SYNTHESIS AND REVIEW

Northern Eurasia Earth Science Partnership Initiative: evolution of scientific investigations to applicable science

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Abstract

The letters collected in this focus issue of Environmental Research Letters on ‘Environmental, socio-economic and climatic changes in Northern Eurasia and their feedbacks to the global Earth system’ represent the third special issue based on the results of research within the Northern Eurasia Earth Science Partnership Initiative (NEESPI: http://neespi.org) program domain. Through the years, NEESPI researchers have presented a diverse array of articles that represent a variety of spatial scales and demonstrate the degree to which abrupt climatic and socio-economic changes are acting across Northern Eurasia and feed back to the global Earth system.

Keywords: land cover land use change, Russia, China, Mongolia, Kazakhstan, Romania, Arctic, boreal

Northern Eurasia is globally significant because it has the size sufficient (about 20% of the global land mass) to affect global change through biogeophysical and biogeochemical feedbacks with the global climate system. The boreal zone holds the largest reservoir of terrestrial carbon, and more than two-thirds of the boreal zone is located in Eurasia (Hare and Ritchie 1972, Zoltai and Martikainen 1996, Alexeyev and Birdsey 1998). Russian forests, alone, constitute about 25% of the world’s forests (Stocks and Lynham 1996). Terrestrial carbon in this region is largely stored in the wetlands and organic matter of these cold forest floors, which have the potential to affect both the carbon and methane cycles. The sensitive Arctic Ocean and ecosystems that span the northern extent of this landmass are experiencing drastic changes in snow cover depth and extent, permafrost thaw, and riverine inflow of fresh water and carbonaceous materials, which could alter global thermohaline circulation. Moreover, not only is this a region where current temperature increases are some of the greatest on Earth, but also where climate models are in agreement that the temperature increases are predicted to be 40% greater than the global mean, both in the summer and winter (IPCC 2007, Groisman and Soja 2009, Gutman and Reissell 2011, Groisman and Gutman 2013).

In the first NEESPI focus issue (Environ. Res. Lett. 2 045008), our goals were to highlight the significance of the NEESPI domain, to draw attention to the tremendous...
unknowns in this remote, often mysterious region, and to emphasize the degree to which this carbon rich, cold region functions as a regional entity and interacts with and affects the rate of the global change through atmospheric circulation, biogeochemical, and biogeochemical feedbacks. Changes in the surface energy balance, hydrologic cycle, carbon and methane budgets feedback to regional and global weather and climate systems. There were indications that the regional land cover may become internally unstable with ongoing and future global warming resulting in large-scale shifts of major ecosystems northward. One large-scale shift noted by Vygodskaya et al. (2007) is the advance of the steppe and semi-desert ecosystems into the area presently occupied by light leaf taiga. We understood that to suggest mitigation strategies to policy- and decision-makers, we needed to elucidate our understanding of these systems and identify our deficiencies in understanding feedbacks, which in turn hamper our understanding of global change rates and patterns.

In the second NEESPI focus issue (Environ. Res. Lett. 4 045002), we argued for expediency in ongoing research in Northern Eurasia by highlighting abrupt alterations in: the solar energy balance (i.e. aerosols on snow/ice/clouds, albedo change due to changes in vegetation and cloud cover, latent and sensible heat fluxes); the distribution of aerosols and trace gases (biogenic and biomass burning); the advance towards a perennial ice-free Arctic Ocean; snow cover; and patterns of precipitation. This focused assembly of articles underscored some of the ongoing progressive research that was necessary to understand these remote systems and an endeavor to comprehend some of the feedbacks that define these interactive systems. The wide spectrum of manuscripts highlighted the interdependence of terrestrial and hydrologic systems with the atmosphere, oceans and solar radiation budgets, which directly and indirectly influence Earth’s climatic processes. That focus issue encompassed results of investigations from the energy and water cycles (7 letters), cryosphere (5 letters), biosphere (13 letters), and socio-economic processes (3 letters) in Northern Eurasia, as well as 4 letters assessing methods for surface monitoring from space.

If we were to highlight the unique feature of the present (third) NEESPI focus issue, it would be in the evolution of the science to include increased consideration of socio-economic factors that influence land use and land cover change, as well as the emphasis on the role of mitigation for decision- and policy-makers. The connection between the science and the socio-economic drivers of change are becoming increasingly difficult to completely separate, such that the decisions that policy-makers present can influence land use and thus the forcings that feedback to our larger terrestrial, atmospheric, hydroospheric and climate systems.

The articles contained in this focus issue characterize a diverse and wide range of systems, from those that are heavily influenced by humankind, such as agricultural, silvics and the Chernobyl disaster, to those that are relatively pristine in the interior and far north, to other works that serve to characterize direct and indirect feedbacks with the atmosphere, hydrosphere and climate systems. This wide range of topics also includes snow cover characterization and riverine input to the Arctic. Additionally, there are three editorial assessments of the status of ongoing regional projects: the interdisciplinary research network for the Baltic region (BALTEX); the East Siberian Arctic Shelf (ESAS) expeditions; and the Dryland East Asia (DEA) synthesis (Reckermann et al 2011, Semiletov et al 2012, Qi et al 2012). The topical partition of this focus issue is similar to the second focus issue encompassing results of studies from the energy and water cycles (5 letters), cryosphere (2 letters), biosphere (10 letters), and socio-economic processes (3 letters). However, the integrative nature of these studies is prominent, and it is difficult to distinguish the scientific partitions, such as ‘biospheric’ assessments of wildfires (e.g., Kharuk et al 2011) or land cover and land use (e.g., Zhu et al 2011) in Siberia from impact studies of socio-economic processes directly addressing farmland abandonment (e.g., Olofsson et al 2011, Lebed et al 2012). Geographically, the present assemblage of articles range from the semi-arid ecosystems in the south, to the forest taiga in the north, to the snow-covered Arctic, and from Romania in the west through the West Siberian lowlands to the far eastern coast of Northern Eurasia.

We further recognize that we are facing a non-linearity in environmental and climatic change in Northern Eurasia that is defined by a dramatic retreat in Arctic sea ice, striking fresh water and carbon inflow into the Arctic Ocean, modifications of cloud cover and changes in patterns of snow cover and precipitation, as well as abrupt changes in permafrost thaw, wetland transformation, and ecosystem and land use shifts. Several specific manuscripts are highlighted below that serve to clarify aspects of this research and suggest directions forward, both in terms of subsequent research and potential for policy-makers to influence future land use and land cover.

1. Changes in the exchange of greenhouse gases (GHG)

The West Siberian lowlands are the largest wetland region in the world and hold 40% of the peat deposits on Earth (Walter 1979), which is a globally significant source of the potent GHG, methane (CH4). Several works in this issue are dedicated to understanding the CH4 exchange between these ecosystems and the atmosphere (Kim et al 2011, Zhu et al 2011, Glagolev et al 2011). For instance, Zhu and colleagues project a net increase in CH4 emissions of 6–51% by the end of this century, and furthermore they suggest the characterization of wetland extent would result in the greatest reduction in uncertainty.

In another work, focused on forest in the Angara region, Ivanova et al (2011) highlight the diverse range of post-fire carbon storage, which can vary by 16 to 49%, depending on the fire intensity, which is directly under the control of weather and climate. This is another example of how weather and climate affect land cover, which in turn feeds back negatively (more reflective young vegetation increases albedo) or positively (black carbon deposition on ice/snow or clouds) to the atmosphere and climate systems. For biomass burning, this feedback can be through direct (emissions
and their transport) or indirect (changes in patterns of precipitation) feedbacks.

In one particularly cross-cutting work, Olofsson et al. (2011) used Landsat data to map forest cover change in Romania, and they determined that under socialism, Romania was a net source of carbon, but it is currently a carbon sink due to forest expansion on unused and abandoned farmland. This is in spite of the fact that the privatization of lands has typically resulted in immediate clear cutting. This is one example of how socio-economic disturbance and policy can influence land use and potentially increase carbon storage on abandoned lands.

2. Potential mitigation of socio-economic-driven disturbance

In an interesting analysis, Hostert et al. (2011) found the collapse of the Soviet Union had at least as much effect on land use as did the Chernobyl disaster, as evidenced by the rates of land abandonment. This research emphasized the importance of the role of policies and institutions to mediate hardships and the effects of socio-economic disturbance. The authors also noted the opportunities for conservation of natural ecosystems (i.e. recovering farmland) that socio-economic change and policy-makers might welcome.

In another positive manuscript that highlights the potential for adaptation to sustain and promote food security, Tchebakova et al. (2011) simulated future (2080) agriculture potential in central Siberia. They concluded agricultural land could increase by 50–85% under current climate change scenarios, and crop production could increase two-fold, although irrigation might be necessary.

Dyukarev et al. (2011) concluded the southern taiga of West Siberia was sustainable, even though forest disturbance had doubled over the last decades. They found the total forest cover loss to be insignificant, and attributed this sustainability to the low population and relatively moist and warm climate that promotes forest growth and sustainability.

3. Improvements in knowledge of our hydrological systems

There are several works in this issue that focus on improving our data and knowledge to advance current and future estimates. Ye et al. (2012) introduced a precipitation bias correction scheme to improve water budget calculations in the Upper Yellow River. Olchev and Novenko (2011) analyzed paleoclimatic and paleobotanical data to estimate potential and actual evapotranspiration of boreal forest ecosystems, which is useful now and for future understanding.

Prokushkin et al. (2011) analyzed what is known about dissolved organic and inorganic carbon to conclude there are two limitations in riverine inflow to the Arctic, one that is defined by the material source (disturbance, weathering, productivity) and secondly, the potential transport of the material (interior, low precipitation). They conclude these are the significant attributes to consider when estimating future riverine source and flux patterns of dissolved carbon.

4. Climate highlights

One of the largest unknowns in our understanding of the climate system is clouds (i.e. microphysical cloud properties and formation, opacity, cloud height (type), cloud extent and fraction of cover) and the extent to which patterns of clouds will be modified as climate changes, which directly alters the solar radiation budget, as well as patterns and quantity of precipitation. Understanding clouds is not only significant for understanding negative and positive feedbacks to the climate system but also for policy-makers who need to know potential water use for vegetation growth and land use planning. In this issue, Chernokulsky et al. (2011) found a general increase in cloud fraction over recent years in Russia, attributable primarily to a decrease in the number of days without clouds in the spring and autumn, which was largely due to an increase in convective and non-precipitating stratiform clouds. Understanding when, where and what type of change is occurring in clouds aids in understanding links between changes in weather patterns and precipitation, and these variables are significant to understanding potential vegetation growth, to include forest and agricultural lands.

Another significant feedback to the climate system is snow cover, which is closely linked to the surface radiation budget. Shi et al. (2011) showed a significant decline in snow cover in North America and the Eurasian pan-Arctic in the spring and summer since the early 1970s, which was primarily attributable to preceding positive trends in net surface radiation.

Then, Bulygina et al. (2011) showed that even though snow cover extent had decreased across Northern Eurasia, snow depth and the water supply has generally increased, unlike trends in Canada and Alaska, which highlights the non-linearity in snow cover characteristics and argues against making simple assumptions based on one snow characteristic.

Also included in this series are manuscripts that serve to evaluate our data sources and models. Shen and Leptoukh (2011) compared MODIS temperature with station data and concluded relationships differ depending on land cover type. The largest differences were found in barren and sparsely vegetated areas during the summer. Ling et al. (2012) found multiple climate model ensembles performed best in the semi-arid region of China, and in an editorial overview, Kryjov (2012) also argued multiple-model ensemble forecasts were more reliable for Northern Eurasia and contended improvements in climate prediction are dependent on accurate seasonal climate forecast. Understanding the uncertainty in our data sources and models is critical to understanding current and future processes and relationships.

5. Land cover and climate feedbacks

Kharuk et al. (2011) showed that in the larch dominated forest in the far north, where human activity is minimal, fire return intervals have decreased and are currently half as long as in the Little Ice Age, meaning an increase in the current extent of fire. This work provides an understanding of how
forest fire regimes changed historically and supports previous predictions of increased fire regimes with climate warming. Voropay et al (2011) found temperature or precipitation had the greatest impact on tree ring growth in the middle and upper regions of the Prianigarye, Siberia, respectively. This underscores the necessity for understanding regional factors controlling vegetation growth, which could vary depending on the most-limiting local factors, even in the same region. In West Siberia, Shulgina et al (2011) found an increase in growing degree days, growing season length and precipitation, which they suggested could enhance vegetation growth in that region.

6. Future prospects and research directions

Since its inception in 2004, the NEESPI initiative has been fueled by strong sentiments in the scientific community that we are unacceptably late to address complex and intrinsic climatic, environmental and socio-economic changes in an enormous landmass where substantial changes are already evident, and these changes are projected to impact the global Earth system. The ability of the Earth science communities and society to investigate these transformations was decimated by abrupt geopolitical change across Eastern Europe, the former USSR and Mongolia (Groisman and Bartalev 2007). Presently, we can certify the previous negative consequences experienced by scientific communities across the region has become less acute (waning gradually), and in a large part, this has been driven by national and international support of Northern Eurasian environmental research, which has reached the world. There has been a significant contribution by NEESPI scientists who have published more than 700 peer-reviewed papers, books and book chapters in the past five years, produced national and international reports, and prepared a new generation of PhD-level early career scientists poised to continue environmental investigations in Northern Eurasia.

In the past two years several integrative regional books were published that focused on environmental change in the Arctic (Gutman and Reissell 2011), in Eastern Europe (Groisman and Lyalko 2012) and Siberia (Groisman and Gutman 2013). There is one more in the final stages of publication (Chen et al 2013). Future plans include a continuing focus on integrative studies across additional sub-domains of Northern Eurasia (e.g., over Central Asia) and on strengthening regional projections for future regional development that will be based on a combination of modern observations and contemporary global, regional, hydrological, biospheric and socio-economic models. To bring these models and data fluxes into a seamless integrated suite, ready to serve the societies of Northern Eurasia, still remains a major NEESPI objective (and an uncompleted goal). The final NEESPI Conference, currently planned for 2015, is expected to be large and will summarize 12 years of NEESPI research. Thereafter, all NEESPI data and research results will be summarized, disseminated and the Initiative will complete its existence, leaving space for a new generation of ideas and investigations.

7. Tribute to Dr Gregory Genrikhovich Leptoukh and Dr Anatoly Ivanovich Sukhinin

Our community mourns the loss of two relatively young and vibrantly interactive members of the NEESPI community, Drs Anatoly I Sukhinin and Gregory G Leptoukh, both of whom passed away in the last year due to cardiac arrest. These scientists will be remembered for their kind and approachable nature and are dearly missed on both personal and scientific levels. Their contributions to the research community are, and will continue to be, notably absent. Anatoly was the lead scientist in the Remote Sensing of Forest and Fire Monitoring Laboratory at the V N Sukachev Institute of Forest in Krasnojarsk Russia, and he will be remembered for his tireless endeavors to highlight the interaction between wildfire and meso-scale weather. Greg was a data manager at the Goddard Earth Sciences Data and Information Services Center, and he will be remembered for his leadership in linking science and technology for data analysis and his vision of making data more readily accessible using the Giovanni data analysis system.

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