Natural and Social Science Research Cooperation in Northern Russia and Norway for Mutual Benefits across National and Scientific Borders (BENEFITS)

Results and collaboration into the future

Proceedings of the final workshop of Norway-Russia cooperation project BENEFITS

Moscow, 24-27 February 2011

Результаты и будущее сотрудничество

Материалы заключительного совещания совместного норвежско-российского проекта BENEFITS

Москва, 24-27 февраля 2011 г.

Международное и междисциплинарное научное сотрудничество в области социальных и естественных наук на севере России и в Норвегии для взаимного блага (BENEFITS)

МОСКОВСКИЙ ГОСУДАРСТВЕННЫЙ
УНИВЕРСИТЕТ ИМЕНИ М.В.ЛОМОНОСОВА
M.V.LOMONOSOV MOSCOW STATE UNIVERSITY

Results and collaboration into the future

Proceedings of the final workshop of Norway-Russia cooperation project
BENEFITS
Moscow, 24-27 February 2011

Edited by O.V. Tutubalina and E.I. Golubeva

Результаты и будущее сотрудничество

Материалы заключительного совещания норвежско-российского проекта
BENEFITS
Москва, 24-27 февраля 2011 г.

Под редакцией О.В. Тутубалиной и Е.И. Голубевой

Географический факультет МГУ
Faculty of Geography MSU
2011

УДК 502.5
ББК 94
Р 34

Рецензенты: член-корр. РАН, доктор геогр.наук А.П.Капица
профессор, доктор геогр. наук Ю.Ф.Книжников

Results and collaboration into the future.
Proceedings of the final workshop of Norway-Russia cooperation project BENEFITS. Moscow, 24-27 February 2011. Edited by O.V. Tutubalina and E.I. Golubeva. Moscow.: Faculty of Geography, M.V.Lomonosov Moscow State University, 2011. 70 pp.

Результаты и будущее сотрудничество.
Р 34 Материалы заключительного совещания норвежско-российского проекта BENEFITS. Москва, 24-27 февраля 2011 г. / Под ред. О.В.Тутубалиной и Е.И.Голубевой. - М.: Географический факультет МГУ, 2011. 70 с.

ISBN 978-5-89575-192-3

This proceedings volume contains papers of the final workshop of Norway-Russia cooperation project BENEFITS, dedicated to the study of structure and dynamics of the tundra-taiga interface in Russia.
For geographers and ecologists specialising in environmental management and global change.

В сборнике приведены материалы докладов заключительного совещания норвежско-российского проекта BENEFITS, посвященного изучению структуры и динамики переходной зоны тайга-тундра в России.
Для географов и экологов, занимающихся вопросами рационального природопользования и глобальных изменений.

УДК 502.5
ББК 94

ISBN 978-5-89575-192-3

Contents

Organizing Committee, Faculty of Geography, Moscow State University

Academician Nikolay Kasimov, Dean of the Faculty of Geography, Head of the Organising Committee

Prof Sergey Dobrolyubov, Deputy Dean of the Faculty of Geography, Deputy Head of the Organising Committee

Prof Andrey Kapitsa, Corresponding Member of the Russian Academy of Sciences, Head of the Department of Environmental Management

Prof Irina Lurie, Head of the Department of Cartography and Geoinformatics

Prof Yuriy Knizhnikov, Head of the Laboratory of Aerospace Methods, Department of Cartography and Geoinformatics

Prof Elena Golubeva, Deputy Head of the Department of Environmental Management, Executive Secretary of the Local Organising Committee

Prof Natalia Lukina, BENEFITS team coordinator, Centre for Forest Ecology and Productivity, Russian Academy of Sciences, Moscow

Prof Olga Solomina, Corresponding Member of the Russian Academy of Sciences, Deputy Head of the Institute of Geography, Russian Academy of Sciences

Dr Olga Tutubalina, BENEFITS team coordinator, Leading Researcher, Laboratory of Aerospace Methods, Department of Cartography and Geoinformatics

Scientific Programme Committee

Prof Annika Hofgaard, coordinator and leader, PPS Arctic and BENEFITS projects, Norwegian Institute for Nature Research, Trondheim, Norway

Dr Gareth Rees, co-coordinator, PPS Arctic, Scott Polar Research Institute, Cambridge, United Kingdom

Dr Tatiana Vlasova, member of PPS Arctic Steering Board, BENEFITS team coordinator, Leading Researcher, Institute of Geography, Russian Academy of Sciences, Moscow, Russia

Prof Elena Golubeva, Deputy Head of the Department of Environmental Management, Faculty of Geography, Moscow State University, Moscow, Russia

Dr Lyudmila Isaeva, BENEFITS team coordinator, Head of Laboratory of Terrestrial Ecosystems, Institute for Industrial Ecology Problems of the North, Kola Science Centre, Russian Academy of Sciences, Apatity, Russia

Prof Natalia Lukina, BENEFITS team coordinator, Centre for Forest Ecology and Productivity, Russian Academy of Sciences, Moscow

Dr Olga Tutubalina, BENEFITS team coordinator, Leading Researcher, Faculty of Geography, Moscow State University, Moscow, Russia

Technical Committee

Elena Glukhova, Konstantin Golubev, Peter Glazov, Pavel Blyumberg, Nikolay Kolupanov, Alexandra Loshkareva, Alexandra Mamykina, Andrey Medvedev, Anna Mikheeva, Anton Novichikhin, Alexandra Tyukavina, Anna Usacheva, Ksenia Silenchuk

Participants

Bartalev Sergey	Institute of Space Research, Russian Academy of Sciences, Moscow, Russia	bartalev@d902.iki.rssi.ru
Blyumberg Pavel	Faculty of Geography, Moscow State University, Moscow, Russia	pavelblumberg@gmail.com
Budarina Olga	Faculty of Geography, Moscow State University, Moscow, Russia	govorova@mail.ru
Dmitrieva Olga	ATKAR, Moscow, Russia	olgonda@yandex.ru
Dobrolyubov Sergey	Faculty of Geography, Moscow State University, Moscow, Russia	science@geogr.msu.ru
Glazov Peter	Institute of Geography, Russian Academy of Sciences, Moscow, Russia	glazpech@mail.ru
Glukhova Elena	Faculty of Geography, Moscow State University, Moscow, Russia	evglukhova@gmail.com
Golubev Konstantin	Faculty of Mechanics and Mathematics, Moscow State University, Moscow	kgolubev@gmail.com
Golubeva Elena	Faculty of Geography, Moscow State University, Moscow, Russia	egolubeva@gmail.com
Golubeva Maria	Faculty of Geography, Moscow State University, Moscow, Russia	mgolubeva@bk.ru
Govorova Anna	Faculty of Geography, Moscow State University, Moscow, Russia	govorova@mail.ru
Hofgaard Annika	Norwegian Institute for Nature Research, Trondheim, Norway	Annika.Hofgaard@nina.no
Isaeva Lyudmila	Institute for Industrial Ecology Problems of the North, KSC RAS, Apatity, Russia	isaeva@inep.ksc.ru
Kamayev Ilya	Centre for Forest Ecology and Productivity, Russian Academy of Sciences, Moscow, Russia	ilyaokamayev@gmail.com
Kapitsa Andrey	Faculty of Geography, Moscow State University, Moscow, Russia	
Knizhnikov Yuriy	Faculty of Geography, Moscow State University, Moscow, Russia	
Kolupanov Nikolay	Faculty of Geography, Moscow State University, Moscow, Russia	kolupanov@yandex.ru
Kraev Gleb	Faculty of Biology, Moscow State University, Moscow, Russia	kraevg@gmail.com
Krasnushkin Anatoly	Faculty of Geography, Moscow State University, Moscow, Russia	ana-kra@yandex.ru
Kravchenko Tatiana	Centre for Forest Ecology and Productivity, Russian Academy of Sciences, Moscow, Russia	tv.kravchenko@rambler.ru
Kravtsova Valentina	Faculty of Geography, Moscow State University, Moscow, Russia	valentinamsu@yandex.ru
Kuznetsova Ekaterina	Faculty of Geography, Moscow State University, Moscow, Russia	ekaterina.p.kuznetsova@gmail.com
Loshkareva Alexandra	Faculty of Geography, Moscow State University, Moscow, Russia	saxa-tortile@mail.ru

Lovelius Nikolay	Federal State Nature Biospheric Reserve "Taimyrskiy", Russia	lovelius@mail.ru
Lukashov Andrey	Faculty of Geography, Moscow State University, Moscow, Russia	
Lukina Natalia	Centre for Forest Ecology and Productivity, Russian Academy of Sciences, Moscow, Russia	lukina@cepl.rssi.ru
Lurie Irina	Faculty of Geography, Moscow State University, Moscow, Russia	lurie@mail.ru
Mamykina Alexandra	Faculty of Geography, Moscow State University, Moscow, Russia	grnika@yandex.ru
Medvedev Andrey	Institute of Geography, Russian Academy of Sciences, Moscow, Russia	a.a.medvedeff@gmail.com
Mikheeva Anna	Faculty of Geography, Moscow State University, Moscow, Russia	Arvin2@yandex.ru
Novichikhin Anton	Faculty of Geography, Moscow State University, Moscow, Russia	novi-mail@mail.ru
Orlova Maria	Centre for Forest Ecology and Productivity, Russian Academy of Sciences, Moscow, Russia	mashunyaorlova@gmail.com
Pligina Svetlana	Faculty of Geography, Moscow State University, Moscow, Russia	nauka@geogr.msu.ru
Potansky Vladimir	Faculty of Geography, Moscow State University, Moscow, Russia	potanski@mail.ru
Rees Gareth	Scott Polar Research Institute, Cambridge, United Kingdom	wgr2@cam.ac.uk
Romanenko Fedor	Faculty of Geography, Moscow State University, Moscow, Russia	farom@gol.ru
Silenchuk Ksenia	Faculty of Geography, Moscow State University, Moscow, Russia	
Solomina Olga	Institute of Geography, Russian Academy of Sciences, Moscow, Russia	olgasolomina@yandex.ru
Tutubalina Olga	Faculty of Geography, Moscow State University, Moscow, Russia	olgatut@mail.ru
Tyukavina Alexandra	Faculty of Geography, Moscow State University, Moscow, Russia	sasha_tyukavina@mail.ru
Usacheva Anna	Faculty of Geography, Moscow State University, Moscow, Russia	usacheva@list.ru
Vashchalova Tatiana	Faculty of Geography, Moscow State University, Moscow, Russia	vtv_53@mail.ru
Vlasova Tatiana	Institute of Geography, Russian Academy of Sciences, Moscow, Russia	tatiana.vlsv@gmail.com
Zaika Yulia	Khibiny Educational and Scientific Base, Faculty of Geography, Moscow State University, Kirovsk, Russia	khibiny_msu@mail.ru
Zimin Mikhail	Research and Development Center SCANEX, Moscow, Russia	ziminmv@mail.ru

Final workshop programme

24 February 2011	
Small-group meetings, starting at Institute of Geography, RAS	
25 February 2011, Faculty of Geography MSU, Room 1801, Sector A, MSU Main Building	
9:30-10:00	*Registration*
10:00-10:10	Welcome from the Faculty
10:10-10:30	Welcome and overview from project coordinator, Dr Annika Hofgaard
10.30-10.45	Gareth Rees, Ekaterina Shipigina. Treeline research at SPRI
10:45-11:15	Olga Tutubalina, Elena Golubeva, Gareth Rees. BENEFITS project: results of the MSU team, an overview
11:15-11:35	*Coffee break*
11:35-12:00	Tatiana Vlasova and the team. BENEFITS project result - “Northern Socially-oriented Observation Network in the Russian North: Past, Present and Future”. Institute of Geography, RAS
12:00-12:20	Tatiana Vlasova, Annika Hofgaard, Gareth Rees. Ideas and ways for synthesis activities in taiga-tundra interface zone observations, investigations and sustainable management in the Russian North. PPS Arctic team
12:20-13:30	*Lunch at MSU canteens*
	Oral presentations:
13:30-13:45	1. Elena Glukhova, Elena Golubeva, Nikolay Kolupanov. Morphology and age structure of the forest-tundra ecotone at Taimyr peninsula and Putorana plateau
13:45-14:00	2. Alexandra Tyukavina, Elena Golubeva, Valentina Kravtsova. Spatial structure of forest-tundra ecotone and active layer depth in the Ary-Mas site, Taimyr Peninsula
14:00-14:25	3. Natalia Lukina, Ludmila Isaeva. BENEFITS project: results of the CEPF and INEP teams, an overview.
14:25-14:45	4. Maria Orlova, Natalia Lukina, Olga Tutubalina, Vadim Smirnov, Ludmila Isaeva, Annika Hofgaard. Plant-induced soil nutrient variability in forest–tundra ecotones on the Kola Peninsula, Russia
14:45-15:00	5. Anna Mikheeva, Olga Tutubalina, Anton Novichikhin, Hans Tømmervik, Mikhail Zimin, Gareth Rees, Annika Hofgaard. Assessment of spectral unmixing techniques for mapping of tundra-taiga ecotone: case study of the Tuliok River valley, Kola Peninsula, Russia
15:00-	6. Anton Novichikhin. GIS of the BENEFITS project for efficient management and analysis of diverse datasets

15:15	
15:15-15:35	*Coffee break*
15:35-18:00	Poster presentations Oral presentation: Yulia Zaika, Mariette Wheeler, Jenny Baeseman, Allen Pope.The Association of Polar Early Career Scientists – strengthening the leadership opportunities of young researchers. Discussion of publications in progress
18:00	*Workshop dinner at MSU*
26 February 2011, Faculty of Geography MSU	
10:00-11:30	Oral presentations continued, including: Valentina Kravtsova. Defining features of taiga-tundra ecotone structure in Lake Lama (Putorana) key site through satellite image interpretation and mapping of vegetation cover (other essential presentations can be added) Discussions of joint publications
11:30-11:50	*Coffee break*
11:50-13:00	Discussion of joint publications, future projects and grant applications
13:00-14:00	*Lunch at MSU canteens*
14:00-15:30	Discussion of future projects and grant applications continued
15:30-15:50	*Coffee break*
15:50-18:00	Wrap-up session
18:00	Free programme
27 February 2011	
tbd	Possibly discussions of joint publications continued; excursions

Foreword

The project with the short name Benefits is a collaboration project between Norwegian Institute for Nature Research, four Russian partner institutes at the Russian Academy of Science and Moscow State University, and Cambridge University. The overall project aim has been to develop a long-lasting scientific and educational collaboration network between Norwegian and Russian institutions with focus on development in northern regions through combined natural- and social science approaches. The network focuses on young scientist and graduated student activities linked to topics related to processes controlling changes in the boreal-arctic transition zone in Northern Norway and Russia.

The overall aim is reached through emphasis on three focal research themes, based on ongoing nationally funded research projects: I) Development and improvement of tools for characterisation and monitoring of spatiotemporal changes in the transition from forest covered regions to arctic tundra; II) Vegetation dynamics and growth responses to environmental changes and stressors; and III) Construction of a Northern Socially oriented Observation System Network.

Through collaboration within these themes the project, which consists of >40 scientists and students, will generate comprehensive information on i) environmental status and spatiotemporal changes of northern forest-tundra ecosystem; ii) distribution and change of human land use and underlying environmental and social drivers; and iii) subsequent consequences to human societies and the environment. The most important instruments for the collaboration are joint workshops and fieldwork, exchange of young scientists, and joint publications. Fieldwork of the summer 2008 and 2009 took place in Kola Peninsula, and in 2010 in Kola and Taimyr. Researchers and student groups collected and analysed social science data, and ground and remote sensed data for further analyses of the status in the forest-tundra transition zone. Four Russian graduate students have had study stay in Norway during the project period. Four workshops were arranged in 2008 (Cambridge, Apatity, Trondheim, Helsinki), two in 2009 (Tromsø, Zvenigorod), one in 2010 (Cambridge). The final meeting is happening in Moscow in February 2011 and this foreword is opening the abstracts volume of the meeting.

BENEFITS is linked to the IPY core project PPS Arctic[1] which is a multidisciplinary research cluster focusing on circumpolar northern regions and sub-arctic environments, and the transition zone to the Arctic. These regions and the zone are internationally recognised due to its exceptional importance in terms of climate feedbacks, global vegetation, and settlements by indigenous people. Large scale changes in the structure and location of this zone (as predicted) will affect the total northern environment with its people, landscapes and sustainability of resource use. In these regards, changes in forest and tundra distribution are key factors. PPS Arctic includes >140 scientists and graduate students from 10 countries, with activities at >30 sites in the circumpolar forest-tundra zone.

Dr Annika Hofgaard,
BENEFITS project leader and coordinator,
Norwegian Institute for Nature Research

[1] ***PPS Arctic*** is the short name for *"**P**resent day processes, **P**ast changes, and **S**patiotemporal variability of biotic, abiotic and socio-environmental conditions and resource components along and across the **Arctic** delimitation zone".* The project is coordinated by Dr. A. Hofgaard, NINA and co-coordinator Dr. G. Rees, Scott Polar Research Institute, Cambridge University, UK.

Oral presentations (alphabetically by first author)

Morphology and age structure of *Larix gmelinii* tree stands in the forest-tundra ecotone of Taimyr Peninsula and the Putorana plateau

Elena Glukhova, Elena Golubeva, Nikolay Kolupanov
Faculty of Geography, Lomonosov Moscow State University, Moscow, Russia
egolubeva@gmail.com , *evglukhova@gmail.com*

Study of the state of tree stand, its age, the nature of the annual radial increment, its morphometric parameters allows us to speak about trends in vegetation ecosystems in the region. Changes in climatic, edaphic conditions and / or human activities are clearly reflected in the growth potential of forest tree species. Therefore, the density of the stand, its closeness, morphometric characteristics and the age structure can be used in dendrochronological and dendroindication studies.

Under the programmes of PPS Arctic (Present day processes, Past changes, and Spatiotemporal variability of biotic, abiotic and socio-enviromental conditions and resource components along and across the Arctic delimitation zone) and Benefits (Natural and social science research cooperation in northern Russia and Norway for mutual benefits across national and scientific borders) projects of the International Polar Year we have studied the morphometry and age structure of stands of *Larix gmelinii* (trees more than 2 m).

Our purpose is the study of age structure and morphometric parameters of the stand, as indicators of climatic trends in the dynamics of (advance or retreat) of the northern / upper limit of forests in the selected sites of Russian Arctic.

To realize this goal in 2010, studies were conducted in northern Central Siberia, in the territory of the Taimyr Biosphere Reserve (Ary-Mas area, transect length 2550 m and 3 plots) and the buffer zone of Putorana State Reserve (Lake Lama area, transect length 1000 m and 6 plots) and were as follows:

1. Study of age structure and morphometric features of *L. gmelinii* stand at the northern limit of its range (Taimyr Peninsula, Ary-Mas);

2. Study of age structure and morphometric features of *L. gmelinii* stand on the top (altitude) limit of its distribution (Putorana, Lake Lama);

3. Determine morphometric and age features of *L.* gmelinii stand in the forest-tundra ecotone, in connection with natural and anthropogenic factors.

In accordance with the recommendations of the PPS Arctic Protocol within the forest-tundra ecotone the work was performed with a single method for transects and test plots, selected on the basis of pre-field analysis and visual field interpretation of detailed satellite imagery, cartographic material, literature and materials from the collections of host Reserves. To obtain dendrological data from each tree on the transect and in the test plots we have measured: height, diameter at root of trunk and at a height of 1.3 m, linear increase in 2010, the presence of signs of damage (due to animals, fire, wind, human cuttings), crown radius in 4 directions. We have also estimated tree vitality and core samples were taken for determination of age and radial growth. Selected trees were located and georeferenced in satellite imagery.

In total in two sites we have measured and cored 700 trees.

Preliminary results of research ore based on selected 30 specimens of trees from the Ary-Mas site have shown the following.

At the forest line:

1. Age of the trees according to preliminary data (19 samples) varies from 80 to 175 years, the average age of the stand is 125 years.

2. The height of tree increases with age from 2 to 5 meters. There is a direct correlation of tree height with age. Maximum height recorded for trees that have reached one hundred years of age is 5 m.

3. A similar trend was observed for changes in the diameter of the trunk with age. Diameter of trunk at a height of 1.3 m increases from 17 cm to 40 cm. The maximum diameter of the trunk was found in trees over one hundred years old and is 40 cm.

At the tree line:

1. Age of the trees according to preliminary data (11 samples) varies from 80 to 245 years, the average age of the stand is 128 years.

2. Height of single trees increases with age from 3 to 5 m.

3. Diameter of trees at a height of 1.3 m also increases with age from 20 cm in trees of 80 years old up to 40 cm in trees older than 100 years.

The studied larch forest belongs to fifth quality class of Russian forestry classification (forests with the lowest productivity). Throughout the transect and the plots were no trees over 7 m in height and trunk diameter, on average, was less than 20 cm.

Figure 1. Larch tree (L. gmelinii) damaged by tundra hare. Ary-Mas, Taimyr peninsula, 2010. Photo by Anna Usacheva.

Among the entire array of data on morphometry of the stand on the transect of Ary-Mas the clearest correlation between height and diameter characteristic was found for mature trees 3.5-4.3 m in height with trunk diameter (at breast height 1.3 m) of 6-9 cm.

Trees with signs of injuries (browsed by animals, and damaged by other natural factors) accounted for about 70% of the total number of trees (Figure 1).

For the plateau Putorana site:

1. Trees with signs of injuries (damaged by rockfalls, screes, wind and other natural factors) accounted for about 30% of the total number of trees.
2. Data on the age structure of the stand are being processed.

Further analysis of morphometric data, age structure and dynamics of radial growth of the stand for study sites will be carried out as processing of field data continues.

Defining features of taiga-tundra ecotone structure in Lake Lama (Putorana) key site through satellite image interpretation and mapping of vegetation cover

Valentina Kravtsova
Faculty of Geography, Moscow State University
valentinamsu@yandex.ru

Why mapping?

A narrow strip of transect and small areas of test plots investigated in the field do not allow to understand features of the taiga-tundra ecotone structure for wider territory. It is possible to investigate such features by interpretation of satellite images of very high resolution. In Lama key site, Putorana Plateau, we used GeoEye images taken on 19.08.2009 with resolution 0.4 m in panchromatic and 2 m in 4 spectral bands; a colour resolution-merged image of these was used. A scheme of visual interpretation was created in the scale of 1:2,000 for a subset of this image covering the area of 1500 x 800 m (6 sheets of A-4 format). The best scale for forest types visualisation and interpretation in these images is 1:1,000, and it was used in the work. Ten the interpretation scheme was reduced and the map was coloured in the scale of 1:4,000.

Legend of the map characterises the type of vegetation, species structure and density of tree layer, dominant species of dwarfshrub and understorey layers, and eudaphic conditions. Divisions of the legend allow to define the position of ***crummholz line*** (between stone tundra with fragments of low dwarfshrub tundra and aldergrove tundra, numbers 1 and 2 in legend), ***tree line*** (the top part of “redina”, or treeline ecosystem - stone surfaces with single larches at distances over 20 m, number 3 in legend) and ***forest line*** (the top part of sparse larch forest with moss understorey and vegetation-covered stone flows or “kurums”, number 4 in legend).

The compiled map shows us specific features of taiga-tundra ecotone spatial structure in this region.

The investigated area is located at the northern slope of a ridge (1070 m in height), 3 km to the south of Lama Lake, and includes the lower part of the ridge slope, from height of 600 m to the channel of the Omon-Yuryakh River tributary. Flat surfaces of traps, typical for Plato Putorana are outside of our key site, but steps of trap slopes are present in the southern part of the key site and cause the specifics of the forest-tundra zone. In the northern part they change with forests at slopes of the Omon-Yuryakh tributary valley.

Fragments of tundra vegetation (low dwarfshrubs with alpine species) are growing in the upper part of the key site at the height of 570 m (all heights are given here approximately). The boundary between tundra and forest-tundra in the northern direction goes down to 500 m , but at both sides of the watershed, where warming influence of neighbouring valleys takes place, this boundary has a higher position, especially at western side. Below the tundra zone, the forest-tundra goes down to heights 350 m and has the width of 400 m. This wide zone consists from some belts connected with traps downstairs. The upper belt (500-450 m) is discrete, consist from islands of vegetation at the background of stone surfaces. There are islands of alder shrub, which may be accounted as shrub tundra and associated with crummholz zone in other regions. Such kind of vegetation prevails in this belt (50%). Other islands are characterised by trees of larch at stone surfaces/ These are single trees with distance between them more than 20 m (“redina”) and sparse larch forests on stone surfaces (with 10 m distance). And the fourth kind of vegetation in this belt is sparse larch forest with dense alder shrub understorey (these spots are clearly seen in false colour infrared images due to red color).

The second belt in the forest-tundra zone (450-400 m) is the stone belt, typical for trap stair; it is practically without vegetation cover.

The third belt (400-350 m) conist mainly of “redina” – single larches at stone surfaces with spots of sparse larch forests on stones and plenty of small islands of sparse larch forests with dense alder understorey. These islands usually take position in the low part of the stone scree, where stone material is smaller and where underground water is surviving. These larch-alder islands are concentrated along the lower borders of the stone belt and stones with “redina” belt.

At slopes below 350 m forests are distributed. As a rule they are sparse forests of larch with different understorey: *Ledum*-mosses on vegetated stone surfaces or *Betula nana* dwarfshrub layer at even slopes. At lower heights and steeper slopes there are birch-larch forests. Areas of very dence birch scrub with alder and larch are situated at very steep slopes and along water flows.

At left bank of the Omon-Yurach River tributary strips of larch forests at vegetated stone mounds caused by debris flows, are alternating with strips of aldergroves in hollows and along watercourses.

All kinds of vegetation types have specific features of their representation in satellite images and they will be analysed for advancing of the interpretation keys. We also plan to create these analyses for areas 30x30 m to find satisfactory ways of using Landsat TM/ETM+images with 30 m resolution for investigation of taiga-tundra ecotone dynamics.

BENEFITS project: results of the CEPF and INEP teams, an overview

Natalia Lukina[1], Ludmila Isaeva[2]
[1]*Centre for Forest Ecology and Productivity (CEPF) of the Russian Academy of Sciences, Moscow, Russia*
lukina@cepl.rssi.ru
[2] *Institute of Industrial Problems of the North (INEP), Kola Science Centre of the Russian Academy of Sciences, Apatity, Russia*
isaeva@inep.ksc.ru

Our work addresses the relationships between plants, soil and soil microfauna, and the potential impacts of vegetation shifts caused by climate change on soil properties in forest - tundra ecotones in the Kola Peninsula, Russia. We studied: 1-vegetation cover structure (PhD student Tatyana Kravchenko and Elena Belova), 2- ground vegetation phytomass (Elena Belova), 3- tree composition and dendrometric characteristics (height and diameters) (Ludmila Isaeva, and students Vyacheslav Ershov, Sergey Kisilev); 4- chemical composition of predominant plants (concentrations of nutrients and secondary metabolites) (Ludmila Isaeva, Natalia Artemkina); 5- soil properties (Maria Orlova, Natalia Lukina), and 6- soil microfauna (PhD student Ilya Kamaev),in the forest–tundra ecotones in the Khibiny Mountains (altitudinal gradient) and in the surroundings of Lake Kanentiavr (latitudinal gradient). We consider the soil-vegetation cover as a composition of spatial functional micromosaic elements, or compartments. We identified these compartments by the detail (1:20 and 1:100 scale) field mapping of vegetation structures in representative areas (10x50, 10x1000 m) in the ecotones, allowing us to characterize vegetation structure and species diversity. For larger areas using high resolution satellite imagery (0.5m) we investigate the tree-line boundary changes in space. We suggest to use these established plots for monitoring of the tree-line boundary dynamics in time. From eight to ten predominant compartments, and tens compartments as a total, have been identified in the ecotones. We have found significant differences in the dynamic soil properties (acidity, fertility) between the predominant compartments as well as between the zones/belts, and ecotones consisting of the compartments. The richer in nutrients were spruce and birch forests, and spruce, willow and birch compartments. The upper soil horizons of latitudinal ecotone were richer in bio-available nutrients whereas soil forming rocks were richer in the Khibiny Mountains ecotones. We attribute all these differences to the effects of predominant plants, e.g. to their senescent organs chemical composition, characteristics of tree crowns (density, length), and age of trees, and also to the effects of soil microfauna. The soil macrofauna abundance and biomass increased from tundra to the birch and spruce forests. The species number of earthworms increased from 1 species in the tundra to 4 in the valley intermontane forests. Earthworms' activity resulted in forming rich in bio-available nutrients zoogenic humus horizons in forest sites.

We suggest that advance of trees and shrubs will result in increasing bio-available nutrient concentrations in soil, and may induce higher rate of the organic matter decomposition in lichen and moss dominated tundra and forest-tundra.

The authors are grateful to the Research Council of Norway for financial support through grants to A. Hofgaard from the program OST, project 185023/S50, and program IPY, project 176065/S30; Maria Orlova also is supported by Young Scientist Support Grant of President of Russian Federation (MK-4046.2011.4); project 10-04-00213-a of the Russian Foundation for Basic Research and by the 'Biological diversity' Programme for basic research of the Presidium of the Russian Academy of Sciences. The paper is a product under the IPY core project PPS Arctic.

Assessment of spectral unmixing techniques for mapping altitudinal forest line: case study of the Tuliok River valley, Kola Peninsula, Russia

Anna Mikheeva[1], Olga Tutubalina[1], Anton Novichikhin[1], Hans Tømmervik[2], Mikhail Zimin[3], Gareth Rees[4], Annika Hofgaard[5]

[1]*Faculty of Geography, Moscow State University, Moscow, Russia*
arvin2@yandex.ru
[2]*Norwegian Institute for Nature Research, Tromsø, Norway*
[3]*Research and Development Center SCANEX, Moscow, Russia*
[4]*Scott Polar Research Institute, Cambridge University, Cambridge, United Kingdom.*
[5]*Norwegian Institute for Nature Research,Trondheim, Norway*

One of the most important features to map and monitor in the forest-tundra ecotone is the northern limit of the boreal forest (henceforward referred to as the forest line). This line is defined as the latitudinal limit at which forest canopy closure ceases and the maximum distance between single trees (height > 3 m) starts to exceed 30 m (Mork, 1970). Such definition, however, can be directly used only to interpret very high resolution imagery, where single trees are resolved.

It is convenient to base the interpretation of coarser resolution multispectral imagery for large areas on results of interpretation of more detailed imagery and on certain reference spectra of trees and forest understory. As we can seldom extract "laboratory-like spectra" (measurements of homogenous objects using spectrometers) for forest stands at the forest line and in the taiga-tundra transition zone, where tree cover is often scattered, we have chosen to evaluate various spectral unmixing techniques on heterogeneous vegetation like pine forests, spruce forests, birch forests, shrubs and mountain heaths. The main objective of this paper is to test the usefulness of these algorithms for detection of the forest/non-forest areas by defining dominant vegetation for different altitudinal zones on the test site in Tuliok valley, Kola Peninsula, Russia. Development of detection techniques will be valuable to establish benchmark forest line positions at the study site for further regional analysis using medium-resolution multispectral satellite imagery.

The Tuliok study site is situated in the Tuliok River valley in the eastern Khibiny Mountains, central Kola Peninsula, Russia. It is a site approximately 3x2 km in size, located on a north-facing slope of Mount Saami (1005 m. a.s.l.). The flood plain and lower part of the slope at the Tuliok site is covered by mixed birch-spruce forest (320-410 m.a.sl.) growing on glacial till. The forest line (birch) is located at 410- 415 m a.s.l. The transition forest-tundra belt above the forest line is present at altitudes up to 530-580 m a.s.l. Above this altitude a krummholz belt is present up to 670-680 m.a.s.l. Above 680 m.a.sl. dwarf shrub-lichen and moss-lichen tundra prevails.

Spectral unmixing techniques are used to reveal sub-pixel information from mainly hyperspectral imagery (Goodenough et al., 2008). Such techniques are composed of two separated processes: extraction of endmembers which are pure pixels of a material depicted in hyper-spectral imagery, ground-based spectrometry or spectral libraries; and calculation of the spatial coverage of the extracted endmembers on a pixel by pixel basis.

The most popular unmixing technique is the linear spectral unmixing method (LSU) where the radiance of an area, depicted in one pixel is interpreted as a sum of radiances of the endmembers, composing this area. Spatial coverage of the end members is derived through a system of linear equations, and thus the number of endmembers detected is limited by the number of spectral bands in an image. Since conventional sensor systems such as Landsat MSS, TM, SPOT HRV, IRS LISS and Terra ASTER only acquire data in a few spectral bands, spectral unmixing methods are not commonly used on such imagery, but Ranson et al. (2004) obtained satisfactory results using spectral unmixing on Landsat, MERIS and MODIS imagery. This method was also tested in this study on a Terra ASTER image.

The second method applied here is Mixture Tuned Matched Filtering (MTMF) which performs a partial unmixing - finding the abundances of user defined materials (endmembers). All the endmembers in the image need not to be known for applying this technique. This technique maximizes the response of the known endmember and suppresses the response of the composite unknown background, thus "matching" the known signature. The matched filtering results appear as gray-scale images with value ranging from 0.0 to 1.0. These images provide a means of estimating relative degree of match to the reference spectrum and approximate sub-pixel abundance, where 1.0 is a perfect match with the reference spectrum and 0.0 is a no match situation. It provides a rapid means of detecting specific materials based on matches to library or image endmember spectra and does not require knowledge of all the endmembers within an image scene (Boardman, 1993).

In this study the main spectral data exposed to experiments of unmixing processing was a Terra ASTER image of 2004-07-30 and the reference data was a QuickBird (QB) image of 2006-06-28. Prior to unmixing the images were converted to units of spectral radiance for improvement of comparability, geometrically corrected and co-registrered.

Two different methods of spectral unmixing - MTMF and LSU - were used for detection of forest/non-forest areas and compared among themselves. Five different classes were intended to be the main endmembers in the classification: stones, birch forest (*Betula tortuosa*), spruce forest (*Picea abies*), white lichens (*Cetraria nivalis*) and dwarf-shrubs (including *Betula nana*, *Empetrum nigrum*, *Vaccinium myrtillus* and their mixtures). These were extracted from the ASTER image manually using ground truth (field vegetation descriptions and photos) and QB image on the same test site. The unmixing methods are very sensitive to the endmembers and usually for the best result ground-collected spectra are needed; our endmembers were collected pixel-by-pixel to ensure that they give a complete representation of the final class.

To evaluate the result of the image unmixing in detail a reference map with vegetation types abundances was produced. We used the same QuickBird multispectral image for the study area and IHS-transformation of this image to classify it to 10 classes (shadowed and lit classes for stones, lichens, dwarf shrubs, deciduous and coniferous trees). The accuracy of the classification was estimated using field data collected on the 1.5 km x 1.8 km test site and random reference points classified visually on the same classes. Random reference points assessment used over 6,400 points initially with equal quantity for each class) for 40 km^2 of the QuickBird scene subset over the Tuliok valley. As we are interested in separating trees/non-tree areas the accuracy assessment results for single classes were merged to analyse only these two types of territory. The results are shown in Table 1.

Table 1. Accuracy assessment for QuickBird classification (6417 points used for 40 km^2 area)

	Number of correct points	Total classified points	Accuracy,%
TREES	840	955	87.96
NON-TREES	4174	5462	76.42

This classification of the Tuliok valley vegetation types was then used for evaluation of the unmixing results. Nine test profiles were created within the study area along the gradient forest – tundra from the bottom of the Tuliok River valley uphill. By means of GIS and with use of a digital elevation model (DEM), sample points of the highest position of closed birch forest line were created along the profiles lines. This set of sample points served as the basis for the further analysis of the position of altitudinal forest line.

MTMF method has shown the most appropriate result of the spectral unmixing experiments. Spectral processing results have been displayed in the form of separate images corresponding to each endmember. MTMF method applied to ASTER image gave 5 score (abundance) images for 5 different classes (endmembers) such as stones, *Betula tortuosa,* white lichens, birch-spruce forest and some shaded pixels and dwarf-shrubs. The “stones” score image showed the target areas very well (all open stones are represented by bright pixels in this image, which was confirmed during the fieldwork and by comparison with QB image).

Results of the LSU method proved not suitable for the further use since they exhibited large errors in comparison with QB classification. Therefore we have not subjected them to detailed assessment.

The problem of false values of classes (false alarms) is also present in the results of the other algorithm, MTMF, but as a whole its results are much better. We have compared the highest position of forest line on each test profile for the unmixing map and the reference classification map, as shown in Table 2.

Table 2. Comparison of the highest forest-line points elevation on the unmixing result and on the reference classification.

Profile N	H, MTMF unmixing result, m.a.s.l.	H, QB classification, m.a.s.l.	Difference of heights MTMF-QB, m
1	436	422	14
2	486	429	57
3	468	423	45
4	478	446	32
5	459	460	-1
6	450	451	-1
7	497	494	3
8	446	434	12
9	494	488	6

The general altitudinal difference between the ASTER and QuickBird - derived forest line positions could be explained by the difference in the spatial resolution of the source imagery, which also means that with decreased spatial resolution of the imagery, the forest line has a tendency to be elevated upslope by 1 to 3 ASTER pixels.

Along the profiles 2-4 the highest forest line values are the most different. This is caused by errors in unmixing result: the uphill dwarf shrubs (*Betula nana*, *Empetrum nigrum*, *Vaccinium myrtillus*) were mixed spectrally with *Betula tortuosa* which is the main forest species there. Along the profiles 5-7 and 9 there were dense white lichen areas and the forest line was sharper on this light background, influencing the spectral unmixing results positively.

The difference of values of forest line heights could also partially be explained by the error of georeferencing of the images averaging 15 m which is expressed in up to 5.5 m of elevation (the predominant slope values in the study area are up to 20°).

Using MTMF method for spectral unmixing shows its applicability for allocation of forested/non – forested territories. However, the spatial accuracy of this allocation is not higher than accuracy of regional vegetation maps (scale 1: 50 000 and smaller). The method is very sensitive to endmembers spectra: the best results are observed in the areas where the top boundary of forest is presented by birch (*Betula tortuosa*).

The research was supported by the Russo-Norwegian project of the Norwegian Research Council BENEFITS (OST 185023/S50), A. Mikheeva and O.Tutubalina were supported by the Russian Programme of Leading Science Schools Support, project НШ 3405.2010.5171 and Russian Scientific Educational Centres program «НОЦ», grant No. 14.740.11.0200.

References

1. Goodenough, D.G., Han, T., and Dyk. A. 2008. Comparing and validating spectral unmixing algorithms with AVIRIS imagery. *Canadian Journal of Remote Sensing,* Vol. 34, Suppl. 1, pp. S82-S91.
2. Mork, E. 1970. The climate in mountain forest at the timberline and its influence on the forest's growth and extension in the alpine zone, *Tidsskrift for skogbruk.* Vol. 78. pp. 198-208.
3. Ranson, K.J., Sun, G., Kharuk, V.I., and Kovacs, K. 2004. Assessing tundra-taiga boundary with multi-sensor satellite data. *Remote Sensing of Environment*. Vol. 93, 283-295.
4. Boardman, J. W., 1993. Automated spectral unmixing of AVIRIS data using convex geometry concepts: in Summaries, Fourth JPL Airborne Geoscience Workshop, JPL Publication 93-26, Vol. 1, p. 11 - 14.

GIS of the BENEFITS project for efficient management and analysis of diverse datasets

Anton Novichikhin
Faculty of Geography, Lomonosov Moscow State University, Moscow, Russia
novi-mail@mail.ru

Polar vegetation studies require both remote and field data analysis. Satellite imagery provides continuous information about ground surface over large territories, so it helps to obtain information about areas inaccessible for fieldwork. Resolution of these data varies from detailed level (IKONOS, QuickBird, GeoEye, etc.) but with small spatial coverage, to middle resolution level (SPOT, Terra ASTER, Landsat ETM+) with broader spatial coverage. Field work is a way to collect the most complete and trusted but very discrete information, because spatial coverage of survey is limited with available time for fieldwork, transportation possibilities and total cost of these activities.

GIS-based integration of discrete data collected during the fieldwork and satellite imagery of different resolution through visualization in 2D or 3D mode could help to use these data together to produce high quality maps and to provide information on present condition and dynamics in polar ecosystems.

Field information is provided in different ways, so the main process of GIS creation gains on good cartographic representation of this data. We applied a dynamic segmentation approach for displaying ground ecological transect and descriptions of its points in 2D/3D aligned with detailed images and products of their processing (image-derived tree heights, crown cover, tree line and forest line positions). DEMs and topographic maps were added to this system to provide i) geographic context to study areas, and ii) to extract certain features and terrain characteristics. Also field interpretation maps compiled on the basis of satellite images were georeferenced and aligned with the rest of data.

When uploading of all remote and field data will be finished and some analysis made, we a going to present results of geographical studies effected during the BENEFITS project in a web map with some data available for open access.

This research is part of PPS Arctic, the IPY project which investigates current status and past changes in the circum-arctic treeline zone, as well as associated social and natural factors. The study is carried out in the Laboratory of Aerospace Methods of the Faculty of Geography, Moscow State University, financially supported by the Benefits Russo-Norwegian project of the Norwegian Research Council (OST 185023/S50).

Plant-induced soil nutrient variability in forest–tundra ecotones on the Kola Peninsula, Russia

Maria A. Orlova [1], Natalia V.Lukina[1], Olga V.Tutubalina[2], Vadim E.Smirnov[3], Ludmila G. Isaeva[4], A. Hofgaard[5]

[1]*Centre for Forest Ecology and Productivity of the Russian Academy of Sciences, Moscow, Russia*

mashunyaorlova@gmail.com

[2]*Faculty of Geography, Moscow State University, Moscow, Russia*

[3]*Institute of Mathematical Problems of Biology of the Russian Academy of Sciences, Puschino, Moscow region*

[4] *Institute of Industrial Problems of the North, Kola Science Centre of the Russian Academy of Sciences, Apatity, Russia*

[5]*Norwegian Institute for Nature Research, Trondheim, Norway*

This work addresses the plant-induced soil nutrient variability in forest - tundra ecotones in the Kola Peninsula, Russia. We have studied changes in the soil nutritional status induced by Norway spruce (*Picea abies* (L.) Karst.), white birch (*Betula pubescens* Ehrh.), shrubs, herbs, green mosses and lichens in the forest–tundra ecotones in the Khibiny Mountains (altitudinal gradient) and in the surroundings of Lake Kanentiavr (latitudinal gradient). This study also addresses the potential impacts of vegetation shifts caused by climate change on soil nutritional status. Comparing ecotones we have found higher concentrations of nutrients in the organic horizons of latitudinal ecotone (Kanentiavr) whereas nutrients in soil forming rock here were significantly lower compared to the Khibiny Mountains ecotones. Comparing zones we have found higher concentrations of soil nutrients in spruce forests compared to birch forests/forest tundra and tundra, and in birch forest/forest tundra compared to tundra against the background of different trends in the soil forming rock. We attribute the differences in soil nutritional status to the effects of predominant plants, e.g. to their senescent organs chemical composition, characteristics of tree crowns (density, length), and age of trees. We suggest that advance of trees and shrubs could result in increasing bio-available nutrient concentrations in soil, and may induce higher rate of the organic matter decomposition in lichen and moss dominated tundra and forest-tundra. This would promote further colonization by trees and shrubs, their successful growth and development, and carbon sequestration in the growing biomass.

The authors are grateful to the Research Council of Norway for financial support through grants to A. Hofgaard from the program OST, project 185023/S50, and program IPY, project 176065/S30; Maria Orlova also is supported by Young Scientist Support Grant of President of Russian Federation (MK-4046.2011.4); project 10-04-00213-a of the Russian Foundation for Basic Research and by the 'Biological diversity' Programme for basic research of the Presidium of the Russian Academy of Sciences. O. Tutubalina has been supported by the Russian Programme of Leading Science Schools Support, project НШ 3405.2010.5171 and Russian Scientific Educational Centres program «НОЦ», grant No. 14.740.11.0200. The paper is a product under the IPY core project PPS Arctic.

Treeline research at SPRI

Gareth Rees, Ekaterina Shipigina
Scott Polar Research Institute, University of Cambridge, United Kingdom
wgr2@cam.ac.uk , es377@cam.ac.uk

In this talk we will present an overview of research at the Scott Polar Research Institute. The two main strands of our research relate to anthropogenic disturbance to the tundra-taiga ecotone, and both focus on the development of automated remote sensing techniques for detecting such disturbance. However, we also give a brief introduction to work on modelling the equilibrium circumarctic distribution of forests.

1. Advanced approach to mapping human impact on vegetation of the European North

The European sector of the Arctic and sub-arctic is the most heavily industrially developed, and human impact is generally significant in the region. It is at least arguable that local to regional-scale anthropogenic effects play a role in determining the location and structure of the treeline. The range of types of impact is large, including industrial atmospheric pollution, fire, mining, urbanisation and infrastructure development, grazing and logging. These phenomena can all be usefully investigated using satellite remote sensing methods, and many studies have been published. However, no systematic study, integrating a number of types of disturbance, has yet been reported for the whole of the European North. This is perhaps not surprising because of the size of the region. In our work we seek to develop new tools that can automate this process to a large extent, providing reproducibility and objectivity in classification of satellite images and achieving a high throughput so that many images can be processed. We try in particular to use free open-source software wherever possible.

2. Automated spaceborne detection of degraded vegetation around Monchegorsk, Kola Peninsula, Russia.

Atmospheric emissions from the industrial complex at Monchegorsk (primarily sulphur dioxide from nickel smelting) is well known to have caused significant damage to surrounding vegetation over many years, and this has been the subject of a number of quantitative and qualitative investigations using satellite remote sensing data. However, many of these can be described as more or less labour intensive, requiring extensive fieldwork and some skill in analysis. The goal of the work described here is to develop a technique that minimises these aspects, so that it can be more confidently applied to areas for which little or no field data are available. The technique is based on establishing an empirical relationship between topographic variables and the normalised difference vegetation index (NDVI), and then identifying statistically significant departures from this relationship. The technique is shown to work well for the (already well known) Monchegorsk area, where the empirical model can explain 64% of the variance in NDVI in unaffected areas and clearly identifies the most heavily damaged areas of vegetation.

3. Are trees invading the arctic?

As part of a collaboration across much of the PPS Arctic group, it is necessary to establish a circumarctic baseline of the 'expected' rate of advance of the treeline to place beside already published scenarios such as that of the Arctic Climate Impact Assessment (ACIA). Equilibrium models assume that the vegetation distribution is in equilibrium with climate variables. In order to be able to extrapolate such models far (say 100 years) into the future and the past it is necessary for them to be based on the comparatively few climate variables that can be estimated or are known for those times. We have experimented with the use of seasonal temperature and precipitation data to provide empirical fits to the current distribution of vegetation (estimated from MODIS satellite data). These suggest rates of advance of the treeline that, while being consistent with those estimated by ACIA, are unrealistically high at a few kilometres per year.

BENEFITS project: results of the MSU team, an overview

Olga Tutubalina[1] Elena Golubeva[1], Gareth Rees[2]
Contributing authors: Maria Golubeva, Anna Govorova, Valentina Kravtsova, Alexandra Loshkareva, Anna Mikheeva, Anton Novichikhin, Alexandra Tyukavina, Mikhail Zimin
[1]*Faculty of Geography, Moscow State University, Russia*
olgatut@mail.ru
[2]*Scott Polar Research Institute, Cambridge, UK*
wgr2@cam.ac.uk

We have built our project research upon integrating i) field ecological research, characterising vegetation, soils and terrain of key sites; and ii) traditional and novel ways of extracting information on position and structure of the ecotone areas from remotely sensed imagery, with particular focus on very high resolution (0.5-4 м, for key sites) and moderately-high resolution (15-30 m, for larger areas) satellite images. Project activities have been carried out in two contrasting regions: north-west Russia (2008-2010, centre and north of Kola Peninsula, as well as Vaigach Island) and north of Central Siberia (2010, Ary-Mas in south Taimyr and south-central shore of Lake Lama in western Putorana Plateau). Key tree species include birch, pine and spruce in NW Russia and larch in Siberian sites. Within sites controlled by mostly natural factors, advance or stagnation of treeline has been recorded; recession of treeline is noted only in sites severely damaged by industrial activity, e.g. near Monchegorsk nickel smelters.

Remotely-sensed images help to identify ecotone features and processes, and highlight tendencies of ecosystem change over large territories. High-resolution images enable to delineate ecotone boundaries and find their links with factors on the ground, in order to create a model of ecotone change. Such model is validated by comparing spectral properties of vegetation *in situ* and in the images, and by field measurements of other parameters. After validation some parameters may be inferred through image analysis. We realised this approach in three years (2008-2010) of the BENEFITS project of the IPY PPS Arctic in Kola Peninsula, Taimyr Peninsula and Putorana Plateau, Russia. The results of the team members include:

1. Research of natural and anthropogenic factors. The anthropogenic/technogenic factor (airborne pollution) has been analysed for ecosystems in Kola Peninsula. Comparative analysis of altitudinal zonality in Monchetundra mountains near Monchegorsk in pre-industrial and current period has demonstrated that technogenically induced treeline vegetation changes occur by the 1-2 orders of magnitude quicker (in years and first decades) than due to natural factors (which can only slightly modify the rate of changes in industrially impacted regions. Impacted areas near Monchegorsk stretch for hundreds of square kilometres. Regeneration of ecosystems after halting the impact would be in some cases impossible without specific remediation measures and in some cases will take hundreds of years.

Natural factors influencing the forest line position have been investigated for the Khibiny Mountains. The forest line is on average located at 350 m asl. Its position is much lower in the eastern Khibiny, supposedly due to orographic effect (shortage of precipitation in the east). On the western slope of Khibiny, wind is a negative factor lowering the forest line. The most favourable conditions for forests are found in large river valleys.

Natural factors such as terrain, soil-forming rocks, winds, hydrothermal parameters have significant influence on the redistribution of man-made pollutants and form a complex picture, making assessment of the state of ecosystems and soil pollution more difficult.

2. **Long-term treeline changes** have been investigated in two key sites in Khibiny, with old airphotos and contemporary satellite imagery. Treelines show consistent upward movement from 1958 to 1999 and to 2006/2008. At Tuliok the measured treeline advance (birch) is 29 m per 48 years; at Umechorr (birch and pine) it is 27 meters per 50 years. The actual advance may be less, due to poor resolution of the old photos.

In Taimyr and Putorana sites, age structures of larch trees, sedlings and saplings are being investigated (currently 200 saplings from each site have been processed), and preliminary results indicate slow treeline advance at Ary-Mas (Taimyr).

3. **Spatial extent and structure of treeline ecotone** has been investigated for the case study of the Ary-Mas site (Taimyr) by ground mapping of vegetation and permafrost along a 2250 m transect and in six test plots using a 5x5 m grid. Larch trees were found to be located in the areas with the shallowest active layer. Other features of the exotone and link to spectral properties of satellite imagery are being studied.

Similar studies of vegetation structure have been effected by the CEPF and INEP teams in Kola Peninsula with our participation.

For the study of the treeline ecotone we have been developing several **remote sensing techniques**. Here are some selected results:

1. Significant negative correlations were found between above-ground phytomass and ground-radiometry NDVI of lichen-dominated samples, suggesting possible mapping of lichen tundra phytomass over wide areas. However, 4-channel ground radiometry overall does not allow to distinguish all significant vegetation components of the forest-tundra ecotone.

2. A method has been developed for automatic extraction of tree locations, tree height, canopy cover and treeline position have been automatically interpreted

from very high resolution multispectral satellite data and validated *in situ*. Trees in sparse forests (shadows do not overlap) are identified with over 80% accuracy for birch (provided it is of sufficient height and diameter to be resolved in satellite imagery) in Kola Peninsula and with somewhat smaller accuracy for larch (Larix gmelinii) in Taimyr Peninsula, due to very thin crowns of larch. QuickBird imagery proved radiometrically better than Ikonos and GeoEye imagery for identification of trees. Height measurements with shape-from-shadow technique have demonstrated accuracy of 3m or better in 70% cases (for a test site in Khibiny Mts).

3. Analysis of subpixel spectral components of Landsat ETM+ and Terra ASTER pixels has been performed by comparison with QuickBird images. Currently ETM+ and ASTER images are not suitable for accurate mapping by spectral unmixing due to many spectrally similar components of the tundra-taiga ecotone. Of particular note is combination of birch crowns and shadows which is similar in spectral reflectance to dwarf shrubs. Mapping altitudinal forest line with ASTER data results in shifting its position upslope by 1-3 ASTER pixels

4. Forest line in Fennoscandia and NW Russia has been mapped from relatively high resolution multispectral imagery (10-30 m) with an accuracy of 50-200 m.

Many young scientists have been involved and professionally developed in this project, including participation in conferences and exchanges, earning conference prizes, writing articles and books and even getting on the executive board of APECS. They continue to carry this project forward.

Future work includes completion of field data processing and seeking ways for more integration with social science approaches in looking at the study areas, in order to suggest practical applications of natural science results in community adaptation to change.

Spatial structure of forest-tundra ecotone and active layer depth in the Ary-Mas site, Taimyr Peninsula

Alexandra Tyukavina, Elena Golubeva, Valentina Kravtsova
Faculty of Geography, Lomonosov Moscow State University, Moscow, Russia
sasha_tyukavina@mail.ru

During field work in the Ary-Mas study site a detailed investigation of six plots with different types of vegetation was performed. Plots were situated in sparse larch forest (PP1, size 50x50 m), larch forest-tundra (PP2, 50x50m; PP5, 20x20 m) and tundra (PP3, PP4, PP6, 20x20 m). Corners of each study plot were fixed with larch-wood poles, coordinates of corners were defined with a hand-held GPS-receiver. Each study plot was divided into squares of 5x5 m. Within each square, geobotanical description of the field layer with counts of projective cover separately for dwarf shrubs, grass, green mosses, lichens, etc. was carried out. On a graph paper in scale 1:100 the position of trunks and crowns of all trees on a study plot was sketched. Tree crowns were measured in 4 directions, according to the sides of the horizon. All trees were marked with metal number plates, and tree number and condition (healthy, damaged, dead) were recorded. Besides, on the field schemes of study plots all bushes and larch seedlings and saplings, with their height (in cm) and a annual linear growth (for larch seedlings and saplings) were marked. Position of stubs and fallen trees was also recorded in the schemes. In addition to geobotanical descriptions and tree layer schemes, morphometric measurements, coring of the numbered trees for age determination, as well as hemispherical photographs and ground spectral measurements were made. The depths of permafrost (active layer) was measured on a regular grid (5 measurements in each square 5x5m), and around each tree 3 additional measurements were added to observe dependencies between active layer depth and tree distribution.

Further processing of field tree layer schemes and geobotanical descriptions included digitizing and precise georeferencing. Vegetation schemes of non-tundra plots (PP1, PP2, PP5) were georeferenced to Ikonos satellite image (17.07.2002) shadows of individual trees and tree groups, reaching location accuracy of 1-2 m. Tundra plots were georeferenced with GPS coordinates with an accuracy about 10-20 m.

In tundra plots (PP3, PP4, PP6) strong correlation between active layer depths and bottom layer type were observed. In general, 5x5 m squares with the predominance of grasses are characterized by the greater active layer depth (40-50 cm), compared to dwarf-shrub and moss-dominated squares (15-20 cm). An exception is plot PP4: its eastern part is occupied by the local moist relief depression with deep active layer (50-60 cm) and bottom layer dominated by *Betula nana*.

Spatial structure of vegetation and active layer depth distribution in the sites with forest vegetation (PP1, PP2, PP5) is more complex. The majority of trees in the given area grow in biogroups (clumps), this is why one shadow on satellite image can correspond either to one separate tree, or to a group of trees. To compare the crown shadow area in the Ikonos image to the real tree crown projection area, field tree schemes were used. The results, given in table 1, show, that within Ary-Mas study site tree crown projection areas could be estimated remotely as half of tree crown shadows area on Ikonos image.

Table 1

№	plot area, m^2	A = percentage of tree crown shadows on satellite image, %	B = percentage of crown projections on the field tree layer scheme, %	ratio A : B
pp1, north	500	21	11	1,9 : 1
pp1, center	600	18	8	2,4 : 1
pp1, south	500	22	11	2,0 : 1
pp2	2500	6	3	2,0 : 1
			mean	2,1 : 1

To find out whether there is a dependence between field layer structure for non-tundra plots, as derived from field geobotanical descriptions, and image spectral characteristics, the Ikonos image-derived spectral graphs averaged within squares of study plots have been analysed. The analysis of graphs shows that insignificant distinctions in brightness (about 10%) are observed only in the NIR channel of Ikonos (0.76 - 0.85 nm). However, the observed distinctions in NIR brightness cannot be explained by the differences in the percentage of field layer core components (dwarf-shrubs, grasses, mosses). Values of average square brightness in NIR vary without dependence on the field layer structure. Presumably, these differences are caused by heterogeneity of soil moisture and, correspondingly, active layer depth. But within the non-tundra plots trees influence greatly the distribution of active layer depths: tree crowns slow down the seasonal permafrost thawing. The depth of active layer under tree crowns reaches 5-7 cm only, while outside the crowns it is 30-40 sm. Hence, the spectral image of bottom layer in non-tundra plots is influenced by tree distribution; 5x5m geobotanical descriptions do not reveal differences in the brightness of field layer.

Northern Socially-oriented Observation Network in the Russian North: Past, Present and Future

Tatiana Vlasova[1]
tatiana.vlsv@gmail.com
Contributing authors: Sergey Artobolevsky[1], Valentina Bulgakova[1], Peter Glazov[1], Grigoriy Kapustin[1], Ivan Lytkin[2], Andrey Medvedev[1], Tamara Rusina[1], Sergey Volkov[2], Alexandre Voropaev[1], Yulia Zaika[3]
[1]*Institute of Geography, RAS*
[2]*Russian Academy of Agricultural Sciences*
[3]*Khibiny Educational and Scientific Base, Faculty of Geography, Moscow State University*;

The Northern Socially-oriented Observation Network (NOSON) was launched in the taiga-tundra interface zone by the IPY PPS Arctic cluster during the International Polar Year 2007-2008 and supported by the Research Council of Norway, as well as Russian Academy of Sciences.

The main objective of Socially-oriented Observations (SOO) is to increase knowledge and intensify observation of changes in living conditions (state of natural environment including climate and biota, safe drinking water and foods, well-being, employment, social relations, access to health care and high quality education, etc.) as well as to reveal trends in human resources and capacities (health, demography, education, creativity, spiritual-cultural characteristics and diversity, participation in decision making, etc.).

SOO have been carried out in industrial cities as well as sparsely populated rural and nature protection areas in observation sites situated in different biomes (from tundra to southern taiga zone) of Murmansk, Arkhangelsk Oblast and Republic of Komi. New key regions are added to the NOSON network from year to year, the latest one is Ust-Tzilma region of Komi Republic, situated in the basin of Pechora River.

SOO methodology emerged from the experience gained during the Arctic Climate Impact Assessment (ACIA) followed by IASC Taiga-Tundra Interface group cooperation and circumpolar discussions devoted to Sustained Arctic Observation Network (SAON) elaboration.

SOO were conducted according to the protocol included in the PPS Arctic Manual. It was based both on local people's perceptions and statistics that helps to identify issues and targets for life quality and human resources improvement and thus to distinguish main SOO indicators for further monitoring. In such a way the Northern Socially-oriented Observation Network is building capacity for community-based monitoring in the Russian North and is intended to contribute to the circumpolar Integrated Arctic Socially-oriented System (IASOS) being important component of the long-term international SAON activities in social observations and monitoring. First results of this network showed that changes in human capital (depopulation, unemployment, lack of sufficient education, marginalization etc.) are becoming the major driving force effecting land use pattern and overall sustainability. Changes in climate and biota (ice melting, tundra shrubs getting taller and more numerous, etc.) have become an add factor in accelerating or influencing social changes.

Although data of observations were presented at numerous conferences and workshops and in many publications, new results of observations are appearing and more methods and instruments (from natural and social science as well as from arts and culture) are added and implemented in the line of appearing changes in quality of life conditions and human capital.

Most attention at present we pay to revealing and observing local strategies of development at municipal level including climate change adaptation strategies. Changes in climate and biota may considerably impact and accelerate changes not only in the economy but in human capital and quality of life conditions especially in remote rural areas. From this point of view, adaptation to climate change issues may positively effect the economic development bringing more ideas to grass-root initiatives in local strategies development. In such a way economic diversification so needed in the Russian North may increase and territorial structure of economy may be also improved. Strategic approach introduced to the methodology of SOO enables us to translate results of observations and research of environmental changes into solutions of quality of life issues. Due to this experience and SOO methodology tested in key observation regions of the Russian North, it is revealed that climate change and other environmental issues are better recognized and perceived by both local people and policy makers when they are addressed by the researchers in the context of people's quality of life challenges that arctic residents and governments recognize. According to strategic approach in order to achieve the main target - the quality of life improvement, it is necessary to adapt and implement the development strategies for sound solution of appearing issues and set strategic goals for quality of life and human capital enhancement in interrelated spheres – social, economic, nature-environmental, legal-management as well as the spiritual-cultural. With the help of the strategic approach introduced to SOO observation protocol, based on people's perceptions and statistics, specially recognized main issues and solutions as well as key indicators to observe trends have been identified.

First results of SOO, carried out in key sites of our observation network are demonstrated in this presentation. It is interesting to note that in many cases they show that environmental changes evident for scientists, such as forested area or treeline changes due to climate change or human impact are not ranked high by residents as limits or opportunities for people quality of life improvement. This is partly a result of insufficient environmental education and awareness among the local people and their greater concern with the low level of material well-being and unemployment. SOO based on strategic approach, including multidisciplinary scientific research, interviewing and local stakeholders observations, as well as statistics, will help to raise people's awareness of many coupled human-nature issues and opportunities of quality of life improvement and in such a way will enable to use scientific information and traditional knowledge in policy development and education.

Although many people are not put here as co-authors, we would like to express great thanks to all participants from local northern communities without whom our observations could not be fulfilled.

Ideas and ways for synthesis activities in taiga-tundra interface zone observations, investigations and sustainable management in the Russian North

Tatiana Vlasova[1], Annika Hofgaard[2], Gareth Rees[3]
[1]*Institute of Geography, Russian Academy of Sciences, Moscow, Russia*
tatiana.vlsv@gmail.com
[2]*Norwegian Institute for Nature Research, Trondheim, Norway*
Annika.Hofgaard@nina.no
[3]*Scott Polar Research Institute, Cambridge, UK*
wgr2@cam.ac.uk

Causal links among changes in natural environment and social environment and their implications for the functioning and sustainability of the entire human-nature system in the circumpolar region are not completely understood. As it has been declared at the 5th PPS Arctic meeting it is important to understand how climate and disturbance interact and the implication of these interactions for ecological, social, economic and cultural sustainability of the circumpolar region.

A key question for the PPS Arctic board latest meeting (November 2010) was how to identify possible synthesis activities, especially those that combine the natural and social sciences, local/indigenous knowledge and remote censing. Although there are some researchers that do not fully understand the importance of integration and consider that they fulfill the goal of synthesis by “putting everything in once basket”, many IPY researchers come to understanding that it is extremely necessary now to find ways and establish synthesis activities for integration.

One of these synthesis activities going to be undertaken at the global and circumpolar scales will be the IPY Montreal 2012 Conference “From knowledge to action”. This Conference is going to become the final event of International Polar Year 2007 - 2008, the largest international program of interdisciplinary polar research ever undertaken. The title of the Montreal conference **“From Knowledge to Action”** points to the necessity to translate those new scientific understandings into policy that will guide activities in and enhance stewardship of the Polar Regions. This conference will not only give one more chance to disseminate the knowledge and scientific results of IPY from around the world but gathering polar scientists together with policy makers, government, industry and indigenous peoples representatives from around the world will provide an opportunity to apply and focus on next steps in synthesis activities.

Tree-line dynamics is only one trend in the taiga-tundra interface zone and since AMBIO journal and then compiling the PPS Arctic IPY proposal, we are making attempts to view holistically different kinds of processes happening in the whole zone as a coupled human-nature system.

Both social and natural science observations undertaken within IPY PPS Arctic project have registered considerable changes happening nowadays in terrestrial, atmospheric and human environments. In order to move forward in projecting and responding to these changes we need to develop synthesis approaches. For this it is suggested:

1. to establish dialogue and new partnerships among all scientific disciplines and with diverse northern communities, decision-makers, funding agencies, all stakeholders to effectively develop adaptation and mitigation strategies from local to circumpolar scales.

2. to advance solution-driven science that can provide scientific knowledge that can be translated into strategies for coping with change for the benefit of different stakeholders and society.

Multi-Disciplinary PPS Arctic Observing Network construction may be seen as a productive instrument for synthesis activities implementation. The Northern Socially-oriented Observation Network (NOSON) launched by PPS Arctic in the Russian North funded by the Research Council of Norway, as well as Russian Academy of Sciences can be viewed as one of possible synthesis approaches in building Multi-Disciplinary PPS Arctic Observing Network. NOSON network will be discussed within other presentation at our meeting.

One of synthesis activities (although both short in time and thematic) could be implemented within discussions undertaken within this meeting. The discussion will focus several questions such as:

1. What changes in natural environment (ecosystems) in taiga-tundra interface zone of the Russian North are happening and most evident? (climate, vegetation including growth rate of dominant trees and populations, fauna, permafrost and soils, etc.). Which of these changes have abrupt (tipping points) character?

2. What changes in human environment in the taiga-tundra interface zone of the Russian North are most evident?

3. Do these changes in natural environment impact and how they can impact the quality of life conditions (climate, natural resources of vital importance to people, economy, migration of people and animals, infrastructure, etc.) and human capital (health, demography, education, creativity, etc.)?

4. Do these changes in human environment (including responses in the form of climate change adaptation, environmental management, forest policy, etc) impact sustainability and how - positively or negatively?

5. What should be done to achieve better quality of life conditions and overall sustainability in nature and society?

This discussion could give good background for writing an integrative paper.

The Association of Polar Early Career Scientists – strengthening the leadership opportunities of young researchers

Yulia Zaika, Mariette Wheeler, Jenny Baeseman, Allen Pope
Association of Polar Early Career Scientists (APECS)
khibiny_msu@mail.ru, mariettewheeler@yahoo.com,
apope00@gmail.com, jbaeseman@gmail.com

The Association of Polar Early Career Scientists (APECS) was created in 2006 by and for young polar researchers to facilitate opportunities to share ideas and experiences and to develop new research initiatives and collaborations. It represents a body of undergraduate and graduate students, postdoctoral researchers, early faculty members, educators and others with interests in Polar Regions and the cryosphere. The key aim of the association is to raise the profile of polar research by providing a continuum of leadership that is both international and interdisciplinary in focus. APECS recognises the need to equip young researchers with the "soft skills" such as communicating with the media, influencing policy, fund raising and project management that usually do not form part of the graduate's training. This is done through diverse activities including: panel discussions; career development workshops at conferences already being attended by polar researchers; online seminars; a comprehensive job listing; formal mentoring; travel support to meetings; and the APECS Virtual Poster Session. Due to APECS' inherently international nature, the APECS website (www.apecs.is) hosts many initiatives to provide information and resources to early-career scientists, as well as to facilitate discussion and interactions between polar researchers from all disciplines. Furthermore, education and outreach activities are promoted to stimulate the next generation of polar researchers. Since its inception, APECS has strived to develop a strong network of partnerships with international organizations and scientific bodies. These partnerships have not only facilitated early-career representation on an international level, but have also forwarded many education and outreach opportunities for young polar researchers. Currently, the membership is over 2000 members in more than 45 countries. APECS is a proof that a community driven effort can become a robust professional organization in just a few short years. A major lesson learned from the establishment of APECS is to build capacity of the membership and the organization by working with senior scientists and other mentors, such as non-science faculty members, educators, members of the media, administrative professionals and policy makers. Additional lessons include nurturing your volunteers and new ideas. Young scientists often have the passion and enthusiasm for new initiatives and it is imperative that the motivation of these talented researchers be strengthened. In a period where the Polar Regions are experiencing rapid environmental change, having the tools and skills to work effectively cross-discipline and within, as well as outside the scientific community will be essential to address the changes through science-based policy and a well-informed public. The lessons learned by APECS will be valuable to other early career initiatives in many disciplines and countries.

Poster session (alphabetically by first author)

Socially-oriented observations of life quality at the scale of Arctic States and their regions

Alexander Akulichev
Geography of the World Economy Department, Faculty of Geography, Moscow State University
akoulichev@gmail.com

The issue of life quality improvement is one of the most important in the sustainable development of the Arctic states and their regions.

Arctic is rich in natural resources, especially oil and gas, but some aspects of life quality are forgotten. Social problems, which people face, could be tackled by federal programs and also regional development plans and strategies. From year to year the extraction of the northern resources grows, but the social difference between the north and main central (southern) regions still grows. So the question is whether economic growth favors quality of life and human capital and capacity improvement. Does mineral and fuel resources extraction growth turn into living conditions improvement? We should admit, that social factor is usually neglected among other components of sustainability (economic growth) and human development is not of great concern in many economically beneficial projects in Russia. This kind of denial may include lack of access to health services and education, inadequate housing, and economic poverty (well-being) inside the region.

The analysis covers the arctic territories of Russian Federation, Canada, United States, Greenland, Iceland, Norway, Sweden and Finland. In our research we are observing some of life quality indicators from census to census for watching the changes in the same regions from time to time, changes between regions and between countries. The data we've used includes total population, life expectancy and infant mortality, personal disposable income, unemployement rate, share of tertiary education graduates in the total population, etc. Such set of indicators can give us the notion about healthcare level, education level, common social conditions and the living conditions of aboriginal population. We take the fresh data and statistics from the past, which would be compared with present and future factors in order to reveal main trends to be observed. The central task of these socially-oriented observations – the comparative analysis of the life quality in the circumpolar Arctic as an important parameter of sustainability. We also try to identify the prospects of the Russian Federation in the Arctic for exchange of most valuable experience on the way to sustainable development.

Heavy metals in the soils of tundra-taiga ecotone in Kola and the forest-tundra ecotone of Taimyr Peninsula and Putorana plateau

Pavel Blyumberg, Anatoly Krasnushkin
Faculty of Geography, Moscow State University, Moscow, Russia
pavelblumberg@gmail.com

Regions under consideration are among the most industrialized regions of northern Russia. In Kola Peninsula the Europe's largest copper and nickel complexes «Severonickel» and «Pechenganickel» are situated. In Noril'sk (north-central Siberia), Russia's largest metallurgical plant «Norilsk Nickel» is located. This is why one of the aspects in the study of ecosystem state of these regions is distribution and accumulation pattern of heavy metals in soils.

On the Kola Peninsula the objects of investigation are three model territories, located along the gradient from the source of air pollution: the first is situated in the immediate impact zone of «Severonickel» complex, the second – in a 50-km distance south of the plant, on the flank of Yumechorr hill, the third – in the south-eastern part of the Khibiny Mountains, in the valley of the Tuliok river.

Soil samples for geochemical analysis were taken from the upper mineral horizon and were investigated using a portable X-ray fluorescence analyzer «Spectroscan» for the content of four elements (Pb, Zn, Cu, Ni). The metal content is given in Clarks.

Wind regime, relief (slopes altitude, steepness and aspect), washout of pollutants from the upper and accumulation in the lower parts of slopes all play important role in the distribution of heavy metals in addition to the distance from the pollution source. Maximum concentrations of copper and nickel are found in the first model area, mainly in the lower parts of windward slopes facing the «Severonickel» complex, and reach 10-20 Clarks.

This research demonstrated that on the slopes higher than 400-500 m a.s.l., even close to the pollution source, heavy metal content does not exceed regional background values. Pattern of spatial distribution of lead and zinc in the soils reflects the dependence of their high content on the transport network.

The content of copper and nickel in the soils and green mosses on the eastern slope of the Khibiny Mountains is within normal limits and does not exceed regional background values.

On the Taimyr Peninsula and Putorana plateau model areas were situated outside the zones of technogenic impact. This is reflected in the content of heavy metals in the upper mineral soil horizon, which values are within the levels of regional background and do not exceed 1 Clark. These data can be used in ecosystem monitoring.

Age structure of seedlings and saplings in the *Larix gmelinii* forest-tundra ecotone in the Taimyr Peninsula and at the Putorana plateau

Olga Budarina, Elena Golubeva, Ksenia Silenchuk
Faculty of Geography, Moscow State University, Moscow, Russia
egolubeva@gmail.com

Study of the recruitment of trees, their age, morphometric parameters and the state allows us to speak about trends in vegetation ecosystems. Changes in climatic, edaphic conditions and / or human activities significantly influences the ability of recruitment for a tree species. Therefore, abundance, morphometric characteristics and age structure of seedlings and saplings can be considered a reliable indicator of modern successional processes and the dynamics of the boundaries of natural zones and belts.

Under the programmes of PPS Arctic (Present day processes, Past changes, and Spatiotemporal variability of biotic, abiotic and socio-enviromental conditions and resource components along and across the Arctic delimitation zone) and Benefits (Natural and social science research cooperation in northern Russia and Norway for mutual benefits across national and scientific borders) projects of the International Polar Year we have studied the age structure of seedlings and saplings in Taimyr and Putorana key sites.

The purpose of this study is to investigate the age structure of seedlings and saplings, as an indicator of trends in the dynamics of (advance or retreat) of the northern / upper limit of forests in the selected sites of the Russian Arctic.

To realize this goal in 2010, studies were conducted in northern Central Siberia, in the territory of the Taimyr Biosphere Reserve (Ary-Mas area) and the buffer zone of Putorana State Reserve (Lake Lama area), which were as follows:

1. study the age structure of seedlings and saplings of *Larix gmelinii* (further L. gmelinii) at the northern limit of its range (Taimyr Peninsula, Ary-Mas);
2. study the age structure of seedlings and saplings of *L. gmelinii* on the upper (altitude) limit of its distribution (Putorana Plateau, Lake Lama);
3. determine morphometric and age features of *L. gmelinii* seedlings and saplings in the forest-tundra ecotone.

In accordance with the recommendations of the PPS Arctic Protocol within the forest-tundra ecotone samples were taken from seedlings and saplings of L. gmelinii (up to 2 m high) at theforest line and at the treeline in several size groups (less than 15 cm, 15-50 cm and more than 50 cm).

For each field sample, its position in the ecotone was fixed, its total length and its linear growth of the current (2010) year were measured. In laboratory conditions, using binoculars and a microscope, age of the sample, its maximum, minimum and average diameter at root collar, and features of growth and damage were determined. Some of the samples were photographed with large zoom. Analysis of the annual dynamics of radial growth is envisaged in further research as we continue to process field data. For each of the two model plots we have analyzed 200 samples (see *Table 1*).

Table 1. Average characteristics for seedlings and saplings of the researched sites

	H(cm)	Ary-Mas				Putorana			
		Height, cm	**Linear growth, cm**	**Diameter**	**Age, years**	**Height, cm**	**Linear growth, cm**	**Diameter**	**Age, years**
Forest Line	<15	13	0.7	0.15	8.0	-	-	-	-
	15-50	36	2.7	0.5	20.0	29.9	4.1		10.6
	50-200	81.9	4.6	1.2	32.0	93.7	5.7		18.3
Tree Line	<15	-	-	-	-	12.7	1.7	0.2	7.0
	15-50	34	4	-	17.3	28.4	2.5	0.3	9.7
	50-200	76.4	7.5	-	24.0	93.0	6.1	1.2	18.6

The following features are specific to seedlings and saplings at Ary-Mas, Taimyr Peninsula:

1. At the forest line the average age of individuals is about 20 years;
    a. For height class below 15 cm the average age is 8 years;
    b. For height class from 15 cm to 50 cm - 20 years;
    c. For height class greater than 50 cm - 32 years;
    d. Diameter of individuals increases with age from 0.15 to 1.2 cm;
    e. Average height of individuals is from 13 to 82 cm.
2. At the treeline, the average age of individuals is 19 years, we note the lack of individuals with height less than 15 cm;
    a. For height class from 15 cm to 50 cm the average age is 17 years;
    b. For height class greater than 50 cm - 24 years;
    c. Average height varies from 34 cm to 76 cm.

The following features are specific to seedlings and saplings at Lake Lama, Putorana Plateau:

1. At the forest line the average age of individuals is 15 years,
    a. For height class up to 50 cm the average age is 10 years;
    b. For height class greater than 50 cm the age almost doubles to 18 years.
2. At the treeline, the average age of individuals is 12 years;
    a. For height class below 15 cm - 7 years;
    b. For height class from 15 cm to 50 cm - less than 10 years;
    c. For height class greater than 50 cm – 18.6 years;
    d. Average height varies from 13 cm to 93 cm;
    e. Diameter of individuals increases with age from 0.2 cm to 1.2 cm.

There is a clear and significant correlation between height and age of individuals, and between diameter and age the correlation is significant for the group of adult individuals (with height over 15 cm). Morphometric parameters clearly reflect the conditions of growth and renewal of L. gmelinii at the north and the upper limit of its range. In both model areas the conditions for growth and survival of the stand are severe enough. This can be seen in the radial (Fig. 1) and a linear gain, the latter is a few centimeters only. However, despite the coarse gravelly soil, steep slopes, and frequent rockslides and landslides at Putorana, much of their toughness, frequent landslides and avalanches, the growth conditions for *L.* gmelinii is better there than at the Ary-Mas site which has more extreme environmental conditions. This is evident from the growth rate of individuals. E.g., although the average height in the class of 15-50 cm is comparable, the age of renewal in Putorana is almost 2 times less (9.7 and 17.3 years respectively).

Figure 1. A larch sample from treeline at Putorana plateau (enlarged): 30 years old, 2.12 cm in diameter. This larch was 142 cm high and had annual linear growth of 11 cm in 2010. Photo by K. Silenchuk

Age of individuals at treeline and forest line in Putorana is almost identical, whereas at Ary-Mas the age of individuals at treeline is 1.5 times less than at the forest line, which may indicate an advancement of larches in the ecotone for thelast 20 -30 years.

Use of hemispherical photography to assess tree canopy cover in the tundra-taiga ecotone of Taimyr Peninsula and Putorana plateau

Konstantin Golubev[1], Mikhail Zimin[2]

[1]*Faculty of Mechanics and Mathematics, Moscow State University, Moscow, Russia,* kgolubev@gmail.com

[2]*Research and Development Center SCANEX, Moscow, Russia,* ziminmv@mail.ru

Canopy cover is one of the most important characteristics of the tree layer, that reflects features of its vertical and horizontal structure. Canopy cover directly controls the amount of light percolating to the ground through the tree layer.

Quantitatively the canopy is measured in percentage and is usually estimated by eye, but for more precise estimates photographic methods are used. This approach has become widespread after invention of the ultra wide-angle lenses (including lenses of the "fisheye" type). Use of digital cameras and computers has made it possible to decrease the time of obtaining and processing the data and to increase amounts of the data analysed.

Hemispherical pictures taken with the use of wide angle lenses allow to obtain figures related to the nature of absorption and reflection of solar energy by different estimates of underlying surface with high accuracy. That, in turn, makes it possible to link the obtained estimates with the results of remote sensing.

The field research was conducted by the faculty members and students of the Geography Faculty of Lomonosov Moscow State University at the Taimyr Peninsula and at the Putorana plateau in the period of July – August, 2010, in the framework of the PPS Arctic project (Present day processes, Past changes, and Spatiotemporal variability of biotic, abiotic and socio-environmental conditions and resource components along and across the Arctic delimitation zone) and the Benefits project (Natural and social science research cooperation in northern Russia and Norway for mutual benefits across national and scientific borders) of the International Polar Year.

Figure 1: Example of a fisheye image

To determine the canopy cover, we have photographed the sky along the ecological transect lines and in test plots. Filming was done with a digital camera Nikon D70s with the fisheye lens Nikon DX AF Fisheye-Nikkor 10.5mm f/2.8G ED. According to the technical specifications of the lens the angle of its field of view is 180°. This means that all objects in front of the camera are presented on the obtained images (Figure 1). Photographing was carried from a small board placed on the ground, established to maintain the horizontal position of the camera. It was experimentally established that all objects at a distance of no more than 5 meters and at a height of not less than 3 meters from the point of shooting, get into the central zone of the frame.

For each of the model territories sets of hemispherical photographs were formed based on the transect lines. Every 25 meters of the transect line, three shots over a segment perpendicular to the line were made (one on the line and two at a distance of 5 meters from it). That allowed forming a buffer zone, in order to avoid statistical errors associated with the possible heterogeneity of the tree layer along the transaction line. The main purpose of the work carried out on the transect line was to record the canopy cover gradient in the transition from forest to the tundra.

Representative plots displaying ecotopes present in the territory and ranging in the size from 10x10 m to 50x50 m were selected in the Ary-Mas and plateau Putorana areas. To ensure coverage of the whole plot with hemispherical images the photos were taken on a grid with the increment of 5 meters, going 5 meters beyond the area on each side of the area. Intersections of the grid were used as shooting points. According to this arrangement, each point of the site, located at the height of more than 3 meters, got into the central zone of at least one frame. In total, over 500 frames were taken for the studied areas.

Figure 2: Transformed fisheye image

All hemispherical images were transformed to plane (flat) ones (Figure 2) using Nikon-supplied software; this allows their use for quantitative characterization of canopy cover, defined by a ratio of the area of the sky to the area of vegetation in the frame. Transformation of the fisheye images to the plane ones is necessary for the quantiative analysis because of high optical distortion of the initial pictures.

Further development of this research implies forming a united coverage of transect lines and test plots with obtained images, that is mosaicking together transformed hemispherical images into one. To reduce distortions, peripheral parts of each photograph should be clipped (Figure 3). Putting together detailed field maps of the test areas, tied to GPS-coordinates, with each tree marked and described, geobotanical and soil descriptions, data on the depth of active layer, soil temperature, results of areal spectroradiometry and on canopy cover, would let us give a comprehensive geographical assessment. This approach may be helpful for monitoring of the dynamics of transition zone, and for validating maps compiled on regional level using remote sensing imagery.

Figure 3: Transformed and clipped fisheye image

Pine revegetation of sandy shores at Tersky Coast of the White Sea, Kola Peninsula

Elena Golubeva, Elena Glukhova
Faculty of Geography, Moscow State University, Moscow, Russia
egolubeva@gmail.com, evglukhova@gmail.com

The aim of our research is the assessment of pine forests established in desert seaside ecosystems at Terskiy coast of the White Sea (southern Kola Peninsula, Russia). More than 20 thousand hectares of sands which are subject to erosive processes are present at the coasts of the White Sea. Permanently active aeolian processes form small hillocks. One of largest sand hills is located in the mouth of the Varzuga River at Terskiy coast, and is known as Kuzomenskie sands with area over 2.2 thousand hectares. This «desert» was formed because of adverse natural factors and economic activities: cattle breeding, wood cutting and forest fires (Cornelissen et al. 2001; Integrated Regional Impact Studies in the European North 2002). Sands advanced towards a channel of the Varzuga River and have changed hydrological regime in its mouth. In 1980 replanting of trees at the Varzuga River coast has been started to stabilize the coast. *Pinus sylvestris L. Lapponica* was chosen as the basic tree species. Also *Juniperus sibirica Burgsd, Betula pubescens Ehrn and Leumus arenaris (L) Hochst.* were planted to promote higher acclimatization of plants.

Study of structure and morphometric parameters of pine plantings was conducted in 2004–2007 in test areas 20x20 in size for forests of four different ages: plantings of 1985, 1990, 1995, 2000. In each area geobotanical descriptions were made and morphometric characteristics of the trees growing in groups and of single trees were described. The following parameters were measured: height of trees, diameter of trunk at root and at height of 1.3m, annual linear growth of trunk and age of needles.

Diversity of species has been also estimated. In total data for 500 trees were statistically analyzed.

The aim of our research is the assessment of these pine forests established in desert seaside ecosystems at Terskiy coast of the White Sea. As a result more than 60 hectares of plantings have been created and they have established well, at present forming 15–20 year old pine forests.

The height of trees varied from 0.5 up to 3.5 meters. At all test areas height of the trees growing in groups exceeded height of single trees in all years of planting. Significant differences in height of the trees growing in group and separately appear when they reach 10 years of age.

Diameter of trunks at root varied from 1 up to 9.1 cm. For trees growing in a group diameter of their trunk at root is more than for separately standing trees of the same age. This distinction becomes significant when trees reach 15 years of age.

The annual linear growth of trees trunks measured in 2006 varied from 13.1 up to 24 cm. The linear growth of a trunk increases with age. In plantings of 2000 it was 13.1 cm, and in plantings of 1985 it was 24 cm. The most appreciable distinctions are characteristic for plantings older than 10 years.

The age of needles changes from 1 year to 4 years. For young plantings (of the year 2000) the age of needles on average is 1 year. For adult plantings the life of needles increases considerably. The age of needles for the trees growing in groups is almost 2 times more than for single trees.

Specific phytodiversity increases from 3 species in plantings of 2000 up to 6 species in plantings of 1985. *Rumex acetosa and Thymus L.* prevail among the new species in young plantings. In adult plantings, *Empetrum nigrum, Vaccinium* *uliginosum, Vaccinium vitis-idaea, and Calluna vulgaris* are present, i.e. plants typical for northern pine woods.

Our research results demonstrate high efficiency of pine plantings on sands, presenting opportunities for solving the problem of erosion development by these methods for the entire Terskiy coast.

The authors are grateful to the Research Council of Norway for financial support through grants to A. Hofgaard from the programme OST, project 185023/S50, and the programme IPY, project 176065/S30.

References

1. Cornelissen, H.C., Callaghan, T.V., &Alatalo, J.M. 2001. Global Change and arctic ecosystems: Is lichen decline a function of increases in vascular plant biomass. Journal of Ecology, 89: 43–49.
2. Integrated Regional Impact Studies in the European North: Basic Issues Methodologies and Regional Climate Modelling. 2002. Ed. By Manfred A. Lange. Munster.

Climate change impacts on natural environment and communities quality of life in the middle taiga zone of Upper Angara and Middle Yenisei regions: socially-oriented observations

Sergei Gorshkov[1], Olga Mochalova[2], Alexey Medvedkov[1], Laurent Touchart[3], Larisa Evseeva[1], Jean-Louis Ballais[4], Yves Simone[5]

[1]*Moscow State University, Russia*

[2]*Centre of ecologic initiatives,Russia*

[3]*Orléans University, France*

[4]*Université de Provence, France*

[5]*Sud Toulon-Var University,France*

spgor-smir@yandex.ru

It is representative that the global climate warming in the southern and western parts of Central Siberian Plateau associates, as everywhere else, with the increase of climate instability, contrast of weather conditions, and rise in the number of extreme events.

This region is a large refugium of wildlife. Its territory is only slightly transformed by human activities, and it is much less developed and populated than the neighboring regions.

Forest fires happen more often although the anthropogenic press on taiga has significantly decreased. If the dry hot period continues for about one month or longer during a summer, a big number of forest fires take place inevitably. People working in the taiga confirm that the main reason for forest fires is dry thunderstorms. It is almost impossible to put out a big forest fire if the area is situated far from a settlement. Navigation on big rivers is often affected by heavy smoke resulting from forest fires. During the summer of 2003 the number of fires reached over 1100 within the Krasnoyarsk Krai.

Natural components of the landscape and the economy of indigenous people are influenced by climate change, and need to adapt.

Now the resources for hunting and fish catching are exhausted significantly. The main reason is deterioration of a fodder base of ecosystems in the middle taiga subzone. An exception is fishery. It grew less several times because of overfishing. Yields of mushrooms, berries, and nuts have considerably decreased because of a climatic destabilization. Impacts of short strong frosts during the blooming period immediately followed by dry heat are equally dangerous for a future yield of the majority of taiga plants. In the beginning of the winter in 2001 a thin snow cover promoted formation of a thick river ice. The earlier spring was too warm and the spring flood with ice run formed a high ice dam in the narrow part of the Stony Tunguska River valley. Destruction of this dam led to the catastrophic flood with the water height of 23.5 m above the level of the low-water period. The floating ice destroyed the majority of houses in the Sulomay settlement. Ice had also cut a lot of trees on both river banks. A new settlement was built in a higher place. Now Sulomay has satellite communications. Income of the majority of native families is not enough for survival. They receive a small financial support from the Baikit district administration, which is a part of Evenki Autonomous Area. The huge oil deposit named Kuymbe was discovered in the 1980s near Baikit. Keto people continue catching fish, killing elks and forest reindeer, collecting berries, mushrooms, nuts and hunting for sable, squirrel, and brown bear just as they did in the past. Unfortunately many of them often do not have money to buy enough food for children and themselves. In Central Siberia the total number of Keto is equal to about eight hundred people. One fifth of them live in Sulomay.

The dynamics of the tree line under pollution impact in the Kola Peninsula

Anna Govorova, Elena Golubeva
Faculty of Geography, Moscow State University, Moscow, Russia
egolubeva@gmail.com

Nowadays the use of a system of biomarkers takes more and more significance in the diagnostics of ecosystem state and in the environmental risk assessment. But there are a lot of questions in this area and the methodology requires a new point of view. In our research we have developed an integrated approach for diagnostics of the ecosystem state, based on the response of the vascular plants to anthropogenic impact, which is expressed on molecular, cellular, physiological and suborganismal levels. Such an approach allows to evaluate all aspects of the modifications and adaptations of organisms to the environment.

We investigated the interaction between different levels of plants organization under pollution impact:

- Membrane

- Cellular
- the level of organs
- population level
- community level

Field research was carried out in the impact zone of the metallurgical complex (“Severonikel”) in northern European boreal ecosystems in the Kola Peninsula. This area is strongly polluted by SO_2, Cu, Ni, Cd and Co with their concentration in the air 50-70 times more than in undamaged ecosystems.

As a test object we have used leaves of *Betula pendula Roth., Betula pubescence Ehrh., Picea obovata Ledeb., Pinus sylvestris L., Vaccinium myrtillis L., Vaccinium vitis-idaea L., Empetrum nigrum L*. We have used a system of physological and biochemical methods, including geochemical, biochemical, geobotanical and electronic microscopy.

Our results show the following:

- The main diagnostic criteria for the assessment of the ecosystem dynamic under pollution impact are parameters at *different levels of plants organisation*.

This system of biomarkers includes:

- On the molecular and physiological level: intensity of oxidation processes in chloroplast’s membranes; ratio between chlorophyll *a* and *b* content; photosynthetic activity.
- On the cellular level: ultrastructure of chloroplasts and the structure of cells of the assimilation parenchyma.
- On the level of organs: morphology of leaves.
- On the level of population: number and structure of the population.
- On the suborganismal level: parameters of floristic and phytocenotic structure.

We ranged ecosystems into 4 categories using geochemical and landscape analysis.

Three models of responses of vascular plants to the pollution impact were created for slightly, moderately, severely damaged ecosystems and technogenic barrens.

3. We have identified 2 types of adaptations of plants to the pollution impact.

Active adaptation:

Under mild pollution: growth of metabolizm due to decrease of sizes of the photosynthetic apparatus at different levels and increase of chloroplasts number. Species and life forms diversity supply the stability of plant communities.

Passive adaptation:

Under moderate pollution: decrease of metabolism with an increase of sizes of the photosynthetic apparatus at different levels and a decrease of chloroplasts number. Under these conditions more resistant weed species very quickly occupy communities, so processes of the unification of the flora take place.

Under strong pollution: damage of all structures of the photosynthetic apparatus causes the degradation of plant communities and whole ecosystem.

Possible influence of various climate changes on the spreading of vegetation in forest-tundra ecotones in the Kola Peninsula

Lyudmila Isaeva[1], Gennady Urbanavichus[1], Valentina Kostina[1], Annika Hofgaard[2]

[1] *Institute of the Industrial Ecology Problems of the North, Kola Science Center, Russian Academy of Sciences, Apatity, Russia;*

[2] *Norwegian Institute for Nature Research, Trondheim, Norway*

isaeva@inep.ksc.ru

Plants are an important component of biological diversity and an essential element of functioning of forest and tundra ecosystems. In ecosystems, lichens along with higher plants also participate in the absorption and circulation of nutrients, in particular, nitrogen, thus, making a certain contribution into global cycles of nutrients (Kallio, 1975; Crittenden, 1983, 1989; Nash, 1996; Kielland, 1997; Longton, 1997) and a significant contribution of biomass in the arctic ещ carbon flow (Nash, 1996; Lange et al., 1998), and exercise a certain influence on the formation of asprouts of higher plants (Brown, Mikola, 1974; Kershaw, 1985). Therefore, the changes of habitat conditions under the impact of global and/or regional climate changes and other abiotic factors can result in changes (disturbances) of lichen populations and other plants.

The climate induced changes of treeline ecotones have been reported and predicted for different locations in the Northern hemisphere, such as Fennoscandia, Urals, the Kola Peninsula, Alaska and Yukon (Kullman, 2002; Moiseev and Shiyatov, 2003; Lloyd, 2005; Kammer et al., 2009; Danby, Hik, 2007; Mathisen et al., 2009). The focus of this paper has been to study the modern condition of vegetation and possible changes in the species composition and spreading of plants in the forest-tundra ecotone in the Kola Peninsula, Russia. Our results in some areas of the Khibiny (altitudinal gradients) and in some areas around the lake Kanentjavr (latitudinal gradient) register the modern condition of vegetation and relations between lichen populations with higher plants.

The obtained data on plants distribution in flat and mountain areas in the Kola Peninsula register the modern condition of plants and relations of lichen populations with higher plants. No evidence of any change of the ground cover situation under the influence of climatic changes (e.g., global warming) has been obtained. To identify any eventual subsequent changes we need to carry out long-term studies in natural conditions, while taking into account and identifying various edaphic, geomorphologic, hydrologic, climatic and biotic factors.

On the eventual consequences of global (or regional) change of climate for species composition and distribution of plants in the Kola Peninsula, we can consider several probable scenarios of plants development in ecotone communities.

In the conditions of the assumed climate warming higher plants will have more advantages in increasing their productivity (biomass) and expansion from the treeline towards forest-tundra and tundra both in the plain, and in the mountains. Lichens, being poor competitors as weak organisms, will decrease their abundance in ecotone communities at the boundary of forest due to the lack of, first of all, arcto-alpine species, less resistant to shading (which will be increasing due to the increase of higher plants cover). The growing quantity of precipitation in the flat conditions will result in the excessive humidification (expansion of water-logged areas), which lichens do not withstand – i.e. a significant degradation of lichen cover will take place. At the same time the consequences of the increasing humidification of climate will not tell much on the condition of the lichen cover on well-drained mountain slopes, as a whole.

In case of climate cooling, more favourable conditions (compared to higher plants) will probably be preserved in ecotone communities along the forest-tundra boundary both in the plain and in the mountains for the lichen cover and the latter will increase its abundance, provided the higher plant abundance decreases along with the decrease of the upper boundary of forest vegetation in the mountains and its retreat southwards in the flat landscapes.

We can assume with a greater probability degree, that with increase of climate humidification in the ground cover, the share of cryophyte lichens species will be reduced, while that of psychrophytes will increase. Whereas, on the contrary, in case of decrease of climate humidification (at the decrease of temperature) more favourable conditions will be provided for cryophytes, while psychrophytes will be in a depressed state.

At the global level, the modern climate warming may exercise a negative effect on boreal species of lichens at the southern edge of their expansion. For example, taiga species, which found so far acceptable habitats in forest-steppe and steppe landscapes of the southern belt of the European Russia, will quickly reduce their local populations due to high summer temperatures with concurrent reduction of summer precipitation. However, a more substantial negative influence in the given conditions will exercise indirect impact on the climate change, and the direct one will be exercised via the increase of frequency and intensity of fires in such territories. At the northern boundaries of distribution of taiga (boreal) lichen species – these, in our case, are northern taiga and forest-tundra landscapes, the modern warming (on condition the amount of precipitation will not be reduced) will exercise a favourable influence.

At the same time, it should be borne in mind that thanks to their specific biological peculiarities lichens do not react so significantly to global climatic changes. In any territory there will always be found some more or less suitable microecotopes (or even meso-), in which, at the background of global climate changes, there will be preserved conditions, comparable with the earlier existing ones in ambient spaces on a large scale.

References

1. Brown, R. & Mikola, P. (1974) The influence of fruticose lichens upon the mycorrhizae and seedling growth of forest trees. Acta Forestalia Fennica, 141, 1–23.
2. Crittenden, P.D. (1983) The role of lichens in the nitrogen economy of subarctic woodlands: nitrogen loss from the nitrogen-fixing lichen Stereocaulon paschale during rainfall. Nitrogen

as an Ecological Factor (eds J.A. Lee, S. McNeill & I.H. Rorison), pp. 43–68. Blackwell, Oxford, UK.
3. Crittenden, P.D. (1989) Nitrogen relations of mat-forming lichens. Nitrogen, Phosphorus and Sulphur Utilization by Fungi (eds L. Boddy, R. Marchant & D.J. Read), pp. 243–268. Cambridge University Press, Cambridge, UK.
4. Kallio, P. (1975) Kevo, Finland. Structure and Function of Polar Ecosystems (eds T. Rosswall & O.W. Heal), pp. 193–223. Ecological Bulletins 20, Stockholm.
5. Kershaw, K.A. (1985) The Physiological Ecology of Lichens. Cambridge University Press, Cambridge, UK.
6. Kielland, K. (1997) Role of free amino acids in the nitrogen economy of arctic cryptogams. Écoscience, 4, 75–79.
7. Kullman L. Rapid recent range-margin rise of tree and shrub speciesin the Swedish Scandes. Journal of Ecology, 90. pp. 68-77.
8. Lange, O.L., Hahn, S.C., Meyer, A. & Tenhunen, J.D. (1998) Upland tundra in the foothills of the Brooks Range, Alaska, U.S.A. lichen long-term photosynthetic CO_2 uptake and net carbon gain. Arctic and Alpine Research, 30, 252–261.
9. Lloyd AH Ecological histories from Alaskan tree line provide insight into future change. Ecology, 2005, 89, 1687-1695.
10. Longton, R.E. (1997) The role of bryophytes and lichens in polar ecosystems. Ecology of Arctic Environments (eds S.J. Woodin & M. Marquiss), pp. 69–96. Blackwell Science, Oxford, UK.
11. Moiseev P.A., Shiyatov S.G. The use of old landscape photograph for studying vegetation dynamics at the tree line ecotone in the Ural highlands, Russia. Alpine Biodiversity in Europe, Ecological Studyies. Vol. 167 (eds. Nagy L., Grabherr G, Korner C) pp. 423-435, Springer, Berlin.
12. Nash, T.H. III (1996) Lichen Biology. Cambridge University Press, Cambridge, UK.

The functional diversity of soil macrofauna in forest-tundra ecotone of the Khibiny Mountains, Kola Peninsula, Russia

Ilya Kamayev
Centre for Forest Ecology and Productivity, Russian Academy of Sciences, Moscow, Russia
ilyaokamayev@gmail.com

Soil macrofauna, an important group in soil-forming, has been diverse and numerous in the Khibiny Mountains. This is not common for subarctic ecosystems under severe climatic conditions. This study is aimed at the functional diversity of soil macrofauna in forest-tundra ecotone. Soil macrofauna was collected by hand-sorting of soil samples (25x25 cm) on 2 tundra, 1 forest-tundra and 3 forest sites in August 2009 and 2010. Five functional groups of soil macrofauna were distinguished on the basis of its trophic preferences and ecosystem functions.

Predictably, the soil macrofauna abundance and biomass increased from tundra to the birch and spruce forests. The density and biomass of the saprophagous grew from tundra to forest. The saprophagous were presented by earthworms only, and their species number increased from 1 species in the tundra to 4 in the valley intermontane forests. The biomass of earthworms was above 10 g per m^2 in forest sites and less than 2 g per m^2 in tundra sites. Earthworms of these forests exceeded in number and biomass those found in any ecosystems of the Kola Peninsula. For example, the biomass of earthworms was less 1 g per m^2 in the spruce forests of Lapland reserve and Kostamus reserve. Earthworm activities in forest sites resulted in forming zoogenic humus horizons rich in bio-available nutrients.

Unlike forests, in tundra the medium-size zoophagous (Aranei, Staphylinidae) and mixophagous (Elateridae) are predominant, and these groups inhabit poorly decomposed litter of mosses, lichens and shrubs. Zoophagous, especially spiders, were numerous and rich by species in all sites, this is typical for most subarctic ecosystems. 68 species of spiders were found in all ecosystems. The lowest number of species was in the forest-tundra.

Thus, the saprotrophic group of soil macrofauna significantly dominated in forest sites whereas zoophagous and mixophagous prevailed in tundra sites. The intermediate trophic structure of soil macrofauna was observed in the forest-tundra.

The author is grateful to the Research Council of Norway for financial support through grants to A. Hofgaard from the program OST, project 185023/S50, and program IPY, project 176065/S30; research also is supported by Young Scientist Support Grant of President of Russian Federation to Maria Orlova (MK-4046.2011.4); project 10-04-00213-a of the Russian Foundation for Basic Research and by the 'Biological diversity' Programme for basic research of the Presidium of the Russian Academy of Sciences.

Micromosaic structure of vegetation cover in forest-tundra ecotone

Tatiana Kravchenko[1], Elena Belova[3], Natalia Lukina[1],Olga Tutubalina[2], Annika Hofgaard[4]

[1]Centre for Forest Ecology and Productivity, Russian Academy of Sciences, Moscow, Russia; tv.kravchenko@rambler.ru

[2]Faculty of Geography, Moscow State University, Moscow, Russia;

[3] Institute of the North Industrial Ecology Problems of the Kola Scientific Centre, Russian Academy of Sciences, Apatity, Russia;

[4] Norwegian Institute for Nature Research, Trondheim, Norway

Vegetation cover in forest-tundra ecotone has a mosaic structure. Spatially similar, elementary vegetation cover groups can be determined in this structure. These are called plant compartments, or microgroups.

The aim of this study is to characterize spatial structure and diversity of forest-tundra ecotone ecosystems for relatively small areas through field mapping of vegetation micro-mosaic structures (at 1:20 and 1:100 scale) and for larger areas using high resolution satellite imagery (0.5 m) to lay the foundation for investigating potential dynamics in tree-line boundary change.

Vegetation cover was studied at 2 main sites, in Khibiny mountains (Tuliok N67.70139, E33,78825) reflecting vertical belt change of vegetation cover density gradient and in Kanentiavr lake area (N68.88811, E34.26546) reflecting latitudinal change gradient.

Field data was analyzed using Multi-Response Permutation Procedures (MRPP) and Nonmetric Multidimensional Scaling (NMS) statistics methods.

Forest-tundra ecotone in Tuliok was presented by tundra with dwarf shrubs, lichens and rocks; and with *Betula nana*, green mosses, dwarf shrubs and lichens; forest-tundra with birch, *Betula nana*, dwarf shrubs and green mosses; spruce forests with low herbs, dwarf shrubs and green mosses.

In Kanentiavr lake area the forest-tundra ecotone was presented by dry and moist tundra with *Betula nana*, lichens, dwarf shrubs, low grass and mosses; forest-tundra with birch, green mosses and dwarf shrubs; and with birch, *Betula nana*, lichens, dwarf shrubs, herbs and green mosses; spruce and pine forests with low herbs, dwarf shrubs and green mosses.

H-index calculated for tundra, forest-tundra and forest shows more diversity of Kanentiavr lake area (2; 2,5; 2,94 in Tuliok and 2,7; 2,7; 3,12 in Kanentiavr). It correlates with total amount of determined plant compartments in the ecotone: 94 in Tuliok and 175 in Kanentiavr. 15% of them were dominant. Hylocomioso-fruticulosum, fruticuloso-hylocomiosum and fruticulosum plant compartments are common for all ecotones in the studied areas. The hylocomioso-fruticulosum compartment dominates in all areas.

In Tuliok plant compartments have more variability of their fragment size and number and greater diversity of vegetation types in tundra and forest and less in forest-tundra, compared to Kanentiavr. This is explained by the average H-index calculated for predominant plant compartments in tundra, forest-tundra and forest, which was 2,9; 2; 2 in Tuliok and 1,8; 2,3 and 1,4 in Kanentiavr and by vascular plant species number (20, 28 and 21 in Tuliok and 17, 46 and 17 in Kanentiavr).

In Tuliok vascular plant species number in dominant microgroups calculated for sample 1 x 1 m squares was 5; 6; 7 in tundra, forest-tundra and forest correspondingly. The general number of vascular plant species in dominant microgroups was 12; 13 and 14.

Eight dominant ground cover types were identified in QuickBird very high resolution satellite imagery: birch crowns, *Betula nana*, cladinoso-fruticulosum, cladinosum, fruticuloso-cladinosum, fruticuloso-hylocomiosum, hylocomioso-fruticulosum compartments and rocks with stones.

The authors are grateful to the Research Council of Norway for financial support through grants to A. Hofgaard from the program OST, project 185023/S50, and program IPY, project 176065/S30; research also is supported by Young Scientist Support Grant of President of Russian Federation to Maria Orlova (MK-4046.2011.4); project 10-04-00213-a of the Russian Foundation for Basic Research and by the 'Biological diversity' Programme for basic research of the Presidium of the Russian Academy of Sciences. O.Tutubalina has been supported by the Russian

Programme of Leading Science Schools Support, project НШ 3405.2010.5171 and Russian Scientific Educational Centres program «НОЦ», grant No. 14.740.11.0200. The paper is a product under the IPY core project PPS Arctic.

Representation of Forest-Tundra Ecotone in Multi-Resolution Satellite Images: from QuickBird to Landsat

Valentina Kravtsova, Alexandra Loshkareva
Faculty of Geography, Moscow State University, Moscow, Russia
valentinamsu@yandex.ru

This study has been carried in the Laboratory of Aerospace Methods, Faculty of Geography MSU, within the PPS Arctic/Benefits projects, which aim to investigate dynamics of the northern forest boundary in connection with climate change. Images from Landsat satellites are available over the last three decades, but their resolution of 30 m is not sufficient for clear representation of sparse northern forests. Therefore it is necessary to know what do we have in situ inside the 30x30 m pixel area? We answer this by analysing a very high resolution QuickBird image.

The study area is located in the northern part of Kola Peninsula, Russia. We compare ETM+/Landsat, ASTER/Terra, and QuickBird images. After fieldwork in 2009 we have made a vegetation map from the QuickBird image by visual interpretation, which we used as a quasi ground truth. Comparison of this map with ETM+/Landsat and ASTER/Terra images demonstrated that 8 ecosystem types discernible in the QuickBird image merge into 3 in coarser resolution images. Forests with dwarf shrub understorey merged with dwarf shrub tundra (which can be with groups of trees, with single trees and without trees). Therefore forest line and tree line disappear from the image.

We have analysed ground cover composition inside the areas of 30x30 m. Subsets of this size were extracted from the QuickBird image for 8 ecosystem types. They were classified into surface types (tree crowns, three shadows, dwarf shrub, lichen, stones); their area and % cover proportion were calculated; spectral signature for each type was obtained and then spectral signatures for Landsat TM pixels were modelled by linear mixing. They are in good agreement with the real Landsat TM image. This analysis has helped to explain the disappearance of forest boundaries in Landsat TM images and enables to select an optimal method for change detection.

Integrated vegetation-soil-permafrost transects in Taimyr and Putorana key sites

Valentina Kravtsova, Alexandra Mamykina, Elena Golubeva
Faculty of Geography, Moscow State University, Moscow, Russia
valentinamsu@yandex.ru

Ground data on modern status of ecotone taiga-tundra vegetation in Taimyr and Putorana key sites (named Ary-Mas and Lama) were gathered at 12 test areas and along 2 transects, shown in Figure 1. Transects were chosen as straight lines stretching for 1-2 km from taiga to tundra zones. They were marked at the ground by wooden sticks and marking tape. All kinds of ground information on vegetation of different layers (tree, shrub, understorey), morphological characteristics of trees, depth of active layer – were fixed in tables and now put into GIS. For a more comfortable use of such information it is represents also at complex graphic profiles of two kinds – electronic profiles, accompanying GIS (they are characterised in A.Novichikhin's presentation in this workshop), and traditional graphic profiles, which are characterised in this paper.

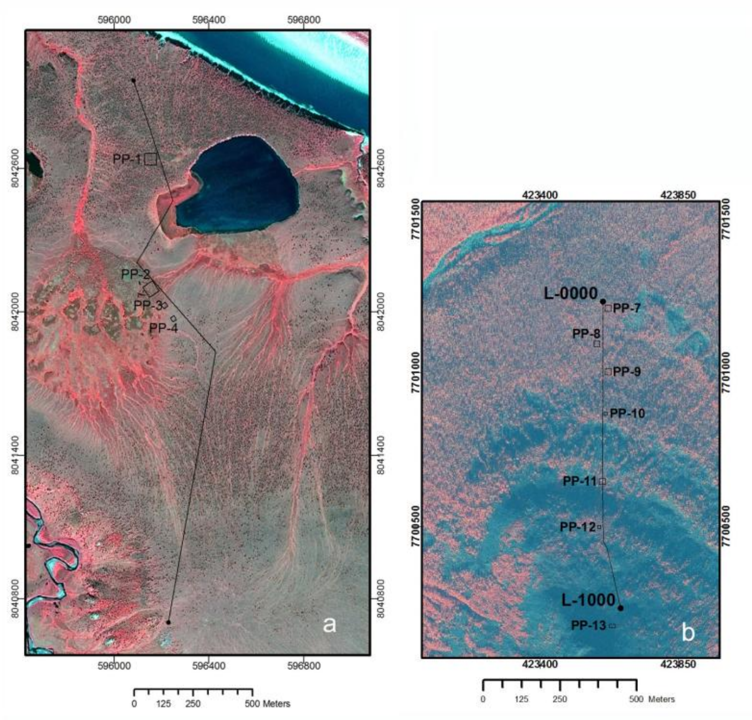


Figure 1. Location of site transects: a- Ary-Mas, b- Lama

Ground relief profile in the Ary-Mas key site was constructed from topographic map in the scale 1:50 000 with countur lines section 10 m. For Lama key site topographic maps of large scale were not available and ground relief line was constructed from ground slope angle measurements, taken for every 25-m section of the transect in the field and controlled by measurements of heights with GPS and barometer.

Both profiles were drawn in the gorisontal scale of 1:2,000 and vertical scale of 1:1,000 for better representation of relief.

The following layers of information are displayed along the relief profile line:

1) tree morphometry (symbols reflect annual linear growth, trunk diameter) and reproduction (presence of cones);
2) trees and shrub layer of vegetation (species, density, life status);

3) dwarf-shrub and understorey layer of vegetation (dominant species);
4) deepness of seasonal melting of permafrost (in Ary-Mas key site only);
5) wetness of soils in their upper level (qualitative characteristic, three gradations).

All this information (geobotanical and soil wetness for every 25 m, permafrost melting for every 2 m) was put onto profiles with graphic symbols, as shown in Figure 2. An example of profile is shown at Figure 3.

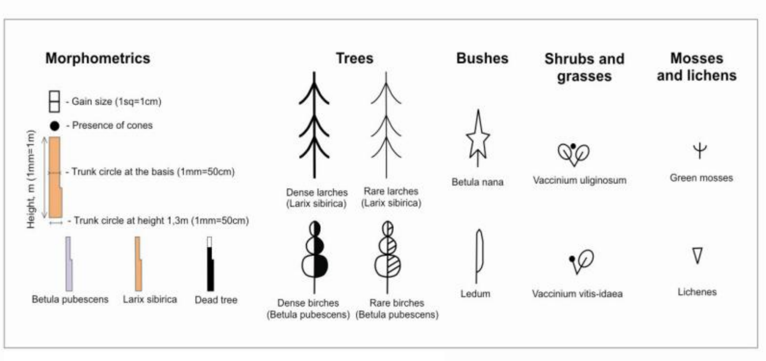


Figure 2. Legend of the profile

Profiles are displayed with a strip of satellite image (subsets of QuickBird image in Ary-Mas key site and GeoEye image in Lama key site). Thanks to this an investigator can see characteristic features of different types of vegetation structure and come to conclusion for interpretation keys for different kinds of forests and ecotone forest-tundra vegetation. The schemes of interpretation of this image strip should be placed under the strip.

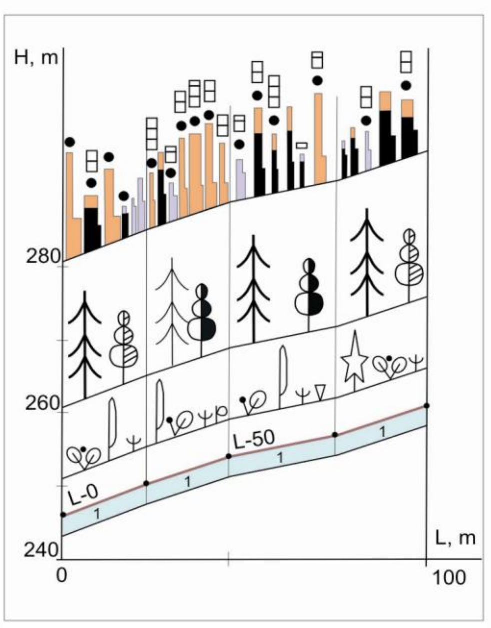


Figure 3. Subset of a profile

Practical work with profiles has shown us some of its advantages and disadvantages.

For example, the advantages are:

1. profile clearly shows the distribution of different forest types with changes of heights;
2. profile shows connection of alder distribution with soil wetness and explain wave-like character of alder clumps appearance at the slope (in Lama key site).

Examples of lacks are:

1. the too narrow strip of the profile does not allow to reflect adequately the tree density in sparse northern forests;
2. the type of dwarf shrub and grass-moss understorey vegetation tier is not clearly represented with graphic symbols of dominant vegetation species, especially in our case, when it is not monodominant, but very complex.

It will be useful to compare possibilities of work with graphic and electronic profiles.

Tree-ring growth variability factors for larch (*Larix sibirica Ledeb.)* in Southern Siberia

Ekaterina Kuznetsova, Daniil Kozlov
Faculty of Geography, Moscow State University
ekaterina.p.kuznetsova@gmail.com

Tree-rings study is one of the most available methods for reconstruction of biological productivity process without stationary observations. The signal in the tree-ring is a reaction of the tree to change of environmental conditions. It depends on biological (genetic traits, age et al.) and ecological factors (climate, soil moisture, competition etc.).

The objectives of this study are identification of tree-ring growth variability factors (number and interpretation) in the 20th century using a dendrochronological method and investigation of environmental conditions influence onto display of these factors in the tree-ring growth.

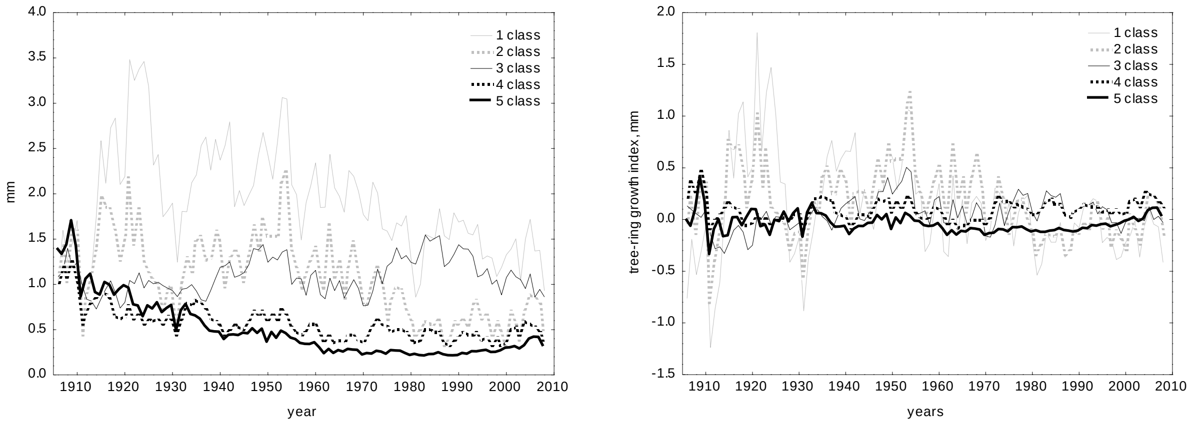
The study area is Lake Terekhol basin, Tuva republic, Russia (51ºN, 97ºE; 1300–1360 m above sea level). It is characterized by extreme continental climate (mean annual temperature -6.7°C, precipitation – 323 mm per year).

Cores and disks of larch (*Larix sibirica Ledeb.*) were sampled in the five classes of sites: forest-steppe communities in the bottom of basin with freestanding larch trees (class №1); closed-canopy boreal forests on the north slope (class №4) and (class №5); interposition classes on the lake terrace (class №3), in the bottom and at the top of the ridges, destroyed by fire (class №2). Each class is a result of the integrated landscape description, comparative ecological analysis, calculation of competition index. It characterizes local environmental conditions.

Tree-ring width was measured with 0.01 mm accuracy using a LinTab5 equipment and TsapWin Professional software. 129 individual chronologies for five classes of sites were obtained. Time period for the analysis is 1904-2008. The total tree-ring growth variability includes the biological and ecological variability (Figure 1). Growth trend demonstrates a biological signal. Growth index curves depend more on the ecological factors. After cross-dating procedure in TsapWin we used Arstan for separation of growth trend (negative exponent or straight line methods) and indexation of chronologies. Principle component analysis was applied for identification of the tree-ring growth variability factors. Using multiple regression we calculated the contribution of each principal component to tree-ring growth variability of site classes and we compared principal components with meteorological data (CRU 2.1.) for their interpretation.

Dynamics of tree-growth variability in the 20th century depends more strongly on ecological factors (62%) than on biological ones (38%).

The biological variability is different between tree sites classes. The highest contribution to tree-ring growth variability is observed in the taiga communities on the north slopes and at the top of the ridge (classes №4, №5), the lowest – in the forest-steppe communities in the bottom of basin (class №1).



a b

Figure. 1. Chronologies for 5 site classes: a – growth curves (total variability), b – indexed curve (ecological variability).

Four principal components (PC) describe 68% of ecological variability (Fig.2).

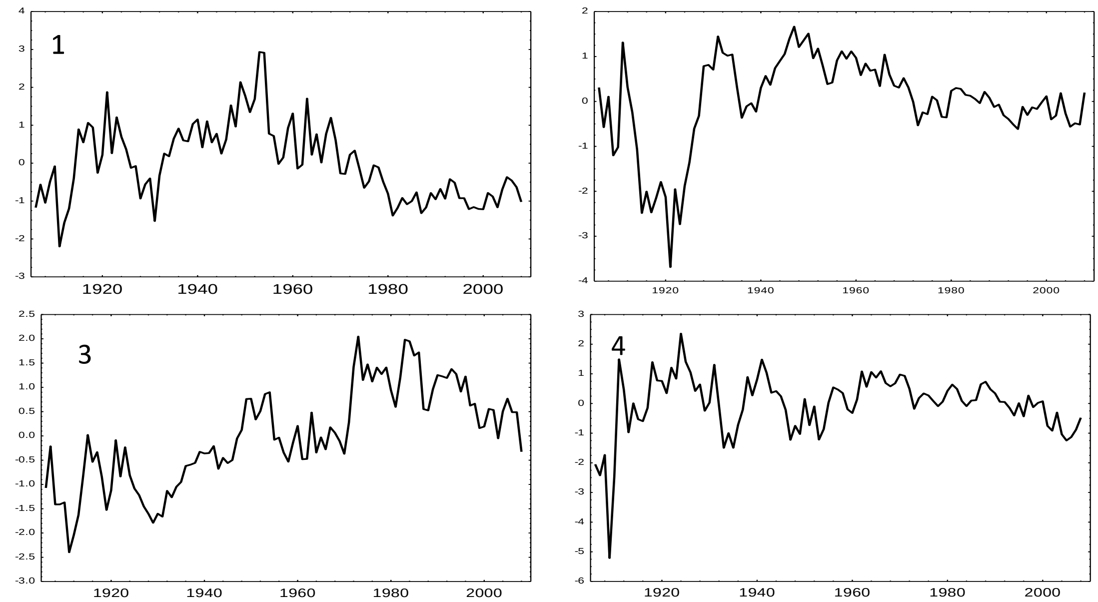


Figure.2. Principal components of ecological variability.

PC1 describes 29.4% of ecological variability. PC1 is significant for classes №1, №2: forest-steppe communities in the bottom of basin; open-canopy transition communities in the bottom and at the top of the ridge destroyed by fire. The contribution of PC1 to ecological variability is 0.39 for each class (R^2 in the multiple regressive model). Cold and snowy February, dry May, but wet July and June of the current and last growing season are advantageous conditions for tree-ring growth (R^2=0.29).

PC2 describes 17.5% of ecological variability. PC2 is significant for classes №1 (R^2=0.15), №2 (R^2=0.23) like PC1. 42% of the PC2 variability relate to summer precipitation of the current and last growing seasons i.e. higher precipitation results in increase of tree growth.

PC3 describes 12.2% of ecological variability. This component is not very important for all classes, but more significant for taiga classes №3 (R^2=0.10), №4 (R^2=0.11), №5 (R^2=0.09) than classes №1 (R^2=0.06), №2 (R^2=0.03). 23% of PC3 variability are described by the winter temperature (January and March) i.e. higher temperatures in these months result in increase of tree growth.

PC4 is independent of climatic conditions and describes specific variability of forest tree sites in 1906-1909 (9%).

We can see that the regional dynamics of meteorological parameters transformed into spatially heterogeneous landscape is the main factor influencing the variability of biological production in the study area.

The forest-steppe communities in the bottom of basin are more sensitive to soil moisture conditions (June-July precipitation of current and last growth season, February, May precipitation of current growth season).

The taiga ecosystems of the northern slopes and at top of the ridge are not sensitive to changes of soil moisture conditions. The main factor influencing the tree-ring growth variability is competitive relation among trees and the temperature regime.

The growth dynamic of larch at the lake terraces depends on variation of ground water level. The last 100 years are characterized by the higher moistening in the middle of 20^{th} century and by higher level of Lake Terekhol in 1948-1954, with subsequent strong decrease in 1970 as a result of very dry weather.

This research has been supported by the Faculty of Geography, M.V. Lomonosov Moscow State University.

Changes of growth pattern for larch in eastern Taimyr

Nikolay Lovelius
Federal State Nature Biospheric Reserve "Taimyrskiy", Russia
lovelius@mail.ru

Research of larch stands in various parts of Russia is covered by extensive literature, as this species grows at the top and the northernmost limits of trees over large areas. In the Taimyr Peninsula stands of larch are the most northerly in the world. The Ary-Mas forest island in the New River basin is unique. It was examined for the first time by geobotanist L.N. Tyulina (1937), detailed studies of the IBE and the MAB Programme was conducted by the Botanical Institute of the USSR, whose results are published in numerous articles and the monograph "Ary-Mas. Natural conditions, flora and vegetation of the northernmost in the world of a forest "(Leningrad: Nauka, 1978).

At present, Ary-Mas is researched by the officers of the Taimyrskiy Reserve and numerous specialists from Russia and foreign countries, arriving to this unique area, which can serve as a benchmark site duet to the absence of settlements and industrial facilities in its vicinity.

In the field season of 2010 field training of students from Faculty of Geography, Moscow State University, has been arranged at this site for the first time. Under the guidance of Professor E.I. Golubeva, other faculty and reserve staff, they have carried out comprehensive work for an international project. The results of these studies will be discussed at a meeting at MSU 25 February 2011.

The author began his comprehensive studies at Ary-Mas in 1970, which allowed to study the seasonal thawing of soil and redistribution of snow cover, depending on the elements of terrain and vegetation. Research has been focused on linear and radial growth of larch at Ary-Mas in the basins of Kotui, Kheta and Khatanga Rivers, Ayan Lake and on the state of forest line in Putorana Plateau. The results are included in many articles, reports, and books.

Figure 1 demonstrates changes in annual rings growth for larch in sparse stands of northern taiga near the village of Khatanga (upper curve) and at Ary-Mas (lower curve) and allow tracking changes in growth conditions of trees for 220 years (correlation coefficient 0.65).

Of particular interest are the coincident dates of extremes in the growth of larch, indicating large-scale environmental factors influencing the formation of tree growth in various microclimatic and edaphic habitats. Minimum growth of larch in the 1830s confirms the period of the most severe conditions for tree growth over the past 300 years, which is also marked by death of forests at the altitudinal forest line in the Putorana Mountains (Lovelius, 1967, 1970). From this date the forest growth conditions improved, then slightly deteriorated in the 1910s and continued until the 1940s.

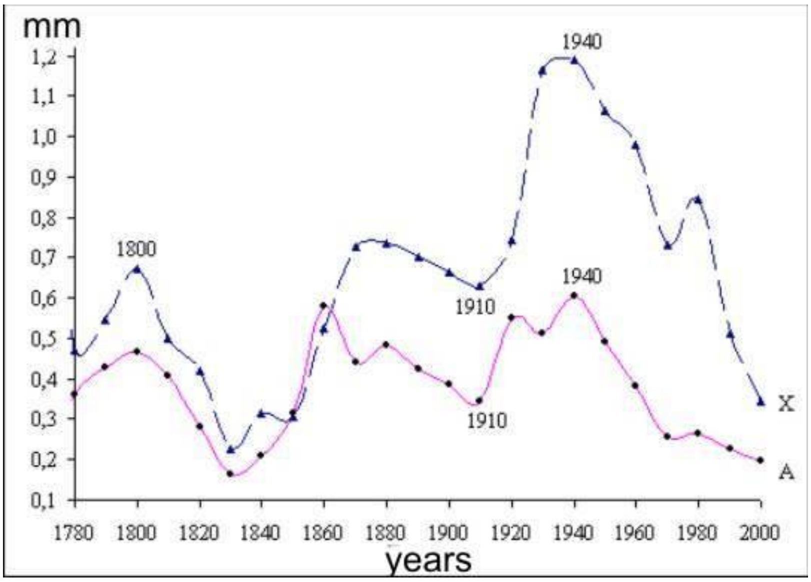


Figure. 1. Radial growth of larch in sparse stands of the northernmost forest island Ary-Mas (A) and near Khatanga village (X)

Period from 1910 to 1940 was called "the Arctic warming", which, as Figure 1 shows, is over. Systematic observations at meteorological stations of the Far North in Russia, as a rule began before the World War II due to the development of the Northern Sea Route and have short data series, hampering retrospective and forward forecast constructions. Use of tree ring growth data from the northern limit of trees makes it possible to trace the changing environmental conditions according to the annual rings of living trees in the last 500 years or more, with precision of up to one year, which makes them an indispensable indicator in geographical research (Lovelius, 1979, 1997).

References

1. Lovelius N.V. 1967. Izmeneniya klimata po dannym dendrokhronologicheskogo analiza [Climate change according to dendrochronological analysis] In: *XX Gertsenovskie Chteniya. Geografiya i geologiya*. Summary reports. Leningrad, 1967 pp. 38-41. In Russian.
2. Lovelius N.V. 1979. *Izmenchivost' prirosta dereviev: dendroindikatsiya prirodnukh protsessov i antropogennukh vozdeistviy* [Variability of tree growth: dendroindication od natural processes and human impacts]. Leningrad: Nauka, 232 p. In Russian.
3. Lovelius N.V. *Dendroindication of Natural Processes*. St. Petersburg: "World & Family-95". 1997. 320 p.
4. Tyulina L.N. 1937. Lesnaya rastitelnost' Khatangskogo raiona u ee severnogo predela [Forest vegetation of Khatanga district at its northern limit] *Trudy ANII*, Leningrad, v. 63, no. 5-6, pp. 453-499. In Russian.

Spatial variability of the upper forest line in Khibiny Mountains (based on remote sensing materials)

Anna Mikheeva

Faculty of Geography, Moscow State University, Moscow, Russia

Arvin2@yandex.ru

Determination of spatial position of the upper forest line in Khibiny Mountains is important to assess its dynamics caused by global environmental changes.

The main goal of this research is to define altitudinal forest line position in Khibiny Mountains, its spatial variations and the factors influencing it. The approach of the study is based on remote sensing materials and GIS analysis mainly but was validated with several field observations.

Forest line position was identified visually in the Terra ASTER satellite images of 30th July 2004 and IRS LISS/PAN of 23th July 2004. Due to the lack of field vegetation descriptions, additional maps were used to improve image interpretation results: topographic map of 1: 50 000 scale and landscape map of A.Myagkova (1988). The absolute heights for every point on the forest line were extracted from a DEM with 50 m resolution produced from the 1: 100 000 topographic maps. Then spatial variability of altitudinal forest line position in Khibiny Mountains was investigated as a deviation of its modern spatial position from the average height calculated for all mountain mass. The deviations were presented in the map of 1: 50 000 scale and conclusions about the factors that influence the forest line were made.

The average height of the top forest line in Khibiny Mountains is 350 m a.s.l. (that approximately in 2.5 times lower, than in the Scandinavian mountains (Payette et al., 2002) and by 150 m lower than in the Subpolar Ural Mountains at the same latitudes (Shiyatov, 1986). But forest seldom grows at the level of the average position, the deviations about 0–40 m below the average are more frequent.

The spatial variations of the forest line strongly depend on the aspect. On the eastern part of the mountains the upper forest line is lower by 50-100 m than in western. There are many river valleys here with the lack of vegetation: Kaliok, Majpaltaiok. That is because of regional variability of precipitation: the western slopes are moistened better and they stop the humid air masses.

At the same time the western part of the mountains is also characterized by negative deviations of the forest line almost everywhere. Most likely, strong winds block the trees growth despite most precipitations emptying on the western slopes. Besides, the wind has drying influence on soils, also strong wind damages trees, especially young (Kryuchkov, 1960). Protected from wind, forests grow better on slopes of the valleys that cross the western macroslope.

Northern slopes have the forest line not higher than 300 m a.s.l. due to lack of solar radiation and strong winds especially in winter.

On the southern macroslope, despite of much solar radiation, the top forest line is not extremely high. It confirms Kruchkov's (1960) assumption that the top forest line in Khibiny Mountains is regulated by relative humidity and water availability, but not by air temperature. Kruchkov also states that «limits of vegetation belts on southern and, possibly, on northern slopes, are below the thermal limits», so the temperature is not the limiting factor of the upper forest line.

Positive deviations of the top forest line are found in the valleys of the large rivers: Kuniok (410-430 m a.s.l.), Malaya Belaya (up to 500 m a.s.l.), upper parts of Tuliok (400-441 m a.s.l.), and also in the hollows of lakes Maly and Bolshoy Vudjavr (480 m a.s.l.). The most significant deviations are at the upper forest line in the valleys of the large rivers (800–1000 m a.s.l.). It is probably controlled by specific humidity conditions. The total amount of precipitation, dropping over the valleys and over plateau tops, is approximately identical (Kryuchkov, 1960) and the differences are significant only for western and east macroslopes in general, as shown above. Soils are moistened unequally and non-uniformly: steep slopes are moistened less than valleys while soils in valleys are saturated by the free moisture needed for a survival of trees. Moisture redistribution between plateaus, slopes and valleys begins even in the winter when due to blizzards the snow accumulates in the valleys in greatest quantity. Besides, relative humidity of air which also defines limits of distribution of forest is higher in valleys for the several reasons: due to frequent temperature inversions, level of condensation of moisture in valleys is higher; also there are no strong winds in the valleys. Thus, forest in valleys of the rivers is provided by the free moisture necessary for growth in soil and is protected from wind influence so the top limit of the forest line is higher.

Coniferous forest on a southern slope of Juksporr Mountain has the greatest altitude of 717 m a.s.l. It is justified by Kruchkov (1960). This slope of Juksporr can be an example of most favorable conditions for the forest growing in Khibiny Mountains: on a slope with the general heights of 600-700 m a.s.l. in the valley of the large river which can have a considerable steepness, but is turned to the southwest and south and is consequently protected from the north winds. During the winter it is covered by thick snow cover, and during the summer a lot of solar radiation is collected here.

The shape of the forest line in Khibiny is controlled everywhere by the relief forms. Mainly the forest grows on gentle slopes, and smoothly bends around the steep sites in places of the greatest congestion of moisture. Often steepness of slopes is the limiting factor for the upper forest line because on very steep slopes soil washout and other erosive processes do not allow soils to be formed, and frequently destroy trees. Usually the limit of steepness for the birch forest is 20–23°. The exception is the mentioned site on a southern slope of Juksporr where the slope steepness exceeds 23°, but the forest grows there. It once again proves that primary factors of the forest growing are soil and air humidity.

The detailed analysis of upper forest line variations and relief variations showed that the higher forest grows, the stronger it is influenced by various factors (including orographical) and the more unstable is the ecosystem. At the high altitudes even insignificant change of aspect and steepness can lead to disappearance of tree forms. Everywhere there is a maximum height, where forest is disappearing and is being replaced by tundra, an ecosystem that has higher stability to changes of factors because of special adaptation mechanisms.

These were only some examples that can be investigated using the map of the upper forest line in Khibiny Mountains. The research was supported by the Russo-Norwegian project of the Norwegian Research Council BENEFITS (OST 185023/S50), by the Russian Programme of Leading Science Schools Support, project НШ 3405.2010.5171 and Russian Scientific Educational Centres program «НОЦ», grant No. 14.740.11.0200. The full paper was published in *Vestnik Moskovskogo Universiteta, Seriya Geografia* in 2010 (Mikheeva, 2010).

References

1. Kryuchkov, V. V. 1960. Faktory, opredelyajushie verkhnie predely rastitelnykh poyasov v Khibinskikh gorakh [Factors defining the upper limits of vegetation belts in Khibiny Mountains]. In: Popov, A. I. (eds.). *Trudy Khibinskoi geograficheskoi stantsii*, pp 1:174-214, Moscow. In Russian.
2. Mikheeva A. I. 2010. Prostranstvennaya izmenchivost' polozheniya verkhnei granitsy lesa v Khibinakh (po materialam distantsionnogo zondirovaniya) [Spatial variability of the upper forest line in Khibiny Mountains (based on remote sensing materials]. *Vestnik Moskovskogo Universiteta, Seriya Geografia*, No.4, pp. 18-22. In Russian.
3. Shiyatov S.G. 1986. *Dendrokhronologiya verkhney granitsy lesa na Urale* [Dendrochronology of the upper forest line in the Urals]. Moscow: Nauka. 136 pp. In Russian.

4. Myagkova, A. S. 1988. Estestvenniye i antropogenniye izmeneniya Khibin za golocen [Natural and anthropogenic changes in Khibiny mountains during the Holocene. Faculty of Geography. Lomonosov Moscow State University, Moscow. Dissertation of the Candidate of Sciences in Geography.
5. Payette, S., Eronen, M., Jasinski , J.J.P. 2002. The Circumboreal Tudra-Taiga Interface: Late Pleistocene and Holocene Changes. *Ambio Special Report*, Vol. 12. Royal Swedish Academy of Sciences.

Change of the treeline ecotone in Khibiny Mountains, Kola Peninsula, over the last 50 years

Anna Mikheeva[1], Ingrid E. Mathisen[2], Olga Tutubalina[1], Annika Hofgaard[2]
[1]*Faculty of Geography, Moscow State University, Moscow, Russia,*
[2]*Norwegian Institute for Nature Research, Trondheim, Norway* [3]*Norwegian*
ingrid.mathisen@nina.no

We present analysis of the treeline ecotone changes using aerial photos of 1958 and 1990, high-resolution satellite imagery of 2006/2008, in comparison with age structure data for two study sites in the Khibiny Mountains, Kola Peninsula and with regional temperature and precipitation data (for Murmansk meteorological station) since 1940. The age structure data were collected in the field during summer 2008 at two separate sites of the Khibiny Mountains. At the birch site (Tuliok), one 20 metre and one 10 metre wide sample bands stretching from the treeline to 100 and 50, respectively, altitudinal metres above the treeline were used (350 m and 150 m long, respectively). Small birch individuals, <5cm in height, are difficult to locate and consequently most likely under-represented in the sample. In addition, 19 birch trees marking the local treeline were selected for age determination. At the pine site (Umechorr), the data was collected in sample plots at treeline and above the treeline. The treeline data were collected in three 50x50 meter adjacent sample plots, the data from above the treeline in eight 50x50 meter adjacent sample plots. All pine/birch individuals were cored for age determination at the base if the diameter of the stem was thicker than 3.5 cm, or otherwise cut at base. Satellite and aerial image analysis consisted in identification of the highest points with growing trees (10 test sites of 10 trees each for Tuliok and 7 test sites of 10 trees for Umechorr), drawing the treelines and comparison of their altitude over the period of change. The following imagery was used: air photos of 14/08/1958 (spatial resolution ca 2 m) for both sites; QuickBird satellite image of 28/06/2006 (2.4-0.6 m) for Tuliok; air photos of 18/07/1999 (1 m) and WorldView satellite image of 29/07/2008 (0.5 m). Airphotos were orthorectified using DEMs created from 1958 (Tuliok) and 1999 (Umechorr) stereo airphotos, and satellite images were rectified to the orthophotos. Ground control points were taken from the 1:50000 topographic maps, thus seriously limiting the achievable accuracy, although additional local adjustments were made during change detection. While the relative height differences are quite accurate, the error in absolute treeline height determination is over 20 m. Daily temperature and precipitation data from the meteorological station in Murmansk 140 km north of the study sites were adapted to monthly, annual and seasonal components. The temperature data show no trend during the last 70 years, while precipitation shows an increasing trend. The age distribution at Tuliok reveals that most of the colonization by birch occurred after the 1960s with establishment peaks from mid-1980s. At Umechorr most of the colonization by pine occurred after 1950s and particularly in the 1970s and 1990s.

Treelines show consistent upward movement from 1958 to 1999 and to 2006/2008. At Tuliok the measured treeline advance (birch) is 29 m in the 48 years; at Umechorr (birch and pine) it is 27 meters in 50 years. The actual advance may be less, because the smallest trees identified in 2 m-resolution airphotos of 1958 are likely taller (up to 4 m) than the smallest trees (2 m) identified in more recent imagery (0.5-1 m resolution). Additionally at Umechorr pine and birch treelines cannot be differentiated. At Tuliok, there were no significant correlations between number of established individuals in each year and monthly, seasonal and annual average temperature, nor monthly, seasonal and annual total precipitation. At Umechorr, there was no correlation between the year of establishment and average temperatures. However, number of individuals established in the respective years significantly correlated with January and February precipitation, and the seasonal total precipitation of winter (December, January and February).

The research was supported by the Russo-Norwegian project of the Norwegian Research Council BENEFITS (OST 185023/S50), A. Mikheeva and O. Tutubalina were supported by the Russian Programme of Leading Science Schools Support, project НШ 3405.2010.5171 and Russian Scientific Educational Centres program «НОЦ», grant No. 14.740.11.0200.

Tree-Height Measurements Using Stereo Images and Shape-From-Shadow Technique in Comparison to Field Data

Anton Novichikhin, Anna Mikheeva, Olga Tutubalina
Faculty of Geography, Lomonosov Moscow State University
novi-mail@mail.ru , arvin2@yandex.ru , olgatut@mail.ru

Height of is one of the criteria for definition of trees in a forest-tundra transition zone. Definition of forest line, tree line and other borders in the transition area is important to study the structure of the forest-tundra ecotone. Estimation of tree height requires very high resolution (VHR) remotely-sensed data (satellite or airborne images), because coarser imagery cannot resolve the necessary detail.

We used GeoEye stereo satellite images acquired on 22 August 2009 for study areas in the Tuliok River valley and Maly Vudiavr Lake area, Khibiny Mountains, Kola Peninsula, Russian Federation.

We compare two methods for tree-height extraction from imagery and validate the measurements on the basis of field data acquired in July 2009 and August 2010.

Field data divides into two datasets: the first was collected with a telescopic measurement pole with 0.1 m accuracy (Tuliok River Valley) and the second with inclinometer measurements with 0.25 m accuracy (Maly Vudiavr Lake). The second dataset was also supplemented by photos of trees, to help us to understand the reasons of errors in remote measurements using satellite imagery.

Classical stereo measurements with 1 pixel parallax accuracy were performed on a panchromatic band with 0.5 m resolution for 50 trees near the tree line.

Shape-from-shadow technique is a combination of local and focal automatic analysis of a VHR image, developed for detailed interpretation of sparse forests. This technique was applied to an image, in which multispectral and panchromatic bands were resolution-merged. Using this technique we can extract the spatial position of trees with an accuracy of 1.5 m and tree heights with an accuracy supposedly about 1.0 – 3.0 m.

Preliminary comparison of stereo and shape-from-shadow technique for Tuliok River Valley is presented in our poster. We need to stress that field tree measurements were effected at the very treeline, and for that reason some trees were very difficult to resolve in the imagery.

Here we present preliminary analysis of the newer 2010 dataset where larger trees were measured specifically to compare with image measurements.

In Figure 1, points represent pairs of measurements made in the field and with shape-from-shadow processing of the GeoEye resolution-merged image. Analyzing this distribution of points we may conclude that most of measurements (70%) lie between +/- 3m. Resolution of images as compared with relatively thin crowns could be the reason of errors. We plan further analyses of field photos of trees to establish main reasons for discrepancies in field and remote height measurements.

We further plan to extend stereo measurements to Maly Vudiavr site, compare these results, calculate more precisely the errors of image measurements and analyze the applicability of these methods to ecotone studies.

The research was supported by the Russo-Norwegian project of the Norwegian Research Council BENEFITS (OST 185023/S50), by the Russian Programme of Leading Science Schools Support, project НШ 3405.2010.5171 and Russian Scientific Educational Centres program «НОЦ», grant No. 14.740.11.0200.

The study is carried out in the Laboratory of Aerospace Methods of the Faculty of Geography, Moscow State University, financially supported by the Benefits Russo-Norwegian project of the Norwegian Research Council (OST 185023/S50), by the Russian Programme of Leading Science Schools Support, project НШ 3405.2010.5171 and Russian Scientific Educational Centres program «НОЦ», grant No. 14.740.11.0200.

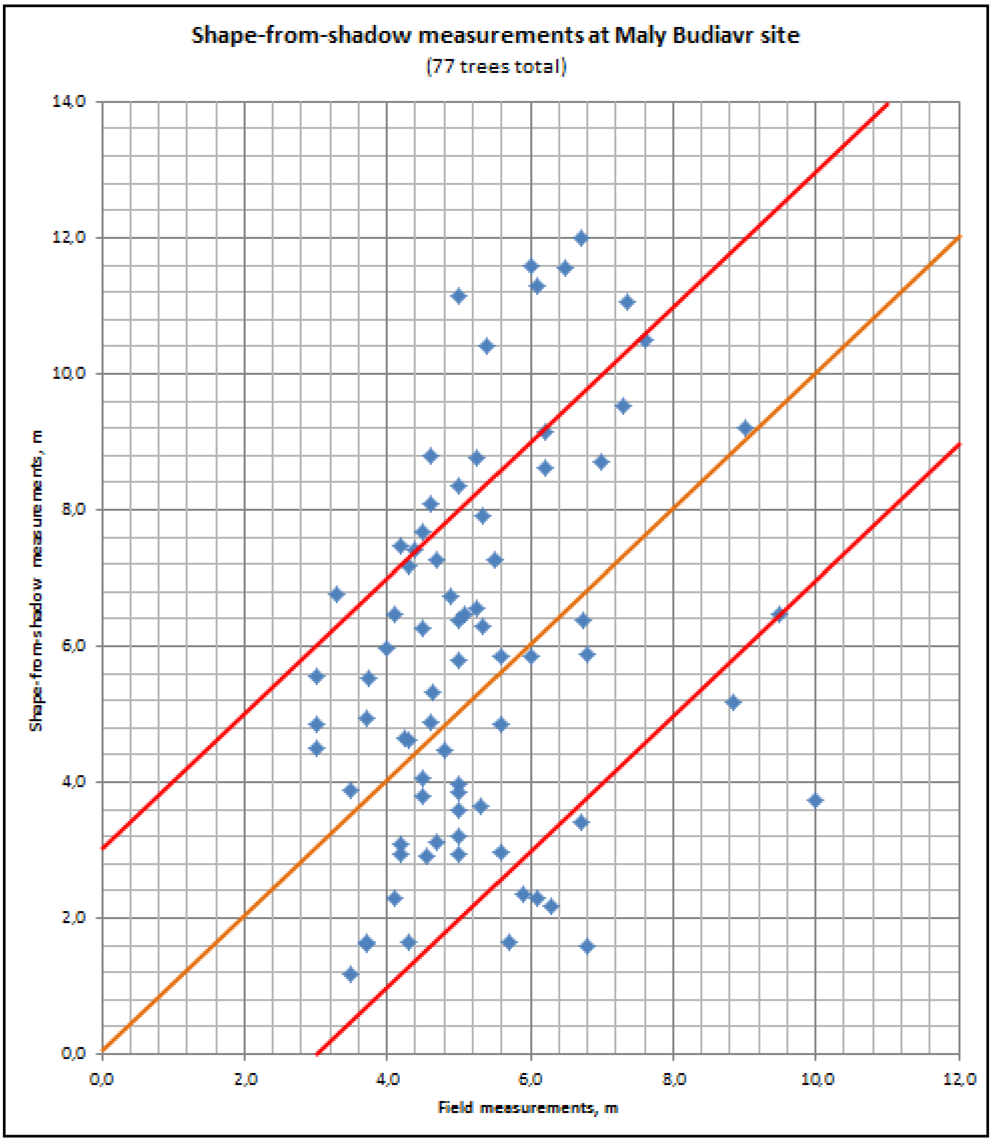


Figure.1. Evaluation of shape-from-shadow measurements of tree heights against field data. Central line: measurement error 0 m; top and bottom line: measurement errors +/- 3 m

Application of different VHR satellite images for detailed mapping of forest spatial structure properties in the forest-tundra ecotone

Anton Novichikhin, Olga Tutubalina
Faculty of Geography, Moscow State University, Moscow, Russia
novi-mail@mail.ru, olgatut@mail.ru

Tree height as well as crown coverage and distances between individual trees are among the criteria for definition of forest, forest-tundra and tundra zones in the forest-tundra ecotone. Definition of forest line, tree line and other boundaries in the transition area is important to study the structure of the forest-tundra ecotone. Estimation of these parameters requires very high resolution (VHR) remotely-sensed data (satellite or airborne multispectral images), because coarser imagery cannot provide the necessary detail.

The goal of this study is apply a local-focal object interpretation method for extraction of detailed information on spatial structure of forest, position of forest line and tree line in forest-tundra ecotone from the very high resolution (VHR) satellite imagery, using images from different sensors and for various areas of the Russian North.

We have analyzed several methods of obtaining detailed information about trees and integrated them into a complex image processing method. This is an enhanced shadow-vegetation method for automated processing of satellite images. It integrates local and focal image processing algorithms, and GIS-analysis of vector data.

We applied the method to several VHR satellite imageries (Quickbird, IKONOS and GeoEye) acquired in summer seasons in 2006-2009 for central and northern Kola Peninsula, Putorana Plateau and south-eastern Taimyr Peninsula.

Using our method we delineated single trees and shrubs in sparse forest in forest-tundra ecotone with accuracy over 80%, as proved by detailed visual interpretation of validation transects. Tree heights have been calculated with accuracy about 3 m using the shape-from-shadow technique. Tree line and forest line have been delineated. Tree canopy cover and distances between individuals have been calculated for various grid sizes, for further comparison with coarser imagery and development of multi-scale mapping approaches.

This study revealed that QuickBird satellite images is more suitable for detailed mapping of forest spatial structure properties than IKONOS or GeoEye images, due to a combination of good radiometric properties and spatial detail.

This research is part of PPS Arctic, the IPY project which investigates current status and past changes in the circum-arctic treeline zone, as well as associated social and natural factors. The study is carried out in the Laboratory of Aerospace Methods of the Faculty of Geography, Moscow State University, financially supported by the Benefits Russo-Norwegian project of the Norwegian Research Council (OST 185023/S50).

Remote Sensing Methods for Mapping the Above-Ground Phytomass of Plants in the Forest-Tundra Ecotone

Yurate Plyushkiavichyute[1], Gareth Rees[2], Elena Golubeva[1], Olga Tutubalina[1]

[1]*Faculty of Geography, Moscow State University, Russian Federation*

[2] *Scott Polar Research Institute, University of Cambridge, United Kingdom*

olgatut@mail.ru

Mapping of above-ground phytomass at the northern limit of forests provides a baseline for monitoring climate-induced changes. This is important for practical applications, such as assessing quality of pasture and defining reindeer migration routes. Use of very high resolution (1 m and better) aerial and satellite images is of particular interest, because then changes at the level of individual trees can be monitored over comparatively large areas.

The goals of this study are to: i) establish relations between phytomass values and structure, and spectral reflectance, derived from ground research; and ii) upscale from ground data to QuickBird satellite imagery to compile maps of above-ground phytomass for key sites.

This research is part of PPS Arctic, the IPY project which investigates current status and past changes in the circum-arctic treeline zone, as well as associated social and natural factors, including climate change. Vegetation changes due to climate would be mostly reflected in the changing structure of phytomass.

The field research focused on two sites in the central and northern parts of the Kola Peninsula, Russia. Over 50 vegetation samples were measured with a Skye Instruments 4-channel radiometer, geobotanically described, separated by species and plant parts, dried at 105^{o}C, and weighed.

These data were compared to derive relationships between reflectance, phytomass values and structure. The ground radiometry data were upscaled to QuickBird imagery of the study sites using spectral unmixing techniques. Finally above-ground phytomass maps of the key sites were compiled from QuickBird imagery.

Mapping the above-ground phytomass in tundra and forest-tundra can be used to predict changes in phytomass structure due to climate change. In the future we plan to develop our results to include relations between soil nutritional status and vegetation composition.

Small-Scale Remote Sensing Mapping of Geosystems in Taymyr–Putoran Region

Alexandra Tyukavina

Faculty of Geography, Lomonosov Moscow State Universit, Moscow, Russia

sasha_tyukavina@mail.ru

The aim of this research which is part of the international IPY PPS Arctic project is to study the modern state of vegetation, as well as geosystems in general, in a large part of north-central Siberia, including the Taymyr Peninsula and southward territories (66o00’- 77o43’N, 85o00’- 115o00’E) by way of compiling a small-scale (1:2,500,000) map of geosystems. The map includes such components of geosystems as vegetation, relief, and geocryological features. The resulting map is aimed to become the basis for large-scale field investigations of treeline ecotone in the region. Monthly MODIS composite images (spatial resolution 250 m) of 2005, processed and refined by the Space Research Institute (Russian Academy of Sciences) serve as the main source of up-to-date environmental information.

Several thematic maps, including the Circumpolar Arctic Vegetation Map (2003, 1:7,500,000), the Vegetation Map of USSR (1990, 1:4,000,000), the Geocryological Map of USSR (1996, 1:2,500,000) have been used to recognize different types of geosystems in satellite images. Map compilation is based on visual interpretation of MODIS images and DEMs (VMAP0, GTOPO30) to match borders of geosystems with natural orographic boundaries.

This research has been carried out at the Laboratory of Aerospace Methods, Department of Cartography and Geoinformatics at the Faculty of Geography, Lomonosov Moscow State University, and financially supported by the Benefits Russo-Norwegian project of the Norwegian Research Council (OST 185023/S50).

Soil features in the forest-tundra ecotone of Taimyr Peninsula and Putorana plateau

Anna Usacheva, Irina Gorbunova, Elena Golubeva
Faculty of Geography, Moscow State University, Moscow, Russia
usacheva@list.ru

Studies of soils in the forest-tundra ecotone were carried out for two model sites in north-central Siberia: Ary-Mas (Taimyr Peninsula) and Lama, western Putorana plateau.

The Ary-Mas site is located on the Taimyr Peninsula in southern tundra. It was investigated along a transect 2550 m length from the watershed to the third river terrace of the Novaya River (left tributary of the Khatanga River) and in six test plots with different character of the microrelief and vegetation. Along the entire transect and at each test area detailed descriptions of vegetation, ground cover were carried out, and the depth of the active layer, or seasonally thawing layer (STL) was measured. 3800 measurements of the depth of STL were made at the transect and 339 measurements around numbered larch trees. In different ecotopes we have laid 10 miniature temperature loggers at a depth of 10 cm, recording soil temperature every 4 hours for the period from 9 to 18 July 2010.

At each test plot soil pits were dug (from one to four). In total 17 soil pits were morphologically described.

All studied soils of theAry-Mas site belong to the class of gley soils in Russian soil classification (Klassifikatsiya i diagnostika pochv Rossii..., 2004), to cryosols in the international soil classification (Mirovaya korrelyativnaya baza pochvennykh resursov..., 2007).

The major organic horizons of soils are litter-peat (O=Oi, from here onwards we show Russian and international soil horizon indices), peat (T=Oe) coarse (AO=He), humus (H=Ha, He) (Polevoi opredelitel' pochv, 2008). All mineral horizons (Bg, Br) have signs of gley processes in different degree. Permafrost starts at a depth of 11 to 64 cm.

One test plot (PP1) along the transect has forest vegetation (sparse larch). Here coarse, humus and cryogenic ferruginated gleezems are formed. Forest ecotopes have the lowest for the whole site average depth of STL (30.5 cm), with the very lowest values of STL detected directly around larch trees (20.2 cm). Soil temperature correlates with the depth of thawing. The lowest temperatures at a depth of 10 cm are confined to the sparse larch forests and range from 3.7° to 5.7°C.

In larch treeline plots (PP2 and PP5) in the very vicinity of larch trees coarse gleezems are formed. The depth of thawing around the trees is more than in sparse larch forests, the average value is 25.9 cm. Soil temperatures are higher than at forest plot by 1.5-2 °C and equal to 5.9-7.3 °C. Apparently, such a distribution of STL depths and temperatures around the larch trees at the treeline is due to better seasonal thawing of the frozen horizon in more open (less forested) spaces.

In areas with tundra vegetation in the absence of trees, the most widespread are the frost mounds complexes (plots PP2, PP3, PP6), whose formation is related to uneven changes in volume during the freezing of the wet loamy soil. In the frost mounds complexes, under-developed soil are formed on the open spots (frost boil), while fringes of these spots are occupied by   humus and coarse gleezems, and in the depressions around the frost mound the peat humus gleezems are developed. Soils in the low parts of this complex are characterized by the highest thickness of organic horizons (10-24 cm) and relatively low depth of soil vertical profile (less than 45 cm). On higher parts if the microrelief on the contrary, the most thin organic horizons (10 cm) and maximum depth of the soil vertical profile (50 cm) are recorded. Such elevated areas also have the highest soil temperature (8.3-12.0 °C), with maximum temperature at the tops of of hillocks, almost devoid of vegetation (12.0 °C), which is over 3.5 °C higher than soil temperature in the depression between the two frost mounds. The difference in the values of the depth of STL and soil temperature are associated with both the general STL depth and with differential warming of soil surface due to cryogenic microrelief.

Soils of the studied ecotones differ sharply among themselves by grain size distribution. Thus, soil of tundra has loamy composition, and soil under forest and treeline are sandy loam. Thus, forests are confined to the soils of light granulometric composition, and this is, apparently, one of the main preconditions for the settlement of pioneer larch trees on the soils.

The second key site is located on a hillside in the western Putorana plateau, on the southern shore of Lake Lama. On the slope of the northern aspect a transect of 1000 m length was marked and described from top to bottom of the mountain slope. Seven plots were selected along the gradient of vegetation change. At each plot, in the most typical conditions one soil pit was made. Just as in the previous site, detailed descriptions of vegetation and ground cover were produced, and morphometric characteristics of trees along the transect, and at the test plots were recorded. Soil temperature was measured by temperature loggers (6 in total) in different ecotopes at a depth of 10 cm from 24 July to 1 August 2010.

The main soils at this site are peat-litozems (leptosols), coarse ferruginated (cryosols), and coarse and illuvial-ferruginous podburs (podzols).

As well as at the Ary-Mas site, soils in western Putorana plateau are thin (19-41 cm), but this is related not to the the depth of seasonal thawing, but with the proximity of parent rocks (gravel of basic gabbro rocks) and the steepness of the slope. Most of the soils are overmoistened, although less, than at Ary-Mas, and they do not contain morphological gleying. This could be due to improved drainage due to detrital (coarse gravelly) nature of the soils. All intermediate mineral soil horizons (B=Bs@, BHF and BF=Bsw) are characterized by a rather bright brown color and good structure (lumpy-granular or granular-lumpy), which is apparently due to the high iron content in these soils caused by the basic character of the source rocks.

In many soil profiles morphological cryogenic signs are revealed such as vertical orientation of the debris caused by cryogenic processes, cryogenic silty horizon BHF (Bsw), cryoturbation, banded cryogenic fabric, frost boil (accumulation of debris), frost sorting, and cryogenic roundness of debris due to of the rapid temperature transition in the soil profile through 0˚ C and prolonged stay in the frozen state.

One of the main reasons for the differentiation of soil and vegetation cover is altitudinal zonation, which determines the conditions of growth for tree species and characteristics of soils (thicker organic horizons and the appearance of organic-mineral (humus) horizons A are observed at lower hypsometric levels).

References

1. Klassifikatsiya i diagnostika pochv Rossii [Diagnosis and classification of Russian soils]. – Smolensk: Oikumena, 2004. 342 p. In Russian.
2. Mirovaya korrelyativnaya baza pochvennykh resursov: osnova dlya mezhdunarodnoi klassifikatsii i korrelatsii pochv [World correlative base of soil resources: a framework for international classification and correlation of soil]. Moscow: KMK Scientific Press Ltd., 2007. 278 p. In Russian.
3. Polevoi opredelitel' pochv [Field Identification of soils]. - Moscow.: Soil Institute named after V.V. Dokuchaev, 2008. 182 p. In Russian.

Notes

Notes

ISBN 978-5-89575-192-3