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

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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

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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

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

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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.

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

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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

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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

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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

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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

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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.

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Keywords: Atmosphere, Aerosol, Greenhouse gases, Wildfires

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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 21st 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

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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.

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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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