Fire-induced forest transformations in the Zabaikalye region, southern Siberia

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Wildfires are one of the main disturbances in Siberia impacting on structure, sustainability, and carbon budget of boreal forests as well as on people' infrastructure and safety. The Zabaikalye region located in the south of Siberia is characterized by one of the highest fire activity in Russia. We have estimated fire disturbances in the Zabaikalye region with a use of Institute of Forest satellite fire dataset and official fire statistic data. Both datasets show trend in significant growth of fire activity in the region. The highest fire activity is observed in the central and southern parts of the Zabaikalye region. Repeatedly burned forest area accounted 20% (6.86 million ha) of the total forest area in the Zabaikalye region with many sites burned 3-6 times over the last 15 years. We have evaluated *in situ* fire impact on tree stands, regeneration, fuel loads, and carbon emissions on a number of sites in light-coniferous (Scots pine and larch) forests of the region. Tree mortality depended significantly on fire type and severity as well as forest conditions. Carbon emissions on repeatedly burned areas were no more than 15-40% of carbon released in the sites previously undisturbed. Regeneration amount depended on the site conditions and fire characteristics. While in the larch forests grown on mesic and wet soils fires result in the increase of tree seedlings, insufficient number of regeneration was registered in the Scots pine stands of the dry poor soils as well as in the repeatedly disturbed sites. Soil erosion was observed at many sites burned by high severity fires and in the repeatedly burned areas. The transformation of forests to steppe ecosystems occurs in many areas of the repeatedly disturbed sites of the Zabaikalye region. We combined field observations with remotely sensed data to develop methods for detecting disturbance level and tracking ecosystem recovery remotely. Climate warming along with antropogenic factors (e.g., agricultural burning, illegal logging, etc.) change drastically fire regimes in the Zabaikalye region. 2015 was characterized by one of the severest fire seasons in the region for the last several decades with more than 500 houses burned and 11 people died. There is an urgent need for planning complex forestry and fire management activities designed specifically for the region that take into account trends in climate conditions and local anthropogenic and natural features of the area. This research was supported by the Russian Foundation for Basic Research (grant # 15-04-06567), Grant of the President of the Russian Federation (# MK- 4646.2015.5), and NASA Land Cover and Land Use Change Program.

Keywords: light-coniferous forests, area burned, fire consequences, carbon emissions, regeneration, steppification

Quantifying wildfires in Central Siberia: linking “top-down” and “bottom-up” observation strategies

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Boreal wildfires are large sources of reactive trace gases and aerosols, and their emissions, accounting for up to 20% of global C emissions from biomass burning, are believed to significantly influence the chemical composition of the atmosphere and the global earth’s climate system. Although the problem of quantifying direct emissions from wildfires has received attention, their calculations still remain uncertain due to problems with emission factors (i), available carbon for combustion (ii), and imprecise estimates of burned areas (iii). Linking simultaneous instrumental observations of atmospheric composition in fire plumes, GIS-based estimates of active fire spots, burned areas and related parameters (fire disturbances of vegetation, fire intensity etc), and *in-situ* calculations of changes in ecosystem C pools prior and after fire is a powerful tool to fill this gap in our knowledge.
Since 2006 the Zotino Tall Tower Observatory (ZOTTO; www.zottoproject.org) a research platform for large-scale climatic observations is operational in Central Siberia (60°48’N, 89°21’E). The data of the high-frequency trace gas measurements at the tower are used in atmospheric inversion studies to infer the distribution of C sinks and sources over central part of Northern Eurasia. We present the results of our multidisciplinary research to reducing uncertainties in quantifiyng fire influence on atmospheric composition deduced from the large-scale fires that occured in 2012 in the tall tower footprint area.
Analysis of air composition in fire plumes was based on time series of $CO/CO_2/CH_4$ mixing ratios measured at 300 m a.g.l. at ZOTTO. Air transport from specific wildfires upwind of the measurement site was traced based on ensembles of 24-hrs backward trajectories from ARL NOAA HYSPLIT model, while active fires were detected from Terra/Aqua MODIS satellite data. Burned areas were estimated based on Landsat ETM 5,8 satellite images. Additionally, a Normalized Burn Ratio index (*dNBR*), further ranged by a complementary field based Composite Burn Index (*CBI*), and a fire radiative power (*FRP*) provided estimates of fire disturbances of vegetation, fire intensity and the amount of biomass combustion. Field investigations were performed on study plots established after fire in the dominant ecosystems of Central Siberia (lichen pine, moss pine, mixed forest, dark forest and peat bog) where estimations of woody C pools and their geographical distribution were determined using a laser-based field instrumentation system. Aforesaid investigations allowed us calculations of total carbon emissions from the specific wildfires. Furthermore, chemical analysis of samples of atmospheric particulate matter (PM) was performed in fire plumes during the same time for identifying biomarkers, or compounds indicative of a unique biological source, and thus served as a powerful tool to trace the origin and transformations of organic matter (OM). Inter alia levoglucosan (1,6-anhydro-b-D-glucopyranose) and its isomers (mannosan and galactosan) as dehydro-monosaccharide derivatives formed exclusively during incomplete combustion of fuels containing cellulose/hemicellulose and lignin phenols (vanillyl, syringyl and cinnamyl phenols) and their compositional changes were used to differentiate signals among tissue types (woody/nonwoody)

and vascular plant groups (angiosperm/gymnosperm). The Lignin Phenol Vegetation Index (LPVI) as a quantitative parameter representing the entire characteristics of the vegetation was used to be an additional tool to partition OM among end-member sources.
This research was supported financially by the Max Planck Society (Germany), project of RSF # 14-24-00113 and RFBR grant # 15-45-04423.

Keywords: Climate, Wildfires, Siberia, Boreal forests, Carbon cycle, Tall tower

Mapping West Siberian wetlands using Landsat imagery for methane emission inventory

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High latitude wetlands are important for understanding climate change risks because of projected growth of methane emissions. Fine scale heterogeneity of wetland landscapes pose challenges for producing the greenhouse gas flux inventories based on point observations. To reduce flux uncertainties at the regional scale, we mapped wetlands in the taiga zone of West Siberia (WS) on a scene-by-scene basis using a supervised classification of Landsat imagery. The training dataset was based on high-resolution images and field data that were collected at 28 test areas distributed across the region. Classification scheme was oriented on methane inventory applications and included 7 wetland ecosystem types composing 9 wetland complexes in different proportions. Accuracy assessment based on 1082 validation polygons indicated an overall map accuracy of 79%. The total area of the wetlands and water bodies was estimated to be 52.4 Mha. Various bogs prevail in the region and occupy 84% of the wetland area, while fens cover only 16% of the wetland area. A new Landsat-based map of WS's taiga wetlands can be used as a benchmark for validation of coarse-resolution global land cover products and wetland datasets in high latitudes.

Keywords: methane emissions, wetland mapping, Landsat

Simulation of CO_2 and CH_4 in Siberia using coupled Eulerian-Lagrangian model

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Siberia is an extensive geographical region with large amounts of plant biomass and soil organic carbon, so this region has a substantial sources and sinks of CO_2 and CH_4. The magnitude and distribution of CO_2 and CH_4 fluxes are still uncertain, so accurate estimation of carbon fluxes and study of CO_2 and CH_4 seasonal cycles in the subarctic regions are essential.
In this work, we use forward simulation employing the Global Eulerian–Lagrangian Coupled Atmospheric (GELCA) model in order to estimate CO_2 and CH_4 seasonal cycles in the subarctic. GELCA consists of an Eulerian National Institute for Environmental Studies global Transport Model (NIES-TM) and a Lagrangian particle dispersion model (FLEXPART). This approach utilizes the accurate transport of the Lagrangian model to calculate the signal near to the receptors, and efficient calculation of background concentrations using the Eulerian global transport model.
We setup a long simulation period to obtain a better understanding of the role of emissions (using a set of CO_2 and CH_4 emissions scenarios), and transport model characteristics, such as the stratosphere/troposphere exchange and tracers concentration variations in the troposphere. We also analyzed modeled and observed long and short-term trend, seasonal cycle of CO_2 and CH_4.
Model results were compared with observations from the World Data Centre for Greenhouse Gases (WDCGG 2015) and the Siberian observations obtained by the Center for Global Environmental Research (CGER) of the National Institute for Environmental Studies (NIES) and the Russian Academy of Science (RAS), from six tower sites (JR-STATION).
The analyses have shown that CELGA is effective in capturing the seasonal variability of atmospheric tracer at observation sites strongly influenced by local emissions and global transport at the same time.

Keywords: atmospheric transport model, carbon cycle, carbon dioxide, methane

How might climate change affect the distribution, structure and productivity of major Siberian forest types?

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Previous regional studies in Siberia have demonstrated climate warming and associated changes in distribution of vegetation and forest types, starting at the end of the 20th century. In this study we used two regional bioclimatic envelope models to simulate potential changes in forest types distribution and developed new regression models to stimulate changes in stand height in tablelands and southern mountains of central Siberia under warming 21st century climate. Stand height models were based on forest inventory data (2850 plots). The forest type and stand height maps were superimposed to identify how heights would change in different forest types in future climates. Climate projections from the general circulation model Hadley HadCM3 for emission scenarios B1 and A2 for 2080s were paired with the regional bioclimatic models. Under the harsh A2 scenario, simulated changes included: a 80-90% decrease in forest-tundra and tundra, a 30% decrease in forest area, a 5-fold increase in forest-steppe, and a 10-fold increase in steppe, forest-steppe and steppe would cover 55% of central Siberia. Under sufficiently moist conditions, the southern and middle taiga were simulated to benefit from 21st century climate warming. Habitats suitable for highly-productive forests (≥30-40 m stand height) were simulated to increase at the expense of less productive forests (10-20 m). In response to the more extreme A2 climate the area of these highly-productive forests would increase 10-25%. Stand height increases of 10 m were simulated over 35-50% of the current forest area in central Siberia. In the extremely warm A2 climate scenario, the tall trees (25-30 m) would occur over 8-12% of area in all forest types except forest-tundra by the end of the century. In forest-steppe, trees of 30-40 m may cover some 15% of the area under sufficient moisture.

Keywords: forest structure and productivity, bioclimatic models, climate change, 21st century, Central Siberia

Satellite assessment of post-fire forest regeneration in the Zabaikal region

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Fires are one of the most significant impacts on forests in Russia. Each year an area of several million hectares is exposed to the forest fires, with a significant increase in the burned area in certain years. In several regions of Russia, especially in the forests of southern Siberia an increase in fire frequency and the duration of the fire season is observed. The forests of Zabaikal region are among the most fire disturbed areas in Russia.
In this study we used MODIS 500-m surface reflectance products (MCD43A4) and 1-km active fire product (MOD14A1) over 2000 –2015 to monitor fire disturbed areas in south-west part of Zabaikal region. Joint analysis of vegetation indices (shortwave vegetation index –SWVI) derived from MODIS data and materials of in-situ research allowed us to distinguish areas with successful and poor forest regeneration on fire disturbed territories. The linear trend of the SWVI after the fire event was used to assess the state of forest regeneration. The area with poor regeneration was estimated to be more than 900 thousand hectares. Large areas of the Zabaikal region considered in this were exposed to repeated fires. An analysis of vegetation indices dynamics showed that areas affected by fires 2 times or more during the study period often experienced forest regeneration failure.
This study was supported by the Russian Foundation for Basic Research grant 15-04-06567.

Keywords: Forest fires, Vegetation indices, Forest regeneration

Gaps and Pathway of Integration between Natural and Social Sciences in Global Change Research

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The transdisciplinary study between natural and social sciences is very challengeable because of their differences in research subjects, objectives, data and methodology. In recent 20 years, the merging sustainability sciences in climate, environment, ecosystem, energy, food, resources and human health provide the new opportunity for integration between natural and social sciences. This talk is focusing some methodologies on how to integrate these two types of sciences in sustainability science. First, the integrated study between natural and social sciences should be solution-oriented, and co-design, co-production with other stakeholders. Secondly, the integrated study should be balanced in top-down (natural) and bottom-up (social) approaches, focusing on the scientific issues in local level, which needs the efforts on social upscaling and natural downscaling by overcoming the uncertainties. To communicate the knowledge of uncertainties is one of the most important tasks for natural scientists when they try to work with social scientists and stakeholders. Last, we bring out some discussion on needs of experts in charge of communication in transdisciplinary study, the tendency of looking down social science in current global change and sustainability research, and the mismatching of current evaluating system to sustainability science.

Keywords: global change, natural and social sciences, vulnerability and adaptation , transdisciplinary

Agricultural and Pastoral Systems as Nexus of Food and Water in Dryland Asia

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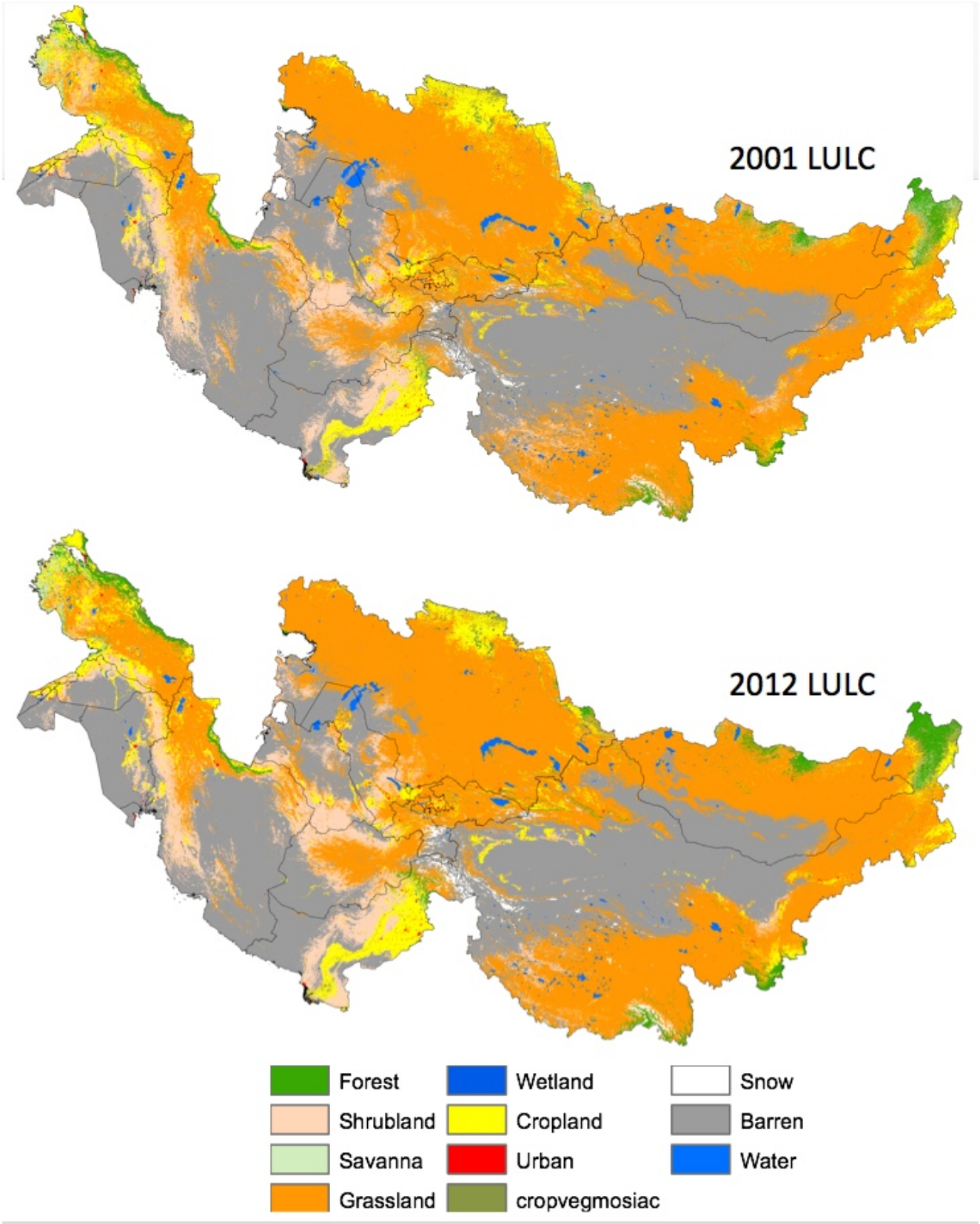
It is estimated that by 2050 the global demand for food will be increased by 60%, water by 55% and energy by 80% (OECD-FAO, 2012; IRENA, 2015) in order to meet the needs of current and additional new 2.2 billion of people on the planet. The demand for additional food lies not only in producing the basic resources needed to sustain a healthy lifestyle, but also from a changing diet, especially in rapidly developing countries around the world. It is projected that the growing demand for meat will require additional 0.2 billion tons per year by 2050, which almost doubles the present meat consumption. These new demands create mounting pressures on agriculture and pastoral ecosystems. Furthermore, the anticipated trajectory of future warmer and drier climates major agricultural regions of the world increases uncertainties in food security, adding further stresses to the already stressed nations particularly those in the Asian dryland belt.
Given the complexity and interplay among the food, water and energy in dryland ecosystems, the questions arise 1) whether or not the existing agricultural and pastoral ecosystems are endowed to have the capability to produce the required food, given its nexus to water and energy, 2) whether or not the current land use and consumption practices are sustainable when considering other ecosystem services critical for societal sustainable development, and 3) what are alternatives to ensure a sustainable trajectory of regional development to meet the new food demand?
This presentation reviews existing practices and proposes alternative solutions from both producer and consumer perspectives. The focus will be specifically on examining the trade-offs between different ecosystem services that drylands in Asian may provide. Preliminary analysis suggested that the current trajectory of meat and milk production is likely not on a sustainable pathway.

Keywords: Drylands Asia, Food and Water Nexus, Food Security, Ecosystem Services



Current state and dynamics of glaciers in the Mountains of Northwest Inner Asia

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The mountains of Northwest Inner Asia have traditionally been a subject of special interest to geographers of St.Petersburg State University. The region is characterized by arid climate, existence of modern glaciation centers and sparse growth of forest cover. One of the key sites is Tavan Bogd Mountains with the largest valley glaciers of the entire Altai region. This mountain massif is located at the junction of the Russian and Mongolian Altai ranges on the border of Russia, Mongolia and China. The glaciers of Tavan Bogd are concerned with formation of the main river in western Mongolia - Khovd river related to the endorheic basin of Grate Lakes Depression. Khovd river plays a critical part in the water supply of submontane desert steppe plains of this region. Current state and dynamics over the past decades of the Tavan Bogd glaciers are investigated on the basis of results obtained in 2013–2015 field glaciological, meteorological and dendrochronological observations as well as remote sensing data acquired from satellites. Ground-based geodetic survey and aerial survey from unmanned aircraft system (UAS) allowed generating high-resolution orthomosaics and DEMs of the glaciers.
This study examined 39 glaciers with a debris-free glacier area of 68 sq.km in the Tsagaan-Gol River basin and 41 glaciers with an area of 31 sq.km in the Tsagaan-Us River basin. The areas of the main glaciers were not much changed since 1989, while the glacier tongue regression was fixed. The total glacier area decreased approximately by 4.5 % (3.2 sq.km) in the Tsagaan-Gol basin and by 6.9 % (2.3 sq.km) in the Tsagaan-Us basin from 1989 to 2013. Kozlov Glacier was retreating at an average rate of 34 m/year between 2001 and 2014. Potanin Glacier was retreating slowly between 1989 and 2001 at an average rate of 5–10 m/year and more active between 2001 and 2014 at an average rate of 28 m/year. On the base of the 2005–2014 weather station data, ablation observations and equilibrium line monitoring the glaciological and climatological characteristics such as temperature lapse rate, ablation–accumulation and precipitation values at equilibrium line altitude were calculated. Ablation–accumulation value amounts to 110 g/sq.cm at mean summer temperature on the equilibrium line of 1°C. These calculations give us an opportunity to pass on to glacioclimatic modelling and mass balance estimations.
Instrumental measurements in this region in general overtake no more than last 50 years. Using the dendrochronological data from 479 living trees of *Larix sibirica* collected on the 38 sites in the Tuva Mountains and Mongolian Altai two regional chronologies were obtained. They reflect growth conditions on the upper (UTL) and lower (LTL) tree lines. Strong statistical signal (R=0.73) allowed receiving reconstruction of June-July air temperature since 1715 year. LTL chronology has strong connection with hydrological records (R=0.65). A May-June streamflow of Buyant river since 1474 year was reconstructed. We detected trends and cyclicity (11-year solar cycle, 30–35 year Bruckner cycle and others) in tree-ring growth and reconstructions.

Keywords: glacier fluctuations, glacioclimatic modelling, dendrochronological reconstructions, Altai region, Tavan Bogd Mountains

Extreme Heat events during 1971-2011 in Xi’an, China

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Exposure to extreme heat is already a significant public health problem nowadays. In this study, the daily data of the maximum temperature and mean temperature in Xi 'an from 1971 to 2011 were used to statistically analyze the monthly, inter-annual and inter-decadal change of heat events and the high temperature days in Xi 'an, and the global mean NCEP reanalysis data were used for explaining the cause of the most and least heat events and high temperature days in 1997 and 1983 respectively. Urban heat island effect was also analyzed using the difference of temperature between Xi’an and the suburbs. The causes of the abnormal high temperature were explained using synoptic weather maps of 500hPa and 700hPa. WMO defined heat wave as the daily maximum temperature is above 32^{0}C and lasts more than 3 days. In this paper, heat wave was defined as the daily maximum temperature was above 35^{0}C and lasted more than 3 days according to the “stove” climate of Xi’an. If the daily maximum temperature is above 38^{0}C and 40^{0}C, it is called severer high temperature and the severest high temperature (or intense heat) day respectively. It revealed that: (1) high temperature in Xi’an appeared frequently in June, July and August. The annual number of high temperature days and heat wave peaked in 1997 and reached a minimum in 1983 in Xi’an. The numbers of high temperature days were 60 and 1 respectively. The heat waves were 9 and zero respectively. The numbers of high temperature days and heat waves were consistent, (2) the average temperature and maximum temperature increased obviously from the 1980’s and increased more outstanding in urban areas than in the suburbs. The linear increase trend of average temperature were 0.621 ^{0}C /10a in downtown, much higher than 0.216 ^{0}C /10a and 0.350 ^{0}C /10a in the suburb of Chang’an district and Gaoling respectively. The average numbers of high temperature days were 27.3, 26.9 and 28.7 in downtown, suburb and outer suburb respectively. And the frequencies of heat wave were 3.9, 3.6 and 3.9 in downtown, suburb and outer suburb respectively. (3) the differences of average temperature between urban and the suburbs (suburb and outer suburb) increased obviously. The linear trends of differences were 0.385 ^{0}C /10a and 0.231 ^{0}C /10a in suburb and outer suburb respectively. Urban heat island effect was a big factor of heat events in Xi’an, (4) circulation analysis showed the cause of the least heat waves in 1983 and the most in 1997. In July 1997, the Tibetan high and Western Pacific subtropical high were very strong and connected each other in northern Xi’an on 500hPa. And south-west and south-east airflow controlled Xi’an during the heat waves, resulting humid and hot weather. In July 1983, the Western Pacific high was weaker and located in lower latitude. Therefore, southern airflow to Xi'an was weak, resulting the least high temperature days in 1983.

Keywords: Heat events, Urban heat island , atmospheric circulation analysis

Climate Change and Urban Infrastructure: Quantitative Assessment for Russian Permafrost Regions

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Planned socio-economic development during the Soviet period promoted migration into the Arctic and work force consolidation in urbanized settlements to support mineral resources extraction and transportation industries. One of the most significant impacts of climate change on arctic urban landscapes is the warming and degradation of permafrost which negatively affects the structural integrity of infrastructure. In this paper we focus on quantitative assessment of potential changes in stability of Russian urban infrastructure built on permafrost in response to projected climatic changes using permafrost - engineering model. To address the uncertainties in climate projections produced by state-of-the art General Circulation Models (GCMs), we have utilized results from six GCMs participated in most recent Climate Model Inter-comparison Project (CMIP5). The analysis was conducted for entire extent of the Russian permafrost-affected area and on several representative urban communities. Our analysis demonstrates that significant climate-induced reduction in urban infrastructure stability throughout the Russian permafrost region should be expected by mid XXI century. Although high uncertainty, resulted from GCM-produced climate projections, prohibits definitive conclusion about the rate and magnitude of potential climate impacts on permafrost infrastructure, the results presented in this paper can serve as guidelines for developing adequate adaptation and mitigation strategy for Russian northern cities.

Keywords: Urban infrustructure, Permafrost, Climate change, Russia

Freezing Precipitation and Freezing Events over Northern Eurasia and North America

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With global climate change in the extratropics, the 0°C isotherm will not disappear and associated precipitation events will continue to occur. The near-0°C temperatures should generally move poleward and to the higher elevations and arrive at many locations earlier in spring or later in autumn. This could potentially affect the seasonal cycle of near-0°C precipitation. The overall warming, together with a larger influx of the water vapor in the winter atmosphere from the oceans (including ice-free portions of the Arctic Ocean) can also affect the amount of near-0°C precipitation. The issue of near 0°C precipitation is linked with several hazardous phenomena including heavy snowfall/rainfall transition around °C; strong blizzards; rain-on-snow events causing floods; freezing rain and freezing drizzle; and ice load on infrastructure.
In our presentation using more than 1,500 long-term time series of synoptic observations for the past four decades, we present climatology and the empirical evidence about changes in occurrence, timing, and intensity of freezing rains and freezing drizzles over five countries of Northern Eurasia and two countries of North America.
The regions with the highest frequency of freezing rains (from 3 to 10 days per year) reside in the northeastern quadrant of the conterminous United States and adjacent areas of southeastern Canada south of 50°N, over the south and southwest parts of the Great East European Plain, and Central Europe. The frequency of freezing drizzle exceeds the frequency of freezing rain occurrence in all areas. During the past decade, the frequency of freezing rain events somewhat decreased over the southeastern U.S. In North America north of the Polar Circle, it increased by about 1 day yr^{-1}. Over Norway, freezing rain occurrences increased substantially, especially in the Norwegian Arctic. In European Russia and western Siberia, the frequency of freezing rain generally increased (except the southernmost steppe regions) while freezing drizzle frequency decreased over entire Russia. The number of days with freezing events over Belarus did not change, however, the duration of these events (in hours) substantially increased. In the mountains of Central Asia (Kyrgyzstan) we documented increases in freezing rain and drizzle frequencies only at high elevations, while they decrease at elevations below 1 km (matching to a similar decrease over the steppe zone of southern Russia).
In the former Soviet Union, instrumental monitoring of ice load has been performed by ice accretion indicator that in addition to the type, intensity and duration of ice deposits reports also their weight and size. Estimates of climatology and changes in ice load based on this monitoring at 958 Russian stations will be also presented.
This work is supported by the Ministry of Education and Science of the Russian Federation (grant 14.B25.31.0026) and the NASA LCLUC Program.

Keywords: freezing precipitation, climatic change, northern extratropics