The role of Northern Eurasia in global sustainability research of Future Earth

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Future Earth is an international research platform with the goal to provide comprehensive knowledge for the pressing challenges of a fundamental transformation to a sustainable world. While the task of transformation is of a global scale, many environmental and socioeconomic issues are region-specific. Research into solutions and in support of good decision making, an ambition shared by both Future Earth and the Northern Eurasia Future Initiative, must therefore be cognisant of regional Earth system characteristics and sensitive to regional to local societal functioning and values. Future Earth is developing transdisciplinary research agendas for a number of integrative topics, addressed though Knowledge-Action Networks. We will discuss where research specific to Northern Eurasia could be integrated with and benefit from the global research Future Earth is facilitating. Knowledge-Action Networks of particular mutual relevance may include those on the food-water-energy nexus, on natural assets, on ocean sustainability, on the decarbonisation challenge, on extremes and disaster risk reduction, and potentially others as well. This session contribution is intended to initiate a dialogue about opportunities for collaboration.

Keywords: Future Earth, sustainability, Northern Eurasia, transdicsiplinarity

Transition from the Northern Eurasia Earth Science Partnership (NEESPI) to the Northern Eurasia Future Initiative (NEFI)

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Since 2004, the Northern Eurasia Earth Science Partnership Initiative (**NEESPI**) –an interdisciplinary program of internationally-supported Earth systems and science research –has addressed large-scale and long-term manifestations of climate and environmental changes over Northern Eurasia and their impact on the Global Earth system. With 40 books and more than 1500 peer-reviewed journal publications to its credit, NEESPI's activities resulted in significant scientific outreach. This created a new research realm through self-organization of NEESPI scientists in a broad research network, accumulation of knowledge while developing new tools (observations, models, and collaborative networks) and producing new, exciting results. These results can now be applied to directly support decision-making for societal needs and it is a right time to develop them. Firstly, during the past decade, the rates of climatic and related to them cryosphere changes increased, especially at high latitudes and in the mountains. Secondly, exponential economic development, urbanization, and anthropogenic pressure on major agriculture and pastoral regions of the interior continental regions of Northern Eurasia overlapped there with spatial and temporal redistribution of water resources that may cause both draughts and excess rainfall. And finally, some large-scale environmental changes (e.g., land abandonment) were caused solely by socio-economic changes that must be not only well understood, monitored, and reported but require a knowledgeable resistance, actions guided by natural ***and*** risk management sciences. Therefore, two years ago, we decided to shift gradually the foci of regional studies in Northern Eurasia towards applications with the following major Science Question: "What dynamic and interactive change(s) will affect societal well-being, activities, and health, and what might be the mitigation and adaptation strategies that could support sustainable development and decision-making activities in Northern Eurasia?". To answer this question requires a stronger socio-economic component in the ongoing and future regional studies focused on sustainable societal development under changing climatic and environmental conditions. The NEESPI Research Team has reorganized itself into "Northern Eurasia Future Initiative" (**NEFI**) and to the end of 2016 developed the NEFI Science Plan. It was split between two programmatic papers submitted to *Progress in Earth and Planetary Science* (PEPS) and *Environmental Research Letters* (ERL). These papers describe respectively the Plan rationale (cf.,presentation by Groisman *et al.* at the M IS03 Session this morning) and the major modeling approach that will be employed in addressing the "what to do" questions of the NEFI Research (cf., presentation by Monier *et al.* at this Session). In the current presentation, we provide a brief resume of the NEESPI achievements and give the outline of the new NEFI research. Throughout the NEESP Initiative duration, support for its studies has been provided by different national and international Agencies of the United States (in particular, the NASA Land Cover and Land Use Change Program), Russian Federation (in particular, the Ministry of Education and Science, e.g., mega-grant 14.B25.31.0026), and the International Belmont Forum (in particular, the ARCTIC ERA Mega-Grant). We anticipate a further extension of similar kinds of support for NEFI.

Keywords: Northern Eurasia, Environmental Changes, Societal adaptations and actions to mitigate the negative consequences of the environmental change and to benefit from the positive consequences, NEFI Science Plan

A Review of and Perspectives on Global Change Modeling for Northern Eurasia

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Northern Eurasia is made up of a complex and diverse set of physical, ecological, climatic, and human systems, which provide important ecosystem services, including the storage of substantial stocks of carbon in its terrestrial ecosystems. At the same time, the region has experienced dramatic climate change, natural disturbances, and land management practices over the past century. For these reasons, Northern Eurasia represents both a critical region to understand and a complex system with substantial challenges for the modeling community. This review is designed to highlight the state of past and ongoing efforts of the research community to understand and model these environmental, socioeconomic, and climatic changes. We further aim to provide perspectives on the future direction of global change modeling to improve our understanding of the role of Northern Eurasia in the coupled human-Earth system. Major modeling efforts have shown that environmental and socioeconomic impacts in Northern Eurasia can have major implications for the biodiversity, ecosystems services, environmental sustainability, and carbon cycle of the region, and beyond. These impacts have the potential to feedback onto and alter the global Earth system. We find that past and ongoing studies have largely focused on specific components of Earth system dynamics and have not systematically examined their feedbacks to the global Earth system and to society. We identify the crucial role of Earth system models in advancing our understanding of feedbacks within the region and with the global system. We further argue for the need for Integrated Assessment Models (IAMs), a suite of models that couple human activity models to Earth system models, which are key to address many emerging issues that require a representation of the coupled human-Earth system.

Keywords: Global change, Northern Eurasia, Earth System Models, Coupled human-Earth system, Climate change, Ecosystems

Urbanization and sustainable societal development under transitional economies and global change: A synthesis of North Asia Cities

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North Asia, extending a vast territory of 13 million km^2 that includes Ural, Siberia, and the Far East Federal District, of Russia, hosted less than 38 million population in 2016. The cities in North Asia have been experiencing new challenges since the collapse of the USSR in 1991, such as de-industrialization, land abandonment, depopulation of remote areas, internal (e.g., from the countryside into the cities) and external (brain drain) migration, weakening of social fabrics, market reforms in health service, moral demise reflected by higher crime rates, corruption, and overexploitation of millions “illegal immigrants” from other republics of the USSR, and interethnic conflicts in North Caucasus. “Democracy” restoration in Afghanistan caused a continuous civil war and a two-order increase of hard narcotics traffic from this country to the northern Asia cities. All the above provides us not only hard –learned tragic lessons but also an experiment opportunity to study the unique dynamics of the urban systems in northern Asia. Our objective is to synthesize the data and knowledge for the urban sustainability of these cities in the context of socioeconomic transformation and (possibly) climatic change. We will link key socioeconomic and biophysical drivers, especially institutional mechanism unique in transitional economies and global climate changes, to the spatiotemporal changes of urbanization and urban sustainability in North Asia. Major lessons include:
(1) Urban development in the forms of population and urban land changes has followed a distinct pattern in North Asia since the collapse of the former Soviet Union, large variations exist in time and space, which are particularly associated with population size, geographic location, and the level of economic development.
(2) Urban sustainability and its three dimensions, i.e., economic development, environmental protection, and social equity, followed very different patterns in time and space.
(3) Transitional economy reflected by policy shifts and increasing links with global communities have exerted different degrees of influence on urban development and sustainability in different parts of North Asia.
(4) Global climate change has affected urbanization in different climate zones and biomes in different ways, with urbanization in some biomes experiencing a much faster pace than that in others.
(5) The evolutions of urban ecosystems in these cities, reflected by various ecosystem services (e.g., air and water pollution, green spaces) have direct connections with urbanization processes and socioeconomic development.

Keywords: Urban, environment, social, transitional economies, North Asia

Ecosystem-Society Interactions on a Changing Mongolian Plateau

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We undertook a multi-disciplinary project aimed at synthesizing data, knowledge, and quantitative models on ecosystem and social resilience to the changing climate and dynamic socioeconomic pressures placed on the fragile ecosystems of the Mongolian Plateau. Our models of natural system (NS) and human system (HS) processes and dynamics, as well as the interactions and feedbacks among them, make use of multiple data sources across the Plateau. Inner Mongolia, in China, and Mongolia have had similar variations in climate, ecosystem, culture, and traditions, but different institutions, land-use intensities, levels of economic development, and demographic changes in the recent past. Among the major lessons are: 1) the spatiotemporal variation of physical and anthropogenic changes, as well as their effects on the ecosystems and societies, appeared much higher than previously expected; 2) though spatially variable, overall grassland biomass has been increasing in the past 15 years as a results of climatic and management changes; 3) human influences on the Mongolian CNH system, especially those related to the major policy shifts, have been stronger than those of the biophysical changes, but that the significance varies over time and among biomes, as well as between Inner Mongolia and Mongolia; 4) grazing, mining, and land uses are strongly affected by and feedback to processes of urbanization, globalization, and economic development; 5) despite some differences in the overall system dynamics in the two countries, the availability of grassland resources in the future will be tied to regional trends in urbanization and national economic development priorities; and 6) extensive forest plantations across semi-arid and arid landscapes need to be critically evaluated with a sound scientific base. The most critical challenge facing the Plateau is similar to that of the broader Northern Eurasian region: societal well-being and health are inextricably linked to environmental variability, and mitigation and adaptive capacity are strongly affected by policy decisions within heterogeneous national and sub-national entities.

Keywords: Socioecological, Mongolia, Land use, Climatic change, sustainability

Development of an interactive tool to raise climate change awareness of public, policy makers, and practitioners

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In the framework of adaptation to climate change and mitigation of its consequences it is necessary to promote and support activities aimed at reducing possible risks. But there is a problem of insufficient awareness among decision-makers, as well a lack of scientific background. Those responsible for making decisions, stakeholders and the public do not have the skills and knowledge to work with the accumulated climate data to development an adaptation and sustainable development strategy. The goal is to provide these groups with tools, skills, thematic information for understanding climate processes occurring in the region.
We believe that the preparation of both the persons responsible for decision-making, and the future specialist in environmental sciences shouldn’ t be realized in artificial learning environment, but on the basis of actual operating computational and information systems used in climate research. Such kind of a system was developed by a team of the Institute of Monitoring of Climatic and Ecological Systems SB RAS. The information-computational Web GIS "Climate" (http://climate.climate.scert.ru) provides opportunities to study regional climate change and its consequences providing access to climate and weather models, a large set of geophysical data and means of processing and visualization. Also, the system is used for undergraduate and graduate students training. In addition, the system capabilities allow creating information resources to raise public awareness about climate change, its causes and consequences, which is a necessary step for the subsequent adaptation to these changes. Currently, an interactive System User Manual as a tool for decision-makers is under development. It contains not only the information needed to use the system and perform practical tasks, but also the basic concepts explained in detail. The knowledge necessary for understanding the causes and possible consequences of the processes is given. The results of implementation of practical tasks are available not only in the form of color surface maps, but also in the form of accessible in the Internet cartographic layers that can be consequently used in usual desktop GIS. The manual will help to prepare qualified users, which in the future will be able to determine the policy of the region to adapt to climate change impacts and hazards.
The work is supported by Russian Science Foundation grant 16-19-10257.

Keywords: climate change , Web-GIS , awarness raising

Interlinked and changing effects of major climate oscillations on snow cover, polar sea ice, and land surface phenology over the northern hemisphere

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Warming in the far northern hemisphere not only significantly affects Arctic Sea ice cover but also snow melt and land surface phenology. We investigated how these three phenomena are related to three major climate oscillations: the Atlantic Multidecadal Oscillation (AMO); the North Atlantic Oscillation (NAO); and the Arctic Oscillation (AO). First, we assembled time series of two daily sea ice products to calculate the first day of open water in the spring, the first day of freeze onset in the fall, the length of time with open water, and the length of time with ice cover. The Sea Ice Concentration product is derived from Nimbus-7 SSMR and DMSP SSM/I-SSMIS Passive Microwave data (v.1) and has a 25km spatial resolution with data available between October 1978 and December 2015. The second sea ice dataset is the IMS product from the National Snow and Ice Data Center based on POES/GOES data, SSMI/I and AMSR-E data, and other ancillary data. We selected the 4km product that has data available between 2004 and 2016. We correlated the results with the climate oscillation indices for the entire time period (1979-2015, 2004-2015), and for overlapping 10-year segments. In addition, we used a time series (2001-2015) of Moderate Resolution Imaging Spectroradiometer (MODIS) Nadir BRDF-Adjusted Reflectance (NBAR) data and land surface temperature data at 0.05º spatial resolution. We then derived land surface phenology metrics focusing on the peak of the growing season by fitting convex quadratic regression models connecting the NDVI time series with the seasonal progress of Accumulated Growing Degree-Days (AGDD) derived from land surface temperature data. We linked the annual information on the peak timing, the thermal time to peak, and the peak magnitude with the three climate oscillation indices and evaluated the effects of nearby ice cover and winter snow cover.

Keywords: Sea Ice, Land Surface Phenology, Remote Sensing

Environmental Changes in Central Asian High Elevation Communities: Land Surface Phenology and Snow Cover Seasonality in Kyrgyz Highlands

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Prior to the Soviet era, highlanders in Central Asia practiced vertical transhumance in raising livestock—sheep and goats—for wool, meat, milk, and hides. Collectivization disrupted this practice with multiple external subsidies. Since 1991 montane agro-pastoralism has been disrupted by withdrawal of external subsides and introduction of a market economy. Moreover, Montane agropastoralism is highly vulnerable to environmental change. Our project evaluates four aspects of environmental change in human settlements and associated pasturelands in representative areas of the Kyrgyz Republic and Uzbekistan during the satellite era and projected changes into the middle of the 21st century to assess impacts on these highland communities and the pastures upon which they depend. The four aspects of environmental change are (1) changes in the thermal regime including growing season timing and extremes, (2) changes in the moisture regime including peak precipitation timing and snow cover duration, (3) changes in socio-economic conditions including income, education, agricultural production and practices, and institutions, and (4) changes in land cover, land use, and land condition including alterations in terrain from landslides and earthquakes. To date we have been focusing on highland communities in four rayons in the Kyrgyz Republic: At-Bashy and Naryn in Naryn oblast, and Alay and Chong-Alay in Osh oblast. Here we will present results of blending Landsat TM/ETM+/OLI and MODIS products with 30 m DEM data to characterize land surface phenology and snow cover seasonality in highland pastures using the thermal time metrics growing degree-days and frost degree-days, respectively, calculated from MODIS land surface temperature data. Of particular interest are the influences of snow cover melt date and snow cover duration on subsequent metrics of land surface phenology—peak height and thermal time to peak—as modulated by terrain (elevation, slope, and aspect).

Keywords: Remote Sensing, Central Asia, Highlands, Environmental Change

Breathing of Siberia: large-scale quantifying of sources and sinks of atmospheric carbon

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The boreal and arctic zone of Siberia represents a «hot spot» area in the global Earth climate system, containing large and potentially vulnerable carbon stocks as well as considerable carbon dioxide (CO_2) and methane (CH_4) exchange fluxes with the atmosphere. Up to the recent time, the Siberian region was only sparsely covered by carbon flux measurements. Solely in the frame of EU-funded projects «Eurosiberian Carbonflux» and «Terrestrial Carbon Observing System –Siberia» (TCOS-Siberia) between 1998 and 2005 several atmospheric and terrestrial ecosystem stations were operational in European Russia and Siberia.
Since 2006, in order to monitor long-term biogeochemical changes, the Zotino Tall Tower Observatory (ZOTTO; www.zottoproject.org), a continental research platform for large-scale climatic observations, is operational in Central Siberia (60˚48' N, 89˚21' E) about 20 km west of the Yenisei river. The observatory was erected as a result of joint efforts of SIF SB RAS (Russia) and MPI-BGC (Germany) and consists of a 304-m tall mast for continuous high-precision measurements of carbon dioxide, methane, carbon monoxide, ozone, reactive nitrogen species, meteorology and a multitude of aerosol properties in the well-mixed planetary boundary layer (PBL). Sampling of the PBL is essential for the «top-down» approach, since it minimizes local effects and permits to capture regional concentration signals. Such measurements are used in atmospheric inversion modelling to estimate sinks/sources at the surface over the large Siberian territory. In turn the PBL measurements at the tall tower are linked with eddy covariance measurements of exchange fluxes of greenhouse gases (GHG) over locally representative ecosystems (a «bottom-up» approach). Since 2008 the eddy covariance flux tower is available in the northern taiga mature larch forest (64˚12' N; 100˚27'E) and two more towers were erected in 2012 in a *Pinus sylvestris* forest and on a peat bog site (60˚48' N; 89˚22' E). Since 2015 and 2016, eddy covariance flux measurements were started in a mid-taiga dark coniferous forest (60˚01' N; 89˚49' E) and in a forest-tundra ecotone (67˚28' N; 86˚29' E), respectively. All eddy covariance stations are integrated into the large-scale observation network «KrasFLUX» lead by SIF SB RAS and MPI-BGC. This network captures exchange fluxes of CO_2 and CH_4 in the representative ecosystems of the main biogeochemical provinces for the whole Yenisey river basin of 2580 thousand km², that can be scaled up to the region using vegetation maps, forest biomass inventories and remote sensing information. Since summer 2017, it is being planned to expand the observation network and erect a new station for a long-term atmospheric monitoring of GHG (CO_2/CH_4/H_2O) near the Dikson city on the shore of the Arctic ocean (73˚33' N; 80˚34' E) - the Dikson Atmospheric Measurement Integration Station (DIAMIS). This new Arctic/oceanic research platform will be complementary to ZOTTO, permitting to better constrain the budgets of biogeochemical trace gases in Central Siberia, trace the ocean-continent transport of GHG, and extend the circum-Arctic observation network.
Here we summarize the scientific rationale of the observation network, infrastructure details of the stations, the local environments and give some results obtained from the measurements.
Research program was funded by the Max Planck Society (Germany) and project of RSF # 14-24-00113.

Keywords: Atmosphere, Carbon dioxide, Methane, Boreal forests, ZOTTO

Decadal changes in the atmospheric water cycle and the terrestrial water storage in Northern Eurasia

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We investigated interannual variations in the atmospheric water circulation pattern and the terrestrial water storage change in Northern Eurasia, using long-term atmospheric reanalysis data and the Gravity Recovery and Climate Experiment (GRACE) data. We found interdecadal modulation in the relationships between the interannual variability of summer precipitation and the atmospheric circulation pattern among the three major Siberian river basins (Lena, Yenisei, and Ob). We also revealed a significant increasing (positive) trend of geopotential height in the low-level troposphere since the mid-1980s over Mongolia, resulting in the increasing trend of westerly moisture flux into the Yenisei and Lena river basins. On the contrary, we revealed that summer evapotranspiration has been increasing in tundra region of the eastern Siberian from 2002 to 2015. The increased summer evapotranspiration could be associated with rapid increase of summer air temperatures in the region.

Keywords: Arctic, Lena river basin, Mongolia

Changes in high ambient temperature extreme and heat stress

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Extreme heat events based on maximum temperature were projected to be more frequent and severe in many regions of the world under a warming climate. However, the concurrence of high temperature and humid weather could be more unbearable and hazardous to human health. In this study, the changes of summer heatwave days (HDs) are assessed based on a heat stress index using the wet-bulb globe temperature (WBGT) which accounts for both changes in temperature and humidity. Projections of temperature and relative humidity derived from five general circulation models (GCMs) outputs are used to estimate the HDs. The projected changes in WBGT-based HDs are compared with those using ambient temperature only. The results show that the difference of changes in occurrence of the extremes appears to be considerable in some regions, suggesting that previous studies using ambient temperature only may underestimate the heat stress risk under a warming climate. This study would be helpful for further assessment of socioeconomic vulnerability and adaptation to climate risk.

Keywords: climate change, heat stress, temperature extreme

Projected changes of growing season length across Northern Eurasia in the 1.5˚C and 2˚C warmer world

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Northern Eurasia, undergoing dramatic climatic and environmental changes, is a key part of the global socioeconomic systems. Projection data of growing season length (GSL) and daily mean temperature in 12 CMIP5 models under the RCP4.5 scenario were employed to investigate responses of ecology in Northern Eurasia to global warming. According to the projections from multi-model ensemble mean under the RCP4.5 scenario, the global mean temperature will increase to 1.5 ℃ and 2 ℃ above pre-industrial levels around 2029 and 2049 respectively. Changes of GSL in the 1.5℃ and 2℃ warmer time period are investigated as differences relative to the reference period (1986–2005) for RCP4.5. Results show that GSL have an evident increase across most of Eurasia under global warming of 1.5℃. However, GSL shows slight decline in several high latitude and altitude areas. Furthermore, in the 2℃ warmer world, GSL increases around the whole Eurasia relative to that in the 1.5℃ warmer world. The margin of increase is lower in northern Europe and East Asia compared to other areas in Eurasia. The changes of GSL under global warming of different thresholds may have far reaching consequences for the ecosystems and agriculture in Eurasia.

Keywords: Growing season length, Global warming, Projection

Virtual research environment for analysis, evaluation and prediction of global climate change impacts on the Northern Eurasia environment

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Description and the first results of development of virtual computational information environment for analysis, evaluation and prediction of the impacts of global climate change on the environment and climate of a selected region is presented. The thematic virtual research environment (VRE) is aimed at development of an Internet-accessible computation and information tools providing specialists, decision-makers and stakeholders with reliable and easy-used tools for in-depth statistical analysis of climatic characteristics, and instruments for detailed analysis, assessment and prediction of impacts of global climate change on the environment and climate of the targeted region. VRE under development comprises best features and functionality of earlier developed information and computing system CLIMATE (http://climate.scert.ru/), which is used in Northern Eurasia environment studies. It also provides computational processing services launching to support solving tasks in the area of environmental monitoring, as well as presenting calculation results in the form of WMS/WFS cartographical layers in raster (PNG, JPG, GeoTIFF), vector (KML, GML, Shape), and binary (NetCDF) formats. Its usage for solving related to Northern Eurasia climate change research problems is illustrated.
The work is supported by the Russian Science Foundation grant No16-19-10257.

Keywords: virtual research environment, web-GIS, climate change

Changes in main components of the water cycle or Lake Khanka during the 1949 - 2015 period.

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Lake Khanka (or Xingkai in China) located on the border between Primorsky Krai (Russia) and Heilongjiang Province (Northeast China) belongs to the Ussuri River basin. The Lake's drainage basin is fed by 28 rivers (8 in China and 20 in Russia), but the only outflow of the Lake is the Sungach River. During the past 15 years (2000-2015) level of the Lake have increased by 1.87 m and exceeded the historical maximum during the period of observations since 1949. It resulted in flooding of river-bank areas and agricultural lands. To understand reasons of these level changes it is necessary to analyze effects of natural and anthropogenic factors that influence the Lake water budget.

During this study of the Lake water balance, we estimated contribution of different hydrometeorological variables on the changes of its level. For these analyses we used regular hydrometeorological observations within the Lake basin from 1949 to 2015. Anthropogenic effects were estimated from the water management information and from statistical and satellite data.

Analysis of the Lake level observations showed an upward tendency since the 1980s, which became most disastrous since 2000. These changes in the Lake level were accompanied by increase of the surface water inflow into the Lake. Furthermore, since 1975, increase of annual precipitation on the Lake surface has been observed. Together, with a wind speed decrease overt the Lake surface during the entire observation period, evaporation from the Lake surface has also decreased.
Anthropogenic impact on the Lake Khanka level is less evident, if compare to natural processes. In particular, during 2000-2015 the effect of natural processes on the Lake Khanka level has been more significant than of anthropogenic factors (Table). Specifically, the total surface water inflow into the Lake, precipitation at the Lake surface, and evaporation from its surface determine the lake level changes by 153 cm (or 82 % of the total change). Anthropogenic factors explain 34 cm or 18% of the Lake level changes. Among them, the effect of the Muling River flood water diversion on the Chinese territory was more important than other anthropogenic factors.

Keywords: Lake Khanka, water budget, climatic and anthropogenic changes

Table. Contribution of natural and anthropogenic factors to the Lake Khanka level changes during the 2000-2015 period.

Factors	Contribution to the Lake level changes	
	in cm	in % of total change
Natural (environmental) factors		
The total surface water inflow into the lake	20	11
Precipitation at the lake surface	43	23
Evaporation from the lake water area	90	48
Subtotal:	*153*	*82*
Anthropogenic factors		
Runoff through the water interception drains	-24	-13
Water consumption e	-11	-6
The Sungach River runoff decrease due to reduction of its outflow from the Lake	35	19
Water inflow from the Small Khanka Lake (on the Chinese territory) due to the Muling River flood water diversions.	34	18
Subtotal:	*34*	*18*
TOTAL CHANGES	187	100

Changes in the wind regime in Russia

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The main objective of this research is to monitoring wind characteristics change in Russia. The wind regime of Russia varies a great deal due to the large size of the country' s territory and variety of climate and terrain conditions. Changes in the regime of surface wind are of great practical importance. They can affect heat and water balance. Strong wind is one of the most hazardous meteorological event for various sectors of economy and for infrastructure.
At meteorological stations wind speed and wind direction are measured at the height of 10-12 meters over the land surface with the help of wind meters or wind wanes.
Calculations were made on the basis of data for the period of 1976-2016. It allowed the massive scale disruption of homogeneity to be eliminated and sufficient period needed to obtain sustainable statistic characteristics to be retained. Data on average and maximum wind speed measured at 1340 stations of Russia were used. The analysis of changes in wind characteristics was made on the basis of point data and series of average characteristics obtained for 9 quasi-homogeneous climatic regions. Statistical characteristics (average and maximum values of wind speed, prevailing wind direction, values of the boundary of 95%- confidence interval in the distribution of maximum wind speed) were obtained for all seasons and for the year as a whole. Values of boundaries of the 95%-confidence interval in the distribution of maximum wind speed were considered as indicators of extremeness of the wind regime. The trend of changes in average and maximum wind speed was assessed with a linear trend coefficient. The analysis of the results allowed seasonal and regional features of changes in the wind regime on the territory of the Russia to be determined. The trends of decreasing wind speed are discovered in the European territory and Western Siberia, especially in the winter and fall seasons. Negative trends in changes of the number of days with strong wind are also dominated, but in the spring at a considerable number of meteorological stations (especially in Western Siberia) recorded growth in the number of days with high velocities.
The work was supported by the Ministry of Education and Science of the Russian Federation (grant 14.B25.31.0026).

Keywords: Wind speed, climate monitoring, seasonal and regional features of changes

Effects of snow cover change on taiga forest ecosystem.

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Global air temperatures continue to rise and an effect of global warming is stronger in the North. The air temperature already increased for 2-3 degrees in Siberia (Serreze and Barry, 2011) and will continue to rise in the future (IPCC 5th report). Increasing air temperatures and winter precipitation may affect vegetation through change in snow cover onset and its depth because these snow parameters possibly affect soil moisture and soil temperature, alter nutrient availability in the following growing season (Walker at al. 1995; Decker et al 2003; Natali et al 2012)
To understand effects of changing snow cover depth on taiga forest ecosystem, snow manipulation experiment was conducted in winter of 2015 in taiga forest dominated by *Larix cajanderi* at Spasskaya Pad experimental forest (the Republic of Sakha, Russia). Snow from 20 x 20 m plot was transported to another plot with the same area and spread out evenly.
In the following growing season small larch trees needle elongation and thaw layer depth was manually measured, and to know initial conditions and estimate the effect of snow manipulation, soil and larch stem were sampled before and after the experiment. Shoot and needle samples were collected only after manipulation. Further water from soil and stem was extracted cryogenically and analyzed for water isotope composition. In addition, needle and shoot carbon and nitrogen content as well as their isotopic ratios were analyzed.
Effects of snow cover depend on vegetation cover and region specific (Juan et al 2014). Boreal and temperate forests with thin organic layer are more susceptible to freezing disruption (Hardy et al 2001). Our results show that after snow manipulation, soil temperature decreased significantly at Snow- plot for soil layers from surface to 80 cm. In spring, advanced snowmelt of reduced snowpack increased summer soil temperature, but decreased soil moisture. Changes affected phenology of larch trees by slowing the speed of needle elongation and decreased nutrient availability in soil and thus decreased nitrogen content in needles in July, although did not affect needle length and nitrogen content in August. We suggest this may be results of reduced nitrogen availability in soil and inability of plant to uptake soil nitrogen due to lowered soil moisture or frost-induced fine-root damage caused by increased frequency of freeze-thaw cycles during snow-free period.
At Snow+ plot, small trees needles at Snow+ plot were significantly longer during early growing season, but at the end of summer the difference in needle length was not significant. Increased nitrogen content of soil and mirroring increase of needle nitrogen content suggest higher nutrient availability and increased uptake of these nutrients with 20% higher soil moisture at Snow+ plot and insulating properties of increased snowpack reduced frequency of freeze-thaw cycles
Higher nitrogen content of needles at Snow+ and larger soil ammonium pool in July may be a result of higher winter soil temperature due to increased insulation by snow cover which led to higher microbial activity (Schimel et al 2004). Lower needle nitrogen content and soil ammonium at Snow- was observed because soil decomposer communities were disturbed by extreme soil frost in winter or freeze thaw cycles in spring (Sulkava et al 2002). Therefore, manipulated snow cover during winter had the effect on larch tree phenology through soil moisture and soil nutrient availability during summer. Expected increase in production (Bosiö et al 2014) will be studied in further research.

Keywords: snow manipulation, phenology, boreal forest, nutrient availability, growing season, stable isotopes

Evaluating climate severity for human comfort in a changing climate of the 21st century in Central Siberia

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In the past, human migrations were associated with climate change. As our civilization developed, humans depended less on the environment, in particular on climate, because technological and economical developments in the span of human history allowed them to adapt to and overcome environmental discomfort of the environment. Siberia is known to be sparsely populated. As can be viewed from night lights imagery, the Siberian population is concentrated along the forest-steppe zone in the south, with its comfortable climate and rich agriculture on fertile soils. In a warming climate, vast Siberian lands may be attractive for population migrations.
Our goal was to evaluate Siberia's climate severity and comfort for humans from a view point of winter conditions (degree-days below 0°C, winter duration, and presence/absence of permafrost) in the contemporary climate and to predict the potential in climate comfort in a warming climate by the 2080s. Additionally, our goal was to evaluate future crop potential that may evolve as the climate changes.
Our study area is Central Siberia within the window 85-105°E and 51-75°N including the Krasnoyarsk territory and the Republics of Khakassia and Tyva. Climate data from 100 weather stations over the study area were used to map the negative degree-days for the 1960-1990 baseline period using a digital elevation model of 1 km resolution using Hutchinson's thin plate splines. The outcomes from ten global climate models (CMIP5) and their ensemble were used to characterize a range of warming by the 2080s. The permafrost distribution in the contemporary climate was calculated as a function of the July and January temperatures and annual precipitation ($R^2 = 0.70$). Stefan's theoretical equation was used to calculate the future permafrost distribution and map its border.
The baseline 1960-1990 negative degree-days maps demonstrated that the contemporary climate should be characterized as severe and uncomfortable for humans especially over the permafrost zone. Only some lands in the forest-steppe zone over Siberia free of permafrost are characterized as mild and comfortable for humans.
As predicted from the CMIP5 models, by the 2080s, Siberia would be characterized by milder and more moderate climates with less permafrost coverage. Superimposing the climate severity, permafrost and crop potential maps onto population density maps demonstrated good correlations between them. Predicted mild climates and doubled crop production might attract the humans to migrate to Siberia during this century.

Keywords: human comfort, climate change, crop potential, Siberia

CO_2 and heat fluxes in a recently clear-cut spruce forest in European Russia.

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Ecosystem carbon dioxide, energy and water fluxes were measured using eddy covariance and portable chambers in a fresh clear-cut surrounded by a mixed spruce-birch-aspen forest in the boreal zone of European Russia. Measurements started in April 2016 following harvest and continued for five months. The clear-cut was a permanent source of CO_2 to the atmosphere. Total ecosystem respiration (TER) and gross primary production (GPP) were about 7.4 gC m^{-2} and 4.1 gC m^{-2} per day respectively. Eddy covariance data showed a reasonable accordance with the chamber measurements. During the mid-spring the mean daily latent (LE) and sensible (H) heat fluxes were similar and the Bowen ratio (Bo=H/LE) averaged about 1.0. During the late spring and summer months the net ecosystem exchange of CO_2 (NEE) remained slightly positive following onset of vegetation growth, while Bo was changing in the range from 0.3 to 0.5. There was strong diurnal variability in NEE, LE and H over the measurement period that was governed by solar radiation and temperature as well as leaf area index (LAI) of regrown vegetation. This study was supported by a grant from the Russian Science Foundation (14-14-00956).

Keywords: Carbon cycle, heat fluxes, eddy covariance, clear-cutting

Assessment of carbon budget of terrestrial ecosystems of Russia and comparison of bottom-up and top-down estimates

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We present a reanalysis of terrestrial ecosystems Full verified Carbon Account (FCA) for Russia for the period of 2000-2012. The methodology relies upon integration of multiple approaches of carbon cycling assessment with following harmonizing and mutual constraints of the results received by independent methods. The landscape-ecosystem approach (LEA) was used for a systemic design of the account and empirical assessment of the LEA based on a relevant combination of pool-based and flux-based methods. The information background of the LEA is presented in a form of an Integrated Land Information System which include the hybrid landcover (HLC) and relevant attributive databases. HLC was developed based on remote sensing multi-sensor concept (using 12 different satellite products), geographic weighted regression and Geo-wiki validation. Carbon fluxes which are based on long-term measurements were corrected based on seasonal climatic indicators of individual years. Uncertainties of intermediate and final results within LEA are calculated by sequential algorithms. Results of the LEA were compared with those obtained by eddy covariance, process-based models of different types, inverse modeling and GOSAT Level 4 Products. Uncertainty of the final results was calculated based on the Bayesian approach. It has been shown that terrestrial vegetation of Russia served as a net carbon sink at range of 0.48-0.65 Pg C yr-1 during the studied period, mostly driven by forest sink, with interannual variation of around 10-20%. The regional variation was significantly higher that depends on specifics of seasonal weather and accompanying regimes of natural disturbances. The overall uncertainty of the Net Ecosystem Carbon Budget is estimated at ~22-25% (± 1 σ) at the annual basis and ~7-9% for the period’s average under an assumption that the methods and data used do not have uncontrolled biases.

Keywords: carbon cycle, North Eurasia

High-resolution CO_2 flux inverse modeling using ground-based observations

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We report recent progress in our development of the high-resolution CO_2 flux inversion system that is based on the Lagrangian-Eulerian coupled tracer transport model and estimates surface fluxes from atmospheric CO_2 data collected by the global in-situ network. We apply the Lagrangian particle dispersion model (LPDM) FLEXPART to estimate the observation footprints at a 0.1 degree spatial resolution. The LPDM is coupled to a global atmospheric tracer transport model (NIES-TM). The adjoint of the coupled transport model is used in an iterative optimization procedure based on a either quasi-Newtonian algorithm or singular value decomposition. A flux error covariance operator is implemented via implicit diffusion. Weekly flux corrections to prior flux fields are estimated for the period of 2008 to 2012 from in-situ CO_2 data from global observation network included in Obspack dataset and data for Siberian station network JR-STATION. High-resolution prior fluxes were prepared for fossil fuel combustion (ODIAC), biomass burning (GFAS), and terrestrial biosphere (VISIT). Terrestrial biospheric flux was constructed using a vegetation mosaic map and separate simulation of CO_2 fluxes at daily time step by VISIT model for each vegetation type. The prior flux uncertainty for terrestrial biosphere is scaled proportionally to monthly mean GPP by MODIS product. The flux estimates were validated by comparing seasonal cycle of the CO_2 fluxes at regional level with the lower resolution inverse model estimates. The use of high-resolution atmospheric transport in flux inversion has advantage of obtaining more accurate flux corrections to natural fluxes by adding an ability to separate observations strongly influenced by local sources such as anthropogenic emissions and forest fires.

Keywords: carbon cycle, data assimilation, inverse modeling

Distribution of trace gases and aerosols in the Siberian air shed during wildfires of summer 2012

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During the last two decades, three strong biomass burning events have been observed in Russia: two of them in 2002 and 2010 in the European part of Russia, and another one in 2012 in West and East Siberia. In this paper we present results of the extensive airborne study of the vertical distribution of trace gases and aerosols carried out during strong wildfire event happened in summer 2012 in Siberia. For this purpose, the Optik TU-134 aircraft laboratory was used as a research platform. A large-scale airborne campaign has been undertaken along the route Novosibirsk–Mirny–Yakutsk–Bratsk–Novosibirsk on 31st of July and 1st of August, 2012. Flight pattern consisted of a number of ascents and descents between close to the ground and 8 km altitude that enabled 20 vertical profiles to be obtained. Campaign was conducted under the weather conditions of low-gradient baric field that determined the low speed transport of air masses, as well as the accumulation of biomass burning emissions in the region under study.

Highest concentrations of CO_2, CH_4 and CO over wildfire spots reached 432 ppm, 2367 ppb, and 4036 ppb, correspondingly. If we exclude from the analysis the data obtained when crossing smoke plumes, we can find a difference between background concentrations measured in the atmosphere over regions affected by biomass burning and clean areas. Enhancement of CO_2 over the wildfire areas changed with altitude. On average, it was 10.5 ppm in the atmospheric boundary layer (ABL) and 5-6 ppm in the free troposphere. Maximum CO_2 enhancements reached 27 ppm and 24 ppm, correspondingly. The averaged CH_4 enhancement varied from 75 ppb in the boundary layer to 30 ppb in the upper troposphere, and a little bit lower than 30 ppb in the middle troposphere. Maximum CH_4 enhancements reached 202 ppb, 108 ppb, and 50-60 ppb, correspondingly. The averaged and maximum enhancements of CO differed by an order of magnitude. Thus, in the ABL the maximum difference in concentration between clean and wildfire areas reached 2300 ppb, while averaged one was 170 ppb. In the middle troposphere maximum enhancements varied from 1000 to 1700 ppb.

The vertical distribution of ozone has its own peculiarities. Ozone concentration decreased in the layers with enhanced aerosol concentration and it increased in the areas with lower aerosol content. At the same time, photochemical production ozone was observed at the plume edges in the zone of fresh air entrainment.

This work was supported by the Russian Foundation for Basic Research (grant No 17-05-00374).

Keywords: Atmosphere, Aerosol, Greenhouse gases, Wildfires

Quantifying historical and future net exchanges of greenhouse gases of CO_2, CH_4 and N_2O between land and the atmosphere in Northern Eurasia

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The largest increase of surface air temperature and related climate extremes have occurred in Northern Eurasia in recent decades, and are projected to continue during the 21st century. The changing climate will affect biogeography, land cover, and carbon sink and source activities in the region, which in turn, will affect how global land use evolves in the future as humans attempt to mitigate and adapt to climate change. Regional land-use changes, however, also depend on pressures imposed by the global economy and environmental changes. Feedbacks from future land-use change will further modify regional and global biogeochemistry and climate. This study uses a suite of linked biogeography, biogeochemical, economic, and climate models to explore how climate-induced vegetation shifts in Northern Eurasia will influence land-use change, carbon cycling and biomass supply across the globe during the 21st century. We find that, at the global scale, while more land will be allocated towards food and biofuel crops (from current 22 to 37 million km^2 at the end of the 21^{st} century) due to increasing population and associated economic development, and changes of land use and vegetation shift in northern Eurasia, under the no-policy scenario. The affected global land-use change and climate result in a global cumulative carbon sink of 52 Pg C under the no-policy scenario (where CO2 equivalent greenhouse gas concentrations reach 870 ppmv by the end of 21*st* century), while under the policy scenario (limits CO2 equivalent greenhouse gas concentrations to 480 ppmv by the end of the 21*st* century), the cumulative carbon is sink of 63 Pg C. The global biomass supply will decrease 36 and 14 Pg under the no-policy and policy scenarios, respectively. In the presentation, we will also discuss our analysis on N_2O and CH4 exchanges between the biosphere and the atmosphere in response to the changes of land cover and climate during this century.

Keywords: Greenhouse gas, biogechemistry models, earth system modeling

Climate change and water sources in Arctic streams; effects on physiochemical variables and biotic communities.

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In Arctic regions climatic change is modifying the relative contributions and temporal dynamics of water sources (rainfall, ice-melt, snowmelt, and groundwater) to river flow. These changes will have significant implications for physicochemical habitat and associated biotic communities. Aquatic systems downstream of glaciers may shift from one of a deterministic nature to one with greater stochasticity, both in terms of their physicochemical variables, associated biological communities and functional trait composition. Nutrient uptake experiments in Svalbard streams indicated most rivers exhibited a low demand for NO_3 and PO_4 but demand for NH_4 and acetate was more variable and in several rivers comparable to sub-Arctic regions. Similar experiments in northeast Greenland showed NH_4 and acetate were the highest in demand but uptake was low compared to Svalbard and other Arctic and sub-Arctic regions. However, diffusing substrate experiments in Greenland streams showed highest primary productivity when NH_4 and PO_4 were added simultaneously, with autotrophic community productivity increasing more than that in heterotrophic communities. These data suggest NH_4 retention and uptake may be facilitated by labile dissolved organic carbon availability in these streams, which may increase with climate change with release from permafrost. Evidence from a number of Arctic and also alpine studies indicates reductions in glacial meltwater runoff are expected to drive an overall increase in local alpha diversity and abundance, but a decrease in regional diversity and rareness as specialist cold water taxa become extinct. Our understanding of potential ecological tipping points and associated indicator taxa is limited but data from a number of regions have identified threshold changes in community composition of stream taxa at <5.1% glacier cover and <66.6% meltwater contribution. An unexpected impact of glacier volume loss has been the liberation of contaminants, including pesticides and other persistent organic pollutants, from the early industrial revolution and onwards. A recent concern has been regarding uncertainty in how climate change is shifting these contaminants from glacial stores to other ecosystems, with potential detrimental effects.

Detecting change amidst uncertainty in digital elevation models: A comparison of SRTM and ASTER DEM products for two oblasts in the Kyrgyz Republic

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Digital elevation models (DEMs) provide a starting point to investigate the landscape structure in terms of key terrain variables, such as elevation, slope, and aspect. However, in changes in the land surface arising geomorphic processes, seismicity, and human activities can significantly alter landscape structure. The fine spatial resolution derived from SRTM and ASTER are widely used but the underlying data are separated in time. The SRTM data were acquired during the Shuttle Radar Topography Mission in 1994. In contrast, the ASTER GDEM product has been built up during ASTER’ s flight onboard Terra. To support an analysis of terrain effects on land surface phenology, we evaluated both DEMs to identify where differences between the DEMs were attributable to land change rather than bias or methodological uncertainty. We discuss the role of relief in influencing population distribution and land surface phenology for Naryn and Osh oblasts in the Kyrgyz Republic.

Keywords: Relief, SRTM, ASTER, Digital elevation model, Kyrgyz Republic

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