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

*Thorsten Kiefer[1], Fumiko KASUGA[2]

1. Future Earth Secretariat, Global Hub in France, 2. Future Earth Secretariat, Global Hub in Japan

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)

*Pavel Groisman[1,2,3], Herman H Shugart[4], Garik Gutman[5], Sergey K Gulev[3], Shamil S Maksyutov[6], Jiaguo Qi[7]

1. NC State University Research Scholar at NOAA National Centers for Environmental Information, Asheville, North Carolina, USA, 2. Hydrology Science and Services Corporation, Asheville, North Carolina, USA, 3. RAS Institute for Oceanology, Moscow, Russia, 4. University of Virginia, Charlottesville, Virginia, USA, 5. NASA Headquarters, Washington, DC USA, 6. National Institute of Environmental Studies, Tsukuba, Japan, 7. Michigan State University, East Lansing, Michigan, USA

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

*Erwan Monier[1], David Kicklighter[2], Andrei Sokolov[1], Qianlai Zhuang[3], Irina Sokolik[5], Richard Lawford[6], Martin Kappas[7], Sergey Paltsev[1], Pavel Groisman[4]

1. Massachusetts Institute of Technology, 2. Marine Biological Laboratory, 3. Purdue University, 4. National Oceanic and Atmospheric Administration, 5. Georgia Institute of Technology, 6. Morgan State University, 7. Georg-August-Universität Göttingen

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

*Peilei Fan[1], Jiquan Chen[1], Zutao Yang[1], Pavel Groisman[2], Tatiana Loboda[3], Garik Gutman[4], Alexander Prishchepov[5], Anna Kavshinina[6], Jiaguo Qi[1]

1. Michigan State University, USA, 2. National Oceanic and Atmospheric Administration, USA, 3. University of Maryland at College Park, 4. National Aeronautics and Space Administration, 5. University of Copenhagen, Denmark, 6. Ural Mountain Nature Reserve , Russia

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

*Jiquan Chen[1], Ranjeet John[1], Ginger Allington[5], Fei Li[1], Changliang Shao[1], Yaoqi Zhang[2], Daniel G. Brown[4], Jiaguo Qi[1], Gang Bao[7], María E Fernández-Giménez[3], Amy Hessl[6], Xiaoping Xin[8]

1. Michigan State University, 2. Auburn University, 3. Colorado State University, 4. University of Michigan, 5. National Socio-Environmental Synthesis Center, 6. West Virginia University, 7. Inner Mongolia Normal University, 8. Chinese Academy of Agricultural Sciences

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

*Evgeny P Gordov[1,2,3], Yulia Gordova[1], Igor Okladnikov[1,2], Alexander Titov[1,2]

1. Institute of Monitoring of Climatic and Ecological Systems SB RAS, 2. Institute of Atmospheric Optics SB RAS, 3. Tomsk State University

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

*Kirsten de Beurs[1], Geoffrey Henebry[2], Braden Owsley[1]

1. Department of Geography and Environmental Sustainability, University of Oklahoma, 2. Geospatial Sciences Center of Excellence, South Dakota State University

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

*Kamilia Kelgenbaeva[1], Monika A Tomaszewska[1], Cole P Krehbiel [1], Geoffrey M Henebry[1], Guangqing Chi[2]

1. South Dakota State University, Geospatial Science Center of Excellence, USA, 2. Department of Agricultural Economics, Sociology, and Education, Pennsylvania State University, USA

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

*Alexey Panov[1], Anatoly Prokushkin[1], Jost V. Lavric[2], Anastasiya Timokhina[1], Vyacheslav Zyrianov[1], Vitaly Avilov[3], Sung-Bin Park[2], Nikita Sidenko[1], Martin Heimann[2]

1. V.N. Sukachev Institute of Forest SB RAS, Krasnoyarsk (SIF SB RAS), Krasnoyarsk, Russia, 2. Max Planck Institute for Biogeochemistry (MPI-BGC), Jena, Germany, 3. A.N. Severtsov Institute of Ecology and Evolution RAS (SIEE RAS), Moscow, Russia

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

*Tetsuya Hiyama[1], Hatsuki Fujinami[1], Kazuyoshi Suzuki[2]

1. Institute for Space-Earth Environmental Research, Nagoya University, 2. Japan Agency for Marine-Science and Technology

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

*Qiuhong Tang[1], Xingcai Liu[1]

1. Institute of Geographic Sciences and Natural Resources Research, CAS

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

*BAIQUAN ZHOU[1], Panmao Zhai[1]

1. Chinese Academy of Meteorological Sciences

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

