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EDITORIAL

Earth science and the integral climatic and socio-economic drivers of change across northern Eurasia: The NEESPI legacy and future direction

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Northern Eurasia is a unique and massive landscape, one that spans from the deserts through steppe and forest ecosystems to the Arctic. This region has undergone rapid changes in patterns of precipitation, increased temperatures, and socio-economic upheavals, well beyond that of other regions. A large portion of this region evolved unique ecosystems, such as the West Siberian lowlands and the permafrost-lain continuous larch forest that spans thousands of kilometers across Siberia. The sheer size of this region provides for the coldest continental and dry landscapes on Earth. These can often hold more than one Rossby wave (large-scale weather system), which can result in multiple droughts, harsh storms, or severe fire assemblages across this landscape at the same time. Additionally, during the last decades, political boundaries have precipitously changed, along with the associated socio-economic transformations, which continue to be a challenging novel area of investigation.

The NEESPI legacy. The scientific significance of northern Eurasia and the continuing rate of change across the region propelled the Northern Eurasian Earth Science Partnership Initiative (NEESPI), which was launched in 2004 with a scientific horizon of 10–12 years. The NEESPI Science Plan was prepared by an international team of more than 100 geoscientists from 11 countries (http://neespi.org/science/science.html). The Plan was written in the broadest possible manner to allow participation in NEESPI for all Earth Science researchers, whose studies are devoted to contemporary and future large-scale environmental change over the NEESPI domain (figure 1). Only two restrictions were imposed on each prospective NEESPI project, they must: (a) be international; and (b) include scientists from the NEESPI domain. The first requirement was geared towards avoiding 'small topics' that did not raise interest beyond specific scientific areas. The second requirement guaranteed infusion and transition of advanced scientific knowledge (e.g. remote sensing products, maps) between scientific communities.

During the past fourteen years, NEESPI has been successful at conducting, highlighting and advancing research in northern Eurasia. The NEESPI Executive Summary was prepared in English and Russian, and then it was translated to Chinese (courtesy of Prof. Panmao Zhai, Chinese Academy of Meteorological Sciences) (Groisman and Bartalev 2007). Over the years, NEESPI progress was reported in several programmatic papers (Groisman *et al* 2009, 2014, Groisman and Soja 2009), overview books (Gutman and Reissell 2011, Groisman and Lyalko 2012, Groisman and Gutman 2013, Chen *et al* 2013, Gutman and Radeloff 2016), and five special issue journals (table 1). This fifth and last special issue is the largest compilation of NEESPI interdisciplinary articles. The NEESPI initiative has accommodated 172 projects focused on diverse environmental issues in northern Eurasia (figure 2). These projects were different in size and scope, funded by multiple national and international agencies, and have involved a total of more than 750 scientists. More than 80 PhD students defended their theses while working within the NEESPI framework. Since 2006, 32 dedicated NEESPI Workshops and 23 NEESPI Open Science Sessions were convened at International Meetings. Ongoing projects have been transitioned to the Northern Eurasia Future Initiative (NEFI) (18 remaining in 2017).

This NEESPI special focus issue represents years of research, with diverse teams of scientists that pulled research from multiple fields to gain an improved understanding of these integral, although typically deemed disparate, systems. The present compellation

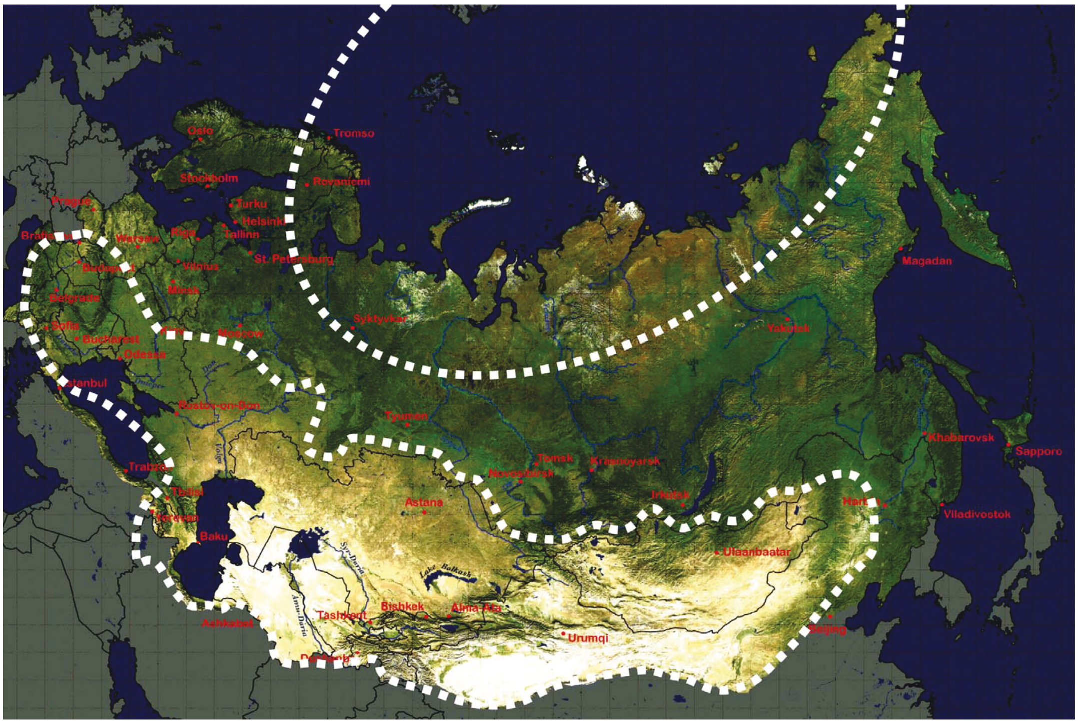

Figure 1. The NEESPI domain showing three major ecozones: (*a*) the Eurasian Arctic, defined by substantial cryosphere variation (retreat in the last decades) and a highly variable surface energy budget; (*b*) the Boreal Forest zone, which holds the largest terrestrial carbon store on Earth; and (*c*) the Dry Latitudinal Belt, which is the largest extratropical acute water deficit region. These ecozones are unstable, and they have varied considerably in the past and are likely to substantially vary in the future, particularly under ongoing climatic and environmental change (Tchebakova *et al* 2016a, 2016b). Groisman *et al* 2009; © American Meteorological Society. Used with permission.

Table 1. NEESPI special issue journals.

- Global and Planetary Change, 56, No.3–4, pp. 215–416 Groisman, Shugart and Sokolik (eds) 2007 Northern Eurasia Regional Climate and Environmental Change, www.sciencedirect.com/journal/global-and-planetary-change/vol/56/issue/3
- Environmental Research Letters (ERL) 1st Special Issue: Northern Hemisphere high latitude climate and environmental change, Groisman and Soja (eds) 2007, http://iopscience.iop.org/article/10.1088/1748-9326/2/4/045008/meta
- ERL 2nd Special Issue: Ongoing climatic change in Northern Eurasia: justification for expedient research, Groisman and Soja (eds), 2009, http://iopscience.iop.org/article/10.1088/1748–9326/4/4/045002/meta
- ERL 3rd Special Issue: Focus on Environmental, Socio-Economic and Climatic Changes in Northern Eurasia and Their Feedbacks to the Global Earth System, Soja and Groisman (eds) 2012, http://iopscience.iop.org/journal/1748-9326/page/NEESPI3
- ERL 4th Special Issue: Focus on Northern Eurasia in the Global Earth System: Changes and Interactions (this issue) 2017, http://iopscience.iop.org/1748–9326/focus/NEESPI4.

of interdisciplinary manuscripts incorporates research across numerous scientific fields and landscapes, as well as across multiple temporal and spatial scales. With the focus firmly based in northern Eurasia, these research papers emphasize a diverse array of spatial scales, timelines, unique research topics, methodologies (e.g. field, laboratory, modeled, satellite) and integrated and distinct ecosystems and systems. This Special Issue hosts 56 manuscripts that can be generally grouped into the following categories: biogeochemical cycles (18), land use (10), human dimensions (4), cryospheric change (6), water and energy cycles (16) and two overview papers. All of these manuscripts are listed below this overview, and we have taken the liberty to highlight a few.

One noteworthy project used model and pollen reconstruction data to investigate the climates and culture that favored agricultural or herding economies from prehistoric times to early human settlements, which has implications for understanding the interaction between futures climates and human settlement possibilities (Blyakharchuk *et al* 2014). Two additional thought-provoking projects focused on the health of grassland ecosystems on the Mongolian Plateau, both of which describe ecosystem health, economic variability (livestock diversity and management), and government interventions as influential. However, the ultimate goal of both these projects was to provide tractable solutions for herders to sustain their livelihood, while conserving grasslands (Brown *et al* 2013, Zhen *et al* 2014).

At a large scale, Miao and colleagues (Miao *et al* 2014) used the Coupled Model Intercomparison Project phase 5 (CMIP5) to assess the performance of climate models in simulating intra-annual, annual and decadal temperatures over northern Eurasia from

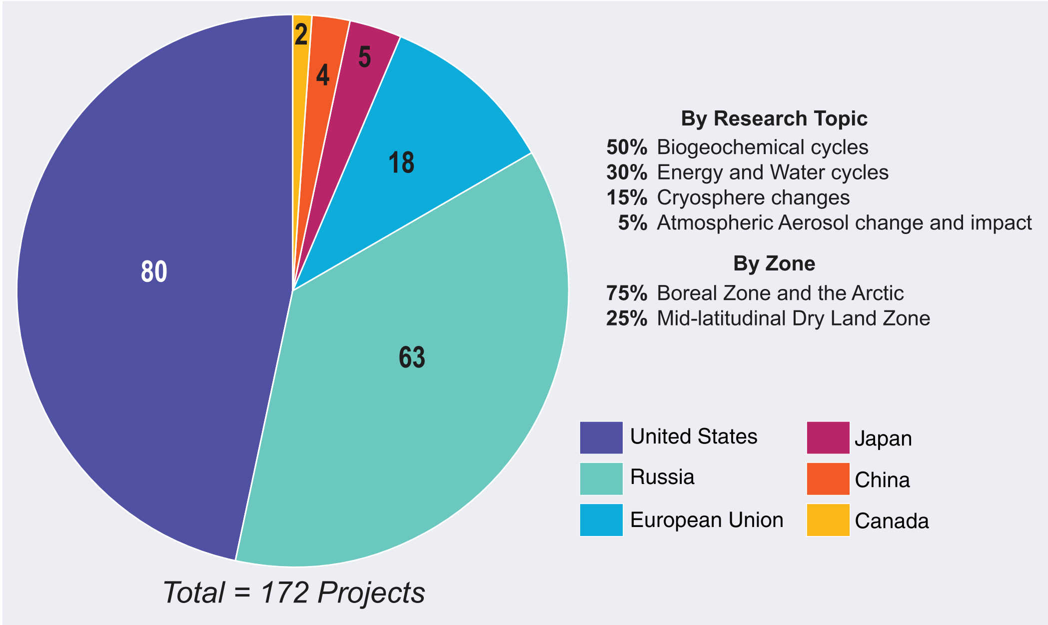

Figure 2. NEESPI projects partitioned by originating countries, topics and ecozones. Active NEESPI-NEFI projects are shown by originating countries (by funding source).

1901–2005, and they found that the contemporary Global Climate Models tended to overestimate temperature changes. In addition, they calculated temperature increases in the 21st century of ~1.03 °C–7.14 °C/100 yr, depending on the scenario modeled, with particularly large increases at high latitudes and in the winter and spring seasons.

At a large temporal and spatial scale, Shiklomanov and Lammers (2014) used stream gauge data from 1955–2012 to analyze the response of ice in six major Russian rivers to Arctic warming. In general, they found that the timing of ice events has occurred earlier, and both ice thickness and the duration of ice extent has decreased. Nevertheless, inconsistencies in relationships to warming led the team to conclude that local conditions could have the largest influence, and they argued for more comprehensive river ice and discharge data archives.

In general, across northern Eurasia, this issue found decreases in glacier size, increases in the duration of snow-ice melt, permafrost degradation, increased summer temperatures, and an increase in Active Layer Depth (ALD—annual depth to which permafrost thaws). Khromova *et al* (2014) analyzed about 15 000 glaciers, comparing historic records and Landsat data, and they found a positive trend in glacier shrinkage in all mountain regions in the later 20th century. Glacier area loss of about 13% (Tien Shan) to 22.3% (Polar Urals) was attributed to increased summer temperatures, however the large degree of individual glacier degradation was attributed to morphology and local meteorological conditions. Zhao *et al* (2014) concluded land-ice snowmelt dynamics on the northern Arctic Islands, Novaya Zemlya and Severnaya Zemlya, were linked to regional sea ice variation.

Streletskiy *et al* (2015a) concluded increases in air temperature over the last forty years have resulted in permafrost degradation and a decrease in seasonal frost, which has lowered the permafrost table, leading to an increased storage capacity in permafrost-affected soils. These changes in permafrost have led to a higher contribution of ground water to river discharge. In a separate investigation, Streletskiy *et al* (2015b) used historic (1963–2013) soil temperature data to identify 'hot spots' in soil temperature and potential change in permafrost ALD. Results indicate a substantially higher rate of change in the thermal regime of permafrost-affected soils from 1999–2013, relative to the last fifty years, which was strongly associated with air temperature in western Russia, with weaker relationships in central and eastern Russia.

In the biosphere, Krylov *et al* (2014) used a variety of remotely-sensed data to show fire-induced forest stand replacement is two times higher than logging in the decade analyzed, and most of these stand-replacement fires were in light conifer forests, which is unlike historic patterns, thus bringing into question the degree to which climate-fire induced forest change is evident. Kukavskaya *et al* (2013) used field campaigns to investigate the impact of logging and fire on stand density, tree mortality, and carbon stocks, and perhaps even more important, the team suggested sustainable, tractable options, such as slash removal and planting trees.

Also under the NEESPI umbrella, the extent of abandoned farmland was mapped (Alcantara *et al* 2013). Thereafter, Griffiths *et al* (2013) concluded that, after the breakdown of socialism, cropland abandonment was most extensive during the transition period and primarily in marginal areas. They also noted considerable forest expansion, and market forces prompted the cultivation of formerly abandoned croplands in high-value agricultural areas since 2000. At a regional scale, Kicklighter *et al* (2014) assessed the potential effects of interactive climate and management decisions on future land use, which have the potential to alter cropland production, reshape landscapes and influence related carbon sequestration.

Numerous investigations highlighted the necessity to consider integrated, interdisciplinary processes and systems. One unique investigation compared lingonberry harvest in the pre-Soviet era to the present day in Kamchatka in an effort to elucidate conservation and sustainable development; Hitztaler and Bergen (2013) emphasized the effect of land cover and forest age, as well as the distance to gathering sites and markets as key drivers of choice. In another investigation, Mátyás and Sun (2014) suggested localities consider both forest and non-forest alternative land uses as viable options in water limited systems. Frost *et al* (2014) suggested Arctic productivity is more complicated than temperature and an overall landscape-scale view can provide. They concluded spatial variability is related to landscape physiography, permafrost attributes, and differences in surficial geology, however the team suggested upland tundra productivity will likely continue, even though tundra systems are highly susceptible to rapid increases in vegetation- and land-cover change.

In this ERL issue, most of the investigations paired traditionally isolated scientific disciplines, and they included social and economic drivers to provide an integrated view of these interactive, interdisciplinary systems. Even though NEESPI scientific research, data and models created a solid knowledge base, changes in the climate, landscapes and socio-economic conditions have resulted in regional environmental changes that have global consequences. These intertwined system of systems call for a bridge that connects climate and environmental studies with economic consequences that are guided by our societal choices and management decisions.

The Next Research Step (NEFI). The Northern Eurasia Future Initiative (NEFI) has been designated an essential continuation of NEESPI (Monier *et al* 2017, Groisman *et al* 2017). A key principle of NEFI is that these developments must be through science-based strategies co-designed with regional decision makers, who are task to lead their societies as they are confronted with environmental and institutional challenges. Another unique goal of NEFI is to develop Integrated Assessment Models that will enable the evaluation of economic decisions in response to changing environmental conditions to provide decision-support tools and products for management consideration to substantiate and justify mitigation and adaptation strategies.

After two years of preparation and review, the NEFI Science Plan has been released (http://nefi-neespi.org/NEFI-WhitePaper.pdf). With this science plan, closing this special issue and the two published reviews (Monier *et al* 2017, Groisman *et al* 2017), the transition from NEESPI to NEFI is complete. Additionally in 2017, NEFI enthusiasts and the ERL Editorial Board launched a new NEFI Special Focus Issue (http://iopscience.iop.org/1748–9326/focus/NEFI) providing an outlet for the NEFI Science Plan contributors and to those whom are interested in northern Eurasian Earth science studies.

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