The Northern Eurasia Earth Science Partnership Initiative (NEESPI)
Executive Overview (*December 2004)*
Version 2.1

Preface

The following overview of the NEESPI Science Plan is intended to provide a concise summary of the NEESPI rationale, the science priorities and general strategies for conducting a large-scale, integrated, regional program of research focusing on the area of Northern Eurasia as it exists in its current phase of development.

Version 2.1 of the full NEESPI Science Plan has been completed after two major Science Plan workshops held in Russia and the Ukraine during 2003, which also included an independent science panel review of a first draft science plan. Responses to the review panel suggestions as well as to additional agreements with the Russian leadership concerning the form and content of the Science Plan have been incorporated into the Science Plan. *However, being a project open to other national and international agencies, the present NEESPI Science Plan has been drafted to be sufficiently flexible to accommodate needs and incorporate contributions from other sides who may express their interest to participate in the Initiative. As such, the NEESPI Science Plan and this overview can be considered to be only preliminary.*

This overview is an attempt to represent the key elements of the Science Plan as can be elaborated at the time of this writing of the overview document in December 2004. The focus of this document is the scientific rationale and science questions. It is hoped that distribution of this overview document can yield additional feedback into the programmatic priorities of interested government agencies and international science programs such that possible adjustment can be made to better reflect those priorities and lead to eventual sponsorship of some elements of the research of the NEESPI. At its full maturity, the NEESPI is intended to be a broad-based international program in scientific participation, project sponsorship, and organizational leadership. It will draw upon and complement existing and planned national and international research programs with the goal of developing a multi-disciplinary, integrated understanding of this important region of the globe and how it relates to the functioning of the global Earth system.

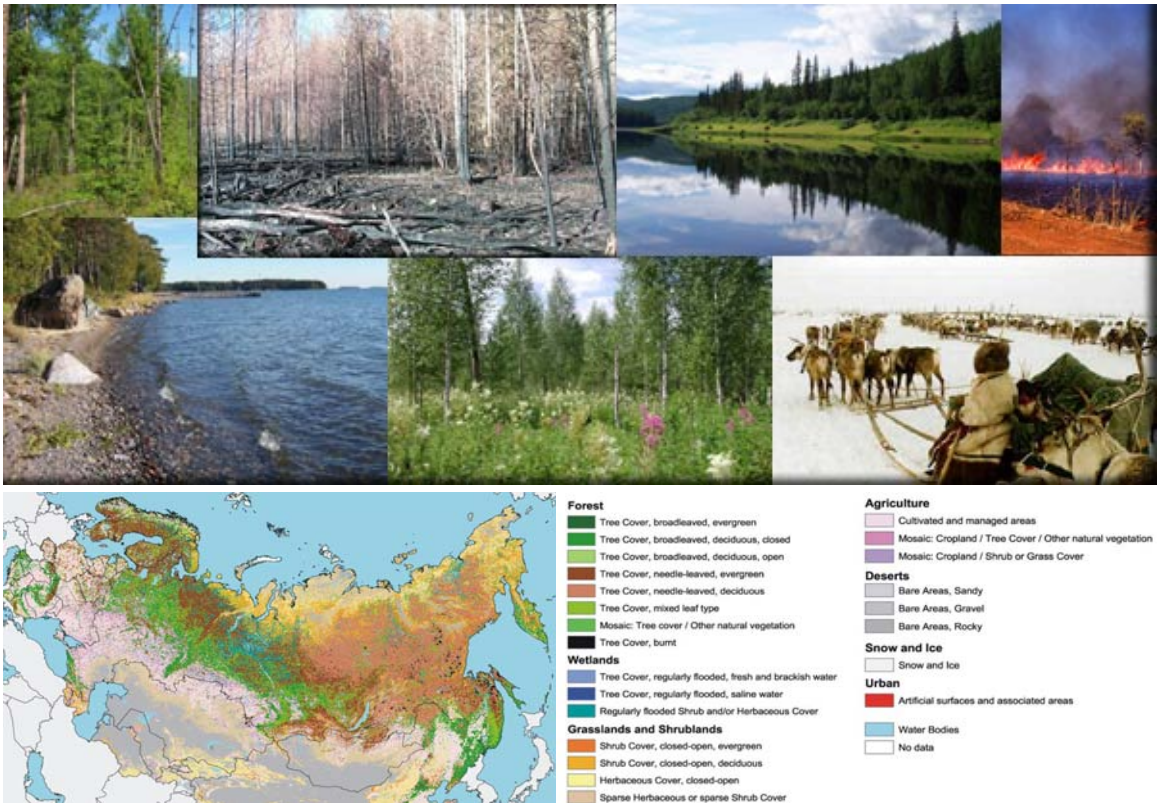
Additional details about the NEESPI can be found at the NEESPI Web site at http://neespi.org/. The full NEESPI Science Plan, an updated Executive Overview of the Science Plan and associated documents and information will be posted on the Web site as they are completed.

The NEESPI Science Plan Development Team

1. INTRODUCTION

Northern Eurasia embodies 19% of the Earth's land surface and 59% of the terrestrial land cover north of 40°N. It is a diverse region. Although covered by tundra in the North and semi-deserts and deserts in the South, Northern Eurasia contains a substantial fraction of the Earth's boreal forests (about 70%) and more than two-thirds of the Earth's land that is underlain by permanent soil ice or permafrost. Thus, Northern Eurasia must be regarded as a key region for studying global change processes for these two biomes and their interactions with the Global Earth System.

Over the past 5,000 years, climatic changes in Northern Eurasia were among the most dramatic in the world. Surface air temperature increases reported by instrumental observations during the past century were the greatest for the interior parts of Northern Eurasia; and model simulations of future climate changes show that this region will have the most substantial changes in the future. Current evidence strongly suggests significant and rapid changes in the atmosphere, hydrosphere, cryosphere, and land cover in Northern Eurasia, but it is important to accurately quantify these changes and the particular processes that caused them. Taking into account the geographic scale and rate of change, the current lack of process understanding must be viewed as unacceptable. It is critical to develop the ability to measure, monitor, and model the processes that will provide accurate future projections of climatic and environmental changes in this region because these changes have the potential to impact the Global Earth System and the human society.

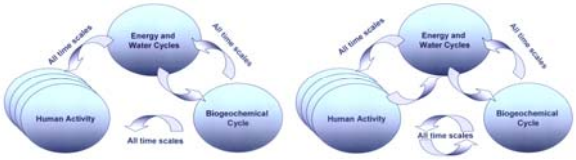


NEESPI study area includes Former Soviet Union, Northern China, Mongolia, Fennoscandia, Eastern Europe and the coastal zone of these countries. Inserted map shows land cover for the region. Source: European Commission, Joint Research Center (Bartalev et al. 2003; Bartholomé and Belward 2005).

The functioning of the Global Earth System can be considered as an interaction of three major types of processes (cycles):

- Biogeochemical Cycles, which affect the composition of the atmosphere and ocean, the formation of soils, and the evolution of biomes.
- Energy and Water Cycles, which affect the transfer of energy, water, aerosols, and trace gases between the atmosphere, land surface, hydrosphere, and cryosphere.
- Human Activity, which began to strongly affect the planetary system on the regional level with the establishment of the first agricultural civilizations, now includes effects on the Global Earth System.

Studying any one of these cycles or activities often requires analyses of its interaction with the other two and of the transitional (non-equilibrium) character of these interactions.



Pre-industrial (up to circa mid 19th century) and present interactions in the Earth Global System.

The science plan is focused on surface and near-surface processes in the Northern Eurasian region and addresses the overarching theme of the Northern Eurasia Earth System Partnership Initiative (NEESPI), which is Terrestrial Ecosystem Dynamics and its Interactions with the Global Earth System. This executive overview first presents the overarching NEESPI science questions and elaborates on the science themes through developing science questions relevant to each of the topical areas. Next follows a brief discussion of the unique and important aspects of the study region that warrant the focus of research attention here. The final major section looks at process studies, modeling, remote sensing and other "tools" needed to address these science questions and outlines elements of the proposed research strategy, which also includes an education component in anticipation that a considerable network of students will gain expertise in this area while working on the Initiative. We conclude by outlining the next decade's goals for the NEESPI.

2. SCIENCE THEMES AND KEY SCIENCE QUESTIONS

The major scientific areas, or science themes, to be addressed in the NEESPI include terrestrial ecosystem dynamics, biogeochemical cycles, surface energy and water cycles, land use interactions: societal-ecosystem linkages, ecosystems and climate interactions, and topics of special interest, which include cold land region processes, coastal zone processes, and atmospheric aerosol and pollution.

The overarching NEESPI science question is:

How do Northern Eurasia's terrestrial ecosystems dynamics interact with and alter the biosphere, atmosphere, hydrosphere, and cryosphere of the Earth?

This question can be reformulated in a pragmatic way as:

How do we develop our predictive capability of terrestrial ecosystems dynamics over Northern Eurasia for the 21st century to support global projections as well as informed decision making and numerous practical applications in the region?

While seemingly different, the two questions converge because, to answer them, the same scientific investigations are required. Specifically, the following questions must be addressed:

- How does the Northern Eurasia ecosystem function and how and why has it been changing during the past centuries?
- What are the linkages between the Northern Eurasia ecosystem, atmosphere, and the World Ocean?

- What has been the role of anthropogenic impacts on producing the current status of the ecosystem, both through local land use/land cover modifications and through global gas and aerosol inputs? What are the hemispheric scale interactions, and what are the regional and local effects?
- How will future human actions affect the Northern Eurasia ecosystems? And, how will changes in these ecosystems feed back to society? How can we describe these processes using a suite of local, regional, and global models?
- What will be the consequences of global changes for the regional environment, the economy, and the quality of life in Northern Eurasia? How can science contribute to decision making on *environmental issues* in the region?

NEESPI studies will secure improved interpretation of current and future remote sensing information in Northern Eurasia and provide the bridge between this information and historical in-situ observations.

Information on the status and dynamics of terrestrial ecosystems, the understanding of the main driving forces, and prediction of the future consequences are essential for global change science, implementation of environmental treaties, development programs, natural resource management, environmental protection, and human health and well-being. Therefore, we need to establish (restore, develop, utilize) a modern observational system capable to retrieve and properly interpret information about the current state and changes of the environment of Northern Eurasia. Thereafter, we need to develop ecosystem level and regional input (data flux, model blocks, and missing parameter values) to contemporary Regional and Global Earth System models, thus merging terrestrial ecosystems dynamics studies in the region with the global change science. Other NEESPI science questions related to the key science themes are presented and discussed below.

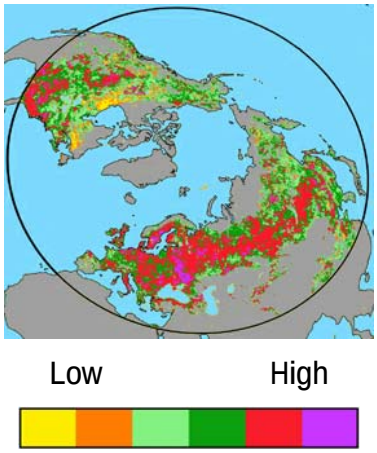
Biogeochemical Cycles

- What are the current geographical and temporal distributions of the major stores and fluxes of carbon and other elements in Northern Eurasia?
- What are the major drivers and feedback mechanisms that control the dynamics of the biogeochemical cycles at local, regional, and continental scales?
- What are the likely future dynamics of biogeochemical cycles that are important to the functioning of the Earth system and the human society?
- What points of intervention and windows of opportunity exist for society to manage biogeochemical cycles in order to mitigate adverse consequences?

Understanding the role and projecting the future dynamics of biogeochemical cycles in Northern Eurasia is critically important for comprehensive, *policy-relevant* knowledge of the global carbon cycle, and for welfare of the populations inhabiting the region. Proposed *diagnostic* analyses include distributed terrestrial measurements, detailed description of the properties and dynamics of individual landscapes and ecosystems, monitoring of disturbance regimes, and studies of hydrologic transfers of carbon and other elements and their sequestration in sediments. These activities will be organized into process-based models, inversion and tracer transport models, and data assimilation schemes; all three supported by interdisciplinary intensive field campaigns. Proposed *process-oriented research* activities will be based on process-oriented models at a regional scale, which would accumulate and explicitly use knowledge on individual landscapes, land use systems, and ecosystems and include studies of responses and feedbacks of terrestrial biogeochemistry to internally-caused perturbations and external forcing. Modeling is the only viable approach to generate predictive capabilities of biogeochemical

cycles. Research related to *management of biogeochemical cycles* will include analyses of economics, land use, and energy policy options for this management, analyses of vulnerability of carbon pools, development of scenarios for incorporation into global Earth models, assessment of sequestration options, and development of anticipatory strategies of adaptation of the NEESPI region's terrestrial ecosystems to environmental changes.

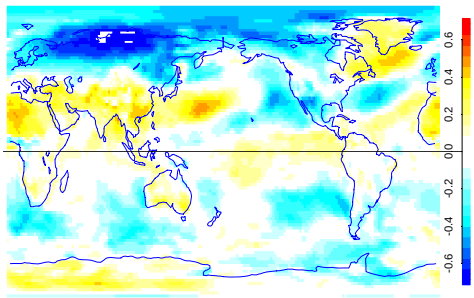
Forest	Area 10^6 ha	Soil Carbon Pg	Plant Biomass Carbon, Pg	Total Carbon, Pg
Boreal	1509	624	51	675
Tropical	1756	216	159	375
Temperate	1040	100	21	121



NASA's data on spatial patterns in persistence of normalized difference vegetation index (NDVI) increase: 1981-1999 (Zhou et al 2003). According to the interpretation of NDVI data by Myneni et al (2001), boreal forest might provide the net sink of 0.68 $\pm$ 0.34 Gt of C yr^{-1} of which nearly 70% is in Northern Eurasia.

Surface Energy and Water Cycles

- What is the relative importance of the major drivers and feedback mechanisms that control the variability and changes of the surface energy and water cycles at local, regional, and continental scales?
- What are the details of surface energy and water cycle dynamics in Northern Eurasia, and how do they improve our understanding of how this region interacts with global cycles?



Correlations of the surface air temperature data with northern hemispheric meridional temperature gradient (zone 0-30ºN minus zone 60º-90ºN) for the winter season (Gershunov 2003). The gradient defines the intensity of zonal circulation in the extratropics.

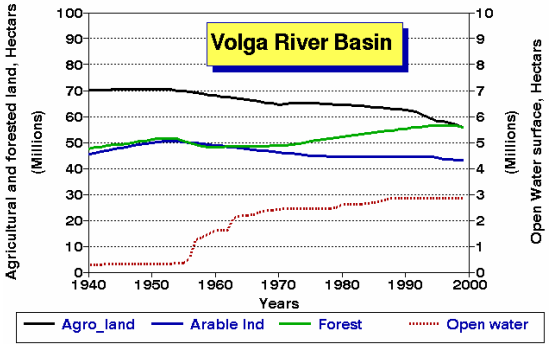
Priorities in surface energy and water cycle studies were set according to two criteria. ***First, attention must be paid to the processes that directly feed back to the global Earth system.*** This justifies the interest of the international community in environmental changes in Northern Eurasia. These processes (listed in Section 3 of this Overview) are also very important on regional and larger scales. In most cases, the feedbacks to the Global Earth System are only feeble manifestations of enormous changes within the subcontinent that "spill out" across the regional borders. Furthermore, by affecting the Global Earth System, they, by definition, affect Northern Eurasia. The fundamental study of land-atmosphere exchange in this region incorporates the need to evaluate the natural dynamics in contrast to large scale land use changes affecting the land-atmosphere exchanges. ***Second, the processes of major societal importance must be addressed.*** They may or may not affect the Global Earth System, but for the region's population, they are of pivotal importance. These include extreme weather events, water supply, thaw of permafrost, desertification, and impacts on agriculture and air and water quality. Major deficiencies in surface energy and water cycle knowledge and observing systems will be addressed by (a) using modern tools of environmental monitoring, (b) integration the results from historical data sets, present observational systems, and process studies into a unified knowledge base, (c) development of an interactive

suite of the land surface models that can account for major land surface process dynamics in Northern Eurasia and interactively feed back to regional and global climate, environmental, and economic models, and (d) performing all necessary studies to make this suite of models a viable working tool.

Land Use Interactions: Societal-Ecosystem Linkages

The central set of land use and society, or "societal feedback," questions to be addressed in the NEESPI are:

- What land use changes are taking place in Northern Eurasia and what are their impacts on the environment and society?



Land use dynamics over the Volga River Basin during the past 60 years (Golubev et al. 2003, updated).

- What lessons can be learned from the responses to dramatic land-use modifications during the "planned" economy period for future sustainable natural resource management?

The Aral Sea from an "in-situ" observation.

- What will be the consequences of socio-economic changes in Northern Eurasia on the environment?
- How can science contribute to development of environmental and economic strategies for society (societies)?

The vast regions of Northern Eurasia and the broad range of lands, ecosystems, and peoples that characterize them – have undergone major fundamental changes resulting from the unprecedented and dramatic transformations of the social, economic, political, environmental, and technological systems in the countries of the region. The changes in land use have altered a number of ecosystem processes (including carbon and water dynamics, greenhouse gas emissions, biodiversity) and land-atmosphere interactions. Current understanding of the linkages and changes in the coupled human, environmental, and climatic systems associated with land sustainability in the region is inadequate. The development of NEESPI research studies related to this topic will focus on: human health and well-being, impact of fires and pollution on humans and ecosystems, biodiversity, agricultural and forestry productivity, water management and quality, and natural hazards. Advances in studies addressing these issues, will provide a direct support to the informed decision making and numerous practical applications in the region. Much of this region is continuing to undergo transformation on a large scale and thus the timing of NEESPI is at the same time both critical and potentially highly rewarding.

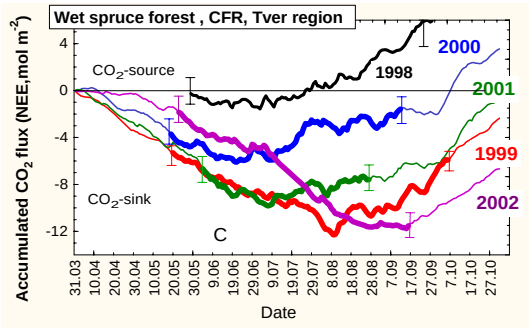
Ecosystems and Climate Interactions

Northern Eurasia is one of the regions where ecosystem and climate interactions play a critical role, and a topical question for the NEESPI is:

- How do we account for the synergy of feedbacks among major processes within the regional terrestrial ecosystems, climate, cryosphere, and hydrosphere of Northern Eurasia and their interactions with society?

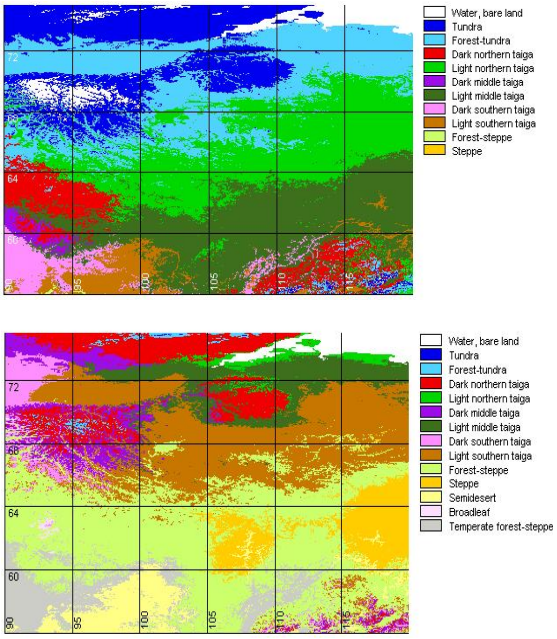
An extensive overview of studies in Northern Eurasia shows that a combination of factors, conditions, and links makes it very difficult to answer the question about even the sign, let alone

the magnitude of the terrestrial ecosystems - climate interactions that are loosely named "biogeochemical and biogeophysical feedbacks". Understanding these feedbacks and their description within a viable blend of models is essential for predicting their future behavior. The main attention should be focused on the most vulnerable ecosystems, "hot" positive feedbacks, or feedbacks which, when initiated, may cause run-away processes in the Earth system, and the key regions. In particular, larger changes in ecosystem-climate interactions across North Eurasia should be expected in the taiga (watch for hydrology-vegetation feedbacks), in the coastal zone (watch for permafrost thaw-greenhouse gases release feedbacks), and at borders of major vegetation zones like forest-tundra (watch for albedo-vegetation feedbacks), forest-steppe (watch for albedo-vegetation and hydrology-vegetation feedbacks), steppe-desert (watch for desertification processes), and in mountains.



Net Ecosystem Exchange (NEE) for 1998-2002 [positive CO_2 flux stands for source to the atmosphere; archive of the Eurosiberian Carbonflux Project]. Sign of annual NEE depends upon weather conditions.

It is concluded that for a reliable regional pattern of environmental changes in Northern Eurasia, which is prone to very strong ecosystem variability and powerful feedbacks, the simultaneous interactive models' runs should be conducted[1]. Thus, a synergetic approach and knowing all substantial climate-ecosystem interactions in Northern Eurasia are a prerequisite to the future projections and/or scenario simulations for the region and for the globe.



Major ecosystems distribution in central and eastern Siberia (top) in the current climate and (bottom) the warmed climate that would be by 2090 derived from the HADCM3GGa1 run (Tchebakova et al. 2003). According to this scenario, the tundra and forest-tundra zones (currently ~ one third of the area) practically disappear while taiga zones (currently about two thirds of Siberia) move northward and reduce to ~40% of the area.

Topics of Special Interest

Cold Regions, Coastal Zone, and Atmospheric Aerosols and Pollution were identified as cross-cutting topics of special interest with the following topical scientific question for each of them:

- How do their changes (or changes in these regions and/or zone) affect regional and global biogeochemical, surface energy and water cycles, and human society?

Cold land region processes. The changing properties of permafrost and glaciers play an important role in driving the ecosystem balance and

[1] Otherwise (e.g., in the GCM simulation of the greenhouse gases increase scenario), large-scale changes in land cover would generate additional regional forcing (actually, biogeophysical feedbacks), and, thus, compromising the GCM run assumptions. Furthermore, the changes in biomass, soil and wetlands carbon, and permafrost thawing (that inevitably must accompany such changes) would generate additional and substantial forcings (actually, both biogeophysical *and* biogeochemical feedbacks) on both the GCM forcing *and* the greenhouse scenario itself.

effecting the carbon, energy, and water cycles in the Cold Land Regions. Presence of large amounts of ice on and below the ground surface makes northern and high elevation ecosystems and infrastructure very vulnerable to present and future climate warming.

> The stability of the ecosystems in the Cold Land Regions relies on the stability of ice that, so far, holds these systems together. In losing the glacier ice and permafrost, we are losing the stability of the systems.

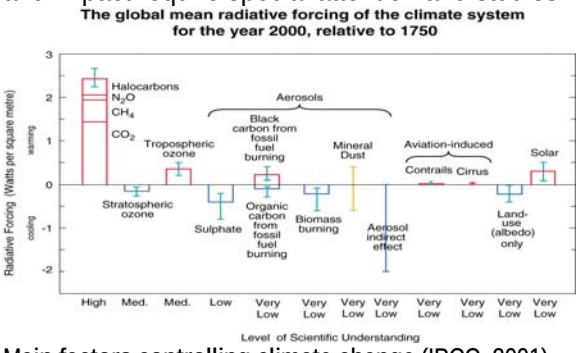
The major threshold occurs when permafrost starts to thaw from its top down and when glaciers start to retreat intensively. At this point, many processes (some of them very destructive) will be triggered or intensified. Even if some ecosystems and infrastructure could avoid complete disintegration, their characteristics will be changed dramatically. Therefore, coordinated efforts are urgently needed to (a) establish and support comprehensive permafrost and glaciers monitoring systems; (b) build reliable models accounting for changes in land ice and its interactions with terrestrial ecosystems, hydrology, atmosphere, and society in the framework of integrated change assessment; and (c) develop mitigation strategies for the regions negatively affected by the permafrost thaw and glaciers retreat.

(Top) Present boreal forest over permafrost and (bottom) two scenarios of its changes when permafrost will thaw: wetlands (under poor drainage conditions) and steppe.

Coastal zone. Several areas of concentrated economic development, large populations, and intensive present and future coastal zone changes require special attention because of *the extreme risk of degradation in the coming decades*. The major issues are: possible intensified erosion of coastal escarpments and depositional bodies, degradation of unique natural coastal and marine ecosystems, damage to local and regional infrastructure affecting quality of life, and change of bottom topography due to coastal and bottom erosion of permafrost rocks that may be significant for future use of the Northern Sea Route and the global biogeochemical cycle. Reasonable, regionally oriented strategies of development in the coastal zone should be introduced. In particular, balances should be found between environmentally sound future development, the necessity to preserve unique ecosystems, and economically advantageous further development.

Top. Endangered oil tanks at the coast of Pechora Sea (20 years ago they were 60 m from the coast; Ogorodov 2003). Bottom. Phytoplankton distribution in Dnepr Estuary demonstrates eutrophication processes in the area. Landsat7. August 10, 1999 (Bands ETM+: 3,2,1)

Atmospheric Aerosols and Pollution. In Northern Eurasia, additional aerosol particles and gaseous pollutants come from emissions from fossil fuel combustion and other industrial processes, anthropogenic enhancements of fires, and increases in atmospheric dust due to human-induced land use changes. The direct and indirect effects of aerosol particles on surface energy and water cycles are currently the most uncertain of the known climate forcings. Atmospheric aerosols and gaseous pollutants can affect terrestrial and marine ecosystems and agricultural production, pose a health threat, and cause property damage. Climate change and population development in the 21st century are expected to cause increases in atmospheric aerosol concentrations. ***Therefore, there is a clear need for improved knowledge of interactions between changing atmospheric aerosols and the Earth System to increase confidence in our understanding of how and why the climate and environment have changed.*** NEESPI will provide a strong scientific underpinning to address this complex problem focusing on Northern Eurasia where pollution levels and several unique features of aerosol production and impact require special attention and studies.



Main factors controlling climate change (IPCC, 2001).


Forest fires and smoke across the Baykal Lake on July 6, 2003 (MODIS image).

Tools: Remote Sensing, Data, Information Technology, and Modeling

Remote Sensing, Data, Information Technology, and Modeling are among the major tools for the NEESPI studies and the topical scientific questions for these areas of endeavor are:

- How can we characterize and improve the accuracy and availability of current remotely sensed data products to meet the needs of the NEESPI science community and resource managers?
- How do we improve the capability of present and future observation systems as well to capture climatic and environmental characteristics and change in the unique conditions of Northern Eurasia?
- How do we reduce the uncertainty of regional and global Earth System modeling related to poor knowledge of major processes and feedbacks in Northern Eurasia?
- How do we secure a societal feedback loop in our models that allows simulation of various scenarios of human activity and, in particular, land use in the region?

3. THE IMPORTANCE OF STUDYING NORTHERN EURASIA

Given that many of the above scientific questions involve the Global Earth System, the question naturally arises as to why we should focus on Northern Eurasia. In brief, the answers are:

- Changes in this region have the potential to affect the global climate and environment and may already be doing so.
- The region has unique features that need to be better understood, parameterized, and accounted for. Without clear understanding of these features, adequate description and modeling of the entire Earth system is not possible.
- The study will have benefits to the societies of the region.

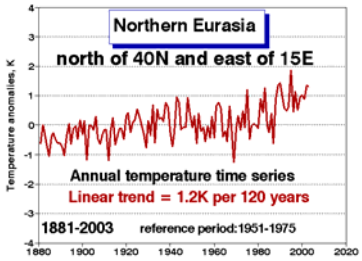
- Northern Eurasia possesses a wealth of scientific talent that can be utilized in this study. It has been studied in detail for more than a century, yet the abundance of data that has been collected (particularly, by Soviet and Russian research projects) has not been utilized enough to study these problems and is in danger of being lost.

The first two of these points are further elaborated below.

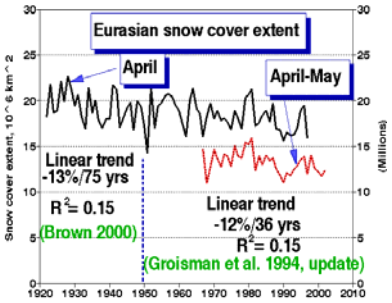
Current and Future Changes and Global Impacts

Being the largest land mass in the extratropics, the largest terrestrial reservoir of carbon in the biosphere, one of the regions with the largest observed and predicted climatic variations, and an area of active land use changes during the past century (and possibly in the future), Northern Eurasia has a unique capacity to generate non-linear, large-scale, and sometimes abrupt changes in regional carbon, surface energy, and water balances. These changes may feed back to the global climate, biosphere, and society. Specifically,

- If we are to understand the global carbon cycle and other biogeochemical cycles, we must know how they function in the NEESPI region which holds more than half of the total pool of terrestrial carbon.
- Accelerated climatic changes across Northern Eurasia may cause changes in global atmospheric circulation and meridional heat transfer.



- Changes in surface albedo (snow/ice cover, shifts in vegetation, land use change) and atmospheric humidity may change the Earth' heat and water balances.

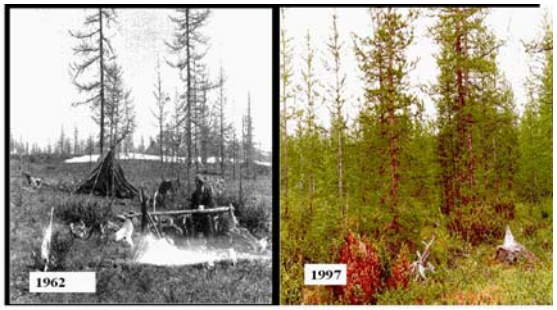


Eurasian snow cover extent in spring (April, April-May; Brown 2000, Groisman et al. 1994, updated).

- About half of the Northern Eurasian terrain has permafrost that controls the hydrosphere and biosphere of the eastern half of the continent. Thawing of permafrost may change the soil carbon cycle and the entire ecosystem above it and, thus, the concentration of greenhouse gases in the atmosphere. It also would produce major changes in land cover and hydrology.

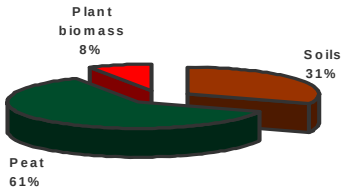
Circumpolar permafrost extent (Brown et al. 1997). Glaciers (dark blue) and areas of continuous, discontinuous, sporadic, isolated, and relict permafrost are shown. Shelf permafrost limit is depicted by the red line.

- Advance/retreat of the forest line, increase/decrease of conditions conducive for forest fires, wind-throw, bogging, and logging may lead to global biogeochemical, energy, and water cycle changes.



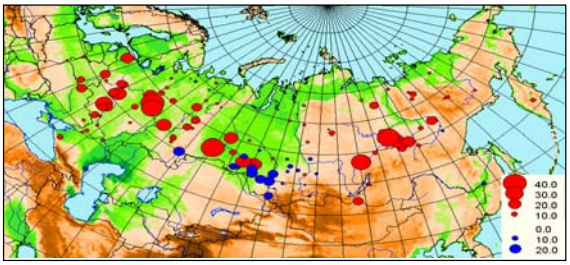
Tree line shift.

- Drying of bogs over expansive areas in West Siberia and the Great Russian Plain may result in their degradation as well as affect the global carbon cycle and runoff formation.



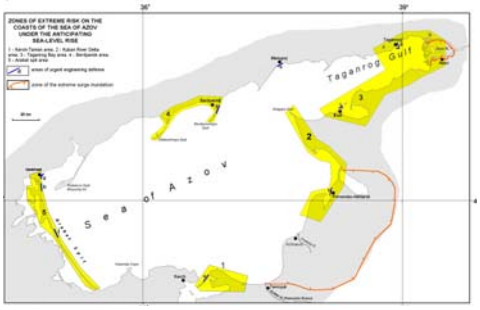
Role of bogs in the carbon storage distribution in boreal ecosystems.

- Changes in the hydrological cycle over the continent control the fresh water transport to the World Ocean and interior lakes. Changes in the fresh water transport to the Arctic Ocean may affect the World Ocean thermohaline circulation.



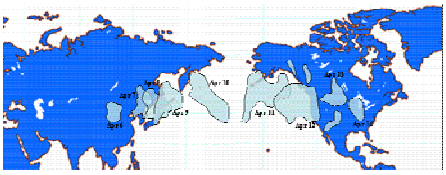
Resent changes in North Eurasian annual runoff. Deviations (%) of runoff for 1978-2000 compared to the long-term mean for ~ previous 55 years. Georgievsky et al. (2002). Runoff increase may affect the World Ocean thermohaline circulation.

- Boundary exchange of fresh water, organic and inorganic matter may affect biochemical processes in the shelf seas and interior lakes. Intensive erosion (currently up to 10 m yr^{-1} in some areas) and other coastal line changes may affect life conditions and cause enormous economic damage.



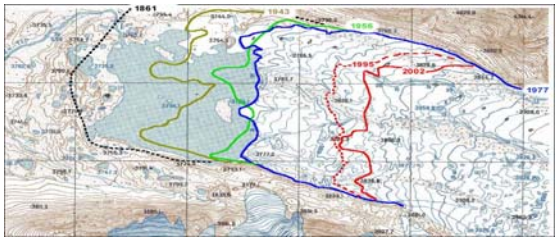
Sea of Azov coastal zones at extreme risk.

- Ongoing aridization of the continental interior may cause a massive aeolian aerosol input into the troposphere that can affect the Earth's heat balance and generate direct biospheric and societal impacts thousands of kilometers away from the origin of these dust storms.



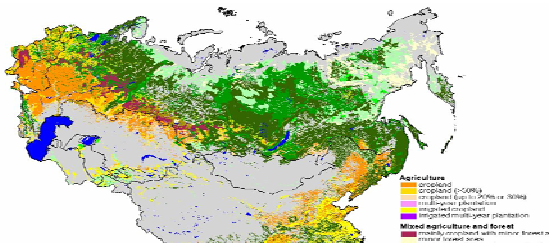
Long-range transport of the dust storm originated over the Gobi desert on April 6th, 2001 (Darmenova et al. 2005).

- Deglaciation in the mountain systems of Central Asia and the Caucasus, increasing water withdrawal, and increasing dryness of steppe and semi-arid zones will affect surface albedo and water resources and their quality of the interior areas of the continent and, thus, the global climate and society.



Example of a central Tien Shan glacier recession. Petrova Glacier in the Akshiyrak area (Kuzmichonok et al. 2004).

- Human activity has changed ecosystem types over most of the steppe and forest-steppe zones and over part of the forest zone causing numerous biogeochemical and biogeophysical feedbacks, near-global environmental changes, and affecting environmental health and quality of life.

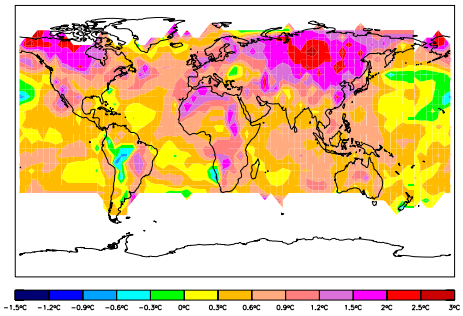


Cropland (orange areas) occupies currently more than 90% of steppe and forest-steppe zones of Northern Eurasia (Fischer et al. 2001b).

Unique Features

Northern Eurasia is the largest contiguous land region in the extratropics. Several unique features of this part of the world are predefined by its location:

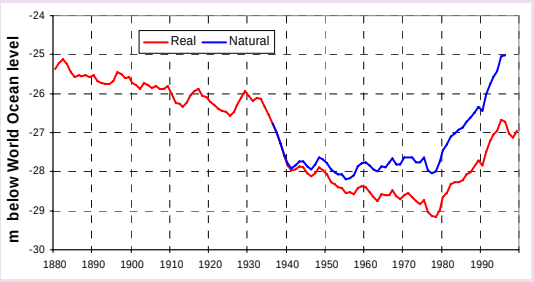
- Northern Eurasia is a major host of the boreal forest and bog ecosystems, which may exercise control over the global biogeochemical cycle affecting the atmospheric composition of such greenhouse gases as methane and carbon dioxide.
- This is the world's largest cold region with two thirds of the permafrost area, two thirds of the area with seasonal snow cover, and more than a third of the mountain glaciers in the Northern Hemisphere. Cold land processes define, control, and put a unique signature on the Northern Eurasian climate, hydrology, and environment.
- This is the region where the most continental climate is observed that affects the intensity of the Eurasian monsoon circulation, which is vital for the densely populated southern half of Eurasia.
- This is the region with the largest river, lake, and reservoir systems on Earth, the largest closed drainage basins, and the most extensive coastal zone exposed to permafrost thaw.



Mean annual temperature change 1965 to 2004 over the globe. Data source: Jones and Moberg 2003.

- In Northern Eurasia, the major ecosystems are frequently under heat and/or moisture stress. Over most of the continent there is a heat deficit and in the regions where the heat is sufficient, the water is typically not. The region is mostly cut off from the humid tropical air masses. Consequently, this region has the highest levels of observed climate and weather variability. The Northern Eurasian surface has modulated, and probably will continue to modulate, any external forcing imposed on the Global Earth System.

The Caspian Sea is the world's largest lake. It does not have outflow and thus is salty. Most of its influx (~80%) comes from the Volga River that has been covered by a set of reservoirs during the 20th century. These reservoirs and water withdrawal for irrigation and other types of water consumption caused a systematic decrease in the River streamflow that affected the Sea level, and thus the coastal zone, fisheries, urban development, and transportation. During the past sixty years, Figure below shows a relatively stable Sea level up to the late 1970s and then an increase in the Sea level that would have happened without the anthropogenic impact. However during the 1950-1980 period, this natural process had been temporarily reversed by the regional anthropogenic impact misguiding the water managers. The misjudgment caused enormous economic and environmental losses when protective measures "to save the Sea" (the dam construction to separate the Kara-Bogaz-Gol Bay from the Sea) were implemented and finally failed.



Observed and "natural" changes of the Caspian Sea level (Shiklomanov 1976; Shiklomanov and Georgievsky 2003). "Natural" changes are the changes that would have happened if there were no anthropogenic impacts on the river inflow into the Sea.

- Extensive variable dry land areas in Northern Eurasia host highly vulnerable natural and agricultural ecosystems that depend upon scarce and highly variable water resources and are the

largest source of dust in the extratropics, polluting areas far away from the source.

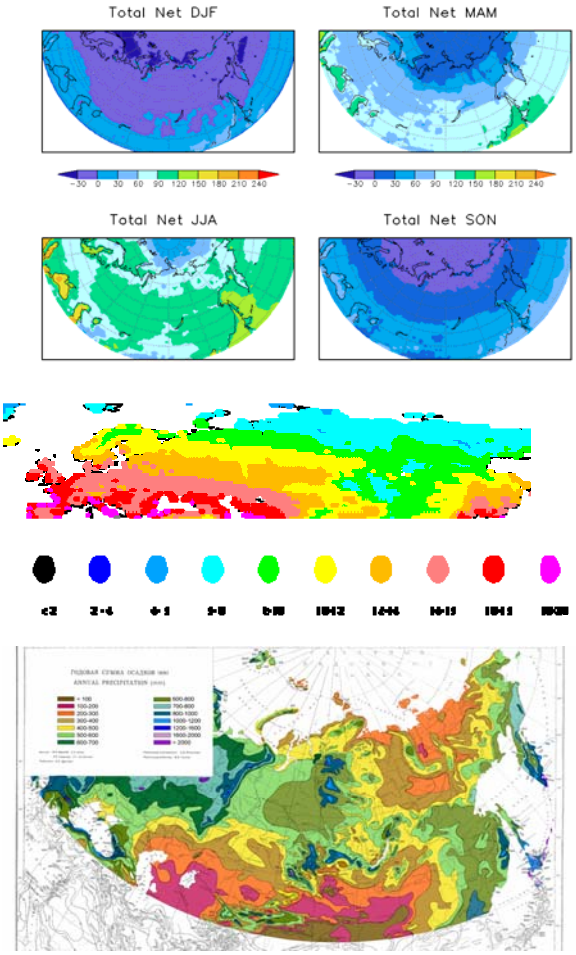
In addition, the regional land use history and social forces that underlie this history are unique within the global environmental science framework and present challenges to social and ecosystem scientists assessing the human dimensions of land cover and land use change.

Comparison with North America

These two major continents in the north, in many respects, complement each other rather than express similarities. Major factors that cause differences are geographical: the size of the Eurasian continent that prevents atmospheric circulation systems from crossing the continent; mountain ranges and plateaus that isolate its northern part from the tropics; and different roles of oceans in the formation of climates of both continents. The geographical differences produce unique ecosystems with different reactions to external forcing and unique controls that vary differently with global Earth system changes. Human activity has added a new and distinctively different feature to each of the continents. Synergy of all the above has generated, and will generate, different feedbacks and patterns of environmental changes. Therefore, to be able to know the processes that define environmental change in the extratropics, comprehensive studies of both continents are required.

Intensity of processes.

Compared to the tropics, the absolute values of the surface energy and water cycle in Northern Eurasia are relatively low and variations in the cycles do not need to be huge to cause significant perturbations. The low intensity but high variability of processes makes it difficult to monitor and study them. Therefore, if we intend to monitor changes in Northern Eurasia with the same precision as in other regions (e.g., remotely), we need more than the usual amount of information about processes causing these changes.



The mean seasonal total net surface radiation budget, W m^{-2} (Stackhouse et al., 2004; top). Annual water vapor content in the atmosphere (surface to 300 hPa; Randel et al. 1996, middle), and precipitation, mm, over Northern Eurasia (Korzun et al. 1974; bottom).

4. RESEARCH STRATEGY AND TOOLS TO ADDRESS NEESPI SCIENCE QUESTIONS

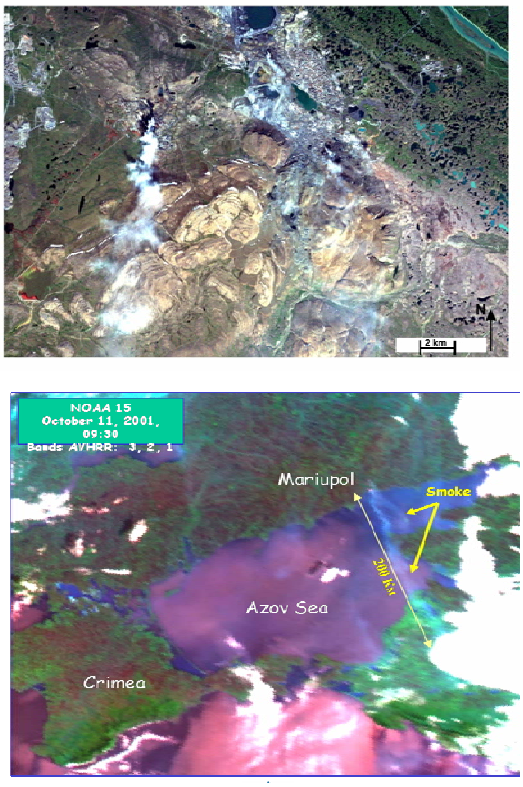
Terrestrial ecosystems, being an integrating component at the land surface and, in some sense, one of the major components of the biogeochemical cycle, absorb, control, transform, react to, and, to some extent, generate the changes in all these cycles. Human activity exercises controls on all these cycles, depends upon them, and reacts to their changes. *Therefore, in Northern Eurasia all components, climatic processes, environmental changes, and*

societal sustainability are closely and substantially interconnected to each other and should be studied together in an interdisciplinary fashion. Moreover, many of the important processes that define the environmental role of Northern Eurasia occur at the boundary between zones and ecosystems. Interdisciplinary studies are critical for understanding these changes. Within the integrative framework of the Northern Eurasian partnership, the NEESPI studies are expected to include learning from and contributing to other relevant regional and global programs.

Research strategies for the science plan include: extraction and preservation of past observations, satellite assessments and monitoring, process studies, studies of impacts of environmental changes on society and the societal feedback, and modeling. The education component is an important, intrinsic part of each component of the research strategy. These research directions are closely linked and overlap one another.

To answer the major science questions of the Science Plan it is necessary to ***better understand the processes and interactions within the regional ecosystems.*** Therefore, process studies will be a key research element of the NEESPI Program. These studies include: (a) biogeochemical cycling in terrestrial ecosystems in Northern Eurasia studies; (b) recovery of the information accumulated during century-long process studies of the past and blending it with a new generation of environmental studies; and (c) new field and process-oriented studies that focus on processes critical to Northern Eurasia (cold land processes, large scale interaction with boreal and tundra ecosystems, sustainable agriculture in zones with high risk of incremented weather). At the plant, patch, and micro-meteorological levels, as well as at the ecosystem, watershed, and regional scales, a set of research questions should be addressed in order to develop model representations of processes and feedbacks associated with the land-surface, terrestrial hydrology, cryosphere, and vegetation and their validation with observations.

Focused societal studies are common in global change assessments. The unique objective of the NEESP Initiative (or at least one that is rarely met) is to elevate these studies to the level of investigation of an equally important *interactive* process that shapes (in substantial manner) the present and future global and regional changes. Therefore, impact of environmental changes on society and the feedback loop will be an important part of the NEESPI research program. Studies that address these societal issues are clustered into the following five major groups. Studies of human health and well-being shall analyze the interconnections between environment, climate, urban and industrial development, pollution, land use, and social/political changes and human health. This includes studies of the vulnerabilities and capacities of humans and



Top. Scorched land around the Norilsk Industrial region. Bottom. Smoke distribution from Mariupol Metallurgical Factory (Donbass) , October 11, 2001.

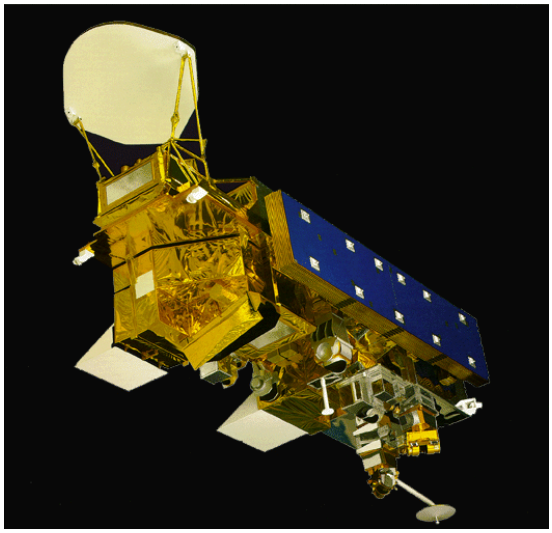
ecosystems to adapt to these changes, possible mitigation actions, and improved decisions and policies for future actions proposed. Ecosystem health studies will focus on the effects of global and

regional changes, in particular pollution, on biodiversity, productivity, and sustainability. Research to improve the quantification of the impacts of climate and environmental variability and change on agricultural and forestry productivity, shall include a feedback loop in consideration and into models that accounts for social, economic, political and governmental policies, practices, and management. Water management and quality studies shall assess past, present and potential impacts of anthropogenic influences and climate change on quality and quantity of the water supply. Implications of this assessment should be analyzed and possible mitigation measures suggested when and where needed. Natural hazards and disturbance studies shall assess the frequency and intensity of extreme events, extensive fires, and other natural disasters in the region, the vulnerabilities of the people to these events, and their capability to cope with disasters. The contribution of regional fires to trace gas emissions and long range transport of particulates outside the region will be also examined. These studies should include improved efforts to monitor, predict, and to feed back that information to people for emergency preparedness and assessment of anticipated additional effects that could result from environmental changes of different origin.

Inherent in the NEESPI research strategy is the incorporation of a variety of "tools" that will be required or helpful in conducting the scientific investigations. These tools include remote sensing, modeling, and data and associated technologies.

Remote Sensing

One of the goals of NEESPI is to involve scientists in the development and testing of the integrated global observing systems (IGOS). Such systems would provide monitoring of Northern Eurasia using satellite facilities and information technologies that include data collection and management, image processing/analysis, spatial data analysis and modeling, data distribution, and users interface. There is a wide range of existing satellite instruments that will cover needs of various applications within Northern Eurasia to study and monitor vegetation status, land use, coastal zone, inland waters (lakes, reservoirs, and rivers), snow cover, ground ice (glaciers) and permafrost characteristics, components of surface energy and carbon budget, precipitation, evapotranspiration, and atmospheric water vapor. The use of remote sensing, however, is hampered by inadequate in situ information needed for validation of the remote sensing products and by lack of understanding of the regional processes required for reliable implementation of the retrieval algorithms. Therefore, validation studies and regional retrieval algorithms development will be an important component of NEESPI.



Aqua Satellite, NASA

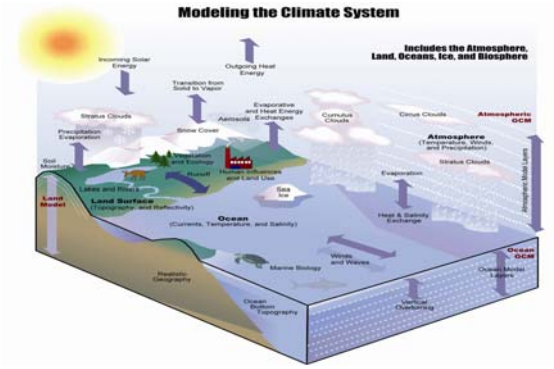
Observations from space allow accurate and comprehensive quantification of many otherwise unavailable characteristics of ecosystems. The accuracy of these products, however, still has to be improved with the help of information from in-situ observations and/or regional model data assimilation. Expanding the modern in-situ environmental networks into Northern Eurasia and strengthening the existing operational and science oriented systems may substantially improve the situation. An investment to properly validate remote sensing algorithms for Northern Eurasia is required. Satellite remote sensing will also provide

an input to early warning systems and timely information for improved resource management.

Remote sensing in Northern Eurasia is of particular importance because vast areas of the region are not well covered by in-situ observations. Currently, NASA, NOAA, NASDA, ESA, and Rosaviakosmos satellites conduct monitoring of various characteristics of the Earth climate, environment and land use. New launches will occur in the years to come. Sensors on board these satellites and techniques for data interpretation rely on understanding of the processes of interaction among radiation, the Earth surface, and the atmosphere. NEESPI studies will secure improved interpretation of current and future remote sensing information in Northern Eurasia and provide the bridge between this information and historical in-situ observations.

Modeling

The triad of the primary functions of modeling (i.e., studying processes, filling gaps in observations, and projecting the future) will be represented in NEESPI. Local, regional, and global scale models are all important, as well as integrated assessment modeling and modeling strategies for prediction (e.g., environmental and societal issues). The overarching, complementary scientific topics for the NEESPI modeling component are processes that control energy, water, and carbon fluxes over Northern Eurasia, direct and feedback effects of environmental changes in Northern Eurasia on the Global Earth System and their evolution, capability of the models to simulate observed environmental changes in Northern Eurasia, and capability of the models to provide an operational interface between on-ground and remote sensing data for data assimilation. The NEESPI modeling efforts will focus on models' improvements to address the above topics, enhancements of the models' capability to simulate the past and to estimate the spectrum of possible future environmental and societal changes both in Northern Eurasia and globally, and assessments the vulnerability of the regional ecosystems and societies to future environmental conditions.

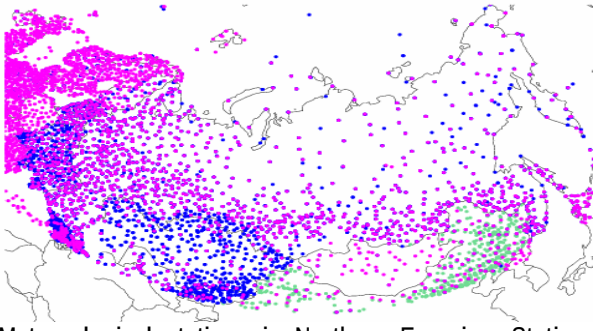


Components of the climate system and the interactions among them (including the human component). All these components have to be modeled as a coupled system including the oceans, atmosphere, land, cryosphere, and biosphere (Karl and Trenberth 2003).

The NEESPI modeling efforts will be organized on three scales: local, regional, and global. The three-scale approach implies using or developing a wide range of models, including atmospheric boundary layer models, soil-vegetation-atmosphere transfer models of different levels of complexity, permafrost models, air pollution models, data assimilation schemes, regional 3-D atmospheric models coupled to comprehensive land surface components, regional high-resolution hydrologic models, models of primary and secondary successions in vegetation and soils, dynamic general vegetation models, global climate models, including, general circulation models and Earth system models of intermediate complexity, socio-economic models, and integrated assessment models. The modeling activity is to be supplemented with developing model diagnosis and inter-comparison tools, data assimilation, and down- and up-scaling techniques. Finally, in the framework of the integrated assessment modeling, a systematic, integrated environmental change assessment study is to be conducted within the framework of a quasi-closed system with an explicit mechanism for incorporating and addressing stakeholders' (decision-makers) questions and concerns regarding global change as applied to Northern Eurasia and for the interests of the major societal and economic activities.

Data and Information and Associated Technologies

Each of the science foci of NEESPI has unique requirements for data. A brief assessment indicates that there is a wealth of information from various sources, but mechanisms to discover, identify and share datasets, and to integrate them into a multi-lateral research program such as NEESPI are lacking. While the first step to remedy this deficiency will be the creation of a metadata archive (i.e., a catalog of existing datasets within NEESPI countries in standard form), significant efforts will also be devoted to preservation and dissemination of past and current observations and organization of an open exchange of data and information among project participants, to the greatest extent allowable by institutional, national, and international regulations. Preservation of existing unique observational programs and stabilization of the density of standard meteorological, hydrological, and environmental observations is a critical task for Northern Eurasia.



Meteorological stations in Northern Eurasia. Stations depicted in pink color are those included in the WMO-A list.

Educational Component

NEESPI needs an increase in the availability of trained scientists working on critical Earth-science issues in the region, the fostering of good international relations through increased cross-cultural and collaborative opportunities, an increase in research and study opportunities for talented students, a broader exposure (access) of scientists in the region to modern technologies and methods of environmental studies, and an avenue for continuing education and re-training of experienced scientists who may have recently faced significant institutional changes. While the presence of an education component will be among the funding requirements of *successful* NEESPI projects, several stages of education and training will be additionally implemented at the following levels: elementary and secondary school, undergraduate education, graduate professional education, graduate Ph.D. education, and continuing education and re-training.

It is coming!

In summary, the NEESPI research strategy plans to capitalize on a variety of remote sensing and other tools and implement a general modeling framework linking socio-economic factors, crop, pollution, land use, ecosystem, and climate models with observational data to address key research questions within Northern Eurasia. As an integral part of these activities, a set of educational activities for students, educators, and the general public is needed as well as interaction with appropriate components of the related ongoing scientific and operational programs. A major objective of NEESPI will be to provide information, which empowers society and decision-makers to plan and react wisely, to mitigate the negative and to benefit from the positive consequences of environmental changes.

5. GOALS AND DELIVERABLES

Through conducting the scientific research during the next decade as addressed in the NEESPI Science Plan the following products are expected:

- *An integrated observational knowledge data base for environmental studies in Northern Eurasia that includes validated remote sensing products*
- *A suite of process-oriented models for each major terrestrial process in all its interactions (including those with the society)*
- *Prototypes for a suite of global and regional models that seamlessly incorporate all regionally specific feedbacks associated with terrestrial processes in Northern Eurasia and which could serve to improve scientific understanding that would enable future environmental change projections and provide input to informed decision-making for land use and environmental protection policies.*
- *Systems demonstrated in the research domain in collaboration with operational partners that can serve the emergency needs of society (early warning / management / mitigation of floods, fire, droughts, and other natural hazards)*