vladimir Kolosov, from Lomonosov Moscow State University (MSU) in Russia, is currently serving as President of the IGU from 2012 to 2016.

Interdisciplinary collaboration is central to the IGU's operations and long-term objectives, as evident in recent initiatives dedicated to urban ecology, geographical education and building a database of related peer-reviewed journals. The most ambitious IGU initiative at present is the UN International Year of Global Understanding (IYGU), aimed at fostering international cooperation based on awareness of the relationships between local actions and global problems. The IGU also facilitates the participation of geographers in world scientific communities through official affiliation with the International Council for Science (ICSU) and the International Social Science Council (ISSC).

The International Geographical Congress is held every four years.The2012 event took place in Cologne, and the next will be in Beijing. IGU Regional Conferences are annual, hosted within the past few years in Tel Aviv, Santiago and Kyoto. The 2014 conference will take place in Krakow, followed by the 2015 programme in Moscow.

IGU 2015 REGIONAL CONFERENCE IN MOSCOW

IGU Moscow 2015 will focus on five main themes: Urban Environment, Polar Studies,

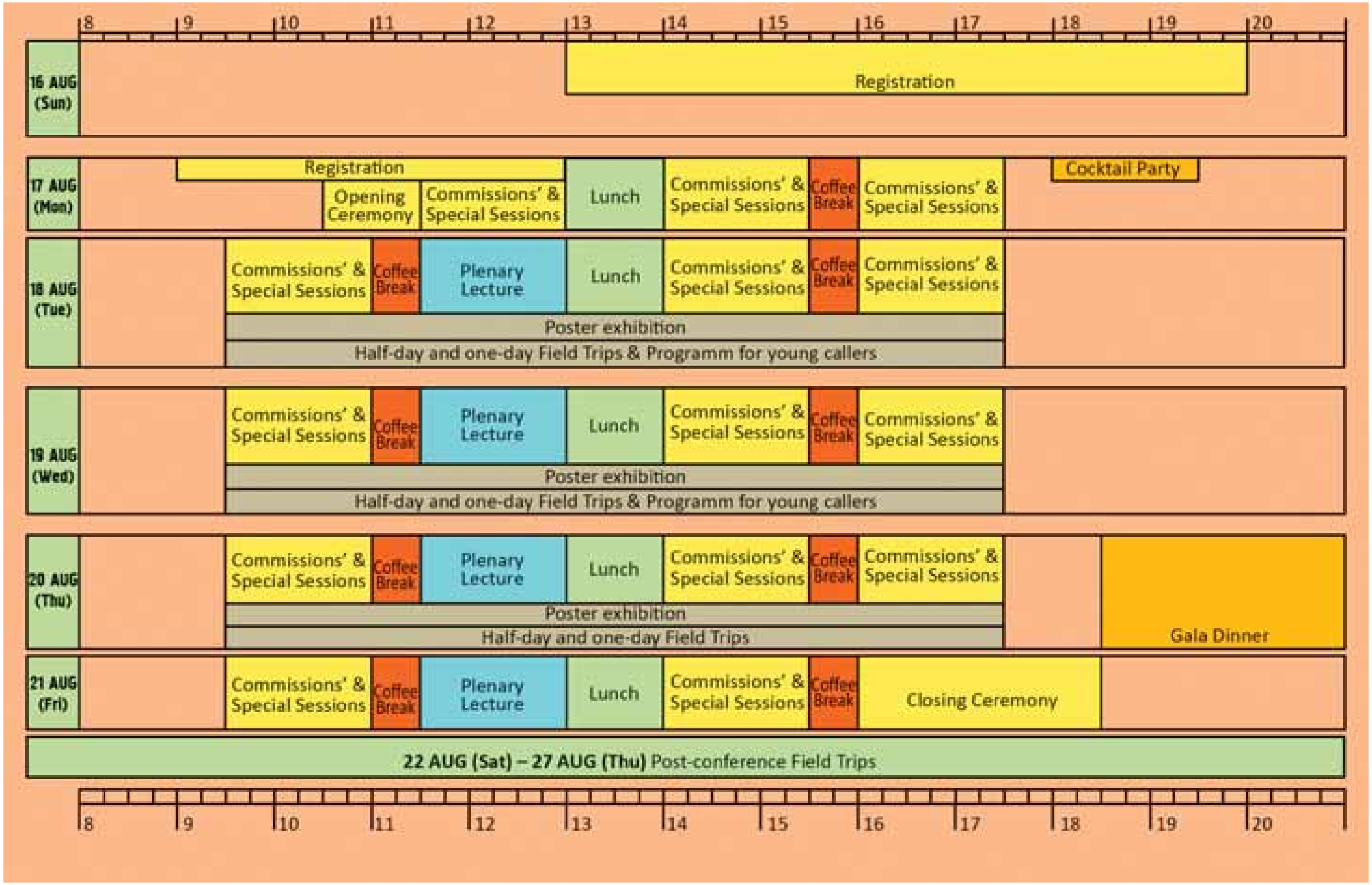

Fig 1. IGU-2015 conference program

Climate Change, Global Conflict, and Regional Sustainability. The programme is rooted in principals of diversity and interdisciplinary exchange. It will feature a variety of meetings, including plenary sessions, lectures, panel discussions, workshops and other events (Fig. 1). It will also provide opportunities for sharing ideas on IGU projects and on the role of geographers in international initiatives such as Future Earth.

Geographical education and integration of young scholars will be central to each of the conference themes. The programme will include two special events: the day of young scholars, with a competition for best presentation and other awards, and the special sessions "Academic Geography for Secondary Schools" and "Teaching Geography in the University." IGU Moscow will also incorporate the 2015 International Geographical Olympiad.

Conference proceedings will take place in the main campus of MSU, Russia's oldest, largest and most prestigious university. This vertical main building is a distinctive work of "socialist realist" architecture, rising 236 meters above a park along the Moscow River. Views of the city from the Department of Geography and museums on the upper floors are among the most breathtaking among many in Russia's capital. The university has two botanical gardens that contain rare plant species and medicinal herbs. It is also within a pleasant walk from the Sparrow Hills Nature Reserve, as well as Gorky Park and the Kremlin further along the river embankment.

The IGU 2015 organising committee encourages conference participants to enjoy campus tours and a variety of other excursions in and around Moscow. Following the conference there will be a series of planned trips to other parts of Russia, including St. Petersburg, the Golden Ring, the Upper Volga, Sochi, Kazan, Novgorod the Great and Valdaysky National Park. Conference excursions will offer a variety of options for informal interaction around geographical, cultural and historical interests.

EXPERIENCING RUSSIA

Russia has a longstanding geographical tradition that has given rise to education and research networks that incorporate 20 institutes of the Russian Academy of Sciences, 20 research organisations of the Russian Hydro-Meteorological Service and more than 100 university departments. Russian geography is known for the study of human impacts on diverse environments, from urban to extremely remote. Local discoveries cover a range from socio-cultural phenomena to new rivers, lakes and mountain ranges added to the map as late as the 1940s. Progressive geographical theory and methods have encountered fertile grounds for development in Russia through practical application in a wide variety of ecosystems.

Russia's extraordinary social, cultural and environmental diversity offers rich material for scientific inquiry. Its territory spans nine time zones and eight climate zones – encompassing mountains, tundra, arid steps, deserts and the earth's largest coastlines, rivers and lakes. It includes landscapes that are comparatively untouched by human activity, covering over 60 percent of state territory. Even densely populated Moscow contains a national park and an extensive network of protected areas within its borders.

Moscow is Russia's ancient core as well as its current political, economic and cultural centre, with over 17 million people living within its metropolitan area. The capital's museums, theatres, public spaces, hotels and financial districts are prominent showcases for domestic and international visitors. At the heart of the city is the Kremlin, open to the public as a museum that features artefacts and settings of great historical importance. The urban environment embodies a history of bold political and economic transformations that remain strikingly present within its fabric. Moscow is also a crossroads between eastern and western destinations, with many forms of transportation to and from the city. Its three international airports are within a three-hour

Table 1. Important dates and deadlines for IGU-2015

Deadline	Activity
15 October 2014	Deadline for submitting session proposals
01 November 2014	Early registration begins
31 January 2015	Deadline for submitting abstracts for papers and posters
01 March 2015	Notification of the results of the abstract review
20 March 2015	Publication of the provisional conference program
10 April 2015	Deadline for early registration fee payment
10 June 2015	Deadline for regular fee payment

of flight of most European capitals, and it can be reached from the Pacific Coast on the Trans-Siberian Railway or by way of inland water routes from St. Petersburg.

Registration for IGU Moscow 2015 begins on 1 November 2014, and can be completed online at www.igu2015.ru. (Table 1).

The IGU 2015 Regional Conference is an important chance for geographers from around the world to share information and ideas in a fascinating location. It will offer a variety of opportunities for dialog within and between disciplines, covering key issues in geography today. In this capacity, it will facilitate the contributions of geographers to global problem-solving through research and education.

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ERRATUM

This is to inform our readers that in the previous issue of GES Journal (01-2014) there is a mistake on page 24 in the article MULTI-ARCHIVE TEMPERATURE RECONSTRUCTION OF THE RUSSIAN ARCTIC FOR THE PAST TWO MILLENNIA by Vladimir Klimenko, Vladimir Matskovsky and Dittmar Dahlmann. One and the same graph was put under letters a) and b) in Fig. 6.
The correct version of Fig. 6 is presented below. The mistake does not affect any discussions and conclusions in the paper.

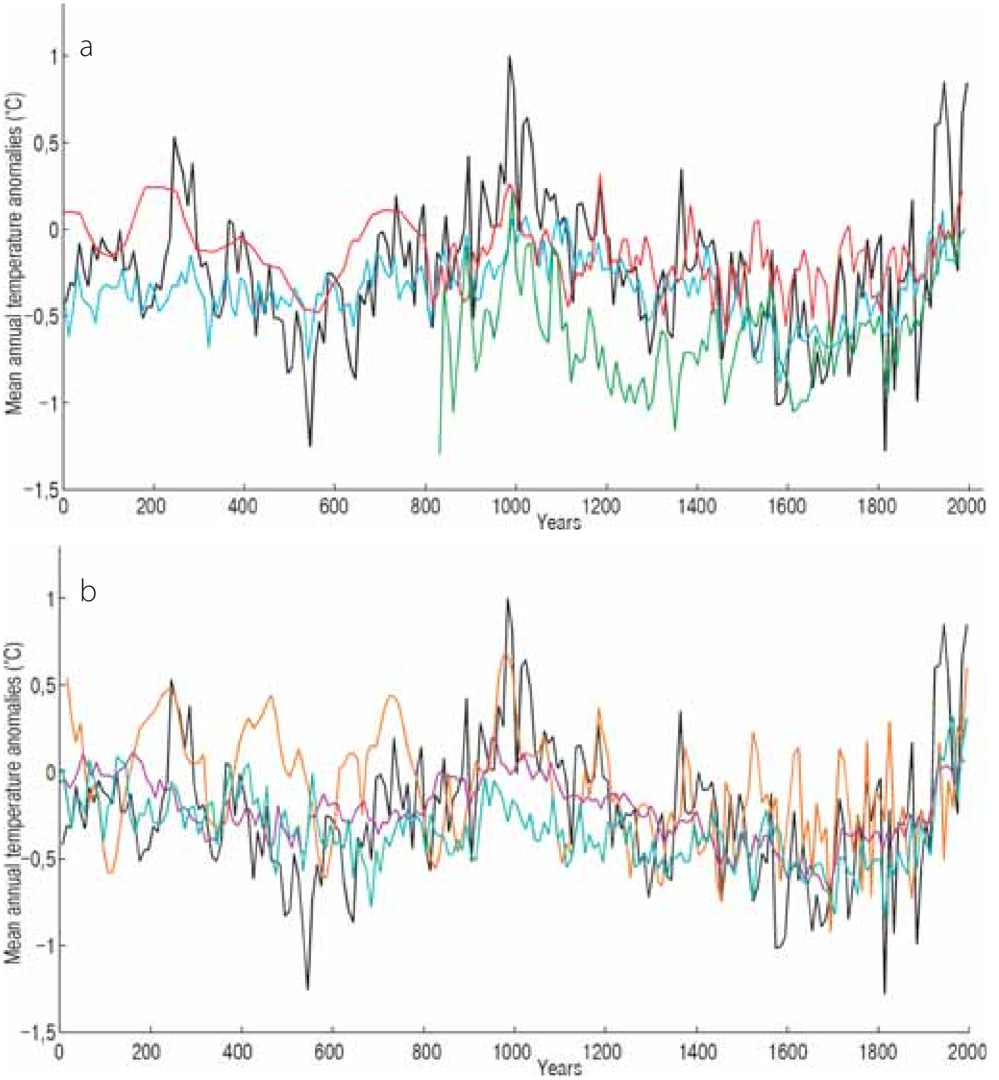

Fig. 6.

a) A comparison of the new chronology for Northeastern Europe (black) with the hemispheric reconstructions of Moberg et al. [2005] (blue), Klimenko [2009] (red) and Esper et al. [2002] (green).
b) A comparison of the new chronology for Northeastern Europe (black) with regional reconstructions: for the extratropical latitudes 30–90°N [Liungqvist, 2010] (purple), Pan-Arctic [Kaufman et al., 2009] (cyan), and the centre of the Russian Plain [Klimenko, Sleptsov, 2003] (orange). Reference period: 1951–1980

We apologize to the authors for the technical error.
The pdf-version of the GES Journal 01-2014 at http://int.rgo.ru and http://www.geogr.msu.ru/structure/GESJournal/ is free of the above-mentioned mistake.

INSTRUCTIONS FOR AUTHORS CONTRIBUTING TO "GEOGRAPHY, ENVIRONMENT, SUSTAINABILITY"

AIMS AND SCOPE OF THE JOURNAL

The scientific English language journal "GEOGRAPHY, ENVIRONMENT, SUSTAINABILITY" aims at informing and covering the results of research and global achievements in the sphere of geography, environmental conservation and sustainable development in the changing world. Publications of the journal are aimed at foreign and Russian scientists – geographers, ecologists, specialists in environmental conservation, natural resource use, education for sustainable development, GIS technology, cartography, social and political geography etc. Publications that are interdisciplinary, theoretical and methodological are particularly welcome, as well as those dealing with field studies in the sphere of environmental science.

Among the main thematic sections of the journal there are basics of geography and environmental science; fundamentals of sustainable development; environmental management; environment and natural resources; human (economic and social) geography; global and regional environmental and climate change; environmental regional planning; sustainable regional development; applied geographical and environmental studies; geo-informatics and environmental mapping; oil and gas exploration and environmental problems; nature conservation and biodiversity; environment and health; education for sustainable development.

GENERAL GUIDELINES

1. Authors are encouraged to submit high-quality, original work: scientific papers according to the scope of the Journal, reviews (only solicited) and brief articles. Earlier published materials are accepted under the decision of the Editorial Board.

2. Papers are accepted in English. Either British or American English spelling and punctuation may be used. Papers in French are accepted under the decision of the Editorial Board.

3. All authors of an article are asked to indicate their **names** (with one forename in full for each author, other forenames being given as initials followed by the surname) and the name and full postal address (including postal code) of the **establishment(s)** where the work was done. If there is more than one institution involved in the work, authors' names should be linked to the appropriate institutions by the use of 1, 2, 3 etc superscript. **Telephone and fax numbers and e-mail addresses** of the authors could be published as well. One author should be identified as a **Corresponding Author**. The e-mail address of the corresponding author will be published, unless requested otherwise.

4. The GES Journal style is to include information about the author(s) of an article. Therefore we encourage the authors to submit their photos and short CVs.

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